To the Graduate Council:

I am submitting herewith a thesis written by Rebecca Barnett Speas entitled "The Functional Application of the Propeller Load Curve for Fixed Pitch Propellers." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

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We have read this thesis and
recommend its acceptance:

Rodney Allison

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Accepted for the Council:

Linda Painter
Interim Dean of Graduate Studies

(Original signatures are on file with official student records.)

THE FUNCTIONAL APPLICATION OF THE PROPELLER LOAD CURVE FOR FIXED PITCH PROPELLERS

A Thesis
Presented for the
Master of Science Degree
The University of Tennessee, Knoxville

Rebecca Barnett Speas
December 2006

DEDICATION

This thesis is dedicated to my husband Brian Oliver Speas for all of his support throughout my education. Additionally, I would like to dedicate this work, to my parents Charles T. Barnett and Phylis M. Barnett who taught me the value of education and sacrificed much for me.

ACKNOWLEDGMENT

I am grateful to the many people who made my time at the University of Tennessee Space Institute very rewarding. I am particularly grateful to the faculty and staff of the Department of Aviation Systems Research and Development. Thanks to Mike Leigh for helping me calibrate all the instrumentation for the flight test. A special thanks to my Thesis Committee, Dr. Ralph Kimberlin, for his guidance and mentorship and to, Professor Rodney Allison and Professor Rich Ranaudo for their invaluable help in the preparation of this thesis.

ABSTRACT

This thesis attempts to help the flight test community by using the propeller load curve (also known as prop load) to find brake horsepower (BHP) easily with only a propeller tachometer. This thesis also covers the equation for the propeller load curve.

The flight test was done using a Piper Cherokee 180 equipped with a Lycoming 0-360-A3A engine. The flight test data were collected at University of Tennessee Space Institute (UTSI). This data were then compared to the prop load from the engine manufacturer.

Based on the result of this flight test, using the prop load equation from the Lycoming will result in BHP that is within 96 % agreement to the flight test BHP. The result of the test will also show that the equation for the propeller load curve at sea level is $HP = K \times (RPM^3)$ where K = constant (Aircraft 1949). This thesis will also prove that if you are not at sea level, the equation then becomes $HP = (\sqrt{\sigma} \times K \times RPM^3)$ where σ = the atmospheric density ratio.

Recommendations include additional tests with multiple engines on a test stand.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

Item	**Description**
AC	Alternating Current
BHP or HP	Brake Horsepower
BHP_{calc}	Brake Horsepower Calculated
BHP_t	Test Brake Horsepower
C	Celsius
dB	Decibels
ft	Feet
Hg	Inches of Mercury
H_p	Pressure Altitude (feet)
$H_{plycalc}$	Pressure Altitude of Calculated Lycoming Data
K	Constant units of (HP/RPM^3)
MAP	Manifold Pressure
min	Minute
mph	Miles Per Hour
OAT	Outside Air Temperature
prop	Propeller
rev	Revolution
RPM	Revolutions Per Minute
RPM_t	Test Revolutions Per Minute
RPM_p	Revolutions Per Minute of the Propeller
Sigma (σ)	Density Ratio
σ_t	Test Density Ratio
UTSI	University of Tennessee Space Institute
W_t	Weight During Test Conditions
W_s	Weight During Standard Conditions

Chapter 1 : Introduction

Purpose

The purpose is to show an equation for the propeller load curve for fixed-pitched propellers, which is good for all altitudes, and to show the usefulness of the curves to flight testing, aircraft engine manufactures, and homebuilders. It is also useful to be able to read one simple chart to analyze the data instead of a complicated chart and can be used when you do not have an available manifold pressure gauge for the flight test. The data can be inserted into the engine manufacturer's prop load curve to get the BHP of the engine.

The *Aircraft Powerplant Handbook* gives equation for propeller load curve $HP = K \times (RPM^3)$ where K = constant at for sea level (Airplane 1949). This thesis will also show if you are at altitude, the equation then becomes $HP = (\sqrt{\sigma} \times K \times RPM^3)$ where K = constant and has units of $\frac{HP}{RPM^3}$.

Chapter 2 : Background

Turning now to the history of fixed pitched propellers, those used in the earliest days were of fixed geometry design generally being carved from solid wood or built up to the required shape from wooden laminations. A propeller of this type absorbs power according to a cube law, that is for a given air density and flight speed there is a unique relationship between power and speed in which the power varies with $(\text{rev/min})^3$.

Engine manufacturers create charts for fixed pitch propeller engines called the propeller load (prop load) curve. It can be understood that it requires more power to drive a propeller at high speeds than it does to drive it at low speeds and that a certain propeller being driven at a given speed will absorb a specific amount of power. The propeller load curve is a graph which shows the relationship between the RPM of a fixed-pitched propeller and the power required to drive it at a given speed. The equation for horsepower at sea level is as follows: $HP = K \times (RPM^3)$ where K = constant (Aircraft 1949). The propeller load curve can be expanded to work at different altitudes by using σ, the atmospheric density ratio in the equation. The theory and usefulness of the propeller load curve has been lost from current literature.

Chapter 3 : Equipment

Description of Aircraft

The aircraft flown for the flight test was a Piper Cherokee 180 as shown in Figure 3-1. The registration number was N9163J. It was recently modified with a low drag main wheel fairings. It was equipped with a Lycoming 0-360-A3A engine and had a 50 gallon fuel capacity. The propeller is a Sensenich fixed pitch, aluminum propeller, model 76EM8S5-0-60 with a 60 inch pitch. The serial number is 34957K. The propeller was installed October 14, 2001, and had a 100 hour inspection on December 8, 2005. The aircrafts maximum rated horsepower was 180 at sea level, standard conditions. At 75% power, its fuel consumption was 10 gallons per hour. The aircraft had a top speed of 148 mph at sea level and a stall speed of 57 mph with full flaps down. It had a maximum gross weight of 2,400 pounds. The empty weight of the aircraft is 1422.5 pounds. Its best rate of climb airspeed was 85 mph with a service ceiling of 15,700 feet. The rate of climb at sea level was 720 feet per minute.

Figure 3-1: Picture of Test Aircraft

Description of Instrumentation

The aircraft had standard instrumentation plus an installed manifold pressure (MAP) gauge. The calibrated instruments aboard included airspeed, altimeter, manifold pressure and temperature gauges. To obtain accurate RPM, an electronic propeller tachometer No. 2545 was used from Cardinal Electronics Inc. The propeller tachometer had an RPM range of 250 to 4500. The accuracy was .025% over the entire range of the instrument. The target acquisition range was greater or equal to 10 feet. The ambient light compensation dynamic range was 94 dB. The calibration of the propeller tachometer was accomplished by holding it to a florescent light and recording the 60 Hertz of the A.C. electric current.

Chapter 4 : Calibration of Instrumentation

Instrument Calibration on Piper Cherokee N9163

The airspeed indicator was calibrated to the National Bureau of Standards by using a water manometer connected to the static port. The pressure on the system was increased in 10 mph increments from 60 mph to 180 mph. At each point, measurements within the cockpit were recorded. Readings were taken at increasing and decreasing airspeeds. Tapped readings were taken to account for friction in the instrument. The raw data was plotted in a chart (Figure D-6) which was be used in helping make instrument corrections for the flight test data.

To calibrate the manifold pressure gauge to the National Bureau of Standards, the manifold pressure line going to the engine was hooked up a vacuum pump barometer. A created vacuum ranging from 10 to 30 inches of mercury was increased in increments of 5 inches. At each point, measurements within the cockpit were recorded. Readings were taken increasing and decreasing in manifold pressure. Tapped readings were taken to account for friction in the instrument. The raw data were then plotted in a chart (Figure D-7) which was used to make instrument corrections for the flight test data.

The outside air temperature gage (O.A.T.) was calibrated by comparison to a lab thermometer. It was determined that the OAT read 3 degrees warmer than the actual outside temperature.

The altimeter/static system was last calibrated on April 28, 2005 under FAR Part 43 Appendix E during the Federal Aviation Administration bi-annual re-certification for instrument flight. This calibration of the altimeter was used for the test.

Chapter 5 : Flight Test Program

Purpose

The purpose of the test was to verify that the sea level equation for the propeller load curve can be modified for use at all altitudes. A comparison was made between the sea level equation and the equation derived from the flight test power curve with Lycoming's prop load curve in Appendix C Figure C-1 (Textron 1967).

