Air navigation aids, in the very high frequency (VHF) band, are found in the band of 108.1 – 117.9 mc.

(a) 108.1 – 111.9 megacycles (mc). – ILS localizer with simultaneous radiotelephone channel transmits on odd-tenth decimal frequencies (108.1 – 108.3, etc.).

(b) 108.2 – 111.8 mc. – VOR stations transmit on even-tenth decimal frequencies (108.2, 108.4, etc.). Terminal VOR stations.

(c) 112.0 – 117.9 mc. Airway track guidance frequencies.

(d) Frequencies from 118.0 – 135.9 are generally used for voice communications. Figure 6-1 graphically displays these and other frequency bands.

Frequencies Used for Navigation and Voice Communications

The pilot will find that all Instrument Landing System (ILS) localizers transmit in the frequency band of 108 mc to 112.0 mc., i.e. – 108.1 mc., 109.3 mc., 110.5 mc., etc. When the localizer frequency is selected (tuned), the glide slope is also automatically selected on most newer sets.

VOR's transmit in the band 108 to 117.9 mc.; however, in that portion where the ILS operates between 108 to 112 mc., VOR's will transmit only on even-tenths (108.2, 108.6, 109.8, etc.). In the VHF band, *all tenths* between whole numbers are used for frequencies.

The ARTCC communicates generally in the frequency range of 118.0 to 135.9 mc. Since frequencies are established for each one-tenth of a whole number, and sometimes in hundredths, it is obvious there are at least 179 different frequency possibilities within this band. With the high density of air traffic and the speed of modern planes, instrument flying should not be undertaken without a radio that has a respectable frequency coverage. A radio with at least 90 different frequency selections is usually considered desirable.

The radio compass frequency band is from 100 to 1750 kilocycles. The facilities that can be received within this band are L/MF range stations, commercial broadcast stations and nondirectional ________.	
The frequencies of each of these facilities are listed on navigation charts. Additionally, all current commercial broadcasting stations are contained in the Jeppesen ________.	*beacons*
The VOR frequency band is from 108 to 117.9 mc. ILS is received on the VOR receiver on odd tenths from ________ to 111.8.	*J-AID*
Terminal VOR navigation stations transmit on even tenth frequencies from ________ to 111.8.	*108.1*
The VHF frequency band from 118.0 to 135.9 is used for ________ communications.	*108.2*
VHF voice communications on frequencies from 118.0 to 135.9 are used by towers, ground control facilities, ATC and Flight ________ ________.	*voice*
The common VHF emergency frequency is 121.5 mc; all other VHF voice communication frequencies are in the ________ to ________ frequency band.	*Service Stations*

The VHF emergency frequency is ______ mc.	*118.0* *135.9*
	121.5

Common Frequencies Used in the United States

The following frequencies are those considered by the FAA to be the most generally available and are listed in preferential order:

121.5 mc —Emergency (World Wide)
*122.1 mc G—Guarded by Flight Service Stations
*122.5 mc G—Guarded by most FAA towers
122.8 mc —UNICOM (airports without towers)—Indicated on Charts and Airman's Guide by "U"
122.9 mc —Aeronautical Multicom Stations for Private Aircraft
122.7 mc —Some FAA towers
122.6 mc —Some FAA towers
121.7 mc —Tower Ground Control
121.9 mc —Tower Ground Control
123.0 mc —UNICOM (airports with towers) pointed out by most charting services and Airman's Guide Publications.
122.4 mc —A few FAA towers
126.7 mc —Flight Service Stations
135.9 mc —Flight Service Stations and when seeking advisories at fields without towers

The pilot must remember when planning a flight, *that it is his responsibility* to ascertain the frequencies required for a particular route and make certain his radio will handle them.

When making a call to a facility, the pilot should give his complete identification, tell the person contacted what he wants and indicate the frequency on which he will receive, if other than normal.

Information on the frequencies required to contact a specific facility, or tower, is included in the communications listing on Jeppesen Avigation Charts and is listed in the Airman's Guide.

If a pilot is departing or arriving and is unfamiliar with an airport, it is to his advantage to inform the control tower of this fact and he will be accorded special handling while at the facility. (Experienced pilots usually follow this procedure.) When asking for assistance, be sure to give the complete identification and location.

Communications Check

Radio operators have a number system that is used to determine the strength and readability of radio transmissions. The numbers run from 1 to 5. The carrier signal strength is represented by a range of 1 to 5 and the modulation is represented by a range from 1 to 5. On a communications check, if the following is received: "I read you 5 by 5", it would mean the carrier is excellent in strength and the modulation readability is excellent. A reading of 3 by 3 would mean that both carrier signal and modulation were becoming marginal. A reading of 1 by 5 would be extremely weak but with excellent readability. On the other hand, a reading of 5 by 1 would be loud (strong carrier signal) but extremely poor modulation. Remember in these checks, the carrier signal number is given first and the modulation

*When a frequency is followed by a "G", this means the facility can receive only on this frequency and will transmit on some other frequency—122.5 G (Receive Only). If there is a "T" after this frequency, this means the facility transmits only and cannot receive on the frequency. *When there is no designation, the frequency is a two-way frequency.* (A legend explanation is contained at the top of the Communications Listing on all Jeppesen Enroute Avigation Charts.)

is second. These numbers, used properly, can tell the pilot very simply how he is being received or could be used to indicate how he is receiving someone else.

In general aviation, the words used to describe excellent radio reception are, "loud and clear". If the modulation is poor, the words "loud but garbled" would be used. If the carrier signal is poor, the words "weak but clear" would be utilized.

Radio operators have a number system that is used to determine the strength and readability of radio ____________.	
The number system has a range from 1 to ____________.	*transmissions*
In the number system, carrier ____________ is given first.	*5*
If both strength and readability of a transmission are excellent, and one asks, "how do you read", the reply would be "5 by ____".	*strength*
If one receives a transmission that is very weak but clear and is asked, "how do you read", the reply would be "________ by 5".	*5*
For a transmission that is strong but unreadable, the number code would be "________ by ________".	*1*
Many pilots prefer to use "loud and clear", "weak but clear", or if a transmission is loud but unreadable; "loud but ________".	*5* *1*
	garbled

PROCEDURES

Procedure Words and Phrases

Word or Phrase	**Meaning**
ACKNOWLEDGE	"Let me know that you have received and understood this message".
AFFIRMATIVE	"YES"
CORRECTION	"An error has been made in this transmission, the correct version is...".
GO AHEAD	"Proceed with your message".
HOW DO YOU HEAR ME	Self-explanatory
I SAY AGAIN	Self-explanatory
NEGATIVE	"That is not correct".
OUT	"This conversation is ended and no response is expected".
OVER	"My transmission is ended and I expect a response from you".
READ BACK	"Repeat all of this message back to me".
ROGER	"I have received all of your last transmission". (To acknowledge receipt shall not be used for other purposes.)
SAY AGAIN	Self-explanatory
SPEAK SLOWER	Self-explanatory

STAND BY	"If used by itself means I must pause for a few seconds! If the pause is longer than a few seconds, or if 'stand by' is used to prevent another station from transmitting, it must be followed by the ending 'out' ".
THAT IS CORRECT	Self-explanatory
VERIFY	"Check with Originator".
WORDS TWICE	(a) As a Request: "Communication is difficult, please say every phrase twice." (b) As Information: "Since communicatic.. is difficult, every phrase in this message will be spoken twice."

Write and *say* tne word to be used to determine if a transmission has been received and understood. ____________	
Write and *say* the word to be used to make a "yes" reply. ____________	*acknowledge*
If a pilot had been contacted by an agency and was ready for the agency to proceed with their message, he would acknowledge the call and add ____________.	*affiirmative*
Write and *say* the phrase to be used to find out how one's own transmitter is working. ____________	*go ahead*
Write and *say* the phrase to be used if a pilot was going to repeat a transmission. ____________	*how do you hear me*
Write and *say* the word for "no". ____________	*I say again*
Write and *say* the word used to terminate a conversation. ____________	*negative*
Write and *say* the word to be used to indicate that a reply to a transmission is expected. ____________	*out*
Write and *say* the words requesting a message to be repeated. ____________	*over*
Write and *say* the phrase used if a reply to a transmission will be delayed. ____________	*say again*
	stand by

Verbal Statement of Figures

Figures indicating hundreds and thousands in round numbers, as for ceiling heights, flight altitudes and upper wind levels up to 9,000′, shall be spoken in accordance with the following examples:

Examples:	500	Five Hundred
	1,300	One Thousand Three Hundred
	4,500	Four Thousand Five Hundred
	9,000	Niner Thousand

Numbers above 9,000 shall be spoken by separating the digits preceding the word *thousand.*

Examples:	10,000	One Zero Thousand
	13,000	One Three Thousand
	18,500	One Eight Thousand Five Hundred
	27,000	Two Seven Thousand

All other numbers shall be transmitted by pronouncing each digit.

Examples:	10	One Zero
	75	Seven Five
	583	Five Eight Three
	1,850	One Eight Five Zero
	18,143	One Eight One Four Three
	26,075	Two Six Zero Seven Five

The digit "9" shall be spoken "niner". When a number contains a decimal point, the decimal is spoken as "point".

Examples:	122.1	One Two Two Point One
	126.7	One Two Six Point Seven

Write and *say* the proper form for 500 feet.

Five Hundred

Write and *say* the proper form for 1,600 feet.

One Thousand Six Hundred

Write and *say* the proper form for 9,000 feet.

Niner Thousand

Write and *say* the proper form for 10,000 feet.

One Zero Thousand

Write and *say* the proper form for 14,000 feet.

One Four Thousand

Write and *say* the proper form for 15,500 feet.

One Five Thousand Five Hundred

Write and *say* the proper form for 10.

One Zero

Write and *say* the proper form for 583.

Five Eight Three

Statement of Time

The 24-hour clock system is used in radiotelephone transmissions. The hour is indicated by the first two figures and the minutes by the last two figures.

Examples:	0010	Zero Zero One Zero
	0935	Zero Niner Three Five

Time may be stated in minutes only (two figures) in radiotelephone communications when no misunderstanding is likely to occur.

Current time at a station shall be stated in the nearest quarter minute, in order that pilots may use this information for time checks. Fractions of a quarter minute less than eight seconds shall be stated as the preceding quarter minute; fractions of a quarter minute of eight seconds or more shall be stated as the succeeding quarter minute.

Examples:		
	9:29:05 AM	Time, Zero Niner Two Niner
	9:29:10 AM	Time, Zero Niner Two Niner and One Quarter
	9:29:28 AM	Time, Zero Niner Two Niner and One-Half

Use of Greenwich Mean Time

The Federal Aviation Agency utilizes Greenwich Mean Time (GMT or "ZULU") for all operational purposes. Pilots are encouraged to use GMT for aeronautical operational purposes; however, FAA facilities will accept local time if the pilot so desires.

To Convert From:	To Greenwich Mean Time
Eastern Standard Time Eastern Daylight Time	Add 5 Hours Add 4 Hours
Central Standard Time Central Daylight Time	Add 6 Hours Add 5 Hours
Mountain Standard Time Mountain Daylight Time	Add 7 Hours Add 6 Hours
Pacific Standard Time Pacific Daylight Time	Add 8 Hours Add 7 Hours

Aviation uses the 24-hour clock, 1:00 AM is 0100, 6:00 AM is ____________.	
Twelve-thirty in the afternoon, using the 24-hour clock, is 1230, 1:30 is ____________.	*0600*
6:00 PM on the 24-hour clock is ____________.	*1330*
Time may be stated in minutes only if no confusion will exist. For example; If a pilot gave a position report at 1040 and the ETA at the next reporting point was 1110, he could state ETA as One Zero. If he reported at 1120 and the ETA was 1205, he could state ETA as ____________.	*1800*
Current station time given to a pilot is given to the nearest quarter minute. 1032:15 would be given to the pilot as One Zero Three Two and One-Quarter. 1032:40 would be given as One Zero Three Two and ____________ ____________.	*Zero Five*
To convert Eastern Standard Time to Greenwich Mean Time add 5 hours. 1300 EST is ____________ GMT.	*Three Quarters*
1000 EST is ____________ GMT.	*1800*

To convert Central Standard Time to Greenwich Mean Time, add 6 hours. To convert Mountain Standard Time to Greenwich Mean Time, add ____________ hours.	*1500*
0600 CST is ____________ GMT.	*7*
	1200

Loss of Communication Procedures

It is obviously impossible to provide regulations applicable to every type of communications problem which might arise. For this reason, pilots are given authority to take action appropriate to the emergency at hand, even though that action might be in violation of regulation. However, a pilot who takes action which deviates from regulation must be prepared to explain his action to authorities. In all emergency situations, pilots are expected to exercise good judgement in whatever action that may be taken.

In order that pilot action may be anticipated by Air Traffic Control authorities, definite procedures applicable to many different types of emergencies have been clearly defined. Pilots who are operating under IFR clearances shall conform with the following procedures when possible.

Any pilot experiencing radio communications failure should listen on any operational radio receiver, since controllers have the capability of transmitting on many navigation facilities in addition to command radio transmitters.

Two-way Radio Communication Failure in VFR Conditions (Instrument Clearance)

If radio communication failure is experienced in VFR conditions, the pilot is expected to remain in VFR conditions, land as soon as practicable and advice ATC of his action. This regulation is not to be construed to mean that the pilot must land as soon as *possible,* but is to mean that the pilot still retains his decision-making prerogative and is to use his judgment in the matter. To conduct an extended flight with no communication capability would be a violation of this rule, however, this rule is not intended to compel the pilot to land at an unauthorized or unsuitable airport, or an airport slightly short of destination.

Pilots are given authority to take any action deemed necessary in an ____________ situation.	
In all emergency situations, pilots are expected to use good ____________.	*emergency*
Authorities have prescribed definite procedures to be followed in the event of communications failure in order that ATC may be able to anticipate pilot action in an ____________.	*judgment*
Pilots experiencing radio communications failure should listen on any operational receiver because controllers have the capability of ____________ on many navigational radio facilities.	*emergency*
In the event radio failure is experienced in VFR conditions, the pilot is expected to remain in ____________ conditions.	*transmitting*
Extended IFR flight in VFR conditions (is) (is not) ____________ a violation of regulation.	*VFR*

If a pilot under an IFR clearance loses radio communication capability in VFR conditions, he should land as soon as it is ______.	*is*
	practicable

Two-way Radio Communication Failure in IFR Conditions

When operating in IFR conditions or when it is impossible to descend and land in VFR conditions, the pilot will comply with the following procedures.

Enroute Procedures

When cleared to the destination airport or destination fix, proceed in compliance with the last ATC clearance received to the navigational aid to be used for the approach. If cleared to a fix short of the destination fix, *do not hold* but proceed to the destination fix via the route specified in the ATC clearance. If no route is specified beyond the clearance limit, proceed to the destination approach fix via the flight planned route.

If given a clearance limit short of the destination with holding instructions and an *expected further clearance time,* hold until the specified time, then proceed to the destination approach fix in accordance with the above paragraph. If given holding instructions for a fix short of the destination approach fix with an *expected approach clearance time,* depart the holding fix so as to be over the destination approach fix as nearly as possible to the time specified, proceeding in accordance with the above paragraph.

If given holding instructions at a fix short of the destination on a different route than requested, ATC will specify a proposed routing which should be followed in lieu of the flight planned route.

If cleared via vector to a fix, radial or airway, proceed via the most direct route possible to the fix, radial or airway and then in accordance with the procedures outlined above. If a flight is taken off the specified route via a vector, the flight should proceed back to the specified route via the most direct route possible and then in accordance with the procedures outlined above.

When a pilot operating IFR has received clearance to the destination airport or fix, he should proceed via the last ATC ______ received.	
If cleared to a fix short of the destination, the pilot (should) (should not) ______ hold, but should proceed to the destination via the route specified in the ATC clearance.	*clearance*
If no route to the destination has been specified, the pilot should proceed to the destination approach fix via the ______ route.	*should not*
If a pilot is given a clearance limit short of the destination with holding instructions and an expected further clearance time, he should hold until the specified time, then proceed to the ______ approach fix in accordance with approved lost communication procedures.	*flight planned*

If a pilot in the holding pattern is given an expected approach clearance time, he should depart the holding fix so as to be over the approach fix as nearly as possible to the expected ____________ ________________ time.	*destination*
If a pilot is cleared to a fix, radial or airway via a vector, he should proceed to the fix, radial or airway by the most direct route possible and then proceed in accordance with approved lost ________________ procedures.	*approach clearance*
a pilot is taken off the specified route via vector, he should proceed back to the specified ________________ by the most direct route and then proceed in accordance with approved lost communication procedures.	*communication*
	route

Altitude Procedures

In the event of radio communication failure, the flight should be continued at the highest of the following altitudes:

(a) The altitude/flight level assigned in the last ATC clearance.
(b) The minimum enroute altitude (MEA).
(c) The lowest cardinal altitude/flight level at or above the MEA of the highest *planned* route structure. (Cardinal altitudes are thousand foot levels: i.e., 22,000, 23,000, etc.) If a climb is mandatory because of this rule, the climb shall be started 10 minutes after passing the first compulsory reporting point over which radio failure prevented communication with ATC.

Approach Procedures

A descent from the enroute altitude/flight level at the destination approach fix shall be commenced at the latest of the following times:

(a) The expected approach clearance time, if received.
(b) The estimated time of arrival indicated on the flight plan, or as amended with ATC.
(c) The actual time of arrival over the facility.

Holding

If it becomes necessary to hold over the approach fix at the destination, the holding and descent to the initial altitude for the approach should be accomplished on the side of the final approach course on which the procedure turn is prescribed.

Should a pilot lose radio communication, he should proceed at the highest of the following altitudes:

(a) the last assigned altitude/flight level
(b) the minimum ________________ altitude
(c) the lowest cardinal altitude/flight level at or above the highest ________________ route structure.

If a pilot has been assigned to a lower route structure than planned, he shall maintain the assigned altitude/flight level or MEA, which ever is higher, until ______________ minutes after passing the first compulsory reporting point over which radio failure prevented communication with ATC.	*enroute* *planned*
Descent from altitude to the approach fix shall be started at the latest of the following times: (a) the expected approach clearance time (b) the actual time of arrival over the facility (c) the estimated time of arrival as indicated on the ______________ ______________, or as amended with ______________.	*10*
Holding over the approach fix is accomplished on the same side as the procedure ______________.	*flight plan* *ATC*
	turn

AIRPORT TRAFFIC CONTROL

Information and instructions issued by an airport control tower are to assist the pilot in avoiding collisions and other dangerous situations. It is important to remember that instructions issued by a tower are permissive in nature and do not relieve the pilot of the responsibility of avoiding hazardous situations.

It must be borne in mind that the pilot has the authority to ask for a change in clearance in any case where he believes another course of action would provide a greater margin of safety or when it is impossible to comply with instructions received.

When utilizing airports equipped with operating control towers, pilots must obtain clearance to taxi onto a runway, to takeoff and to land. The receipt of a clearance to taxi to a runway constitutes authorization to cross runways that might intercept the taxi route unless specific instructions to the contrary are received. Clearance to a runway *does not* constitute authorization to taxi onto the runway.

Takeoff Restrictions

Air carrier or commercial aircraft carrying passengers or operating for compensation or hire shall not be cleared for takeoff under the following conditions: (1) when the runway visual range (RVR) for the departure runway is less than 2,000 feet, or (2) if the RVR is not available, when the visibility for the departure runway is less than one quarter mile, or (3) if neither RVR or runway visibility are available, when the field visibility is less than one quarter mile. When the aircraft is not carrying passengers or cargo for hire, the above restrictions do not apply.

Information issued by a control tower is provided to assist ______.	
Control tower instructions are permissive in nature. Pilots are responsible for avoiding accidents on the ______.	*pilots*
The pilot always has the prerogative of requesting a change in ______.	*ground (airport)*
When operating at a controlled airport, pilots must have a clearance before landing, taking off or taxiing onto the active ______.	*clearance*
Clearance to a runway (does) (does not) ______ constitute clearance to taxi onto the active runway.	*runway*
In order for an air carrier aircraft carrying passengers to be cleared for takeoff, the RVR must be ______ feet or more.	*does not*
When the RVR is not available, an air carrier aircraft carrying passengers, may be cleared for takeoff when the runway visibility is ______ ______ mile or more.	*2,000*
	one quarter

Departure

Prior to departure, pilots are required to be familiar with established departure procedures and shall comply with such procedures upon departure unless specifically cleared otherwise by the controlling authority.

Standard Instrument Departures (SID's)

SID's are utilized at high density airports for frequently used departure routes to simplify clearance delivery and expediate traffic. They provide the pilot with detailed departure routes in graphic and narrative or just narrative presentation. SID's will be used in cases considered appropriate by ATC when air carrier aircraft on IFR flight plans are concerned. In the case of civil aircraft other than air carrier, SID's will only be used in connection with an IFR flight plan and when so requested by the pilot.

Radar Departures

Departing aircraft, under most conditions will utilize radio navigation facilities. However, when deviation from established routes is necessary to provide for separation or to avoid weather, radar guidance will be provided until the aircraft is established on course and is receiving the appropriate navigation facility. If the pilot of an aircraft under radar control experiences two-way radio failure, the flight should be continued as cleared by ATC prior to the failure.

Pilots are required to be familiar with established departure ________.	
Standard Instrument Departures aid in clearance delivery and expediting ________.	*procedures*
SID's are used at high density airports for frequently used departure ________.	*traffic*
An air carrier pilot may expect a SID clearance when he is operating on an ________ flight plan.	*routes*
The pilot signifies that he is familiar with the pertinent SID when it is requested on the ________ ________.	*IFR*
Radar departures are used when deviation from established routes is necessary for traffic separation or for avoidance of adverse ________.	*flight plan*
When a radar departure is utilized, guidance will be provided until the aircraft is receiving the appropriate navigational ________.	*weather*
If a pilot experiences radio failure while under radar control, he should continue the flight as cleared by ________	*facility* *(radio)*
	ATC

ENROUTE

Reporting Procedures

Pilots who are operating under an IFR clearance are required to maintain a continuous listening watch on communication channels appropriate to the route being flown. They are also required to furnish position reports at various reporting points along the route of flight as specified by ATC.

Compulsory reporting points are shown on airway charts as a solid triangle (▲). All of these points must be reported except when a non-compulsory indicator "NR ►" is shown adjacent to the airway. This symbol is used on Coast and Geodetic Survey charts and indicates that a report is not required at the next charted compulsory reporting point if the flight is proceeding in the direction of the arrow. On Jeppesen Charts, the symbol ╱▲╲ indicates that a position report is not required at the fix if the flight is continuing on through the fix. In the case of both symbols explained above, the fix must be reported if so requested by ATC.

"On request" reporting points are designated by an open triangle (△) on airway charts and are not compulsory unless so designated by ATC. The pilot may be requested to report reaching an "on request" point or any other fix along his route of flight.

All position reports should be made as soon as possible after passing the reporting point. However, regardless of when the report is made, the time reported to ATC will be the actual time over the reporting point.

Each IFR position report shall include the following information.

REQUIRED PORTION OF REPORT	EXAMPLE
Identification (state if jet)	"Skyways one one four
Position	over Oakhill
Time	at one eight
Altitude (also required for VFR on-top flight plans when operating at flight level 240 or above)	niner thousand
Type of flight plan (not required if report is given to ARTCC or Approach Control)	instrument flight plan
Name and estimated time of arrival (ETA) over next reporting point	Jasper one seven four five
Name of next succeeding reporting point	Maulden".

