NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Washington, D.C. 20594

September 11, 2009

Hover Study

by John O'Callaghan

A. ACCIDENT

Location: Weaverville, CA
Date: August 5, 2008
Time: 19:41 Pacific Daylight Time (PDT)[1]
Aircraft: Sikorsky S-61N helicopter, registration N612AZ
NTSB#: LAX08PA259

B. GROUP

Not Applicable

C. HISTORY OF FLIGHT

On August 5, 2008, about 1941 Pacific daylight time, a Sikorsky S-61N helicopter, N612AZ, impacted trees and terrain during the initial climb after takeoff from Helispot 44, located at an elevation of about 6,000 feet in mountainous terrain near Weaverville, California. The airline transport pilot, the safety crewmember and seven firefighters were killed; the commercial copilot and three firefighters were seriously injured.[2] Impact forces and a postcrash fire destroyed the helicopter. The helicopter was being operated by the United States Forest Service (USFS) as a public flight to transport the firefighters from Helispot 44 to another location. The helicopter was registered to Carson Helicopters, Inc. (CHI) of Grants Pass, Oregon, and leased to Carson Helicopter Services, Inc. (CHSI) of Grants Pass. The USFS had contracted with CHI for the services of the helicopter.[3] Visual meteorological conditions prevailed at the time of the accident, and a company visual flight rules flight plan had been filed.

This Hover Study presents the results of computing the maximum weight at which the helicopter could hover out-of-ground-effect (HOGE) as a function of time for the seven takeoffs recorded on the helicopter's Cockpit Voice Recorder (CVR). The calculations are based on:

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[1] Local time at Weaverville on the day of the accident was Pacific Daylight Time (PDT). PDT = UTC - 7 hours. Times in this Study are in PDT unless otherwise noted.

[2] The safety crewmember was a USFS Inspector Pilot.

[3] Initially, the NTSB was informed that the contract was between the USFS and CHSI. For further information refer to the Operations Factual Report.

- The gas-generator speed (N_g) of the two engines obtained from a sound-spectrum analysis of the engine sounds recorded on the CVR.
- The shaft horsepower required to HOGE as a function of helicopter weight and atmospheric conditions, as provided by the appropriate performance chart in the Rotorcraft Flight Manual (RFM).
- The shaft horsepower (SHP) provided by each engine as a function of N_g, as generated by General Electric (GE) (the engine manufacturer) using mathematical models of the engines' performance.
- Helicopter gross weight values provided by the Operations Group.

The results of the calculations indicate that on the accident takeoff from Helispot 44 (H44), the helicopter was operating within 100 lb. of the HOGE weight corresponding to the shaft horsepower generated by the engines at their maximum ("topping") N_g. The results also indicate that the helicopter was operating under similar but slightly less critical conditions during two previous (successful) takeoffs from H44.

D. DETAILS OF THE INVESTIGATION

I. N_g speeds from sound-spectrum analysis of CVR recordings

Reference 1 contains the transcript of the Cockpit Voice Recorder carried on N612AZ. The CVR recorded 2 hours of information, including during the following takeoffs:

- From Helispot 36 (H36) at about 17:51 (1st H36 takeoff)
- From H44 at about 18:14 (1st H44 takeoff)
- From H36 at 18:29 (2nd H36 takeoff)
- From H44 at 18:43 (2nd H44 takeoff)
- From H36 at 18:54 (3rd H36 takeoff)
- From Trinity base at 19:23 (Trinity takeoff)
- From H44 at 19:40 (3rd H44 takeoff – accident)

Reference 2 documents the sound-spectrum analysis of the engine sounds recorded on the CVR. This analysis resulted in a time-history of gas-generator speeds (N_g) for each engine. While two independent sound signatures for each engine are identifiable on the CVR, It is not possible to identify which signature corresponds to which engine; hence, the N_g speeds are associated with "Engine A" and "Engine B," instead of left or right engines, or #1 or #2 engines. Engine A could be either the left or the right engine, and so could Engine B.

The N_g values for each engine for each of the seven takeoffs listed above are plotted in the top chart of Figures 4-10.

II. RFM HOGE charts

Figure 1 is the "Power Required to Hover Out of Ground Effect" chart, for 103% rotor speed (N_R), for the S-61N equipped with composite blades, as presented in the Carson Rotorcraft Flight Manual Supplement #8. This chart relates the weight of the helicopter and atmospheric conditions defined by pressure altitude (h_p), outside air temperature (OAT), and headwind, to the total shaft horsepower (SHP) required to HOGE.

The atmospheric and helicopter gross weight conditions for each of the seven takeoffs are documented in References 3 and 4, and listed in Table 1. Using the atmospheric conditions listed in this Table and the HOGE chart shown in Figure 1, the specific SHP required to HOGE was computed as a function of weight for each of the seven takeoffs. The results of these calculations are shown in Figures 2a-b. Note that a calm wind was assumed for all takeoffs (regardless of actual wind conditions) except for the 1st H44 takeoff; SHP for both a calm wind and a 5 kt headwind was computed for this case, to quantify the effect of wind on the HOGE weight. The sensitivity of the HOGE weight to variations in atmospheric conditions is considered further Section D-V.

III. Shaft horsepower available as a function of N_g

General Electric computed the shaft horsepower available from the helicopter's CT58-140 engines as a function of gas generator speed, for each of the seven takeoffs, using a mathematical model for a minimum specification engine. The results were adjusted to account for installation losses and the performance of N612AZ's engines based on torque-margin tests performed on August 4, 2008. These tests indicated the #1 engine had a +1.5% torque margin (i.e., 1.5% more power than the specification engine), and the #2 engine had a +4.5% torque margin. GE estimated the installation losses to be about 3%; this resulted in the #1 engine producing 1.5% less than the SHP specified in the math model, and #2 engine producing 1.5% more SHP than specified in the math model. Consequently, the average power output of the engines is equal to that predicted by the math model. GE's SHP calculations are summarized in Table 2.

The SHP produced by the #1 and #2 engines are averaged to compute the power from each engine, since it is not possible to associate a given N_g trace with a specific engine. This average SHP per engine is plotted vs. N_g in Figures 3a-b. The SHP for the accident takeoff (3rd takeoff from H44) was computed for two OAT values: 23° C, the OAT value specified in Table 1, and 20° C, to quantify the effect of temperature on the HOGE weight.

The time-history of N_g shown in the top plots of Figures 4-10 can be used with the SHP values shown in Figures 3a-b to generate a time-history of SHP delivered by each engine during the seven takeoffs, as shown in the middle plots in Figures 4-10. It is assumed in these results that each engine is producing the average SHP indicated in Table 2.

IV. Time-history HOGE weight calculations

The time-history of SHP delivered by the engines during each of the seven takeoffs is used along with the SHP required to HOGE plots shown in Figures 2a-b to generate a time-history of HOGE weight. When the engines are operating at topping speed (between 102% and 103% N_g), this weight will correspond to the maximum HOGE capability of the helicopter. When the engines are below topping speed, there is additional power available, and the maximum HOGE capability will be higher than that produced by the calculation.

The results of the calculations are shown in the bottom charts in Figures 4-10. For the three takeoffs from H36 and the takeoff from Trinity, the N_g is well below the topping speed, and so the HOGE weights for these takeoffs do not represent the maximum HOGE weight possible. Indeed, in Figure 4 (1st takeoff from H36), the computed HOGE weight is lower than the actual takeoff gross weight of the helicopter. This indicates that for this takeoff, the helicopter most likely did not ascend vertically out of ground effect, but instead transitioned to forward flight while in ground effect, thereby reducing the climb power required. Note that if the wind speed shown in Table 1 for this case (5-10 kts) is assumed to be a headwind component, this will reduce the SHP required to hover at a given weight, and correspondingly increase the HOGE weight calculation shown in Figure 4.

In Figure 6 (the 2nd takeoff from H36), the HOGE weight calculation is well above the actual weight of the helicopter. In this case, the engines are delivering power in excess of that required for HOGE, so the helicopter is likely climbing at a high rate during the period shown.

The 3rd takeoff from H36 and the takeoff from Trinity (Figures 8 and 9, respectively) also show less-than-maximum power and HOGE weight calculations that exceed the takeoff weight of the helicopter, suggesting healthy climb rates. Where the HOGE weight calculation tips to or below the estimated takeoff weight, the helicopter is most likely in forward flight and has much reduced power requirements for climb, compared to power required to HOGE or climb vertically.

Figures 5a-b, 7, and 10a-b indicate that the engines were producing topping power for significant times during the three takeoffs from H44. For the accident takeoff, the engines were at topping for the last 30 seconds of the CVR recording; for the previous two takeoffs from H44, the engines were at topping for about 20 seconds before the power demand was reduced.

While the engines are at topping, the HOGE weight calculation represents the maximum HOGE weight achievable. Significantly, for the 1st takeoff from H44 (Figures 5a-b), this weight is about 230 lb greater than the takeoff weight listed in Table 1, assuming a calm wind. For a 5-kt headwind, the maximum HOGE weight is about 380 lb greater than the takeoff weight.

For the 2nd takeoff from H44 (Figure 7), during the period the engines are at topping speed, the maximum HOGE weight is about 790 lb greater than the takeoff weight listed in Table 1.

For the accident takeoff (3rd from H44, Figures 10a-b), during the time the engines are at topping speed, the maximum HOGE weight is about 90 lb greater than the takeoff weight for an OAT of 23° C, and is about 330 lb greater than the takeoff weight for an OAT of 20° C.

Hence, for the conditions listed in Table 1 (using a calm wind for the 1st takeoff from H44, and 23° C OAT for the accident takeoff), of the three takeoffs from H44, the accident takeoff has the least margin between the maximum HOGE weight and the actual helicopter weight (90 lb, vs. 230 lb. for the 1st takeoff and 790 lb for the 2nd takeoff). In terms of a percentage of the maximum HOGE weight at each condition, these weight margins are equivalent to a 1.2% margin for the 1st takeoff, a 4.2% margin for the 2nd takeoff, and a 0.5% margin for the accident takeoff.

For the three takeoffs from H36 and the takeoff from Trinity base, the engine N_g is well below the topping speed, and so the HOGE weights calculated in this Study for these takeoffs do not represent the maximum HOGE weight possible. The excess power available in these cases will make their maximum HOGE weights greater than those shown in the calculations.

V. HOGE weight sensitivity study

Overview

The maximum HOGE weight values presented in Figures 5, 7, and 10 are defined by the power required to HOGE, and the power available from the engines. These, in turn, depend on the atmospheric conditions (pressure altitude, temperature, and wind), and the actual power available from the engines compared to the specification power. This section of the Study examines the sensitivity of the HOGE weight values to these variables. The "HOGE sensitivity" is defined here as the variation in HOGE weight as a function of small variations in temperature, wind, and engine performance about the nominal conditions underlying the results presented in Section D-IV.

