

Flying Training

AIRCRAFT PERFORMANCE – RECIPROCATING AND TURBINE ENGINE AIRCRAFT

AFM 51-9, 25 March 1968, is changed as follows:

1. Page changes:

Remove Pages

10-1 thru 10-40

Insert Pages

10-1 thru 10-39

2. Filing. After posting the changes, file this change sheet in the back of the manual.

BY ORDER OF THE SECRETARY OF THE AIR FORCE

OFFICIAL

JOHN D. RYAN, *General, USAF*
Chief of Staff

JOHN F. RASH, *Colonel, USAF*
Director of Administration

DISTRIBUTION: F

Mission Planning and Flight Logging

This chapter is presented in two parts for purposes of discussing (1) essential preliminary information and (2) the entries required on the AF Form 796, Aircraft Performance Log/Plan. You may use the form either as a flight plan during the planning stage of a mission or as a performance log during the actual flying of the planned mission.

From the entries made on the flight plan copy, using applicable performance charts from your -1 flight manual, you have a record of the planned mission data to compare with the actual aircraft performance in flight. This provides you with a sound basis for analysis of the aircraft performance after flight.

This chapter discusses first, the **entries** made on the form before flight in the **planning stage** and later, the inflight logging of performance data and after-flight analysis. Although the Aircraft Performance Log Plan serves a two-fold purpose as suggested by its title, we refer to it as the flight plan in our discussion of flight planning.

The success of any mission depends largely upon how well it is planned. With all the complexities of our modern bombers and transports, mission planning involves many people and many technicalities. Since the flight engineer is, in effect, the "powerplant manager" of the aircraft, he is deeply concerned with the planning of the mission.

The importance of adequate planning to the successful performance of any mission is well known. However, we limit the scope of this discussion of mission planning to considerations of aircraft performance and associated planning procedures. Equal importance must be given other phases of mission planning such as navigation plans, communications schedules, loading manage-

ment, and weight-balance checking, but these are treated in detail in other publications.

The mission planning procedures suggested by the examples which follow facilitate safe operation of the airplane in all phases of the mission and enable the crew to use better judgment and take quicker action in an emergency.

Mission planning serves two purposes. First, taking into account all foreseeable conditions, you can determine in advance the initial, the intermediate, and the final airspeeds to be flown. Also, the altitudes, headings, elapsed time and distance for the takeoff, the climb and cruise, the descent, and the landing can be planned. Secondly, mission planning determines the maximum cargo that can be delivered to a given point and the maximum range of the aircraft. Then, too, the mission planning determines the fuel necessary to safely accomplish a mission for which cargo and distance are known. The charts in this chapter provide basic data from which you can accomplish a detailed mission plan.

The procedures in the various phases of mission planning are based on the experience of tactical organizations in actual operation, and constitute the best methods to reduce mission failures, crew fatigue, and aircraft maintenance. Local considerations may require that you vary the exact sequence to meet a given situation. However, the principles and fundamentals described in this chapter are generally applicable to any mission.

This chapter sets forth procedures applicable to the flight engineer's position. Procedures for other crew members, however, are dealt with as necessary to coordinate them with the flight engineer's function.

The procedure for the accomplishment of a specific mission of considerable importance and

magnitude is usually staged in three phases: (1) general mission planning, (2) formal briefings, and (3) detailed briefing.

GENERAL MISSION PLANNING

General mission planning is usually initiated at wing level. An operations order from that level then prescribes the specific planning that must be done by the individual squadrons involved in the mission. The final details of the mission are the responsibility of the individual crew. The exact requirements for mission planning are set forth in Air Force, major command, and local directives with which the crew should be familiar.

When more than one aircraft is involved in a tactical mission, a master plan is made up by tacticians of the appropriate command headquarters. The master plan is then detailed for each crew specialty with mimeographed instructions, graphs, charts, overlays, and so forth. These instructions are called flimsies, and when assembled for the complete aircrew, they are called the aircraft commander's flimsy. The whole operation from tactical planning to preparation of flimsies is called an operations order.

Think of the general mission plan as a coordinated, collective effort to establish the overall requirements of the mission. From there, the operations order goes to the mission participants to be explained in formal briefings.

FORMAL BRIEFING

For the formal briefing, the crews must be assembled by the aircraft commanders and notified of the impending flight. At this time, the crews learn which aircraft are to be flown, the purpose of the mission, and the time schedule.

Formal briefing, like general mission planning, is an important function of all planning staffs. Formal briefing is the result of the collective efforts of units to work out detailed data for flying each phase of the mission. Flimsies should be distributed to each crew and checked for adherence to altitudes, airspeeds, and tactics called for by the master plan. The briefer must point out and discuss any special operating procedure or technique that has been devised to meet new or special problems. The engineer's flimsy should specify the points to be considered in preparation and operation of the aircraft to obtain the desired results.

Formal briefing is usually accomplished on the day before the planned mission, or at least 24 hours before the mission. Overall, the formal briefing is to acquaint all crew members with the intended or proposed mission, and to advise them of their part in the plan. Points in question should be discussed at this time to assure complete understanding and to correct any false information relative to the particular mission. Then with the major points of the mission clearly fixed in mind, the individual crews can efficiently work out the finer points in their detailed briefing.

DETAILED BRIEFING

The individual aircraft mission is nearly always planned, briefed, and executed by the crew. In this manner, the process may be simplified although the responsibility has been increased. The responsibility of individual crew management rests with the aircraft commander, but the appropriate crew members form the planning staff. The principles of good planning do not change. Regardless of the preplanning done by others, the crew is responsible for the successful completion of the mission. Many things remain to be done; therefore, usually immediately after the formal briefing, a detailed briefing is held with the crew.

With preliminary coordination out of the way, each member of the crew is then ready to complete his phase of the mission planning. During the detailed briefing, the crew members will coordinate all the known information with one another, so that each may plan his part of the mission. For example, the pilot's and engineer's duties would be as follows.

Pilot's Duties

Initiate and complete the following forms: clearance forms, flight orders, loading lists, weather briefing, and the like.

Study the operations order to determine tactics and communications to be employed on the mission.

Engineer's Duties

Confirm all operating conditions previously agreed on.

1. Establish a more exact relationship between load, distance, and altitude, consistent with the required fuel reserve.

2. Check on any possible less-than-normal engine operation, so that a fuel reserve can be accurately established.

3. Using the altitude profile and the mission previously determined, acquire information that may be used for the flight plan.

To further assist you in flight planning, many times the basic weight and other pertinent information on a specific aircraft can be obtained from the flight log files in operations, or from engineers who have previously flown the particular aircraft.

With these duties before him, the engineer uses the tools of the trade to work out the details.

MISSION PLANNING DEVICES

Detailed mission planning is greatly simplified by an understanding of the tools and devices used by the planner. The flight engineer needs the following to complete his mission planning:

Mission Profile

The mission profile is a graph of altitude plotted against time and/or distance with general notations concerning terrain elevation, temperatures, wind aloft, and destination distance. This profile may be drawn in detail and entered on the flight plan in the Remarks block or retained on a separate sheet for use in flight.

Standard Planning Factors

This is a locally devised listing of data to provide standardization in planning missions for items such as warmup, taxi, takeoff, normal fuel required, reserves required, and so forth. Suggested fuel requirements for these items are in this chapter; however, exact amounts vary with local command.

Operational Data

These are charts and graphs depicting the aircraft performance characteristics. Current operating data are found in the Appendix 1 of the flight manual for the particular aircraft. Information on the aircraft, if other than standard, must also be acquired for planning purposes.

Dividers

A standard set of dividers is extremely useful in arriving at pinpoint accuracy when interpolating values from the performance charts.

AF Form 796, Flight Log/Plan

This form is used for the orderly collection and recording of predicted data and of actual performance data before and during the flying of the mission. The flight plan is discussed in the first part of this chapter and the flight log in the latter part.

FINAL BRIEFING

The detailed briefings discussed above are concise and adequately cover all major points of the mission. Before flight, however, a final briefing is made to decide the following:

1. Times and places for any additional meetings, plus crew inspection, station times, takeoff time, etc.
2. Arrangements for messing or inflight lunches.
3. Transportation facilities.
4. Items of personal and crew equipment requirements.
5. Resolution of any questions arising.

After dismissal, each crew member attends to individual equipment requirements and completes any detailed planning dictated by the mission review and local SOPs.

PREFLIGHT INSPECTIONS

Prior to flight ground safety check and an electrical power-on check are made on the aircraft IAW the appropriate -1 TO.

Ground Safety Check (Electrical Power—OFF)

The ground safety check consists of a visual inspection of the aircraft to insure that cowling and safety locks are in place; appropriate protective covers and gust locks are removed; and that adequate maintenance stands, power units, wheel chocks, fire equipment, and other items such as ground-handling equipment are readily available. Switches are checked for proper positioning and the landing gear handle is checked DOWN. A check must be made to assure that the aircraft

status is properly entered on the AFTO Form 781, Aircraft Flight Report and Maintenance Record. The crew chief and his assistants must know your requirements and understand communications and signals for use during the engine start, runup, and taxi operations.

Electrical Power-on Check

Following the ground safety check, the electrical power-on check is performed. This check involves the efforts of all members of the crew, with each man having definite responsibilities and duties. On some aircraft, this check is called an operational check.

Using established checklists, the crew completes an operational check of all equipment to be used during the flight. The flight engineer, being the coordinator between operations and maintenance, should check on the aircraft status with the crew chief and should be briefed on any existing discrepancies.

For engineers, Section II (Normal Procedures) of the appropriate -1 technical order flight handbook amplifies the flight crew inspection procedures based on the assumption that maintenance personnel have completed all requirements for preflight inspection IAW the appropriate -6 TO inspection requirements. Section VIII of the same technical order (Crew Duties) supplements Section II. All crew duties not necessary for operation of the aircraft and engines are covered. The technical order should be constantly reviewed by crew members for technical correctness and for the best way of doing the job.

Following the electrical power-on check, the disposition of any critical maintenance items noted on the preflight inspection discrepancy list should receive particular attention from responsible crew members.

At this point, the aircraft is ready for flight, having been inspected and having had discrepancies corrected. The crew must only recheck flight safety items at "First Station" time to see that nothing has been disturbed before the flight.

The flight engineer is ready to make his detailed flight plan, since he knows what aircraft he is to fly, its configuration, its average ΔF value from the previous flight, its weight, and the information contained in the mission profile.

ADJUSTING PERFORMANCE DATA TO MEET EXPECTED CONDITIONS

Before actually planning a detailed predicted flight plan, the engineer must have an understanding of the variables he will have to consider in preparing his flight plan. By considering the variables, he can make calculations to insure that the aircraft will attain maximum efficiency for the conditions under which the mission is to be flown.

As you recall from chapter 9, the performance data charts that are used to predict the flight plan are based on standard day conditions and standard aircraft configuration. From this, you can see that considerable emphasis must be placed on non-standard conditions when you work out the details of your flight plan.

Adjusting for Atmospheric Conditions

Standard sea-level atmospheric conditions are a common standard to which, and from which, actual conditions must be adjusted. Since the atmospheric condition often varies from standard, a density altitude chart which expresses the relationship of density, pressure, and temperature is used to determine the degree of variation. Later in this chapter, a chart is used for convenience in determining the smoe factor, which is the reciprocal of the square root of the density ratio $\frac{1}{\sqrt{\sigma}}$ for any pressure altitude (H_p) and ambient air temperature (OAT). The smoe factor bears a direct relationship to density altitude (H_a). The power and true airspeed required for a condition vary according to density altitude. The use of the smoe factor makes possible mathematical conversions of the power and true airspeed required for any atmospheric condition.

Standard atmosphere also accounts for average specific humidity. Power schedule curves are based on standard values of specific humidity. The effect of variable humidity is plotted in conjunction with the takeoff performance data chart. In cruise, the effect of humidity is negligible.

Adjusting for Variations in Reciprocating Powerplant Efficiencies

Density of the input fuel charge varies with temperature and pressure as indicated by carburetor air temperature (cat) and absolute manifold pressure (MP). Bmep power schedules are

based on a given value for cat . Recommended MP corrections for variations of cat are indicated on these schedules. When fuel-air ratio curves are provided, corrected MP must be correlated with specific values of density altitude and rpm, and calibrated fuel flow must result in fuel-air ratios that fall within the accepted range, particularly under best economy operation obtained through the manual leaning process. Valid fuel-air ratios, coupled with the manual leaning process, result in the maximum engine economy consistent with long engine life. (Jet engine variables are not discussed as they are automatically compensated for by the fuel control.)

The factors rpm, MP, fuel flow, cat , CHT, and exhaust back pressure are controllable factors representing engine input. Combinations of these produce various bmeq, fuel-air ratio, and bhp—indicated by torque-indicating systems—as engine output. Brake specific fuel consumption (BSFC) is the measure of engine efficiency and thus a measure of your ability to prepare and operate the engines efficiently. BSFC, by definition, is the pounds of fuel consumed per bhp/hour. Since fuel flow in lbs/hr and bhp/hr are easily determined, BSFC can be easily found by dividing the first factor by the second and finding BSFC in terms of fuel flow in lbs/bhp.

Propeller efficiency (η) varies with propeller rpm, true airspeed (V), and other variables. Propeller efficiency remains fairly constant between 80% and 85% in the optimum cruising range, including cruise descents. The propeller efficiency can be checked in the -1 flight manual. During takeoff, climb, high-rpm, high-altitude, and high-air-speed cruises, propeller efficiency drops off significantly. As the equivalent speed of the tips of the blades approaches the speed of sound, a sharp increase in drag and decrease in lift of the blades occur. Propeller shaft bhp times propeller efficiency equals thrust horsepower ($\text{bhp} \times \eta = \text{thp}$).

Substituting thp for bhp in the specific fuel consumption (SFC) formula, we can compute thrust specific fuel consumption (TSFC). TSFC is a measurement of overall powerplant efficiency excluding the drag induced by variable engine cooling flaps. Cooling requirements are considered during engine operation, but the resultant cooling drag is treated as a part of the total aircraft drag since total drag equals parasite drag plus induced drag. Adjusting all of these variables to produce

the power required (thrust), while obtaining the best TSFC with the least induced cooling drag within specified engine operating limits, sets the stage for achieving maximum aerodynamic efficiency.

Adjusting for Aircraft Correction Factors

Assuming that acceptable standards for aircraft and engine conditioning, aerodynamic cleanliness, and weight and balance control have been met and the adjustments indicated above have been properly considered and applied, then we have a final adjustment to compensate for nonstandard aircraft performance. This adjustment is called the aircraft correction factor.

Correction factors to compensate for apparent variations from standard aircraft configuration are needed to predict performance accurately. Addition or subtraction of external drag items, such as wing tanks or tip tanks, jet pods, antennas, refueling booms and receptacles, and the like, obviously causes the actual performance to differ from charted performance. The equivalent flat plate area for such drag items must be computed; the result is called the delta F factor. This factor is then used to determine the delta F bhp required for all conditions.

The information for correction factors must be computed and used in predicting the flight plan. A previous log on the specific aircraft would furnish the information needed. By means of in-flight analysis, the previous engineer will have established any unknown correction factors in the form of delta F or delta F bhp that you can use in predicting your mission. If no information is available, then during the walkaround preflight inspection, you should note any part of the configuration that is other than standard on the aircraft and use this information in computing the predicted flight plan.

DETAILED PREFLIGHT MISSION PLANNING

The three general categories of missions are: (1) maximum load missions, (2) given payload missions, and (3) given time and distance missions.

Maximum Load Missions

The maximum load mission is restricted by four main factors.

- Aircraft design
- Rate of climb at liftoff
- Runway length
- Obstacle clearance

Under maximum load missions there are two types of missions: maximum pay load to destination mission, and maximum off-load mission.

MAXIMUM PAY LOAD MISSION. After determining the maximum takeoff weight with the existing conditions, such as runway length, temperature, obstructions, etc., the flight plan is worked forward from takeoff to destination. In this way the fuel required for the mission is determined. The difference between the operating weight plus fuel required and the start engines gross weight is the amount of cargo that can be carried on the mission. This mission is the one which is planned later in this chapter.

MAXIMUM OFF-LOAD MISSION. This type of mission includes two types of operations: a cargo mission or a refueling mission. The prime objective of this type of mission is either to carry a maximum cargo load to a cargo drop zone, or to carry the maximum fuel off-load to a refueling point. We must know: (1) how the mission can best be accomplished, and (2) the maximum off-load or cargo off-load that can be carried. By combining forward and reverse planning, the maximum off-load can be determined. Again the maximum takeoff weight is determined by local conditions, runway length, obstructions, and so forth. The fuel required for the mission up to the refueling point or drop zone is then determined.

After you determine the amount of fuel required up to the off-load point, you determine the ending gross weight. Then determine the amount of fuel required for the return flight to the off-load point by working a reverse plan. You can find the weight of the cargo or of the off-load fuel that can be carried by subtracting the gross weight anticipated for the end of the forward part of the flight plan from the beginning weight of the backward flight plan. The additional fuel required for rendezvous procedures or drop zone procedures depends on local SOPs.

Given Pay Load Missions

Under this mission category there are also two general types: known off-load and given load to destination. In both of these types of missions

the exact weight of the cargo is known, but the amount of fuel required to fly the mission is unknown. The takeoff gross weight is therefore unknown. The flight plan cannot be computed forward, since performance is determined by gross weight, so these are reverse planning-type missions. The minimum landing gross weight can be determined by using the operating weight (including cargo) at traffic pattern altitude over destination. With this weight known, add the required fuel reserve and then work the flight plan backwards from destination to takeoff. After this is done, the fuel required for the mission is known and the takeoff weight can be computed.

Given Time and Distance Missions

These types of missions are generally used for patrol work. They fall into three categories: given time, given distance, and maximum time or distance. Given time and given distance missions are backward planned types. A time or distance is furnished, but the amount of fuel required is unknown. Working the plan backward for the time or distance to find the fuel required establishes the takeoff weight.