Scope

Test and Test Conditions

The evaluation was conducted at Tullahoma Regional Airport, Tullahoma, Tennessee under daylight visual meteorological conditions. The evaluation consisted of two flight tests lasting a total of 1.6 flight hours. Testing was conducted within the limits of the pilot's operator's manual (Piper).

The weather for both days had moderately smooth conditions with temperatures 20 (+/- 5) degrees C. Wind speeds were less than 4 knots on both days. All the data were hand recorded.

Method of Test

The test consisted of four test altitudes: 1500, 3000, 5000 and 7000 feet H_p. At each specified altitude in steady level flight, the aircraft was accelerated at full throttle and maximum cruise RPM to maximum level flight speed. Once stabilized, data were collected from the propeller using the electronic tachometer to get RPM, O.A.T. gauge, airspeed, and manifold pressure. After the data were collected, the manifold pressure was reduced an increment of 1 or 2 in. Hg. The airspeed was allowed to stabilize and the data were collected again. This procedure was repeated until the aircraft reaches the back side of the power required curve where manifold pressure must be increased to maintain altitude and achieve a lower airspeed. Test conditions were steady during the duration of data recording and no anomalies affected the accuracy of the data. The distance between the electronic propeller tachometer and the propeller was 6 feet which was within the target acquisition range for the instrument.

Chapter 6 : Results of Flight Test

The flight test data were corrected for instrument errors and to standard day conditions using the 1962 U.S. Standard Atmosphere. The data were then used to calculate the brake horsepower (BHP) by using the engine manufacturer's power chart shown in Appendix C Figure C-2 (Textron 1967). The BHP obtained from the power chart was compared to the BHP from the equation for the propeller load curve.

The equation for propeller load curve (prop load curve) for sea level is $HP = K \times (RPM^3)$ where K = constant and has units of $\frac{HP}{RPM^3}$ (Airplane 1949). The propeller load curve is a graph which shows the relationship between the RPM of a fixed-pitched propeller and the power required to drive it at a given speed. The power absorbed by the fixed-pitched propeller is proportional to the cube of the its RPM. With a fixed-pitched propeller, the only way to regulate the torque of the engine is airspeed. Torque relates to the power output of the engine. Therefore, if the power output is changed (torque), the engine will then try to accelerate or decelerate until a RPM is achieved at which the power provided to the engine is equal to the power absorbed by the propeller.

The above equation can not be used for flight test data because it is only accurate for standard sea level conditions. For flight test data at non-sea level conditions, the equation then becomes $HP = (\sqrt{\sigma} \times K \times RPM^3)$ where K = constant. Density ratio must be included in the equation to correct for non-standard atmospheric conditions which takes test day data to standard day conditions. Figure 6-1 shows that the flight test data from a variety of altitudes can be reduced to a single line by including the density ratio.

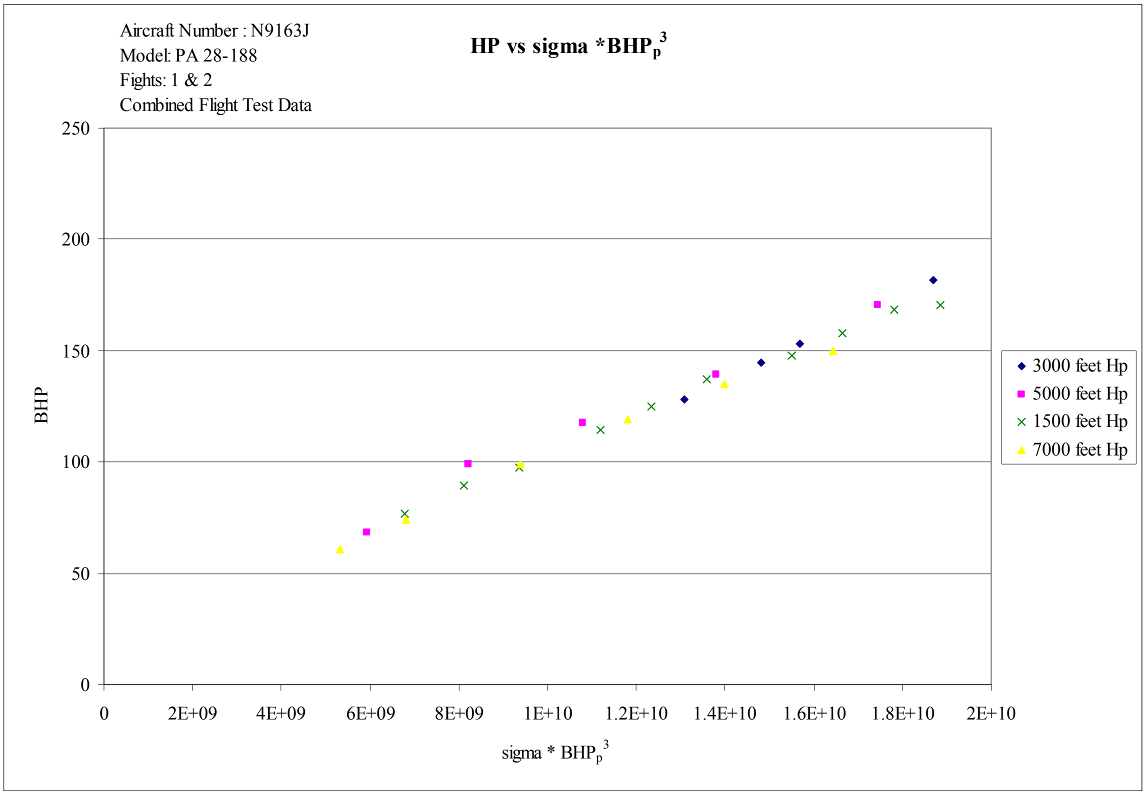

Figure 6-1: BHP vs. Sigma * BHPp^3

However, it was found that when density ratio, sigma, was inserted into the equation and compared to the BHP obtained from the engine manufacturers power chart that the derived horsepower did not compare favorably. In Figure 6-2, the tolerance lines for the engine are +5% and -2% which is given by Lycoming in the 0-360-A engine power chart (Textron 1967). Root sigma was then used in the equation instead of sigma because it compares more favorable with the power obtained by the engine manufacturer's power chart and the tolerance for the engine as shown is Figure 6-2.

All the flight test data were reduced to standard sea level by using the data reduction method of PIW vs. NIW.