In a steady hover at the maximum HOGE weight, the power required to hover exactly matches the maximum power available from the engines:

$$P_{REQD}\left(h_P, T, W, V_W\right) = P_{AVAIL}\left(h_P, T, N_g, f\right) \qquad [1]$$

P_{REQD} is the required power, P_{AVAIL} is the available power, and the parentheses indicate that these terms are functions of the quantities enclosed in the parentheses:

h_p = pressure altitude
T = static temperature
W = helicopter weight
V_W = wind speed
N_g = gas generator speed
f = torque margin relative to minimum specification engine

Since P_{REQD} must always equal P_{AVAIL} for the helicopter to hover, any change in P_{REQD} must be balanced by a corresponding change in P_{AVAIL}:

$$\Delta P_{REQD}\left(h_p, T, W, V_W\right) = \Delta P_{AVAIL}\left(h_p, T, N_g, f\right) \qquad [2]$$

Both P_{REQD} and P_{AVAIL} are non-linear functions of the terms in parentheses in Equations [1] and [2]. However, for small changes in these terms about an equilibrium state, the dependence of P_{REQD} and P_{AVAIL} on the terms can be linearized, and the change in P_{REQD} and P_{AVAIL} expressed in terms of their partial derivatives with respect to each of the terms:

$$\Delta P_{REQD}\left(h_p, T, W, V_W\right) = \frac{\partial P_{REQD}}{\partial h_p}\Delta h_p + \frac{\partial P_{REQD}}{\partial T}\Delta T + \frac{\partial P_{REQD}}{\partial W}\Delta W + \frac{\partial P_{REQD}}{\partial V_W}\Delta V_W \qquad [3]$$

$$\Delta P_{AVAIL}\left(h_p, T, N_g, f\right) = \frac{\partial P_{AVAIL}}{\partial h_p}\Delta h_p + \frac{\partial P_{AVAIL}}{\partial T}\Delta T + \frac{\partial P_{AVAIL}}{\partial N_g}\Delta N_g + \frac{\partial P_{AVAIL}}{\partial f}\Delta f \qquad [4]$$

In this case, the values of h_p and Ng are known with more confidence than the other terms, and so Δh_p and ΔN_g are assumed to equal zero in this sensitivity study. With this assumption, combining Equations [2], [3], and [4] and solving for ΔW gives

$$\Delta W = \frac{\left(\frac{\partial P_{AVAIL}}{\partial T} - \frac{\partial P_{REQD}}{\partial T}\right)\Delta T + \frac{\partial P_{AVAIL}}{\partial f}\Delta f - \frac{\partial P_{REQD}}{\partial V_W}\Delta V_W}{\frac{\partial P_{REQD}}{\partial W}} \qquad [5]$$

Equation [5] shows the variation in maximum HOGE weight (W) as a function of variations in T, f, and V_W. Using the definitions

$$\frac{\partial W}{\partial T} = \frac{\left(\frac{\partial P_{AVAIL}}{\partial T} - \frac{\partial P_{REQD}}{\partial T}\right)\Delta T}{\frac{\partial P_{REQD}}{\partial W}} \qquad [6]$$

$$\frac{\partial W}{\partial f} = \left(\frac{\frac{\partial P_{AVAIL}}{\partial f}}{\frac{\partial P_{REQD}}{\partial W}}\right) \qquad [7]$$

$$\frac{\partial W}{\partial V_W} = -\left(\frac{\frac{\partial P_{REQD}}{\partial V_W}}{\frac{\partial P_{REQD}}{\partial W}}\right) \qquad [8]$$

and substituting these into Equation [5] gives

$$\Delta W = \left(\frac{\partial W}{\partial T}\right)\Delta T + \left(\frac{\partial W}{\partial f}\right)\Delta f + \left(\frac{\partial W}{\partial V_W}\right)\Delta V_W \qquad [9]$$

The takeoffs of interest in this sensitivity study are the first takeoff from H44, and the third takeoff from H44 (the accident takeoff); these takeoffs have the least margin between the maximum HOGE weight and the actual weight of the helicopter. The values of the partial derivatives in Equation [9] at the conditions of these takeoffs can be evaluated from the results shown in Figures 1, 2 , 5, 7, and 10, as described below.

Temperature sensitivity

$\partial W/\partial T$ for the first takeoff from H44 can be determined from Figures 5 and 7. From Figure 5, with calm winds at h_p = 6106 ft. and T = 29° C, the maximum HOGE weight is about 18600 lb. From Figure 7, under the same conditions but with T = 29° C, the maximum HOGE weight is 18760 lb. Consequently,

$$\left.\frac{\partial W}{\partial T}\right|_{H44\#1} = \frac{18600\text{ lb} - 18780\text{ lb}}{29^\circ\text{ C} - 27^\circ\text{ C}} = -90\text{ lb}/^\circ\text{C} \qquad [10]$$

$\partial W/\partial T$ for the third takeoff from H44 (the accident takeoff) can be determined from Figure 10. With calm winds at h_p = 6106 ft. and T = 23° C, the maximum HOGE weight is about 19100 lb. Under the same conditions but with T = 20° C, the maximum HOGE weight is 19340 lb. Consequently,

$$\left.\frac{\partial W}{\partial T}\right|_{H44\#3} = \frac{19100\text{ lb} - 19340\text{ lb}}{23^\circ\text{ C} - 20^\circ\text{ C}} = -80\text{ lb}/^\circ\text{C} \qquad [11]$$

Power margin sensitivity

$\partial W/\partial f$ can be computed by first computing $\partial P_{AVAIL}/\partial f$ and $\partial P_{REQD}/\partial W$ and then using Equation [7]. $\partial P_{AVAIL}/\partial f$ for the first takeoff from H44 can be determined from Figure 5. At topping, the total output of the engines is about 2226 HP; as described above, this corresponds to engines with an average 3% power margin above minimum specification engines, reduced by 3% to account for installation losses. Hence, the nominal min-spec engines at this condition produce 2226 HP. If the engines produced 1.5% more power than min-spec, their combined output would be (2226 HP)(1.015) = 2259 HP. It follows that

$$\left.\frac{\partial P_{AVAIL}}{\partial f}\right|_{H44\#1} = \frac{2259\text{ HP} - 2226\text{ HP}}{1.5\% - 0\%} = 22\text{ HP}/\% \qquad [12]$$

$\partial P_{REQD}/\partial W$ for the first takeoff from H44 can be determined from Figure 2. As noted above, at topping the engines are producing about 2226 HP. The HOGE weight corresponding to 2294 HP (a little more than topping power) is 18969 lb; the HOGE weight corresponding to 2132 HP (a little less than topping power) is 18089 lb. Consequently,

$$\left.\frac{\partial P_{REQD}}{\partial W}\right|_{H44\#1} = \frac{2294\text{ HP} - 2132\text{ HP}}{18969\text{ lb} - 18089\text{ lb}} = 0.184\text{ HP/lb} \qquad [13]$$

Using the values from Equations [12] and [13] in Equation [7],

$$\left.\frac{\partial W}{\partial f}\right|_{H44\,\#1} = \left(\frac{\left.\frac{\partial P_{AVAIL}}{\partial f}\right|_{H44\,\#1}}{\left.\frac{\partial P_{REQD}}{\partial W}\right|_{H44\,\#1}} \right) = \frac{22\text{ HP}/\%}{0.184\text{ HP/lb}} = 120\text{ lb}/\% \qquad [14]$$

$\partial W/\partial f$ for the third takeoff from H44 (the accident takeoff) can be computed in a manner similar to that just described for the first takeoff from H44. From Figure 10, at topping, the total output of the engines at 23° C is about 2300 HP. A power margin of +1.5% at this condition would yield (2300 HP)(1.015) = 2335 HP. Hence

$$\left.\frac{\partial P_{AVAIL}}{\partial f}\right|_{H44\#3} = \frac{2335\text{ HP} - 2300\text{ HP}}{1.5\% - 0\%} = 23\text{ HP}/\% \qquad [15]$$

From Figure 2, with calm wind at 23° C, the HOGE weights for power outputs slightly above and below the 2300 HP topping power are 19276 lb at 2316 HP, and 19110 lb at 2281 HP. Hence

$$\left.\frac{\partial P_{REQD}}{\partial W}\right|_{H44\#3} = \frac{2316\,\text{HP} - 2281\,\text{HP}}{19276\,\text{lb} - 19110\,\text{lb}} = 0.211\,\text{HP/lb} \qquad [16]$$

Using the values from Equations [15] and [16] in Equation [7],

$$\left.\frac{\partial W}{\partial f}\right|_{H44\,\#3} = \left(\frac{\left.\frac{\partial P_{AVAIL}}{\partial f}\right|_{H44\,\#3}}{\left.\frac{\partial P_{REQD}}{\partial W}\right|_{H44\,\#3}} \right) = \frac{23\,\text{HP/\%}}{0.211\,\text{HP/lb}} = 108\,\text{lb/\%} \qquad [17]$$

Wind sensitivity

$\partial W/\partial V_W$ for the first takeoff from H44 can be determined from Figure 5. With calm wind, the maximum HOGE weight is about 18600 lb. With a 5 kt headwind, the maximum HOGE weight is about 18750 lb. Consequently,

$$\left.\frac{\partial W}{\partial V_W}\right|_{H44\#1} = \frac{18750\,\text{lb} - 18600\,\text{lb}}{5\,\text{kt} - 0\,\text{kt}} = 30\,\text{lb/kt} \qquad [18]$$

$\partial W/\partial V_W$ for the third takeoff from H44 (the accident takeoff) can be determined from Figures 1 and 10. At T = 23° C, hp = 6106 ft, and calm wind, Figure 10 indicates that the power at topping is about 2300 HP and the maximum HOGE weight is about 19100 lb. With this power at these conditions, Figure 1 indicates that the maximum HOGE weight with a 5 kt headwind is about 19250 lb. Hence,

$$\left.\frac{\partial W}{\partial V_W}\right|_{H44\#3} = \frac{19250\,\text{lb} - 19100\,\text{lb}}{5\,\text{kt} - 0\,\text{kt}} = 30\,\text{lb/kt} \qquad [19]$$

Sensitivity study results

The results obtained in Equations [10]-[19] are summarized in Table 3. These values can be used to determine the variation in HOGE weight resulting from small deviations in temperature, power margin, and wind from the nominal values.

The effect of variations in temperature and wind on the HOGE weight margin are shown graphically in Figure 11 for the first and third takeoffs from H44. The “weight margin” is defined as the difference between the maximum HOGE weight and the actual helicopter gross weight for the conditions shown. The weight margin is shown both in absolute pounds, and as a percentage of the maximum HOGE weight for each takeoff. The weight margins corresponding to the nominal temperature and wind conditions for the takeoffs are denoted by the red circles.

The magnitude of the weight margin can be put into perspective by considering the margin that would be provided by the USFS operational guidelines. Reference 5 indicates that the maximum HOGE weight for the accident takeoff conditions, using the charts provided in the RFM, is 17550 lb. In addition, Reference 5 notes that for “non-jettisonable” loads the USFS requires a 550 lb safety margin from the maximum HOGE weight defined in the RFM. Consequently, USFS operational guidelines limit the maximum helicopter gross weight for the accident takeoff to 17000 lb.

As indicated in Figure 10, the actual maximum HOGE weight for the accident takeoff (accounting for the additional power margin in the engines, and the engine’s maximum power output) is 19100 lb. Consequently, the USFS guidelines provide a weight margin from the actual maximum HOGE of (19100 lb – 17000 lb) = 2100 lb, or 11% of the actual maximum HOGE weight.

For the actual takeoff weight of 19008 lb, this weight margin was reduced from 2100 lb to 92 lb, or from 11% to 0.5% of the maximum HOGE weight.