Maximum time and maximum distance missions are forward planned missions. Either full or partially full tanks are used and the aircraft is flown the maximum time or distance for the fuel on board.

Standard Factors in Mission Planning

The previous information shows that the different types of missions require different planning procedures. However, to provide as much standardization as possible in mission planning, each wing or separate squadron should set forth valid and tested information peculiar to organizational equipment and procedures not reflected in current handbooks. Accepted methods of allotting fuel for starting engines, runup, taxi, takeoff, and landing, and establishing fuel reserves are necessary factors.

Another check on planning is the quick prediction. The use of long-range summary curves and long-range prediction for distance and time curves provides a fairly accurate check for detailed planning. By this procedure, a check and balance of the detailed flight plan may save a costly and time-consuming error.

DATA RECORDING PROCEDURES

Any mission may be divided into the following periods: warmup and taxi, takeoff, climb, cruise, descent, and landing and taxi. Similarly, the flight plan is divided into conditions covering each of these periods.

The warmup and taxi period includes all operation before the start of the takeoff run. To predict the bhp to be used during this period of operation is impossible since it includes starting the engines, warming up the engines, taxiing to the end of the runway, checking out the engines before takeoff, and standing by awaiting clearance from the tower for takeoff. Absolute accuracy could be achieved only by performing this operation in a normal manner, then stopping the engines before takeoff and determining, by sight gages, dipsticks, and servicing, how much fuel had been used for the warmup and taxi period. Obviously, a better procedure for determining the fuel required for warmup and taxi is to make an allowance of a specified amount determined by practical experience. This amount varies from aircraft to aircraft.

Takeoff is the period of operation from the time the throttles are pushed forward to maximum power for the takeoff run until the power is reduced for climb. The time required for this operation is usually 2 to 5 minutes and an allowance of a specified amount of fuel for this operation is determined from practical experience.

At the end of the takeoff period, when the aircraft speed, direction, and trim have been stabilized, the power to be used for the initial climb is established and maintained until the cruising altitude is attained. During the initial climb, the power and airspeed should be maintained at the desired values, allowing the rate of climb to vary. To obtain the greatest range from the aircraft, all climbs should be accomplished at rated power and at the recommended airspeed for climb. In predicting the elapsed time, fuel used, and distance covered in a climb, use the rate of climb curve, based on the predicted power and airspeed to be used.

The cruising portion of a mission is defined as all level-flight operation. While most missions are long range, parts of the cruise may be constant power, constant airspeed, long range, maximum range, emergency three-engine, cruise to alternate airport, cruise to destination in minimum time on fuel available, or other types of operation.

Secondary climbs are intermediate climbs made between two cruising altitudes. They are usually incorporated as a delay in reaching the final cruising altitude. The climb data for secondary climbs is obtained from the climb control curves in the same manner as for initial climbs.

The descent portion of a mission is, as the name implies, that portion in which the aircraft descends from a higher to a lower altitude. Descents may be flown in numerous ways and the procedure for predicting the data depends upon the prevailing conditions. The major factor which determines the type of descent to be flown is the weather condition at the various altitudes. Tests and experience have proved that every little range difference is obtainable regardless of the rate of descent flown. In general, the energy from descent provides 2.2 nautical miles additional free range for each 1,000 feet descended. Fuel used during this period is predictable from fuel flow charts.

The landing and taxi portion of the mission includes all operation from the end of the final cruise or descent, as the case may be, until the engines are stopped on the ramp. The power requirements for these operations, like the power requirements for warmup and taxi, are unpredictable. The fuel required for the landing and taxi operation is usually expressed as a specified amount based on previous experience.

THE ENGINEER'S PREDICTED FLIGHT PLAN

The engineer's predicted flight plan is, in general, a summary of the predicted altitudes, airspeeds, and fuel required for a mission that is to be flown. A flight plan may be completed as much as a week in advance of the planned mission. In some instances you may be able to use a flight plan from a previous mission from your squadron or wing completed-mission file. Usually the flight plan is computed the day before the mission.

The entries and calculations on the flight plan are based on planning data provided by base operations, the aircraft commander's flimsy, the aircraft navigator, and the base weather station.

Since the AF Form 796 serves a two-fold purpose, it may be used at this stage of the mission planning to record the flight plan data. For practical purposes of discussion, the form is divided into three sections. These sections accommodate the entries for each phase of the mission; before

flight, during flight, and after flight. The after flight entries, however, depend on variables which occur during flight and are not made until completion of the mission.

Applicable blocks of the form may be filled out as your predicted flight plan. These numbered block headings are self-explanatory, but the entries for each are discussed in terms of flight planning. This form, completed before flight along with the takeoff and landing data (TOLD) card, constitutes all data needed to plan the mission. The flight plan with required entries is sufficiently comprehensive for the average mission, but a supplemental maintenance form may be used if it is required for a particular type of mission.

The takeoff and landing data and the engineer's predicted flight plan as they pertain to a maximum load mission are illustrated in this chapter. Further, for this mission, assume that the takeoff gross weight is restricted to 300,000 lbs because of obstacle clearance.

The purpose of the following flight plan and TOLD card, then, is to determine the maximum cargo load that can be delivered at a point 2.747 nautical miles from the point of takeoff. To determine the cargo load we must determine, first, the amount of fuel required for the distance. This fuel subtracted from the 300,000 lb obstacle clearance weight restriction determines the cargo load to be delivered.

Mission flight planning begins with computing the takeoff and landing data.

Takeoff Planning (TOLD Card)

Since takeoff planning is a most critical phase of flight planning, an outlined procedure should be followed to lessen the possibility of overlooking a point necessary for safety. Also, the planning should include data for a safe return to the field for landing in case trouble is experienced immediately after takeoff. Careful consideration of the essential factors and proper entry of the data in the TOLD card will promote safety of the mission.

Normally, takeoff planning involves a determination of: (1) takeoff gross weight of the aircraft, (2) thrust factor and takeoff factor, (3) runway available, (4) stabilizer trim setting, (5) critical field length, (6) rotation speed, and (7) climbout and flap retraction speeds. Careful computations for the exact value for each of the above must be accomplished from the performance charts and en-

tered on a takeoff and landing data card such as the one shown in figure 10-1, prepared for a C-141 aircraft. This procedure affords a logical sequence for your takeoff planning and eliminates the possibility of omitting a step necessary for safety.

For our takeoff problem for a typical turbine engine powered aircraft, the known data are as follows:

Gross weight	300,000 lbs
OAT	4° C
Pressure Altitude	2,000 feet
Wind (direction velocity)	40° / 20K
Runway condition	Wet
Runway heading	360° / 11,500 feet available
Runway slope	0.5% uphill
C.G.	26%

From these known data, we shall compute the necessary entries for the TOLD card. Notice the entries on the TOLD card in figure 10-1 as we proceed with the solution. The computed values do not appear consecutively on the TOLD card as we proceed through the problem, but rather in the order of logical sequence.

The first value that we need to determine is the expected thrust, expressed as EPR. For this value, enter the thrust chart shown in figure 10-2 at the bottom with the runway ambient temperature of 4° C, then proceed vertically to the pressure altitude line. Notice with this temperature we intersect the curved altitude line before we reach the 2,000 feet altitude line. Then read the engine pressure ratio, EPR, in the left margin as 1.983. Enter this value in the appropriate block of the TOLD card, labeled Takeoff Rated Thrust (TRT) EPR.

In addition to the takeoff rated thrust value, compute a go-around EPR for emergency power. This is necessary in the event a go-around becomes necessary, if you have to return for an immediate landing after takeoff. Enter the chart shown in figure 10-3 at the bottom with the runway temperature (4° C). Move vertically to the curving pressure altitude line and read the go-around EPR in the left margin as 1.995. Enter this value in the appropriate block of the TOLD card. These computations account for the power.

Now consider the effective wind for takeoff. Notice that the wind is given as 40°/20K in our problem known data. Notice, also, that the

TAKE-OFF AND LANDING DATA		TAKE-OFF
CONDITIONS		TRT
GW <u>300,000</u> CG <u>36%</u> OAT <u>4</u> °C PA <u>2,000</u> ft		<u>1,983</u>
WIND-DIR <u>40°</u> VEL <u>20</u> kts OBST-HT <u>1780</u> DIST <u>34,000</u> ft		V _{GO}
RWY-HDG <u>360°</u> AVAIL <u>11,500</u> SLOPE <u>.5</u> UP RCR WET RSC <u>-</u>		<u>134</u>
COMPUTATIONS		V _{ROT}
TRT <u>1,983</u> EPR-GO AR <u>1,995</u> REV LIM <u>-</u>		<u>134</u>
X-WIND <u>12.8</u> COMP <u>15.5</u> CALC <u>7.8</u> GUST <u>-</u>		V _{MCO}
TF <u>18.98</u> TOF <u>48.7</u> CFL <u>-</u>		<u>144.5</u>
GW(CFL) <u>316,000</u> + GW(3 ENG) <u>316,000</u> + GW(OBST) <u>300,000</u>		V _{MFR}
V _{MCG} <u>113</u> V _R <u>155</u> V _{ROT} <u>134</u> V _{B(MAX)} <u>182</u>		<u>169.5</u>
STAB. ST <u>+3.15</u> V _{MCO} <u>144.5</u> V _{MFR} <u>169.5</u>		STAB. SET <u>+3.15</u> REV LIM
EMERGENCY RETURN		EMER RET
THRESH. <u>132</u> LDG DIST <u>3,150</u> ft		THRESH.
FUEL DUMP G <u>300,000</u> -257500 = <u>43,500</u> F <u>100,000</u> -75000 = <u>25,000</u>		<u>132</u>
- <u>42,500</u> F <u>42,500</u>		EPR-GO AR
E <u>257,500</u> F <u>57,500</u> TIME <u>8.4</u>		<u>1,995</u>
		LDG DIST <u>3150</u> DUMPTIME <u>8.4</u>
DESTINATION		LANDING
CONDITIONS		THRESH
OAT _____ °C PA _____ RWY-HDG _____ LGTH _____		EPR-GO AR
RCR _____ SLOPE _____ WIND-DIR _____ VEL _____		V _{MCO}
COMPUTATIONS		V _{MFR}
GW _____ EPR-GO AR _____ REV LIM _____		LDG DIST _____ REV LIM _____
TF _____ X-WIND _____ COMP _____ CALC _____ GUST _____		
THRESH. _____ LDG DIST _____ V _{MCO} _____ V _{MFR} _____		

Figure 10-1. Sample Takeoff and Landing Data Card

runway direction is 360°. Refer to the crosswind component chart in chapter 9 (figure 9-14) and determine the crosswind component as 12.8 knots. Also, determine from this chart that the runway component is 15.5 knots. This is a head-wind component. The calculated wind which we will consider in our computations is 50% of the head-wind component or 7.8 knots. Enter these three velocities: 12.8, 15.5, and 7.8 knots in the appropriate blocks of the TOLD card.

Now we are ready to determine the thrust factor and the takeoff factor. Enter the thrust factor chart in figure 10-4 with the obtained engine pressure ratio 1.983. Move down to the pressure altitude line (2,000 feet) and then directly to the left to a thrust factor of 18.98. Take this thrust factor number into the bottom of the take-off factor chart, figure 10-5. Move up to the temperature line

(4°C) and to the right to a reference number of 7.6. Enter the right-hand portion with this reference number, then continue to the right and intersect the 2,000 feet pressure altitude line. The takeoff factor appears directly beneath this point as 48.7. Enter the thrust factor (18.98) and the takeoff factor (48.7) in the appropriate blocks of the TOLD card.

For safety purposes, check the charts applicable to the critical field length for the runway available and gross weight for our given problem. In this case, we find that the runway available is sufficient for a gross weight in excess of 316,000 lbs. Enter 316,000 ± in the GW_{fl} block of the TOLD card.

Next we need to compute the climbout factor. For safety, we use the three engine performance chart to obtain a climbout factor, as illustrated in figure 10-6. Enter at the bottom with the thrust

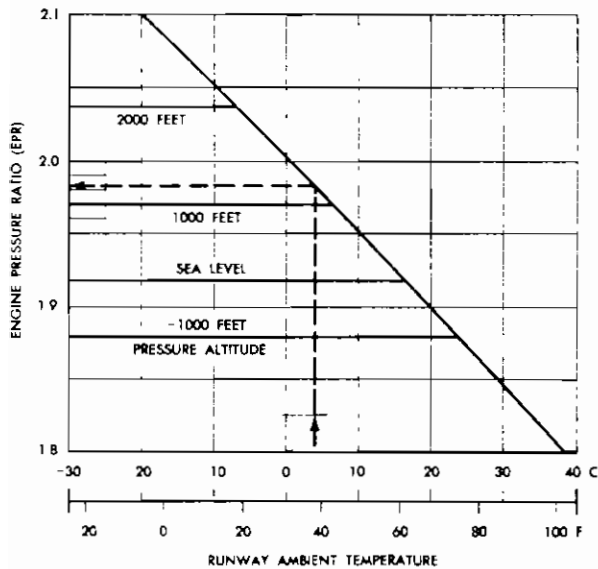


Figure 10-2. Thrust—EPR

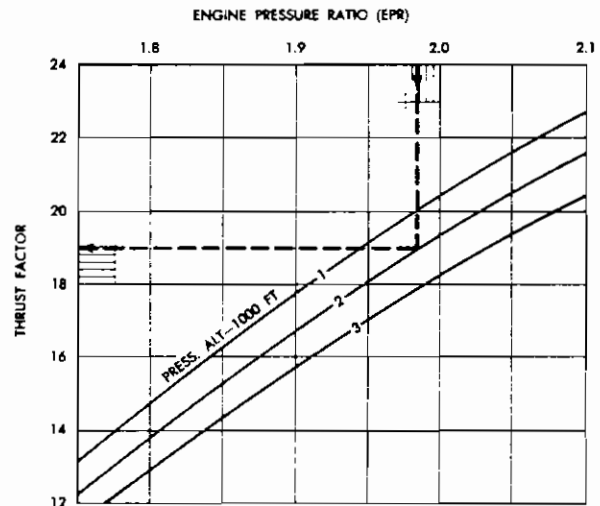


Figure 10-4. Thrust Factor

factor (18.98), move vertically to the gross weight line (300,000 lbs) and read the climbout factor as 75.5 in the right-hand margin. Of course, this step would have been accomplished previously because this is the factor which restricts the aircraft gross weight to 300,000. However, for safety, you would double check the flight manual charts to make certain that the 1,780 ft high

obstacle can be cleared with a gross weight of 300,000 lb. and a COF of 75.5.

After you consult the charts and find that our gross weight will allow ample clearance of any obstacle after takeoff, compute the ground minimum control speed. This, as you know, is the minimum speed at which an engine failure can be experienced during the takeoff run and allow the pilot to maintain directional control of the aircraft by use of the rudder control.

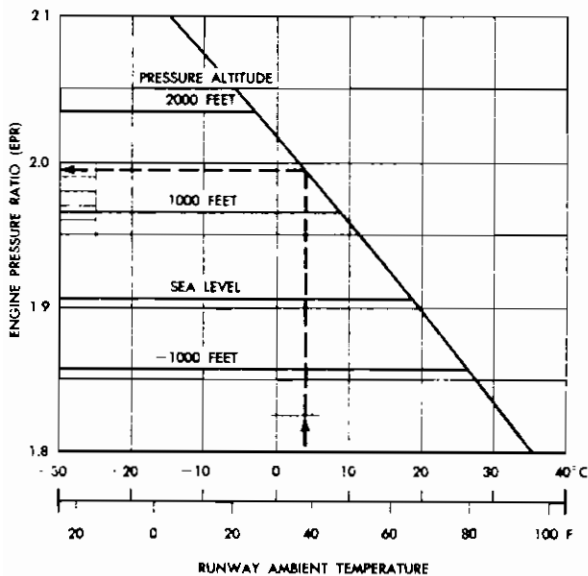


Figure 10-3. Go Around—EPR

Notice carefully, from figure 10-7, the adverse effect of a wet or icy runway on the minimum ground control speed in contrast to a dry runway. You find this computed value to be 113 knots for entry into the TOLD card in the block labeled V_{mcg} .

Next in the sequence of computations for takeoff, determine a refusal speed. As you compute this value, notice that the runway available for takeoff is sufficient to allow acceleration to takeoff speed and then to permit the aircraft to stop in the remaining distance in the event trouble should develop which would necessitate an abort. For reasons of safety, however, check the refusal speed regardless of runway length. Figure 10-8 reveals a refusal speed of 155 knots after accounting for gross weight, runway length, runway slope, effective wind, and runway condition. Enter 155 knots in the V_R block of the TOLD card, even though the refusal speed exceeds the takeoff speed.

