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ARMY AIR FORCES
AIR MATERIEL ~~COMMAND~~ COMMAND
Engineering Division
MEMORANDUM REPORT ON

HSB:lg:2-0132

SUBJECT: Power Plant Selection Investigation for Six Engine Heavy Bombardment Type Aircraft. AMC Design 924.

Date 30 September 1946

SECTION Aircraft Laboratory

Contract No.
Expenditure Order No. 426-253
Purchase Order No.

SERIAL No. TSEAC4-4261-10-1

A. PURPOSE:

1. To report the results of an investigation of power plant selection for six engine heavy bombardment type aircraft.

2. This study was made as a further effort to determine the effect of various parameters on long range aircraft.

3. This study also fulfills the request of TSESA2 in Routing and Record Sheet dated 13 August 1946 for this type investigation.

B. FACTUAL DATA:

1. The XB-52 airplane, which has a design gross weight of 360,000 pounds, a wing loading of 110 pounds per sq. ft. at design gross weight, and is powered with six Wright T35-1 turbo propeller engines appears to have a very high gross weight for the range it achieves because of the combination of high speed and range requirements. There is no improvement in range in this airplane over other contemporary bombers which are of a much lower gross weight. The range of the XB-52 airplane is 8,300 miles with 10,000 pounds of bombs at design gross weight.

2. Performance studies were made based on the XB-52 airplane with various types of power plants. The power plants used in this study were the Wright T35-1 turbo propeller engine, the Lycoming R7755-3 engine, and the Pratt and Whitney R4360-C two-stage compound engine with dual feedback turbines. The ratings of these power plants are given in Table 1, Appendix II. Further power plants details are discussed in item 7 of the discussion.

3. A performance study was made of the XB-52 airplane, keeping the same design gross weight of 360,000 pounds and wing loading of 110 pounds per sq. ft., with six Lycoming R7755-3 engines turbo-supercharged to 35,000 feet in lieu of six Wright T35-1 turbo-propeller engines.

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4. In an effort to get better range characteristics by virtue of lower cruising speeds, further performance studies were made for a reduced wing loading of 75 pounds per sq.ft. as compared to the original wing loading of 110 pounds per sq.ft. The same design gross weight of 360,000 pounds and a six engine airplane were used in this phase of the study. This investigation was made for the three different type power plants referred to in paragraph B-2.

5. Further studies were made with a wing loading of 75 pounds per sq. ft. for a six engine airplane with the different type power plants to determine the effect of cruising speed and gross weight on range. This was accomplished by maintaining a constant design range of 8,000 miles and determining the gross weight of the airplanes necessary to achieve this range for various average cruising speeds.

6. All range figures quoted are based on a bomb load of 10,000 pounds. The range figures do not include allowances for takeoff, climb, reserve, etc. All high speeds are at design gross weight less one-half fuel unless otherwise specified. All range and speed figures are at 35,000 feet altitude.

7. Appendix I is a general discussion of this study.

8. Appendix II, Table 1 gives the power plant ratings.

9. Appendix II, Table 2 shows the comparative performance of the airplanes.

10. Appendix II, Table 3 is a group weight statement for this study.

11. Appendix III contains a list of referenced reports of previous studies made for long range heavy bombardment type aircraft.

12. Appendix IV contains the performance curves of the study.

C. CONCLUSIONS:

1. It is concluded that the use of six Lycoming R7755-3 engines, turbo supercharged to 35,000 feet altitude in lieu of the six Wright T35-1 turbo-propeller engines in the XB-52 type airplane with a wing loading of 110 pounds per sq.ft. and a design gross weight of 360,000 pounds, resulted in a slight decrease in range from 8,300 to 8,000 miles and an increase in high speed from 450 to 487 miles per hour. The average cruising speed decreased from 410 to 325 miles per hour.

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2. Reducing the wing loading of the XB-52 type airplane from 110 pounds per sq. ft. to 75 pounds per sq. ft. for the design gross weight of 360,000 pounds, the range is greatly increased with both the Lycoming and Pratt and Whitney engines. The range increases from 8,300 miles with the T35-1 to 9,530 miles with the R7755-3 and to 10,800 miles with the R4360-C. The high speeds are 462 with the Lycoming, 445 with the Pratt and Whitney and 430 with the Wright.

3. For a given design range, relatively high cruising speeds result in corresponding large size airplanes.

4. For range characteristics and also for high speed at a tactical operating altitude of 35,000 feet, both the R7755-3 and R4360-C engines are superior to the T35-1 turbo-propeller for a six engine installation in an airplane with a design wing loading of 75 pounds per sq. ft.

5. For range characteristics only the R4360-C two-stage compound which has a much lighter installed weight than the R7755-3 with comparable specific fuel consumptions, is shown superior to the R7755-3 engine.

RECOMMENDATIONS:

It is recommended that:

1. This study be used as an aid in the preparation of future Military Characteristics for bombardment type aircraft.

2. Since the aerodynamic art determines the relationship between high speed, cruising speed, range, and weight, care must be taken in preparing military requirements of aircraft to establish the primary factor and indicate the range of desirabilities for the others. Unless this is done, unduly large compromises result in the performance of the airplane.

3. This study be reviewed by the Power Plant Laboratory with particular regard to effect of type power plants studied herein on speed, range and size of future bombardment type aircraft.

4. The development of the Pratt and Whitney R4360-C two-stage compound engine with dual feedback turbines be expedited.

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5. The development of compounding the R7755-3 engine be more strongly urged so that much lower specific fuel consumptions may be realized with a small increase in engine weight.

6. Emphasis be placed on the development of low specific fuel consumption engines with low specific installed engine weights rather than increased power for long range heavy bombardment type aircraft.

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Appendix I

Discussion

1. This study was made to determine the effect of performance with various type power plants based on the XB-52 type airplane. The following performance studies were made:

a. Performance of the XB-52 airplane with Lycoming R7755-3 engines in lieu of the Wright T35-1 turbo propeller engines.

b. Performance of the XB-52 airplane, reducing the wing loading from 110 pounds per sq. ft. to 75 pounds per sq. ft., with the T35-1, R7755-3 and R4360-C engines.

c. For a design range of 8,000 miles, wing loading of 75 pounds per sq. ft. and the best cruising speed for range; the size airplane necessary was calculated.

d. For the same given design range of 8,000 miles and wing loading of 75 pounds per sq. ft., but fixing the cruising speed; the size airplane necessary was calculated.