Pilots operating on an instrument clearance must maintain a continuous listening watch on the appropriate enroute ________.	
Compulsory reporting points are designated by a solid ________.	*frequency*
The symbol "NR ►" on Coast and Geodetic Survey charts, indicates that a position report is not required for the next charted compulsory reporting point in the direction of the ________.	*triangle*
The symbol on Jeppesen charts indicating that a position report is not required if the flight is continuing through the fix is shown on charts as "________".	*arrow*
Open triangles are used to designate "________ ________" reporting points.	╱▲╲
ATC may request a pilot to report at any fix along the route of ________.	*on request*
The time given ATC in the voice report will be the actual time over the ________.	*flight*
The first portion of a position report concerns the identification of the flight. In this part of the report, the pilot must so state if he is in a ________ airplane.	*fix*

The fourth item in sequence given in a position report after identification, position and time is the altitude. This is required on VFR on-top flight plans only when operating at or above flight level ____ ______________.	*jet*
The next item in a position report is the type of flight plan under which the flight is being conducted. This portion of the report is not required if the report is being given directly to an __________________ or approach control.	*240*
	ARTCC

Other compulsory voice reports to the controlling agency are as indicated below:

1. At any time it is apparent that a previously reported ETA will be in error by more than three minutes.
2. At any time the average true airspeed (TAS) at cruising altitude varies by ten knots from the TAS given in the flight plan.
3. When leaving a previously assigned altitude/flight level for a newly assigned altitude/flight level.
4. The time and altitude/flight level upon entering a holding pattern or reaching a point to which cleared.
5. When initiating a missed approach.
6. When leaving a previously assigned fix.
7. When leaving the approach fix inbound on final approach.
8. When encountering unforecast weather conditions. Pilots are encouraged to report at the time they encounter unforecast weather. However, regulations make the report mandatory no later than the end of the next position report given after the weather is encountered.

An amended report must be given ATC when it is apparent that an ETA will be in error by more than ________________________________.	
ATC must be notified when the actual true airspeed varies from the planned true airspeed by ________________ knots or more.	*three minutes*
ATC must be advised when a flight is leaving an altitude/flight level, when leaving a previously assigned fix or, when leaving a fix inbound on final ___________________.	*ten*
A report is mandatory when a flight has entered a holding pattern, reached a clearance limit or initiated a missed __________________.	*approach*
A report must be given ATC when a pilot encounters weather conditions that have not been ______________________.	*approach*

The report concerning unforecast weather conditions must be forwarded to ATC no later than the end of the next position report after encountering the unforecast __________.	*forecast*
	weather

Airway Systems

There are two air navigation route systems established in the United States. Both systems utilize the VHF omni range (VOR) as the primary system of navigation, but each covers a different altitude range.

Each *Federal Airway* within the continental United States includes the air-space extending upward from 700 feet (in some cases 1,200 feet) above the surface of the earth to but not including 18,000 feet MSL. This airway system is designed for short and medium haul aircraft.

Each *jet route* extends from 18,000 feet MSL to and including flight level 450. This system is designed for long haul aircraft.

The two airway structures in the United States utilize the VHF __________ __________ as the primary navigational aid.	
Federal airways within the continental United States extend upward from __________ feet (in some cases 1,200 feet) above the surface to but not including __________ feet MSL.	*omni range*
Jet routes extend from __________ feet MSL to and including flight level __________.	*700* *18,000*
The jet route system is geared to __________ haul aircraft.	*18,000* *450*
	long

Climbing and Descending

To facilitate traffic control, pilots on instrument flight plans are requested to adhere to special aircraft climbing and descending procedures. Unless cleared otherwise by ATC, aircraft should climb as rapidly as practicable to 1,000 feet below the newly assigned altitude then transition to a 500 foot per minute rate of climb until reaching the assigned altitude. Likewise, when descending, the descent should be made as rapidly as practicable to 1,000 feet above the newly assigned altitude then a transition made up to a 500 foot per minute rate of descent until reaching the assigned altitude.

When an aircraft is cleared for a descent, the pilot should descend as rapidly as practicable to __________ feet above the assigned altitude then transition to a __________ foot per minute rate of descent.	
Traffic will move in a more expeditious manner if, when pilots are cleared for an ascent, they climb as rapidly as practicable to 1,000 feet below the assigned altitude and then transition to a 500 foot per minute rate of __________.	*1,000* *500*

climb

Holding

The holding pattern is a device employed by ATC to aid in the orderly management of air traffic. The terminology and general features of the holding pattern are illustrated in Figure 7-1.

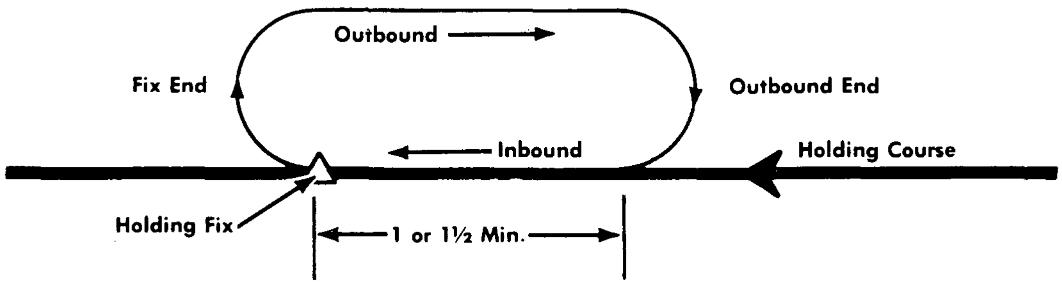


Fig. 7-1—The Holding Pattern

Standard and Nonstandard Holding Patterns

The standard holding pattern consists of right turns and inbound legs that are flown for one minute or less when holding at or below 14,000 feet. When the holding aircraft is above 14,000 feet the inbound legs should be flown for one and one-half minutes or less as shown in Figure 7-1. Upon entry into the holding pattern, the first outbound leg should be flown for one minute or one and one-half minutes as the altitude dictates. However, subsequent outbound legs should be adjusted as necessary to obtain the proper inbound leg time.

The nonstandard holding pattern consists of left turns plus any further changes requested by ATC.

Holding Procedures

An aircraft is considered to be in the holding pattern upon arrival over the holding fix. Thus, pilots are expected to reduce speed to the appropriate maximum holding airspeed or less within three minutes prior to the estimated arrival over the holding fix.

The maximum indicated airspeed for propeller driven aircraft in the holding pattern is 175 knots.

The maximum indicated airspeed for civil turbojet aircraft in the holding pattern up to and including 6,000 feet is 200 knots. The maximum indicated airspeed in the airspace above 6,000 feet up to and including 14,000 feet is 210 knots and when above 14,000 feet is 230 knots.

Pilots will execute all turns while in the holding pattern at a 30° angle of bank (25° if a flight director system is used) or at 3° per second rate of turn, which ever requires the least angle of bank.

If the operating limitations of a particular aircraft preclude compliance with the holding regulations, the pilot is expected to advise ATC in order that adequate separation may be effected.

When holding, a turn toward the outbound leg should be initiated upon receipt of the first positive indication of arrival over the holding fix. For example, when holding at a VOR station, the turn should be commenced upon the first complete reversal of the TO-FROM indicator.

The timing of the outbound leg is begun when the aircraft is abeam the holding fix outbound. If the abeam position cannot be accurately determined, the timing should begin when the fix end turn is completed. Wind effect should be compensated for so as to keep the aircraft on the approximate no-wind track.

A standard holding pattern shall be used unless otherwise advised. ATC will issue a clearance specifying left turns when a nonstandard pattern is to be utilized.

The holding pattern is used by ATC as an aid in the orderly and safe management of air ________.	
The direction of a turn in a nonstandard holding pattern is ________.	*traffic*
When in a standard holding pattern at 9,000 feet, the inbound leg should be flown for ________ minute(s) or less.	*left*
After the initial outbound leg of a holding pattern, the outbound legs are adjusted so as to achieve the proper ________ leg time.	*one*
In a standard holding pattern, all turns should be made to the ________.	*inbound*
When holding at 16,000 feet, the inbound leg should be flown for ________ minutes or less.	*right*
Upon arrival over the holding fix, an aircraft is considered to be in the ________ ________.	*one and one-half*
An aircraft is expected to be at or less than the maximum holding pattern airspeed within ________ minutes prior to the estimated arrival over the holding fix.	*holding pattern*
The maximum indicated holding airspeed for propeller driven aircraft is ________ knots.	*three*
When holding in the airspace from above 6,000 feet up to and including 14,000 feet, civil turbojets must have an indicated airspeed no greater than ________ knots.	*175*
When in the holding pattern, a turn toward the outbound leg should be started at the first indication of arrival over the holding ________.	*210*
While in the holding pattern, the pilot should adjust his heading so as to compensate for any existing ________.	*fix*
Unless otherwise specified in the holding clearance, a ________ holding pattern shall be utilized.	*wind*
	standard

Holding Clearance

Clearance to hold will always include the following instructions:

1. The general area in which to hold in relation to the holding fix. (General areas are specified by using the eight cardinal points of the compass such as north, northeast, east, southeast,

south, etc. This information is provided to prevent the possibility of holding on the wrong side of the fix).

2. The DME leg length when appropriate.
3. The specific radial, course, airway or magnetic bearing on which to hold.
4. The time to expect further clearance or approach clearance. (This information is given to provide for general flight planning and to insure against a misunderstanding between controller and pilot in the event of communication failure).

Example of a holding clearance:

Global four five, hold northeast of Henderson VOR on the zero seven four radial. Expect approach clearance at one seven four five.

When a pilot receives clearance to depart a holding fix, he should shorten the leg length of the holding pattern as necessary so as to depart the fix at the time specified by ATC.

Holding clearance from ATC will include the direction from the fix; DME leg length when appropriate; specific radial, course, airway or magnetic bearing; and the time to expect ____________ ____________.	
It is a good practice to be sure that the *expected further clearance time* is clearly understood, since it will prove useful in the event of a ____________ failure.	*further clearance*
A pilot should always depart a holding fix at the time specified by ATC. This procedure is followed even though it might be necessary to ____________ the holding pattern.	*communication (radio)*
	shorten

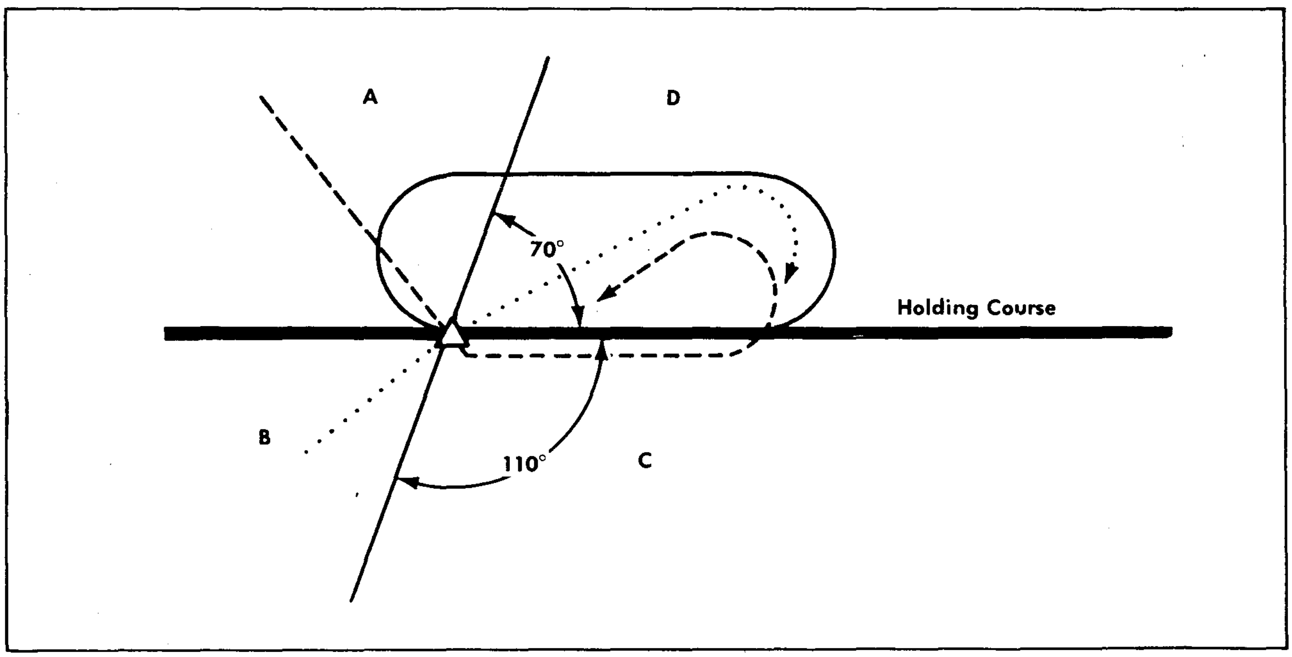


Fig. 7-2—Holding Pattern Entry

Holding Pattern Entry

Recommended procedures for holding pattern entry are illustrated in Figure 7-2. Notice in this Figure, that entry procedures are governed by an imaginary line drawn through the holding fix at a 70° angle to the inbound holding course. Note also that, for the purpose of this discussion, the area around the holding fix has been divided into four sectors—A, B, C and D.

Aircraft entering the pattern from sector "C" or "D" will execute a right turn over the holding fix and continue in the holding pattern. Aircraft entering from sector "A" will parallel the holding course outbound, then execute a left turn so as to return to the fix or intercept the holding course inbound. This procedure is illustrated in Figure 7-2. Aircraft entering from sector "B" will continue through the holding fix on a track of 30° or less to the holding course, then execute a right turn teardrop maneuver to intercept the inbound course as shown in Figure 7-2.

Procedures utilized for entry into the nonstandard holding pattern are oriented to the 70° line on the holding side of the airway just as in the standard entry procedures.

The holding pattern entry procedures are governed by an imaginary line drawn through the holding course at an angle of ________ degrees.	
The recommended procedure for aircraft entering the holding pattern from sectors "C" or "D" (see Figure 7-2) is to execute a ________ turn and continue in the holding pattern.	*70*
It is recommended that aircraft entering from sector "B" continue through the holding fix at an angle to the holding course of 30° or less, then turn right to intercept the ________ ________.	*right*
Aircraft entering from sector "A" should parallel the holding course outbound then turn left to return to the ________ or intercept the holding ________.	*holding course (inbound course)*
If the holding course is 270° as illustrated in Figure 7-2, an aircraft entering the pattern on a course of 030° would make an initial (right) (left) ________ turn.	*fix* *course*
Using Figure 7-2 again, what would be the initial direction of turn for an aircraft entering the pattern on a course of 180°? ________.	*right*
	left

DME Holding

Distance Measuring Equipment (DME) holding involves the same procedures as standard holding except that distance, as read on the DME indicator, is utilized in lieu of time values. VORTAC (or DME in conjunction with VOR) gives the pilot the added advantage of being able to establish a holding fix at a given distance on any specified radial. In the following illustrated DME holding pattern, the fix is 10 miles from the navigational aid, the inbound course is toward the navigation aid and the legs are 7 miles in length.

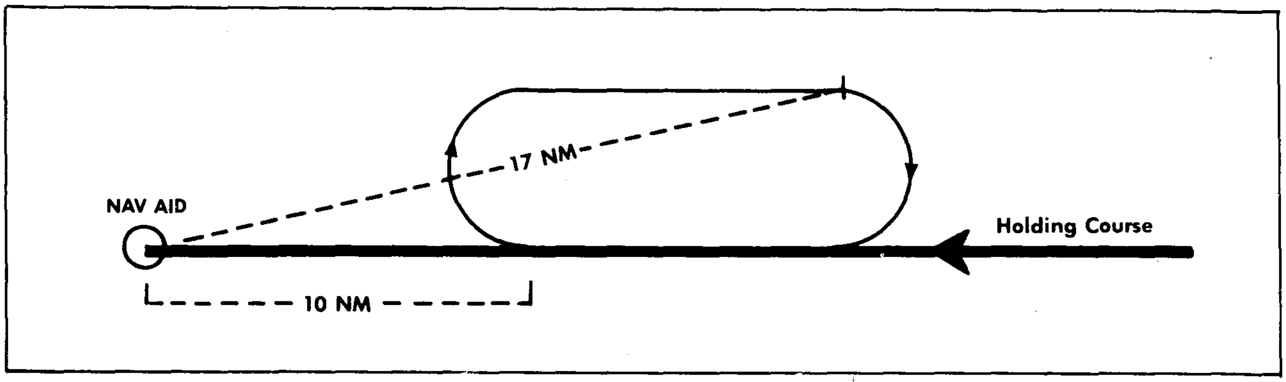


Fig. 7-3 – DME Holding

When DME holding is used, the controlling factor is distance instead of ____________.	
DME allows a holding fix to be established at a given distance on any given ____________.	*time*
If a pilot were actually utilizing the DME holding pattern illustrated in Figure 7-3, the turn to the outbound course would be initiated at ____________ miles.	*radial*
In the situation described in the above frame, the turn to the inbound course would be started at a distance of ____________ miles.	*ten*
	seventeen

Enroute Radar Procedures

Air Route Traffic Control Centers (ARTCC) and many high density air terminals utilize Federal Aviation Agency (FAA) operated radar units to provide for safe, efficient handling of air traffic. Any pilot desiring radar service should contact the appropriate FAA control tower or an ARTCC for initial instructions.

Radar assistance may be provided, at the discretion of the controller, to aircraft on VFR flight plans when such aircraft can be radar identified, are within radar range and can communicate with the radar facility. Pilots are reminded that radar controllers are not always aware of the weather conditions into which they direct aircraft. Therefore, caution should be excercised if the pilot is not fully equipped and qualified for instrument flight.

As IFR air traffic has increased, radar coverage has been greatly expanded. Instrument pilots must be prepared to operate in accordance with radar procedures when on an instrument flight plan.

Radar separation standards vary with the distance from the radar antenna site. When aircraft are within forty miles of the radar antenna site, a minimum of three miles horizontal separation is maintained unless standard non-radar separation exists. When controlled aircraft are more than forty miles from the radar antenna site, a minimum of five miles separation is maintained unless standard non-radar separation exists.

Radar Traffic Information

Radar traffic information is a service provided by radar air traffic control facilities for the purpose of advising pilots of any potentially hazardous situation. This service is provided to aid the pilot, but is not designed to supplant his responsibility to see and avoid other aircraft.

Traffic advisories are routinely provided to IFR traffic unless a pilot advises that he does not desire the service, or the controller discontinues the service due to traffic volume, radio frequency congestion or other limiting factors.

Vectors to avoid traffic may be provided upon the pilot's request to the extent possible as determined by the radar operator. Pilots are reminded that the decision to provide or not to provide traffic information is completely at the discretion of the controller.

Advisory information includes the following information concerning the traffic in question.

COMPONENT	EXAMPLE
Azimuth (oriented to 12 hour clock)	traffic four o'clock
Distance	five miles
Direction of traffic movement	south-bound

A pilot who desires radar service can contact the appropriate FAA ______ ______ or ARTCC for initial instructions.	
Radar service may be extended to VFR flights at the discretion of the ______.	*control tower*
Pilots who are not equipped or qualified for instrument flight should be wary when being directed by radar, since controllers are not always aware of the ______ conditions into which they direct flights.	*controller*
When on an instrument clearance, a pilot should be prepared to operate in accordance with ______ procedures.	*weather*
Unless standard non-radar separation exists, a radar controlled aircraft within 40 miles of the radar antenna site will have a minimum horizontal separation from other aircraft of ______ miles.	*radar*
When standard non-radar separation does not exist between aircraft over forty miles from the radar antenna site, an aircraft separation minimum of ______ miles is maintained.	*three*
Radar Traffic advisory service is designed to provide the pilot with information pertaining to possible ______ situations.	*five*
Even though radar traffic information is available, the pilot is still responsible for seeing and ______ other aircraft.	*hazardous*
The decision as to whether radar advisory service will be provided or not is at the discretion of the ______.	*avoiding*
Radar advisory information will include the azimuth, the distance and the direction of movement of the ______.	*controller*

traffic

The Air Traffic Control Radar Beacon System

The Air Traffic Control Radar Beacon System (ATCRBS) was designed for use by the FAA to provide for radar target reinforcement and rapid aircraft identification. This system is comprised of a ground based interrogator, an airborne transponder and a ground based decoder for deciphering the coded replies from the transponder.

The ground interrogator transmits short bursts of radio energy which activates the transponder in the target aircraft. If the transponder is set to the proper channel, it will receive the signal and transmit a reply. The reply is decoded and displayed on an air traffic control radar scope enabling positive identification of the target aircraft.

The ATCRBS interrogator is capable of interrogating on six different signals referred to as modes. Only mode "A" however, is used by civil aircraft in the United States. The airborne transponder will accept, from the interrogator, only the mode selected in the cockpit. Upon accepting an interrogation, the transponder will transmit a code appropriate to the selection made by the pilot upon the request of the radar controller. Remember that an interrogator transmits on modes and a transponder transmits on codes.

The code numbering system begins with 00 and extends through 77. However, there is a total of only 64 codes in the system because no 8's or 9's are included.

Code utilization is based on a concept designed to minimize code changes required of the pilot and to enable the controller to quickly identify aircraft under his control. Pilots of aircraft equipped with a transponder will be instructed to reply on a specified code which is determined by factors such as altitude/flight level, type of flight plan, altitude transition and position in relation to a terminal area. Code 77 is used in any emergency situation.

The Air Traffic Control Radar Beacon System provides target reinforcement and rapid aircraft ________.	
The components of this system are the ground based interrogator, the decoder and the airborne ________.	*identification*
The decoder is used to decipher the ________ replies from the transponder.	*transponder*
The transponder, if set to the proper channel as directed by ATC, will receive the signal from the interrogator and transmit a coded ________.	*coded*
The reply is displayed on the controller's radar scope, providing for positive aircraft ________.	*reply*
The ground based interrogator is capable of transmitting on ________ modes.	*identification*
Civil aircraft in the United States use only mode "________".	*six*
The airborne transponder transmits on ________.	*A*

There are a total of ______ codes, however, no ______ or ______ are included in the code numbering system.	*codes*
The code on which the pilot is requested to reply is determined by such factors as altitude/flight level, type of flight plan, altitude transition and position in relation to a ______________ area.	*64* *8's* *9's*
	terminal

ARRIVAL

Inbound IFR flights are normally issued clearance for a specific instrument approach by Air Traffic Control. This procedure is designed to minimize radio transmissions and expedite traffic. If a pilot does not desire to execute the specified approach, he may request any other appropriate approach. However, he must be prepared for a delay until traffic conditions permit compliance with his request. The omission of a specific approach in the initial approach clearance indicates to the pilot that he is free to utilize any approved approach.

Any pilot not familiar with a specified approach should advise ATC. In this situation, the clearance will include detailed instructions concerning the execution of the approach.

Traffic sometimes becomes congested in the vicinity of high traffic density terminal areas. Often it is necessary for subsequent arriving aircraft to hold at successively higher altitudes over the terminal fix (or any local fix designated by ATC) while awaiting clearance for an approach. Under these conditions, ATC will provide advance notice to each pilot in the approach sequence as to the time when he can depart the holding fix for an approach to the airport.

To minimize radio transmissions and expedite traffic, ATC will usually issue clearance for a specific ______________ to inbound terminal traffic.	
The pilot is authorized to request any appropriate approach at the destination, however, he must be prepared for a ______________ because of possible crowded traffic conditions.	*approach*
ATC will issue detailed approach instructions if the pilot advises that he is unfamiliar with the specified ______________.	*delay*
When in a holding pattern in the vicinity of a terminal area, ATC will provide advance notice as to when aircraft may depart the ______________ ______________ for an approach.	*approach*
	holding *fix*

An air traffic clearance is an authorization issued by Air Traffic Control (ATC) for an aircraft to proceed under specified conditions within controlled airspace. Clearances provide for separation between aircraft which are operating under Instrument Flight Rules. However, all pilots are responsible for their own separation when flying in VFR conditions regardless of the type of clearance under which they are operating. Since ATC may not have knowledge of VFR flights, positive separation cannot be assured in VFR weather conditions.