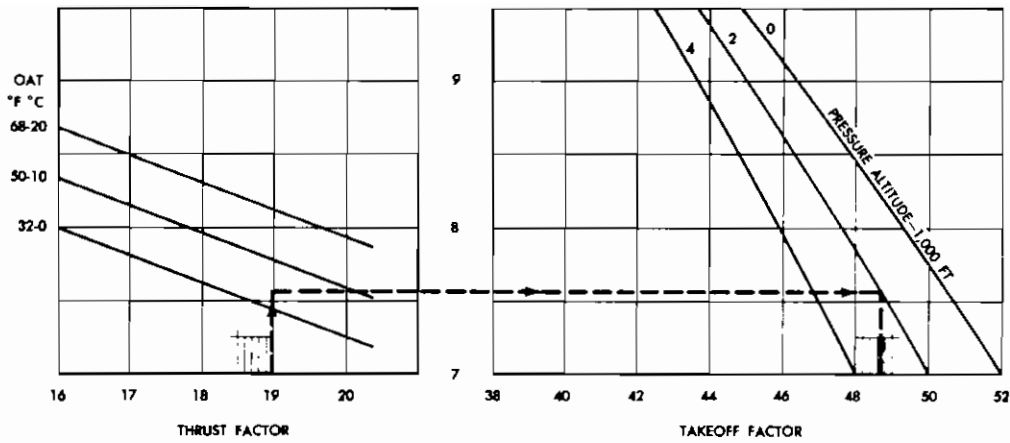


Figure 10-5. Takeoff Factor

Compute the rotation speed from the chart shown in figure 10-9. For some aircraft, the rotation speed occurs shortly before takeoff speed (approximately 3 seconds). But for the turbine engine powered aircraft selected for our illustrative problem, takeoff occurs at the same time as the completion of rotation. Consequently, rotation speed and takeoff speed are the same. So enter 134 knots in the V_{rot} block of the TOLD card, as the computed value from the chart in figure 10-9.

visable in the event trouble develops for which an abort becomes necessary, and you need to brake to a stop. Enter the chart in figure 10-10 with the gross weight (300,000 lbs). Move in to the pressure altitude line (2,000 feet), and descend to the OAT scale and interpolate the existing temperature (4° C). From there, move to the right to the slope % scale and account for 0.5% uphill gradi-

As you compute the safety factors for each takeoff, consider the maximum braking speed for the type of aircraft you are operating. This is ad-

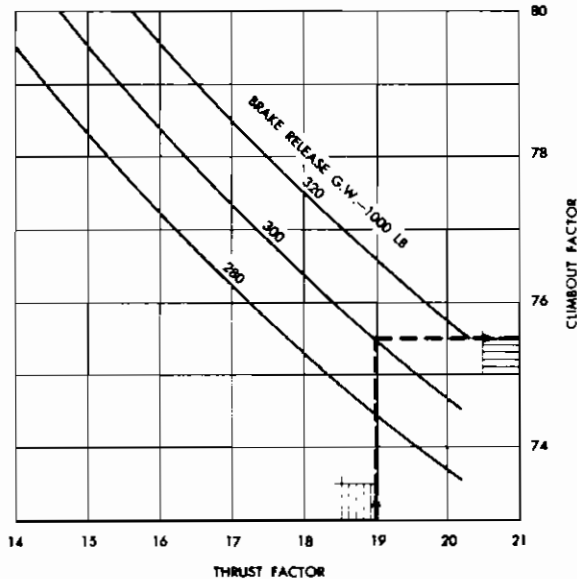


Figure 10-6. Climbout Factor

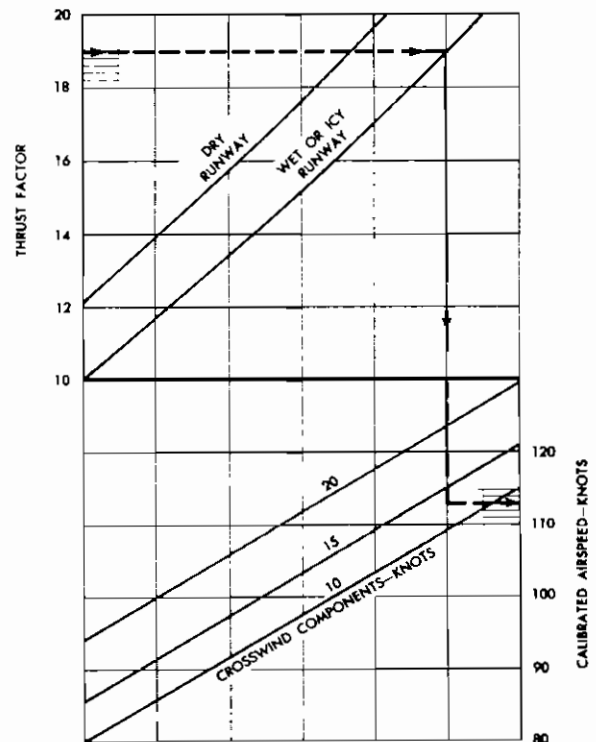


Figure 10-7. Minimum Ground Control Speed

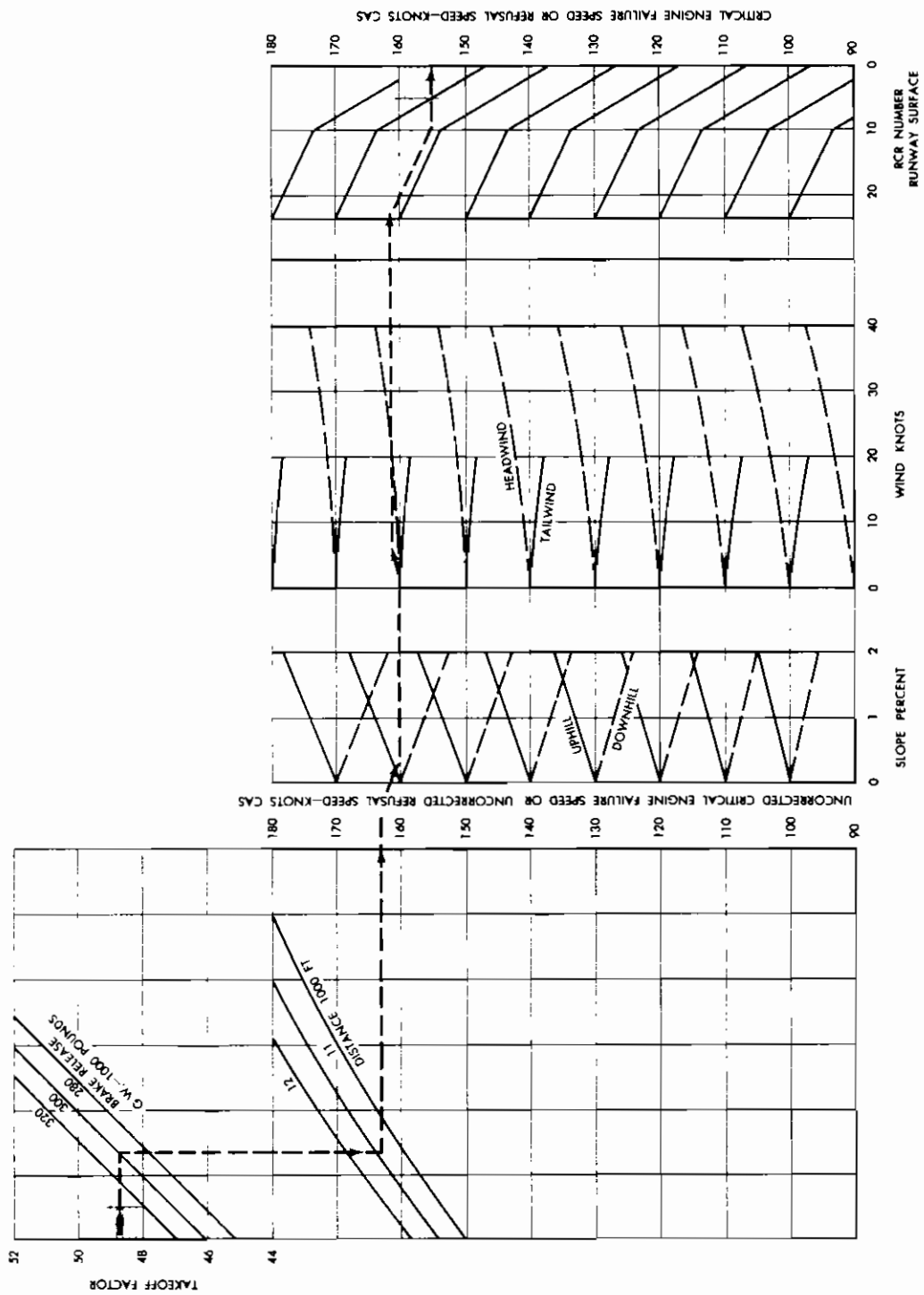


Figure 10-8. Refusal Speed

ent. Then after you account for the effective wind as shown, read the maximum braking speed as 182 knots in the right-hand margin. Enter this figure in the TOLD card block labeled VB_{max} .

Now that you have computed the rotation, refusal, and maximum braking speeds let's discuss GO speed (V_{go}). Notice that the TOLD card, figure 10-1, has a block in the quick reference

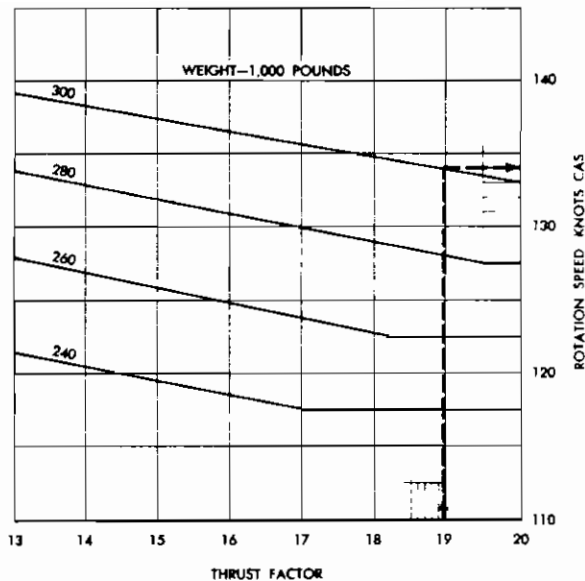


Figure 10-9. Rotation Speed

area (right hand margin) for V_{200} . V_{200} is the speed at which the pilot becomes committed to continue a takeoff should trouble arise. This speed is the lowest of either rotation, refusal, or maximum braking speeds. For our planning, rotation speed, 134 knots, is the lowest of the three speeds and is the V_{200} speed.

For the aircraft selected for this problem, the horizontal stabilizer trim must be set before takeoff. This setting is calculated from the gross weight and center of gravity percent as shown in figure 10-11. For this problem, assume the center of gravity is to be 26% of the MAC. Enter the chart at the bottom with the gross weight (300,000 lbs). Follow that weight grid line up to the CG line (26%). Then directly to the left-hand margin, you read the stabilizer setting as 3.15 for entry into your TOLD card.

Finally, determine the climbout and wing flap retraction speeds, and the information required for the normal takeoff portion of the TOLD card is complete. Plot the climbout speed first by entering the chart in figure 10-12 with the thrust factor (18.98). Notice again that the 3-engine chart is used for safety. Proceed horizontally to the gross weight line (300,000 lbs) and read the climbout speed directly below as 144.5 knots. For the aircraft used in our illustrative problem, add 25 knots to the climbout speed (144.5) to establish a minimum wing flap retraction speed. Determine this speed as 169.5 knots, and enter it

along with the climbout speed in the appropriate blocks of the TOLD card.

In addition to the recorded information required for takeoff, you will notice on the TOLD card that there are required entries for an emergency return. However, before the emergency return data can be computed we must know the total fuel aboard in order to compute fuel jettison information. So, we will come back to the emergency return data after computing the fuel required for the mission. We shall discuss the fuel prediction now.

Inflight Computations

The inflight condition of any mission begins when takeoff power is set on the engines at the beginning of the takeoff run, and ends when the engines are shut down after the landing. The entire flight consists of the takeoff, climb, cruise, descent, landing and taxi. Each of these conditions must be accurately recorded on the aircraft performance log/plan in the planning stage of your flight.

Since we begin at this point to make the flight plan entries for the mission, let's first discuss the peculiarity of some of the blocks of the performance log/plan.

AF Form 796, shown in figure 10-13, is sufficiently comprehensive to accommodate the entries required for flight of reciprocating or turbine engine aircraft in use by the Air Force. However, when additional information is required to identify trends in engine failure or for special test programs, the directing headquarters usually furnishes necessary supplemental forms.

Blocks of the performance log are identified by number. Some of the multi-purpose blocks are indicated by a slash (/) mark. For instance, you may enter the OAT C in block 12 or the temperature variation from standard required for some aircraft as indicated by /VAR. Block 14 may reflect the density altitude or the optimum altitude for the condition (HD/HO). The indicated, equivalent, or knots calibrated airspeed may be entered at your discretion in block 20 as shown by IAS/EAS KCAS. Block 22 indicates that either TASK or IMACH may be recorded. Finally, block 25 may show the oil quantity, the exhaust gas temperature, or the turbine inlet temperature (EGT/TIT) whichever is applicable to the aircraft being flown.

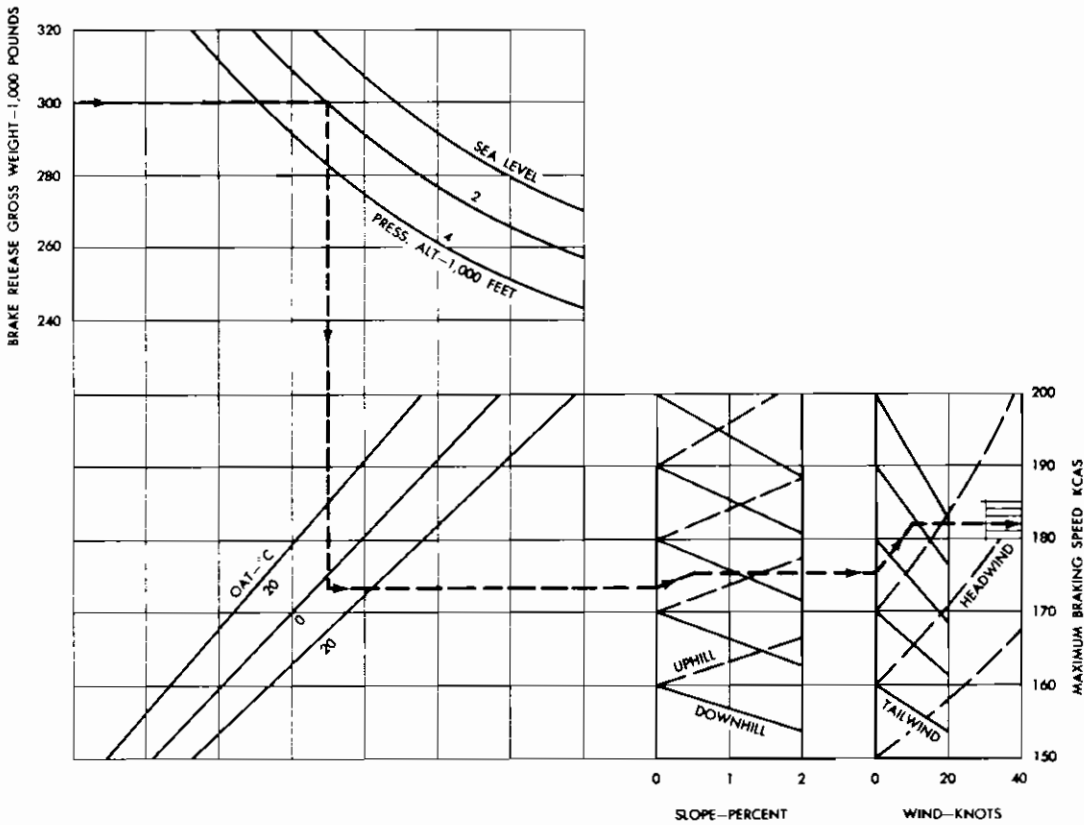


Figure 10-10. Maximum Braking Speed

Before we make the flight plan entries, let's discuss the blocks as they are numbered on AF Form 796.

The form heading is self-explanatory. This, as you can see, reflects general information concerning the aircraft serial number, type, model, and series. The mission information disclosed in the general mission briefing is entered in the heading blocks.

Block 1 reflects the mission fuel data. This is a record of the fuel required and the fuel reserve. In addition, a space is provided to record any extra fuel carried which is in addition to the mission fuel and reserve fuel requirements. Aerial refueling operation by tanker aircraft is provided for under block 1 in the space designated "Refueling Tanks." The record of the fuel carried for aerial refueling as well as the total fuel offloaded to receiver aircraft is kept here.

Block 2 is a record of the aircraft fuel quantity as indicated by the fuel tank quantity indicators. Notice that provisions are included to accommo-

date aircraft which have up to 12 fuel tanks. The flight engineer need only record the fuel tank number designator under the "tank" column. Provision is made for both before and after flight entries.

Block 3 is a record of the oil quantity in each of 4 engine oil tanks and, when applicable, the center or reserve oil tank. Immediately below the center oil tank entry space is provided to record the oil transferred to the engine oil tanks during flight.

Block 4 shows the weight and balance computations for the mission. This block reflects the quantities extracted from your DD Form 365F, Weight and Balance Clearance Form. Notice that the first weight entered is the aircraft operating weight. Remember, from chapter 8, that this weight includes the weight for all items necessary to perform the assigned mission with the exception of fuel, water (or ADI), and cargo. Three lines are left open to add weights for last minute changes, special mission equipment, etc. Total air-

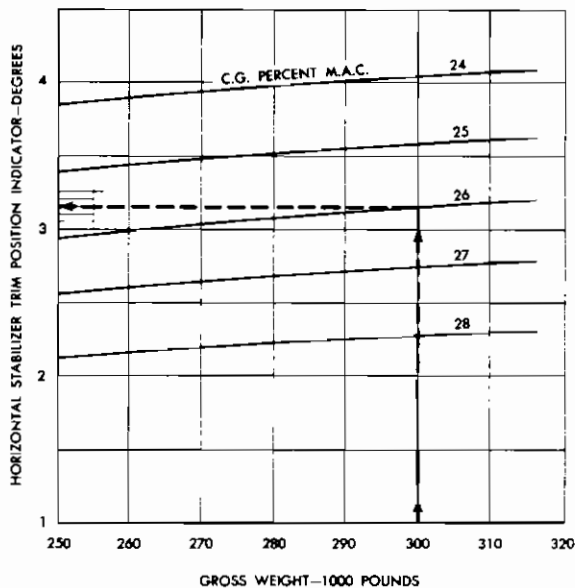


Figure 10-11. Stabilizer Setting

craft ramp weight is the sum of the individual aircraft weights just before engine start. Also recorded in this block is the aircraft center of gravity for those aircraft utilizing stabilizer trim settings prior to takeoff or for any aircraft that must take into consideration the C.G. location for inflight computations.