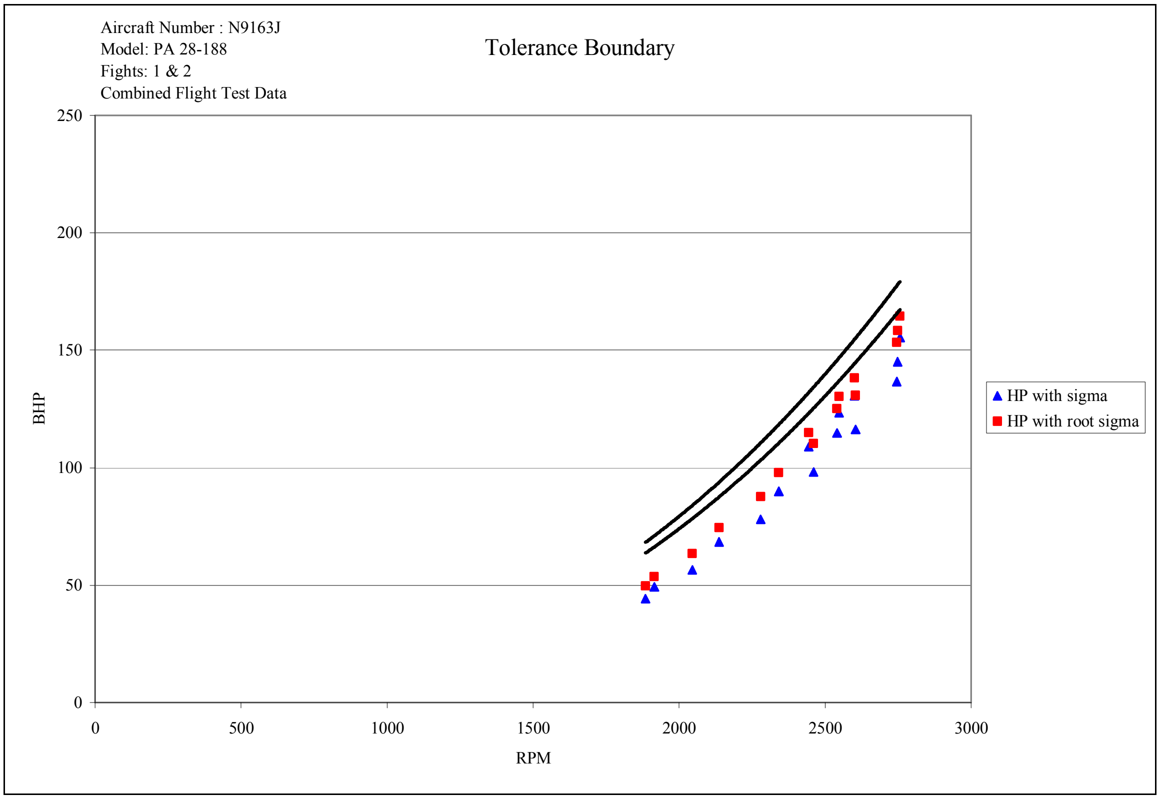

Figure 6-2: BHP vs. RPM

The plot of PIW vs. NIW provides one curve good for all air densities and airplane weights which were used relate the engine power to RPM. PIW is used to correct BHP for density and weight. The equation for PIW is $PIW = \left(\frac{\sqrt{\sigma_T} \times BHP_T}{\left(W_T / W_S\right)^{3/2}}\right)$. NIW is used to correct RPM for density and weight. The equation for NIW is $NIW = \left(\frac{\sqrt{\sigma_T} \times RPM_I}{\sqrt{W_T / W_S}}\right)$ (Kimberlin 2003). The equation received from the PIW vs. NIW propeller load curve was $HP = (8.317 \times 10^{-9})(RPM^3)$ shown in Figure 6-3.

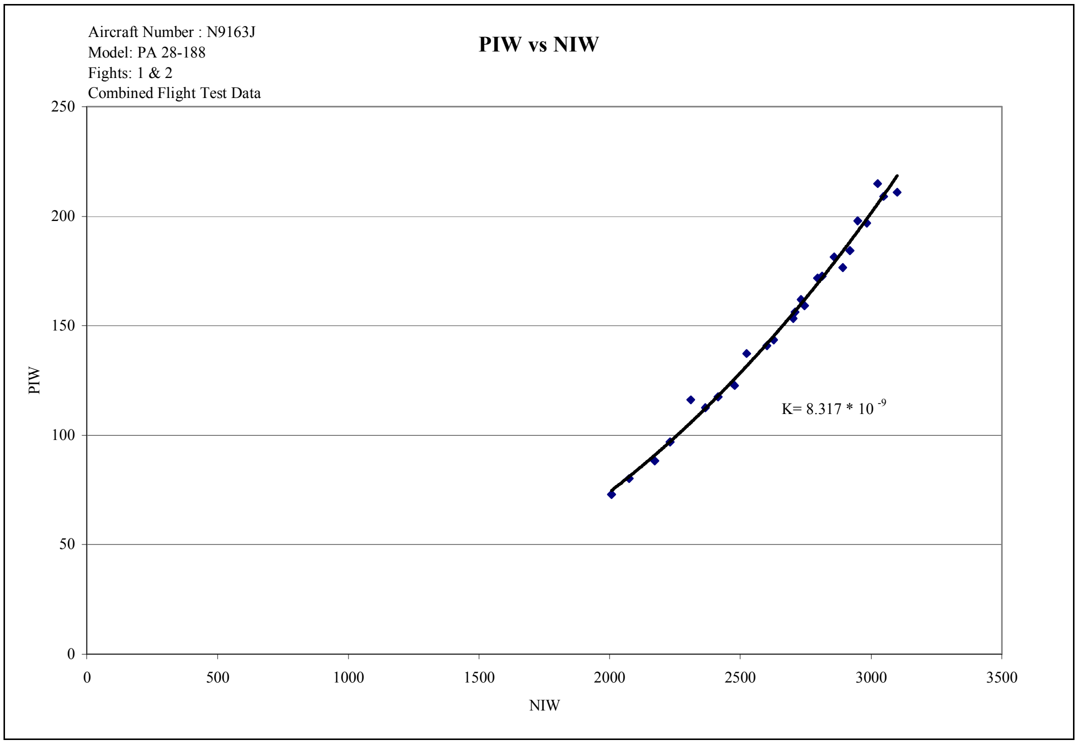

Figure 6-3: PIW vs. NIW Prop Load Curve for all Test Data

The data from the flight test were entered into the equation for BHP $HP = (\sqrt{\sigma} \times K \times RPM^3)$ where K = 8.317×10^{-9} with units of $\frac{HP}{RPM^3}$ and then compared to the BHP calculated from the engine manufacturer's power chart. For the equation based BHP, only 10 of the 24 data points exceeded 10 % error compared to the Lycoming power chart. Therefore, this analytical model is considered to have an agreement of 59 % for determining BHP. It is even more accurate above 2440 RPM with error less then 6 % and 20 % of the data points above 2440 RPM are agreeable to 1%.

The flight test data were then compared to the engine manufacturer's propeller load curve shown in Figure C-1 (Textron1967). The equation for the prop load curve from Lycoming was $HP = (9.1449 \times 10^{-9})(RPM^3)$. The equation received from the PIW vs. NIW flight test data propeller load curve was $HP = (8.317 \times 10^{-9})(RPM^3)$. The prop load curve for the test data is shown in Figure 6-3.

The prop load curves were then drawn for each altitude. A comparison was made for each test altitude between the BHP from the engine manufacturer's power chart and the calculated Lycoming BHP. The Lycoming BHP_{calc} was found by using the equation $HP = (\sqrt{\sigma} \times K \times RPM^3)$ with K = 9.1449×10^{-9} with units of $\frac{HP}{RPM^3}$ and inserting the flight test data into it. This resulted in the charts shown in Appendix D. The result of the equations for the Lycoming BHP_{calc} and prop load curve calculated from the engine power chart at 3000 feet H_p is shown in Figure 6-4.

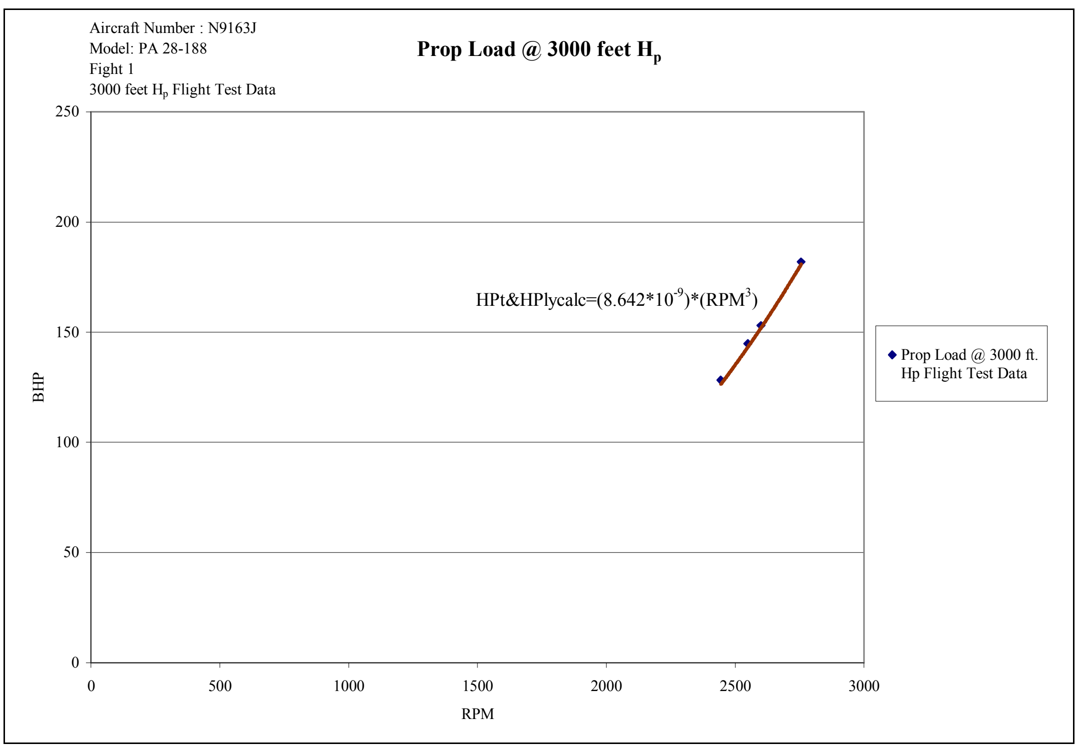

Figure 6-4: Prop Load at 3000 ft H_p.