2. Using the same design gross weight of 360,000 pounds and a wing loading of 110 pounds per sq. ft. at design gross weight, a performance study was made of the XB-52 airplane with six R7755-3 engines, turbo-supercharged to 35,000 feet altitude, in lieu of the six T35-1 turbo-propeller engines. The installation of the R7755-3 engines resulted in a decrease in fuel load of approximately 35,000 pounds due to the increase in installed power plant weight. However, the range was only decreased from 8,300 to 8,000 miles. The high speed, however, was increased from 450 to 487 miles per hour because the R7755-3 engine maintains full power at 35,000 feet altitude whereas the T35-1 power drops off at the higher altitudes. The R4360-C engine was not used in this part of the study because the high wing loading necessitated high cruising speeds and this engine does not have sufficient cruise power for these high cruising speeds at the higher gross weights.

3. To improve the range characteristics by virtue of lower cruising speeds, the wing loading was arbitrarily decreased from 110 pounds per sq.ft. to 75 pounds per sq. ft. using the same design gross weight of 360,000 pounds for the three different power plants. With the lower cruising speeds, lower specific fuel consumptions with the reciprocating engines were utilized. Although the weight empty of the airplane with the 75 pound sq.ft. wing loading was increased over that with the 110 pound per sq. ft. wing loading due to more

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Discussion (Continued)

structural weight for the larger wing and therefore a lesser fuel load, the range with the R7755-3 and R4360-C engines was far greater than the original range of the XB-52. With the T35-1 the range remained the same, 8,300 miles. With the R7755-3 engines the rangeincreased from 8,000 to 9,530 miles and with six R4360-C engines the range was further increased to 10,800 miles. However, with these increases in range, there is a corresponding decrease in high speed due to the added drag of the larger wing. The high speed is reduced from 487 to 462 with the R7755-3, 450 to 430 with the T35-1 and is 445 miles per hour with the R4360-C.

4. Using a constant design range of 8,000 miles and a wing loading of 75 pounds per sq. ft. and utilizing the best cruising speed for range with the three different type power plants, the gross weights of the airplanes necessary to accomplish the range were calculated. The following table shows the results:

	Lycoming R7755-3	Pratt & Whitney R4360-C	Wright T35-1
Design Gross Weight (lbs)	300,000	256,000	345,000
V cruise (mph)	290	300	325
V max (mph)	475	462	435
Fuel (lbs).	96,500	90,600	154,000
Design Range (Mi)	8,000	8,000	8,000

The R7755-3 and R4360-C are both far superior to the T35-1 because of their lower fuel consumptions. As far as range characteristics are concerned, the R4360-C compounded is better than the R7755-3 because it has a lower installed engine weight and has comparable specific fuel consumptions. After obtaining the above results, the effect of cruising speed on range was calculated for the above airplanes. From Figure 9, Appendix III, it can readily be seen that by changing the cruising speed to either a higher or lower value from the optimum the range decreases. When cruising at the lower speeds, full advantage is not taken of the cruise power available for low specific fuel consumption. When cruising at the higher speeds, the best cruise power is exceeded resulting in high specific fuel consumptions.

5. Again using a constant design range of 8,000 miles and a design

wing loading of 75 pounds per sq. ft. but now fixing the average cruising speed at 350 mph in one case and 400 mph in another case, the gross weights of the airplanes necessary to achieve the range were calculated. The following tables show the results:

Range = 8,000 miles; Ave. Vcr = 350 mph

	Lycoming R7755-3	Pratt & Whitney R4360-C	Wright T35-1
Design Gross Weight (lbs)	325,000	280,000	364,000
Fuel (lbs)	108,000	105,000	163,000
Vmax (mph)	470	460	425

Range = 8,000 miles; Ave. Vcr = 400 mph

Design Gross Weight (lbs)	365,000	365,000	400,000
Fuel (lbs)	129,500	148,000	186,000
Vmax (mph)	465	445	425

From the above table it can readily be seen that for a given design range and an airplane with a given power plant, higher cruising speeds will result in relatively larger size airplanes. This effect is caused by the high cruise power required for these higher speeds which result in high specific fuel consumptions. Therefore, for a given design range with a given power plant, the higher specific fuel consumptions necessitate greater fuel loads resulting in greater design gross weights for the airplane.

6. Comparing the R7755-3 and R4360-C engines, this study has indicated the R4360-C compounded to be superior to the R7755-3 as far as range characteristics are concerned. Both have comparable specific fuel consumptions, but the R4360-C has a much lighter installed weight, approximately 4,000 pounds savings per engine. Therefore, for a given design gross weight, more fuel can be carried when using the R4360-C engines and as a result more range. However, the R7755-3 has better speed characteristics because of its greater power available. Both, the R7755-3 and R4360-C engines, are far superior to the T35-1 for high speed and range characteristics at a tactical operation altitude of 35,000 feet.

Discussion (Continued)

7. In this study it should be borne in mind that comparison was made between a Pratt and Whitney R4360-C compounded engine and a Lycoming R7755-3 uncompounded engine whose power figures are initially conservative for the first engine. Single cylinder testing of the R7755-3 predicts 6,000 horsepower military rating. In addition compounding studies are being initiated by Lycoming which will further increase the power and improve fuel economy. No definite figures are yet available from these compounding studies. When the figures are available further performance studies will be made which will give a more exacting comparison between the Pratt and Whitney R4360-C compounded engine and the Lycoming R7755-3 compounded engine.

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Appendix II

Table 1

Power Plant Ratings

Pratt and Whitney R4360-C Two-Stage Compound with Dual Feedback Turbines
Reference Report TR-27 dated 19 July 1946

Takeoff	BHP/RPM/ALT	4,000/2,800/s.l.
Military - wet	" " "	4,300/2,800/35,000
Military - dry	" " "	3,800/2,800/35,000
Normal Rated	" " "	3,200/2,600/35,000

- - - - - - - - - -

Lycoming R7755-3 Single Stage Turbo Supercharged
Reference Specification No. 2031-A dated 4 June 1945

Takeoff	BHP/RPM/ALT	5,000/2,600/s.l.
Military	" " "	5,000/2,600/35,000
Normal	" " "	4,000/2,300/35,000

- - - - - - - - - -

Wright T35-1 Turbo-Propeller
Reference Specification No. AC-105a dated 4 December 1945

	Equi. Shaft HP	Prop. RPM	Altitude
Takeoff	5,000	800	s.l.
Rated	5,000*	800	27,000

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* At 500 MPH true and 1,500°F