Block 5—ENGINE START: Enter the GMT (Z) clock time at which the first engine is started. Adjacent to block 5 is an unnumbered block labeled CREW NR. for use by those units that identify their personnel by a crew number designation.

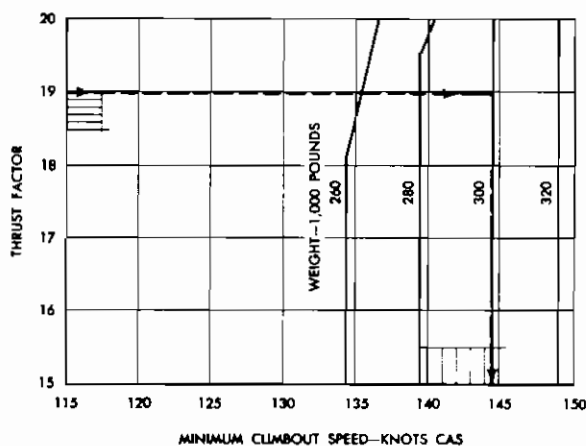


Figure 10-12. Climbout Speed

ignation. Enter your crew number designation in this block.

Block 6—(R) STATIC MAP: Enter the static manifold pressure for reciprocating engines. With these entries available, the manifold pressure gage errors will be compensated for during engine runup checks requiring local field barometric manifold pressure settings.

Block 7—COND: Enter the operating condition. The symbols used for this block to designate your operating condition are as follows: a. WU/TAX TO indicates the warmup, taxi, and takeoff condition. b. Initial climb is indicated by the symbol (1↗) whereas the secondary climb is shown as (2↗). c. Cruise operating conditions are indicated by the number in the cruise sequence and an arrow (1→, 2→, 3→, etc.). Descents are shown as (↘¹, ↘², etc.). Do not confuse descents with the final letdown to land when your landing procedures began. This loss in altitude is indicated by e. (L & T). Landing and taxi is that condition from the end of the last entry in the sequence of descents to engine shutdown on the ramp. Holding time, however, must be accounted for as an additional cruise (→) condition after descent when necessary.

Block 8—END: The engine clock time for each condition will be shown in this block in GMT. Cruise condition time (→) normally will be of not more than 1 hour duration. However, it must be recognized that some missions demand cruise power reductions in gross weight increments such as patrol type missions. These cruises may extend over 1 hour in duration. Also, consideration is given to those cruises immediately before en route climbs and final descents. These cruises may also extend over 1 hour. The maximum cruise duration should not exceed the maximum of 1 hour and 30 minutes.

Block 9—SET: Enter the increment time duration for each flight condition. Enter all warmup and taxi time in the circle of the first SET block. This differentiates the ground operational time from the actual flight time which begins when the throttles are advanced to maximum power for takeoff.

Block 10—TOTAL: Enter the accumulative total time from the SET block. This time begins with the takeoff duration of :02 minutes and accumulates as each condition SET time is added.

Block 11—OAT1: Enter the outside indicated air temperature as read from the temperature gage.

AIRCRAFT PERFORMANCE LOG/PLAN															
AIRCRAFT NUMBER		AIRCRAFT T/M/S		AIRCRAFT COMMANDER		FLIGHT ENGINEER		FLIGHT ENGINEER							
DATE		TO		FROM		MISSION NUMBER		WING/SQUADRON							
1 FUEL DATA (LBS)		2 FUEL GAUGE (POUNDS)				3 OIL GAUGE (GALLONS)			4 WEIGHT AND BALANCE DATA						
FUEL REQUIRED		TANK	BEFORE	AFTER	TANK	BEFORE	AFTER	OPERATING WEIGHT	1	3	0	9	3	8	
81960															
FUEL RESERVE								FUEL (RAMP)	1	0	0	0	0	0	
18040								WATER							
EXTRA								CARGO		6	9	0	6	2	
REFUELING TANKS															
BEFORE		AFTER													
FWD															
AFT															
OFF-LOAD TOTAL		TOTAL						OIL TRANSFERRED	TOTAL ACFT WT (RAMP)		3	0	0	0	
									C.G%	TAKEOFF	2	6		LANDING	
														20	
5 ENGINE START		Z CREW NR		6 (R) STATIC MAP				26 ENGINE INST F/F LBS/HR		FUEL USED		FUEL REMAINING		36 FUEL AND/OR WATER USED	
0800				1	2	3	4					37			
												38			
												39			
7 COND	9 SET	11 OATI	13 HP	16 RPM	20 IAS/EAS KCAS	22 TASK/IMACH	25 OIL QUAN EGT/TIT	1	27 PERIOD	30 PERIOD	33 PERIOD	38 END GR WT			
8 END	10 TOTAL	12 OATC/VAR	14 HD/MO	17 MAP	18 TOP	21 NMPP	23 DIST	2	28 EXTRA	31 TOTAL	34 TOTAL	39			
			15 $\frac{1}{\sqrt{0}}$	19 BHP/EPR			24 TOTAL AIR DIST	3	29 TOTAL	32	35				
WU/TAX TO	(15)		2000				1555							300000	
			1200				2							3000	
0817	:02	+4	1.0180	1.983			3							-	
			34900		280	376	4		3000					297000	
			34900			132								8800	
0847	:32	0	-	2.160		132			11800					288200	
			34900			421.5		3200	12800					12800	
			34900			421.5		3200	-					-	
0947	1:32	0	-	1.800		553.5		3200	24600					275400	
			34900			421.5		3000	12000					12000	
			34900			421.5		3000	-					-	
1047	2:32	0	-	1.750		975.0		3000	36600					263400	
			34900			421.5		2850	11400					11400	
			34900			421.5		2850	-					-	
1147	3:32	0	-	1.725		1396.5		2850	48000					252000	
			34900			421.5		2810	11240					11240	
			34900			421.5		2810	-					-	
1247	4:32	0	-	1.69		1818.0		2810	59240					240760	

Figure 10-13. Performance Log Plan (Front)

On some aircraft, this is also known as total temperature.

Block 12—OATC/VAR: This is a dual purpose block for entry of (1) the corrected outside air temperature, and/or (2) the degree of temperature variation from standard for your flight altitude.

Block 13—HP: Enter the pressure altitude for the condition.

Block 14—HD/HO: Enter either the density altitude or the optimum altitude to meet the requirements of the aircraft being flown.

Block 15— $\frac{1}{\sqrt{\sigma}}$: Enter the smoe factor as determined from a density altitude chart.

Block 16—RPM: Enter the average engine rpm for reciprocating engines commensurate with the required brake horsepower for the flight condition.

Block 17—MAP: Enter the average manifold pressure for reciprocating engines which, with the rpm from block 16, produces the brake horsepower desired for the flight condition.

Block 18—TOP: Enter the maximum torque oil pressure or brake mean effective pressure (BMEP) reading indicated for the brake horsepower desired for the flight condition.

Block 19—BHP EPR: Enter the brake horsepower obtained from the RPM and TOP (or BMEP) set for the flight condition for reciprocating engines. For jet aircraft, enter the engine pressure ratio reading set for the flight condition.

Block 20—IAS EAS KCAS: Various aircraft performance charts are based on either indicated, equivalent or knots calibrated airspeed. Enter the applicable average airspeed for the flight condition.

Block 21—NMPP: Enter the *charted* air nautical miles per pound of fuel value during cruise conditions.

Block 22—TASK IMACH: Enter the average true airspeed in knots or the indicated mach number obtained for the flight condition.

Block 23—DIST: Enter the *air* distance flown for the flight condition duration. This block reflects the result of multiplying the SET time, in hours or tenths of hours, by the average TASK for the flight condition.

Block 24—TOTAL AIR DIST: Enter the accumulative air distance flown during the successive conditions.

Block 25—OIL QUAN-EGT TIT: Enter either the oil quantity for reciprocating engine air-

craft or the exhaust gas temperature/turbine inlet temperature as applicable to the aircraft being flown.

Block 26—ENGINE INST F/F LBS·HR: Enter the fuel flow instrument readings for individual engines in pounds per hour. Enter the total of the individual readings in the remaining space provided.

Block 27—PERIOD (fuel used): Enter the fuel used for the flight condition. This block reflects that portion of the total fuel flow from block 26 which was consumed during the duration of the present flight condition.

Block 28—EXTRA (fuel used): Enter the extra fuel used during the flight condition period for fuel jettisoning, heaters, GTU, APU, etc. The fuel required for these operations is determined from charts in the appropriate flight manual.

Block 29—TOTAL (fuel used): Enter the accumulative total of fuel used for successive conditions. This block represents all fuel consumed to the END clock time entered in block 8.

Block 30—PERIOD (calculated fuel remaining): Enter the amount of fuel consumed (block 27 plus block 28) for the flight condition as determined by calculations.

Block 31—TOTAL (calculated fuel remaining): Enter the total amount of the calculated fuel remaining by subtracting the amount in block 30 from the amount in block 31 of the previous flight condition. This total reflects the calculated fuel remaining at the END clock time entered in block 8.

Block 32—This block is unlabeled to facilitate the entering of the total *ramp* fuel from block 4, weight and balance data. Enter the ramp calculated fuel aboard obtained by either the dip-stick or by the total fuel quantity gage reading and applying any known correction factor.

Block 33—PERIOD (gage fuel remaining): Enter the fuel used for the flight condition as determined by fuel gage readings. The fuel figure entered in this block is obtained by subtracting the total fuel quantity gage readings for the present flight condition from the total fuel quantity gage readings from the previous flight condition (block 34).

Block 34—TOTAL (gage fuel remaining): Enter the total fuel remaining as indicated by the total of the fuel gage readings.

Block 35—This block is unlabeled to facilitate the entering of the total ramp fuel aboard as de-

terminated by adding the quantities of the individual fuel quantity gages (block 2).

Block 36—FUEL AND OR WATER USED: The fuel entry for this block is obtained from the total of blocks 27 and 28. Where a large amount of water is used, add the quantity used in pounds to the fuel total of blocks 27 and 28.

Note: After aerial delivery of troops or equipment or after aerial refueling, block 36 should include the weight loss or gain as applicable.

Block 37— Δ GR. WT: Enter any weight correction factor (change) determined by comparing the calculated gross weight of the aircraft with the actual performance gross weight. Attach either a plus (+) sign (if the aircraft performs heavy) or a minus (-) sign (if the aircraft performs light) to the Δ gross weight.

Block 38—END GR WT: Enter the aircraft gross weight at the end of the condition period. This is determined by subtracting the quantity entered in block 36 from the end gross weight of the previous flight condition (block 38). This block reflects the aircraft gross weight at the END clock time entered in block 8.

Block 39—This block is unlabeled to facilitate the entering of the total aircraft *ramp* gross weight from block 4, weight and balance data.

Block 40—REMARKS: Enter any remark pertinent to the flight which you feel is noteworthy.

With the foregoing discussion of the aircraft performance log plan in mind, let's proceed to make the required entries.

As you recall, the known data were stated earlier in this chapter for computations of the TOLD and takeoff flight plan entries. The parts of those data which apply to the computations for takeoff entries for the flight plan are as follows: Gross weight 300,000 pounds, OAT C — 4° C, and pressure altitude 2,000 feet. Now, from these data, we can complete the takeoff portion of the flight plan.

Block 1 through 6 of the performance log may be completed as the known data. Let's assume that the engine start time for our illustrative problem is 0800 Z. Enter this time in block 5 of the flight plan. Further, let's assume that the planned takeoff time is 0815 Z. This gives us an elapsed time of 15 minutes from engine start to takeoff. Enter 15 minutes in the circle of block 9 (set) and :02 minutes in block 10 (total). This de-

signates :15 minutes for engine start and taxi and :02 minutes for takeoff. The end clock time for the condition is 0817.

Enter the OAT —4°, in block 12 OAT C. Notice that block 11 is blanked out for the takeoff condition since we use only calibrated temperature for this period.

Enter the field pressure altitude (2,000 feet) in block 13. To determine the correct density altitude for the pressure altitude of 2,000 feet, refer to the density altitude chart in figure 10-14. Enter the bottom of the chart with the existing temperature (4° C). Move vertically to the 2,000-foot pressure altitude line, and read the density altitude in the left hand margin as 1,200 feet. Then stay on the 1,200-foot density altitude grid line and move to the right hand margin and read the smoe factor as 1.0180. Enter the density altitude in block 14, and the smoe factor in block 15.

We do not use blocks 16, 17, and 18 in this problem since these blocks are used for reciprocating engine aircraft only.

In chapter 2, you learned that the slide rule or computer can be used to determine density altitude and smoe. At this stage of the mission, however, the density altitude chart of the flight handbook is more expedient.

Block 19 reflects the engine pressure ratio, EPR. As you recall, the EPR was previously computed and recorded on the TOLD card. Merely enter the computed figure here as it appears on the TOLD card as 1.983.

Notice that blocks 20 and 21 are blanked out, since the airspeed and the fuel consumption are precomputed for the takeoff condition period. Likewise, no values are entered in blocks 22, 23, and 24 for the takeoff condition.

Enter the maximum exhaust gas temperature (EGT) in block 25. The turbine engine aircraft selected for our problem has a limit of 555 degrees for the EGT.

Block 26 is blanked out for the takeoff condition since the weight of fuel used for this period is of a precomputed value. For the same reason, blocks 27 and 28 are left blank.

Block 29 shows the total fuel used for the warm-up, taxi, and takeoff (WU/TAX/TO) period. For practical reasons, each command has individual regulations which specify a definite amount of fuel as standard for the WU/TAX/TO period. For instance, the aircraft used for our illustrative problem has a standard amount of fuel of

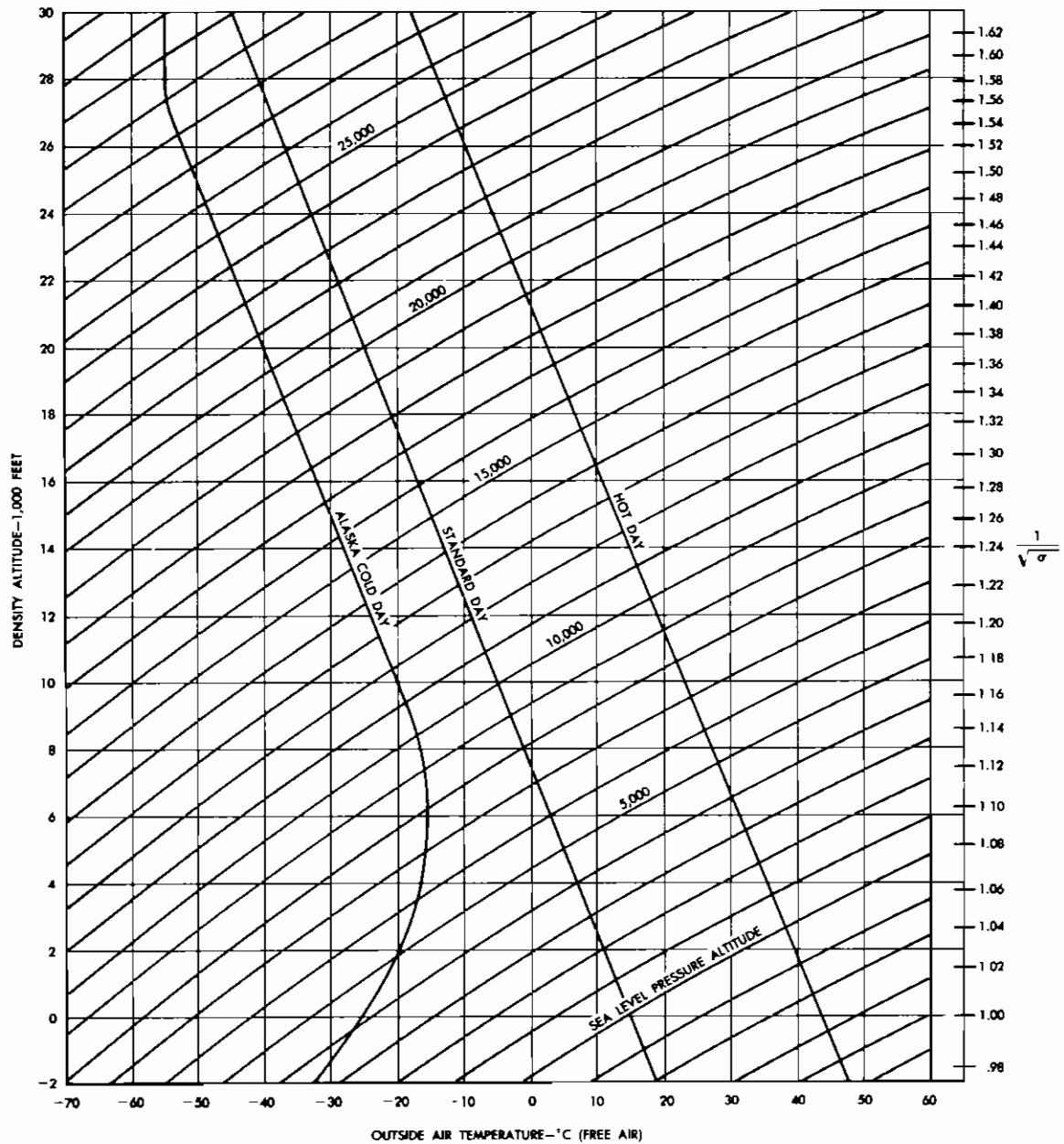


Figure 10-14. Density Altitude

1,500 pounds for takeoff plus 100 pounds per minute, from engine start until takeoff. Consequently, the amount of fuel used for WU/TAX/TO is 3,000 pounds: 1,500 pounds for a 2-minute takeoff plus 100 pounds per minute for a period of 15 minutes. By clock time, this means we start engines at 0800 Z, takeoff at 0815 Z, and set climb power at 0817 Z. Enter 3,000 pounds in block 29 for calculated total fuel used.

Enter 3,000 pounds in block 36 for fuel used in the gross weight column.

