Cylinder Head Temperatures in Four Airplanes with Continental A-65 Engines

By

S. H. LOWY
Instructor in Aeronautical Engineering

Bulletin No. 27

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Engineering Experiment Station
Oregon State System of Higher Education
Oregon State College
Corvallis

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I. SUMMARY AND ACKNOWLEDGMENTS

1. **Summary.** This investigation includes the determination of cylinder head temperatures, encountered in various conditions of flight and ground operation, for four different aircraft using the Continental A-65 engine. Tests were conducted for full-throttle and part-throttle climb, cruise, taxi, and idling conditions. Results are shown in the form of cylinder-head temperature rise above outside air temperature.

The aircraft used were a Taylorcraft BC-12, a Luscombe Silvaire 8A, an unmodified Aeronca 7-AC, and a modified Aeronca 7-AC. It was found that the highest head temperatures occurred on the unmodified Aeronca, with the Taylorcraft, the modified Aeronca, and the Luscombe following in that order.

The investigation indicates that high temperatures exist under certain operational conditions. It is generally believed that high temperatures are the major cause of valve sticking. This study indicates that operational procedures can be used that will, to a large extent, avoid high head temperatures.

2. **Acknowledgments.** The author is grateful to Thompson Products, Inc., for valuable information pertaining to valve problems; to Smith-Livingston Air Service, Inc., for furnishing the necessary aircraft, pilots, and mechanics; to Professor B. F. Ruffner, professor of aeronautical engineering, for suggestions and advice; to Professor S. H. Graf, director of the Engineering Experiment Station, for suggestions and editorial counsel; and to Mrs. Eloise Hout for preparation of the script and drawing of the figures.

II. INTRODUCTION

1. **Reason for Investigation.** Considerable difficulty with exhaust valve sticking was being experienced by light-plane operators throughout the state, especially during the warm months of the year. The problem was so severe that maintenance costs were

excessively high. In the spring of 1948 it was suggested by B. F. Ruffner, chairman of Oregon State Board of Aeronautics, that the author conduct several flight tests in an attempt to discover if excessively high temperatures were existing in the aircraft on which this trouble was being experienced. Accordingly, arrangements were made with S. H. Graf, director of the Engineering Experiment Station, and Smith-Livingston Air Service, Inc., of Corvallis, and flight tests were started in June 1948.

2. **Utility of Investigation.** It is believed that the results of this investigation will prove helpful to the light-plane operators of the state in that excessively high head temperatures can, for the most part, be avoided.

3. **History.** Valve troubles, in one way or another, have long been a nemesis to all those dealing with internal combustion engines. It has been stated that over 90 per cent of all poppet-valve failures are due to sticking and burning (2). Valve burning will invariably follow prolonged valve sticking. Sticking is a condition wherein the valve train does not follow the cam contour. Severe sticking can be described as the valve frozen in the guide. Less severe cases of sticking result in sluggish operation.

The cause of sticking is an accumulation of carbonaceous material on the valve stem and guide. The material results from the oxidation and decomposition of oil on the stem at certain high temperatures, and is resinous in composition. The deposit is hardened further by the mixing of gum and lead from the fuel with the varnish (2). These deposits may easily cause bell-mouthing of the guide.

As temperatures increase, the guide expands and the bell-mouth opens further. This permits even more deposits to collect on the valve stem. On cooling and contraction the valve stem becomes pinched, the valve sticks and burning results upon subsequent operation (4).

It is apparent that high temperatures "set the stage" for valve sticking. High temperatures are usually associated with high power and hard operation which cause oils to oxidize more rapidly than under less severe conditions. Also, when oil is added, oxidized oils will, under certain conditions, deposit "granular carbon" and varnish on internal parts (6).

For an engine suffering valve sticking, the problem becomes one of eliminating the deposits by removal as they form, or by preventing the formation entirely. One method of removal tried by the operators was by the use of a commercial detergent oil. Several

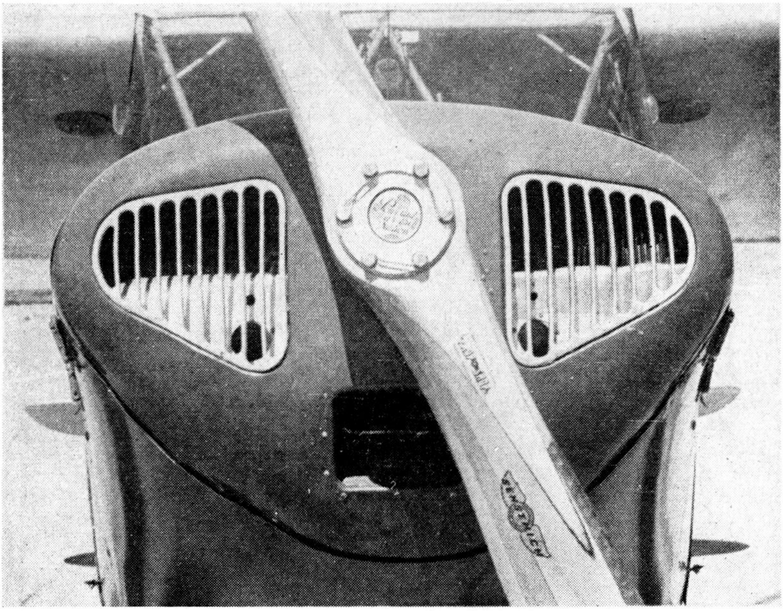


Figure 1. Taylorcraft airplane.

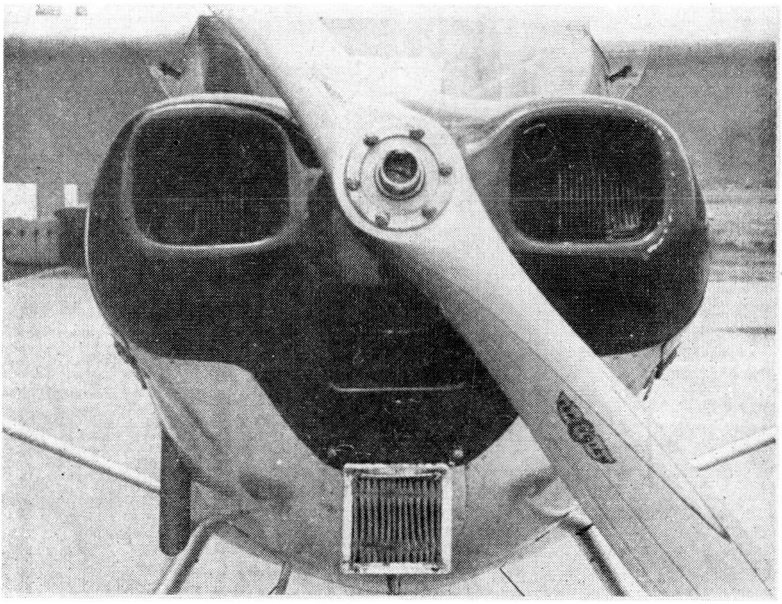


Figure 2. Luscombe airplane.

of these oils were used with little or no success, the deposit being too hard for the detergent to have any noticeable effect on it. Another method used was undercutting of the guide, thereby reducing the bearing area where oil and other products have the greatest tendency for forming deposits. This too failed to alleviate the situation, and the operators had to search for other methods.

It was at the time the operators were seeking a successful method of preventing valve sticking that this project was suggested.

4. **Scope.** The purpose of the project was to obtain sufficient flight data, relating to temperature, for several aircraft using the engine under investigation. In one of these aircraft considerable trouble was being experienced with valve sticking. In others, little or no trouble had been experienced. Therefore it was reasoned that a comparison of engine temperatures would possibly indicate the cause of the trouble. The test was limited to the determination of head temperatures and power under various conditions of flight and ground operations.

III. APPARATUS

1. Engines and Aircraft Used in Test.

(a) Continental A-65 engine with a rating of 65 brake horsepower at 2,300 rpm, No. 5126868 used with a Met-L-Prop propeller on a Taylorcraft BC-12, Serial No. 7930, NC-95630. (See Figure 1.)

(b) Continental A-65 engine with a rating of 65 brake horsepower at 2,300 rpm, No. 3651358 used with a Sensenich propeller on a Luscombe 8A Silvaire, Serial No. 2080, NC-45553. (See Figure 2.)

(c) Continental A-65 engine with a rating of 65 brake horsepower at 2,300 rpm, No. 3703968 used with a Sensenich propeller on an Aeronca 7-AC, Serial No. 6593, NC-3007E. This aircraft is referred to as the "unmodified Aeronca." (See Figure 3.)

(d) Continental A-65 engine with a rating of 65 brake horsepower at 2,300 rpm, No. 5707168 used with a Flottorp propeller on an Aeronca 7-AC, Serial No. 4958, NC-1396E. This aircraft is referred to as the "modified Aeronca." The modification applies to the engine cowling, and was announced by the Aeronca Corporation in the summer of 1948. It consisted of enlarging the two frontal intake cooling air ducts and also enlarging the lower exit cooling air space. (See Figure 4.)

2. Instrument Description and Test Setup.

(a) The instruments used were those installed in the aircraft, a manifold pressure gage, a Fahrenheit mercury thermometer for

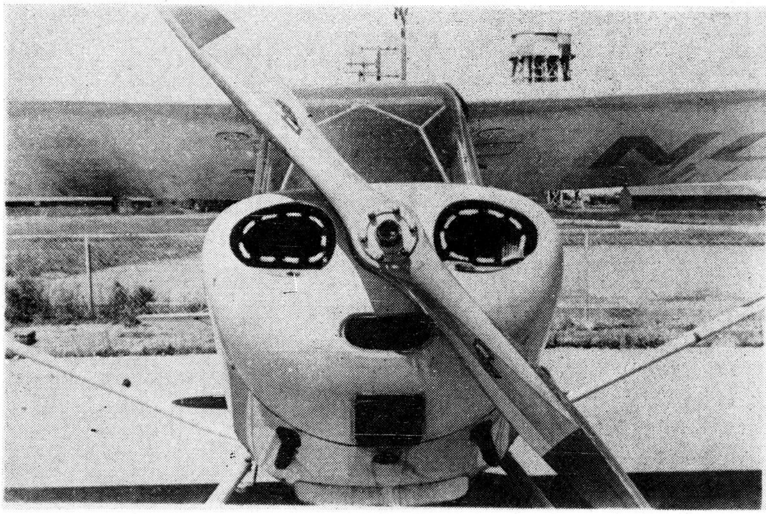


Figure 3. Aeronca airplane. Dotted lines show cowl openings before modification.