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Appendix II

Table 2

Comparative Performance

	W/S = 75			W/S = 110	
	Wright	Lycoming	P & W	Lycoming XB-52	Wright
Design Gross Weight - lbs.	360,000	360,000	360,000	360,000	360,000
Fuel - lbs.	162,724	127,860	146,460	134,934	171,514
Range/Vcr - Mi/mph	8270/325	9530/300	10800/290	8000/350	8300/410
Vmax - mph	430	462	445	487	450
Rate of Climb - fpm	1,950	1,280	740	1,035	1,590
Takeoff Distance over 50' - ft.	4,000	4,300	5,500	6,700	5,500
Bomb Load - lbs.	10,000	10,000	10,000	10,000	10,000
Alternate Gross Weight - lbs*	400,000	400,000	400,000	400,000	400,000
Fuel - lbs.	195,400	163,000	181,600	170,000	205,000
Range/V_{cr} - Mi/mph	9870/330	11330/305	12430/295	9300/355	9500/410
Takeoff Distance over 50'-ft.	5,250	5,600	7,600	8,750	7,200
Rate of Climb - fpm	1,750	1,080	590	800	1,250
Bomb Load - lbs.	10,000	10,000	10,000	10,000	10,000

* Overloaded condition of D.G.W. = 360,000 lbs and W/S = 75 lbs per sq. ft.

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Appendix II

Table 3

Weight Data

	W/S = 75			W/S = 110	
	Wright	Lycoming	P & W	Lycoming	Wright
Wing	55,000	55,000	55,000	46,520	46,520
Tail	4,580	4,580	4,580	4,260	4,260
Fuselage	16,980	16,980	16,980	16,980	16,980
Alighting Gear	18,890	18,890	18,890	18,890	18,890
Nacelle	10,000	10,000	10,000	10,000	10,000
Power Plant Group	53,350*	78,594	58,439	79,725	53,350*
Fixed Equipment	19,870	19,870	19,870	19,870	19,870
Weight Empty	178,950	203,914	183,759	196,245	170,160
Crew	2,500	2,500	2,500	2,500	2,500
Fuel	162,724	127,860	146,460	134,934	171,514
Oil	750	10,650	12,205	11,245	750
Guns and Ammunition	4,536	4,536	4,536	4,536	4,536
Bomb	10,540	10,540	10,540	10,540	10,540
Useful Load	181,050	156,086	176,241	163,755	189,840
Gross Weight	360,000	360,000	360,000	360,000	360,000

* Includes 2,200 pounds for bomb bay tank installation.

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Appendix III

References

1. 500,000 Pound Long Range, Heavy Bombardment Type Aircraft. 12 May 1944. ENG-51-4261-3-4.

2. Long Range, Heavy Bombardment Type Aircraft. 29 June 1944. ENG-51-4261-3-5.

3. Preliminary Studies of Heavy Bombers, ATSC Designs 535A and 535B. 20 May 1946. TSEAC4-4261-6-2.

4. Summarization Report of Studies on Madium Bombers, ATSC Designs 902, 903, 904 and 905. 20 May 1946. TSEAC4-4261-3-11.

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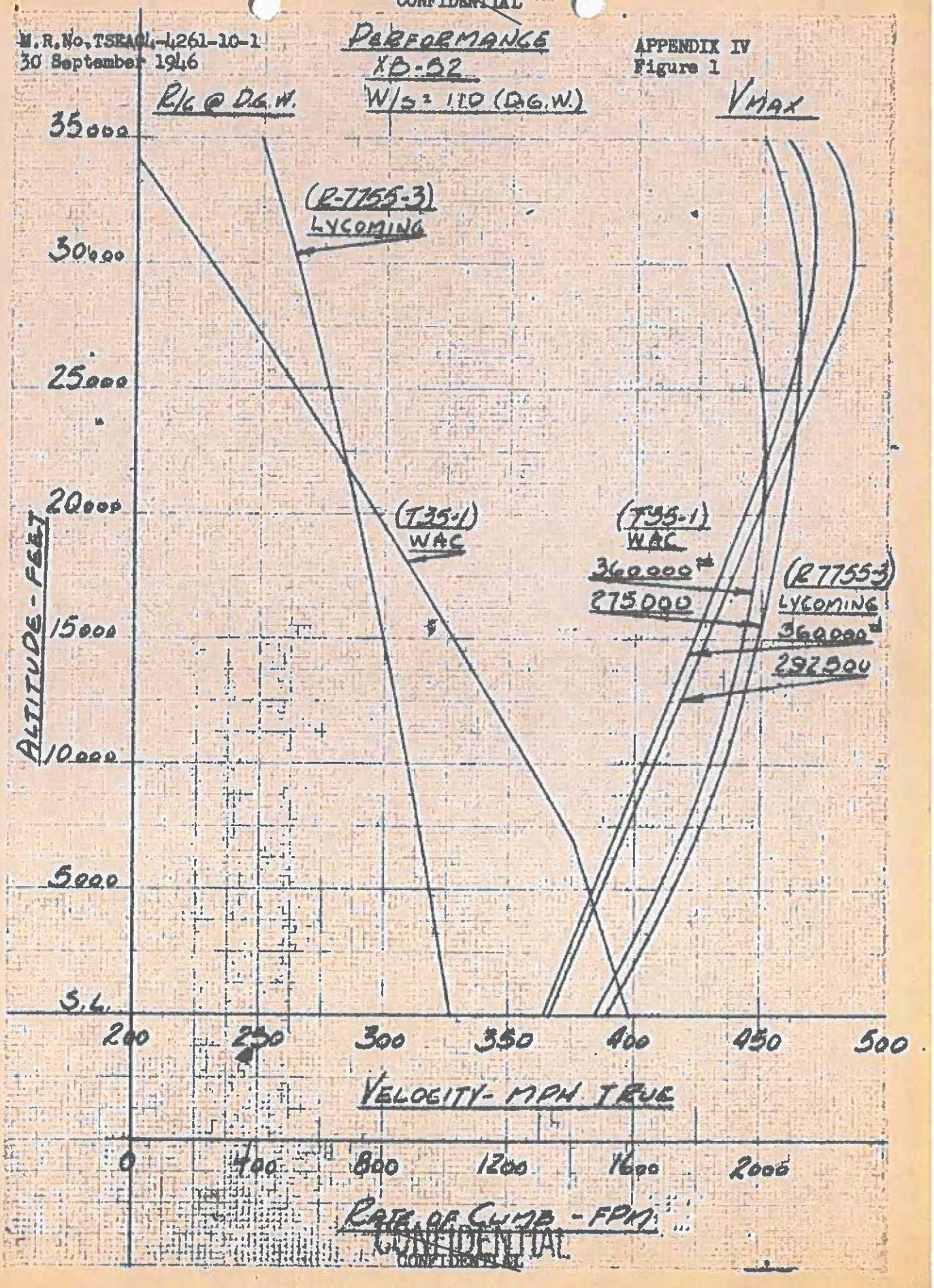
PERFORMANCE
XB-32
W/S² 110 (D.G.W.)