Figure 6-4 shows the equations for the Lycoming BHP_{calc} and prop load curve calculated from the engine power chart follow the same curve. This is also shown in the 5000 feet chart shown in Appendix D Figure D-4. However, the curve for 1500 feet H_p and 7000 feet H_p were not on the same line, but are very analogous as shown in Figure D-2 and D-5. Figure 6-5 shows the prop load curve at 1500 feet H_p. This shows that the equations for the Lycoming BHP_{calc} and prop load curve calculated from the engine power chart does not agree. A possible error for the disagreement was the human pilot and the accuracy to which the instruments could be read.

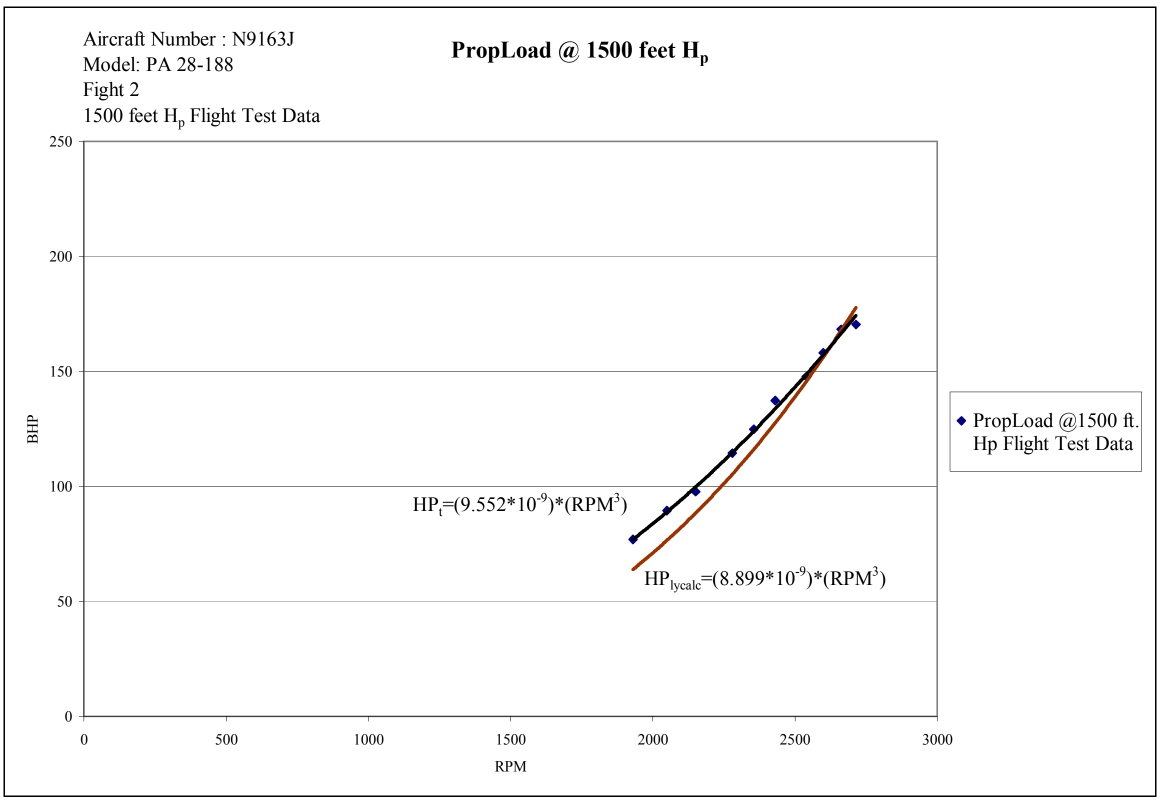

Figure 6-5: Prop Load at 1500 ft H_p

The data from the flight test were entered into the equation for Lycoming BHP_{calc} $HP = (\sqrt{\sigma} \times K \times RPM^3)$ where K = 9.1449×10^{-9} and then compared to the BHP calculated from the engine manufacturer's power chart. The equation received from the PIW vs. NIW flight test data propeller load curve was $HP = (8.317 \times 10^{-9})(RPM^3)$ shown in Figure 6-3. For the equation based BHP, only 5 of the 24 data points exceeded 10 % error compared to Lycoming power chart. Therefore, this analytical model is considered to have an 80 % agreement for determining BHP. It is a more accurate above 2440 RPM with error less then 4% and 75 % of the data points above 2440 RPM are agreeable to 1%.

Chapter 7 : Conclusion

There are several factors that need to be addressed on why the service propeller does not agree with the test club propeller. The engine manufacturers prop load curves are generated from engines on a test stand with a test club propeller which is weighted in order to get a generic view of the engine performance. The prop load curve is created by taking an average of many calibrated engines. These factors are potential areas for error which can not be factored into the equations.

The technique of using the engine manufacturer's prop load curve is also beneficial when you do not have an available manifold pressure gauge for the flight test. The data can be inserted into the engine manufacturer's prop load curve to get the BHP of the engine.

In conclusion, the most accurate results always come from the flight test to determine the prop load curve with the service propeller. However, the engine manufacturer's prop load curve can be used to help reduce data. Therefore, because the accuracy at high power is good, the prop load curve from Lycoming can be used instead of having to do a flight test to determine the specific power curve for that engine.

Chapter 8 : Recommendations

In the flight testing industry, time vs. money means everything. The more time the airplane is in the flight test phase, the less money the company is making. Therefore, the more ideas we have to save some time during the flight test phase, especially since it is the end of the aircraft's development, the more money the company is making on the aircraft. It would be good to get additional research for this method to see if using the propeller load curve to find brake horsepower (BHP) with only a propeller tachometer would save time and money for aircraft development.

The following recommendations constitute additional testing in engines, aircraft, and propellers. If time and money would allow, it would be good to get additional tests with multiple calibrated engines on a test stand with service propeller. Before flight testing, recommend the airplane manufacturer have Lycoming develop a prop load curve with the service propellers.

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Appendices

Appendix A

Flight Test Plan

Flight Test Plan

Purpose

The purpose of the test is to determine if the propeller load curve can be reduced to a sea level curve and to determine the equation.

Scope of Test

Test and Test Conditions

The evaluation will be conducted at Tullahoma Regional Airport, Tullahoma, Tennessee under daylight visual meteorological conditions (VMC). The evaluation will be conducted in 2 or 3 flight test.

Test Envelope

Testing will be conducted with the limits of the operator's manual (Piper).
The test will include a low altitude, medium altitude, and high altitude point.

Test Loadings

Test loading will be varied only by the number of personnel aboard the aircraft and the amount of fuel used during the test.

Test Configuration

The aircraft configuration for all tests will be: low drag main wheel farings.

Method of Test

The test will consist of four test altitudes: 1500, 3000, 5000 and 7000 feet H_p. The test will be conducted by climbing to each specified altitude. At a constant altitude in steady level flight, the aircraft is accelerated at full throttle and maximum cruise RPM to maximum level flight speed. Once stabilized, data are collected from the propeller using the electronic tachometer to get RPM, O.A.T. gauge, airspeed, and manifold pressure. After the data are collected, the manifold pressure was reduced an increment of 1 or 2 in. Hg. The airspeed is to stabilize and the data are collected again. This procedure is repeated until the aircraft reaches the back side of the power required curve where manifold pressure must be increased to maintain altitude and achieve a lower airspeed.

Instrumentation and Data Extraction/Processing

The external equipment required to collect the desired test data are: a propeller tachometer and a manifold pressure gauge. Data will be recorded by hand.

The following will be taken at each data point:

1. Pressure altitude
2. RPM standard gauge
3. RPM tachometer reading
4. OAT
5. Manifold Pressure
6. Airspeed

Special Precautions

Safety Considerations

The test crew must have a thorough knowledge of aircraft limitations. All level flight testing shall be conducted within the established flight envelope and the normal operating limitations contained in the Aircraft Operator's Manual. The crew will terminate the test in the event of any unusual handling characteristics or vibrations. During all test the crew must remain vigilant to air traffic and obstacle avoidance.

Risk Management

The flight shall be conducted in VFR conditions during daylight. Emergency actions will be developed and briefed by the aircrew prior to the installation of experimental (non-standard) equipment. The overall risk associated with the conduct of this test is assessed to be low.