D. CONCLUSIONS

The results of the calculations presented in this Study indicate that on the accident takeoff from Helispot 44 (H44), the helicopter was operating within 100 lb. of the HOGE weight corresponding to the SHP generated by the engines at their maximum (“topping”) speed. The results also indicate that the helicopter was operating under similar but slightly less critical conditions during two previous (successful) takeoffs from H44. Specifically, of the three takeoffs from H44, the accident takeoff has the least margin between the maximum HOGE weight and the actual helicopter weight (90 lb, vs. 230 lb. for the 1st takeoff and 790 lb for the 2nd takeoff). In terms of a percentage of the maximum HOGE weight at each condition, these weight margins are equivalent to a 1.2% margin for the 1st takeoff, a 4.2% margin for the 2nd takeoff, and a 0.5% margin for the accident takeoff.

For the accident takeoff, the USFS operational guidelines limit the helicopter gross weight to 17000 lb, and provide a weight margin of 2100 lb, or 11%, from the actual maximum HOGE weight of 19100 lb. For the actual takeoff weight of 19008 lb, this weight margin was reduced from 2100 lb to about 90 lb, or from 11% to 0.5% of the maximum HOGE weight.

For the three takeoffs from H36 and the takeoff from Trinity base, the engine N_g is well below the topping speed, and so the HOGE weights calculated in this Study for these takeoffs do not represent the maximum HOGE weight possible. The excess power available in these cases will make their maximum HOGE weights greater than those shown in the calculations.

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F. REFERENCES

1. National Transportation Safety Board, Office of Research and Engineering, *Group Chairman's CVR – FDR Factual Report, Sikorsky S-61N, Weaverville, CA, August 5, 2008,* NTSB Accident Number LAX08PA259, (Washington, DC: NTSB, March 25, 2009). (Contact NTSB at pubinq@ntsb.gov).

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3. National Transportation Safety Board, Office of Aviation Safety, *Meteorological Factual Report, Sikorsky S-61N, Weaverville, CA, August 5, 2008,* NTSB Accident Number LAX08PA259, (Washington, DC: NTSB, June 15, 2009). (Contact NTSB at pubinq@ntsb.gov).

4. National Transportation Safety Board, Office of Aviation Safety, *Attachment #70 to the Operations Factual Report: Mission Profile of Departures, Sikorsky S-61N, Weaverville, CA, August 5, 2008,* NTSB Accident Number LAX08PA259, (Washington, DC: NTSB, 2009). (Contact NTSB at pubinq@ntsb.gov).

5. National Transportation Safety Board, Office of Aviation Safety, *Operations Factual Report, Sikorsky S-61N, Weaverville, CA, August 5, 2008,* NTSB Accident Number LAX08PA259, (Washington, DC: NTSB, September 9, 2009). (Contact NTSB at pubinq@ntsb.gov).

TABLES

Takeoff ID	Time, PDT	OAT, °C	Wind, kts	Pressure. altitude, ft	Gross weight, lb
1st H36	17:51	34	WNW 5-10	1500	17500
1st H44	18:14	29	Calm	6106	18368
2nd H36	18:29	33	WNW 5-10	1500	15732
2nd H44	18:43	27	Calm	6106	18001
3rd H36	18:54	31	W 3-10	1500	15415
Trinity	19:23	27	SE 2-8	3168	16950
3rd H44	19:40	23	Calm	6106	19008

Table 1. Conditions for takeoffs recorded on CVR.

CT58-140 Cycle Deck #75029; NTSB Final Runs, Feb 2009
Estimated Installed Performance

1st H44 - 101% Nr				2nd H44 - 101.5% Nr				3rd H44 - 100% Nr				3rd H44 - 100% Nr			
6,106 ft PA; 29ºC OAT				6,106 ft PA; 27ºC OAT				6,106 ft PA; 23ºC OAT				6,106 ft PA; 20ºC OAT			
Ng	**SHP #1**	**SHP #2**	**Average**	**Ng**	**SHP #1**	**SHP #2**	**Average**	**Ng**	**SHP #1**	**SHP #2**	**Average**	**Ng**	**SHP #1**	**SHP #2**	**Average**
79.6%	78	80	79	79.6%	81	83	82	79.6%	89	92	90	79.6%	94	97	95
82.3%	122	126	124	82.3%	127	131	129	82.3%	139	143	141	82.3%	148	152	150
85.0%	187	193	190	85.0%	193	199	196	85.0%	206	212	209	85.0%	219	226	222
87.7%	276	284	280	87.7%	286	295	290	87.7%	307	316	312	87.7%	323	333	328
90.4%	391	403	397	90.4%	404	416	410	90.4%	430	443	437	90.4%	451	465	458
93.1%	531	547	539	93.1%	546	563	554	93.1%	577	594	586	93.1%	603	621	612
95.7%	698	719	709	95.7%	718	740	729	95.7%	759	782	771	95.7%	795	819	807
98.4%	905	932	919	98.4%	923	951	937	98.4%	956	985	971	98.4%	982	1012	997
101.1%	1069	1101	1085	101.1%	1084	1117	1100	101.1%	1105	1139	1122	101.1%	1122	1156	1139
102.3%	1126	1160	1143	102.4%	1142	1176	1159	102.7%	1164	1199	1182	103.0%	1188	1224	1206

1st H36 - 103% Nr				2nd H36 - 102% Nr				3rd H36 - 103% Nr				Trinity - 103% Nr			
1,500 ft PA; 34ºC OAT				1,500 ft PA; 33ºC OAT				1,500 ft PA; 31ºC OAT				3,168 ft PA; 27ºC OAT			
Ng	**SHP #1**	**SHP #2**	**Average**	**Ng**	**SHP #1**	**SHP #2**	**Average**	**Ng**	**SHP #1**	**SHP #2**	**Average**	**Ng**	**SHP #1**	**SHP #2**	**Average**
79.6%	80	82	81	79.6%	83	86	84	79.6%	85	88	86	79.6%	87	90	88
82.3%	126	130	128	82.3%	130	134	132	82.3%	133	137	135	82.3%	138	142	140
85.0%	199	206	202	85.0%	204	210	207	85.0%	209	215	212	85.0%	212	218	215
87.7%	295	304	299	87.7%	300	309	305	87.7%	311	320	316	87.7%	316	326	321
90.4%	423	436	429	90.4%	430	443	437	90.4%	444	457	451	90.4%	447	461	454
93.1%	582	600	591	93.1%	591	609	600	93.1%	608	626	617	93.1%	606	624	615
95.7%	770	793	782	95.7%	780	804	792	95.7%	802	826	814	95.7%	798	822	810
98.4%	1010	1041	1025	98.4%	1023	1054	1039	98.4%	1049	1081	1065	98.4%	1028	1059	1044
101.1%	1221	1258	1240	101.1%	1227	1264	1246	101.1%	1249	1287	1268	101.1%	1208	1245	1226
102.4%	1307	1347	1327	102.5%	1312	1352	1332	102.5%	1335	1376	1355	102.7%	1284	1323	1304

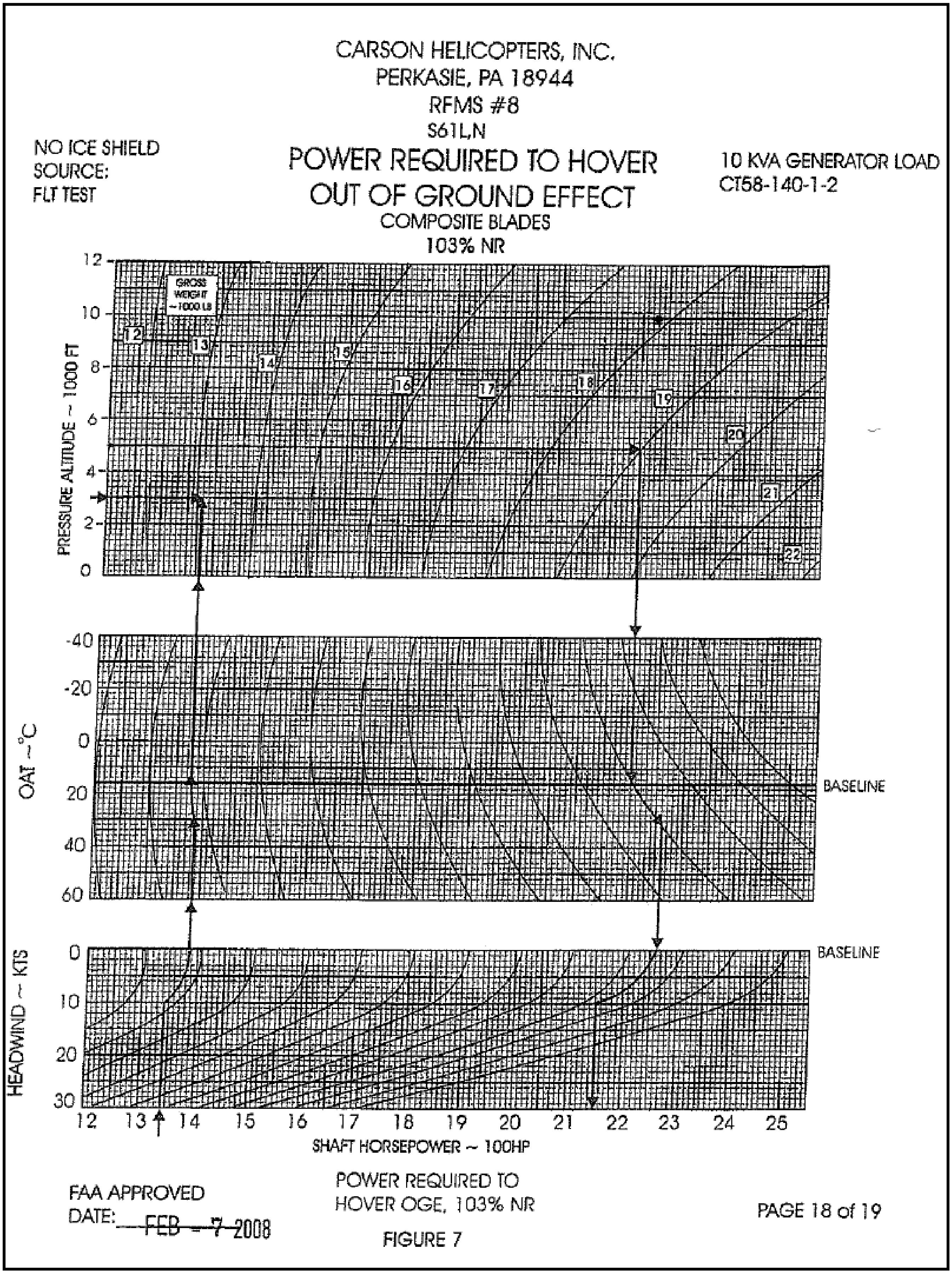
0 knots airspeed; No horsepower or bleed extraction
Installation losses due to inlet and exhaust systems estimated to be ~3%
#1 engine torque margin on 8/4/08 was +1.5%, ie. net margin of -1.5% (+1.5% minus 3%)
#2 engine torque margin on 8/4/08 was +4.5%, ie. net margin of +1.5% (+4.5% minus 3%)

Table 2. Engine power as a function of Ng, as computed by General Electric using a mathematical model of the CT58-140 engine.