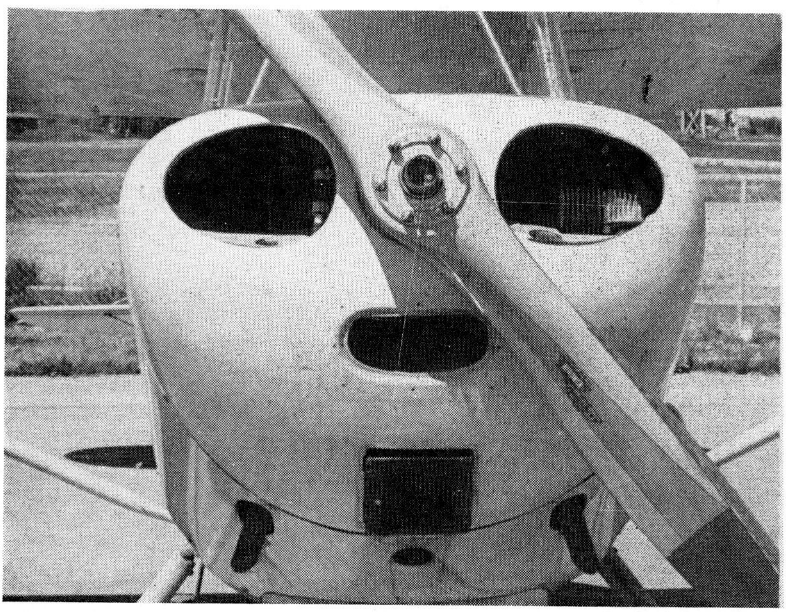


Figure 4. Modified Aeronca airplane.

measuring outside air temperature, and an aircraft cylinder head temperature gage. Thermocouples used were made of iron-constantan No. 14 duplex wire, eight feet in length. Sufficient resistance was added as required by the instrument. Only one cylinder head temperature gage was necessary, the various connections being made by switches. (See Figure 5.)

(b) The manifold pressure gage and cylinder head temperature gage were mounted together in a box unit. The connection for manifold pressure was made downstream of the throttle. All thermocouples were brought into the instrument unit and connected to the temperature gage by means of four three-way switches. (See Figures 6 and 7.) This permitted the use of eight thermocouples: four to measure cylinder head temperatures, one for carburetor air temperature, one for valve guide shoulder temperature, and two for measuring air temperatures behind cylinders one and two.

The top spark plug gaskets were replaced by thermocouple gaskets and aluminum shields were installed across the cooling fins of sufficient length to prevent direct airflow across the thermocouple gaskets. Number one cylinder valve cover was drilled to allow thermocouple wires to reach the exhaust valve guide shoulder.

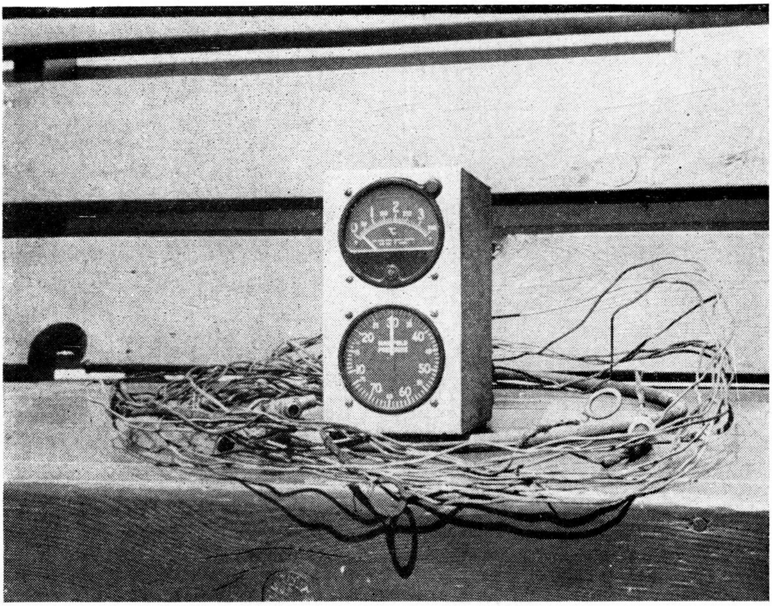


Figure 5. Manifold pressure and cylinder head temperature instruments.

IV. PROCEDURE

1. Definitions of Terms and Symbols.

(a) *CHT,* cylinder head temperature. Temperature existing at top of cylinder between spark plug and cylinder head as measured by a thermocouple. Thermocouple wires were attached to the spark plug gasket.

(b) *OAT,* outside air temperature. Temperature existing outside of the aircraft as measured by a mercury thermometer.

(c) Δt, difference between average cylinder head temperature and outside air temperature.

(d) BHP_c, brake horsepower corrected. Brake horsepower output at manifold pressure and rpm specified at some particular altitude as obtained from sea level altitude power curves corrected for carburetor air temperature. (See sample calculations in Appendix.)

(e) Part-throttle low and high power settings obtained by flying aircraft in straight and level flight at 1,000 feet indicated altitude, and adjusting throttle to an rpm value of 2,100 and 2,200, respectively.

(f) *MAP,* manifold absolute pressure in inches mercury.

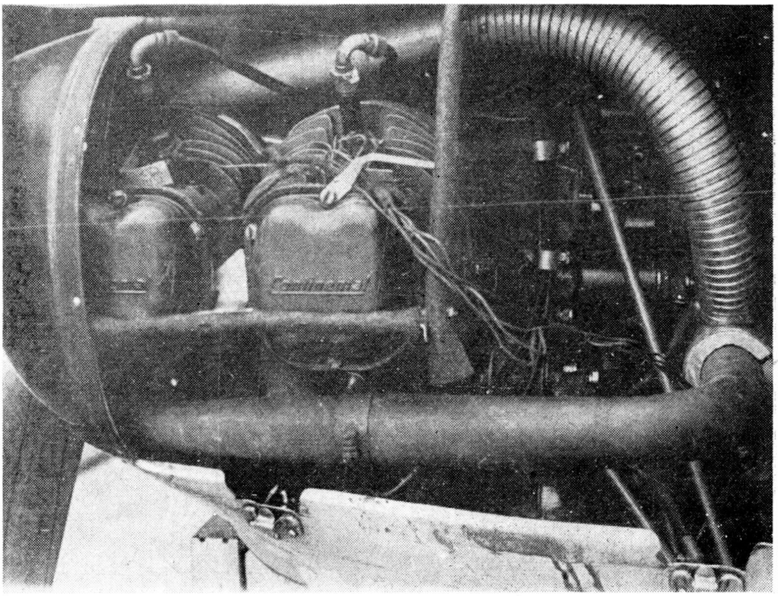


Figure 6. Continental A-65 engine installation showing thermocouple arrangement.

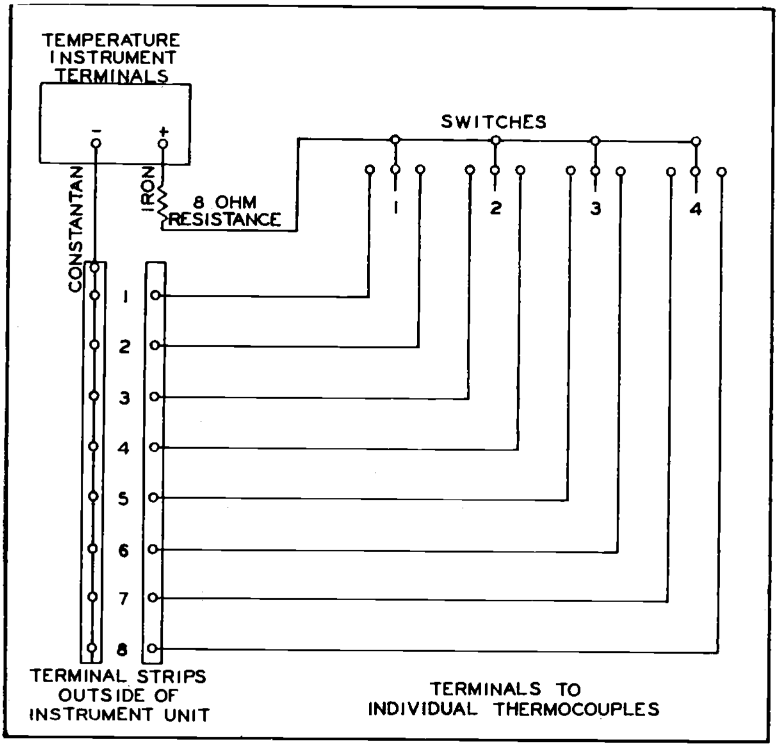


Figure 7. Internal wiring of instrument unit for thermocouple selection.

2. **Assumptions.** The nature and amount of valve sticking that was experienced led to the belief that excessive temperatures were possibly the cause of the trouble. Therefore, it was decided to check head temperatures in order to determine the range encountered during the various conditions of flight. It should be pointed out here that after the first aircraft was tested, the manufacturer announced a cowling modification of the Aeronca which, it was claimed, lowered head temperatures approximately 50 degrees Fahrenheit. (See Figures 3 and 4.)

3. **Methods of Conducting Test.** Each aircraft was instrumented and subjected to the following tests:

(a) Idling condition ranging from approximately 650 rpm to 1,200 rpm.

(b) Taxi condition ranging from approximately 800 rpm to 1,400 rpm.

(c) Cruise condition ranging from 1,800 rpm to full-throttle rpm.

(d) Climb conditions consisting of three parts: full-throttle, part-throttle high, and part-throttle low. Part-throttle high was set by cruising the aircraft in straight and level flight at about 1,000 feet with throttle set for 2,200 rpm. Part-throttle low was set similarly except that 2,100 rpm were used. The aircraft was then put in various climbing attitudes with the throttle remaining untouched. All climbing tests were made at several different airspeeds and originated at approximately 1,000 feet.

The following items were recorded: Time of test, barometer, wet and dry bulb temperatures, take-off and landing weights, gas and oil consumption, altitude, airspeed, rpm, manifold pressure, oil temperature, oil pressure, outside air temperature, cylinder head temperatures, valve guide shoulder temperature, and carburetor mixture temperature.

Each run was terminated when it was observed that the difference between average cylinder head temperature and outside air temperature had passed a maximum value. Readings were taken every two minutes. The altimeter was set to the barometric pressure at sea level existing just prior to take-off.