Flight Brief	10 June 2005
Flight Test	10 June 2005 and 20 October 2005

Appendix B

Weight and Balance

Piper Cherokee N9163J Weight and Balance for 6/10/05 and 10/20/05			
	Weight (lbs.)	Arm aft Datum (inches)	Moment (pound-inches)
Licensed Empty Weight	1442.5	88.64	126084
Oil (2 Gal)	15	32.5	488
Pilot and Passenger	310	85.5	26505
Fuel (50 Gal)	300	95	28500
Passengers (Rear Seat)	0	118.1	
Baggage	0	142.8	
Total Loaded Plane	2067.5		181577

87.8244256	Inches (arm aft Datum)

Appendix C

Lycoming Prop Load Curve and Power Chart

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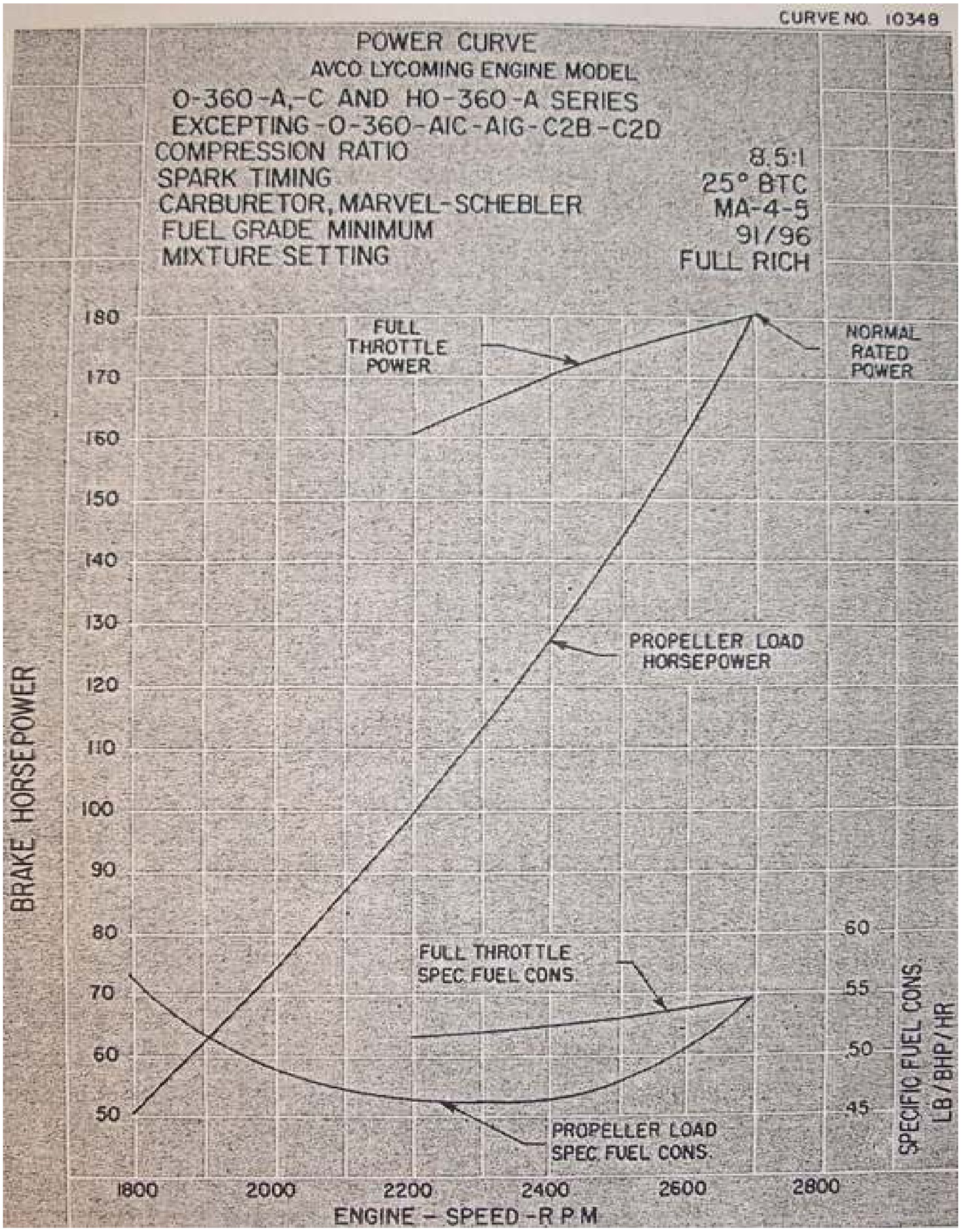

Figure C-1: Lycoming 0-360-A engine prop load curve (Airplane 1949)

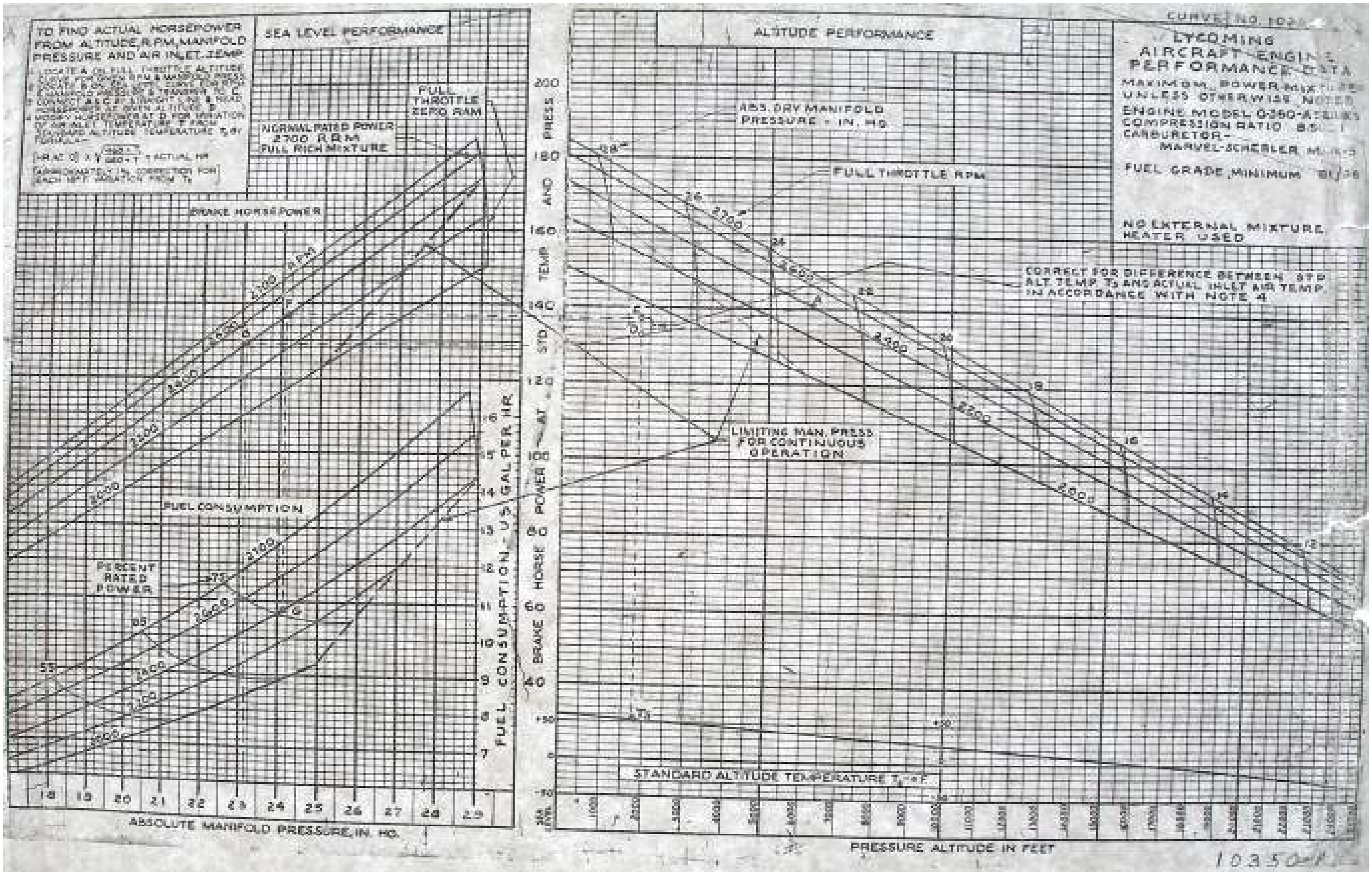

Figure C-2: Lycoming 0-360-A power chart (Textron 1967)