Parameter	Value at H44 #1	Value at H44 #3 (accident)
$\partial W/\partial T$	-90 lb/°C	-80 lb/°C
$\partial W/\partial f$	120 lb/%	108 lb/%
$\partial W/\partial V_W$	30 lb/kt	30 lb/kt

Table 3. Sensitivity study results: values of partial derivatives of HOGE weight (W) with respect to temperature (T), engine power margin (f), and wind (V_W) for 1st and 3rd takeoffs from H44.

FIGURES



CARSON HELICOPTERS, INC.
PERKASIE, PA 18944
RFMS #8
S61L,N

NO ICE SHIELD
SOURCE:
FLT TEST

POWER REQUIRED TO HOVER OUT OF GROUND EFFECT

COMPOSITE BLADES
103% NR

10 KVA GENERATOR LOAD
CT58-140-1-2

FAA APPROVED
DATE: FEB - 7 2008

POWER REQUIRED TO
HOVER OGE, 103% NR

FIGURE 7

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Figure 1.

Maximum HOGE weight as a function of power
Per Carson S-61N RFM Supplement #8

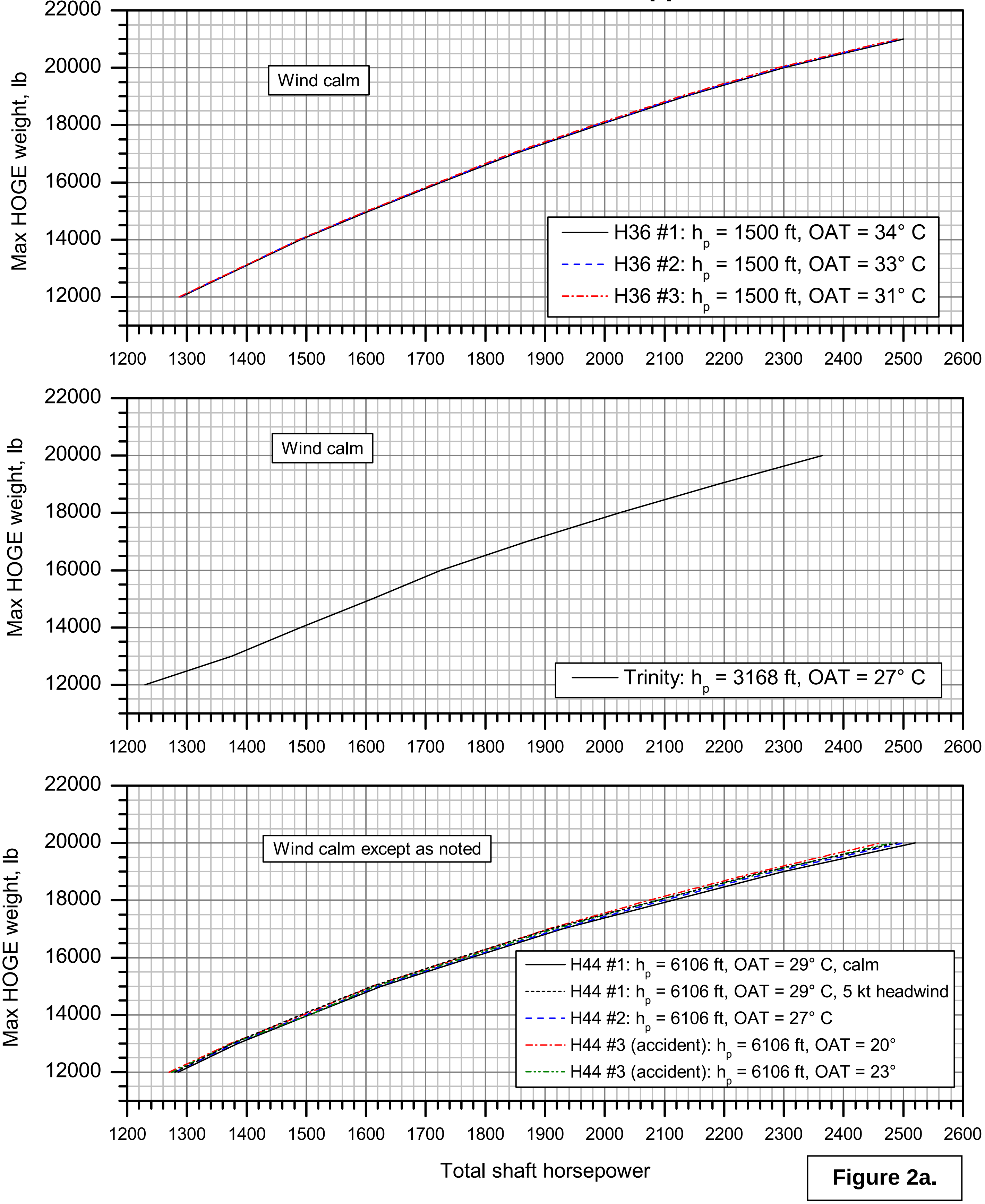


Figure 2a.

Maximum HOGE weight as a function of power
Per Carson S-61N RFM Supplement #8 (detail)

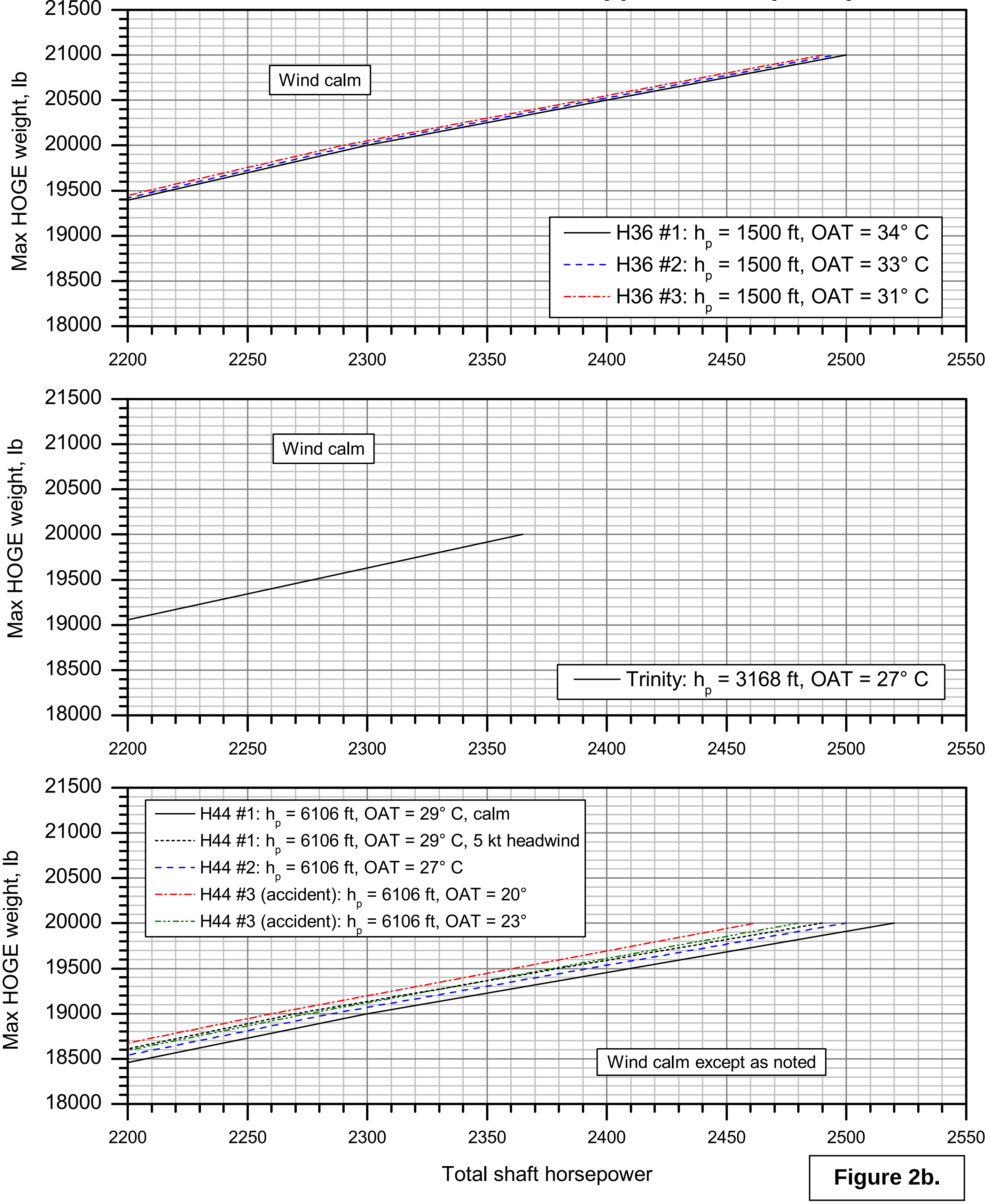
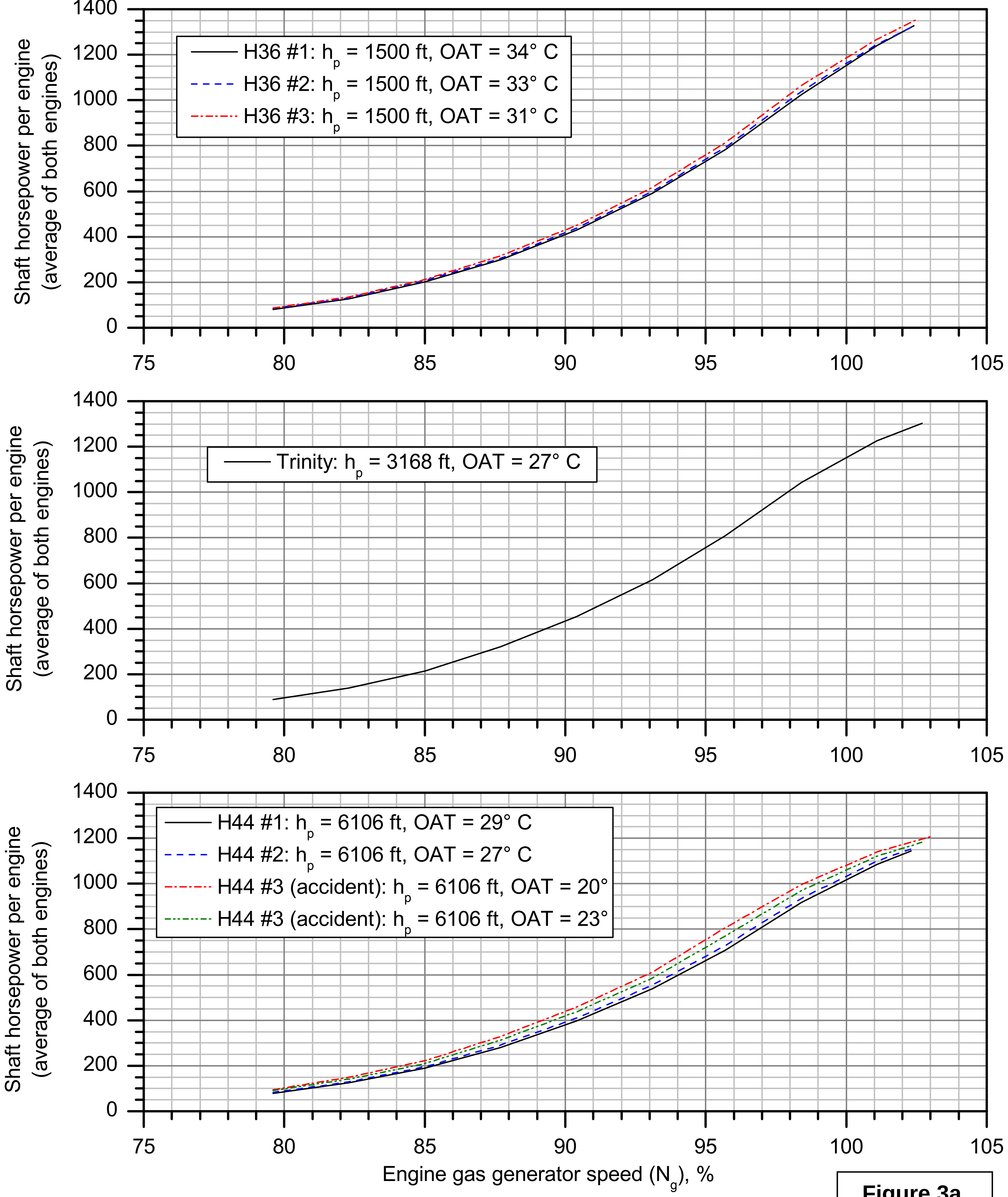


Figure 2b.