APPENDIX IV
Figure 1



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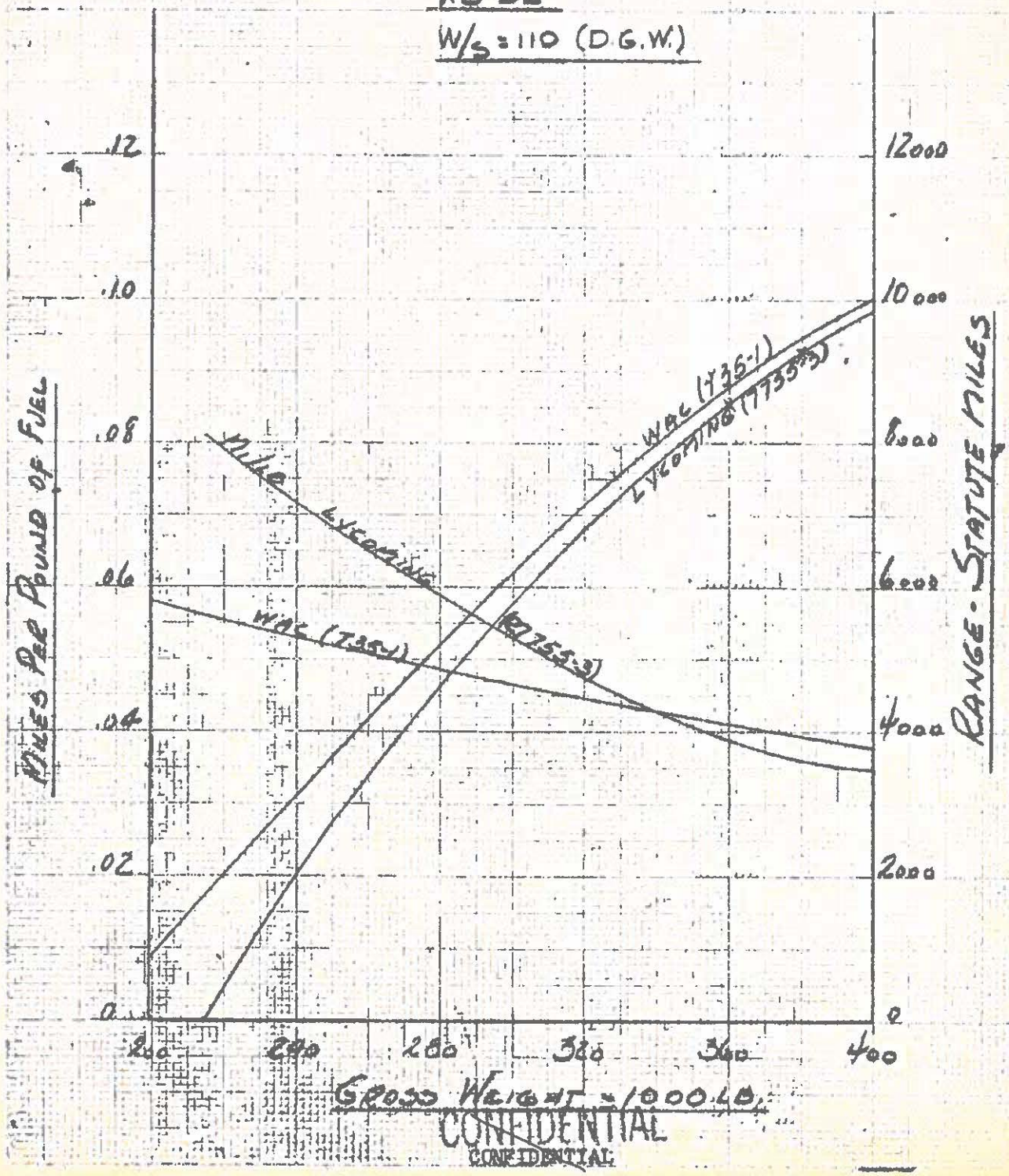
APPENDIX IV
Figure 2

RANGE & M./LB FUEL
VS.
GROSS WEIGHT

XB-52
W/S = 110 (D.G.W.)



GROSS WEIGHT - 1000 LB.