The filing of an instrument flight plan indicates that the pilot is qualified and the aircraft is equipped for instrument flight as prescribed by regulation. The receipt of a clearance does not consititue authority for the pilot to violate any Federal Aviation Regulation.

Aircraft Separation

ATC provides aircraft separation laterally by assigning different courses, vertically by assigning different altitudes and longitudinally by providing for a minimum time separation between aircraft on identical courses.

Standard separation will be maintained for all aircraft on IFR clearances except when a "VFR on-top" clearance has been requested by the pilot and authorized by ATC or when a pilot has requested and received clearance to conduct any portion of an IFR flight under Visual Fight Rules.

An air traffic clearance is an authorization issued by ________ ________ ________ (ATC).	
An air traffic clearance authorizes a pilot to fly an airplane under specified conditions within controlled ________.	*Air Traffic Control*
IFR clearances provide separation between only those planes operating under ________ flight plans.	*airspace*
Since ATC may not be aware of VFR air traffic, all pilots are responsible for separation in ________ weather conditions.	*instrument*
When a pilot files an IFR flight plan, he is indicating that he is instrument rated and that his aircraft is equipped for ________ flight.	*VFR*
A clearance in no way authorizes a pilot to violate any Federal Aviation ________.	*instrument*
Separation is maintained between IFR traffic by the assignment of different altitudes, courses, and ________.	*Regulation*
Standard IFR separation will be maintained between all IFR operations except when a "VFR on-top" clearance is in effect or when any portion of an IFR flight is being conducted under ________ ________ Rules.	*times*
	Visual Flight

VFR On-Top Clearance

The "VFR on-top" clearance authorizes the pilot to conduct a flight at an altitude (or flight level) of his own choosing as long as he remains in VFR weather conditions. However, with this type of clearance, the pilot assumes full responsibility for aircraft separation. A "VFR on-top" flight must be conducted in accordance with VFR cruising altitude rules.

A "VFR on-top" clearance is never issued except on the request of the pilot. Even though this type of fligh' plan is associated with VFR weather conditions, it is considered to be an IFR operation. With this type of flight plan, the pilot must request and receive clearance to fly at a specific altitude prior to entering IFR weather conditions.

"VFR on-top" flights are not allowed in Positive Controlled Airspace.

Clearance Terminology

The prefix "ATC clears" always preceeds a *clearance* issued by an Air Route Traffic Control Center (ARTCC). Information or advisory messages originating in an ARTCC are prefixed with "ATC requests" or "ATC advises." This terminology is utilized even though the clearance is relayed through a control tower or other communication station.

Traffic control agencies may use the phrase "via flight planned route" in lieu of lengthy portions of the clearance. This is done only when the clearance is identical to the one filed by the pilot. It should be remembered that the terminology "via flight planned route" does not include authorization for flight at the altitudes requested by the pilot on the flight plan. A specific altitude assignment will be included in each clearance as issued by ATC.

The term "cruise" preceeding an altitude/flight level assignment in a clearance, authorizes the pilot to fly the clearance route, descend at his own discretion and make an approach without further clearance from Air Traffic Control. This type of clearance is usually utilized for short flights and in areas of low air traffic density.

The term "maintain" preceeding an altitude/flight level indicates that the aircraft must remain at the specified altitude/flight level until an amended clearance is received or until leaving controlled airspace.

Being granted a VFR on-top clearance allows the pilot a choice of flight ______________.	
A pilot is responsible for his own separation when operating on a ________ ________-__________ clearance.	*altitudes (levels)*
A VFR on-top clearance is not issued except upon the ______________ of the pilot.	*VFR on-top*
A VFR on-top flight is considered to be an __________ type operation.	*request*
VFR on-top flights are prohibited in Positive Controlled ______________.	*IFR*
A clearance issued by ATC is always preceeded by the phrase "________ ________".	*Airspace*
"ATC requests" or "ATC advises" always preceeds information data or advisory ______________.	*ATC clears*
When a clearance is delivered to a pilot by ATC, the phrase "via flight planned route" is often substituted for portions of the ______________.	*messages*

The phrase "via flight planned route" is only used when the route clearance is identical to the flight plan as submitted by the ____________.	*clearance*
The phrase "via flight planned route" (does) (does not) ________ authorize the pilot to proceed at the flight planned altitude.	*pilot*
The term "cruise" is used in some situations in low density traffic areas. When a pilot is cleared to "cruise" at a given altitude/flight level, he may descend and make an approach at destination without further clearance from ____________.	*does not*
The term "maintain", when used in connection with an altitude/flight level, indicates that the pilot must remain at the given altitude until an ____________ clearance is received, or until leaving ____________ airspace.	*ATC*
	amended *controlled*

Clearance Limits

A clearance limit is the fix to which an aircraft is cleared by ATC. When a clearance limit has been specified in the air traffic clearance, it is the responsibility of ATC to issue an appropriate further clearance prior to the time the aircraft reaches the limit. The pilot may receive clearance to continue on his route of flight or may receive holding instructions. However, if the pilot receives no further clearance by the time the clearance limit is reached, he should request a clearance and enter a standard holding pattern over the limit fix at the last assigned altitude.

Clearance Amendments and Cancellations

A traffic controller may amend a clearance at any time such action becomes necessary to maintain the safe flow of traffic.

A pilot may request an amended clearance at any time he feels a different action would be safer or more practicable. Also, a pilot may cancel an IFR flight plan at any time simply by notifying ATC, however, the aircraft must be in VFR weather conditions at the time of cancellation. If, at any time, it becomes necessary to file a flight plan in flight, the pilot may do so by supplying ATC with pertinent information incident to the type of clearance desired.

A fix to which an aircraft is cleared is referred to as a ____________ ____________.	
It is the responsibility of ATC to provide further clearance to an aircraft after a ____________ ____________ has once been established.	*clearance* *limit*
If a pilot reaches a clearance limit without having received further clearance, he must request a ____________ and enter a ____________ ____________ ____________.	*clearance* *limit*

The standard holding pattern should be entered at the last assigned ____________.	*clearance standard holding pattern*
If holding becomes necessary, the pattern must be over the fix designated as the ____________ ____________.	*altitude*
Traffic controllers may alter a clearance at any time such action would contribute to the safe flow of air ____________.	*clearance limit*
At any time a pilot deems an alternate procedure or method safer or more practicable, he may request an amended ____________.	*traffic*
A pilot may cancel an IFR flight plan any time at which his aircraft is operating in ________ weather conditions.	*clearance*
A pilot may file a flight plan in flight simply by supplying the required data to ________.	*VFR*
	ATC

Complying With The Air Traffic Clearance

After an ATC clearance has been applied for and obtained, no deviation from the clearance is allowed unless an amended clearance is authorized or an emergency situation arises.

When the pilot requests and is granted clearance to conduct any portion of an IFR flight under Visual Flight Rules, he is in no way relieved of the responsibility of adhering to the planned route or other provisions of the clearance.

ATC should be notified at once should it become impossible for a pilot to comply with a clearance. In the event that a pilot must deviate from a clearance in an emergency situation, ATC must be notified of the deviation as soon as possible. If a pilot, in an emergency, is given priority over other traffic he must submit a detailed report of the emergency to the nearest FAA regional office within 48 hours after the emergency.

It is the pilot's responsibility to immediately advise ATC of any malfunctioning navigational radio receiver which might render the pilot incapable of complying with an ATC clearance.

Clearance Delivery

At high density airports, clearances will be obtained on a radio frequency especially reserved for clearance delivery. The appropriate frequency may be found on approach charts or enroute charts.

No deviation from an ATC clearance is permissible unless an amended clearance is authorized or in case of an ____________.	
In some cases, it may be more expeditious to conduct a climb or a descent under Visual Flight Rules even though the flight is an IFR operation. If a pilot is cleared to conduct a portion of an IFR flight under Visual Flight Rules, he is not excused from adhering to the planned ____________.	*emergency*

ATC must be notified at once if it becomes impossible for a pilot to comply with a ________________.	*route*
In an emergency situation in which it is impossible to comply with a clearance, __________ must be notified of the deviation as soon as the situation permits.	*clearance*
If, in an emergency, ATC gives an aircraft priority over other traffic, the pilot concerned must make a report to the nearest FAA regional office within ______ hours.	*ATC*
The pilot must advise ATC of any navigational radio receiver loss which would interfere with compliance with a ____________.	*48*
At many high density airports, a tower frequency is reserved for ________________________.	*clearance*
	clearance delivery

This section is devoted to the general areas of preflight considerations which are not discussed elsewhere in this course.

Instruction in the use of the flight computer was not deemed necessary in this course because of the experience and efficiency level expected of applicants for the Airline Transport Pilot Certificate. However, familiarity with all phases of computer operation is an absolute necessity. The pilot must be knowledgeable in the following areas: Time-speed-distance; fuel consumption; pressure, density and true altitude; indicated, calibrated and true airspeed; Mach number; true heading and course; magnetic heading and course; off course corrections, and wind computations.

Air Compressibility and Friction

With the advent of high speed airplanes, air compressibility and friction became definite factors when computing true airspeed from indicated or calibrated airspeed.

At high speeds, air is compressed in front of an aircraft causing a greater ram air pressure to be exerted on the pitot system. As a result, the airspeed indication is given an erroneous magnification. When calibrated airspeed is corrected for the effects of compressibility, *equivalant airspeed* is the result.

High airspeeds also produce a heating of the airplane skin due to friction. This of course, causes the outside air temperature (OAT) gauge to indicate an erroneously high temperature.

Most modern computers incorporate methods for correcting true airspeed values for errors induced by temperature and friction, however, one or two extra steps are usually necessary for these computations. The Jeppesen CR Computer automatically corrects for these errors, thus avoiding any extra calculations.

The airline transport pilot must be familiar with all phases of computer ______.	
When dealing with the high speed aircraft, compressibility and skin ______ become significant factors.	*operation*
At high speeds, the airspeed indicator will register an erroneously high reading because of increased pressure on the ______ system.	*friction*
Calibrated airspeed corrected for compressibility effect equals ______ airspeed.	*pitot*
Heat is generated on the skin of high speed aircraft due to ______.	*equivalent*
Skin friction produces an erroneously (high) (low) ______ indication on the outside air temperature gauge.	*friction*
Erroneously high instrument indications are produced by friction and ______.	*high*
	compressibility

Fuel Considerations

One of the more important factors incident to flight planning is the calculation of the fuel required for a specific operation. Regulations state that for an IFR flight, the airplane must carry enough fuel to fly to the destination, on to the farthest alternate, and then for an additional 45 minutes at normal cruise fuel consumption. When calculating the estimated fuel consumption, consideration shall be given to forecast wind and weather conditions and any other condition which might extend the flight.

In some instances it may be necessary to calculate estimated fuel requirements in terms of *specific fuel consumption* (SFC). SFC is the amount of engine fuel consumption in pounds per hour per brake horse power (BHP), or per pound of thrust. Fuel flow per engine may be determined by the following equation:

$$\text{fuel flow} = \text{BHP} \times \text{SFC}$$

Assume that a four engine aircraft which is operating at 1800 BHP has a SFC of .295. When these values are inserted in the above equation, the result would be as follows:

$$\text{fuel flow lbs./hr.} = 1800 \times .295 \text{ lbs./BHP/hr.} = 531 \text{ lbs./hr.}$$

Since a four engine aircraft has been used in this example, the fuel flow must be multiplied by four to arrive at the total pounds per hour required in this particular configuration.

By regulation, an aircraft on an IFR clearance must carry sufficient fuel to fly to the destination, on to the alternate and for ______ additional minutes.	
Estimated fuel consumption must be calculated with consideration being given to forecast wind and other conditions which might ______ the flight.	*45*
The amount of fuel consumption in pounds per hour per BHP (or pound of thrust) is referred to as specific ______ ______.	*extend*
Fuel flow is equal to Brake Horse Power multiplied by ______ fuel consumption.	*fuel consumption*
The SFC is .315 lbs./BHP/hr. on either engine of a twin engine transport aircraft. If the engines are operated at 2200 BHP, what would the fuel flow be in pounds per hour per engine? ______.	*specific*
Referring to the data in the above frame, what would be the fuel flow in gallons per hour? (Assume 1 gallon = 6 pounds.) ______.	*693 lbs./hr.*
Referring again to the data in frame 12, what would be the fuel flow in pounds per hour for both engines? ______	*115.5 gal./hr.*
	1386 lbs./hr.

PHYSIOLOGICAL FACTORS INCIDENT TO FLIGHT

Hypoxia

The altitudes at which high flying jet transports operate today make it imperative that crews have an operating knowledge of the affects of decreased atmospheric pressure and oxygen content on body systems.

Hypoxia, or the lack of sufficient oxygen in the body, is one of the most dangerous physiological conditions associated with high altitude flying because of its treacherous and insidious nature. In fact, hypoxia can cause death with little or no warning of its presence.

Hypoxia can be caused at the ground level by such things as carbon monoxide or cyanide poisoning and shock. However, this discussion will be concerned with hypoxia caused by deficient oxygen in the lung due to low atmospheric pressure.

With an increase in altitude, there will of course, be a decrease in air pressure exerted on the body. Pressure decrease is always accompanied by a corresponding decrease in oxygen available to the blood stream which carries the oxygen throughout the body.

The affects of hypoxia vary greatly with the individual, however, those who will likely be affected first are persons who:

1. are in poor physical condition
2. have over-indulged in alcohol
3. have taken certain types of medicine
4. are smokers

Pilots of high performance aircraft must be knowledgeable concerning the effect of decreased atmospheric __________ on body systems.	
The condition in which there exists a lack of sufficient oxygen in the body is referred to as __________.	*pressure*
Hypoxia is very dangerous because it can cause death with little or no __________.	*hypoxia*
An increase in altitude results in decreased __________ pressure on the body.	*warning*
Decreased atmospheric pressure causes a corresponding decrease in __________ available to the body.	*atmospheric*
Individuals vary greatly in their response to __________.	*oxygen*
Hypoxia will have the greatest adverse affect on those who have over-indulged in alcohol, taken certain types of medicine, or who are smokers or are in poor physical __________.	*hypoxia*
	condition

The average pilot will react to oxygen deficiency as follows:

1. Night adaption of the eyes is adversly affected at altitudes as low as 5,000 feet.
2. Mental and physical sluggishness sets in after four to six hours at 8,000 to 10,000 feet.
3. The pilot exhibits fatigue, poor judgement and drowsiness when at 10,000 to 15,000 feet for over two hours.
4. At 15,000 to 18,000 feet, the pilot has an erroneous sense of well-being. He exhibits poor reasoning and a faulty memory. Unconsciousness may occur at this altitude.
5. At over 18,000 feet, the pilot will lose muscle control, judgement and memory. He may experience emotional outbursts such as uncontrolled fits of laughing or crying.

6. The average person will lose consciousness in four to five minutes at 26,000 feet and in 30 seconds at 40,000 feet.

Much of the danger incident to hypoxia stems from the fact that the power of accurate judgement is one of the first functions to be lost. This, coupled with the false sense of well-being, often makes it difficult for the pilot to correct the situation by himself.

The following are early symptoms of oxygen deficiency and should be remembered by the pilot as an aid in recognizing the first stages of hypoxia:

1. sleepiness, headache and impaired vision
2. blue lips and blue fingernails
3. increased pulse and respiration rate

Prevention of Hypoxia

Modern methods and systems made available to the pilot are his safeguard against hypoxia. However, the pilot must be aware of his own limitations and the limitations of the equipment being used. It is an excellent practice to inspect oxygen equipment regularly both prior to and during flight.

The lack of oxygen will have an adverse affect on a pilot's night vision at altitudes as low as ______ feet.	
Without supplemental oxygen, the average pilot will exhibit mental and physical sluggishness after four to six hours in the altitude range of 8,000 to ______ feet.	*5,000*
At 15,000 to 18,000 feet without supplemental oxygen, the average pilot has an erroneous sense of well-being and self-confidence. He exhibits poor reasoning, poor judgement and a faulty ______.	*10,000*
One of the first functions to be lost when a pilot is affected by hypoxia, is accurate ______.	*memory*
Loss of accurate judgement accompanied by an erroneous sense of self-confidence, often make recovery from a dangerous situation very ______.	*judgement*
It is well for a pilot to be familiar with the early symptoms of hypoxia. Some of the first symptoms which most persons exhibit are sleepiness, headache and impaired ______.	*difficult*
It is a good practice for pilots of high performance aircraft to go through a low pressure chamber exercise in order that they may observe reactions to mild hypoxia. Symptoms which would probably be observed are blue fingernails and lips, and also an increased ______ and ______ rate.	*vision*
As a precaution in order to prevent hypoxia, pilots should regularly inspect ______ equipment.	*respiration* *pulse*
	oxygen

The Eye and Flight

Vision is probably the most important sense in situations where flying is involved. A pilot with good vision is fortunate indeed. However, just as important as good vision, is an understanding of the capabilities and limitations of one's own eyes.

The retina at the rear portion of the eye can be likened to the photo-film of the camera. The retina contains nerve-endings, referred to as cones and rods which, when stimulated by light, transmit impulses to the brain. The cones are densely packed behind the pupil of the eye and become sparce as they spread out toward the periphery. It is the center of the eye which makes possible visual acuity and color discrimination. However, this section of the eye is only useful in the daylight.

The rods are dense at the periphery of the eye and decrease in number toward the center. Rods are not capable of sharp, acute vision and color differentiation, but do provide for sight when there is little illumination. The rods come into operation when the illumination decreases to that of moonlight. Thus, it is the rods which provide a pilot with night vision.

The facts stated above lead to three important points which are of concern to pilots. The first of these points concerns the *scan*. The center of the eye which provides perception of detail, is only about 5° in diameter and requires time to focus on an object. Thus, most details are perceived not by using a long sweeping glance, but by using short, regular spaced movements.

The second important fact concerns the so called "blind spot" in the focal center of the eye at night. Since the rods, which are used for night vision, are concentrated in the periphery of the eye, one must look to one side of an object to see it. Off center vision is to some extent natural, however, night vision can be greatly improved if the construction and operation of the eyes are remembered.

Thirdly, good night vision requires dark adaption. This means that the average person requires about 30 minutes of darkness to attain the maximum night vision. It has been established that the rods are affected very little by red light, thus it is possible to dark-adapt while reading under a darkly tinted red light or while using red tinted goggles. Remember however, that only a few seconds in bright light can void any night adaption that a pilot might have.

Probably the most important sense in a flying situation is ______________.	
The nerve endings in the retina of the eye are referred to as cones and ______________.	*vision*
Both the cones and rods transmit impulses to the ______________.	*rods*
The nerve-endings which are concentrated at the periphery of the eye are ______________.	*brain*
The cones are the most densely packed at the ______________ of the eye.	*rods*
The nerve-endings which provide visual acuity and color discrimination, are the ______________.	*center*
The rods are used when there is (much) (little) ______________ illumination.	*cones*
The scan is most efficient when short, regular spaced ______________ are used.	*little*

Since the rods, which are used for night vision, are concentrated at the periphery of the eye, there is a ____________ ____________ in the focal center of the eye at night.	*movements*
To observe an object very closely at night, the pilot must look "past" the object, or to one ____________ of the object.	*blind spot*
Excellent night vision requires dark ____________.	*side*
Maximum night vision requires about ____________ minutes of dark adaption.	*adaption*
Night vision is affected very little by ____________ light.	*30*
Night vision may be completely voided by being in a ____________ light for only a few seconds.	*red*
	bright

Weight and Balance

The weight of a loaded airplane and the distribution of the load within the airplane is of vital importance to the air transport pilot. The improper loading of an airplane will contribute to slower cruising speeds, poor landing characteristics and a possible dangerous situation at low landing or takeoff speeds. However, a properly loaded airplane will provide for more efficient and more economical operation.

In some situations the pilot may not be directly responsible for the actual loading of the airplane, however, he is *always responsible* for the safety of the flight. Because of the pilot's responsibility to authorities and to his crew and passengers, he must be acquainted with the principles of weight and balance.

Familiarity with the following terms is necessary in order to understand the basic principles of weight and balance.

Maximum gross weight—The maximum weight authorized by the flight manual for an aircraft and its contents.

Empty weight—Weight of the aircraft, including only fixed furnishings, items of equipment and residual fuel and oil.

Zero fuel weight—The maximum weight authorized for an airplane with no disposable fuel and oil.

Operating weight—The empty weight of the airplane in addition to oil, crew, crew baggage, passenger equipment and emergency equipment.

Datum line—An imaginary reference line from which all calculations or measurements are taken for weight and balance purposes

Of vital importance to the ATR pilot is the weight and ______________ of the airplane.	
A properly loaded airplane contributes to an efficient and ______________ operation.	*balance*
Proper loading of an airplane is the final responsibility of the ______________.	*economical*
The weight authorized by the flight manual as maximum for the airplane and contents is called ______________ ______________ ______________.	*pilot*
The weight of equipment, residual fuel and oil and the basic airplane together are referred to as ______________ weight.	*maximum gross weight*
The empty weight of the airplane in addition to the weight of the oil, crew, crew baggage, passenger equipment and emergency equipment is called the ______________ weight.	*empty*
An imaginary reference line used for weight and balance calculations is called a ______________ ______________.	*operating*
The maximum weight authorized for an airplane with no disposable fuel or oil is known as the ______________ ______________ weight.	*datum line*

	zero fuel

Moment—The tendency, or the measurement of the tendency, to produce rotation about a point or axis. Moment can be determined by multiplying the weight of a mass by its horizontal distance from the datum line.

Moment arm—The horizontal distance from the center of gravity of an object to the datum line.

Center of gravity—That point in an aircraft around which all weight is evenly distributed or balanced. The point of balance in an aircraft.

Empty weight center of gravity—The center of gravity of an airplane in an empty weight condition.

Operating center of gravity range—The distance between the fore and aft center of gravity limits.

Mean aerodynamic chord (MAC)—The mean chord of an airfoil. When used in connection with weight and balance, MAC is utilized as a reference to establish the center of gravity and center of gravity range of an airplane.

The point of balance, around which all moment is evenly distributed in an aircraft, is called the ________ ____ ________.	
The center of gravity of an airplane at its empty weight is called ________ weight center of ________.	*center of gravity*
The result of multiplying the weight of a mass times its horizontal distance from a datum line is the ________.	*empty gravity*
The tendency to produce rotation about a point or axis is referred to as ________.	*moment*
The horizontal distance from the datum line to the CG of an object is called the moment ________.	*moment*
The moment arm is the horizontal distance from the center of gravity of an object to the ________ ________.	*arm*
A datum line is an ________ reference line used in weight and balance calculations.	*datum line*
Zero fuel weight is the maximum weight of an airplane and contents with the exception of disposable ________ and oil.	*imaginary*
Maximum gross weight is the maximum gross weight of the airplane and contents authorized in the ________ manual.	*fuel*
When used in weight and balance considerations, the longitudinal range used for CG travel is along the mean aerodynamic ________ (MAC).	*flight (operating)*
The distance between fore and aft CG limits is known as the CG ________	*chord*

	range (travel)

The Center of Gravity (CG)

Every object of every conceivable size, shape or form has a center of gravity (CG). The CG is merely the point about which all moments are equal in all directions. An object possesses only one CG and its position does not change unless the physical properties of the object change.

The CG of an airplane is very important to the pilot since the CG must remain within established limits to insure the aerodynamic stability of the airplane.