Appendix D

Flight Test Data

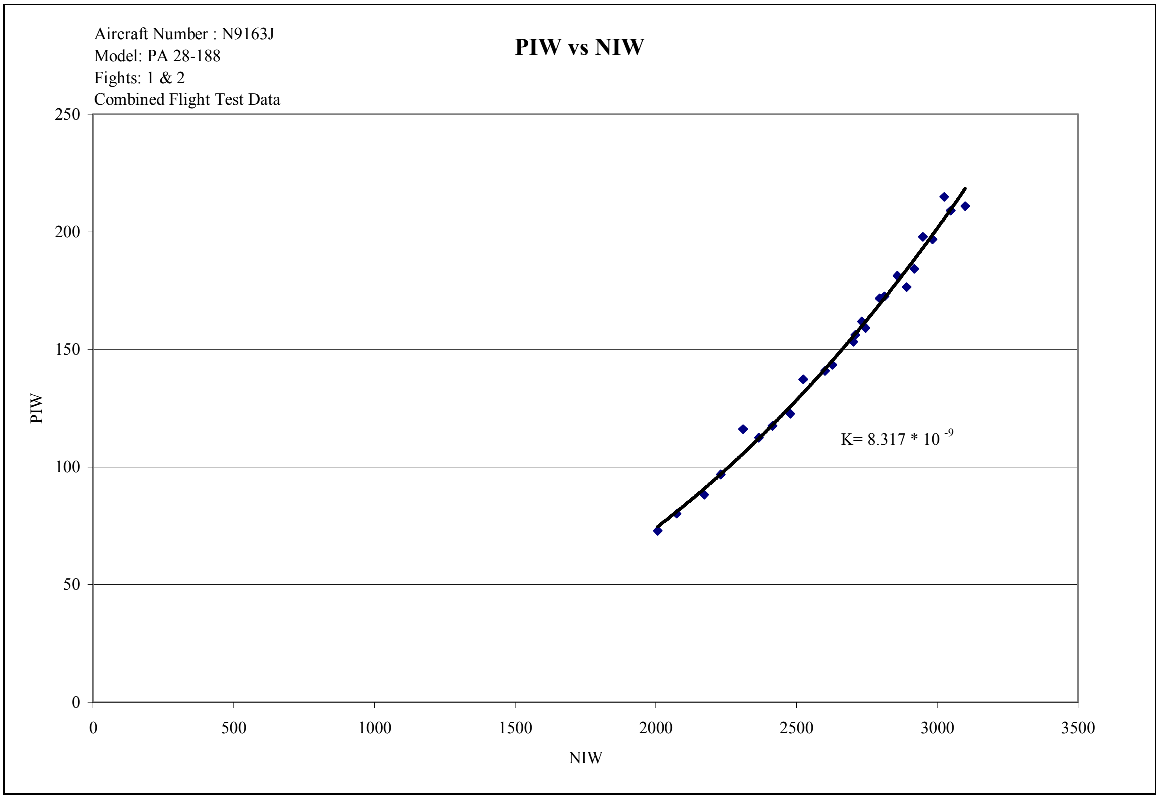

Figure D-1: PIW vs. NIW Flight Test Data Prop Load Curve

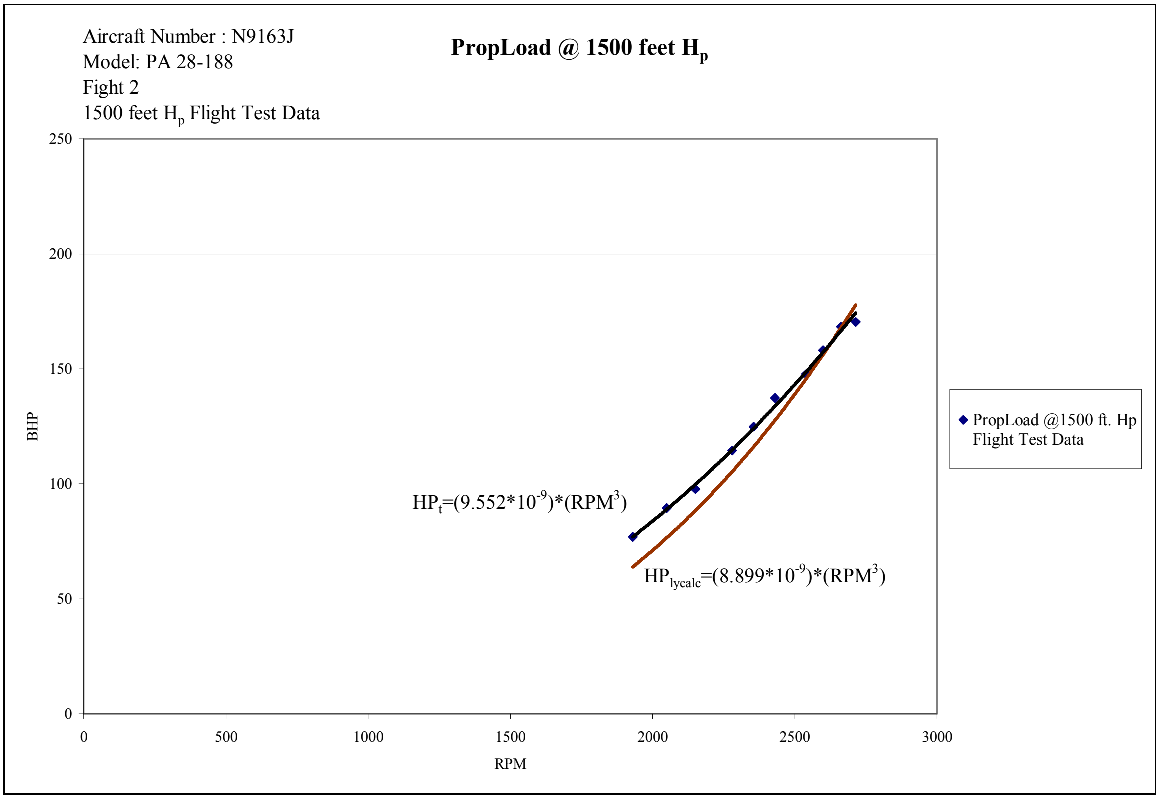

Figure D-2: Prop Load at 1500 ft H_p

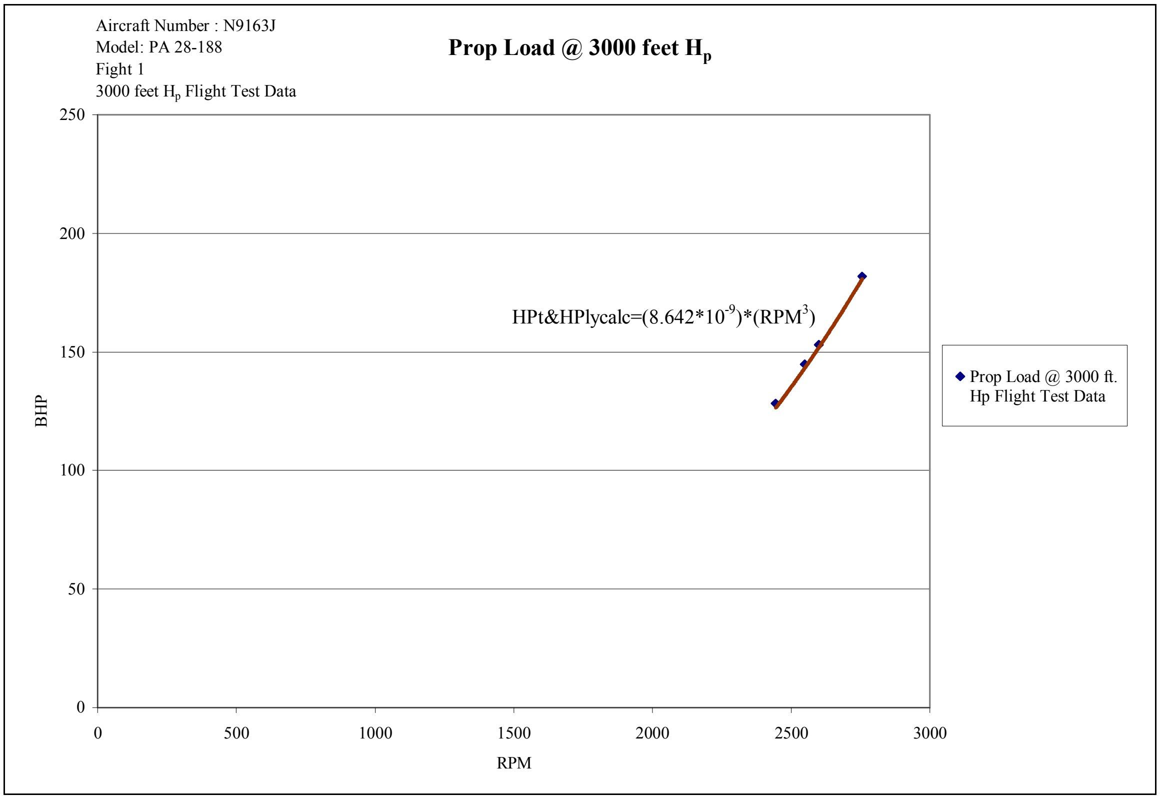

Figure D-3: Prop Load at 3000 ft H_p

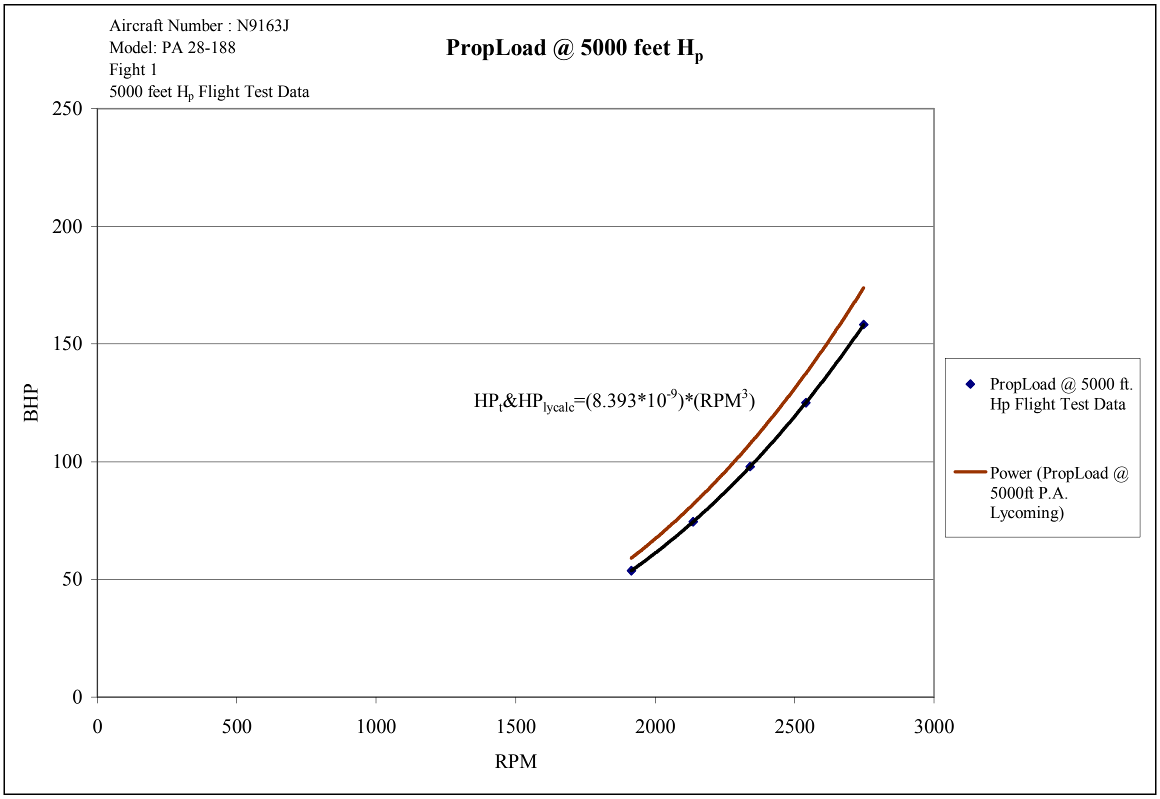

Figure D-4: Prop Load at 5000 ft H_p

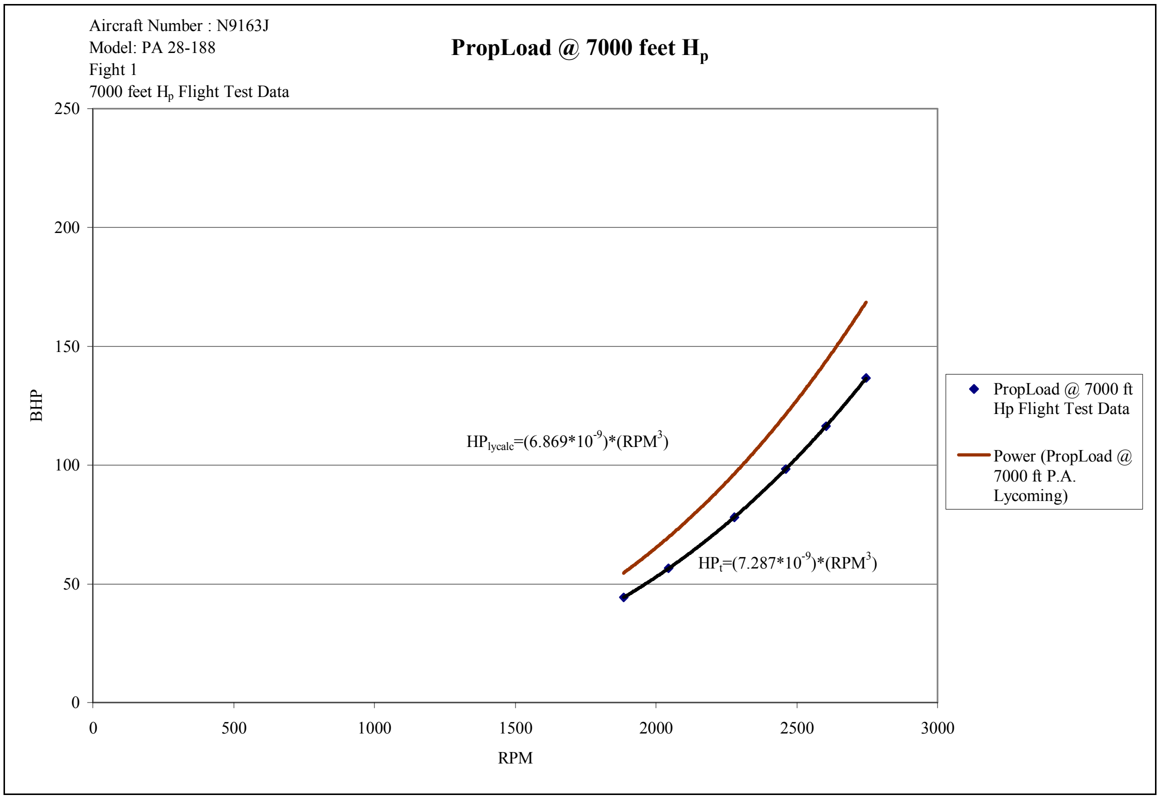

Figure D-5: Prop Load at 7000 ft H_p

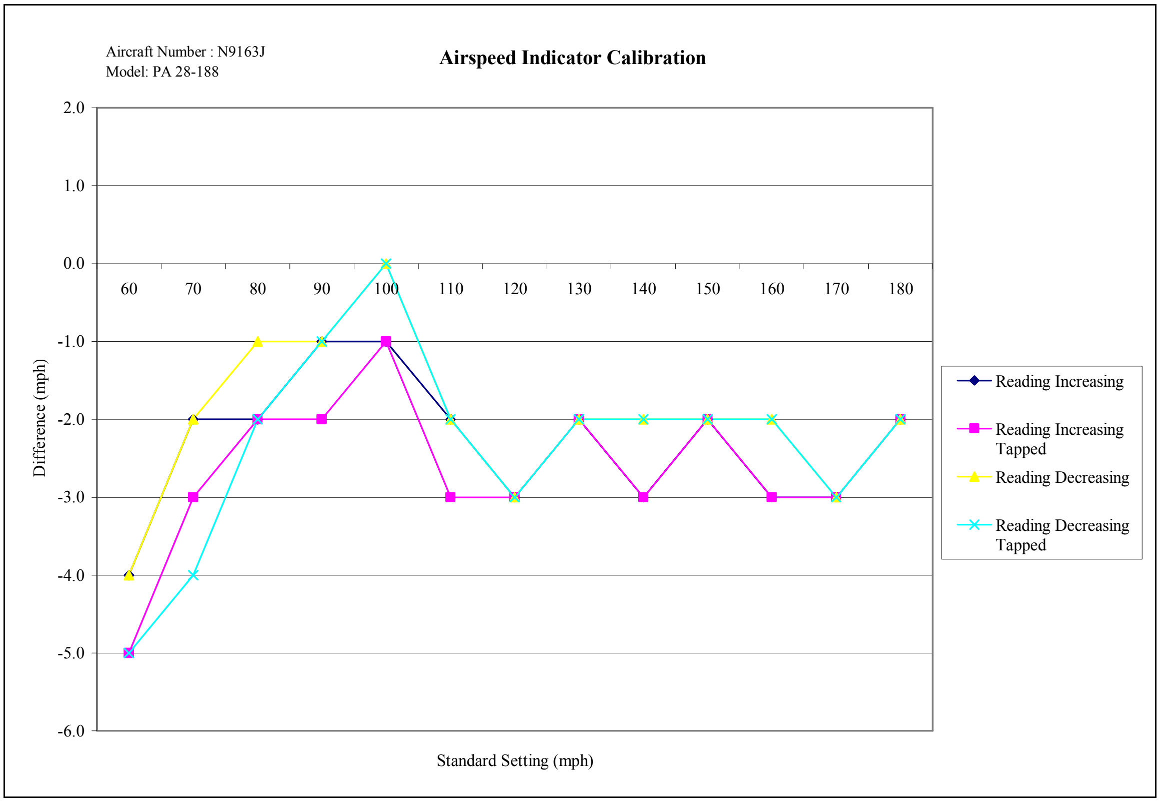

Figure D-6: Airspeed Indicator Calibration Correction

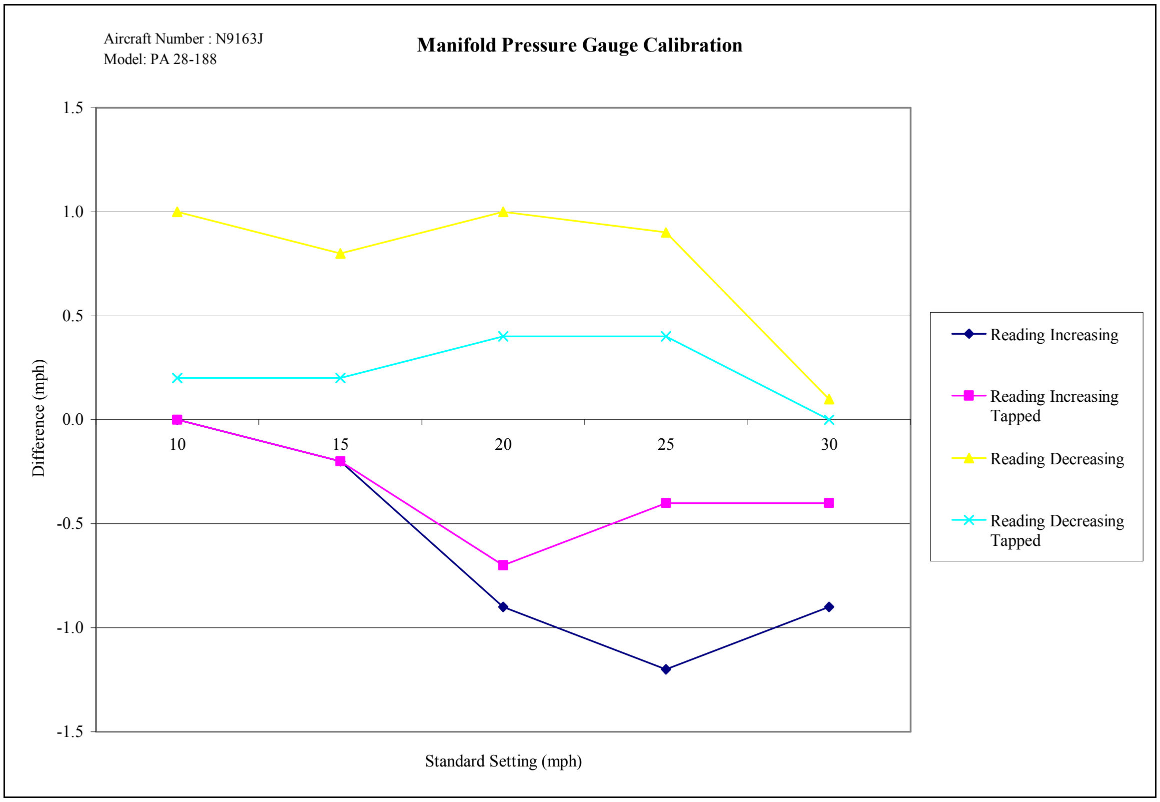

Figure D-7: Manifold Pressure Gauge Calibration Correction

Table D-1: Fight Test Raw and Reduced Data

H_p	H_{pc}	RPM_p	OAT C	OAT_c C	V_o (mph)	V_c (mph)	MAP (" of Hg)	MAP_c (" of Hg)	BHP	$BHP_{tempcor}$	s = (d/q)	d (table)	q=Ta/288.16
1510	1510	2714	19	16	148	145	25	25.8	164	170	0.9436	0.9469	1.0035
1510	1510	2662	18.5	15.5	145	143	24.9	25.7	162	168	0.9453	0.9469	1.0017
1510	1510	2600	18	15	140	138	24	24.8	152	158	0.9469	0.9469	1.0000
1510	1510	2540	18	15	136	134	23	24	142	148	0.9469	0.9469	1.0000