Engine horsepower as a function of gas generator speed
Average of both engines from GE engine cycle deck runs

Figure 3a.

Engine horsepower as a function of gas generator speed
Average of both engines from GE engine cycle deck runs (detail)

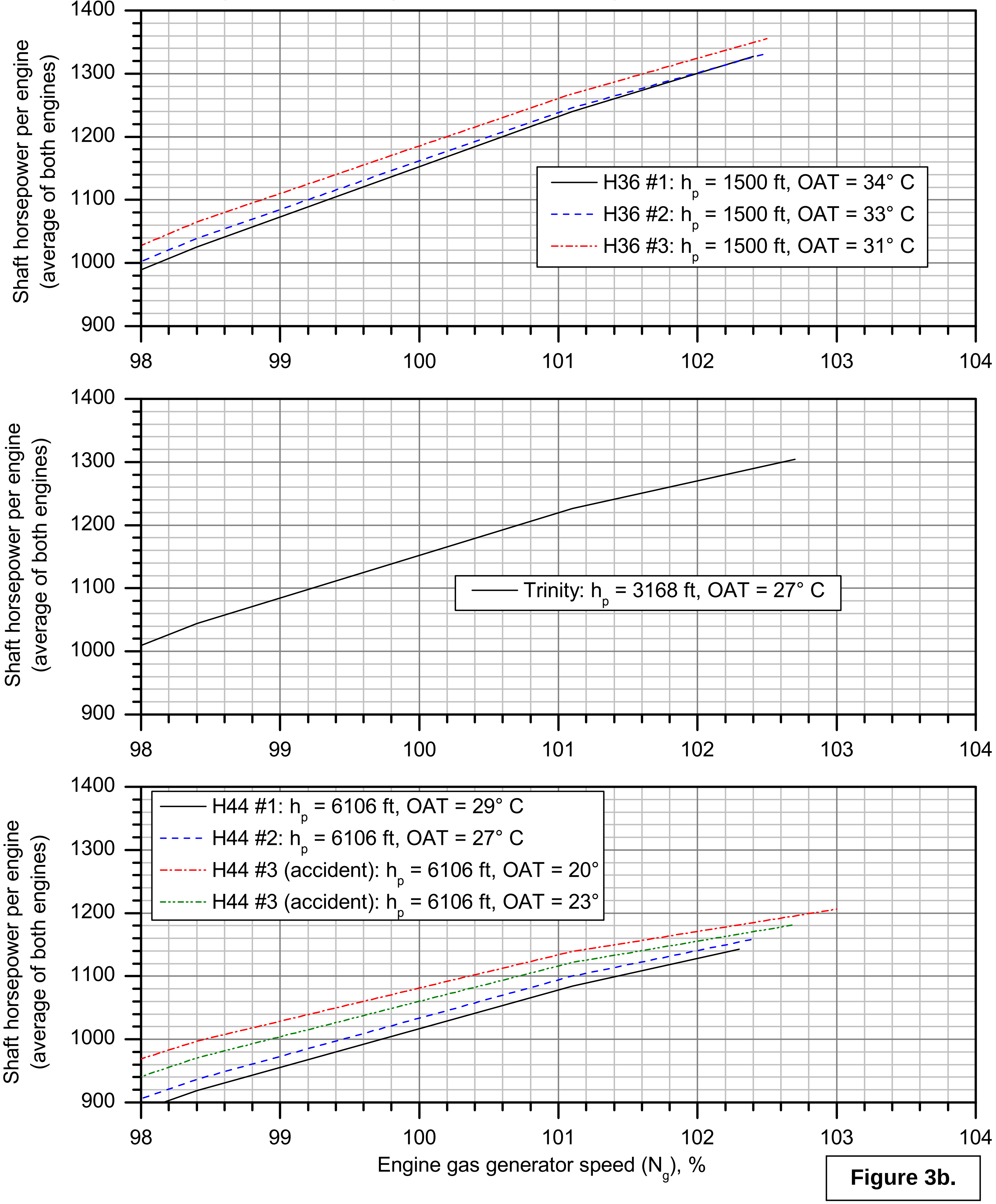


Figure 3b.

Engine and rotor speed, engine power, and HOGE weight vs. time
H36 takeoff #1: h_p = 1500 ft, OAT = 34° C, wind calm

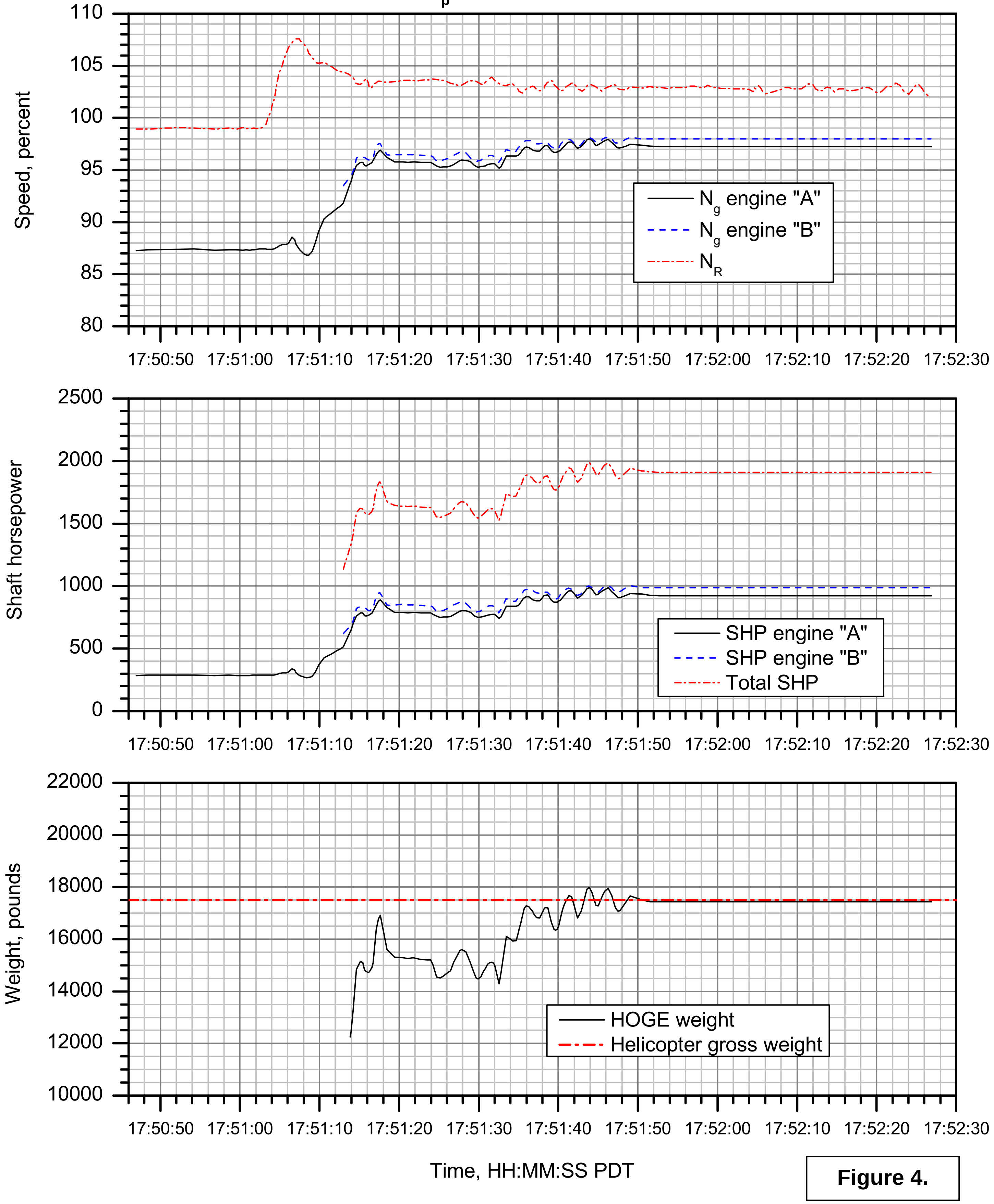


Figure 4.

Engine and rotor speed, engine power, and HOGE weight vs. time
H44 takeoff #1: h_p = 6106 ft, OAT = 29° C, wind calm & 5 kt headwind