4. **Reduction and Analysis of Data.** It was decided to use the difference between average cylinder head temperature and outside air temperature as the basis for comparison since it was obviously impossible to hold outside air temperature constant and the cylinder head temperature varies as outside air temperature varies. The head temperature for any one cylinder exceeded the average head temperature by 16 degrees Fahrenheit at the most, and averaged about 10 degrees Fahrenheit higher. Highest head temperatures occurred on number four cylinder in all cases. This temperature difference was plotted against time in minutes of run for the various conditions obtained. The resulting curves gave a series of maximum temperature differences that were plotted against rpm for the two main flight conditions, and also for the idling condition. These curves show fairly well the average cylinder head temperature conditions existing during operation.

The decision not to plot curves for the part-throttle climbs was made because there is a question of power duplication when setting up the high and low conditions prior to climbing. However, the information derived from these tests was utilized in plotting Figures 13, 14, 15, and 16.

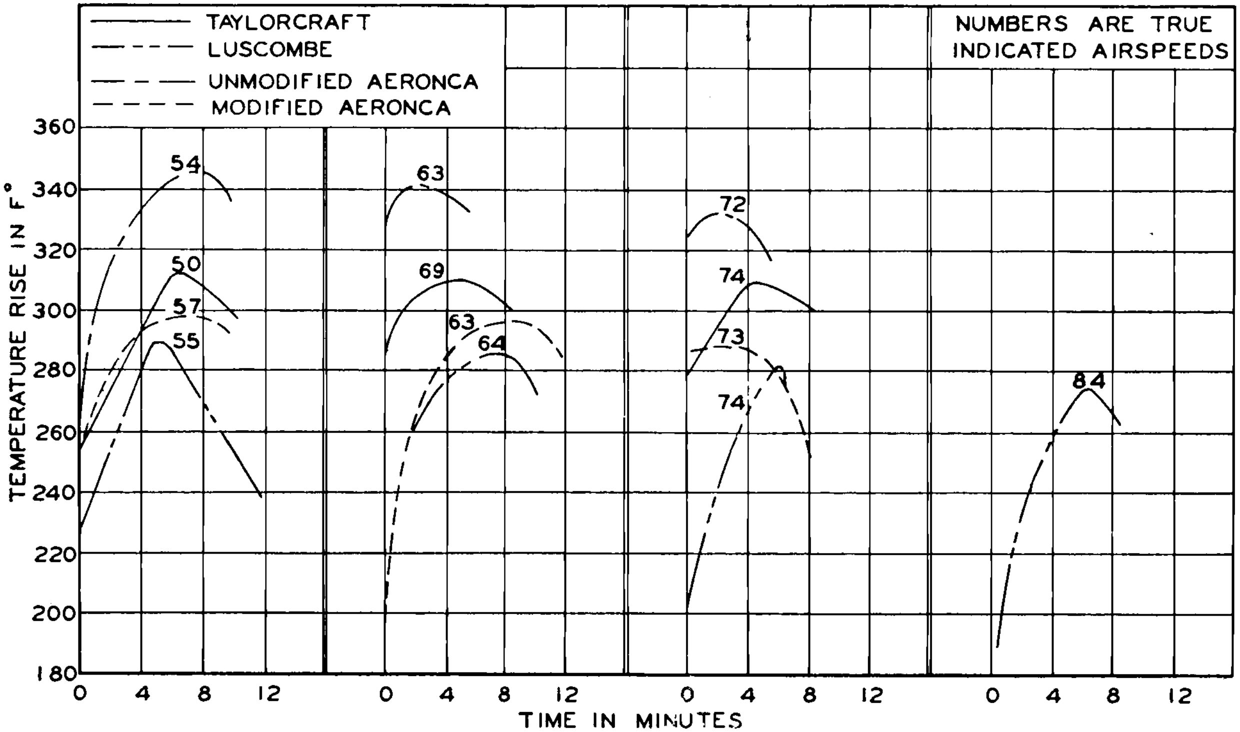


Figure 8. Temperature rises for full-throttle climb.

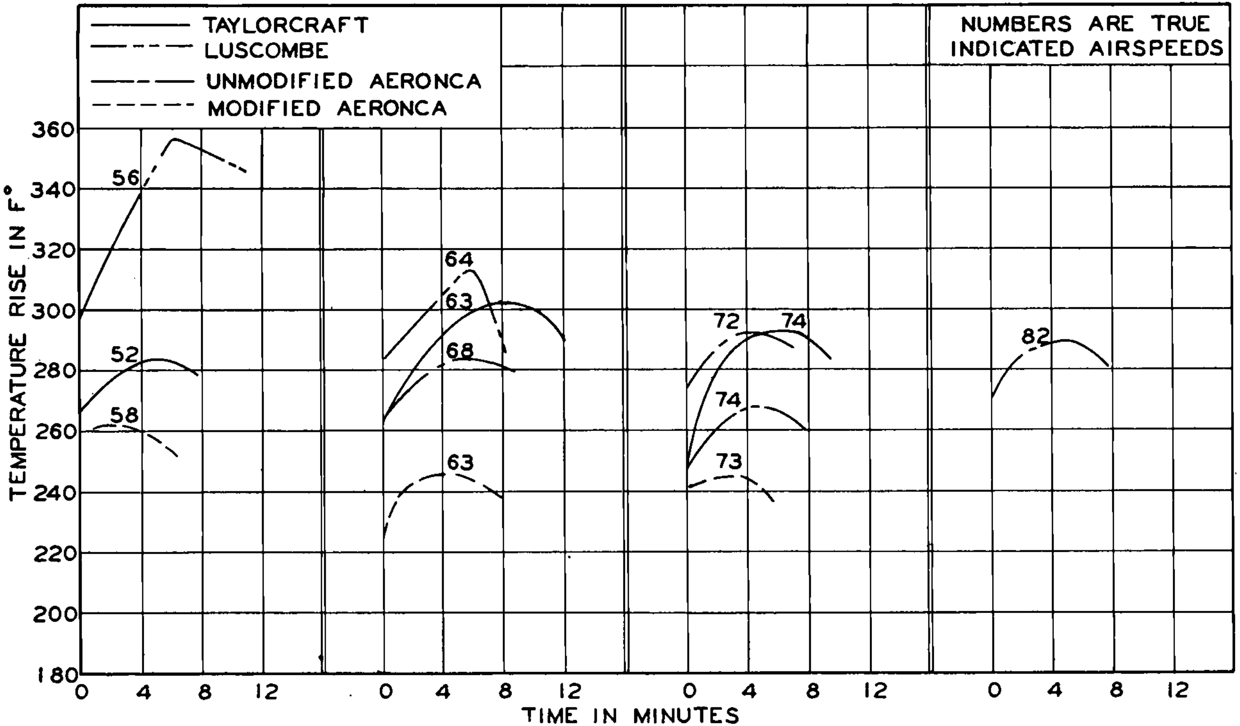


Figure 9. Temperature rises for part-throttle climb.

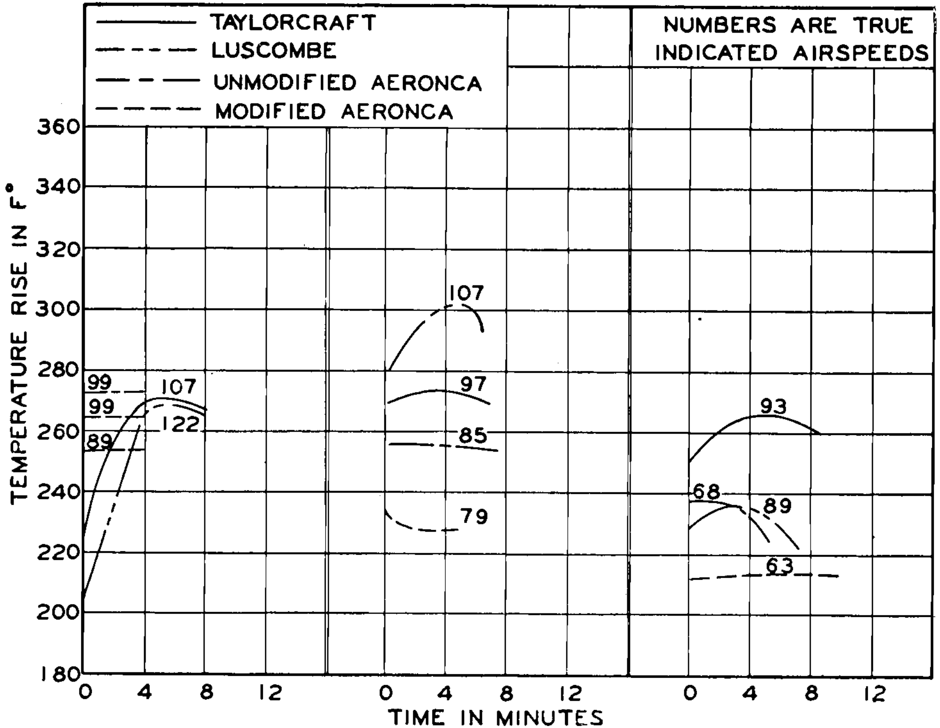


Figure 10. Temperature rises for cruise conditions.