Remember, you are predicting the fuel needed for this mission. Therefore, the fuel remaining column, blocks 30 through 35 will not be used. However, during the actual flying of this mission, you must enter each period fuel used in this column. In that manner, the fuel remaining capabilities are always known.

5 ENGINE START Z 0800 Z			CREW NR		6 (R) STATIC MAP				26 ENGINE INST F/F LBS/HR		FUEL USED		FUEL REMAINING		36 FUEL AND/OR WATER USED									
					1		2		3		4		CALC		37 GAGE △ GR WT									
7 COND			9 SET		11 OATI		13 HP		16 RPM		20 IAS/EAS KCAS		22 TASK/IMACH		25 OIL QUAN EGT/TIT		27 PERIOD		30 PERIOD		33 PERIOD		38 END GR WT	
8 END			10 TOTAL		12 OATC/VAR		14 HD/MO		17 MAP		21 NMPP		23 DIST		24 TOTAL AIR DIST		28 EXTRA		31 TOTAL		34 TOTAL		39	
WU/TAX TO			:15		2000		-		-		1555		-		-		-		-		-		300 000	
0817c			:02		1200		-		-		2		↓		-		-		-		-		3 000	
			+4		1,0180		1.983		-		3		↓		-		-		-		-		-	
											4		↓		3000								297 000	

Figure 10-15. Flight Plan-WU TAX TO Condition

To determine the aircraft gross weight after takeoff, subtract 3,000 pounds of fuel from the ramp gross weight figure (300,000) and arrive at 297,000 pounds.

Figure 10-15 shows the aircraft performance log/plan with entries completed through the WU TAX/TO condition period for the mission.

Now, with takeoff computations completed and the data properly entered on the flight plan, we are ready to compute the data for the climb. The climb speed for our aircraft is 280 knots. Three factors must be considered for proper climb computations: (1) time, (2) fuel, and (3) temperature variation from standard. Compute the climb time first.

Notice from the chart in figure 10-16 that the optimum cruise climb altitude for the gross weight is 34,900 feet. Therefore, our plan should reflect the time needed to climb to this altitude. Determine the climb time from the chart shown in figure 10-16. Enter the chart at the bottom with the aircraft gross weight computed for the end condition of the takeoff (297,000 pounds). Move vertically to the pressure altitude line of 34,900 feet, and follow that grid line horizontally to the right. As shown on the chart, intersect the zero line of the temperature deviation section. Assume the existing temperature to be standard at -55° C. We need not work with a variation of temperature when predicting fuel requirements unless variations are known to exist. Obtain 30 minutes as the time for climb and enter this figure in block 9 of the flight plan climb condition.

In blocks 12, 13, and 14 of the climb condition, record the temperature variation of 0° C, the pressure altitude of 34,900 feet, and the density

altitude of 34,900 feet respectively. The smoe block 15 may be left blank as it is not important for this flight plan.

The engine pressure ratio for climb is obtained basically the same as the EPR computed for takeoff. That is, the temperature and pressure altitude combination is used to obtain an EPR setting. For this climb condition, enter 2.160 in block 19.

The indicated climb speed for our aircraft, as you recall, is 280 knots. Enter this speed in block 20 and the resultant true airspeed, 376 knots, in block 22. Now you are ready to obtain the distance traveled during the climb.

For the distance, block 23, compute the nautical miles traveled in the climb from the range chart, figure 10-17. Enter at the bottom with the gross weight as illustrated. Follow that grid line up to the optimum altitude line. Move from there to the right and read the range covered during climb as 132 nautical miles in the right-hand margin. Enter 132 NM in block 23 as the distance traveled in this condition period. Also enter 132 NM as the total air distance traveled.

Now we must find the fuel needed for the climb. Enter the climb fuel chart shown in figure 10-18. Following the guide lines, compute the total fuel used for climb as 8,800 pounds. Enter this figure in blocks 27 and 36 of the climb condition. Add 8,800 lbs climb fuel to the 3,000 lb previous total and enter 11,800 lb of fuel used in block 29 of the end climb condition. Subtract 8,800 lb of fuel from the previous gross weight (297,000 lb) and obtain 288,200 lb gross weight as the end of climb gross weight.

A strip of the flight plan depicting the climb condition is illustrated in figure 10-19.

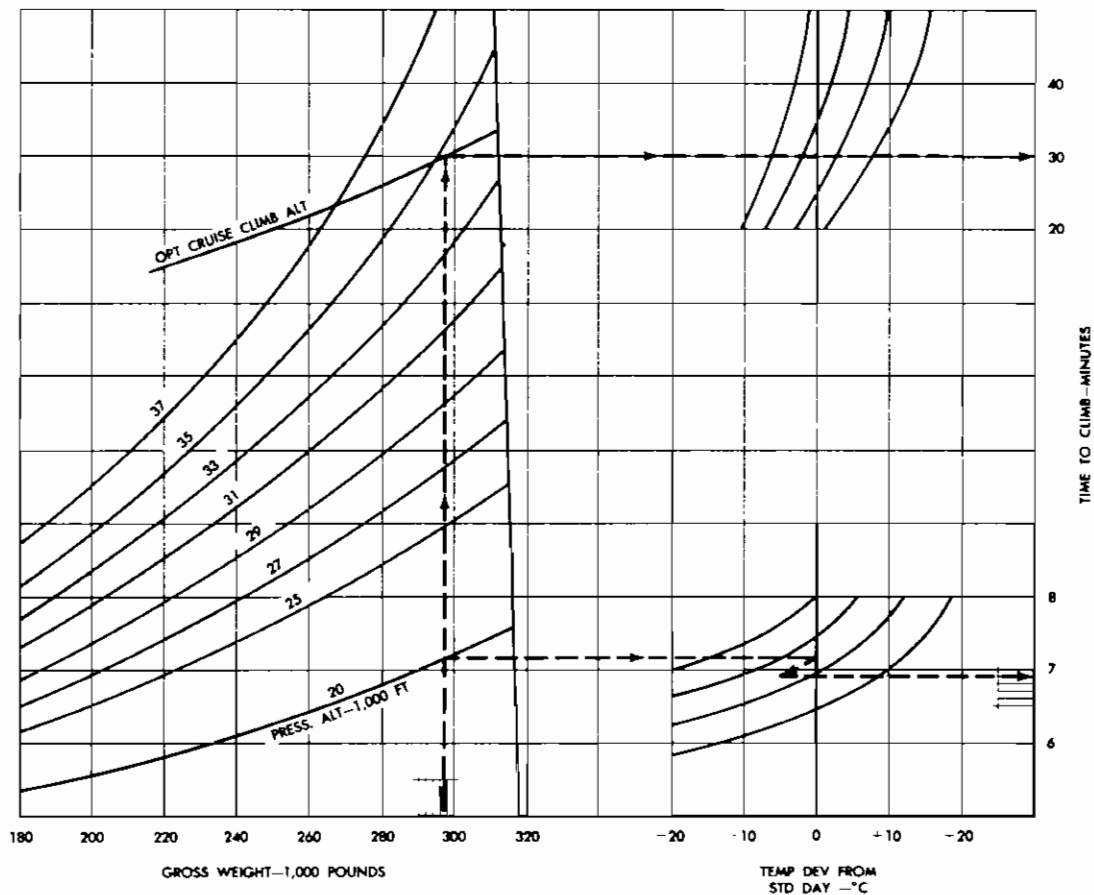


Figure 10-16. Climb Time

Now, with the end of climb gross weight, fuel used, time consumed, and distance traveled properly computed, you are ready to establish the condition for the first cruise.

The first consideration for the cruise period will be time. Normally this is based on 1-hour increments. The horizontal arrow in block 7 of the flight plan indicates the first cruise period, and the END block 8 will reflect the condition ending time of 0947 Z hours.

Block 9, SET time will show 1 hour, and the TOTAL block 10 will indicate the total elapsed time of the mission which is 1 hour and 32 minutes (1:32).

The standard temperature for the cruising altitude is minus 55 degrees. Let's assume the temperature to be standard which results in no temperature variation. So, enter zero in block 12 (VAR).

The pressure altitude (H_p) is 34,900 feet for entry into block 13. Since the temperature is

standard for this altitude, the density altitude (H_d) is the same as the pressure altitude (H_p). So enter 34,900 feet in block 14.

Now we are ready to establish a cruise engine pressure ratio (EPR) and a cruising speed. Enter the thrust EPR setting chart in figure 10-20 with the level-off gross weight, 288,200 pounds. Move inward on that gross weight grid line and interpolate the 34,900 foot pressure altitude line. The normal cruising speed is 0.74 True MACH. Descend directly on the chart from the 34,900 foot pressure altitude line to the curving line which depicts MACH 0.74 as illustrated. Then read the EPR of 1.80 directly in the left-hand margin, and enter that number in block 19.

Now we must convert the MACH number to a true airspeed in knots to determine the distance traveled during the first cruise. To do this, enter the chart shown in figure 10-21 at the left-hand margin with MACH number 0.74. Move horizontally to the right and interpolate the tempera-

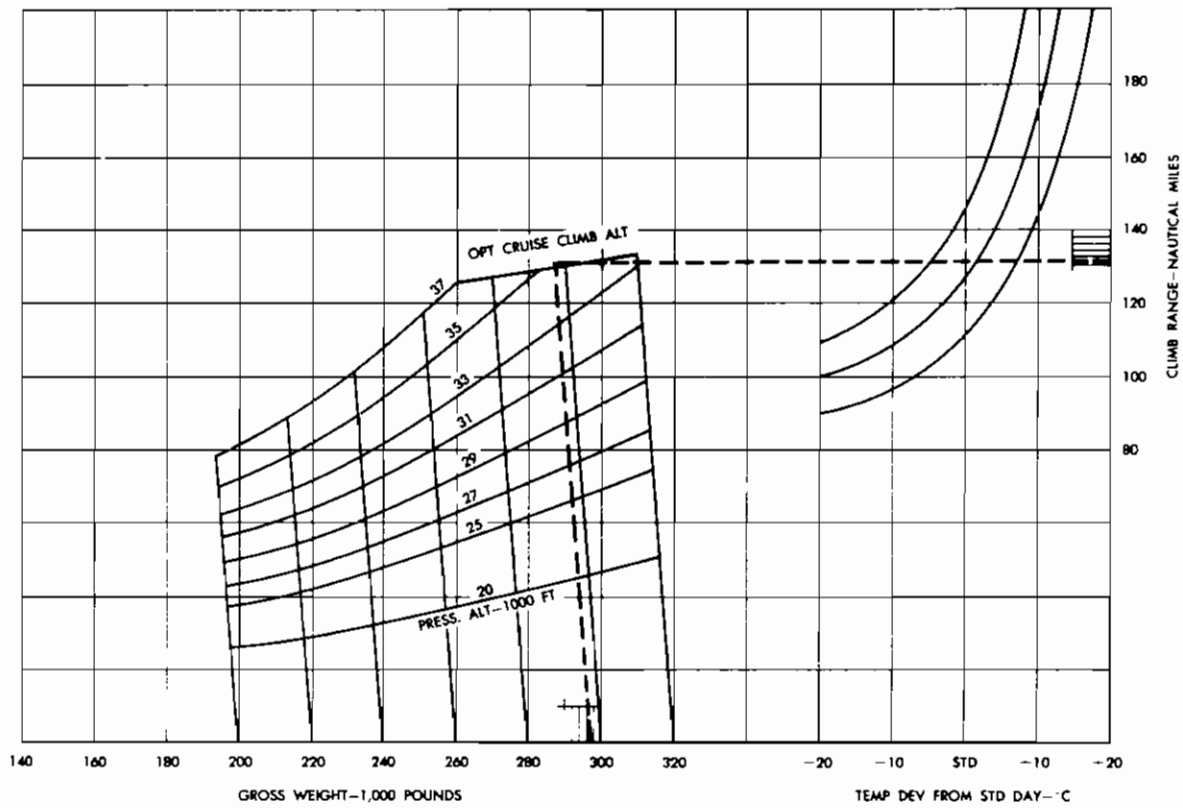


Figure 10-17. Climb Range

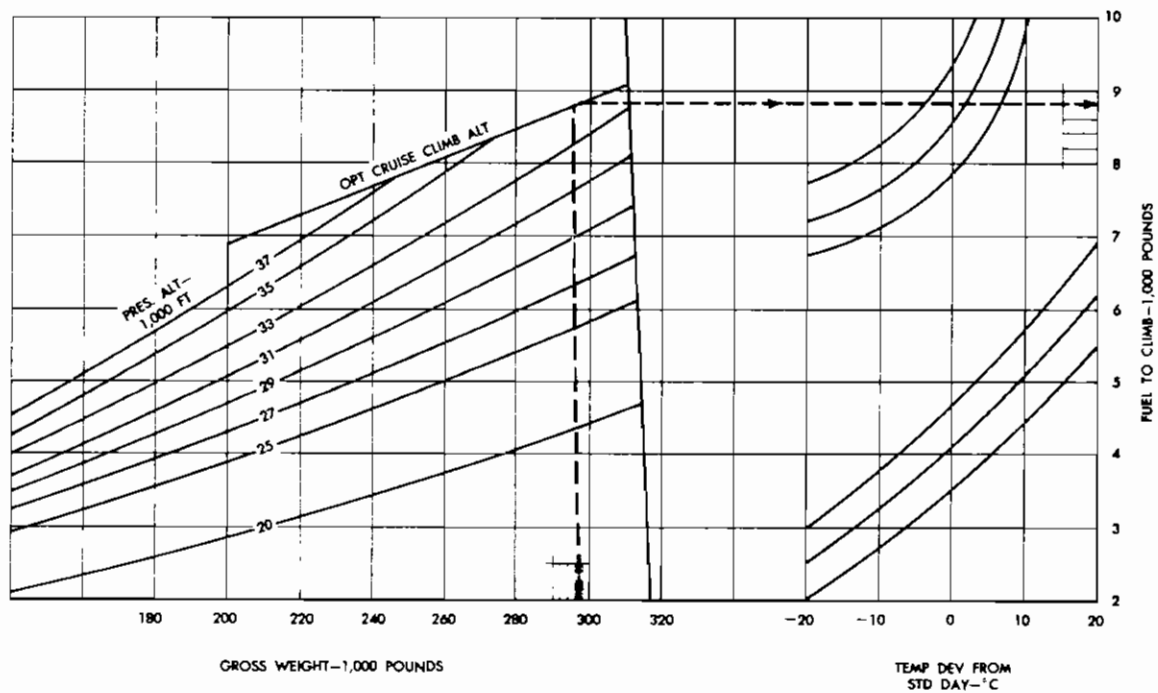


Figure 10-18. Climb Fuel

↗	:30	-	34900	-	280	376	↑	-	8800		8800
			34900	-		132		-			
0847	:32	↘	-	2.160	-	132	↓	-	11800		288200

Figure 10-19. Flight Plan—Climb Condition

ture of -55 degrees. From that point, move directly downward to read the true airspeed of 421.5 knots. Enter this speed in block 22 of the first cruise condition. Normally, indicated MACH is entered here for jet aircraft. However, because you are trying to determine the fuel needed for a specific distance traveled, it is more practical to use TASK. Remember, that this cruise is 1 hour in duration, therefore, you will travel a period distance of 421.5 NM. Enter this distance in block 23 and add 421.5 to the previous total of 132 and obtain a total distance of 553.5 NM for block 24.

Now determine the fuel used in 1 hour of cruise at the present condition. Enter the first part of the fuel flow chart illustrated in figure 10-22 at the bottom with the EPR, 1.80. Move vertically to 0.74 MACH then directly to the reference number (12) indicated in the illustration to the right. With this reference number, move inward to the temperature line (-55° C) and vertically to the pressure altitude line (34,900). Then directly to the left, read the fuel flow as 3,200 pounds per hour for one engine. Enter this amount in the appropriate spaces provided for each individual engine fuel flow, block 26. Total the amounts entered as 12,800 pounds for all engines, and enter this figure in blocks 27 and 36. Add 12,800 lbs to the total fuel figure of the climb condition and arrive at 24,600 pounds of fuel used thus far. Now subtract 12,800 pounds of fuel from the previous gross weight of 288,200 and arrive at the first cruise ending gross weight of 275,400 lbs.

A strip of the flight plan depicting the cruise 1 condition period is illustrated in figure 10-23.