The CG of an object is a point about which all moments are ____________ in all directions.	
Every object of every conceivable size, shape or form has a ________ ________ ________.	*equal*
The location of the CG does not change unless the ________ properties of the object are changed.	*center of gravity*
The aerodynamic stability of an airplane requires that the ________ ________ ________ remain within established limits.	*physical*
	center of gravity

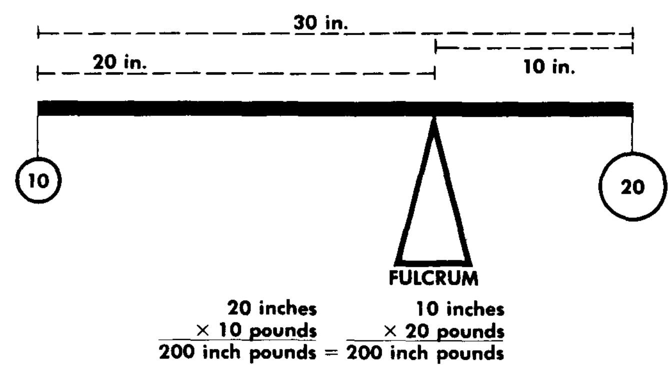


Fig. 10-1 — Weights and Moment Arms

Center of Gravity and Balance

In order to understand the basic principles of balance as they apply to air transportation, consider the bar and the arrangement of weights illustrated in Figure 10-1. Assume that the bar in the figure is weightless.

Notice in Figure 10-1 that the bar is balanced on a fulcrum which is not equidistant from both ends of the bar. Notice also that a 10 pound weight is suspended on the left side of the bar and a 20 pound weight is suspended on the right side of the bar. The bar, in this case, is balanced because the

10 pound weight is acting through a moment arm (lever) which is twice as long as the moment arm which is associated with the 20 pound weight.

The rotating or twisting force exerted by the two weights in Figure 10-1 can be referred to as "moment". Moment, in this particular situation, is expressed in inch-pounds because moment is equal to the weight of an object multiplied by the length of its moment arm. Thus, the moment of the 10 pound weight in Figure 10-1 is equal to 10 pounds × 20 inches = 200 inch-pounds. The moment of the 20 pound weight is equal to 20 pounds × 10 inches = 200 inch-pounds. Since the moment on either side of the fulcrum is 200 inch-pounds, the weights are balanced and the point on the bar directly over the fulcrum must be the CG.

In Figure 10-1, the two weights are balanced on the ____________.	
When two unequal weights are balanced (as in Figure 10-1), the heavier weight has a shorter moment (lever) ____________.	*fulcrum*
Conversely, the lighter weight has a longer ________ ________ arm.	*arm*
In fact, since the 10 pound weight is half as heavy as the 20 pound weight, it must have a moment arm ____________ as long.	*moment (lever)*
The length of a moment arm in inches multiplied by a weight in pounds gives an answer in ________ ________.	*twice*
The 10 pound weight multiplied by its moment arm of 20 inches gives a total "moment" of ____________ inch-pounds.	*inch-pounds*
The heavier weight (Figure 10-1) of 20 pounds has a moment of 200 inch-pounds, when multiplied by the moment arm of ____________ inches.	*200*
In this situation, the weight of the object balanced, multiplied by the length of its moment arm in inches is called the ____________, and is expressed in inch-pounds.	*10*
In the Figure 10-1, the point on the fulcrum where both weights are balanced is called the ________ ________ ________ of the bar.	*moment*
	center of gravity

Airplane Weight and Balance

Airplane weight and balance works on the same physical principles as outlined above. However, because the CG of an airplane changes with each loading situation, it cannot be used as a reference point. In order that a constant reference point may always be available for use in computations, a "datum line" is established. A datum line is an arbitrarily chosen point about which all moments are computed. Moments are referred to as positive (+) when they result in a clockwise rotation around

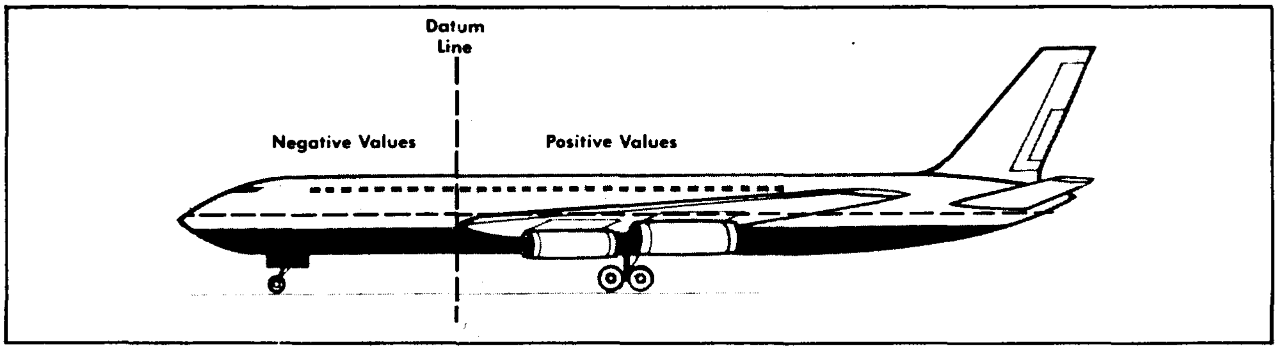


Fig. 10-2—Datum Line Position

the datum line and negative (–) when they result in a counterclockwise rotation. Thus as seen in Figure 10-2, moments to the right of the datum line are positive (+) and moments to the left are negative (–). For the purpose of standardization in all weight and balance computations, the nose of the airplane is always considered to point to the left.

To standardize the compution of positive and negative moments, the nose of the airplane is always considered to point to the ________.	
A datum line is an imaginary (arbitrary) line or point about which all ________ are computed.	*left*
Moments are considered to be positive when they tend to move ________ about the datum point.	*moments*
When moments tend to rotate about the datum in a counter-clockwise direction, the moment is said to be ________.	*clockwise*
A fixed datum line rather than the CG is used for a constant reference point in weight and balance computations because the CG ________.	*negative*
When two weights are balanced on a fulcrum, or about a CG, the heavier weight has a (longer) (shorter) ________ moment arm.	*changes (moves)*
Moments tend to rotate about an imaginary point or line called the ________ line.	*shorter*
	datum

In many modern transport airplanes, the datum line is located at or ahead of the nose in order to avoid computation with negative values. As is seen in Figure 10-3, all of the moments are positive when the datum line is located at or to the left of the nose. Remember it does not matter where the datum line is located. However, once the datum line is established, it must be the basis from which *all measurements* are calculated.

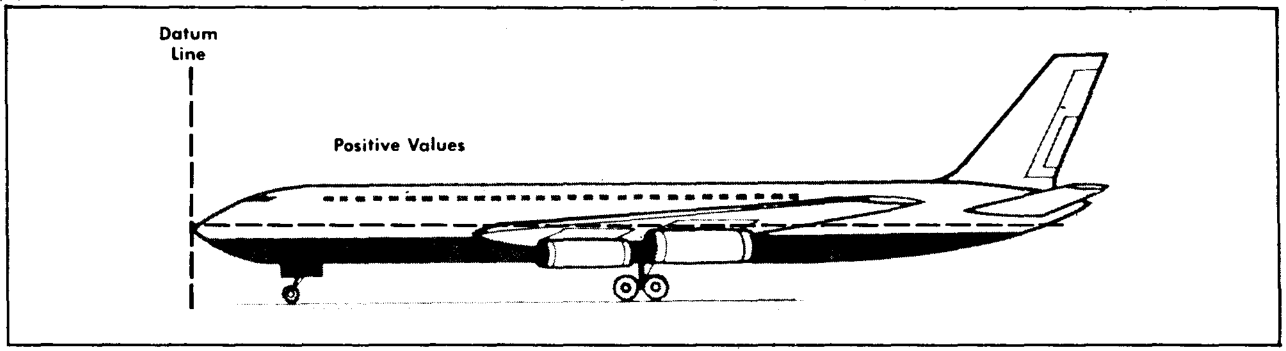


Fig. 10-3—Datum Line Position

The datum line is arbitrarily located and may be positioned as shown in Figure 10-2, or it may be at the ______________ as in Figure 10-3.	
Since all measurements are calculated from a common point, the ______________ line should remain fixed for all airplane weight and balance calculations.	*nose*
When the datum line is at (or left of) the nose as in Figure 10-3, all moments are of (positive) (negative) ______________ value.	*datum*
	positive

Determining Center of Gravity

It is a simple matter to determine the CG of a bar by the use of an arbitrarily chosen datum line. Suppose, for example, that a weightless bar is 60 inches long with a 5 pound weight on the left side and a 15 pound weight on the right as illustrated in Figure 10-4. It makes no difference where the datum line is placed. However, for purposes of this example, it is positioned at a point 20 inches from the left end of the bar.

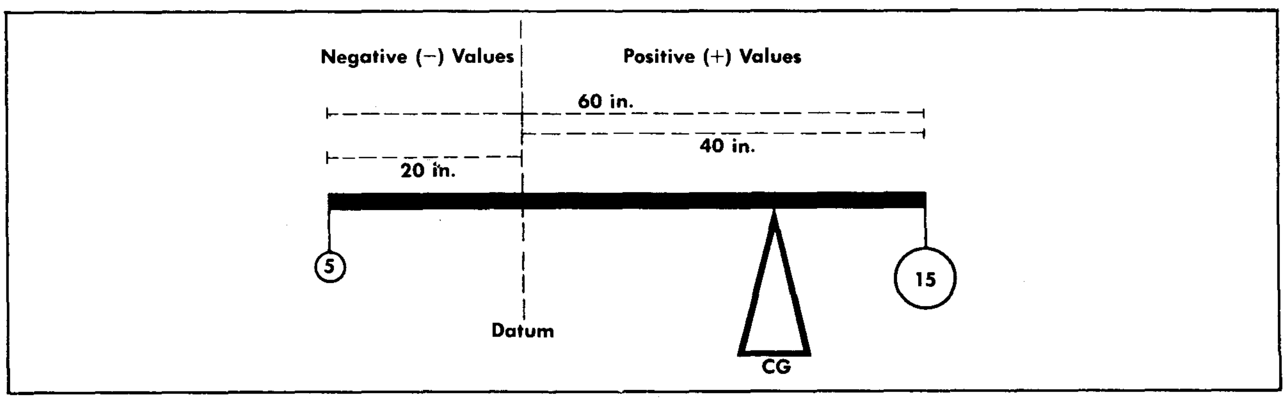


Fig. 10-4—Positive and Negative Moment

In Figure 10-4, the moment on the negative side of the bar is equal to:

$$20 \text{ inches} \times 5 \text{ pounds} = -100 \text{ inch-pounds.}$$

The moment on the positive side is equal to:

$$40 \text{ inches} \times 15 \text{ pounds} = +600 \text{ inch-pounds.}$$

To find the CG, simply divide the algebraic sum of the moments by the total weight suspended on the bar as shown in steps 1 and 2 below.

Step 1

MOMENT ARM (inches)		WEIGHT (pounds)		MOMENT (inch-pounds)
20	×	5	=	−100
40	×	15	=	+600
		20 (pounds)		+500 (inch-pounds)

Step 2

$$\frac{+500 \text{ (inch-pounds)}}{20 \text{ pounds}} = +25 \text{ inches}$$

The answer (25 inches) must be applied to the datum line to arrive at the CG. Since the algebraic sum of the moments is a positive value, the CG will be 25 inches to the right of the datum line. Had the algebraic sum of the moments been a negative value, the CG would be 25 inches to the left of the datum line.

This same system of weight and balance applies regardless of the number of weights involved or the position of the datum line. Remember that the algebraic signs must be observed in accordance with the position of the datum line.

With the datum line as a reference point in Figure 10-4, the moment of the 5 pound weight is the product of 5 pounds × ______ inches, which equals ______ inch-pounds.	
With the same reference, the moment of the 15 pound weight equals ______ inch-pounds.	*20* *100*
The moment of the 5 pound weight acts counterclockwise and has a ______ value.	*600*
The moment of the 15 pound weight acts ______ and has a positive value.	*negative*
Once the total moments about a point are known, the CG can be found by dividing the algebraic sum of the moments by the total ______	*clockwise*
In the situation shown in Figure 10-4, the total moment is (−) 100 inch-pounds algebraically added to (+) 600 inch-pounds which equals ______ inch-pounds.	*weight*
Since the total weight is 5 + 15 pounds or 20 pounds the distance to the CG is $\frac{500 \text{ inch-pounds}}{20 \text{ pounds}}$ = ______ inches.	*+500*
The location of the CG, since the total moments are positive, is 25 inches to the right of the ______ line.	*25*
	datum

Figure 10-5 is an example of a problem which illustrates the datum line positioned so that no negative algebraic signs are necessary.

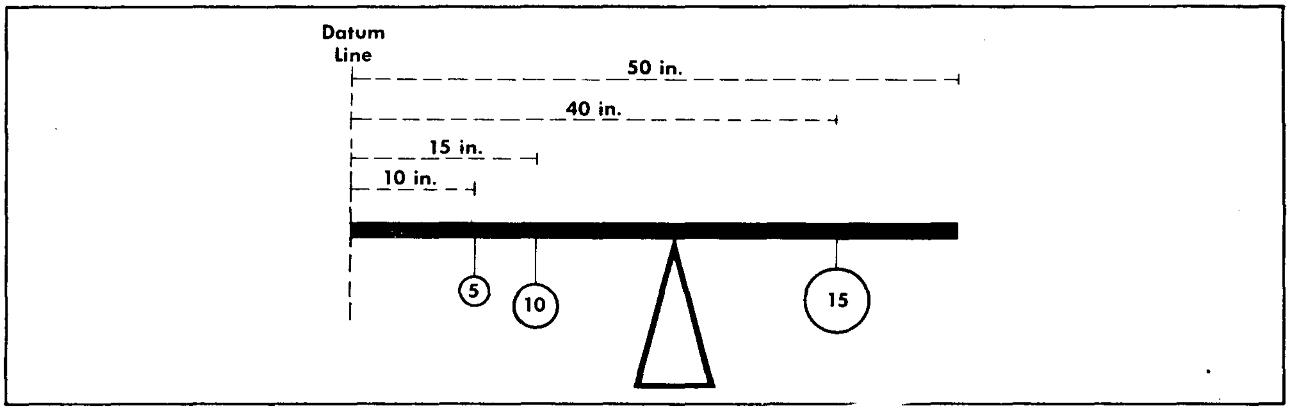


Fig. 10-5 – Positive Moment

To determine the CG for the bar in Figure 10-5, complete the following steps:

Step 1. Determine the total weight and moment.

MOMENT ARM		WEIGHT		MOMENT
10 inches	×	5 pounds	=	+ 50 inch-pounds
15 inches	×	10 pounds	=	+150 inch-pounds
40 inches	×	15 pounds	=	+600 inch-pounds
		30 pounds		+800 inch-pounds

Step 2. Divide the total moment by the total weight.

$$\frac{800 \text{ inch-pounds}}{30 \text{ pounds}} = 26.6 \text{ inches}$$

Step 3. Establish the center of gravity 26.6 inches to the right of the datum line.

In Figure 10-5, the datum line is to the left of all of the moment arms. Therefore, all moments will be (positive) (negative) ______________.

The moment of the 15 pound weight in Figure 10-5, calculated from the datum line, is the product of 15 pounds × 40 inches = (+) ______________ inch-pounds. — *positive*

The moment of the 5 pound weight is the product of 5 pounds × ______________ inches = 50 inch-pounds. — *600*

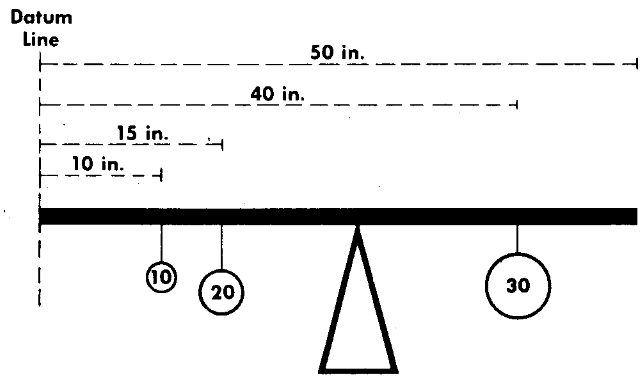
The moment of the 10 pound weight is equal to (+) ______________ inch-pounds. — *10*

The total moment for all three weights in Figure 10-5 is (+) (−) ______________ inch-pounds. The total weight is ______________ pounds. — *150*

To find the distance of the CG location, divide as follows:

$$\frac{\underline{\qquad\qquad} \text{ inch-pounds}}{30 \text{ pounds}} = \underline{\qquad\qquad} \text{ inches}$$

+800
30

The center of gravity is located 26.6 inches to the right of the ______ line because all moments are (positive) (negative) ______.	*800* *26.6*
 In this illustration the total moments are positive and equal to ______ inch-pounds.	*datum* *positive*
In the previous example the total weight is ______ pounds.	*1,600*
The location of the CG equals ______ inches from the datum line.	*60*
	26.6

Empty Weight Center of Gravity Location

The empty weight CG location is determined by weighing and ascertaining the moment incident to each landing gear. Suppose for example, that the datum line on a particular airplane is located at the nose as illustrated in Figure 10-6. Upon determining the weight at each landing gear and finding the distance of each from the datum line, the problem can then be treated as those explained previously.

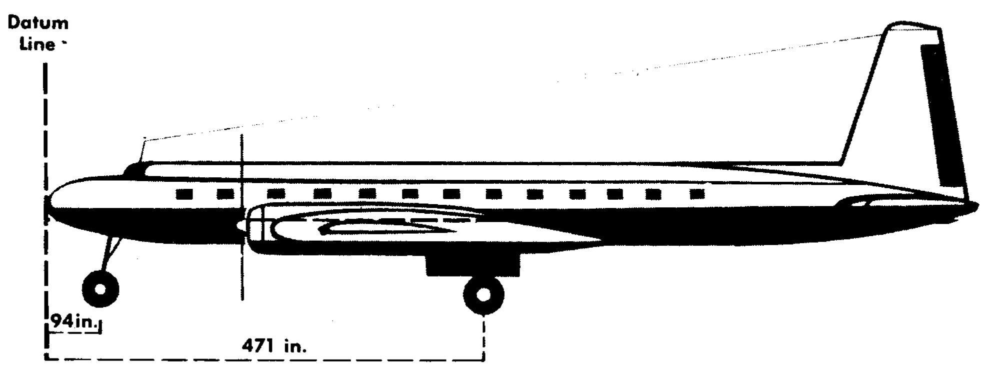


Fig. 10-6—Empty CG Location

Translated into actual figures, the problem would look like this:

Step 1. Determine the total weight and moment for the empty airplane.

	MOMENT ARM		WEIGHT		MOMENT
Nose gear	94 inches	×	8,400 pounds	=	+789,600 inch-pounds
Left main gear	471 inches	×	20,600 pounds	=	+9,702,600 inch-pounds
Right main gear	471 inches	×	21,000 pounds	=	+9,891,000 inch-pounds
			50,000 pounds		+20,383,200 inch-pounds

Step 2. Divide the total moment by the total weight.

$$\frac{20{,}383{,}200 \text{ inch-pounds}}{50{,}000 \text{ pounds}} = 407.66 \text{ inches}$$

Step 3. Establish the empty weight center of gravity at 407.66 inches from the datum line.

The first step in determining the CG of an empty airplane is to find the weight on each landing gear and then the distance of each gear from the ______________ line.

Next, multiply the weight on each gear times its ______________ (in inches) from the datum line.

datum

Add these moments (inch-pounds) to find the ______________ ______________.

distance

Divide the total moment by the total airplane ______________ to find the location of the ________ ________ with reference to the datum line.

total moment

An airplane has the following empty weight data:

	MOMENT ARM	WEIGHT	MOMENT	
Nose gear	100 in.	8,800 lbs. =	+______________	in.-lbs.
Left main gear	500 in.	20,500 lbs. =	+______________	in.-lbs.
Right main gear	500 in.	21,000 lbs. =	+______________	in.-lbs.
Totals		50,300 lbs.	+______________	in.-lbs.

Find the moments and total moment for this airplane.

weight
CG

Find the empty weight location of the CG as ______________ inches from the datum line in the above example.

880,000
10,250,000
10,500,000
21,630,000

430.02

Mean Aerodynamic Chord (MAC)

The CG location in an airplane is often given in terms of a percent of the mean aerodynamic chord (%MAC). A chord is the distance from the leading edge to the trailing edge of the wing. The *mean aerodynamic chord* is that chord that passes through the center of gravity (center of mass) of the wing. It may or may not be the average chord depending on the shape of the wing. The MAC is located on the lateral axis of the airplane and thus is a definite reference for longitudinal stability (pitching moment). The longitudinal stability of an airplane is of prime consideration when weight and balance is concerned.

Notice the relationship between the CG of the airplane and the MAC in Figure 10-7. Since the lateral axis originates at the CG and always crosses the MAC, it is convenient to establish CG limitations in reference to the MAC.

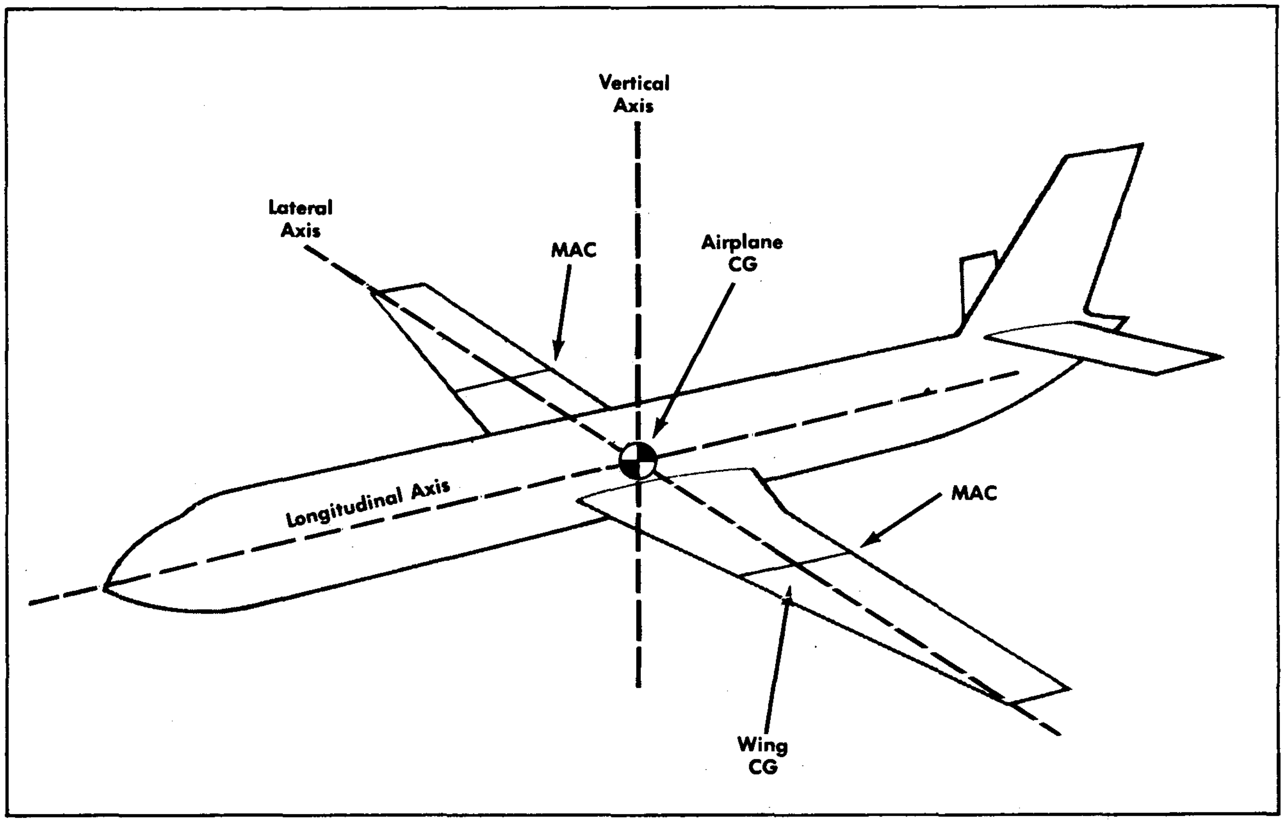


Fig. 10-7 – Mean Aerodynamic Chord

The wing chord is the distance from the leading edge to the ______ edge of the wing.	
That chord which passes through the center of gravity (center of mass) of the wing is the ______ ______ chord (MAC).	*trailing*
The mean aerodynamic chord (MAC) may or may not be the average ______, depending on the shape of the wing.	*mean aerodynamic*
The lateral axis of the airplane passes through the ___ ___ ___.	*chord*
The MAC is used as a reference in establishing fore and aft CG ______.	*MAC*
Since the MAC passes through the lateral axis of the airplane, the ___ ___ ___ is an important reference for pitching moments or longitudinal stability of the airplane.	*limits*
	MAC

The length of MAC is established by the manufacturer and can be found in the airplane manual. When the length of MAC and the CG position are known it is an easy task to determine the CG in %MAC.