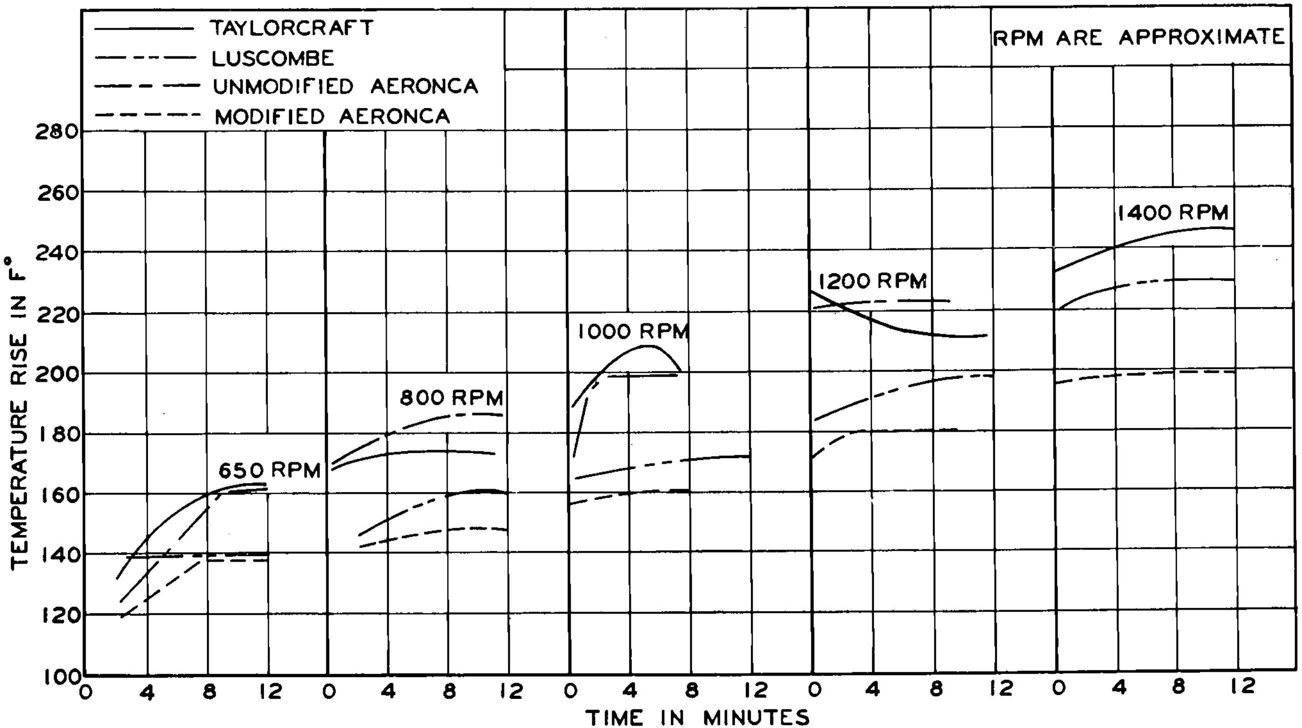


Figure 11. Temperature rises for idle condition.

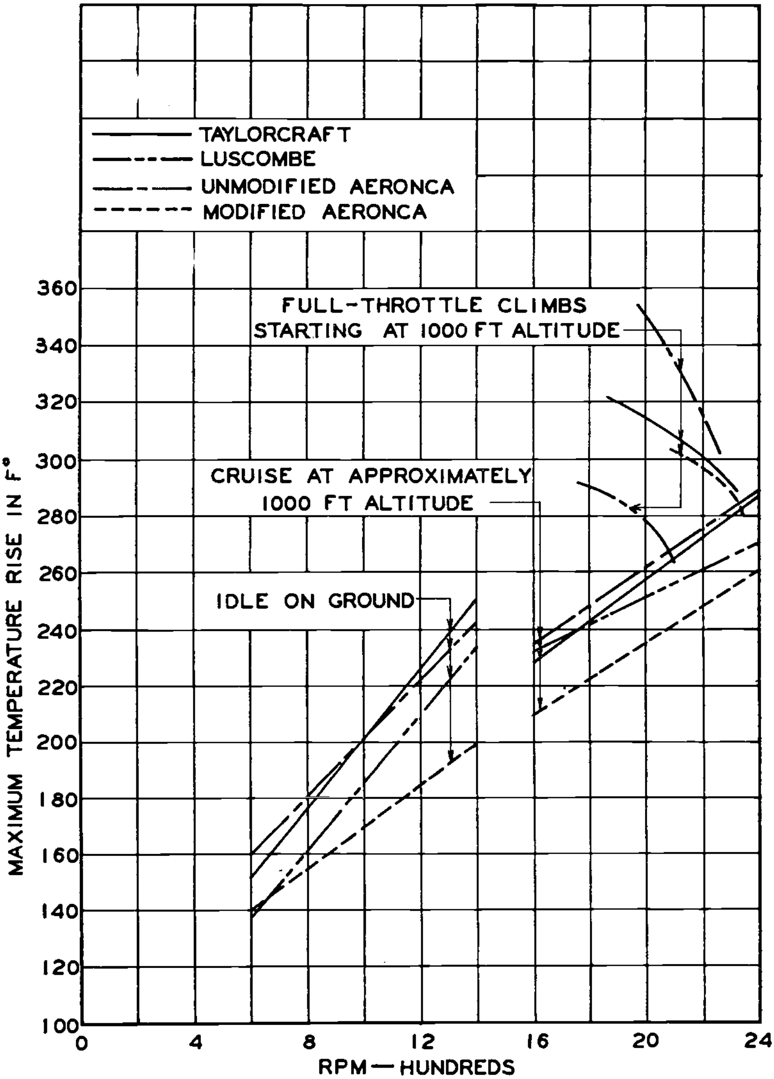


Figure 12. Maximum temperature differences versus engine speed for three operating conditions.

5. **Results.** The curves of Δt versus time for the full-throttle climb (Figure 8), show that the temperature rise increases to some maximum point and then drops off, and as the airspeed is increased the maximum Δt decreases. This is to be expected since as the airspeed increases, the mass airflow for cooling purposes increases. The reason for the Δt decreasing after a maximum value is attained is due to the fact that as altitude is increased the power decreases. This combination results in an overall Δt decrease.

The curves of Δt versus time for the high part-throttle climb condition (Figure 9), shows apparent inconsistencies that are attributed to a failure to duplicate the same conditions of power prior to starting each run. This is borne out by an examination of the data for those runs.

The curves of Δt versus time for the cruise condition (Figure 10), show that for the modified and unmodified Aeronca, the maximum Δt decreases as power decreases, which is a normal condition since energy input in the form of fuel is lessened.

The curves for Δt versus time for the idling condition (Figure 11), show that a maximum Δt is reached at each rpm, and the higher rpm results in a higher Δt. Except for two or three cases, the Δt did not decrease after a maximum point was reached, but remained at the maximum value.

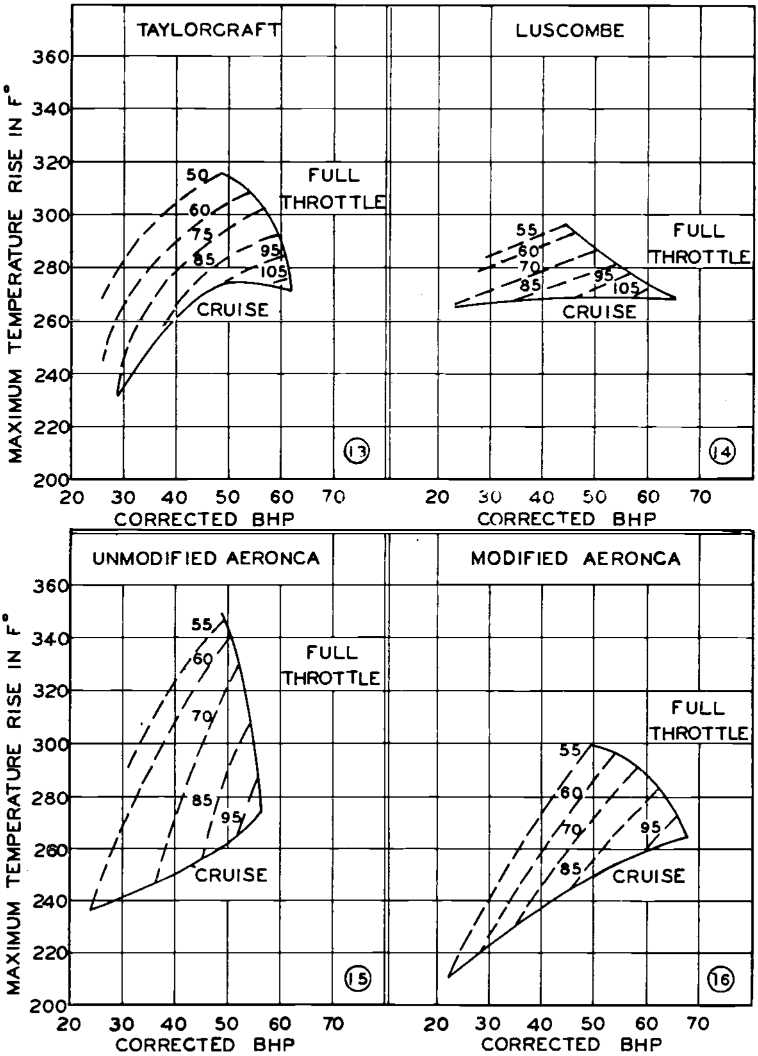
In plotting maximum temperature differences against rpm, (Figure 12), only three conditions of operation were used: Full-throttle climb, cruise, and idle. Curves for part-throttle climbs were omitted because of the question of power duplication, and curves for the taxi condition were omitted because they fall below the curves for idling condition. In general, these curves show that under conditions of full-throttle climb, the unmodified Aeronca operated at the highest temperature, followed by the Taylorcraft, the modified Aeronca, and the Luscombe. Indications are that the unmodified Aeronca would be operating at cylinder head temperatures above 400 degrees Fahrenheit if the outside air temperature exceeded 60 degrees Fahrenheit. This condition exists during the summer season, and it is during this season that the valve sticking problem is most severe. One operator estimates that during student instruction the aircraft is operated as much as 20 to 25 per cent at full-throttle climb. If the aircraft were an unmodified Aeronca, then excessive cylinder head temperatures would be experienced during the warm months for almost one-fourth of the operational time of the aircraft. For the Taylorcraft, outside air temperatures of 90 degrees Fahrenheit and over would result in cylinder head temperatures in excess of 400 degrees Fahrenheit during full-throttle climb. The assumption here is that climbs would be made at approximately 55 or 60 miles per hour true indicated airspeed. The modified Aeronca and the Luscombe would operate at cylinder head temperatures over 400 degrees Fahrenheit when climbing at approximately fifty-five miles per hour, true indicated airspeed and full-throttle, if outside air temperatures exceeded 100 degrees Fahrenheit and 110 degrees Fahrenheit, respectively.

Considering the cruise condition curve it is seen that the Taylorcraft operates at the highest average cylinder head temperature. The unmodified Aeronca, the Luscombe, and the modified Aeronca follow in that order. Cylinder head temperatures of 400 degrees Fahrenheit would be obtained during a full-throttle cruise of the Taylorcraft if outside air temperature was of the order of 125 degrees Fahrenheit. This temperature is quite rare in the north temperate zone.