For cruise 2, the condition period time blocks, 8 and 9, will be the same as the time for cruise

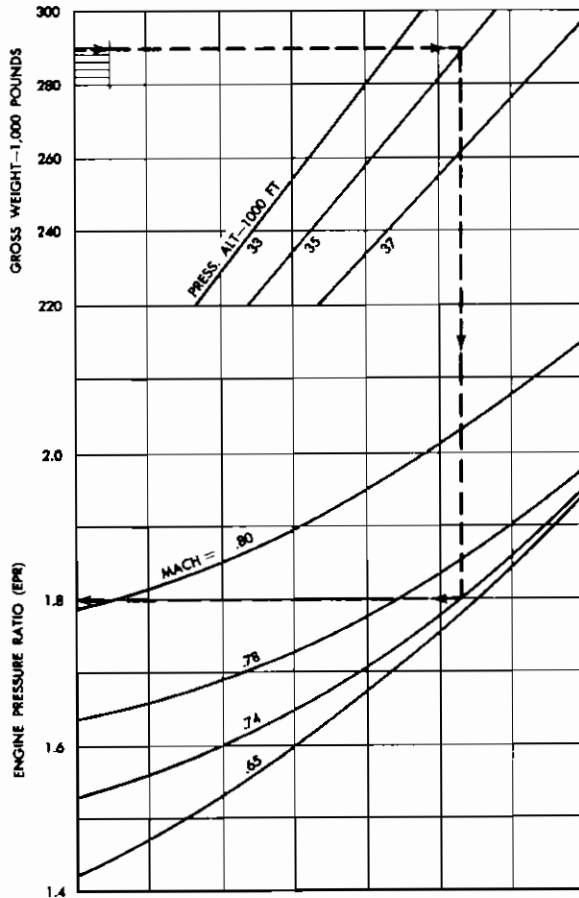


Figure 10-20. Thrust EPR

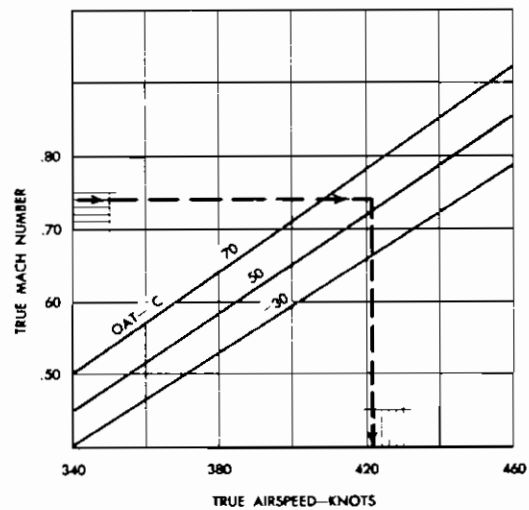


Figure 10-21. Conversion (Mach-True Airspeed)

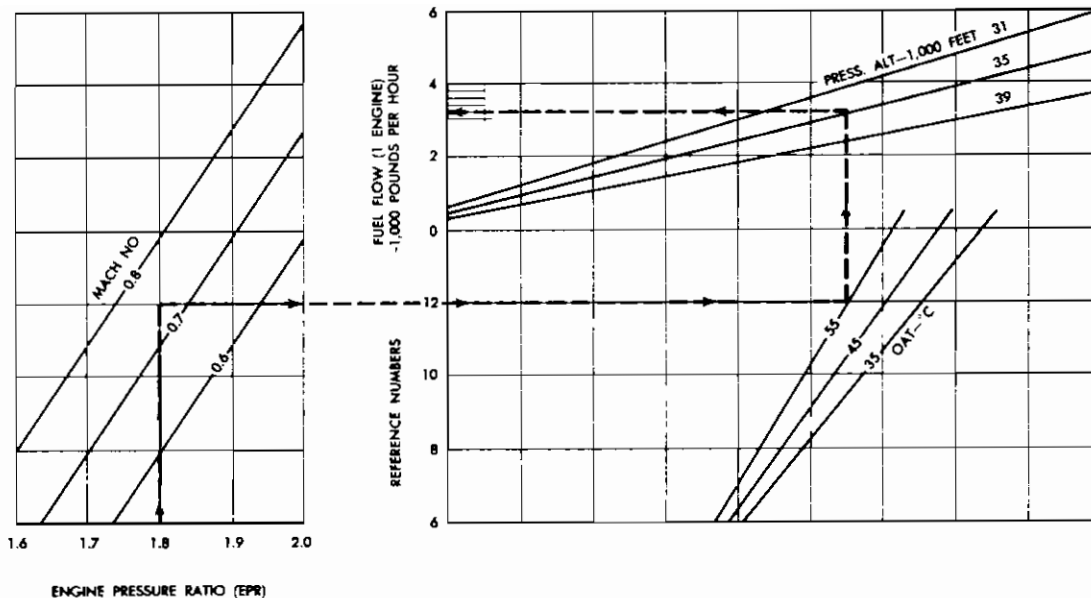


Figure 10-22. Cruise Fuel Flow

1, that is, 1 hour in duration. The total flight time shown in block 10, however, will increase by 1 hour, making a total flying time of 2 hours and 32 minutes. Blocks 12, 13, and 14 remain the same since the temperature, pressure altitude and density altitude do not change for cruise 2. However a new EPR must be computed for cruise 2.

To compute the new EPR for cruise 2, reenter the thrust chart in figure 10-20. Use the ending gross weight from cruise 1 (275,400 lbs) for entry into the chart. Follow the same steps as previously outlined and arrive at a cruise 2 EPR of 1.75. Enter that number in block 19 (see figure 10-24).

Blocks 22 and 23 remain the same for cruise 2 (421.5 knots) since the MACH number, pressure altitude, and temperature have not changed from those entered in cruise 1. Add the cruise 2 condition period distance to the total distance from cruise 1 and enter that total (975NM) in block 24.

A fuel flow for cruise 2 is obtained from figure 10-22 in the same manner as that obtained for cruise 1; however, use the cruise 2 EPR of 1.75. You should obtain a single engine fuel flow of 3,000 lbs/hr. Enter this figure in each individual engine fuel flow space, block 26. Total the individual engine fuel flows as 12,000 pounds of fuel per hour. Enter this figure in blocks 27 and 36 of cruise 2. Add block 27 to the previous cruise 1 total and obtain 36,600 pounds of fuel used. Subtract block 36 from the previous cruise 1 ending gross weight and obtain 263,400 as cruise 2 ending gross weight.

A strip of the flight plan depicting the cruise 2 condition is shown in figure 10-24.

For each successive cruise, as the flight plan progresses through the mission, reenter the charts as illustrated for cruise 1 and 2. This procedure will obtain current totals of fuel, gross weight, and distance. Figure 10-25 shows the cruise conditions for the succeeding 3 periods (cruises 3, 4, and 5)

1	1:00	-	34900	-	-	421.5	↓	3200	12800		12800
			34900	-	-	421.5	↓	3200	-		-
0947	1:32	0	-	1.800	-	553.5	↓	3200	24600		275400
								12800			

Figure 10-23. Flight Plan - Cruise 1

2	1:00	-	34900	-	-	421.5		3000	12 000		12 000
			34900	-	-	421.5		3000	-		-
1047	2:32	0	-	1.750	-	975.0	↓	3000			
								12000	36600		263 400

Figure 10-24. Flight Plan—Cruise 2

which gives us a total distance traveled as 2239.5 NM. Notice that this distance is quite close to the mission distance of 2747 NM. This is sufficiently close enough that you should now determine the point from which the descent to landing should begin.

For the turbine engine powered aircraft selected for your problem, an en route type descent is best for both economy and penetration. This is the type descent used here. To find the point at which the descent should begin, first compute the mission distance remaining from the end of cruise 5. This distance amounts to 507.5 NM (2747 NM—2239.5 NM). Some portion of the 507.5 NM remaining will be covered during descent. The distance to be covered during descent is found by extending cruise 6 to the total mission distance of 2747 NM and obtaining a gross weight at that point.

Notice in figure 10-26 that the cruise 6 fuel flow will be 10.400 lbs/hr. By ratio and proportion we find that if 421.5 NM requires 10,400 lbs of fuel then 507.5 NM requires 12,500 lbs of fuel. Subtracting 12,500 lbs from cruise 5 ending gross weight of 229,960 lbs leaves 217,460 lbs as the projected gross weight at the end of cruise 6 if the cruise was extended to the total mission distance (2747 NM).

Now, with the projected cruise 6 ending gross weight of 217,460 lbs, you can use the chart in figure 10-27 to determine an approximate distance which will be traveled during descent.

Enter figure 10-27 chart with the pressure altitude of 34,900 ft and intersect 217,460 lbs. Read straight down from this intersection to the range covered, 92 NM. This means that 92 NM of the range remaining, 507.5 NM, will be used for descent. Subtracting 92 NM from 507.5 NM leaves 415.5 NM remaining before descent.

Notice that the cruise 6 TASK is 421.5. This means, then, that cruise 6, as shown, will be only 59 minutes in duration at which time the descent will begin.

DESCENT SPEED. To predict the speed used during descent, use the chart shown in figure 10-28. Enter with the cruise altitude (34,900 ft). Move inward to the weight line which depicts the ending cruise weight of cruise 6. From that point, descend vertically to the bottom of the chart to determine the rate of descent as 2,350 feet per minute. Then return to the intersection of the gross weight and cruising altitude lines. Follow that grid line horizontally to the MACH 0.74 line. Directly above this intersecting point, read the descent speed as 252 knots calibrated airspeed.

3	1:00	-	34900	-	-	421.5		2850	11400		11 400
			34900	-	-	421.5		2850	-		-
1147	3:32	0	-	1.725	-	1396.5	↓	2850			
								11400	48000		252 000
4	1:00	-	34900	-	-	421.5		2810	11 240		11 240
			34900	-	-	421.5		2810	-		-
1247	4:32	0	-	1.690	-	1818.0	↓	2810			
								11240	59 240		240 760
5	1:00	-	34900	-	-	421.5		2700	10 900		10 800
			34900	-	-	421.5		2700	-		-
1347	5:32	0	-	1.650	-	2239.5	↓	2700			
								10800	70 040		229 960

Figure 10-25. Flight Plan—Cruises 3, 4, and 5

6	:59	-	34900	-	421.5	2600	10 220		10 220
			34900	-	415.5	2600			-
1446	6:31	0	-	1.635	2655.0	2600	80260		219 740
						10400			

Figure 10-26. Flight Plan — Cruise 6

Previously you have logged TASK in block 22. However, because distance traveled during descent is obtained from a chart instead of by calculation, you may log the calibrated airspeed (KCAS) during descent.

DESCENT TIME. Determine the descent time from the chart shown in figure 10-29. First, enter with the cruising altitude, then move upward to the gross weight line. Read the descent time at the bottom of the chart as 15.8 minutes. Round this

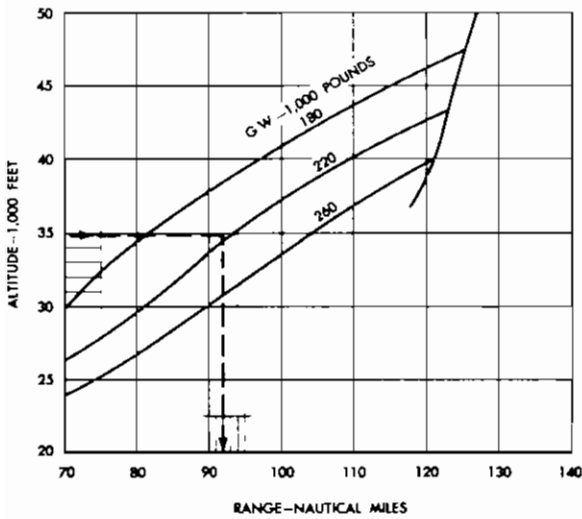


Figure 10-27. Descent Range

off to 16 minutes, and enter this descent time in block 9. Add the descent set time (16 minutes) to the total elapsed time shown in block 10 to determine the total flying time to the end of descent as 6:47. Also add the descent duration to the clock time and obtain the end clock time as 1502 for the end of descent, block 8.

DESCENT RANGE. The descent range has been previously computed as 92 NM. Add this figure to the end of cruise 6 distance to obtain the total distance traveled to the end of the descent as 2747 NM. Enter this figure in block 24.

DESCENT FUEL. Determine the descent fuel from the chart in figure 10-30. Enter with the cruising altitude, account for the gross weight, and plot the fuel required for descent as 700 lbs. This figure is a total fuel figure, therefore, dividing 700 lbs by 4 to obtain individual engine fuel flows is not important and merely the word *descent* need be entered in block 26. Add the required descent fuel to the previous total fuel required at the end of cruise 6 and enter the total (80,960 lbs) in block 29.

LANDING AND TAXI FUEL. The landing and taxi operation begins at the end of the descent, at traffic altitude over the destination. The time for landing and taxi may vary, depending on the traffic conditions and weather; however, 20 minutes is considered as the average landing and taxi time.

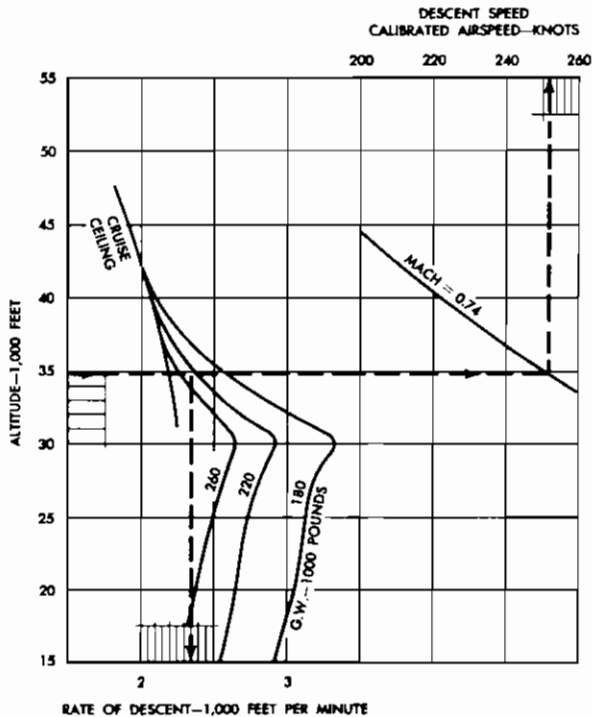


Figure 10-28. Descent Speed

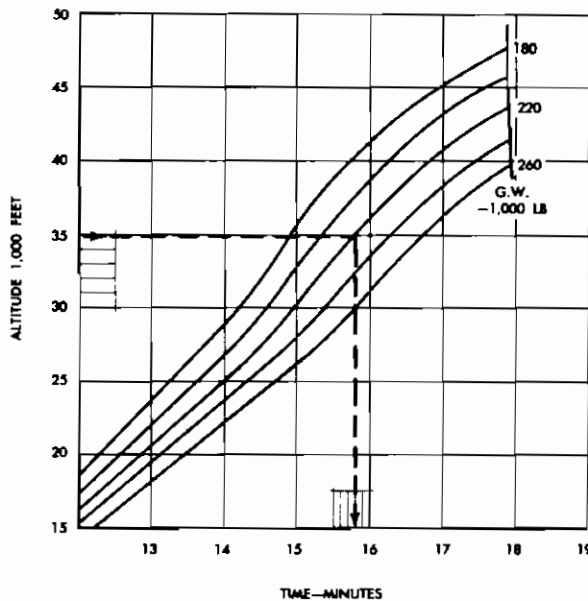


Figure 10-29. Descent Time

The power setting and thrust during landing and taxi varies considerably, so no EPR is recorded on the predicted flight plan. A standard fuel flow in pounds is calculated for use in landing and taxi. For the turbine engine aircraft for our problem, a standard fuel consumption of 1,000 pounds is used. No airspeed is recorded on the predicted flight plan for the landing and taxi operation. Since this operation usually takes place as the aircraft circles the destination in the traffic pattern, no distance along the course is recorded. The significant flight plan entries for the landing and taxi operation are those relating to time elapsed and fuel consumed.

Block 7 reflects the flight condition as L&T, and block 9 shows the SET time as 20 minutes (:20). Add the 20 minutes to the ending clock time of the descent condition period and enter 1522 in block 8 as the END clock time for landing and taxi. This represents the end-of-mission time.

Enter the standard landing and taxi fuel weight of 1,000 pounds in block 27. Add that figure to the total fuel used figure (80,960 pounds) reflected in block 29 for the descent condition. Enter the sum of the added figures 81,960 pounds in block 29 for the total fuel used at the end of the landing and taxi operation. This figure represents the total fuel used during the entire mission.

Enter the 1,000 pounds of fuel for landing and

taxi in block 36. Then, subtract that amount from the ending gross weight for the descent condition period.

Finally, subtract the landing and taxi fuel weight (1,000 pounds), entered in block 36, from the ending gross weight for the descent condition period. The result shows the mission termination gross weight of 218,040 pounds, at the end of the landing and taxi operation condition period.

A strip of the flight plan entries for the descent, and the landing and taxi condition periods is shown in figure 10-31.

Thus you have the operational data for the flight plan completed. From the computed data, you may now determine the mission fuel required and the fuel reserve. As you recall, computations of fuel reserve requirements were previously discussed in chapter 9. If you find a review of the subject necessary at this time, reread the section of chapter 9 entitled FUEL RESERVES.

The discussion previously presented is of a general nature to include the procedure used for reserve fuel computations for aircraft of all types. However, the provisions of Air Force Manual 60-16, General Flight Rules, individual command regulations, and local policies must be adhered to when computing reserve fuel requirements. At any rate, the total of the wind reserve, three-engine reserve, and the endurance reserve, will be entered in the fuel reserve section of block 1 of the flight plan. For illustrative purposes, the computed total fuel reserves for our flight plan problem

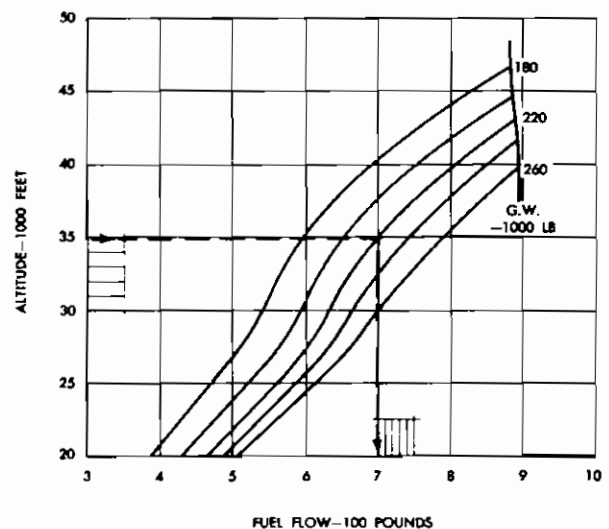


Figure 10-30. Descent Fuel

is 18,040 pounds. The fuel required for the mission, based on chart computations is 81,960 pounds. The total of the required fuel and reserve fuel equals 100,000 pounds, as reflected in the total fuel aboard.

Enter the required fuel and the reserve fuel in the fuel data block 1 of the flight plan as previously illustrated in figure 10-13.

Note: Local policy may prescribe reserve fuel for heaters, for auxiliary power units, and for possible flight to alternate airports.

Now that the three reserves have been reviewed let's return to the flight plan and apply the reserve fuel to the fuel requirements.

It would be advantageous at this time to look at your fuel requirements closely to fix firmly in your mind what has taken place. So, let's list the items that your flight plan has revealed.