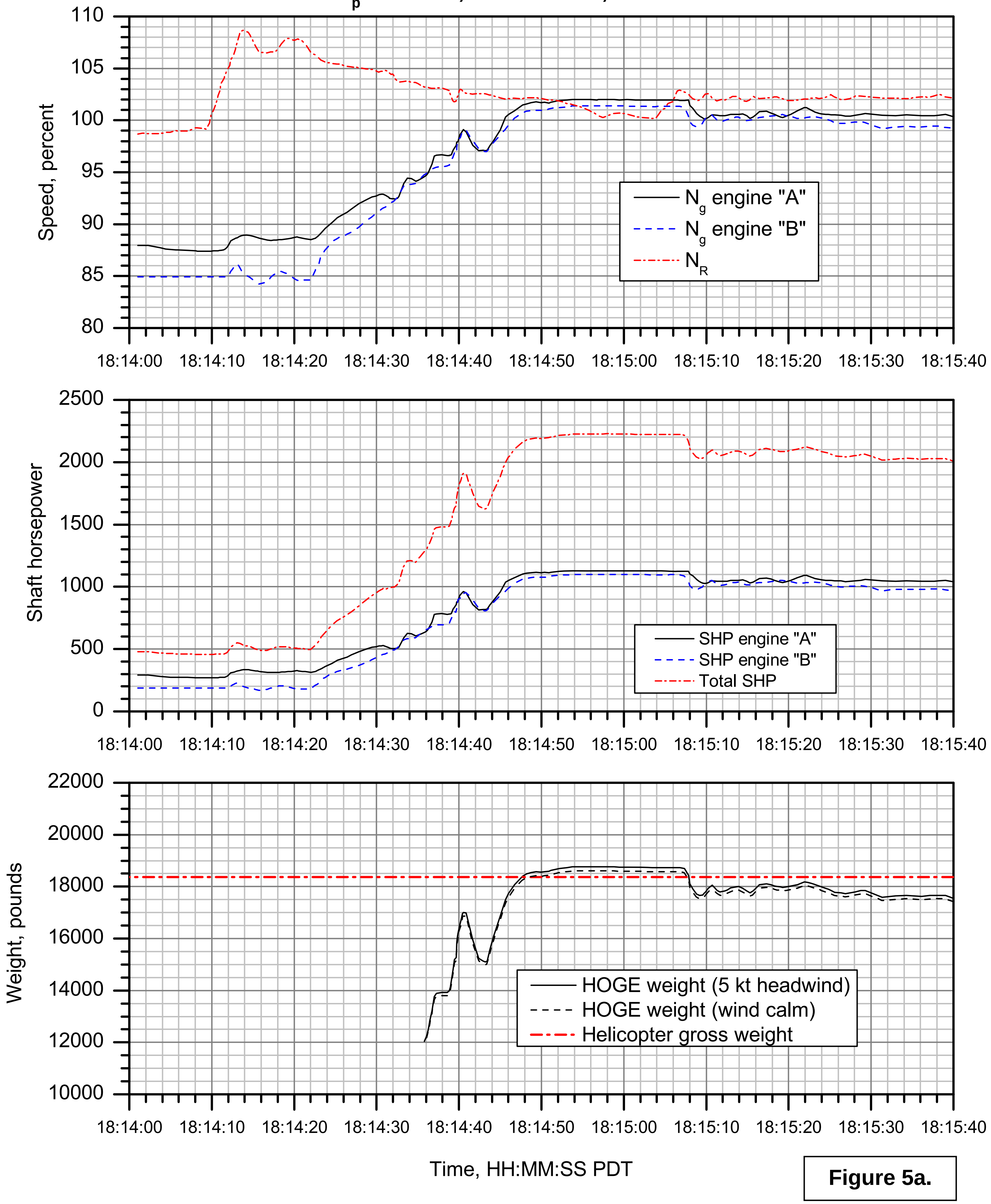


Figure 5a.

Engine and rotor speed, engine power, and HOGE weight vs. time
H44 takeoff #1: h_p = 6106 ft, OAT = 29° C, wind calm & 5 kt headwind (detail)

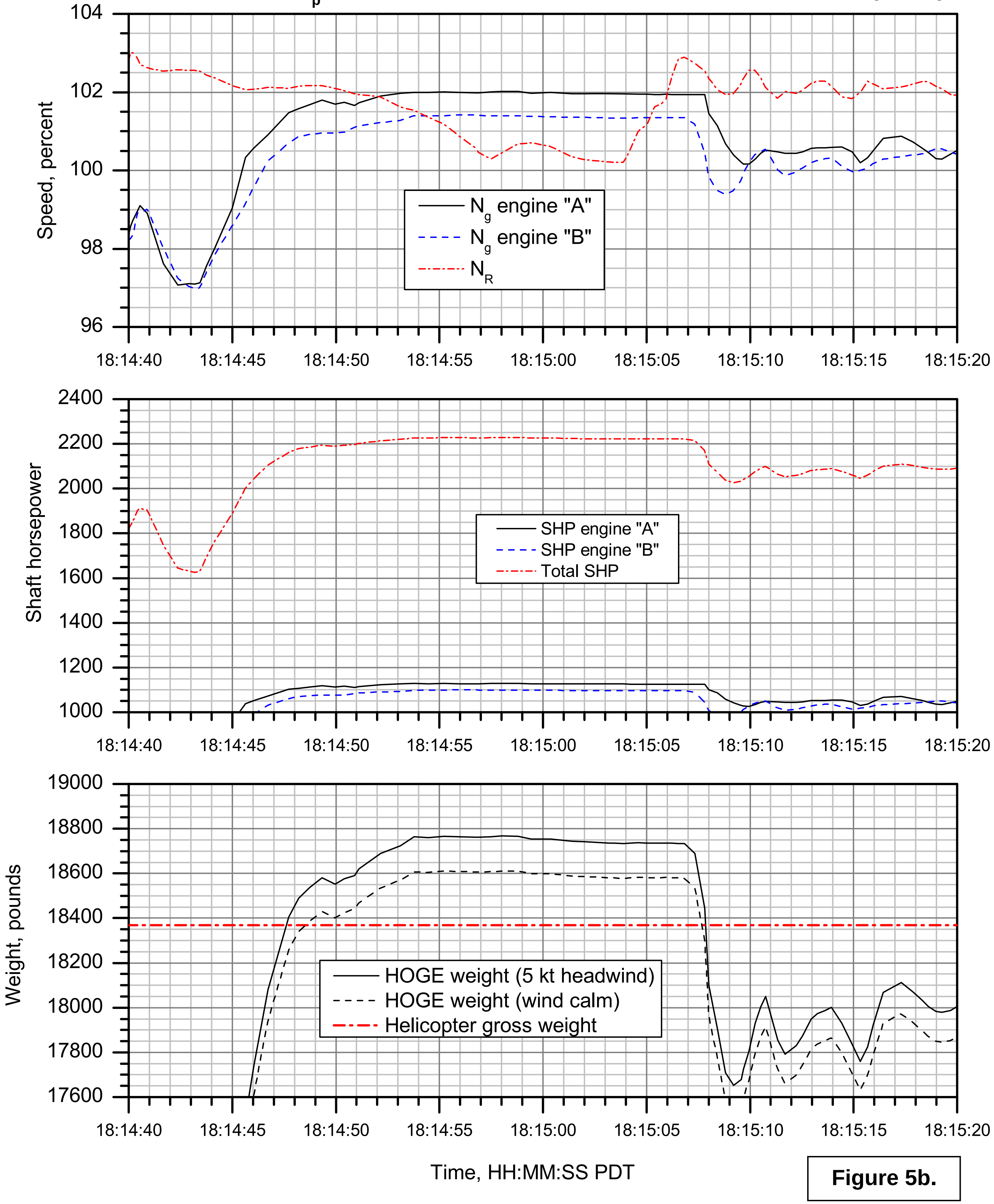


Figure 5b.

Engine and rotor speed, engine power, and HOGE weight vs. time
H36 takeoff #2: h_p = 1500 ft, OAT = 33° C, wind calm

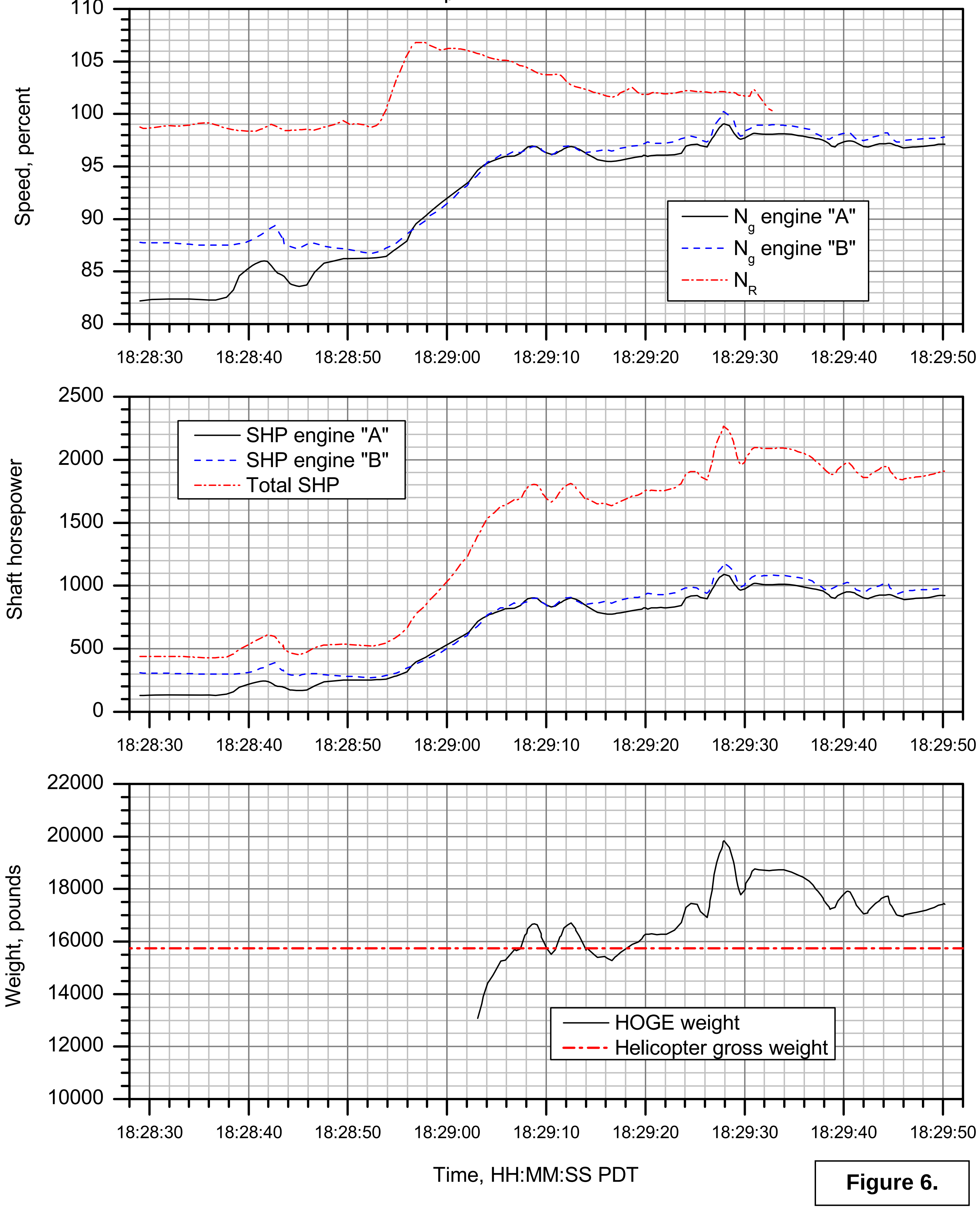


Figure 6.