Considering the idling condition curves, which lie in the same order as those for the cruise condition, it can be seen that head temperatures will increase as rpm, and therefore power, increases. This indicates that prolonged ground idling will not result in excessive cylinder head temperatures. For an outside air temperature of 85 degrees Fahrenheit, the cylinder head temperatures (approximately) for the various aircraft idling at 1,400 rpm would be (from Figure 12):

Taylorcraft	340 F
Unmodified Aeronca	330 F
Luscombe	320 F
Modified Aeronca	290 F

Figures 13, 14, 15, and 16 are plots of maximum Δt versus corrected brake horsepower for the full-throttle climb and cruise conditions. Shown also are lines of constant true indicated airspeed, indicated by the dashed lines. Operation between the lines of full-throttle climb and cruise would be at a part-throttle climb condition. It can be seen that for any of the climb conditions, maximum Δt decreases with an increase in airspeed. Increasing the airspeed for the cruise condition necessitates an increase in power, which results in an increase of maximum Δt. The curves also show that for any given climbing speed, part-throttle operation results in lower temperatures than does full-throttle operation. Using Figures 13 through 16 in conjunction with Figure 12, it is possible to determine the maximum Δt, probable true indicated airspeed, and corrected brake horsepower for a particular type of flight operation if the engine speed (rpm) is known.



Figures 13, 14, 15, and 16. Temperature differences versus corrected brake horsepower.

Curves for valve guide temperature have not been plotted since the temperatures were approximately equal to cylinder head temperatures. Therefore, the valve guide temperatures may be determined from the cylinder head temperature curves.

V. CONCLUSIONS

1. The investigation indicates that the highest cylinder head temperatures are obtained for the aircraft in which the most valve sticking difficulties had been experienced.

2. The manufacturer's claim that modifying the Aeronca 7-AC cowling as specified, will lower head temperatures approximately 50 degrees Fahrenheit, is substantially correct.

3. Except for the unmodified Aeronca 7-AC, none of the aircraft tested would operate at cylinder head temperatures in excess of 400 degrees Fahrenheit except in very hot weather.

4. Prolonged ground running at engine speeds below 1,200 rpm does not result in excessive head temperatures for any of the aircraft tested. It is therefore desirable to bring the engine and oil up to normal operating temperatures before attempting flight. This policy should ensure good lubrication to all engine parts and proper combustion of fuel during one of the most critical periods of flight.

5. Use of part-throttle as soon as possible after take-off will aid in keeping down cylinder head temperatures. Climbs at an airspeed higher than the airspeed giving maximum rate of climb is also recommended whenever possible.

VI. RECOMMENDATIONS

The following recommendations are made for the reduction of cylinder head temperatures:

1. Increase the mass airflow for cooling purposes by modification of existing cowling.

2. Ascertain that all cooling baffles are in their correct positions.

3. When climbing at full-throttle, use a relatively high true indicated airspeed.

4. Throttle engine to a lower power as soon as possible after take-off, and proceed with climb at part-throttle setting.

5. Allow engine and oil to reach normal operating temperatures before attempting flight in order to ensure proper combustion and proper lubrication to all parts.

The following are also recommended as possible aids to operators encountering valve sticking troubles:

1. The use of detergent oils now undergoing test.

2. Mechanical scraping of valve stems and seats by positive valve rotation. This should break deposits as they form.

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VIII. APPENDIX

Sample Calculations

1. $F = \frac{9}{5}(C) + 32$, where F = Fahrenheit degrees and C = Centigrade degrees

   Assume $C = 200$, then

   $$F = \frac{9}{5}(200) + 32 = 360 + 32 = 392.$$

2. Δt = (average cylinder head temperature, CHT) — (outside air temperature, OAT).

   Assume $CHT = 392$ F, and $OAT = 60$ F, then

   $\Delta t = 392 - 60 = 332\ F.$

3. Determination of corrected brake horsepower, BHP_c

   Assume: Manifold pressure ....25.2 inches mercury
   Engine speed ....2,000 rpm
   Pressure altitude ....1,600 ft
   Carburetor air temperature, CAT ....74 F

From the sea level altitude power curves for the engine, find the point of intersection on the sea level chart of 25.2 inches mercury and 2,000 rpm and project this point horizontally to the right until it intersects the zero altitude line of the altitude chart. Call this point A. On the altitude chart find the point of intersection of 25.2 inches mercury and 2,000 rpm and call this point B. Connect points A and B with a straight line. At an altitude of 1,600 feet, construct a vertical line until it intersects A-B. Call this point C. Project point C horizontally to the left and read brake horsepower, BHP, on the vertical scale. Because the charts are based on standard temperature, the BHP must be corrected for temperature if the CAT is not standard for the particular altitude. Standard air temperature for 1,600 feet is close to 58 F. Therefore, it is nècessary to correct BHP as follows:

$$BHP_c = \frac{BHP}{\sqrt{\dfrac{460 + CAT}{518}}}$$

Continuing the example: $BHP = 45.5$ and $CAT = 74$ F,

$$BHP_c = \frac{45.5}{\sqrt{\dfrac{460+74}{518}}} = \frac{45.5}{\sqrt{\dfrac{534}{518}}} = \frac{45.5}{(1.01)} = 45.0$$

4. The calculation of the determination of V_{cal} of true indicated airspeed involves actual flight of the aircraft over a measured course. The aircraft must be flown over the course against the wind, and then with the wind at various indicated airspeeds, and the time recorded with a stop-watch for each of these runs. Also record sea level barometer, altitude, and temperature. This results in a ground speed (V_g) determination, from which true indicated airspeed (V_{cal}) can be calculated as follows:

$$V_{cal} = V_g\sqrt{\sigma}$$

where: $\sigma = (P/P_0)(T_0/T) =$ density ratio,
$P =$ pressure corresponding to altitude, inches mercury,
$P_0 =$ standard sea level pressure $= 29.92$ inches mercury(
$T_0 =$ standard sea level temperature $= 520$ Rankine,
$T =$ temperature at altitude flown $= (460 + t)$ Rankine,
and $t =$ outside air temperature F degrees.

The following data are taken from those of the Taylorcraft calibration at 80 mph indicated airspeed. Distance is 6,900 feet, pressure altitude is 1,000 feet, and outside air temperature is 68 F.

IAS	Time south	Time north	fps south	fps north	fps avg	mph V_g	P/P_0	T_0/T	σ	$\sqrt{\sigma}$	mph V_{cal}
80	64.3	60.6	107.2	113.9	110.5	65.4	0.965	0.985	0.951	0.976	73.6

Time is given in seconds.
fps = feet per second.

Calibration curves of instruments are shown in Figures 17, 18, 19, 20, and 21.

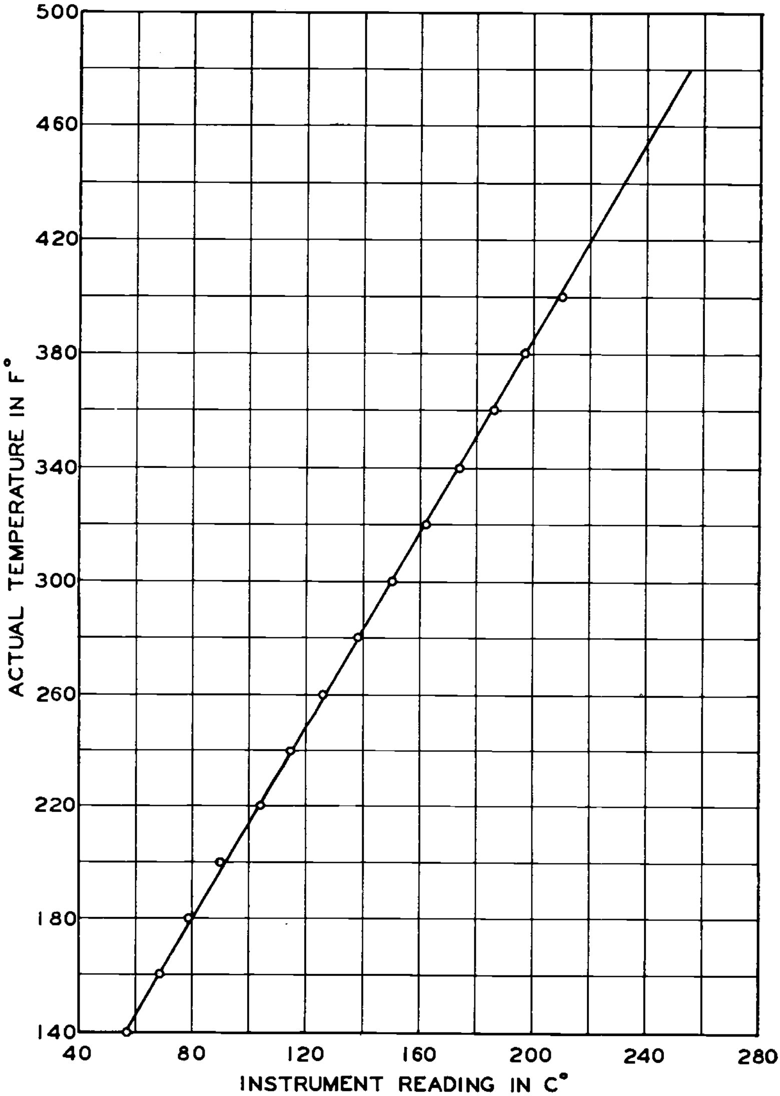

Figure 17. Calibration curve of cylinder head temperature gage.

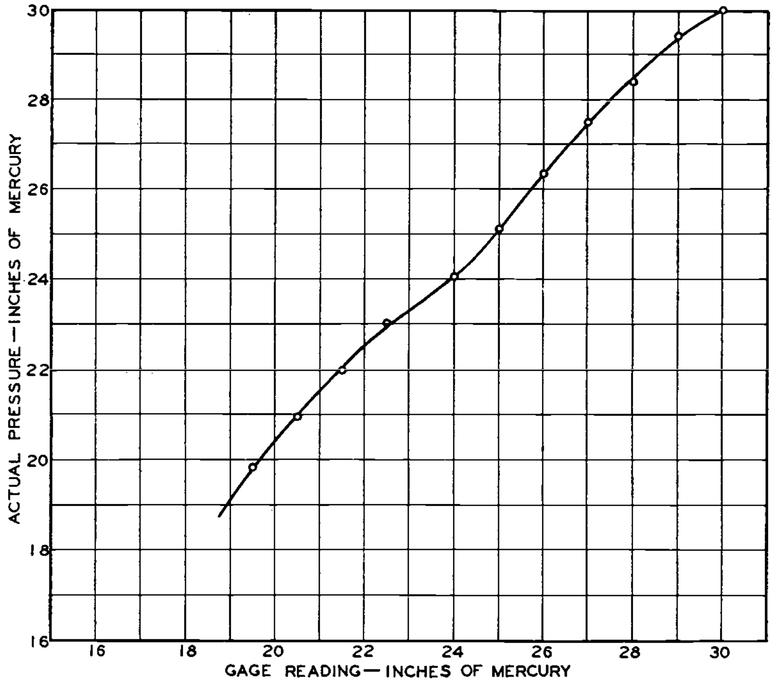

Figure 18. Calibration of manifold pressure gage.