- (1) Warmup and taxi fuel = 1,500 lbs.
- (2) Takeoff fuel = 1,500 lbs.
- (3) Climb fuel = 8,800 lbs.
- (4) Cruise fuel = 68,460 lbs.
- (5) Descent fuel = 700 lbs.
- (6) Landing and taxi fuel = 1,000 lbs.
- (7) Reserve fuel = 18,040 lbs.
- (8) Total mission fuel required = 100,000 lbs.

With the total required mission fuel weight known, the determination of your maximum cargo load is relatively simple.

As shown in figure 10-13 the operating weight of your aircraft is 130,938 lbs. Add to this figure the required mission fuel weight of 100,000 lbs and obtain 230,938 lbs. Because of obstacle clearance, the aircraft is restricted to a takeoff weight of 300,000 lbs, therefore, subtract 230,938 lbs from 300,000 lbs. The remainder, 69,062 lbs is the maximum cargo load for your mission. Notice one thing at this point: the 1,500 lb warmup and taxi fuel provides you with a margin of safety to ascertain that the obstacle, which restricts the gross weight, will be cleared after takeoff. In other words, the 1,500 lbs of fuel will be consumed prior to the start of takeoff reducing the gross weight to 298,500 lbs. Of course, if this margin of safety is not desired, then the ramp gross weight can be increased to 301,500 so that at the completion of the warmup and taxi period the gross weight will be 300,000 lbs. This procedure will allow a cargo load increase of 1,500 lbs or 70,562 lbs total.

Now that you know your total fuel aboard you

can return to the TOLD card, figure 10-1, and complete the emergency return data.

EMERGENCY RETURN DATA. As you recall, emergency return data is computed in the event the pilot elects to return to the landing field immediately after takeoff. For this reason, some air commands compute the return data using the brake release gross weight. However, for this problem, we shall assume that fuel will be jettisoned; reducing the gross weight to the recommended landing weight of 257,500 lbs.

As you can see in figure 10-1 the emergency return data consists of 10 blocks. The first unknown is threshold speed. Threshold speed is obtained from the chart in figure 10-32. Enter this chart with the landing gross weight, 257,500 lbs and intersect the takeoff/approach flap line and read 132 knots directly below this intersection at the bottom of the chart. Enter this speed in the appropriate block of the TOLD card.

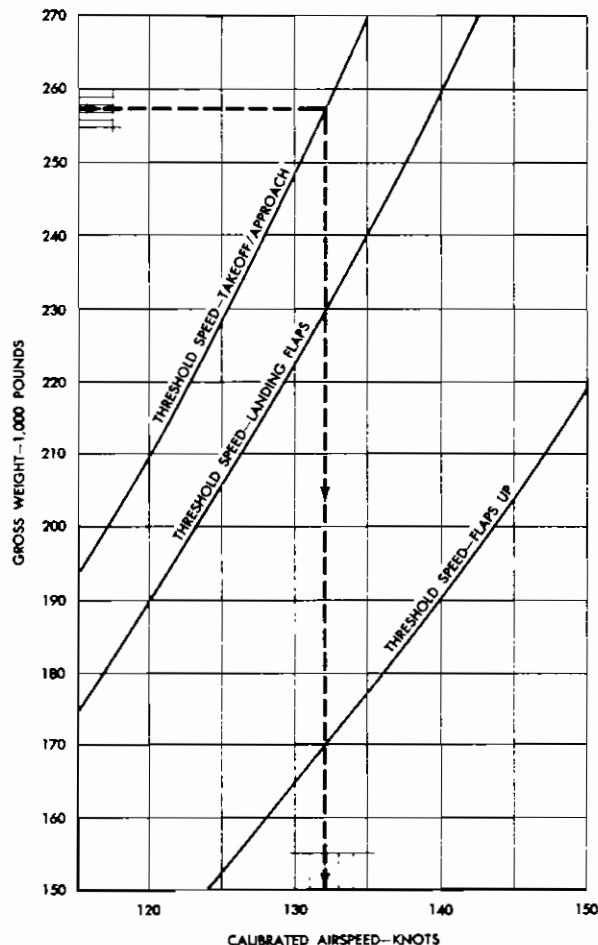


Figure 10-32. Threshold Speed

The landing distance is obtained from figure 10-33. The value derived from this chart presupposes the use of landing flaps, spoilers, and antiskid brakes after touchdown. Landing ground roll charts are also available in the flight handbook for aircraft which are not equipped with antiskid brakes. Select the chart applicable to your aircraft when you compute the landing ground roll. Enter the chart shown with the OAT C (4°) and move into the pressure altitude line (2,000 ft). Then descend to the gross weight line and interpolate 257,500 pounds and read the UNCORRECTED landing ground roll in the right-hand

margin as 2,300 feet. Continue directly into the adjoining portion of the chart and account for the runway condition (wet). Then plot the runway slope percent, the effective headwind, and read the CORRECTED landing ground roll in the extreme right-hand margin as 3,150 feet. Enter this figure in the LDG DIST block for your emergency return data.

Now, for the final items of your emergency return data you must compute fuel jettison information. We have a total fuel load of 100,000 pounds on board, and we would need to dump 42,500 pounds of the total fuel to reduce the air-

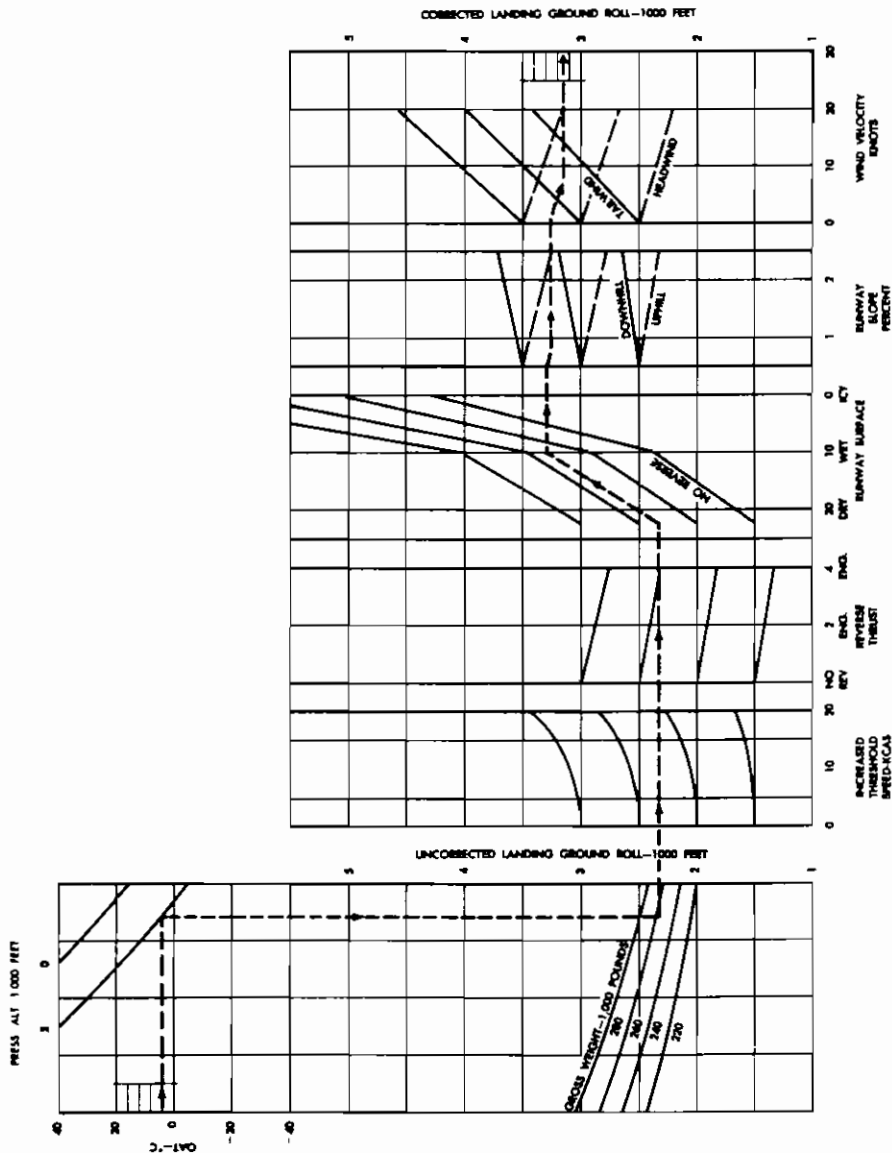


Figure 10-33. Landing Ground Roll

FLYING THE MISSION

craft gross weight to a recommended weight limit for landing. This leaves 57,500 pounds of fuel remaining with an aircraft gross weight of 257,500 pounds for the landing. Enter these known figures in the emergency return section of the TOLD card as follows: Fuel dump start weight 100,000 pounds; fuel dump end weight 57,500 pounds. Then enter 257,500 pounds for the aircraft gross weight after fuel dump.

Enter the fuel jettison time chart, figure 10-34, with the total fuel weight (100,000 lbs), and follow that weight line horizontally into the FUEL ABOARD line as illustrated. Read that time directly below on the time scale as 8.6 minutes. Now continue on down the fuel aboard line until you intersect the horizontal grid line which represents the END dump fuel weight (57,500 lbs). Directly below that point, read that time as 17.0 minutes. Then subtract the first obtained figure (8.6 minutes) from the second (17.0 minutes) and arrive at 8.4 minutes to jettison 42,500 pounds of fuel. Enter this figure in the TIME block of the emergency return section.

You may have noticed on the TOLD card that there are provisions for recording conditions and computations at your destination. This portion of the card is completed when you approach your destination.

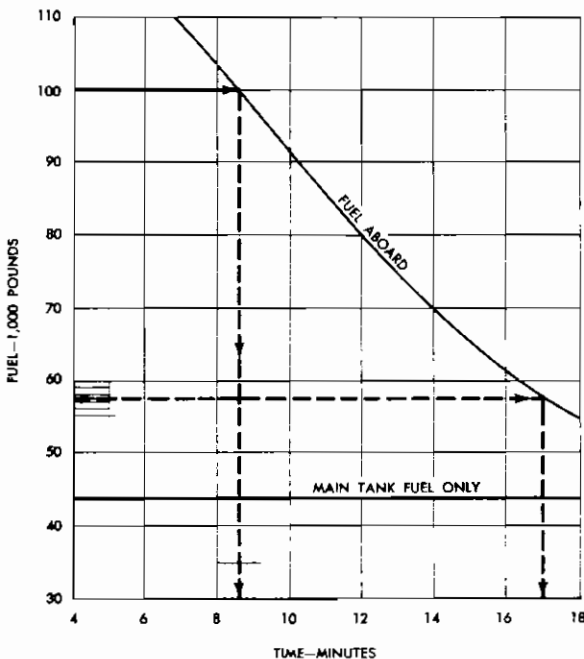


Figure 10-34. Fuel Jettison Time

The successful accomplishment of the mission is the end result of applying all the knowledge gained through previous study, through training and experience, and through the application of judgment. Regardless of the type of aircraft flown, the essential demands of the mission are the same—to obtain safe, economical operation within the performance capability of the specific aircraft. Once an aircraft is designed and built around a given powerplant, little can be done to change its performance characteristics. However, much can be done within these design limitations to obtain operational economy and reliability. It is the duty of the flight engineer to study these performance characteristics, and to develop methods, techniques, and procedures that result in efficient, economical operation of the aircraft-powerplant combination.

During flight, it is the flight engineer's responsibility to advise and assist the aircraft commander in accomplishing the assigned mission. The flight engineer should be aware of the forces acting on the aircraft, and he should understand what means are at his disposal for controlling these forces.

Aircraft performance is not a hit or miss proposition; it is predictable and controllable through the correct use of the proper relationship of altitude, airspeed, and horsepower or thrust. AF Form 796, as studied previously, is an example of how performance is predictable at all stages of the flight. When it comes to flying the actual mission, however, the predicted and actual flying conditions seldom coincide because of the presence of unpredictable variables. Therefore, as flight engineer, it is your duty to determine the exact performance characteristics of the aircraft early in the mission and to use this information in replanning subsequent phases of the mission. You accomplish this by making inflight entries on the performance log. Then, as the mission progresses through the condition periods of the flight, you compare the actual flight entries with those which you had made on the predicted flight plan. Thus, you have readily available the predicted data and the actual flight data on which to base your analyses of the aircraft and engine performance.

Final Station

At a time established during the detailed briefing for the mission, the final station procedures are completed. Final station time is usually 2 hours before the scheduled takeoff time. The procedures vary somewhat with local SOPs, but with slight variations, the following routine prevails:

- Crew inspection
- Final crew briefing and TOLD card presentation
- Boarding the aircraft
- Initiating the flight log

CREW INSPECTION. The aircraft commander conducts an inspection of the crew members and their equipment required for the mission. The crew inspection assures the aircraft commander that all crew members are present with the proper equipment to sustain the mission through normal and possible emergency conditions dictated by the mission plan. In order that these inspection procedures may be standardized, individuals and their personal equipment are usually aligned in appropriate rows, and the rollcall and inspection proceeds in a military manner.

FINAL CREW BRIEFING. This final meeting is generally used for the following purposes:

- To make a final check on crew members and passengers.
- To obtain results of the preflight inspection.
- To complete any final entries in Form 781 and Form F.
- To review pertinent emergency signals, routine scanner reporting, emergency positions and exits, oxygen positions, and "abort takeoff" procedures.
- To cover any changes in route, altitude, or duration of flight dictated by weather or the clearing authority.
- To answer any questions the crew might have.

At this time, the flight engineer presents the TOLD card to the aircraft commander and answers any questions that may arise from the computations on the card.

BOARDING THE AIRCRAFT. As indicated during the preflight operational equipment check, a good mission starts from the individual crew stations aboard the aircraft. Go aboard, stow your equipment properly, and proceed directly to your station with proper equipment and check lists. A station

check establishes the conditions that must be set up prior to a good preflight, such as electrical power ON, ignition power switches OFF, and the like; it also places individuals in communication so that items requiring coordination may be checked. The priority of checks should determine the order in which crew members enter the aircraft, consistent with the physical aircraft arrangement. This, roughly, would be the reverse of a bailout order, with the pilot substituting for the aircraft commander. The commander likes to "bring up the rear" whenever possible.

The pilots and engineers have several duties to perform between the time they board the aircraft and start the engines. Approximately 15 minutes should be allowed for this period to make sure the remaining schedule is not interrupted. Normally, a good time schedule would be to board the aircraft 30 minutes before takeoff, and to start engines 15 minutes before takeoff. Since the pilot and engineer have the most duties to perform before engine start, they should be the first to enter the aircraft after their dismissal from the final briefing.

INITIATING THE FLIGHT LOG. To keep a record of actual operating conditions, you record various data in the aircraft performance log. The log must, however, be initiated before starting the engines. The heading of this log provides spaces for general information such as aircraft number, aircraft commander, squadron, and so forth. The general procedure is to complete the log with the information available up to and including the climb condition. Then, at the top of the climb, the actual time in the climb is computed and entered on the log.

Starting Engines

After completing the before-starting-engines check list, the engineer, on command from the aircraft commander, starts the engines. This procedure varies somewhat for turbine engine aircraft. For the sake of economy and engine life, an effort should be made to start the engines as close to takeoff time as the situation and the experience of the crew will permit (usually 15 minutes). The start-engines time is entered in the flight log at the time the first engine is started.

Engine Warmup

All engines require a certain warmup and stabilization period (excluding jets). Reciprocating engines may require from 3 to 10 minutes, de-

pending on the weather. The time required for engine warmup must be used intelligently to insure completion of as many checks as possible. Use this time (1) to establish normal electrical power output, (2) to note whether instrument readings are consistent with normal operating conditions, and (3) to clear wheel chocks and ground handling equipment prior to taxiing.

Taxiing

Taxiing is begun as soon after engine start as practicable, consistent with the attainment of proper engine temperatures and the completion of the before-taxi check list requirements. During taxi, proper rpm must be maintained for controlled taxi speed. Also during taxi, the engineer must monitor instruments and complete specific checks pertaining to the taxi check list.

Engine Runup

After taxiing to a suitable runup area, complete all the required power checks in accordance with the standard check list while you await clearance for lining up on the takeoff runway. You should know the engineer's amplified check list so that you will understand the exact runup procedure and sequence. The recognition of acceptable instrument readings during power checks should be "second nature." Power checks should be made as rapidly as engine operating limitations will permit.

Engineers and pilots should indicate by proper signals or interphone communications what they are doing at all times to allow appropriate crew members or ground observers to anticipate their activities where coordination is required. Under a single preflight runup system, the required checks are held to a minimum consistent with safety and with essential rechecks of maintenance corrections. Each pound of fuel saved during ground operation prior to takeoff means more distance, if needed, during inflight operations.

Before Takeoff

Panel-equipped aircraft require close coordination among the aircraft commander, the pilot, and the flight engineer, as well as with other crew members observing and reporting on various phases of the operation. The aircraft commander, the pilot, and the flight engineer are the "key three" during takeoff, and must be prepared to perform with precision and perfect coordination. To set

this up, takeoff procedures are standardized as reflected on the standard check lists. Takeoff performance is predicted on the TOLD card, and this information is checked by the aircraft commander. Takeoff performance should be fixed in the aircraft commander's mind so that he may arrive at logical decisions more rapidly during the busy takeoff period.

The flight engineer is responsible for having this information computed completely and accurately for the safety of the flight. With the takeoff performance data firmly in mind, continue takeoff preparations by completing the before takeoff section of the standard check list. Use your check list and follow it carefully. No matter how proficient you are or how well you know your procedures, you are inviting trouble when you fail to use the check list. It is not just a list of items to be read from a piece of paper; nor is it a reflection on the ability of the flight engineer. The intent is to provide a positive recheck of each item which could have any bearing on the safety of the aircraft during takeoff. The flight engineer's takeoff procedure usually includes appropriate interphone communication to assure the aircraft commander and himself that his panels are properly set up for takeoff. Stand by to set takeoff power at the aircraft commander's request.