1510	1510	2430	18	15	127.5	125	22	22.8	132	137	0.9469	0.9469	1.0000
1530	1530	2355	18	15	121	118.5	21	21.8	120	125	0.9445	0.9445	1.0000
1530	1530	2280	18	15	117.5	115.5	20	20.8	110	114	0.9445	0.9445	1.0000
1540	1540	2150	18.5	15.5	110	109	19	19.8	94	98	0.9429	0.9445	1.0017
1540	1540	2050	18.5	15.5	100	100	18	18.8	86	89	0.9429	0.9445	1.0017
1550	1550	1930	18.5	15.5	90	89	17.2	18	74	77	0.9429	0.9445	1.0017
3000	3050	2756	19	16	143	141	25.7	26.7	176	182	0.8931	0.8962	1.0034
3000	3050	2600	19	16	135	133	23.2	24	148	153	0.8931	0.8962	1.0034
3000	3050	2548	18	15	130	127.5	22.5	23.3	140	145	0.8962	0.8962	1.0000
3000	3050	2444	18	15	123	121.5	20.8	21.6	124	128	0.8962	0.8962	1.0000
5000	5000	2748	15	12	138	136	24	25	165.5	171	0.8408	0.8320	0.9896
5000	5000	2541	15	12	124	121	21.4	22.2	135	139	0.8408	0.8320	0.9896
5000	5000	2341	14.5	11.5	112	110.5	19.6	20.4	114	118	0.8423	0.8320	0.9878
5000	5000	2136	14	11	99	98	17.7	18.5	96	99	0.8437	0.8320	0.9861
5000	5000	1915	14	11	75	73	15.4	16.2	66	68	0.8437	0.8320	0.9861
7000	7000	2746	10	7	134	132	22.2	23	150	154	0.7937	0.7716	0.9722
7000	7000	2604	10.5	7.5	124	121	20.5	21.3	135	139	0.7922	0.7716	0.9739