Engine and rotor speed, engine power, and HOGE weight vs. time
H44 takeoff #2: h_p = 6106 ft, OAT = 27° C, wind calm

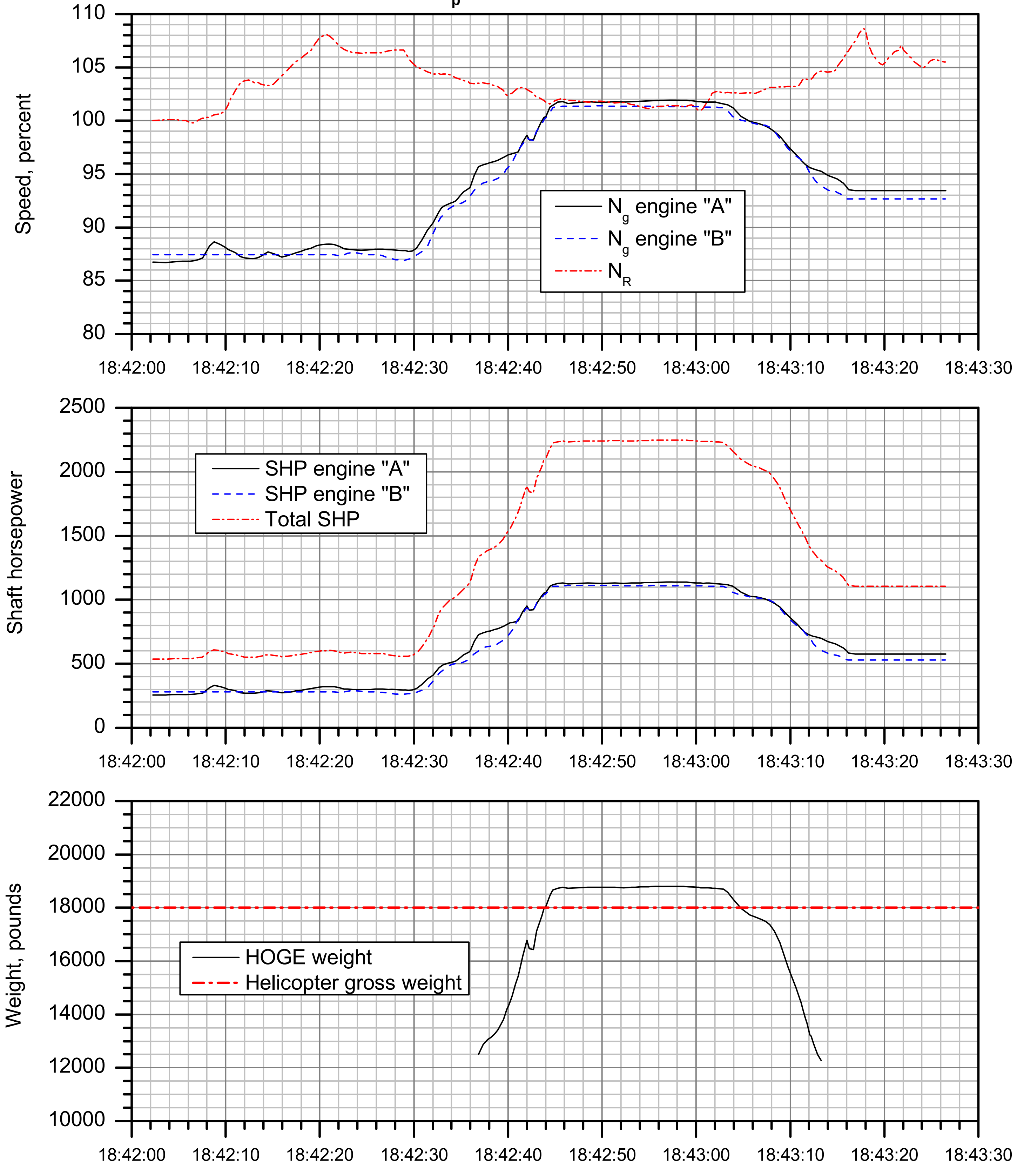


Figure 7.

Engine and rotor speed, engine power, and HOGE weight vs. time
H36 takeoff #3: h_p = 1500 ft, OAT = 31° C, wind calm

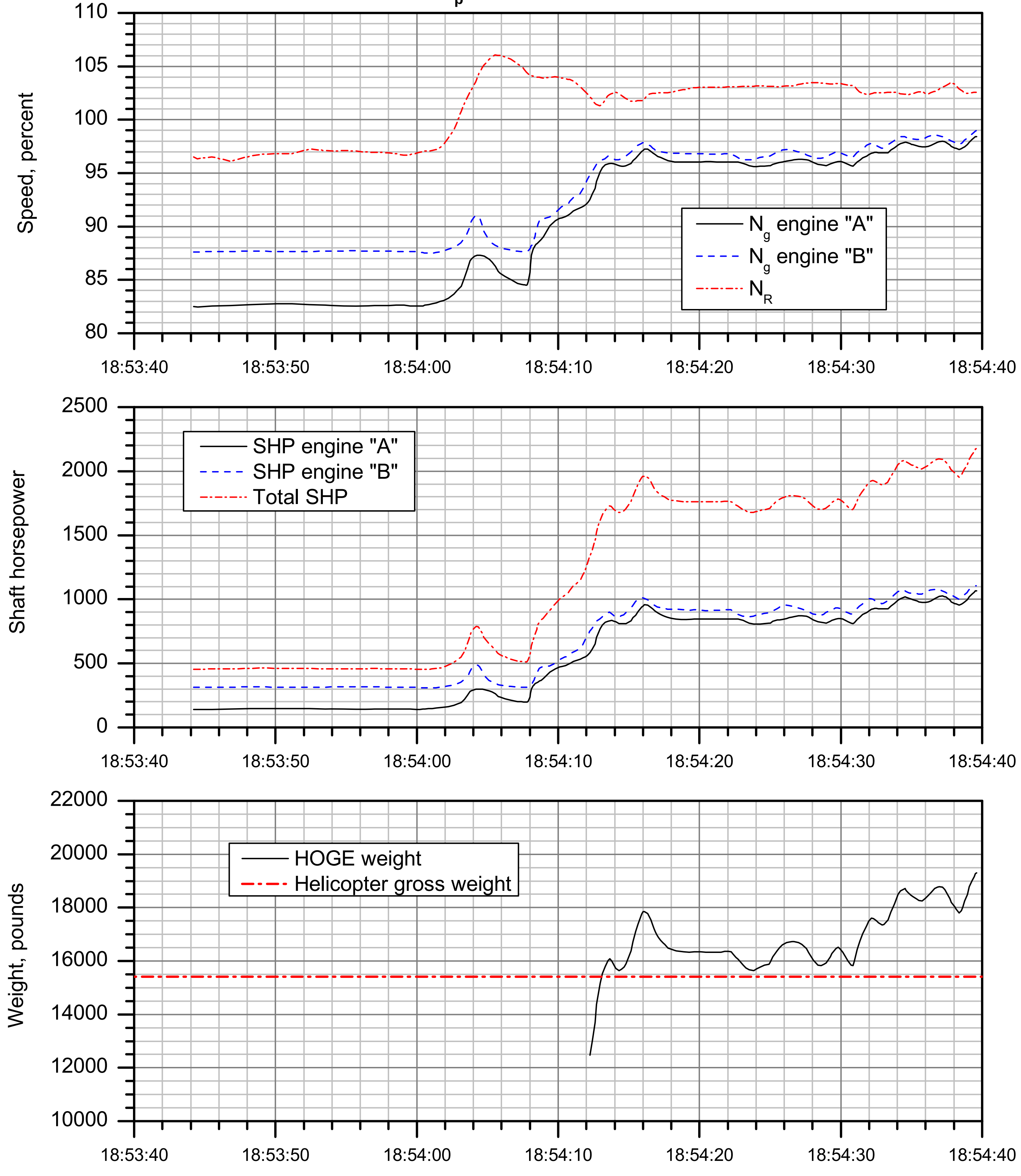
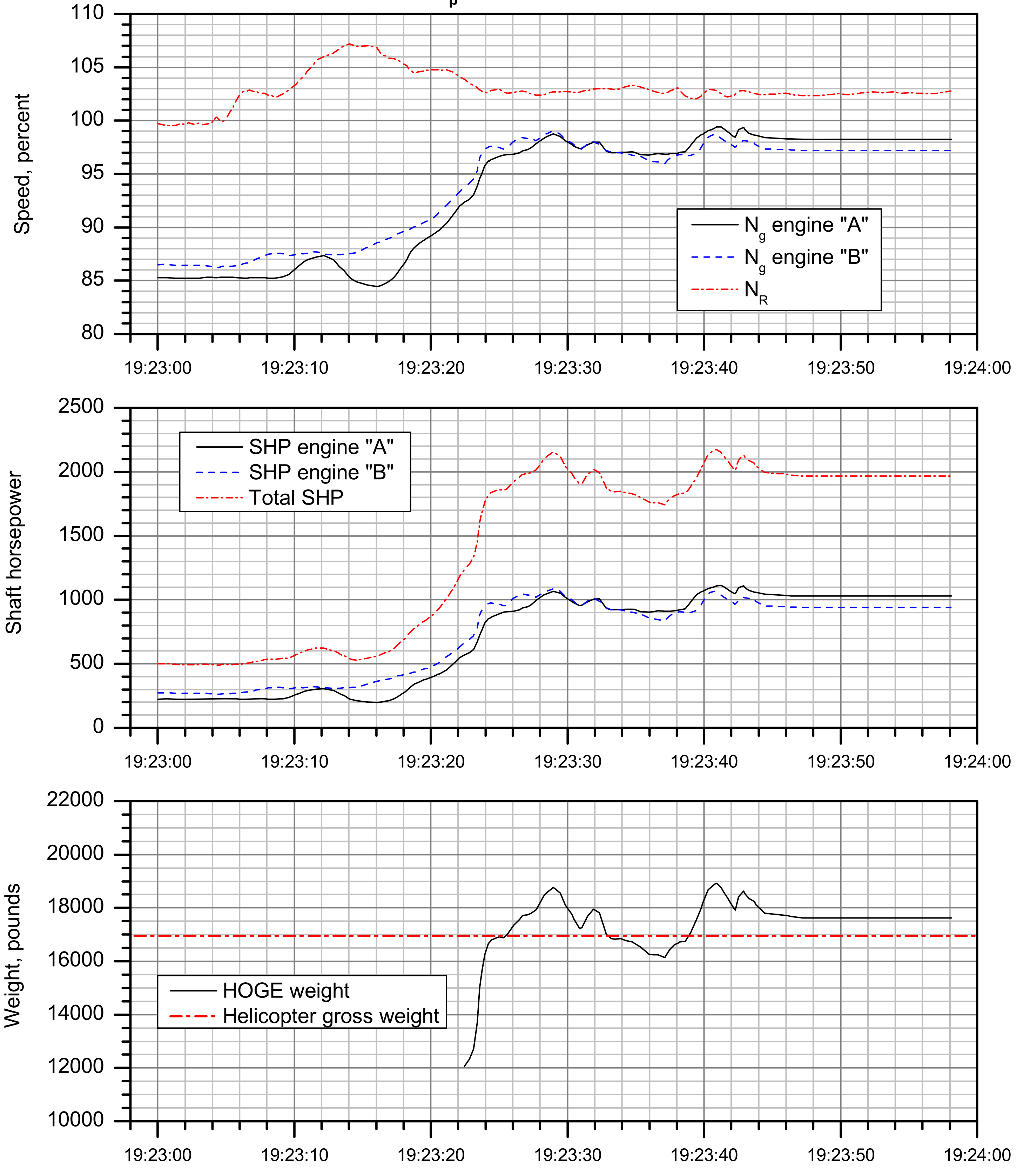


Figure 8.

Engine and rotor speed, engine power, and HOGE weight vs. time
Trinity takeoff: h_p = 3168 ft, OAT = 27° C, wind calm



Time, HH:MM:SS PDT

Figure 9.