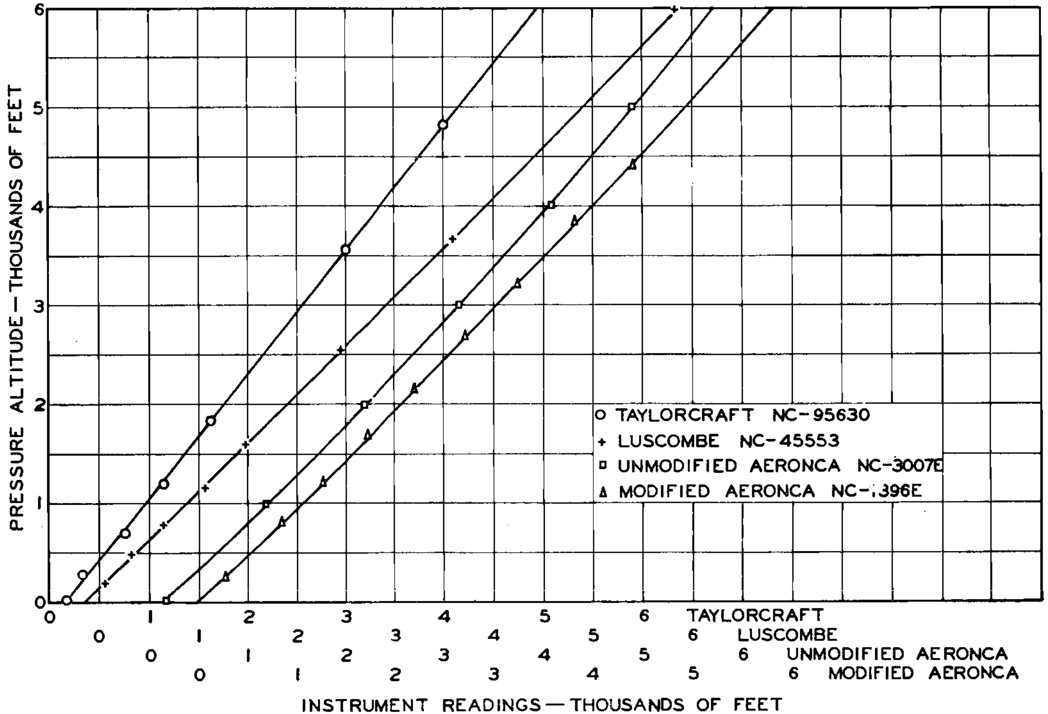

Figure 19. Calibration curves of altimeters.

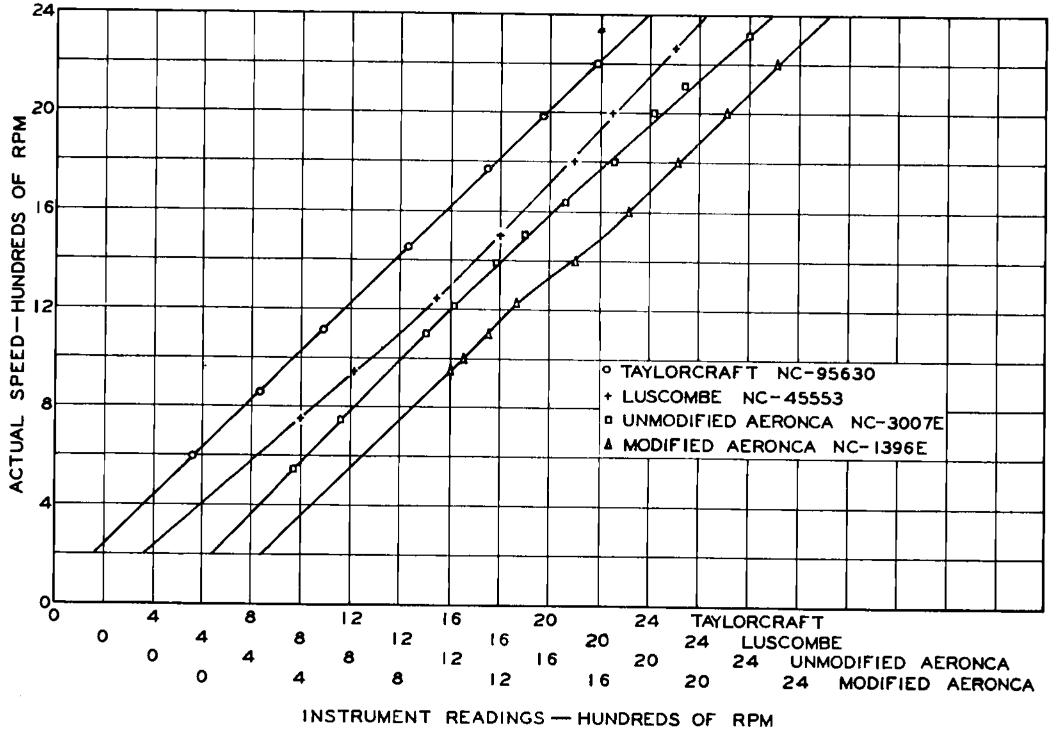

Figure 20. Calibration curves of tachometers.

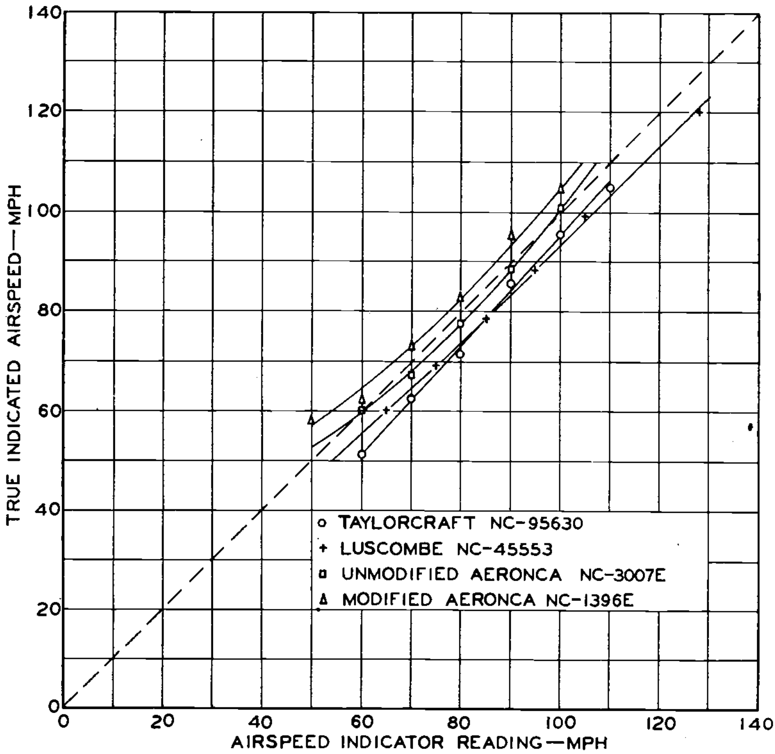

Figure 21. Calibration curves of airspeed indicators.

Table 1. SUMMARY OF TEMPERATURE RISES Δt TAYLORCRAFT NC-95630
FULL-THROTTLE CLIMB

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
51 mph						
0	228	28.5	2,060	240	60	54.5
2 minutes	279	28.0	2,040	1,020	57	53.3
4 minutes	294	28.0	2,040	2,100	53	53.0
6 minutes	312	26.9	2,040	3,250	47	50.6
8 minutes	308	25.8	2,040	4,450	44	48.8
63 mph						
0	283	27.5	2,060	1,350	55	53.0
2 minutes	309	27.5	2,060	2,670	50	52.5
4 minutes	308	26.3	2,060	3,870	44	49.7
6 minutes	308	25.2	2,060	5,000	42	48.1
8 minutes	......	......	....	....	....	......
74 mph						
0	278	27.5	2,110	1,020	55	54.2
2 minutes	287	27.5	2,110	2,540	51	53.9
4 minutes	311	26.3	2,110	3,450	46	52.5
6 minutes	308	25.8	2,110	4,600	42	50.5
8 minutes	......	......	....	....	....	......

Table 2. SUMMARY OF TEMPERATURE RISES Δt TAYLORCRAFT NC-95630
PART-THROTTLE CLIMB

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
51 mph						
0	266	26.1	2,210	1,020	66.0	53.0
2 minutes	276	24.8	1,910	1,410	64.0	42.1
4 minutes	285	24.7	1,910	2,060	60.0	41.9
6 minutes	284	24.6	1,910	2,730	58.0	42.0
8 minutes	......	......	....	....	......	......
10 minutes	......	......	....	....	......	......
63 mph						
0	261	25.1	2,210	1,020	66.0	50.6
2 minutes	281	24.6	2,010	1,350	64.0	43.8
4 minutes	291	24.6	1,985	2,000	61.0	43.2
6 minutes	300	24.6	1,985	2,780	59.0	44.0
8 minutes	302	24.3	1,985	3,440	57.0	43.3
10 minutes	301	23.8	1,985	4,160	56.0	42.4
74 mph						
0	229	25.5	2,210	1,020	66.0	51.7
2 minutes	278	25.0	2,060	1,400	64.0	46.2
4 minutes	290	24.8	2,060	2,180	62.0	46.0
6 minutes	292	24.8	2,060	2,820	60.0	46.5
8 minutes	291	24.2	2,060	3,600	58.0	45.2
10 minutes	......	......	....	....	......	......