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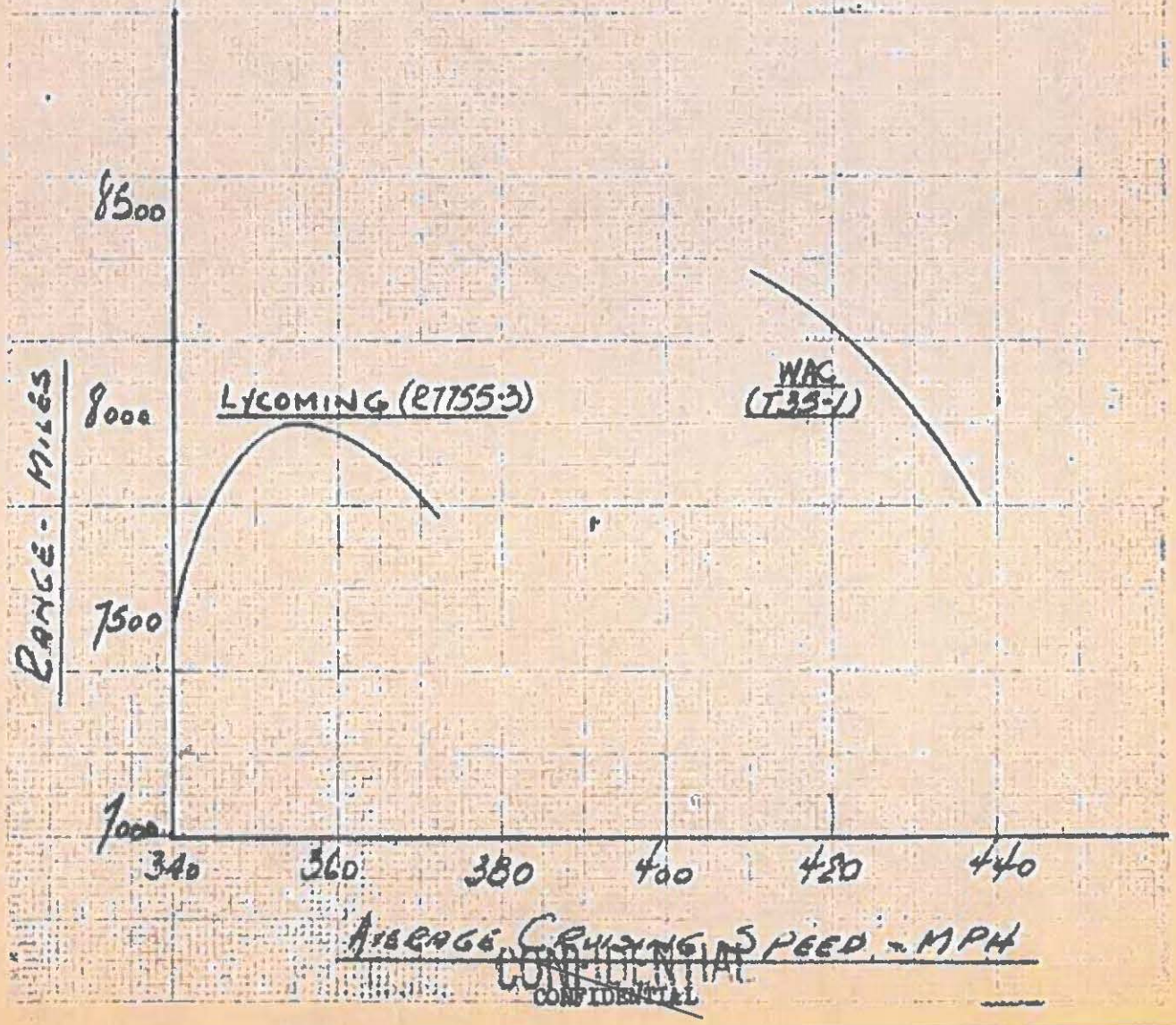
APPENDIX IV
Figure 3

RANGE VS. AVE. VCR
XB-52 (D.G.W.)
W/S = 110



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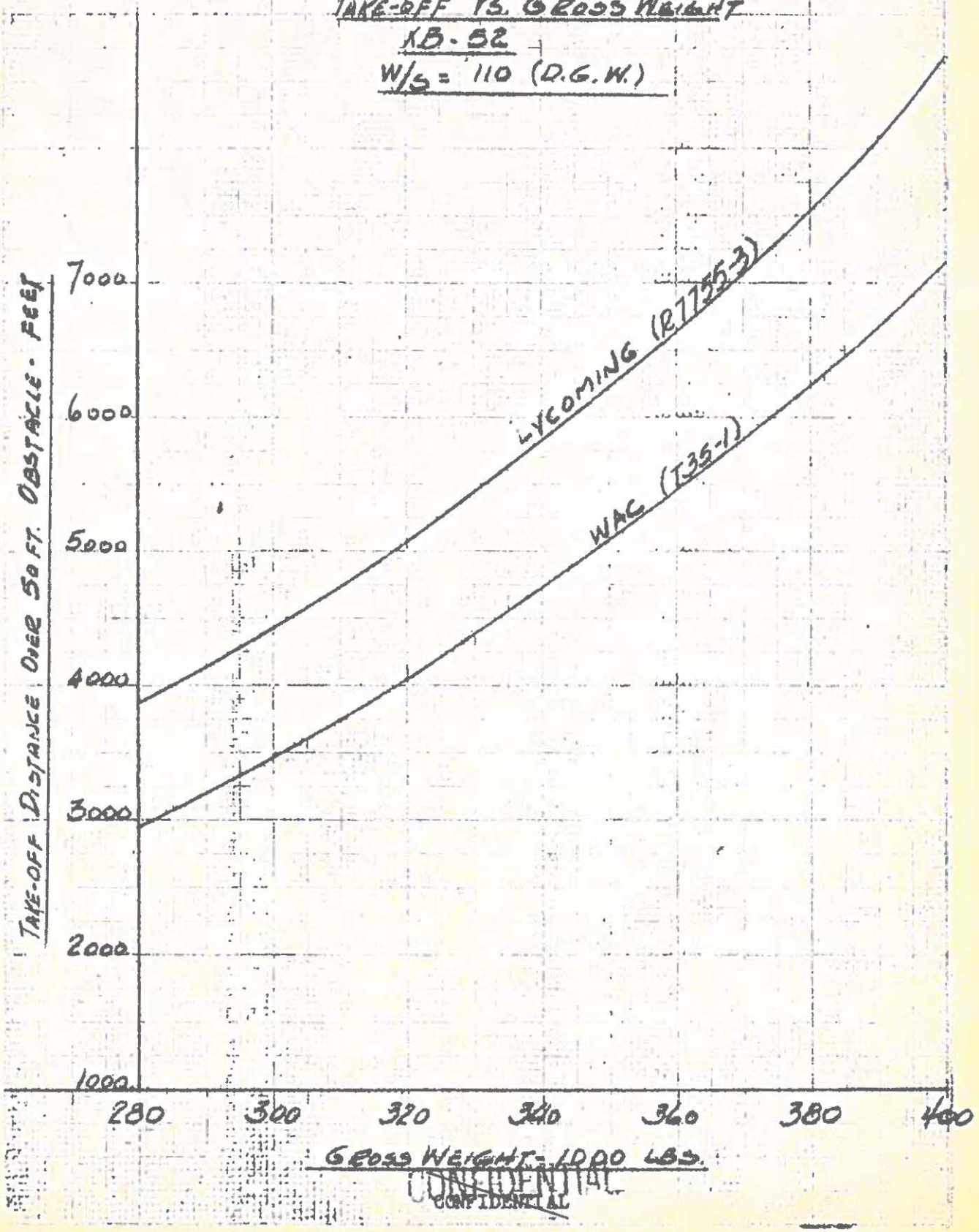
APPENDIX IV Figure 4

TAKE-OFF VS. GROSS WEIGHT
XB-52
W/S = 110 (D.G.W.)