Engine and rotor speed, engine power, and HOGE weight vs. time
H44 takeoff #3 (accident): h_p = 6106 ft, OAT = 23° C & 20° C, wind calm

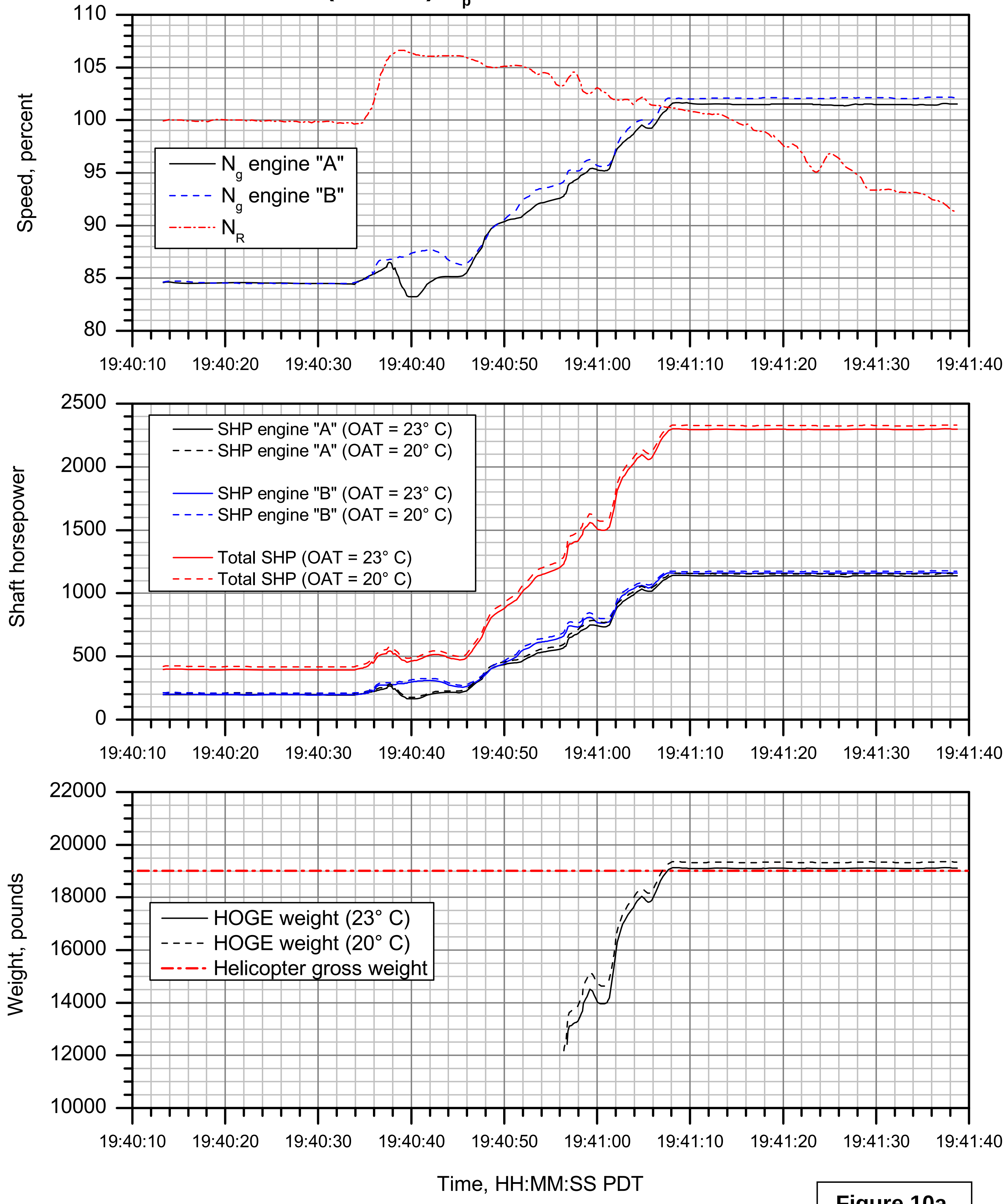


Figure 10a.

Engine and rotor speed, engine power, and HOGE weight vs. time
H44 takeoff #3 (accident): h_p = 6106 ft, OAT = 23° C & 20° C, wind calm (detail)

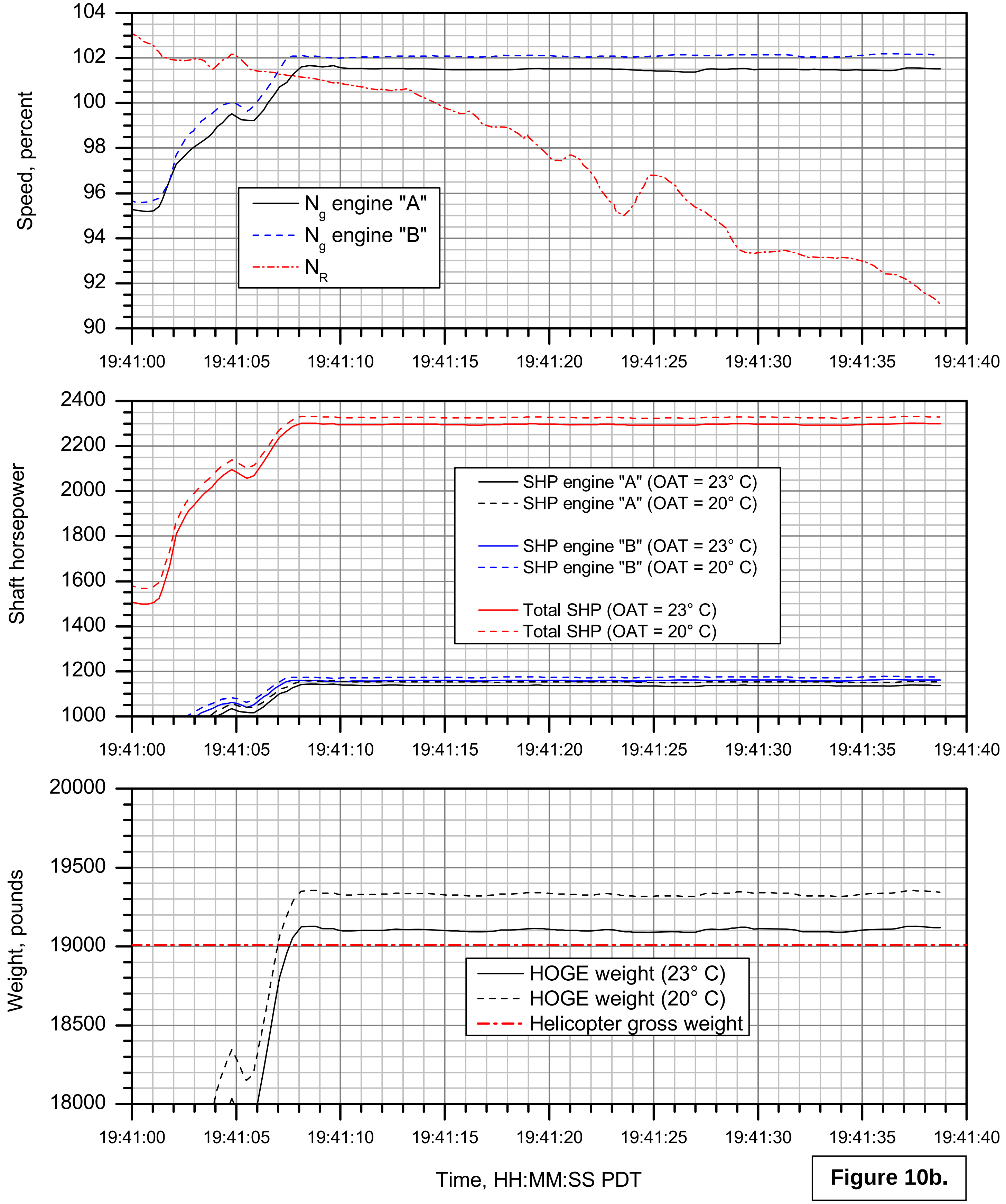


Figure 10b.

Weight margin sensitivity to variations in temperature and wind H44 takeoffs #1 and #3 (accident)

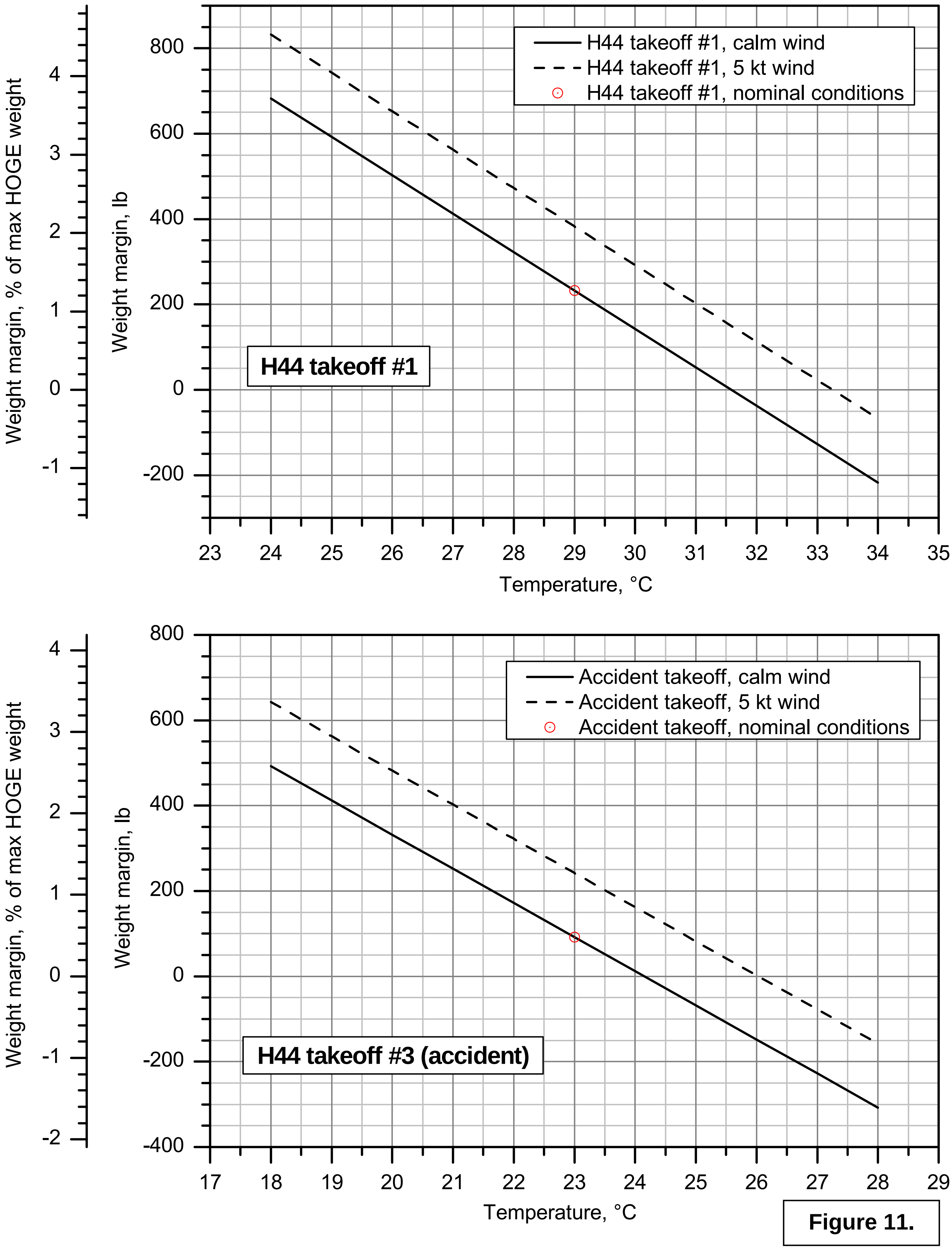


Figure 11.