Table 2a. SUMMARY OF TEMPERATURE RISES Δt TAYLORCRAFT NC-95630 PART-THROTTLE CLIMB

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
51 mph						
0	269	23.2	2,110	1,020	63.0	42.5
2 minutes	287	23.7	1,890	1,420	62.0	38.2
4 minutes	299	23.4	1,890	2,050	60.0	38.0
6 minutes	302	23.4	1,890	2,550	58.0	38.3
8 minutes	301	23.3	1,890	3,170	58.0	38.4
63 mph						
0	249	24.0	2,110	1,020	64.0	44.5
2 minutes	279	23.7	1,940	1,330	63.0	39.5
4 minutes	289	23.5	1,940	1,940	60.0	39.4
6 minutes	291	23.4	1,940	2,560	59.0	39.7
8 minutes	289	23.1	1,940	3,380	58.0	39.5
74 mph						
0	232	23.3	2,110	1,020	64.0	43.0
2 minutes	267	23.4	1,985	1,400	63.0	39.1
4 minutes	278	23.4	1,985	2,000	62.0	40.0
6 minutes	281	23.4	1,985	2,580	59.0	40.3
8 minutes	275	23.3	1,985	3,150	58.0	40.3

Table 3. SUMMARY OF TEMPERATURE RISES Δt TAYLORCRAFT NC-95630 CRUISE

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
93 mph						
0	246	23.3	2,110	1,020	64.0	43.1
2 minutes	264	23.3	2,110	1,020	64.0	43.1
4 minutes	267	23.3	2,110	1,020	64.0	43.1
6 minutes	266	23.3	2,110	1,020	65.0	43.1
96 mph						
0	269	24.6	2,210	1,020	66.0	49.0
2 minutes	274	25.0	2,210	1,020	66.0	50.2
4 minutes	274	25.0	2,210	1,020	66.0	50.2
6 minutes	......	......	....	....	......	......
107 mph						
0	222	27.5	2,400	1,020	58.0	63.3
2 minutes	257	27.5	2,400	1,020	58.0	63.3
4 minutes	270	27.5	2,350	1,020	58.0	62.1
6 minutes	270	27.5	2,350	1,020	58.0	62.1

Table 4. SUMMARY OF TEMPERATURE RISES Δt TAYLORCRAFT NC-95630
IDLE

Time	Δt	*RPM*	*OAT*	BHP_c
0	129	690	62.0	2.5
2 minutes	148	690	62.0	2.5
4 minutes	155	690	62.0	2.5
6 minutes	160	690	62.0	2.5
8 minutes	163	690	62.0	2.5
10 minutes	163	690	62.0	2.5
0	167	835	62.0	4.1
2 minutes	172	835	62.0	4.1
4 minutes	174	835	62.0	4.1
6 minutes	174	835	62.0	4.1
8 minutes	......	....	......	....
10 minutes	......	....	......	....
0	187	1,030	62.0	7.4
2 minutes	196	1,030	62.0	7.4
4 minutes	209	1,030	62.0	7.4
6 minutes	208	1,030	62.0	7.4
8 minutes	......	....	......	....
10 minutes	......	....	......	....
0	228	1,230	62.0	11.7
2 minutes	218	1,230	62.0	11.7
4 minutes	216	1,230	62.0	11.7
6 minutes	213	1,230	62.0	11.7
8 minutes	......	....	......	....
10 minutes	......	....	......	....
0	234	1,420	62.0	17.1
2 minutes	241	1,420	62.0	17.1
4 minutes	236	1,420	62.0	17.1
6 minutes	241	1,420	62.0	17.1
8 minutes	246	1,420	62.0	17.1
10 minutes	246	1,420	62.0	17.1

Table 5. SUMMARY OF TEMPERATURE RISES Δt LUSCOMBE NC-45553
FULL-THROTTLE CLIMB

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
55 mph						
0	227	28.7	1,930	250	34.0	52.8
2 minutes	240	28.7	1,810	950	38.0	48.8
4 minutes	282	27.7	1,810	1,850	40.0	47.0
6 minutes	263	27.0	1,810	2,660	40.0	46.0
8 minutes	259	27.3	1,810	3,450	46.0	44.0
10 minutes	261	26.5	1,810	4,130	44.0	42.7
12 minutes	239	25.6	1,810	4,780	42.0	42.2
64 mph						
0	192	28.7	2,050	1,120	40.0	55.7
2 minutes	260	28.4	1,900	2,140	40.0	50.8
4 minutes	275	27.5	1,900	3,050	45.0	48.7
6 minutes	306	26.5	1,900	3,980	44.0	46.7
8 minutes	285	25.4	1,900	4,800	42.0	44.8
10 minutes	......	......	....	....	......	......
12 minutes	......	......	....	....	......	......
74 mph						
0	196	28.5	2,050	1,120	40.0	55.6
2 minutes	241	28.5	1,960	1,630	40.0	52.7
4 minutes	264	27.6	1,960	2,740	44.0	50.7
6 minutes	283	26.6	1,960	3,750	46.0	48.8
8 minutes	254	25.4	1,960	4,700	42.0	46.6
10 minutes	......	......	....	....	......	......
12 minutes	......	......	....	....	......	......
84 mph						
0	143	28.5	2,100	1,120	43.0	56.2
2 minutes	234	28.0	2,050	1,920	40.0	54.5
4 minutes	......	......	....	....	......	......
6 minutes	276	26.3	2,050	3,880	44.0	50.8
8 minutes	266	25.5	2,050	4,720	42.0	49.0
10 minutes	......	......	....	....	......	......
12 minutes	......	......	....	....	......	......

Table 6. SUMMARY OF TEMPERATURE RISES Δt LUSCOMBE NC-45553
PART-THROTTLE CLIMB

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
55 mph						
0	298	27.6	1,780	1,900	31.0	46.2
2 minutes	322	26.9	1,780	2,550	31.0	45.3
4 minutes	338	26.2	1,780	3,150	31.0	43.7
6 minutes	357	25.5	1,780	3,700	31.0	42.3
8 minutes	353	25.1	1,780	4,180	31.0	41.5
64 mph						
0	282	25.6	1,810	1,500	31.0	42.5
2 minutes	302	25.6	1,810	2,290	31.0	43.0
4 minutes	301	25.4	1,810	3,000	31.0	42.6
6 minutes	314	24.8	1,810	3,690	31.0	41.5
8 minutes	286	24.1	1,810	4,350	30.0	40.1
74 mph						
0	243	26.3	1,875	1,810	30.0	46.0
2 minutes	262	25.3	1,875	2,610	31.0	43.9
4 minutes	269	24.7	1,875	3,330	31.0	42.5
6 minutes	267	24.1	1,875	3,950	31.0	41.2
8 minutes	......	......	....	....	......	......

Table 6a. SUMMARY OF TEMPERATURE RISES Δt LUSCOMBE NC-45553
PART-THROTTLE CLIMB

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
60 mph						
0	271	24.1	1,700	2,550	33.0	35.8
2 minutes	276	24.1	1,700	2,970	30.0	36.2
4 minutes	290	23.8	1,700	3,400	28.0	35.9
6 minutes	287	23.4	1,700	3,840	26.0	35.1
8 minutes	295	23.1	1,700	4,290	23.0	35.0
10 minutes	289	22.9	1,700	4,670	22.0	34.8
69 mph						
0	245	24.5	1,750	2,660	32.0	38.7
2 minutes	270	24.1	1,750	3,200	30.0	38.0
4 minutes	266	23.5	1,750	3,750	27.0	37.1
6 minutes	275	23.2	1,750	4,290	25.0	36.3
8 minutes	278	22.7	1,750	4,720	23.0	35.6
10 minutes	278	22.4	1,750	5,260	23.0	35.3
79 mph						
0	258	23.3	1,810	3,680	26.0	38.1
2 minutes	262	22.9	1,810	4,080	24.0	37.2
4 minutes	278	22.6	1,810	4,440	22.0	36.8
6 minutes	284	22.4	1,810	4,900	20.0	36.4
8 minutes	297	22.1	1,810	5,300	18.0	36.0
10 minutes	288	21.7	1,810	5,680	16.0	35.3
89 mph						
0	210	25.1	2,050	1,110	28.0	47.4
2 minutes	291	24.4	1,900	1,370	25.0	41.6
4 minutes	298	24.1	1,900	1,840	25.0	41.2
6 minutes	303	23.8	1,900	2,250	26.0	40.4
8 minutes	304	23.5	1,900	2,640	25.0	40.0
10 minutes	290	23.2	1,900	2,910	26.0	39.4

Table 7. SUMMARY OF TEMPERATURE RISES Δt LUSCOMBE NC-45553
CRUISE

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
122 mph						
0	206	27.8	2,360	1,120	28.0	65.4
2 minutes	230	27.8	2,360	1,120	28.0	65.4
4 minutes	269	27.8	2,360	1,120	28.0	65.4
6 minutes	268	27.8	2,360	1,120	28.0	65.4
107 mph						
0	278	24.8	2,050	1,120	28.0	47.5
2 minutes	245	24.9	2,100	1,120	28.0	48.0
4 minutes	303	25.0	2,100	1,120	28.0	49.4
6 minutes	299	25.2	2,100	1,120	28.0	49.7
89 mph						
0	228	21.3	1,700	1,120	28.0	31.3
2 minutes	236	21.0	1,700	1,120	28.0	30.3
4 minutes	232	20.8	1,700	1,120	28.0	29.7
6 minutes	232	20.4	1,700	1,120	28.0	28.7

Table 8. SUMMARY OF TEMPERATURE RISES Δt LUSCOMBE NC-45553
IDLE

Time	Δt	*RPM*	*OAT*	BHP_c
0	139	620	51.0	1.9
2 minutes	142	620	51.0	1.9
4 minutes	139	620	51.0	1.9
6 minutes	139	620	51.0	1.9
8 minutes	......	....	......	....
10 minutes	......	....	......	....
0	143	800	51.0	3.7
2 minutes	145	800	51.0	3.7
4 minutes	152	800	51.0	3.7
6 minutes	157	800	51.0	3.7
8 minutes	161	800	51.0	3.7
10 minutes	161	800	51.0	3.7
0	164	940	51.0	5.7
2 minutes	166	940	51.0	5.7
4 minutes	167	940	51.0	5.7
6 minutes	170	940	51.0	5.7
8 minutes	171	940	51.0	5.7
10 minutes	171	940	51.0	5.7
0	187	1,120	51.0	9.4
2 minutes	188	1,120	51.0	9.4
4 minutes	193	1,120	51.0	9.4
6 minutes	196	1,120	51.0	9.4
8 minutes	198	1,120	51.0	9.4
10 minutes	198	1,120	51.0	9.4
0	219	1,310	51.0	14.3
2 minutes	233	1,310	51.0	14.3
4 minutes	245	1,310	51.0	14.3
6 minutes	229	1,310	51.0	14.3
8 minutes	229	1,310	51.0	14.3
10 minutes	......	....	......	......