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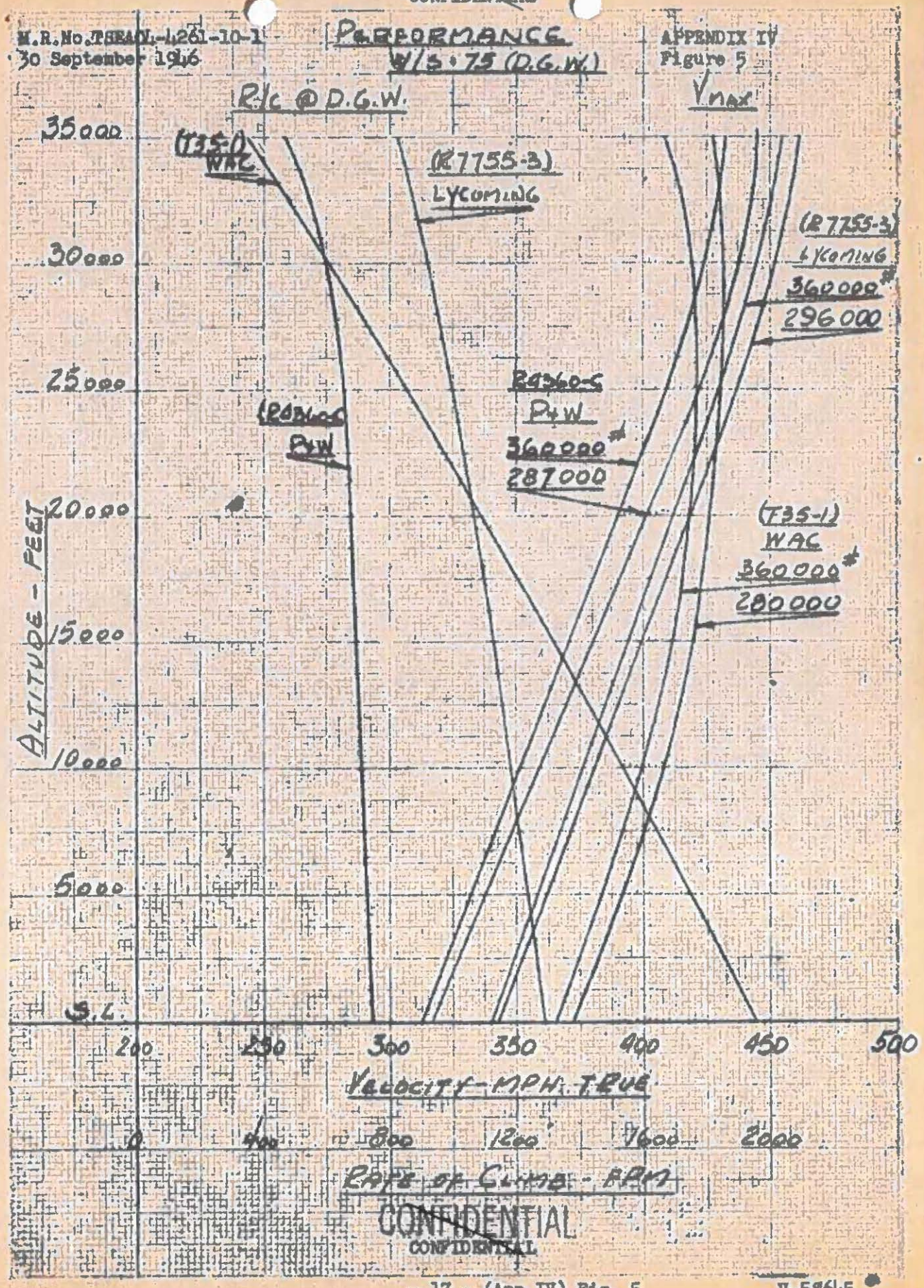
APPENDIX IV
Figure 5



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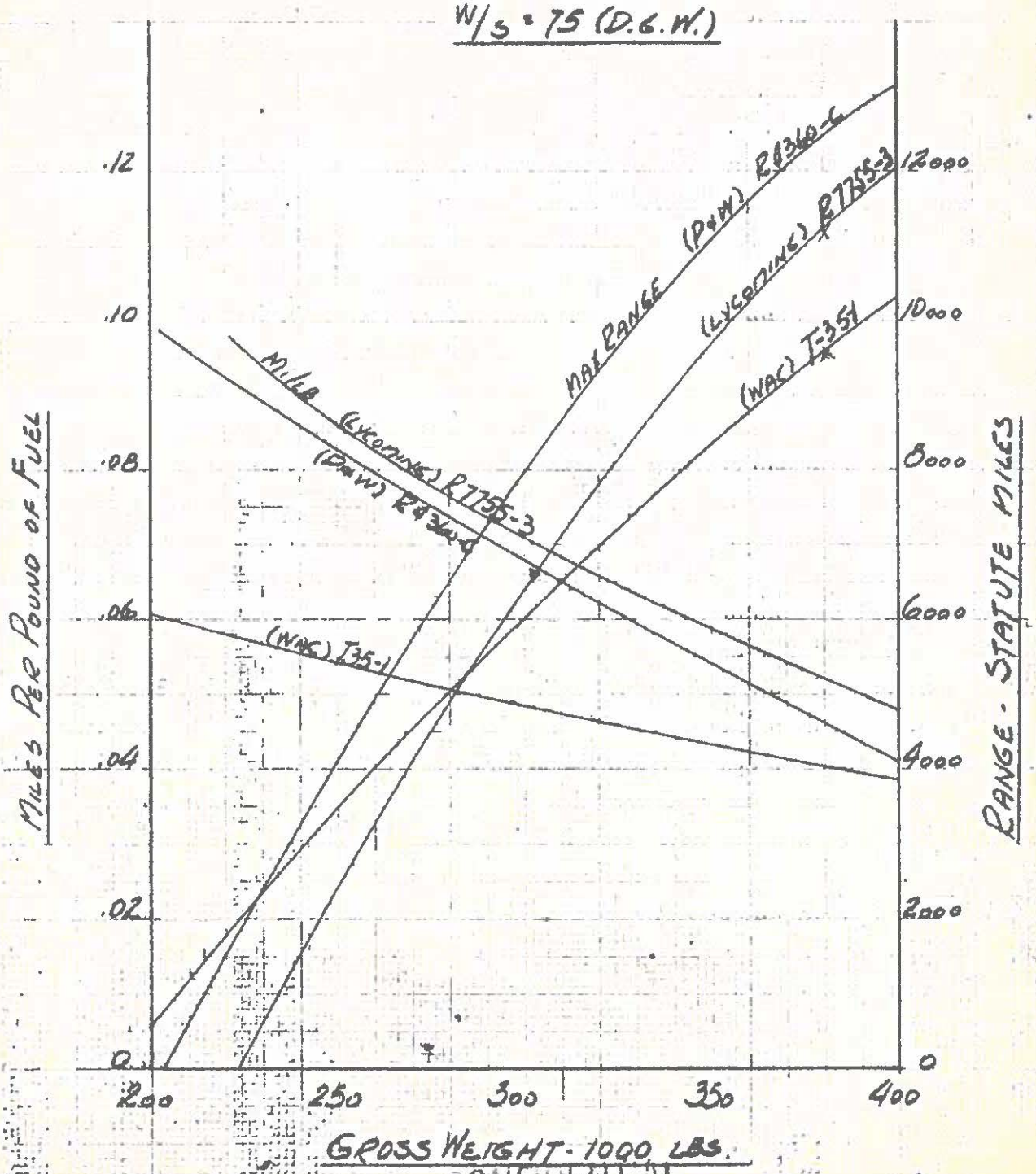
RANGE & MILES/LB FUEL VS. GROSS WEIGHT W/S = 75 (D.C.W.)