Assume for example, that the MAC of an airplane is 192 inches in length and the leading edge of MAC (LEMAC) is 395 inches to the right of the datum line (Figure 10-8). The CG is located 48 inches aft of LEMAC.

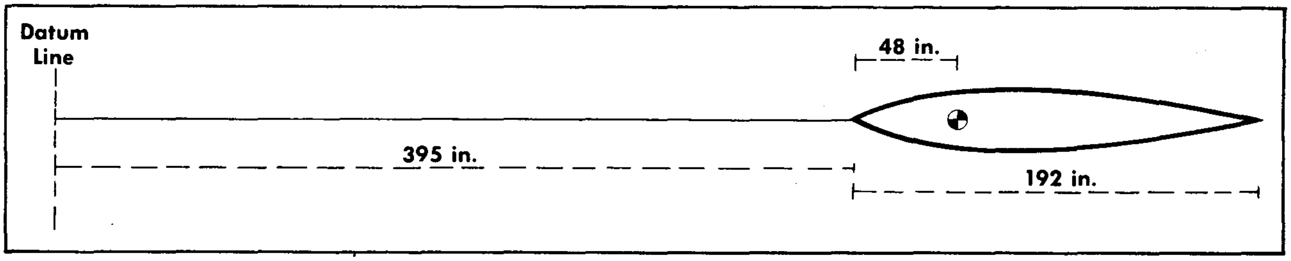


Fig. 10-8—Wing Cross Section at the MAC

The %MAC is determined by dividing the length of MAC into the distance between LEMAC and the CG location as illustrated below.

$$\frac{48\text{ inches}}{192\text{ inches}} = .25 = 25\%\text{ MAC}$$

The CG location can also be expressed in inches from the datum line. In this case, the distance between LEMAC and the CG is added to the distance between the datum line and LEMAC as illustrated below.

$$\begin{array}{r} 48\text{ inches} \\ \underline{+395\text{ inches}} \\ 443\text{ inches} \end{array}$$

Thus, the CG location can be expressed as being at 25% MAC or at 443 inches from the datum line.

The "leading edge of the mean aerodynamic chord" is abbreviated L __ __ __ __.	
$\frac{\text{The distance, LEMAC to CG}}{\text{Length of MAC}} = \%$ ____ ____ ____.	*EMAC*
The distance, LEMAC to CG = 55.44 inches. The length of the MAC = 168 inches. Using the formula in the previous frame, the % MAC = ________%.	*MAC*
The distance of the CG from the datum line equals ("Datum to LEMAC") + (LEMAC to CG).	*33.*
Using the formula above, if the distance from the datum line to LEMAC = 419 inches, and the distance, LEMAC to CG = 52 inches, the distances from the datum line to CG = ________ inches.	*no response*

The CG location can be expressed in "inches from datum line" or in terms of % ______ ______ ______.	*471*
	MAC

Center of Gravity Limits

In order to assure the aerodynamic stability of the airplane, certain limits on the position of the CG must be established. The limits are usually given in terms of % MAC. For example, assume that the fore and aft CG limits of an airplane are 18% MAC and 34% MAC respectively. In this case, the CG position of 25% MAC that was previously computed falls within the acceptable CG limits.

If after the airplane is loaded, it is found the CG position falls outside the accepted limits, then a change in the loading configuration must be made. It is well to remember that any weight placed between the limits of the CG will not force the CG from a position within the limits Also note that a weight placed directly on the CG will not change the CG position.

Aerodynamic stability of an airplane is assured by keeping the ______ ______ within predetermined limits of travel.	
CG limits are usually established in terms of limiting percentages of ______ ______ ______.	*CG*
Thus specific fore and ____________ limits of CG travel within the MAC are established..	*MAC*
A change in loading configuration must be made if the CG falls outside accepted ____________.	*aft*
Weights placed at the CG or between the limits of CG travel (will) (will not) ____________ ordinarily move the CG outside its limits.	*limits*
	will not

A Typical Weight and Balance Problem

The following exercise is given as an example of a typical weight and balance problem. In this particular problem the datum line is positioned at the nose of the airplane. It is assumed that the empty weight CG position has already been established.

Given:

MAC is from 395 inches to 542 inches (147 inches)
CG limits are from 18% MAC to 34% MAC (421 inches to 445 inches)
Empty weight CG position is 25.9% MAC (433 inches)
Empty weight moment is 22,516,000 inch-pounds
Empty weight is 52,000 pounds
Maximum gross weight is 98,000 pounds

Personnel and Cargo to be loaded:

1. crew = 350 pounds at +82 inches
2. 50 gallons of oil = 375 pounds at +435 inches
3. 2,500 gallons of fuel = 15,000 pounds at +465 inches
4. crate = 900 pounds at +450 inches
5. crate = 1,100 pounds at +350 inches

Required:

1. Total weight
2. Total moment
3. CG location in inches and % MAC

Solution:

1. Construct a chart like the one shown below to ascertain total weight and moment.

ITEM	MOMENT ARM		WEIGHT		MOMENT
empty airplane	433 inches	×	52,000 pounds	=	+22,516,000 inch-pounds
crew	82 inches	×	350 pounds	=	+28,700 inch-pounds
oil	435 inches	×	375 pounds	=	+163,125 inch-pounds
fuel	465 inches	×	15,000 pounds	=	+6,975,000 inch-pounds
crate	450 inches	×	900 pounds	=	+405,000 inch-pounds
crate	350 inches	×	1,100 pounds	=	+385,000 inch-pounds
			69,725 pounds		30,472,825 inch-pounds

2. Divide the total weight into the total moment to ascertain the distance from the datum line to CG.

$$\frac{30{,}472{,}825 \text{ inch-pounds}}{69{,}725 \text{ pounds}} = 437 \text{ inches}$$

3. Having established the CG at 437 inches, it is now necessary to subtract LEMAC from this figure and compute the % MAC as shown below.

$$\begin{array}{r} 437 \\ -395 \\ \hline 42 \end{array} \qquad \% \text{ MAC} = \frac{42}{147} = .286 = 28.6\% \text{ MAC}$$

Since 28.6% MAC is within the allowable limits, no shifting of the load will be necessary.

In calculating weight and balance problems, the product of the "moment arm in inches" multiplied by the "weight" equals the ______________.	
The algebraic sum of all of the "moments" gives the ________ ________.	*moment*
$\frac{\text{Total moments}}{\text{Total weight}}$ = Distance from datum to ________ ________.	*total moment*
(Distance of CG from Datum) − (L____ ____ ____ ____. equals distance of ________ ________ from LEMAC.	*CG*
$\frac{\text{Distance of CG from LEMAC}}{\text{Length of MAC}}$ = % ________ ________ ________.	*EMAC*
	CG

Problem Data:

ITEM	MOMENT ARM	WEIGHT	MOMENT
empty airplane	434 in. ×	51,000 lbs. =	________ in.-lbs.
crew	80 in. ×	380 lbs. =	________ in.-lbs.
oil	420 in. ×	360 lbs. =	________ in.-lbs.
fuel	450 in. ×	14,000 lbs. =	________ in.-lbs.
cargo	480 in. ×	1,100 lbs. =	________ in.-lbs.
cargo	330 in. ×	1,400 lbs. =	________ in.-lbs.
TOTALS		68,240 lbs.	________ in.-lbs.

MAC

Using the data in the above tabulation, the distance from the datum line to CG = ________ inches.

22,134,000
30,400
151,200
6,300,000
528,000
462,000
29,605,600

If the distance from the datum line to the leading edge of MAC, called LEMAC, is 387 inches, the distance of the CG from the leading edge is ________ inches.

434

If the CG range is 152 inches, which is from 18% to 34% MAC, then the CG is at ________ % of MAC.

47

The CG is (within) (outside) ________ allowable limits of travel.

30.9

within

Index Units

As is seen in the problem just solved, many of the values assume cumbersome proportions. In order to alleviate this problem, a system referred to as unit index or moment index was devised. This incorporates the use of reduction factors to reduce the size of the figures utilized in weight and balance computation. Any reduction factor can be used so long as it is utilized throughout the entirety of one problem.

Reduction factors such as 1,000 and 10,000 are commonly used depending on the individual problem. For example, in a previous problem the following figures were utilized.

$$\frac{30{,}472{,}825 \text{ inch-pounds}}{69{,}725 \text{ pounds}} = 437 \text{ inches}$$

Using a reduction factor of 1,000 the computation would look like this:

$$\frac{30{,}472.8}{69.7} = 437$$

Reduction factors are applied to weight and balance problems to reduce the size of numbers. Two formulas used to apply reduction factors are:

$$\frac{\text{moment}}{\text{reduction factor}} \text{ and/or } \frac{\text{weight}}{\text{reduction factor}} = \text{reduced numbers}$$

If a moment of 37,169,427 inch-pounds is reduced to a multiple of 1,000, then $\frac{37,169,427}{1,000}$ = ______________, the new multiple.	*no response*
If a weight of 59,936 pounds is reduced to a multiple of 1,000, then $\frac{59,936}{1,000}$ = ______________, the new multiple.	*37,169.4*
If multiples of 1,000 or 10,000 are used in solving weight and balance problems, then *all* weights and ______________ must be reduced.	*59.9*
If all units are reduced to multiples of 1,000 then the moments are termed as "moments/1,000 inch-pounds".	*moments*
	no response

Out of Balance Corrections

One of the most frequently encountered problems in weight and balance concerns an out of balance condition after the airplane has been loaded. The problem can be approached in two ways. First, weight may be added or removed to bring the CG within allowable limits. Second, weight may be shifted within the airplane to bring it into a balanced condition.

Added Weight Correction

As an example of the first problem, consider an airplane with a gross weight of 94,000 pounds with the fore and aft CG limits at 421 inches and 445 inches respectively. Any weight added to the airplane must be placed at 270 inches (station 270). After the airplane is loaded it is found that the CG is at 448 inches which is 3 inches out of tolerance with respect to the aft CG limit. Thus, the problem is to calculate the amount of weight which must be added to station 270 to bring the CG to the nearest limit which in this case is 445 inches.

In this type of problem, three values must be known.

1. Total weight (94,000 pounds)
2. Distance the CG is out of limits (3 inches)
3. The moment arm of the added weight. This is the distance from the location of the added weight to the new CG. In this case it is equal to 445 minus 270 which is 175. (In this type of problem the moment arm is measured from the CG not the datum line.)

The formula is:

$$\text{Weight which is to be added} = \frac{\text{distance CG must be moved} \times \text{total weight}}{\text{moment arm of added weight}}$$

When the appropriate values are substituted, the equation would look like this:

$$\text{Weight which is to be added} = \frac{3 \text{ inches} \times 94,000 \text{ pounds}}{175 \text{ inches}} = 1,611 \text{ pounds}$$

Thus 1,611 pounds is the minimum weight which must be added at station 270 to move the CG to the aft limit.

If the CG is outside limits it is necessary to correct the out of balance condition. This can be accomplished by adding or subtracting weight or by ______________ weight within the airplane.	

A formula to be used when it is necessary to add weight to balance the airplane is: $\frac{\text{(Distance CG must be moved)} \times \text{(Total weight)}}{\text{Moment arm of added weight}}$ = weight to be added.	*shifting*
To apply the formula above: Distance CG must be moved = 5 inches Total weight = 87,000 pounds Moment arm of added weight = 185 inches The weight which must be added = ________________ pounds.	*no response*
Applying the formula again: Distance CG must be moved = 7 inches Total weight = 27,000 pounds Moment arm of added weight = 100 inches The weight which must be added = ________________ pounds.	*2,351*
	1,890

Shifting Weight Correction

To understand this type of correction, consider an airplane configurated just as the one described in the first out of balance correction problem. Assume that any weight moved is to be taken from station 720 and placed in station 270. The total weight remains at 94,000 pounds and the CG position remains 3 inches behind the aft CG limit. Thus enough weight must be shifted from station 720 to station 270 to move the CG 3 inches forward.

The formula to correct the CG position by shifting weight is:

$$\text{Weight of cargo to shift} = \frac{\text{distance CG must be moved} \times \text{total weight}}{\text{distance weight is to be shifted}}$$

When the appropriate values are substituted, the equation would look like this:

$$\text{Weight of cargo to shift} = \frac{3 \text{ inches} \times 94{,}000 \text{ pounds}}{450 \text{ inches}} = 627 \text{ pounds}$$

Thus 627 pounds must be shifted from station 720 to station 270 in order to move the CG forward to the aft CG limit. It is well to note that it requires much less shifted weight than added weight to balance an airplane.

The formula to correct CG position by shifting weights: $\frac{\text{(Distance CG must be moved)} \times \text{(total weight)}}{\text{Distance weight is to be shifted}}$ = weight of cargo to shift	
Using the above formula: Distance CG must be moved = 5 inches Total weight = 37,000 pounds Distance weight is to be shifted = 300 inches The weight of cargo to be shifted = ______________ pounds.	*no response*

To determine how far a given cargo weight must be shifted to balance the airplane, this formula is used: $\frac{\text{(Distance CG must be moved)} \times \text{(total weight)}}{\text{Weight of cargo to be shifted}} = $ Distance weight must be shifted	*617*
Using the above formula: Distance CG must be moved = 4 inches Total weight = 41,000 pounds Weight of cargo to be shifted = 1,000 pounds The distance weight must be shifted = ______________ inches.	*no response*
	164

Before a pilot initiates the takeoff roll in a transport airplane, he must be acutely aware of the many takeoff variables that can affect the safety of his passengers and crew.

Temperature

Air temperature is a very important factor and must be considered in any air transport operation. An increase in air temperature will produce a decrease in the density of the air and a resultant drop in engine performance and aerodynamic lift. A decrease in air density at the ground level produces the same effect on airplane performance as does an increase in altitude.

Since both reciprocating and jet engines are less efficient when operating in warm air, pilots should take temperature into consideration when computing minimum runway takeoff lengths and maximum permissible gross weights. Conversely, cooler air results in a more dense condition and will allow operation at higher gross weights and on shorter runways.

The computation of the effects of temperature variations upon aircraft performance is referred to as "temperature accountability". Computations incident to temperature accountability will be discussed in detail later in this section.

Humidity

Regulations do not require that the pilot take into account the effects of humidity on piston powered airplane performance, however, the pilot should be aware of its effects. The capability of air to hold moisture varies directly with the air temperature. As the temperature of the air increases, its capacity to hold water increases. Conversely, as the temperature of the air decreases, its capacity to hold water decreases. Moist air is relatively less dense than dry air because water vapor is one of the lighter components of those elements of which the air is composed. Thus, a high relative humidity is definitely a factor that tends to reduce aerodynamic lift and engine power output.

Two important variables affecting the performance of an airplane are ______ and ______.	
An increase in air temperature decreases the ______ of the air.	*temperature* *humidity*
Engine performance is improved when the air is more dense and conversely, engine performance is ______ in less dense air.	*density*
An increase in air temperature (improves) (depreciates) ______ engine performance.	*decreased* *(lessened)*
Air density decreases with altitude and thus engine performance ______ with altitude (other factors remaining equal).	*depreciates*
High temperatures have the same effect on engine performance as an increase in ______.	*decreases*
Colder air (decreased temperature) has the effect of ______ engine performance (other factors being equal).	*altitude*

Performance of both reciprocating and jet engines is affected by changes in ____________ and density.	*improving*
When computing minimum runway lengths for takeoff with either jet or piston airplanes, air ____________ and ____________ should be considered.	*temperature*
The computation of effects of temperature variation on aircraft performance is referred to as "temperature ____________".	*temperature density*
As air temperature increases, the capacity of the air to hold water vapor ____________.	*accountability*
Conversely, colder air is capable of holding less ____________ vapor.	*increases*
Warm, moist air is relatively less ____________ than dry air.	*water*
Since decreased air density reduces engine performance, and since high relative humidity decreases air density, high humidity is a factor to consider relative to engine ____________.	*dense*
	performance

Wind

It is readily apparent that less runway length will be required when taking off into a head wind rather than with a calm or tail wind condition. The pilot should be familiar with the regulations that apply to the adjustment of takeoff data when the wind is considered to be a significant factor. Regulations stipulate that not more than 50% of any head wind and not less than 150% of any tail wind may be figured into takeoff planning data.

Many airplane manufacturers take this wind factor into account when constructing takeoff data charts. That is, 150% of the reported tail wind and 50% of the reported head wind are incorporated into the chart. In instances where this has been accomplished, no additional wind correction is required when computing takeoff performance.

Runway Gradient

Gradient is the ratio of change in runway elevation to the actual runway length. It is usually expressed as a percentage value. A 1.0% gradient consists of one unit of vertical change for every 100 units of horizontal distance. In ratio form, a 1.0% gradient could be expressed as the fraction 1/100.

The average gradient of a runway can be determined by dividing the difference in elevation of the two ends of the runway by its length. This figure is then multiplied by 100 to convert the answer to a percentage value. For example, consider an 8,000 foot runway. The elevation of one end of the runway is 950 feet and the other is 1,070 feet. The difference, 120 feet, is divided by 8,000 feet to get .015. This figure, multiplied by 100, gives the gradient of 1.5%.

Any gradient (slope) of the runway will definitely affect the runway length required for takeoff. For this reason, regulations require that operators of transport category airplanes account for any existing runway gradient.

Operators of non-transport category airplanes are not required to account for gradient unless it exceeds an average of .5%.

Takeoff data corrections to provide for runway gradient will be discussed later in this section.

Runway Composition

Runway surface composition is another variable that affects the length of takeoff roll. Regulations do not require that this factor be taken into consideration in takeoff planning data, however, the pilot should be aware that a rough, uneven surface will decrease takeoff performance. Takeoff data charts for transport category airplanes are constructed on the basis of performance on smooth, hard surface runways.

Extreme care should be exercised when operating on runways where braking action is less efficient because of weather conditions. There is no method of accurately determining performance on a wet or icy runway, thus any decision the pilot makes in this regard should be carefully considered.

All pilots realize that less runway is required when taking off into a __________ wind.	
Regulations stipulate that only 50% of the reported __________ __________ may be used to compute takeoff distances of a T-Category aircraft.	*head*
T-Category regulations require that __________% of a reported tail wind be used to compute takeoff distance.	*head wind*
Takeoff data charts are usually constructed to take into account __________% of the head wind and __________% of the tail wind, making it unnecessary for the pilot to calculate wind percentages.	*150*
Operators of T-Category airplanes (are required) (are not required) __________ __________ to consider runway gradient in takeoff distance computations.	*50* *150*
The ratio of change in runway elevation compared to runway length is known as runway __________.	*are required*
The average gradient of a runway can be determined by dividing the difference in elevation of the two ends of the runway by its __________ in feet.	*gradient*
The difference in elevation between the two ends of a particular runway is *120* feet. The runway is 8,000 feet long. $\frac{120}{8000} \times 100$ equals the runway gradient. The gradient in this case is __________%.	*length*
One end of a given 10,000 foot runway has an elevation of 4,000 feet and the other end has an elevation of 4,200 feet. Thus $\frac{200}{10,000} \times 100$ is the formula to find the runway gradient, which is calculated to be __________%.	*1.5*

Takeoff data charts for T-Category airplanes have provisions for application of runway ______________ in determining takeoff distances.	*2.0*
Although other than hard surfaced runways are not considered in takeoff data charts, pilots should be aware that variations *from hard surfaced runways will reduce takeoff* ______________.	*gradient*
Wet or icy runways can significantly increase stopping ______________.	*performance*
	distances

Runway Elevation

Since air density generally decreases as altitude increases, the altitude of a runway is a definite consideration in any air operation. At high altitude, due to reduced air density, less air is introduced into the engine than when operating at sea level. This reduction in available air results in reduced engine performance, reduced wing lift and consequently an increased takeoff distance.

Charts incorporating runway altitude data are constructed using standard atmospheric conditions. When the temperature varies from standard, then the density will vary and the actual takeoff performance will differ from the computed takeoff performance. For this reason airplane and engine performance is based on density altitude rather than pressure altitude. Density altitude can be defined as pressure altitude corrected for any deviation from standard temperature.

Any deviation encountered between density altitude and pressure altitude may be compensated for by observing the procedures outlined in the temperature accountability portion of this section.

Takeoff Limitations

Airplane manufacturers establish two critical takeoff speeds for every transport category airplane. These are called the "critical engine failure speed" (V_1) and the "takeoff safety speed" (V_2).

V_1 is the calibrated airspeed (CAS) at which the takeoff may be safely continued even though the critical engine has failed. It might also be explained as the CAS at or below which the airplane can be stopped within the minimum takeoff runway length, and above which the takeoff can be continued if the critical engine fails. The critical engine is defined as the engine which would impart the greatest adverse effect if it failed.

V_2 is defined as the CAS at which the climb-out can be safely executed with the critical engine inoperative and the airplane in the takeoff configuration. This speed requirement is designed to provide maximum obstacle clearance during takeoff and still give a safe margin above stall and minimum control speeds.

Runway elevation is a definite consideration in determination of runway takeoff and landing distance because air density decreases as ______________ increases.	
This reduction in air density with altitude reduces engine performance and results in ______________ takeoff distances.	*altitude*

The standard atmosphere is represented by standard density altitudes in performance charts. Density altitude may be considered to be pressure altitude corrected for ________ deviations from standard.	*increased*
The pilot can determine pressure altitude by setting the altimeter to 29.92 inches of mercury, then reading the pressure ________ on the altimeter.	*temperature*
Charts usually use a combination of pressure altitude and temperature to determine density altitude because the pilot can read pressure altitude and ________ from the instruments in the cockpit.	*altitude*
However, in using runway elevation charts, standard density altitude of runways are shown, and the pilot applies a ________ correction for non-standard conditions, when necessary.	*temperature*
The two critical takeoff speeds established for T-Category aircraft are: (1) the "critical engine failure speed" (V_1), and (2) the "takeoff ________ speed" (V_2).	*temperature*
The "critical engine failure speed" is known symbolically as the ________ speed.	*safety*
The "takeoff safety speed" is referred to as the ________ speed.	*V_1*
The calibrated airspeed (CAS) at which the takeoff roll may be continued after the critical engine has failed is the ________ speed.	*V_2*
The failed engine which would cause the most adverse effect is called the ________ engine.	*V_1*
The V_1 speed may also be defined as the CAS at or below which the airplane can be stopped within the minimum takeoff ________ length.	*critical*
The CAS at which the climb-out can be safely executed with one engine inoperative and with the airplane in the takeoff configuration is called the ________ speed.	*runway*
V_2 speed is designed to provide maximum ________ clearance, with a safe margin above the stall speed and ________ control speed.	*V_2*
	obstacle *minimum*

Another value determined by the manufacturer and closely related to V_1 and V_2 speeds is the "accelerate-stop distance". It is defined as the distance required to accelerate an airplane to V_1 and then bring the airplane to a stop assuming failure of the critical engine at V_1.