7000	7000	2460	10	7	114	112	19.2	20	119	122	0.7937	0.7716	0.9722
7000	7000	2279	10	7	104	104	17.4	18.2	99	102	0.7937	0.7716	0.9722
7000	7000	2045	9.5	6.5	84	83	15.5	16.3	74	76	0.7951	0.7716	0.9705
7000	7000	1885	9.5	6.5	70	67	14.8	15.6	61	63	0.7951	0.7716	0.9705

Table D-2: Comparison of BHP Equations and Charts

	From Lycoming power chart		From Test Prop Load Equation		From Ly Prop Load Equation
Hp	BHP	BHP temp corrected	HP calc with sigma	HP with rootsigma	HP with Ly rootsigma
1510	164	170	157	162	178
1510	162	168	148	153	168
1510	152	158	138	142	156
1510	142	148	129	133	146
1510	132	137	113	116	128
1530	120	125	103	106	116
1530	110	114	93	96	105
1540	94	98	78	80	88
1540	86	89	68	70	77
1550	74	77	56	58	64
3000	176	182	155	165	181
3000	148	153	131	138	152
3000	140	145	123	130	143
3000	124	128	109	115	126
5000	166	171	145	158	174
5000	135	139	115	125	138
5000	114	118	90	98	108
5000	96	99	68	74	82
5000	66	68	49	54	59
7000	150	154	137	153	169
7000	135	139	116	131	144
7000	119	122	98	110	121
7000	99	102	78	88	96
7000	74	76	57	63	70
7000	61	63	44	50	55

VITA

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