Table 9. SUMMARY OF TEMPERATURE RISES Δt UNMODIFIED AERONCA NC-3007E
FULL-THROTTLE CLIMB

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
54 mph						
0	255	28.5	2,040	110	72.0	53.8
2 minutes	314	28.0	2,000	570	70.0	51.5
4 minutes	338	27.3	2,000	1,200	66.0	49.9
6 minutes	344	27.2	2,000	1,470	64.0	49.8
8 minutes	347	26.8	2,000	2,180	61.0	49.5
10 minutes	338	26.0	2,000	2,700	60.0	49.0
64 mph						
0	326	28.0	2,040	960	68.0	52.7
2 minutes	342	27.0	2,040	1,680	65.0	50.7
4 minutes	339	26.1	2,040	2,510	62.0	49.2
6 minutes	......	......	....	....	......	......
8 minutes	......	......	....	....	......	......
10 minutes	......	......	....	....	......	......
72 mph						
0	323	28.0	2,065	970	69.0	53.2
2 minutes	332	26.9	2,065	1,570	66.0	51.2
4 minutes	330	26.1	2,065	2,410	62.0	49.6
6 minutes	......	......	....	....	......	......
8 minutes	......	......	....	....	......	......
10 minutes	......	......	....	....	......	......

Table 10. SUMMARY OF TEMPERATURE RISES Δt UNMODIFIED AERONCA NC-3007E
PART-THROTTLE CLIMB

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
62 mph						
0	259	25.8	2,135	910	64.0	50.4
2 minutes	......	......	....	....	......	......
4 minutes	282	25.8	1,950	1,560	62.0	45.3
6 minutes	285	25.2	1,950	2,030	59.0	44.2
71 mph						
0	264	26.3	2,135	760	66.0	51.5
2 minutes	289	26.3	2,000	860	64.0	47.6
4 minutes	293	26.3	2,000	1,260	62.0	47.9
6 minutes	291	25.8	2,000	1,970	58.0	47.0
82 mph						
0	268	26.3	2,135	650	68.0	50.0
2 minutes	......	......	....	....	......	......
4 minutes	290	26.3	2,040	820	65.0	48.4
6 minutes	289	25.8	2,040	1,450	60.0	47.5

Table 10a. SUMMARY OF TEMPERATURE RISES Δt UNMODIFIED AERONCA NC-3007E
PART-THROTTLE CLIMB

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
62 mph						
0	......	......	....	600	......	......
2 minutes	303	25.2	1,950	1,310	74.0	43.4
4 minutes	303	24.1	1,950	1,630	74.0	40.6
6 minutes	......	......	....	....	......	......
71 mph						
0	......	......	....	650	......	......
2 minutes	293	26.9	2,000	960	74.0	48.5
4 minutes	296	26.3	2,000	1,260	74.0	47.2
6 minutes	296	25.8	2,000	1,610	74.0	45.9
82 mph						
0	......	......	....	750	......	......
2 minutes	262	24.6	1,950	850	65.0	41.8
4 minutes	264	24.1	1,950	1,260	61.0	41.0
6 minutes	......	......	....	....	......	......

Table 11. SUMMARY OF TEMPERATURE RISES Δt UNMODIFIED AERONCA NC-3007E; CRUISE

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
67 mph						
0	237	19.0	1,765	2,570	54.0	27.7
2 minutes	238	19.0	1,765	2,550	55.0	27.7
4 minutes	233	19.0	1,765	2,520	56.0	27.7
85 mph						
0	256	23.7	2,040	2,630	54.0	45.4
2 minutes	256	23.7	2,040	2,630	54.0	45.4
4 minutes	......	......	....	....	......	......
99 mph						
0	273	26.3	2,225	2,630	54.0	56.3
2 minutes	273	26.3	2,225	2,630	54.0	56.3
4 minutes	......	......	....	....	......	......

Table 12. SUMMARY OF TEMPERATURE RISES Δt UNMODIFIED AERONCA NC-3007E; IDLE

Time	Δt	*RPM*	*OAT*	BHP_c
0	120	630	74.0	1.9
2 minutes	140	630	73.0	1.9
4 minutes	145	630	73.0	1.9
6 minutes	156	630	73.0	1.9
8 minutes	162	630	74.0	1.9
10 minutes	162	630	74.0	1.9
0	168	790	73.0	3.6
2 minutes	177	790	74.0	3.6
4 minutes	180	790	74.0	3.6
6 minutes	184	790	74.0	3.6
8 minutes	186	790	74.0	3.6
10 minutes	186	790	74.0	3.6
0	......	1,000	74.0	6.7
2 minutes	199	1,000	74.0	6.7
4 minutes	199	1,000	74.0	6.7
6 minutes	......	....	......	....
8 minutes	......	....	......	....
10 minutes	......	....	......	....
0	221	1,200	74.0	10.9
2 minutes	222	1,200	74.0	10.9
4 minutes	222	1,200	74.0	10.9
6 minutes	......	....	......	....
8 minutes	......	....	......	....
10 minutes	......	....	......	....

Table 13. SUMMARY OF TEMPERATURE RISES Δt MODIFIED AERONCA NC-1396E
FULL-THROTTLE CLIMB

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
56 mph						
0	254	27.5	2,200	1,030	62.0	56.5
2 minutes	278	27.5	2,170	1,800	60.0	56.0
4 minutes	294	26.9	2,170	2,580	56.0	52.2
6 minutes	300	25.8	2,170	3,630	50.0	49.5
8 minutes	......	......	....	....	......	......
62 mph						
0	193	28.5	2,245	50	70.0	60.0
2 minutes	258	28.5	2,245	1,060	64.0	60.0
4 minutes	289	28.0	2,245	1,750	60.0	59.8
6 minutes	291	26.9	2,245	2,570	56.0	56.9
8 minutes	296	26.3	2,245	3,620	51.0	55.5
73 mph						
0	286	28.0	2,290	1,200	64.0	60.7
2 minutes	289	27.5	2,290	1,920	60.0	59.9
4 minutes	287	26.9	2,290	2,490	58.0	58.8
6 minutes	......	......	....	....	......	......
8 minutes	......	......	....	....	......	......

Table 14. SUMMARY OF TEMPERATURE RISES Δt MODIFIED AERONCA NC-1396E
PART-THROTTLE CLIMB

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
57 mph						
0	......	......	....	....	......	......
2 minutes	263	23.3	2,000	2,030	64.0	40.9
4 minutes	262	22.4	2,000	2,350	63.0	39.1
6 minutes	......	......	....	....	......	......
62 mph						
0	......	......	....	....	......	......
2 minutes	243	22.9	2,020	1,050	70.0	39.3
4 minutes	245	22.4	2,020	1,410	68.0	38.8
6 minutes	245	22.0	2,020	1,550	68.0	37.6
73 mph						
0	......	......	....	....	......	......
2 minutes	245	23.3	2,065	1,030	70.0	41.5
4 minutes	245	23.3	2,065	1,170	70.0	41.6
6 minutes	......	......	....	....	......	......

Table 14a. SUMMARY OF TEMPERATURE RISES Δt MODIFIED AERONCA NC-1396E
PART-THROTTLE CLIMB

True indicated airspeed	Δt	*MAP*	*RPM*	Pressure altitude	*OAT*	BHP_c
57 mph						
0	......	......	....	510	......	......
2 minutes	260	23.3	1,900	1,050	70.0	37.5
4 minutes	260	22.4	1,900	1,270	70.0	35.9
6 minutes	......	......	....	....	......	......
62 mph						
0	......	......	....	610	......	......
2 minutes	241	22.0	1,925	830	72.0	35.2
4 minutes	240	21.5	1,925	950	71.0	34.5
6 minutes	......	......	....	....	......	......
73 mph						
0	......	......	....	610	......	......
2 minutes	233	22.0	2,000	580	75.0	36.0
4 minutes	235	22.0	2,000	750	75.0	36.1
6 minutes	235	22.0	2,000	800	75.0	36.1

Table 15. SUMMARY OF TEMPERATURE RISES Δt MODIFIED AERONCA NC-1396E; CRUISE

True indicated airspeed	Δt	MAP	RPM	Pressure altitude	OAT	BHP_c
62 mph						
0	212	18.0	1,700	970	64.0	23.7
2 minutes	214	19.0	1,700	900	64.0	22.2
4 minutes	214	18.0	1,700	940	64.0	23.7
79 mph						
0	234	21.5	2,000	970	66.0	35.2
2 minutes	229	21.5	2,000	970	66.0	35.2
4 minutes	229	21.5	2,000	970	66.0	35.2
89 mph						
0	254	25.8	2,290	890	66.0	55.0
2 minutes	254	25.8	2,290	900	66.0	55.0
4 minutes	......	......	....	....	......	......
99 mph						
0	264	28.5	2,470	970	66.0	68.0
2 minutes	264	28.5	2,470	970	66.0	68.0
4 minutes	......	......	....	....	......	......

Table 16. SUMMARY OF TEMPERATURE RISES Δt MODIFIED AERONCA NC-1396E; IDLE

Time	Δt	RPM	OAT	BHP_c
0	117	600	74.0	1.7
2 minutes	126	600	74.0	1.7
4 minutes	133	600	74.0	1.7
6 minutes	139	600	74.0	1.7
8 minutes	139	600	74.0	1.7
10 minutes	139	600	74.0	1.7
0	141	750	74.0	3.1
2 minutes	142	750	76.0	3.1
4 minutes	145	750	76.0	3.1
6 minutes	148	750	76.0	3.1
8 minutes	148	750	76.0	3.1
10 minutes	148	750	74.0	3.1
0	156	950	78.0	5.8
2 minutes	158	950	76.0	5.8
4 minutes	161	950	75.0	5.8
6 minutes	160	950	76.0	5.8
8 minutes	......	....	......	....
10 minutes	......	....	......	....
0	171	1,160	76.0	9.9
2 minutes	180	1,160	76.0	9.9
4 minutes	179	1,160	77.0	9.9
6 minutes	180	1,160	76.0	9.9
8 minutes	......	....	......	....
10 minutes	......	....	......	....
0 minutes	196	1,340	79.0	14.8
2 minutes	196	1,340	79.0	14.8
4 minutes	198	1,340	78.0	14.8
6 minutes	198	1,340	78.0	14.8

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