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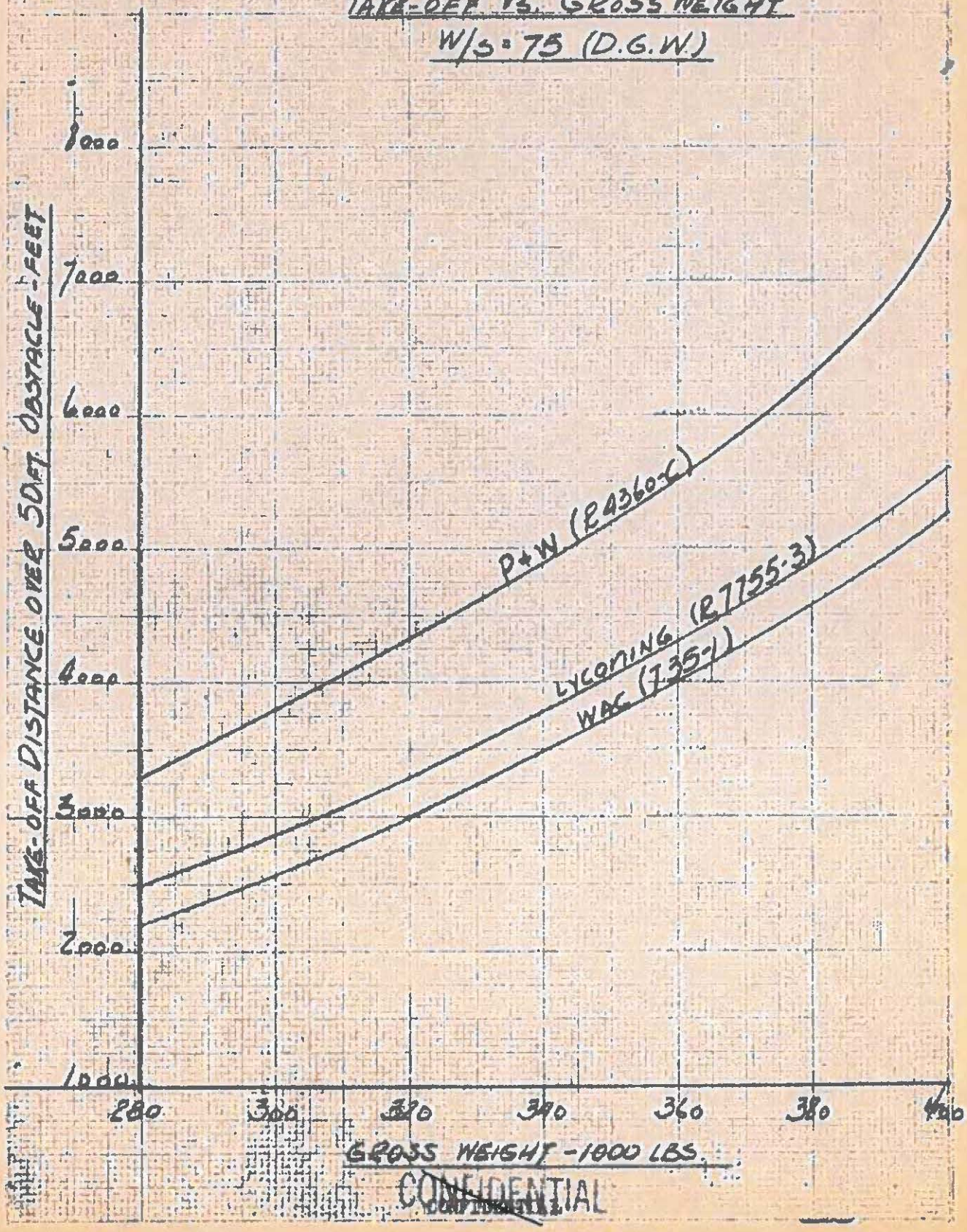
Appendix IV
Figure 7