The "accelerate-stop distance" data is used in the construction of critical engine failure speed charts such as the one illustrated in Figure 11-1. This is a typical chart used by reciprocating engine air carriers. As an example of the use of this chart, consider an airplane with a gross weight of 85,600 pounds operating on a runway 2,000 feet above sea level. Notice that in Figure 11-1, a dashed line has been drawn vertically on the 85,600 pound gross weight line to the 2,000 foot runway altitude line. From this intersection the line continues horizontally left to the wind speed line which in this case has been arbitrarily chosen as +10 kts. The V_1 speed, 110 kts., is read on the slanted CAS line on the left side of the chart.

The "accelerate-stop distance" is the distance required to accelerate to V_1 speed and then to stop the airplane, assuming failure of the ________ engine at ________ speed.	
Figure 11-1 is a typical chart for determination of "critical engine failure speeds" which are also known as ________ speeds.	*critical* *V_1*
In using the chart, Figure 11-1, proceed vertically upward from *gross weight* to intersect an ________ ________ line.	*V_1*
Next, proceed horizontally to the left to intersect the V_1 lines; in the meantime, proceed vertically upward from a *wind value* to intersect the projected horizontal line. Where these two lines intersect is the ________ ________ ________ failure speed, sometimes called the ________ speed.	*airport* *altitude*
In the example depicted by dashed lines on the chart, Figure 11-1, the critical engine failure speed (V_1) is ________ knots (CAS).	*critical engine* *V_1*
Again using the chart, Figure 11-1, assume an airport elevation of 2,000 feet, airplane gross weight 80,000 pounds, and a zero wind; the critical engine failure speed is ________ knots (CAS). It is called ________ speed.	*110*
	100 *V_1*

Minimum Takeoff Runway Length

The minimum takeoff length can be defined as the distance required to accelerate the airplane to V_1, then either:

(a) reduce power and bring the airplane to a safe stop on the runway utilizing approved braking methods, or;

(b) cut the power to the critical engine, continue the ground roll to V_2, takeoff and climb to 50 feet with the critical engine windmilling, the remaining engine(s) at takeoff power, the flaps in takeoff position and gear retracted after takeoff.

CONDITIONS
- Wing Flap Setting 17°
- Hard Surface Runway
- No Runway Slope
- Standard Atmospheric Conditions

NOTE:
1. If the Critical Engine Fails at V_1, the Distance to Stop is Equal to the Distance to Climb to 50 Ft.
2. 150% of Reported Tailwind and 50% of Reported Headwind used in Construction of This Chart.

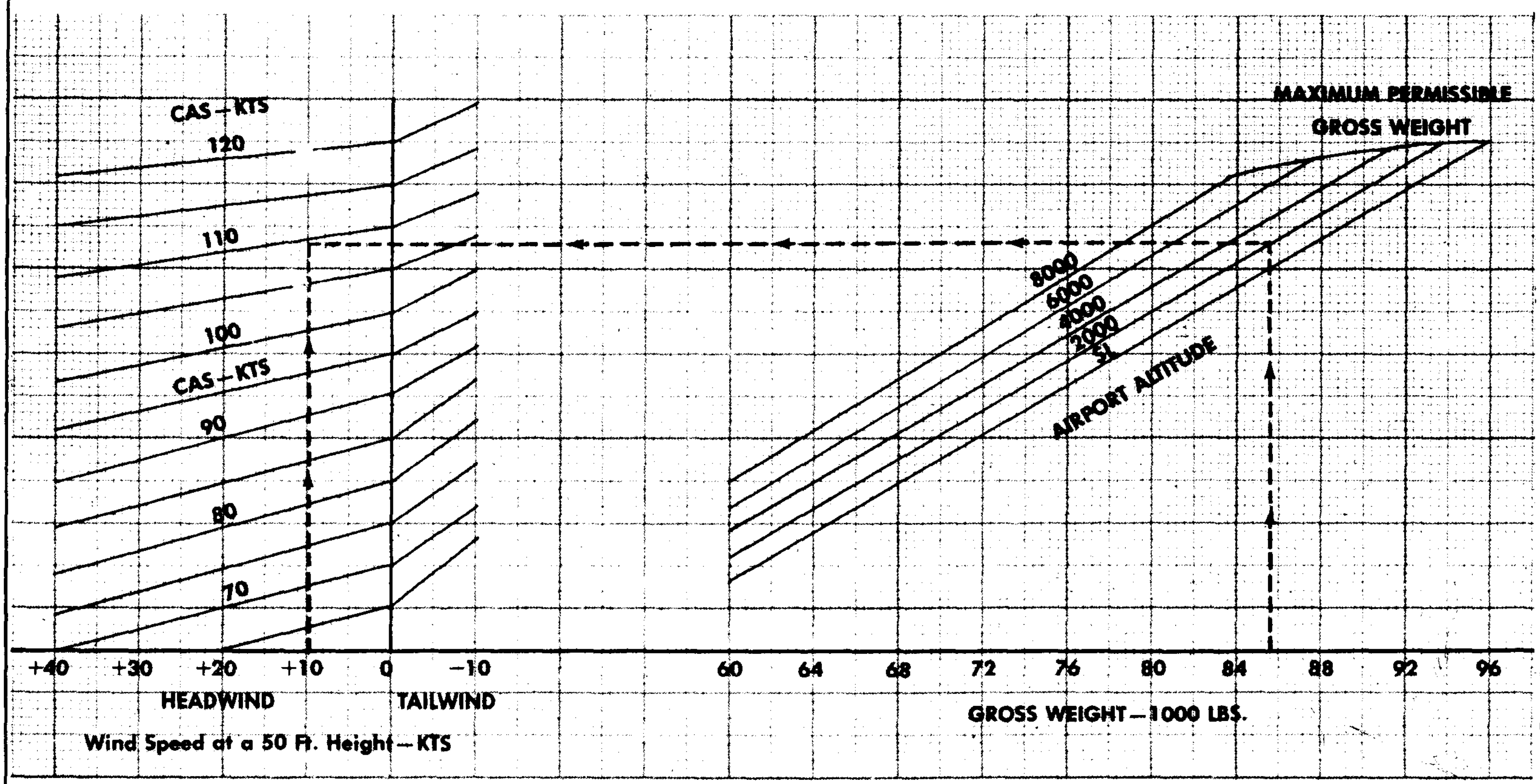


Fig. 11-1 – Critical Engine Failure Speed Chart (V_1)

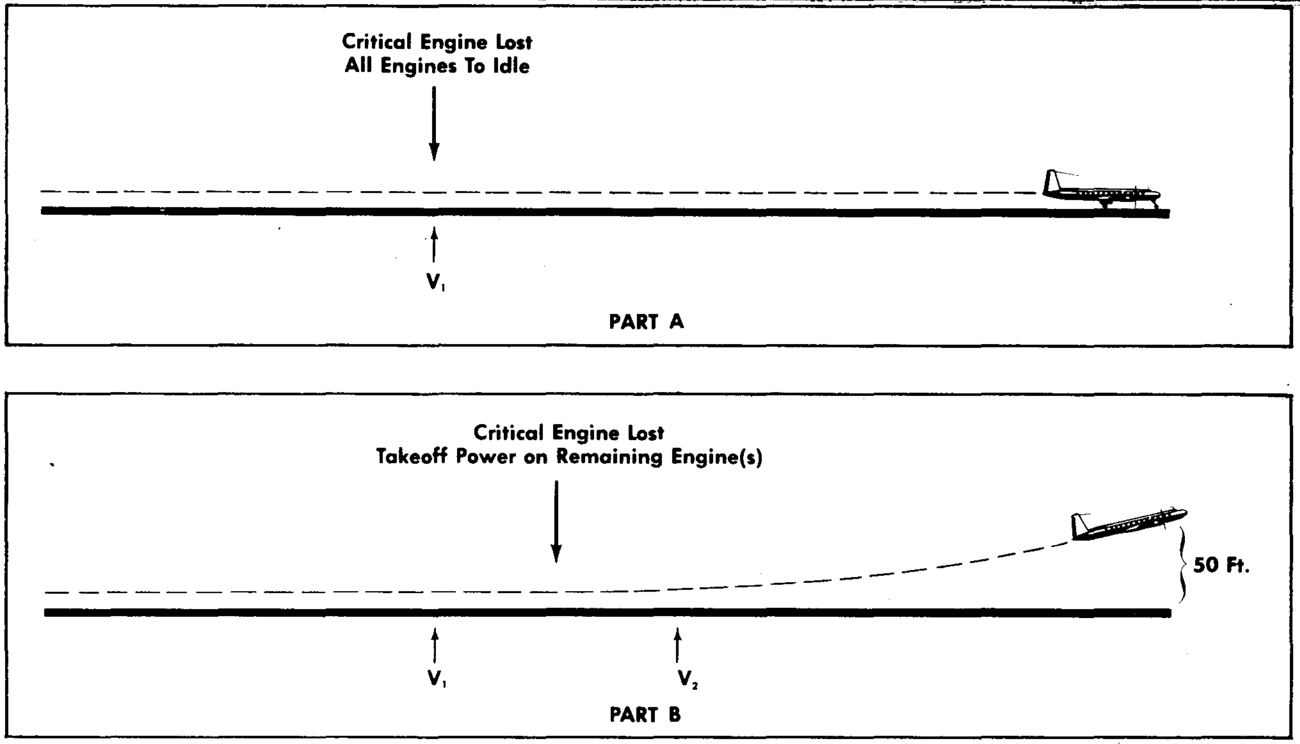


Fig. 11-2—Minimum Takeoff Runway Length

The minimum takeoff runway length is designed to afford a margin of safety in the event of engine failure. Part (A) in Figure 11-2 which corresponds to part (a) in the definition above, shows an airplane being brought to a stop on the runway after losing the critical engine at the V_1 speed. Part (B) in Figure 11-2, which corresponds to part (b) in the definition above, shows the airplane losing the critical engine after V_1, then accelerating to V_2 and climbing to a 50 foot height.

Many transport airplanes are designed so that the distances described in (a) and (b) are equal. However, if they are not equal, the longer distance shall serve as the minimum runway takeoff length.

The regulations governing the minimum takeoff runway length are not to be construed to mean that the pilot must discontinue or continue the takeoff roll at any certain point upon losing an engine. Taking off or aborting a takeoff is at the pilot's discretion. However, the regulations do state that the airplane must be capable of the operation outlined in the definition.

The minimum takeoff runway length chart (Figure 11-3) is very similar to Figure 11-1 and is interpreted in the same manner. Notice that the slanted lines at the left of the chart represent runway length instead of speed as in Figure 11-1. When the same values (85,600 pounds, 2,000 foot altitude and +10 knot wind) as were used in Figure 11-1 are used in Figure 11-3, the minimum takeoff runway length is 4,600 feet. This figure represents the minimum distance that must be allowed for takeoff under present regulations.

The distance required to accelerate the airplane to V_1 speed, then reduce power and bring the airplane to a safe stop on the runway utilizing approved braking methods, is one portion of the definition of the *minimum* __________ __________ *length.*

CONDITIONS:
- Wing Flap Setting 17°
- Hard Surface Runway
- No Runway Slope
- Standard Atmospheric Conditions

NOTE:
1. If the Critical Engine Fails at V_1, the Distance to Stop is Equal to the Distance to Climb to 50 Ft.
2. 150% of Reported Tailwind and 50% of Reported Headwind used in Construction of this Chart.

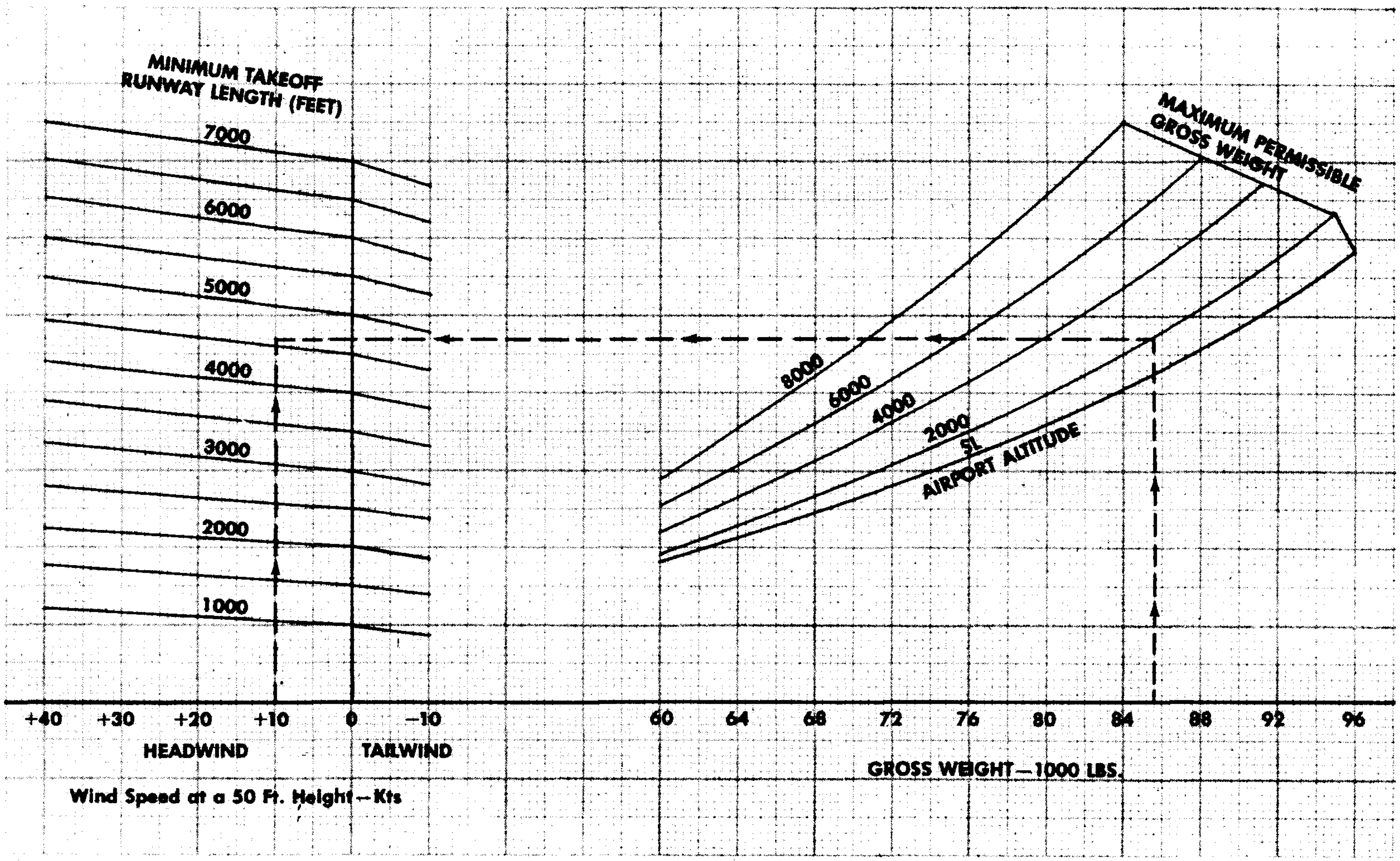


Fig. 11-3—Minimum Takeoff Runway Length Chart

A second portion of the definition of the *minimum takeoff runway length* is the distance required to accelerate to V_1, cut power on the ________ engine, continue to V_2 and then takeoff and climb to ________ feet with critical engine windmilling, and remaining engines at ________ power, flaps in takeoff position and gear retracted after takeoff.	*takeoff runway*
The minimum takeoff runway length is designed to afford a margin of safety in case of ________ failure during takeoff.	*critical* *50* *takeoff*
Regulations define the minimum takeoff performance of T-Category airplanes. The decision to continue or discontinue a takeoff is made by the ________.	*engine*
In the Takeoff Distance Chart, Figure 11-3, the minimum takeoff runway length in the example shown by dashed lines and arrows is ________ feet.	*pilot*
To use the chart, Figure 11-3, proceed vertically upward from airplane gross weight to a line which represents ________ ________.	*4,600*
Next, proceed horizontally to the left to intersect the lines representing *minimum takeoff runway length;* meanwhile proceed vertically upward from the *wind value* to intersect the projected horizontal line. This point of intersection represents the minimum ________ ________ length.	*airport* *altitude*
Using the chart, Figure 11-3 with 80,000 pounds gross weight and runway altitude of 2,000 feet, and with a zero wind, the minimum takeoff runway length is ________ feet.	*takeoff runway*
Under the same conditions, except with a tailwind of 10 knots, the takeoff length would be increased by ________ feet.	*4,000*
	200

Gradient Corrections

Now, assuming the minimum takeoff runway length has been established at 4,600 feet, consider the effect of runway gradient on takeoff distance. For example, suppose that the takeoff runway has an uphill gradient of +1.5%. Referring to Figure 11-4, notice that a vertical dashed line has been drawn on the 4,600 foot takeoff length line. This dashed line is continued until it intersects the slanted runway gradient lines at 1.5%. From this point, follow the horizontal dashed line to the left to 5,600 feet, which is the minimum runway takeoff length corrected for gradient.

To use the Runway Gradient Chart, Figure 11-4, proceed vertically upward from *minimum takeoff runway length without gradient* to intersect a *runway gradient line,* then proceed horizontally left to takeoff length with ________.	

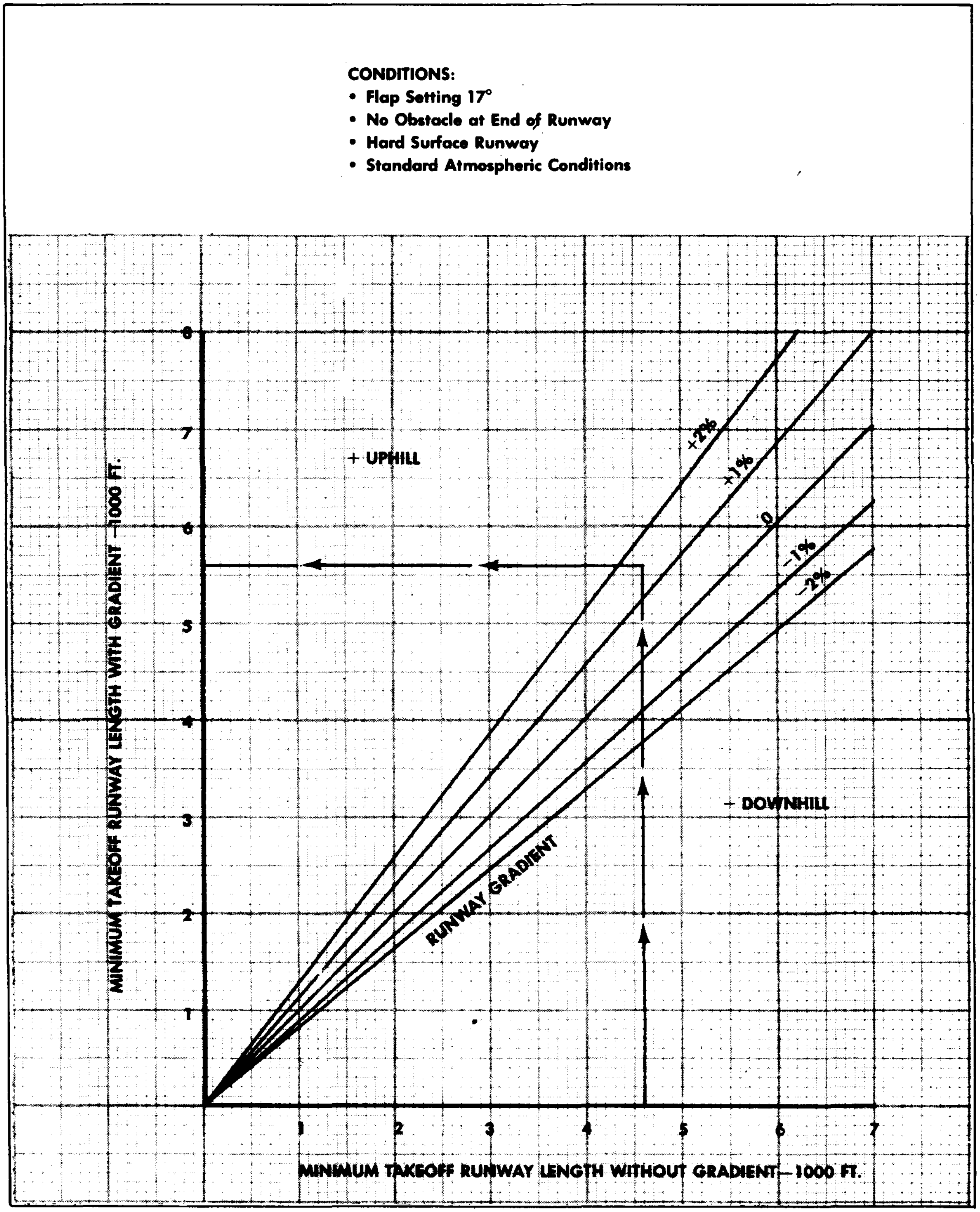


Fig. 11-4—Effect Of Runway Gradient On The Minimum Takeoff Runway Length

The takeoff length with gradient in the dashed line example on the chart, Figure 11-4, is ______ feet.	*gradient*
Again using the chart, Figure 11-4, assume the runway length without gradient is 5,000 feet and the actual runway gradient is +2.0%. The minimum takeoff runway length with gradient is ______ feet.	*5,600*
	6,450

Temperature Accountability

Temperature accountability can be approached in two different ways. If it is desired that the airplane gross weight remain constant, then the minimum required runway length must be amended as the temperature varies. If it is desired that the minimum required runway length remain constant, then it may be necessary to change the maximum gross weight with temperature variations.

For example, consider an airplane with a gross weight of 85,600 pounds. Assuming that the airplane must carry this load, the minimum required runway length will probably have to be corrected when the temperature varies appreciably from standard (59°F. at sea level).

Temperature accountability data will vary from airplane to airplane. However, for the purpose of this example use 12 feet as the amount that must be added to the minimum required takeoff runway length for each degree above standard temperature. Likewise, for every degree below standard, 6 feet may be subtracted.

A runway temperature of 90°F. would be 31° above standard temperature. Multiplying 31 × 12, we find that 372 feet must be added to the minimum required takeoff length.

When the takeoff runway length must remain constant, it may be necessary to adjust the gross weight to conform with temperature variations. In the case of the hypothetical air carrier, the maximum gross weight must be reduced 70 pounds for each Fahrenheit degree above standard temperature. For every Fahrenheit degree that the temperature drops below standard, 50 pounds may be added provided the maximum allowable gross weight is not exceeded. Remember that the figures given above are for example only, each type of airplane will require a different temperature correction.

Stall Speeds

Figure 11-5 depicts the effect of gross weight and airplane configration on stalling speed. The chart is read in the same manner as those previously studied in this section. The example utilized in Figure 11-5 concerns an airplane weighing 85,600 pounds with the landing gear retracted and the flaps at 17°. In this situation the stalling speed would be 95 knots IAS.