This completes the preparation phase of the mission. If your planning is complete and accurate and if the aircraft is in good condition, the mission should be a successful one.

INFLIGHT LOGGING PROCEDURES

During the takeoff, the flight engineer should continuously monitor the engine and systems instruments. He should not attempt to make log entries during takeoff since this activity would divert his attention from the instruments. Therefore, to assure an accurate, useful flight log, this log should be initiated properly before starting the engines, and the start engines time should be entered after the first engine has been started as we mentioned earlier. Then, while monitoring instruments, the flight engineer should note and remember certain instrument readings during the takeoff. By having a properly initiated flight log, and by remembering certain definite instrument readings, the flight engineer can enter this accurate informa-

tion in his log after the initial climb has been established.

To initiate a log properly, all information that is known up to and including the initial power setting of climb number 1 must be entered.

Time cannot be determined at this point. There are no speeds nor distances involved in warmup, taxi and takeoff. Total fuel used for warmup, taxi, and takeoff is an average figure, used to arrive at an ending weight for the condition. Remember that this figure is correct for one type of engine. Other types of engines require the use of other figures.

Only the power setup can be entered when initiating the flight log. For cruise 1, the power setup as entered on the predicted flight plan is entered here and should be set up on reaching cruise altitude.

When the mission is started and the log is initiated, there are certain readings that the engineer must note and enter on the flight log to keep it current. The readings are:

Start Engine Time—This is the clock time at which the first engine was started.

Warmup and Taxi—This time is entered and circled but is not counted in total time. For this entry, the flight engineer need only note the ending time of this period which is the time the take-off roll begins. Some SOPs may require that a clock time be recorded when the chocks are pulled.

Takeoff—For this condition the engineer should closely monitor the engine power, electrical system, and all related systems for proper reading at about the time lift-off speed is reached. Enter the takeoff time after climb power is set and stable.

Climb—The time for climb power is established at the ending time for the takeoff condition. During the climb, the engineer should obtain average settings for power, fuel flow, and temperatures, as well as the average IAS used throughout the climb. Climb entries are made on the log at 2/3 climb altitude.

Initial Cruise—In most cases, the aircraft is leveled out at the cruising altitude on the pilot's altimeter. This reading is almost always different from the reading on the flight engineer's altimeter because the pilot's altimeter is set on local altimeter setting while the flight engineer's altimeter should be set on 29.92 to read true pressure altitude. The difference in altitude may require a different bhp or EPR for cruise 1 than that computed before takeoff. The engineer should not attempt to make

a power correction at this time. He should establish the power setting as determined on the predicted plan and enter it in the flight log for cruise 1, regardless of the altitude variation.

Different pilots use different techniques to establish the cruise condition and to bring the aircraft into a stabilized condition. Changing the power frequently to make airspeed or altitude compensations lengthens the time required to stabilize the aircraft. The easiest method to attain effective coordination between the flight engineer and the pilot is for the engineer to establish his predicted power and for the pilot to manually fly the aircraft until the altitude, airspeed, and cooling flap requirements are stable. In most cases this should require from 5 to 10 minutes.

As soon as the engineer is reasonably certain the aircraft is stable, he should record the instrument readings for power, airspeed, temperature, and altitude. Then, by means of the readings and notes he had jotted down during takeoff, climb, etc., he should bring the log up to date by entering the fuel used and thus determine the new values for the fuel and weight columns.

Climb entries are completed as follows:

- Enter the end clock time (time condition ends), time in condition, and total time.
- Enter OAT1 and OAT C and temperature variation as observed and calculated at the end of the climb.
- Compute and enter the density altitude at end of the climb.
- Compute and record the two-thirds H_d and $\frac{1}{\sqrt{\sigma}}$ (smoe) for the climb.
- Correct the IASK to BASK, then to CASK, then to EASK, and multiply the EASK by the two-thirds $\frac{1}{\sqrt{\sigma}}$ to obtain a climb TASK and record these values.
- With the TASK and the time in the climb, compute and record the air distance covered.
- Compute and enter fuel used in the climb by using time and fuel flow. Compute and enter the new fuel remaining and gross weight values.

At this time, your log will be current. The aircraft will have been stabilized and engine readings for cruise 1 may be entered. By now you will be approximately one-half hour into cruise 1. All entries on cruise 1 should now be entered except time, speed, distance, fuel used, and ending weight.

These are all ending values and hence cannot be determined at this time.

With the information now available on the log, the engineer is able to analyze the performance of his aircraft.

AIRCRAFT PERFORMANCE ANALYSES

Let us consider an analysis which applies principally to reciprocating engine aircraft operation. However, you should apply the principles to turbine engine aircraft as applicable. The many variables affecting aircraft and engine performance make it necessary for the flight engineer to compare the actual performance of his aircraft to the charted (standard) performance of the aircraft. Therefore, as soon as the aircraft has stabilized in cruise, the engineer should analyze the aircraft's performance in relation to charted values.

Analyzing the various cruise conditions during flight enables the flight engineer to determine how much the aircraft and engine performances vary from their charted values. Comparing and analyzing the results usually discloses the cause of this variation.

A very effective method of evaluating aircraft performance is to compare logged air and ground NMPP with charted NMPP (block 21 of the log).

Charted NMPP

Since you know what the actual NMPP is for cruise 1, $\frac{\log \text{ TASK}}{\log \text{ fuel flow}}$, you can evaluate aircraft engine and crew performance by comparing this performance with the charted NMPP. If the charted NMPP value *exceeds* the actual value, performance is not as good as charted. On the other hand, if charted performance is *lower* than the actual value, performance is better than charted.

To find the charted NMPP, it is necessary to establish the charted bhp required (bhp req.) with the following formula:

$$\text{Charted bhp req} = \frac{\text{logged bhp for cruise}}{\text{SMOE for cruise HD}} \times$$

the SMOE from the nearest 5,000 ft HD specific range chart (NMPP chart).

Next, the average cruise 1 gross weight is established by subtracting $\frac{1}{2}$ of the total fuel flow from cruise 1 from the cruise 1 beginning gross weight as follows:

Average gross weight = beginning gross weight — $\frac{1}{2}$ increment fuel flow. (This assumes that the cruise duration is 1 hour.)

Finally, enter the NMPP chart, which is nearest your cruising density altitude, with the average gross weight and charted bhp. Where these two values intersect you will find:

1. The charted NMPP value.
2. The charted EASK.

Compare the actual NMPP value and airspeed with those values entered for this condition on your flight log. The difference, plus or minus, between the charted and actual computations is the amount of correction required for subsequent performance throughout the flight.

Air NMPP

Air NMPP represents the performance of the aircraft and engines compared to air miles covered. Air NMPP is computed by dividing the logged TASK by the logged fuel flow in pounds per hour for the cruise being analyzed.

Ground NMPP

Ground NMPP value represents the performance of the aircraft and engines, including the effects of winds, compared to ground miles covered. Ground NMPP is the groundspeed (TASK \pm wind) divided by the logged fuel flow. The effect of wind on the aircraft is obtained from the navigator. If, for instance, in cruise 1 you encounter a 12k headwind, your groundspeed would be the TASK of the aircraft minus the velocity of the headwind.

Analyzing NMPP Values

Comparison of these NMPP values indicates the variations in performance, which in most cases can be attributed to changes in drag, improper crew techniques, instrument errors, or unfavorable weather conditions.

A comparison of the charted NMPP with the air NMPP indicates a loss or gain in NMPP value resulting from aircraft and engine performance.

A comparison of the air NMPP with the ground NMPP indicates the loss or gain in NMPP caused by winds.

A net loss or gain in NMPP can be determined by algebraically adding the losses or gains brought about by variations in aircraft and engine performance and by winds.

Upon completion of this analysis, if the comparison of charted NMPP and air NMPP indicates a loss due to aircraft or engine performance, the engineer should make a thorough check of all the controllable items affecting the drag of the aircraft to see if this loss can be decreased. The engine operating temperature should be checked for the possibility of further closing the cowl flaps. Wing flaps, wheel well doors, and the like should be checked for creeping. Check the CG to see that it is within limits and ask the pilot to retrim the aircraft. If performance in terms of NMPP does not increase after these checks, the engineer can be sure that the difficulty is due either to drag-creating factors that cannot be controlled in flight or to improper powerplant management, which causes excessive fuel consumption. After all corrections have been made to reduce drag within the margins of safety and to improve powerplant management, the flight engineer must adjust the bhp to maintain the EASK which produces the most efficient L/D for the weight of the aircraft.

Analyzing Weights and Delta F Corrections

Further analysis of the cruise is made by computing a weight correction factor, which is indicated by the weight change symbol (Δ) shown in block 37 of the performance log. This weight correction factor is like an additional amount of weight equal to the excessive drag affecting the speed of the aircraft for any given power and gross weight. To determine the amount of weight correction affecting the aircraft, the following procedure is used.

To determine the weight correction factor, a comparison of charted and actual EASK is necessary. Compute charted EASK in the same manner as before for a charted NMPP value. Smoe the logged bhp to the charted altitude and subtract the ΔF bhp to obtain a charted bhp_{corr}. To obtain the charted EASK, enter the appropriate NMPP chart with this bhp and the average gross weight for the condition being analyzed.

The charted EASK represents the speed the aircraft should fly for that particular bhp and gross weight. Compare the actual (logged) EASK for the cruise being analyzed with the charted EASK. If the logged EASK is lower than the charted EASK, the aircraft has a plus (+) correction factor because it is flying more slowly as if it weighs more. If the logged EASK is greater than the charted EASK, the correction factor is minus

(-) meaning that the aircraft is performing as though it weighs less.

Computing Weight Correction Factor

The total weight correction factor used in the flight log for cruise 2 is computed from the difference between the actual average gross weight of cruise 1 and the average performance weight for cruise 1. The performance weight is one of the indications as to how the aircraft is flying. Therefore, actual conditions are used to find performance weight. Two facts from the log are used to obtain this performance weight: logged bhp and logged EASK. To use the NMPP chart, convert the logged bhp to a bhp_{corr}. When the conversion is made, interpolate an average performance gross weight (lbs) at the intersection of bhp_{corr} and the logged EASK line on the appropriate NMPP chart. The difference between the average performance weight and the actual weight is the weight correction factor. In other words, the aircraft flies as if it weighs more than it actually does when a plus (+) correction factor is indicated and less than it actually does when a minus (-) correction factor is indicated. Remember that speed is determined from the actual weight, and power is determined from performance weight when applying weight corrections.

Inasmuch as a weight correction factor is valid for only narrow speed ranges such as long range airspeed, it is recommended that ΔF correction factors be used in inflight replanning. By using ΔF bhp you simplify the planning process. These ΔF bhp factors are valid for all speed, power, and weight ranges. Remember, however, that the ΔF factor itself changes during flight because of such factors as oil leaks, engine exhaust deposits on the aircraft, changes in CG position, or changes in an engine's condition that may bring about changes in cooling requirements. For these reasons, the flight engineer should recompute the ΔF factor frequently to keep his planning effective.

INFLIGHT REPLANNING

As soon as possible after the analysis has been completed, make the necessary bhp corrections to fly the succeeding cruise condition at the proper airspeed. How the aircraft performs after the planned bhp is established demonstrates the de-

gree for either weight correction or ΔF correction in each condition. The weight or ΔF correction factor enables the engineer to determine the bhp from the NMPP fuel chart for a specific airspeed, even though the performance of the aircraft and engines is not the same as that which is charted.

Use of Weight Correction Factor

To find the bhp for cruise 2 by using weight correction, you must determine what the approximate average gross weight is for cruise 2. This is determined by using the ending weight of cruise 1, minus one-half of the fuel in cruise 1.

Enter the appropriate NMPP chart with this weight to find an airspeed that gives the desired angle of attack. Then to apply the weight correction factor, add a plus (+) correction or subtract a minus (-) correction from the average gross weight to obtain a performance weight.

Use of Delta F Correction Factor

You have seen how the weight correction factor can be used to determine the power for cruise 2; now let us use the more simplified ΔF bhp correction for the same cruise. In applying the ΔF factor for replanning, you must first determine the average gross weight for the condition just as you did when you used weight correction.

At the time selected to terminate the cruise being analyzed, set up the cruise power that was computed with the ΔF correction, but do not enter this new bhp or its settings on the flight log at this time. Allow the aircraft to stabilize with the new power to see if the aircraft is flying at its proper airspeed. If it doesn't fly at the proper speed, further adjustment is needed.

FINAL ANALYSIS

On the reverse of the flight log a section is devoted to REMARKS, where you may record the analysis of the mission. This analysis is a comparison of the flight engineer's log with the predicted flight plan. The results indicate both the degree of engine and aircraft efficiency and the proficiency of the crew. Average NMPP values for the entire mission are used in this comparison in much the same manner as was done in cruise analysis. Values used for this comparison are *average charted*, *actual average air*, and *actual average ground NMPP*.

Average Charted NMPP

Average charted NMPP indicates how the aircraft and engines should perform during the mission according to the charts used to complete the predicted flight plan. Obtain the average charted NMPP by dividing the predicted ground distance to be flown by the predicted fuel to be used to cover the distance (total fuel used less fuel used for warmup, taxi, takeoff, and landing and taxi).

$$\text{Average charted NMPP} = \frac{\text{Predicted ground distance}}{\text{Predicted fuel}}$$

Actual Average Air NMPP

Actual average air NMPP indicates how the aircraft and engines actually performed according to data recorded on the flight log. Obtain the actual average air NMPP by dividing the air miles flown by the actual amount of fuel used to cover the distance (total fuel used less fuel used for warm-up, taxi, and takeoff, and for landing and taxi).

$$\text{Average air NMPP} = \frac{\text{Air miles flown}}{\text{Actual fuel used}}$$

Average Ground NMPP

Actual ground NMPP is computed from data recorded on the flight log and indicates how the aircraft and engines actually performed in the winds encountered in flight. Obtain the actual ground NMPP by dividing the ground NM flown by the fuel used to cover the distance (total fuel used less fuel for warmup, taxi, and takeoff, and for landing and taxi).

$$\text{Average ground NMPP} = \frac{\text{Ground miles flown}}{\text{Actual fuel used}}$$

Comparison of NMPP Values

The comparison of these NMPP values indicates variations in performance for the entire mission. A comparison of the actual average air NMPP value to the average charted NMPP indicates the loss or gain in NMPP caused by various characteristics of aircraft and engine performance. When the actual air NMPP is less than that which had been charted, there is a performance loss. When the air NMPP is greater than that which had been charted, there is a gain in performance.

A comparison of the actual average ground NMPP to the actual average air NMPP indicates the loss or gain in NMPP caused by winds. When

ground NMPP is less than air NMPP, a performance loss is indicated. When ground NMPP is greater than air NMPP, a performance gain is indicated. A net loss or gain in NMPP can be determined either by comparing the actual average ground NMPP to the average charted NMPP, or by adding algebraically the loss or gain caused by aircraft and engine performance and by winds.

A properly computed flight log, when accurately filled out, is an asset to any organization. When filed, it becomes a running history of that particular aircraft's performance for use by both aircrew and maintenance personnel. For aircrew personnel, it serves as a guide for planning future missions; for maintenance personnel, it provides background information for effective troubleshooting.

PILOT-ENGINEER TEAM

There are many aerodynamic factors that affect aircraft performance which are controllable only by close coordination between the pilot and the flight engineer. If coordination between these two men is lost or ineffective, economy of operation is lost and performance is low. This can be illustrated in a cruise condition where bhp, pressure altitude, and EAS are constant. For instance, let us assume that the engineer has planned and established a bhp and EAS for this particular gross weight. As fuel is burned off in the cruise, gross weight decreases, causing the aircraft to climb. Because the pilot is interested in maintaining a constant pressure altitude, he (improperly) changes the angle of attack with the trim tab control to hold straight and level flight at cruising altitude. This is where the pilot and the engineer start "pulling in opposite directions." The engineer is expecting an increase in EAS which would

normally permit him to reduce power and increase his average NMPP and still maintain the recommended cruising EAS. But, because the angle of attack was changed with the trim tabs, lift was reduced but only at the expense of increased drag. As a result, the normal bhp gain was used to overcome the drag induced by the trim tabs.

The proper method to establish cruise with a constant altitude and EAS is to make frequent small power reductions when the aircraft tends to climb. The reduction in power causes the airspeed to decrease slightly. To control airspeed, the pilot should then reduce the angle of attack by use of the elevator control. The reduced angle of attack reduces drag, which allows the airspeed to increase to its original value. At the same time, the Coefficient of Lift (C_L) has decreased to create just enough lift to equal the new gross weight so that altitude remains constant.

If this procedure is followed closely, the altitude and airspeed changes are so slight that they appear to be constant. However, from a fatigue standpoint, you cannot ask the pilot to fly the aircraft manually throughout the entire mission. For this reason, most cruises are flown by the automatic pilot. Since the autopilot uses trim instead of elevator control to maintain constant altitude, you are not able to control altitude by making power reductions. Therefore, to obtain a fair NMPP value for the mission, you must periodically ask the pilot to release the autopilot and remove all trim induced (thereby removing drag) so you can make your power reductions.

A flight engineer's success in obtaining the maximum economy for any type of cruise depends on a harmonious crew relationship, on an understanding of the aerodynamic forces acting on an aircraft, and on a knowledge as to how they are created and controlled.

BY ORDER OF THE SECRETARY OF THE AIR FORCE

OFFICIAL

JOHN F. RASH, *Colonel, USAF*
Director of Administration

J. P. McCONNELL, *General, USAF*
Chief of Staff

Summary of Revised and Added Material

Adds the performance of turbine engine aircraft to that of reciprocating and turboprop aircraft and develops fully the use of the Aircraft Performance Log Plan (AF Form 796) which was developed specifically for this revision. Changes in Chapters 1 through 8 reflect performance data for aircraft currently in the Air Force inventory. Chapters 9 and 10 update the training to include problems relating specifically to the C-141A aircraft and generally to other turbine engine cargo aircraft.