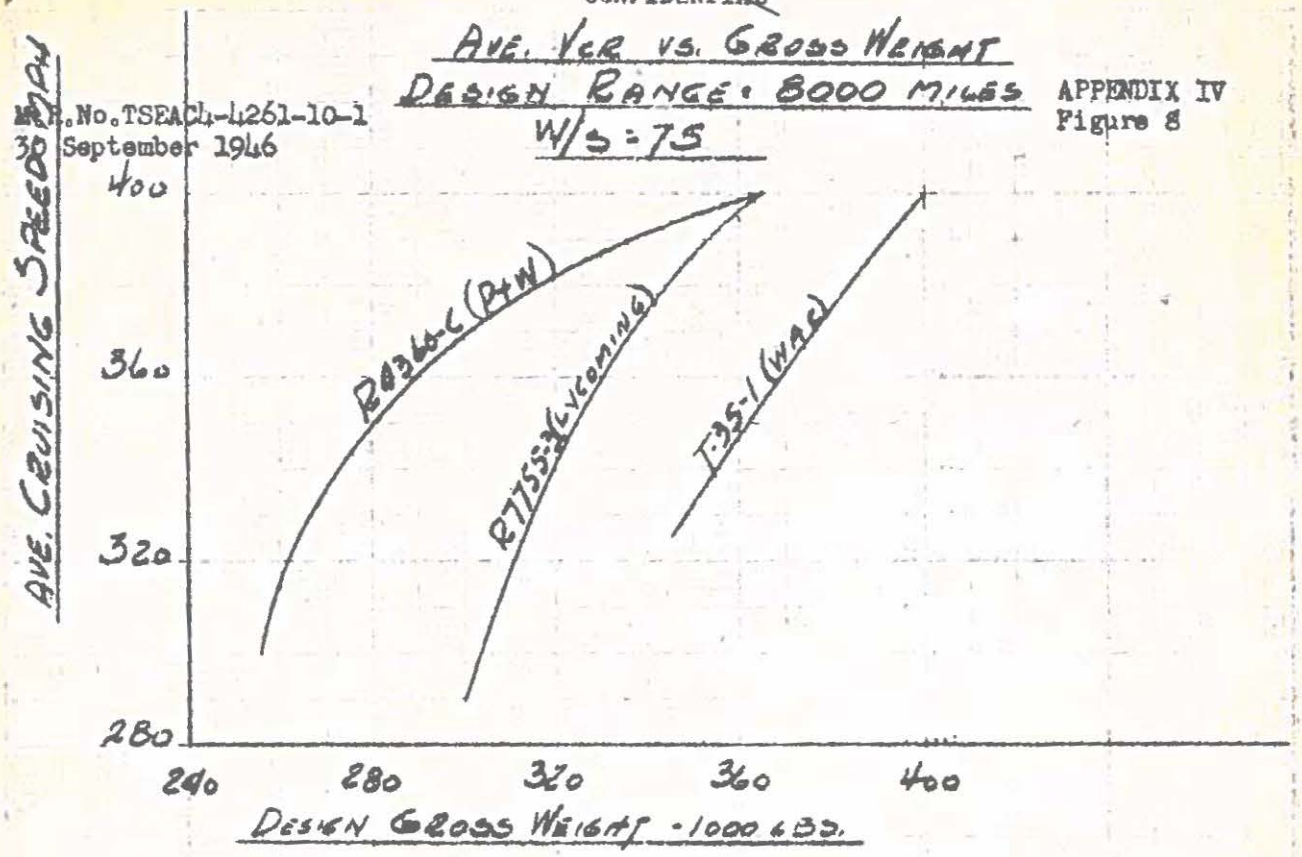

AVE. VCR VS. GROSS WEIGHT
DESIGN RANGE: 8000 MILES
W/S: 75
AVE. CRUISING SPEED MPH
400
360
320
280
R4360-C (P&W)
R7755-3 (LYCOMING)
T-35-1 (WRAC)
240
280
320
360
400
DESIGN GROSS WEIGHT - 1000 LBS.

FIGURE 9

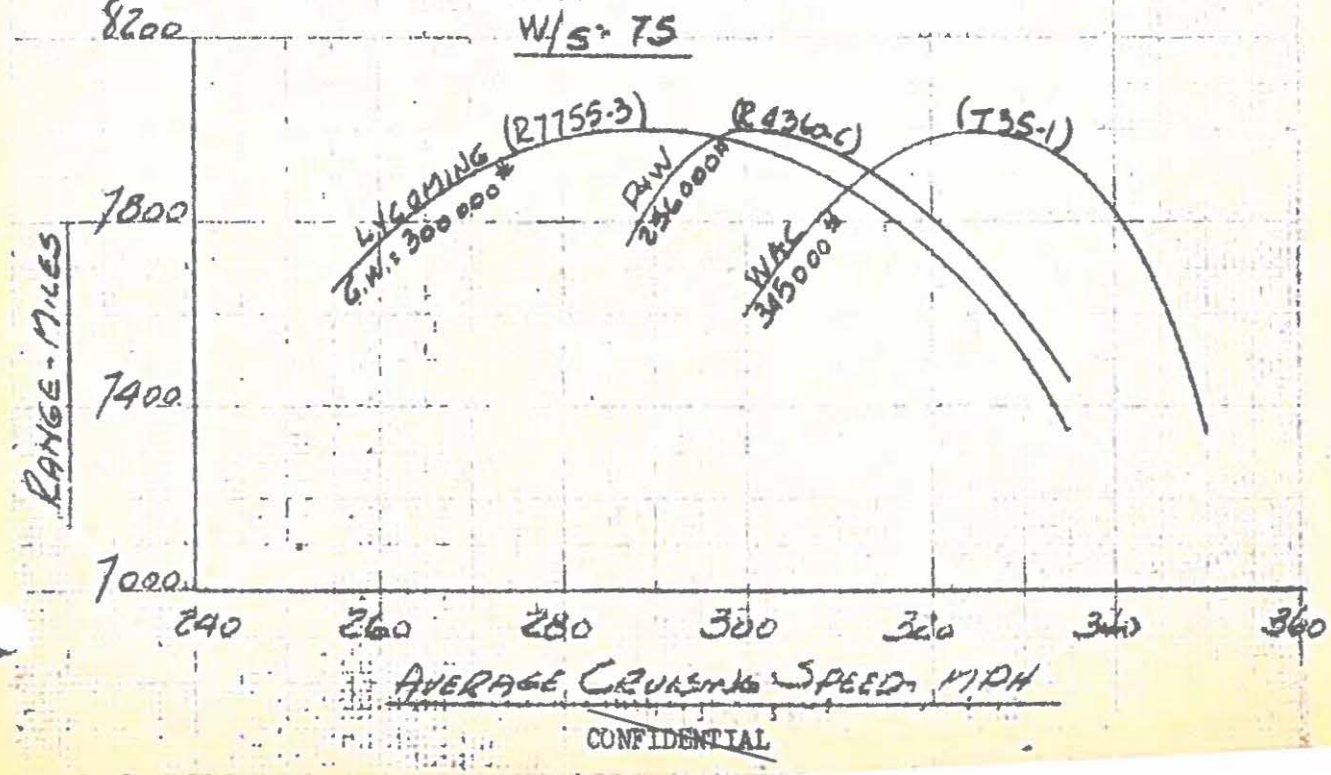

AVE. VCR VS RANGE
DESIGN RANGE: 8000 MILES
W/S: 75
8200
7800
7400
7000
RANGE - MILES
LYCOMING (R7755-3)
G.W.: 300,000 #
P&W
236,000 #
R4360-C)
WRAC
345,000 #
(T35-1)
240
260
280
300
320
340
360
AVERAGE CRUISING SPEED, MPH

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Figure 10