Since airplane performance varies with temperature, because of the variation of air density, the required runway length changes with ______ changes (assuming equal airplane gross weights).	
Higher temperatures tend to increase minimum takeoff runway lengths required, whereas lower temperatures tend to ______ the minimum takeoff runway length.	*temperature*
The standard temperature for a sea level runway is 59°F. If *12 feet* are added to runway length for each degree of temperature above standard, then for a temperature of 79°F. at sea level, add ______ feet to runway length required.	*decrease*

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DATE: 1 June 1966

REF: 2000 - 1

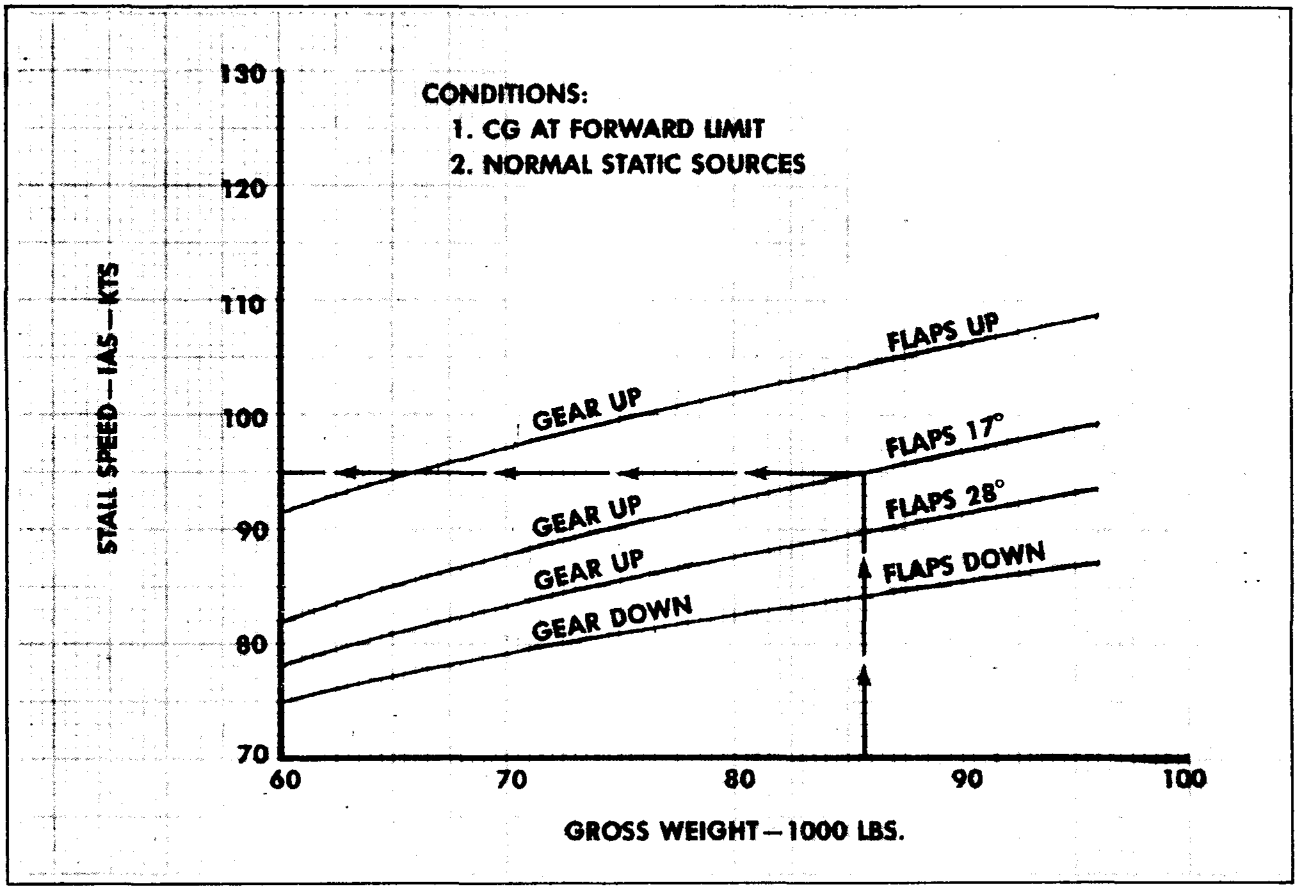

Fig. 11-5—Zero Thrust Stall Speeds

The runway length is decreased *5 feet* for each degree of temperature below standard in the above example. If the temperature was 41°F. the runway length required would be (increased) (decreased) ______________ by ______________ feet.	*240*
Using a constant runway length, the airplane gross weight is decreased as temperature increases and conversely can be ______________ as temperature ______________.	*decreased* *108*
If weight is reduced 70 pounds for each degree above standard, then at an airport at 3,000 feet (standard temperature at 3,000 feet is 48°F.) with a temperature of 90°F., the weight should be reduced ______________ pounds.	*increased* *decreases*
In the chart, Figure 11-5, the example represented by the dashed lines and arrows results in a stalling speed of ______________ knots (IAS).	*2,940*
Using the chart, Figure 11-5, with a *gross weight of* 90,000 pounds, gear-up and flaps-up, the stalling speed would be ______________ knots (IAS).	*95*
	106

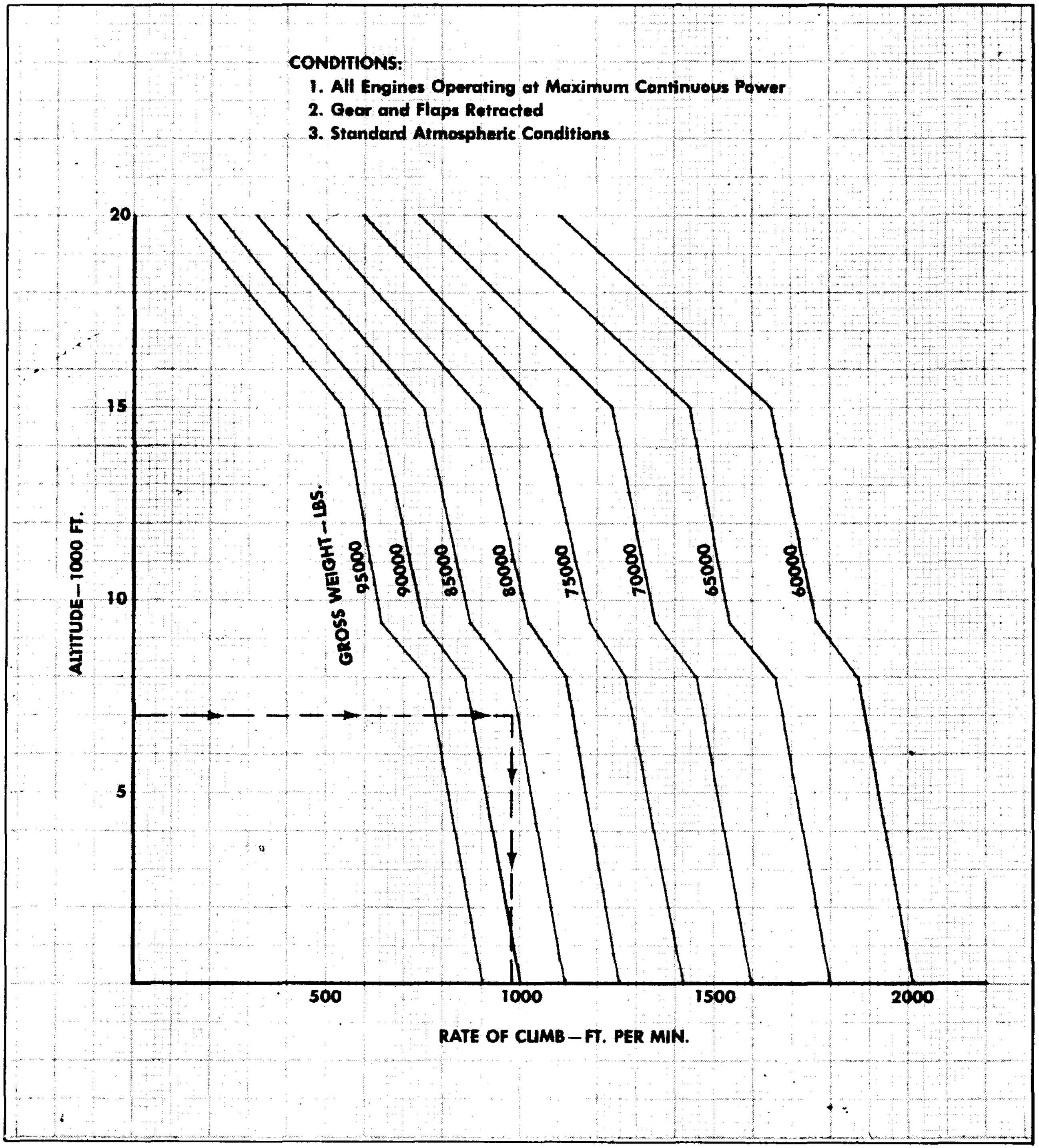

Fig. 11-6—Four Engine Climb

Climb Performance

Figure 11-6 contains climb performance data for a reciprocating engine transport airplane with all four engines operating at maximum continuous power. Similar charts, constructed for two and three engine performance are not shown, however such charts would be interpreted in the same manner.

As an example, refer to the chart in Figure 11-6 to determine the rate of climb at an altitude of 7,000 feet if the gross weight of the airplane is 86,000 pounds. Notice, on the left side of the chart, that a dashed line has been drawn on the 7,000 foot line to the line representing a gross weight of 86,000 pounds. From this intersection, the dashed line has been drawn vertically on the line representing a 980 foot-per-minute rate of climb.

It should be noted that the rate of climb decreases more rapidly at the 8,000 and 15,000 foot altitudes. These two points represent engine critical altitudes for the low and high supercharger speeds respectively. The *critical* or *full throttle altitude* for a given power setting is that altitude at which the throttle must be fully opened to maintain the given manifold pressure.

It should be noted in Figure 11-6, that the rate of climb is definitely increased at the 9,400 foot level. This represents the point at which a shift is made from low to high blower.

Climb performance of aircraft is indicated on charts similar to the one in Figure 11-6. By following the dashed lines and arrows horizontally to the right beginning at an altitude of 7,000 feet to a gross weight of 86,000 pounds, then vertically downward, the rate of climb is found to be ______________ feet per minute.	
Using the chart, Figure 11-6, at an altitude of 12,000 feet, with an airplane gross weight of 70,000 pounds, the rate of climb is ______________ feet per minute.	*980*
The gross weight lines on the chart, Figure 11-6, bend to the left at 15,000 feet reflecting a decrease in rate of climb. This decrease occurs because the ______________ altitude of the engines is being exceeded.	*1,300*
The blower shift altitude is shown where the lines bend left and then right again at approximately the ______________ foot altitude.	*critical*
The altitude above which an engine can no longer deliver rated power is a ______________ altitude.	*9,400*
In the chart, Figure 11-6, the critical altitude for low blower operation occurs at 8,000 feet and the critical altitude for high blower operation occurs at ______________ feet.	*critical*
	15,000

Ceiling Performance

Various ceilings are established according to the rate of climb of the airplane at a specific altitude. The "absolute ceiling" is defined as the maximum altitude at which a given airplane can maintain level flight in a standard atmosphere. The "service ceiling" is the altitude at which an airplane is unable to attain a vertical velocity of more than 100 feet per minute in a standard atmosphere. These ceilings will vary somewhat as turbulence is encountered.

Changes in air density and temperature will have the same effect on airplane performance at altitude as when at sea level. The pilot can expect better performance in dense, cold air than he can expect in warm air of less density.

Power Control Charts

Power charts and curves are considered, by many pilots, to be overly dull or too academic and thus of little value to anyone except the aeronautical engineer. However, a thorough knowledge of the use of power charts will enable the pilot to analyze and predict reciprocating engine performance. Power charts give the pilot the capability of calculating, among other things, critical altitudes, efficient RPM—manifold pressure combinations, and safe engine operating limits.

Each power chart is intended for a specific engine configuration and is not interchangeable. Fuel grade, mixture setting, supercharger speed ratios, fuel metering and many other variables affect the engine power output to the extent that erroneous readings would result from the use of the wrong power chart.

Most power charts are divided into two parts, as illustrated in Figure 11-7. The left portion contains sea level data and the right portion contains altitude data. With few exceptions, the two portions cannot be used independently of each other.

The RPM lines on the sea level chart in Figure 11-7 are referred to as "*part* throttle constant RPM lines". This is because many engines designed to operate at altitude have cylinder pressure restrictions that prohibit full throttle application at sea level. The RPM lines on the altitude chart are called "*full* throttle constant RPM lines" because less air density at altitude allows full throttle application. The MAP lines in the altitude chart are constant manifold pressure lines and are based on full throttle operation.

Since manifold pressure (MAP) lines and RPM lines in the altitude chart are based on full throttle operation, the critical altitude for any power setting may be easily determined. For example, notice in Figure 11-7 that a vertical line has been drawn from the intersection (point X) of the lines representing 1800 RPM and 22 inches manifold pressure. The altitude line (12,000 feet) on which these two lines intersect is the critical or full throttle altitude for this particular power setting.

Problems involving power charts usually fall into two general categories: (1) The computation of brake horse power (BHP is the power actually delivered to the propeller) when manifold pressure, altitude and RPM are known, and (2) the computation of manifold pressure when BHP, RPM and altitude are known. Problem one will be considered first.

Problem 1. (Figure 11-7)

Given: Manifold pressure (MAP)	28 inches
RPM	2000
Altitude	4,000 ft.

Required: BHP

Solution:

1. In Figure 11-7, locate the intersection of 28 in. manifold pressure (MAP) and 2000 RPM on the *sea level calibration chart.* This point has been labeled A.
2. Project point A horizontally to the BHP axis on the altitude calibration chart. This point is labeled B.
3. Locate the intersection of 28 inches manifold pressure and 2000 RPM on the altitude calibration chart. This point is labeled C.
4. Connect points B and C with a straight line.
5. Locate the intersection of the 4,000 foot line and line BC. This point is labeled D.
6. Project point D horizontally to the BHP axis (point E). The correct answer of 520 BHP is read at point E.

It should be noted that in this case, the engine is not operating at full throttle since point D lies well below the given full throttle, constant RPM line of 2000.

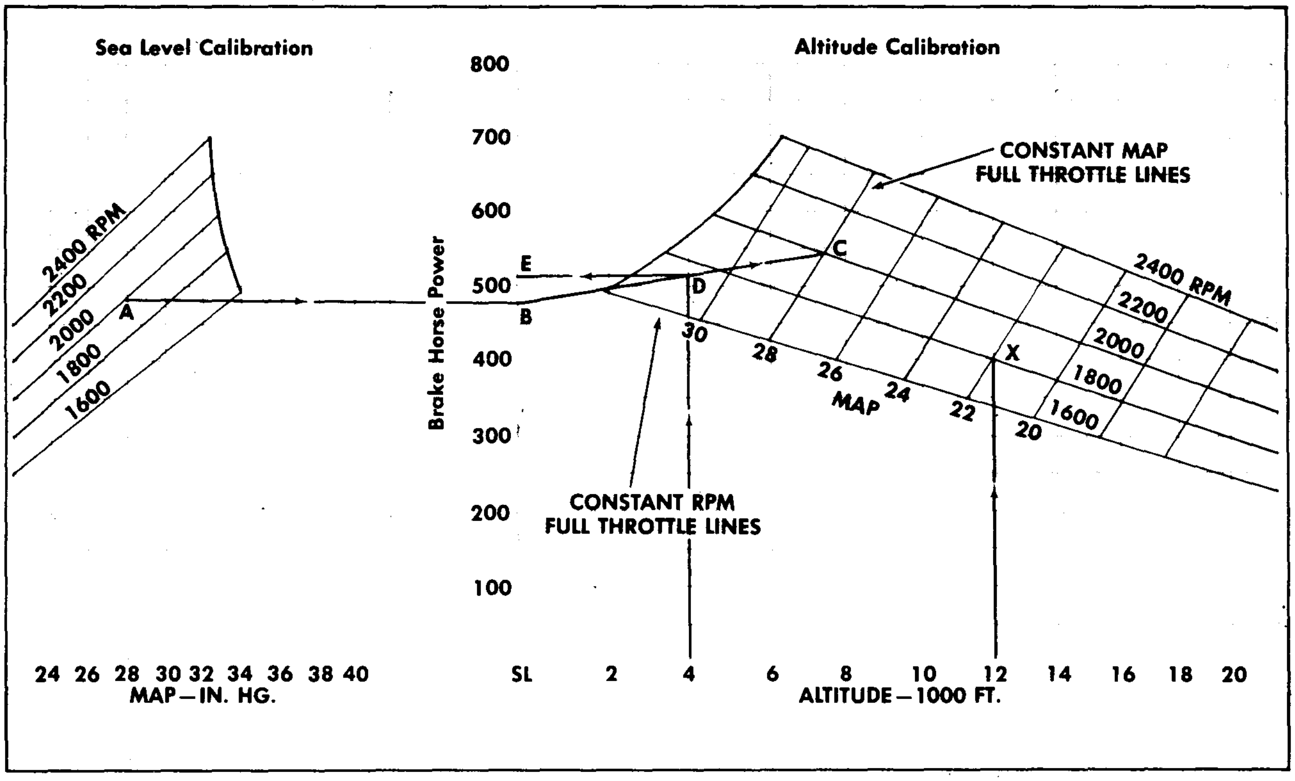

Fig. 11-7—Power Chart

The maximum altitude at which an airplane can maintain level flight, in a standard atmosphere is called "the absolute ____________".	
The "service ceiling" is an altitude, in a standard atmosphere, at which an airplane is unable to attain a vertical (climb) velocity of more than ________ ________ feet per minute.	*ceiling*
A professional pilot has need for knowledge of ____________ charts.	*100*
Most power charts, as in the example of Figure 11-7, have two parts: (1) a sea level calibration, and (2) an ____________ calibration.	*performance (power)*
The two parts of a power chart are related, and in most cases are used ____________.	*altitude*
Intersections of RPM and MAP lines, based on full throttle setting, will, for a given power setting, indicate the ________ altitude for that power.	*together*
Power charts are normally used to determine either (1) manifold pressure required, or (2) ____________ horse power available.	*critical*

(a) To find brake horse power, use the dashed line in Figure 11-7 as an example. First find the MAP/RPM point on the sea level calibration, which is point "__________" in the sample problem.	*brake*
(b) Project point "A" horizontally to the right to the Brake Horse Power *axis* on the altitude calibration chart. This is point "__________".	*A*
(c) Find the intersection of MAP/RPM again on the altitude calibration chart. This is point "C". Connect points "B" and "C" with a __________ __________.	*B*
(d) Since the problem gives an altitude of 4,000 feet, find where the vertical 4,000 foot line intersects line "B – C", which is point "__________".	*straight line*
(e) Project point "D" horizontally left to point "E" on the BHP axis. At this point read the BHP of __________ which is the answer in the example problem.	*"D"*
In problem one, the engine (is) (is not) __________ __________ operating at full throttle.	*520*
Here is another example problem: Given MAP equals 30 inches; RPM equals 2100 RPM; altitude equals 6,000 feet. In this example the resultant BHP is __________.	*is not*
	600

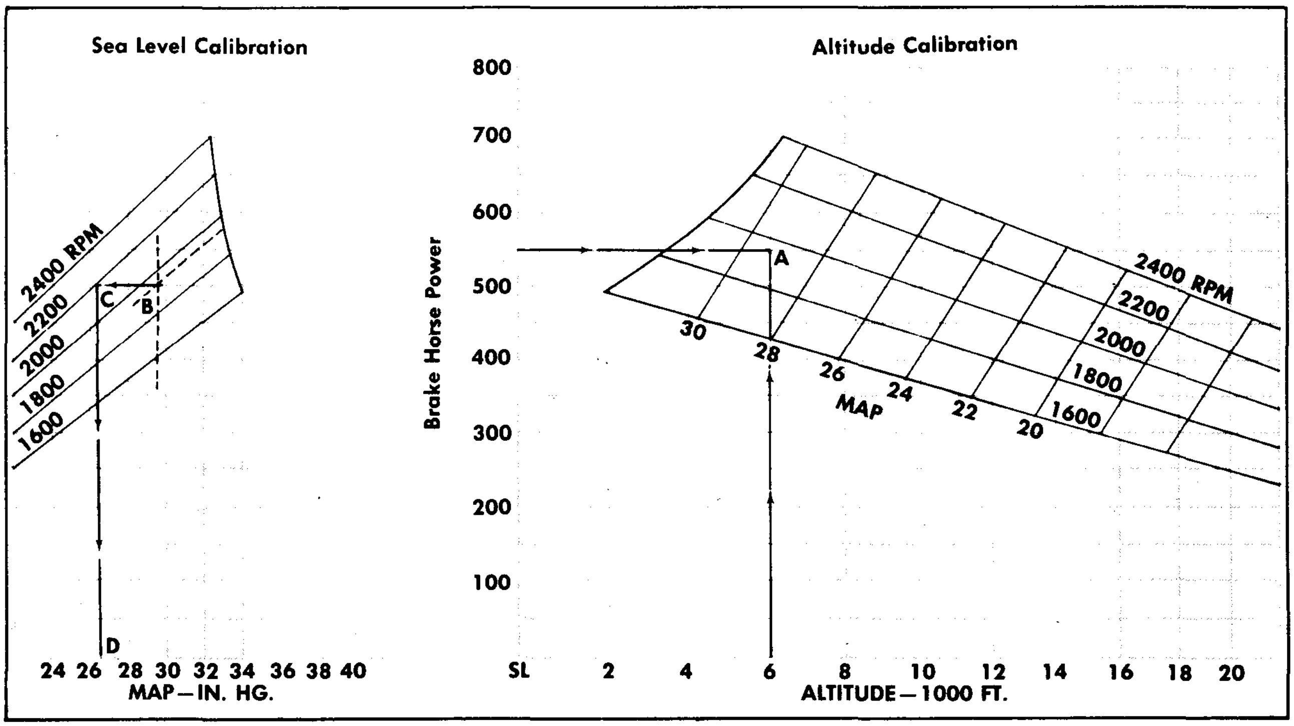

Fig. 11-8—Power Chart

Problem 2. (Figure 11-8)

Given: BHP 550
RPM 2200
Altitude 6,000

Required: Manifold pressure

Solution:

1. In Figure 11-8 locate the intersection of the lines representing 550 BHP and 6,000 feet altitude (point A) on the *altitude calibration chart.*
2. Determine the full throttle, constant RPM line (1950 RPM) and the constant manifold pressure line (29.5 inches MAP) at point A.
3. Transfer these values (1950 RPM and 29.5 inches MAP) to the sea level calibration chart (point B).
4. Project intersection B horizontally until it intercepts the given 2200 RPM line at point C.
5. Project point C vertically to the MAP axis and read the required MAP of 26.5 at point D.

(a) The example problem shown in Figure 11-8 is used to determine required manifold pressure (MAP), with certain known factors: BHP 550; RPM 2200; altitude 6,000 feet. On the altitude chart locate the intersection of lines representing 550 BHP and 6,000 feet altitude, which is point "________".	
(b) At point "A" read 1950 RPM and 29.5 inches MAP. On the sea level calibration chart locate a point representing 1950 RPM and 29.5 inches MAP which is at point "________".	*A*
(c) Project point "B" horizontally left to intersect the 2200 RPM line (per original problem factors) at point "C". Project vertically downward from point "C" to read required MAP of ________ inches.	*B*
In another example, find MAP with BHP 550, RPM 2200 and altitude 8,000 feet. The MAP required in this example is ________ inches.	*26.5*
	25.5

Power charts are based on standard atmospheric conditions. Deviation from these conditions will not affect the use of the power chart, however, it should be noted that power charts are calibrated in terms of density altitude which is the same as using pressure altitude in a standard atmosphere. For this reason it is recommended that the altimeter be indexed to standard sea level pressure (29.92 inches) when gaining data for use in power charts.

Carburetor Air Temperature Correction

Another factor of which the pilot must be aware is the correction made when carburetor air temperature (CAT) deviates from standard. Since temperature affects the density and thus the weight of the fuel-air mixture, BHP will definitely be affected by CAT variation.

The correction to BHP is made as follows:

1. To the BHP calculated from the power chart, add 1% of power for each 6°C. (10°F.) that CAT is below standard temperature; or
2. Subtract 1% of power for each 6°C. above standard temperature.

For example, on a flight at 5,000 feet pressure altitude, the BHP is computed to be 635 and the CAT gauge reads 23°C. Since 23°C. is 18° above standard (5°C. is standard at 5,000 feet), 3% or 19 BHP must be subtracted, giving a total of 616 BHP. If the CAT gauge had read −7°C., i.e. 12°C. below standard, 2% of 635 BHP would be added. In this case, 13 would be added to 635 giving a total of 648 BHP.

When the problem involves the calculation of manifold pressure from the power chart, corrections for deviation in CAT are made in the following manner.

1. To the MAP obtained from the power chart, add ¼ inch for each 6°C. above standard temperature.
2. Subtract ¼ inch for each 6°C. below standard temperature.

For example, on a certain flight at 6,000 feet pressure altitude, the MAP required is computed to be 33 inches and the CAT gauge reads 9°C. Since 9°C. is 6° above standard (3°C. is standard at 6,000 feet) ¼ inch must be added to the computed 33 inches to arrive at the actual MAP required. Thus, the correct answer would be 33.25 inches. If the CAT gauge had read −9°C., i.e. 12° below standard, ½ inch would be subtracted from 33 inches giving a required MAP of 32.50 inches.

Density altitude is used in power charts. Density altitude is a function of pressure altitude and standard ________.	
For use in power charts, the pilot may read pressure altitude directly from the altimeter when it is set to ________ inches.	*temperature*
For some types of calculations, outside air temperature (OAT) is used. For power chart use, however, ________ air temperature (CAT) is used.	*29.92*
CAT has an effect on engine power because it affects the air ________.	*carburetor*
One method of correcting BHP for CAT effects is for each *6°C. (10°F.)* that CAT is *below standard,* add ________% to BHP.	*density*
If the CAT is *above standard* (add) (subtract) ________ one percent (1%) of power for each ________°C. above standard temperature.	*1*
Standard Temperature in this example is 15°C; actual CAT is 33°C. A BHP of *600* should be corrected to ________ BHP as a result of the CAT.	*subtract* *6*
Another rule for use in power charts states that for each 6°C. CAT above standard, add ________ inch to the MAP obtained from the chart.	*582*
Conversely, if CAT is below standard (add) (subtract) ________ ¼ inch from MAP for each 6°C. that CAT is below standard.	*one-fourth*
If the CAT is 18°C. below standard, then the MAP of *26.5* inches read from the power chart would be corrected to ________ inches.	*subtract*
	25.75

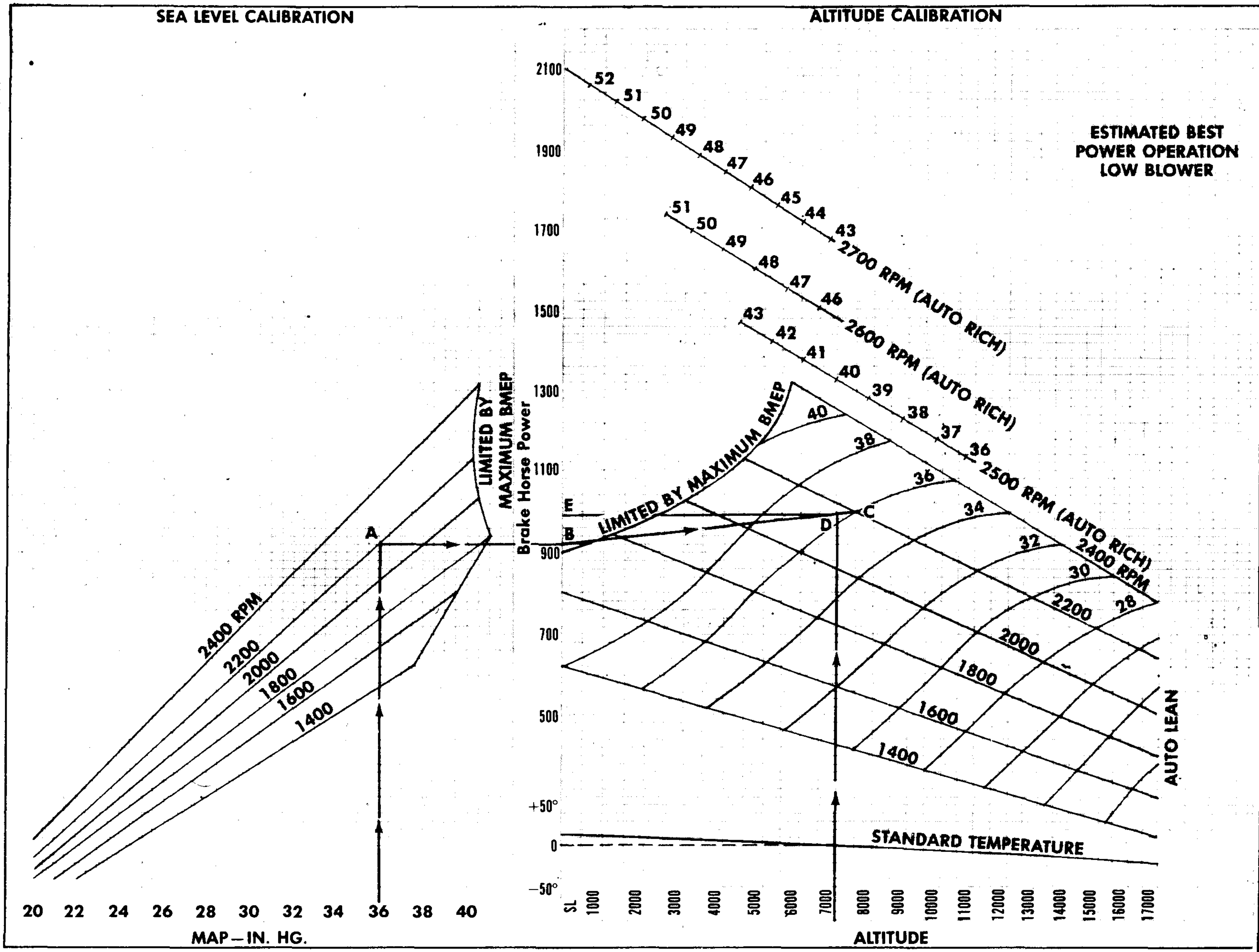

Fig. 11-9—Power Chart

Figure 11-9 depicts a typical power chart currently in common use. This chart is very similar to those illustrated in previous figures except that auto rich RPM lines have been added on the altitude calibration side of the chart. Also, a standard altitude temperature line has been drawn in the lower portion of the altitude calibration chart. This line makes it possible to calculate the approximate standard temperature at any given altitude. For example, if the standard temperature at 7,000 feet is required, enter the chart at the 7,000 foot line at the bottom of the figure. Follow this line until it intersects the slanted standard temperature line. Project this intersection horizontally to the left until reaching the temperature axis. The dashed horizontal example line is located at 1°C. which is approximately the standard temperature at 7,000 feet.

Use the power chart in Figure 11-9 to solve the following problem.

Given:

RPM	2200
MAP	36 inches
Altitude	7,000 feet
CAT	+7°C.

Required:

BHP

Solution:

1. Plot the intersection of 36 inches and 2200 RPM on the sea level chart. This point is labeled A.
2. Project point A horizontally to the BHP axis. This point is labeled B.
3. Plot 36 inches and 2200 RPM on the altitude chart. This point is labeled C.
4. Connect points B and C with a straight line.
5. Plot the intersection of the 7,000 foot altitude line and line BC. This point is labeled D.
6. Project point D horizontally to the BHP axis and read the correct BHP of 995. This point is labeled E.
7. Subtract 1% of BHP because of CAT deviation from standard temperature. BHP equals 985.

In the example problem, Figure 11-9, it is required that BHP (corrected for CAT) be determined when RPM equals 2200, MAP equals 36 inches, altitude equals 7,000 feet and CAT equals +7°C. In the solution, first locate 2200 RPM and 36 inches MAP on the sea level calibration chart which is at point "__________".	
Next, project "A" horizontally right to the BHP axis at point "B". Locate 36 inches MAP and 2200 RPM on the altitude calibration chart which is at point "__________".	*A*
Connect points "B" and "C" with a __________ __________. Find a point where the vertical 7,000 foot altitude line intersects line "_____"–"_____" at point "D".	*C*
Project point "D" horizontally left to a BHP of __________. Apply the CAT correction of 1%/6°C. to find a corrected BHP of __________.	*straight line* *B–C*

Do another example. Find the corrected BHP if RPM equals 2000; MAP equals 34 inches, altitude equals 7,000 feet and CAT equals −5°C. First locate point "A" on the sea level calibration chart where ______ and ______ interesect.	*995* *985*
Next project point "A" horizontally right to the BHP axis at point "B", then locate point "C" on the altitude chart where ______ and ______ intersect.	*MAP 34 inches* *RPM 2000*
Draw line "BC" and where it intersects the vertical 7,000 foot line, locate point "______".	*MAP 34 inches* *RPM 2000*
Project point "D" horizontally left to the BHP axis and read a BHP of ______. After correcting for a CAT of −5°C., (standard temperature at 7,000 feet is +1°C.) the corrected BHP becomes ______.	*D*
	830 *838*

Determination of Cruise Altitude

Desirable cruise altitudes are established to aid the pilot in determining the altitudes that are best suited for a given operation. The maximum desirable cruise altitude is that maximum altitude at which the optimum long range cruise airspeed can be maintained. While the airplane will climb above its maximum desirable altitude, it will only do so while sacrificing airspeed.

Under a given power setting condition, airspeed will vary with gross weight, thus gross weight is a function of the maximum desirable cruise altitude. Notice that in the Maximum Desirable Cruise Altitude Chart (Figure 11-10), the gross weight is plotted against pressure altitude. The slanted BHP lines establish the maximum desirable cruise altitude for a given gross weight. It must be remembered that the critical altitudes referred to in this instance will only remain true under the specific conditions given in the chart. The data given here should not be confused with critical altitude information established under maximum continuous power conditions.

As an example in the use of the Maximum Desirable Cruise Altitude Chart, consider a transport airplane operating at 1100 BHP and with a gross weight of 84,000 pounds. Notice on the chart, that a dashed example line has been drawn vertically on the line representing 84,000 pounds until it intersects the slanted line representing 1100 BHP. This intersection is projected horizontally to the pressure altitude axis, giving an answer of 16,000 feet. Thus, 16,000 feet is the maximum desirable altitude for the airplane under the prescribed conditions.

This chart is based on standard atmospheric conditions. For precise computation, a correction must be made when the temperature deviates from the standard temperature at a given altitude. The maximum desirable cruise altitude should be:

(1) increased by 100 feet for each degree Centigrade deviation below standard temperature.
(2) decreased by 100 feet for each degree Centigrade deviation above standard temperature.

In using the Maximum Desirable Cruise Altitude Chart (Figure 11-10), obtain the maximum desirable cruise altitude by proceeding vertically upward from the gross weight line to the slanted ______. Next, proceed horizontally left to read the desirable ______ ______.	

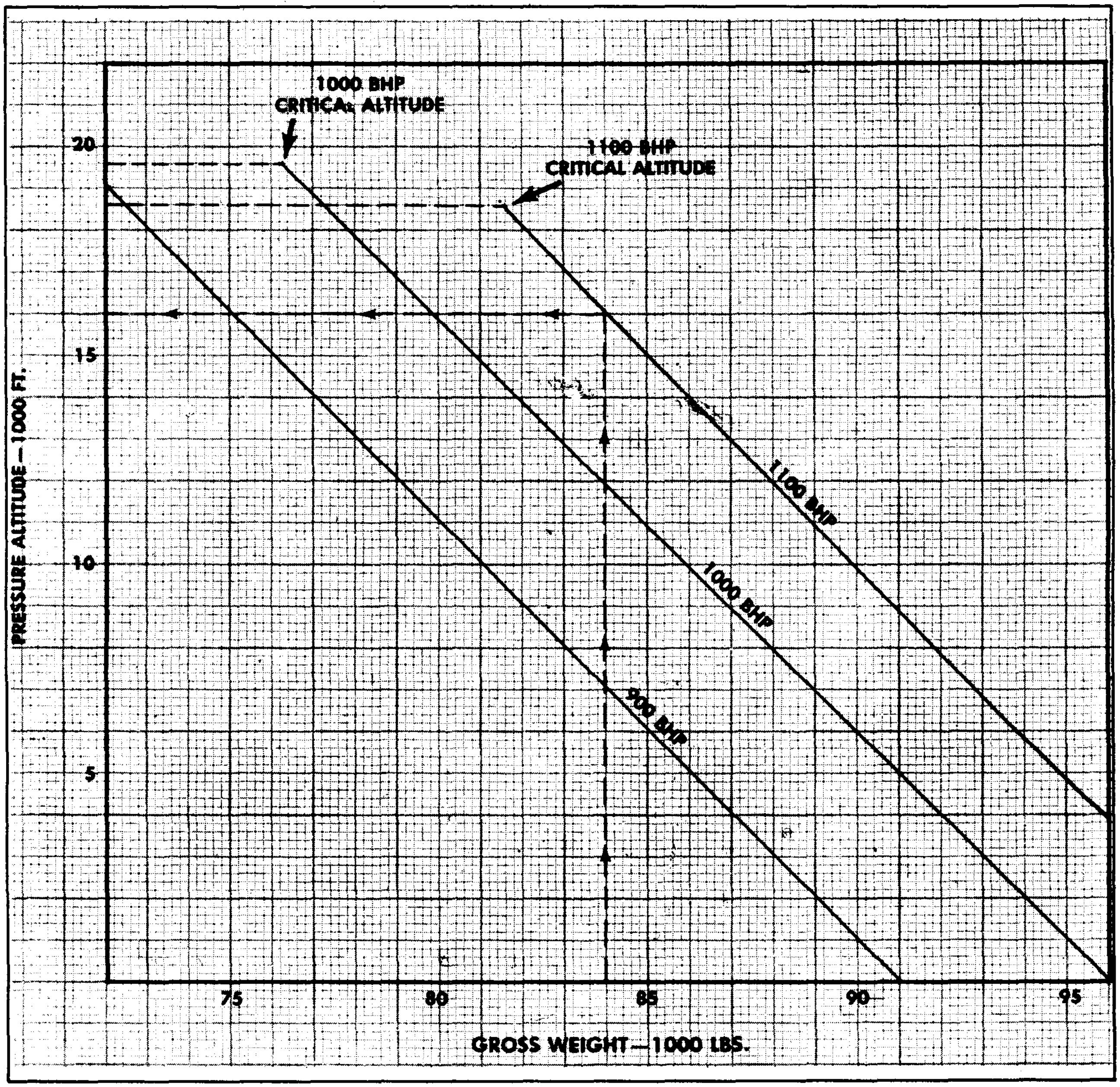

Fig. 11-10—Maximum Desirable Cruise Altitude

Increase or decrease altitude determined by the chart (Figure 11-10) 100 feet for each degree temperature (°C) deviation below or above __________ __________.	*BHP* *pressure altitude*
For a gross weight of *86,000 pounds,* using *1,000* BHP for cruise, the maximum desirable cruise altitude is __________ feet.	*standard* *temperature*
	9,900

Effective Runway Length

Takeoff and landing lengths are often spoken of in terms of effective lengths. The effective length of a runway must be considered when an obstruction is located in a potentially hazardous position with respect to the takeoff and approach paths associated with that runway.

The effective length of a runway is determined by an obstruction clearance line which is tangent to or clears all obstructions along a takeoff or landing path. This line is projected from the runway at a slope of 20 to 1 as illustrated in Figure 11-11.

The effective runway length may or may not be equal to the actual runway length depending on the position of obstructions in the airport vicinity. If there are no obstructions in the takeoff or approach paths, the effective and actual runway lengths will be equal. If obstructions do exist in the flight path area, the effective length may be less than the actual runway length.

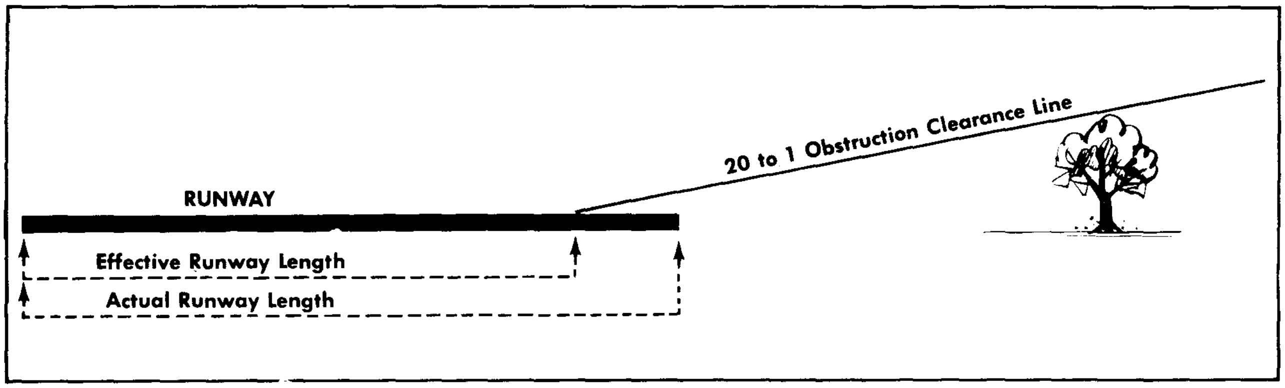

Fig. 11-11—Effective Runway Length

Landing Considerations

Regulations state that a transport airplane shall not be taken off in excess of that weight which would allow the airplane to be brought to a stop at the conclusion of the flight on 60% of the effective runway at the intended destination. It is assumed that the weight of the airplane will be decreased by the fuel and oil consumed enroute to the destination.

The actual landing distance is measured from a point 50 feet above the intersection of the obstruction clearance line and the runway. This distance can be determined by referring to the chart in Figure 11-12.

As an example, in the use of the landing distance chart (Figure 11-12), consider the following problem.

Given: Landing gross weight: 70,000 pounds
Field altitude: 1,000 feet
Wind condition: +25 knots

Required:
Landing distance from a 50 foot height.

Solution:
Notice, by referring to the dashed line, that the chart is entered at the gross weight of 70,000 pounds. The dashed line is drawn vertically until it intersects the 1,000 foot airport altitude line. This intersection is projected horizontally to the +25 knot wind line. Interpolation between the slanted landing distance lines at this intersection will give a landing distance of approximately 2,280 feet.

CONDITIONS:
- No Runway Slope—Standard Atmospheric Conditions
- Hard Surface Runway—Flaps Full Down

NOTE: This Chart Constructed Using 50% of Reported Headwind and 150% of Reported Tailwind.

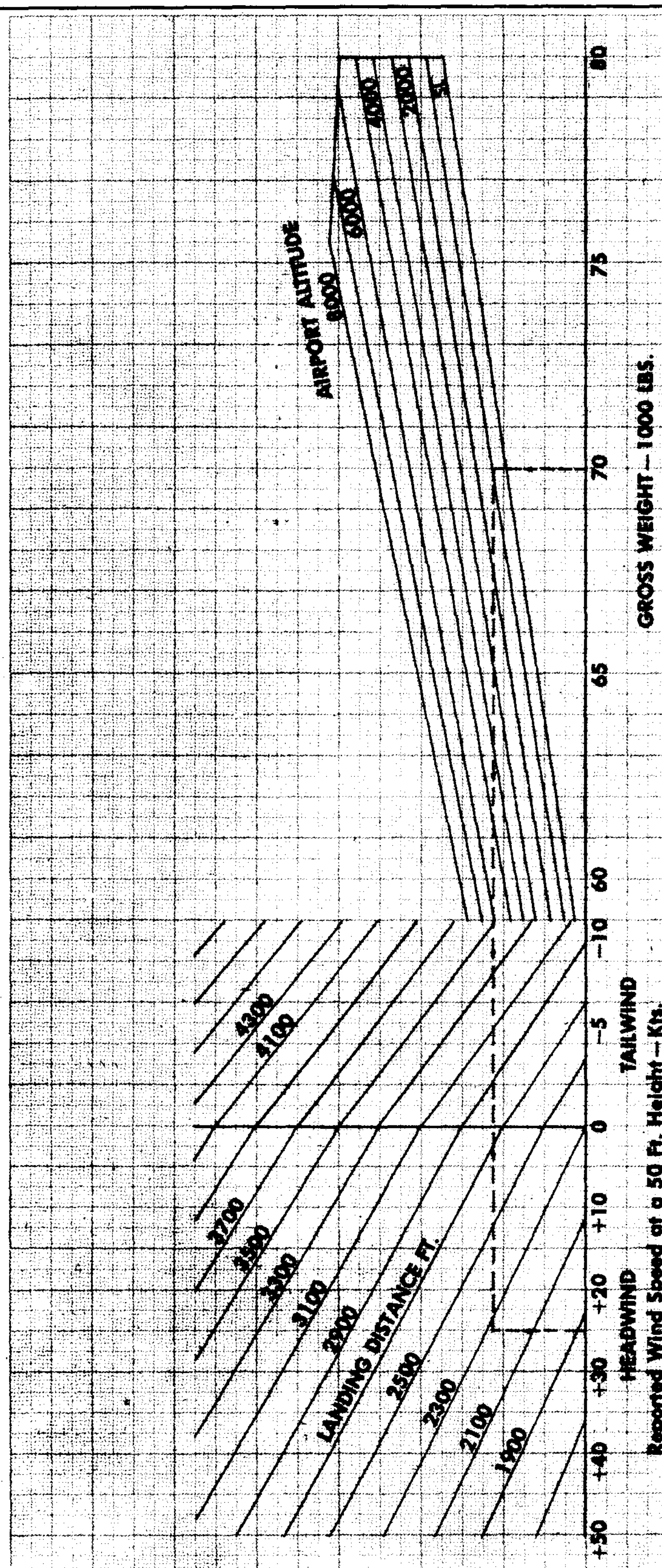

Fig. 11-12—Landing Distance From a 50 Ft. Height

The takeoff gross weight shall not be greater than that which would allow, after normal fuel burn-out, the airplane to land and be brought to a stop within ________% of the effective runway at the ________.	
The "effective length" of a runway is determined by an "obstruction clearance line" which is tangent to or clears all obstructions located along the takeoff or ________ path.	*60* *destination*
The slope of the "obstruction clearance line" is ________ to 1.	*landing*
Where obstructions exist along the flight path area, the effective runway length may be (less than) (greater than) ________ the actual runway length.	*20*
In the chart, Figure 11-12, Landing Distance from a 50 Foot Height, the solution of the dashed line example proceeds vertically upward from a *gross weight of 70,000 pounds,* to intersect the slanted line representing a runway altitude of ________ feet.	*less than*
This point is projected horizontally left to intersect a vertical line drawn upward from a wind of ________ knots. The intersection of these lines represents a landing distance of ________ feet.	*1,000*
Using the chart in Figure 11-12, assume a gross weight of 72,000 pounds, an airport altitude of 2,000 feet, and a wind of +20 knots. The landing distance from a 50 foot height would be ________ feet.	*+25* *2,280*
	2,500

The landing distance must be, by regulation, no more than 60% of the effective length of the runway. The minimum required effective runway length may be determined by referring to the chart in Figure 11-13. If the same values used in the initial example problem (70,000 pounds, 1,000 feet and +25 knots) are utilized in the chart in Figure 11-13, the minimum required runway length will be 3,800 feet. Thus, in this case, an effective runway length of 3,800 feet must be available at the intended destination. Note that the landing distance figure of 2,280 feet is 60% of the minimum effective runway length figure of 3,800 feet.

The weight requirements for an alternate airport are identical to those required for the destination except that the landing distance may be 70% of the minimum effective runway length.

In the dashed line example in the Minimum Effective Landing Runway Length Chart (Figure 11-13), proceed from a gross weight of ________ pounds vertically upward to intersect the airport altitude of 1,000 feet.	

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CONDITIONS:

- No Runway Slope — Standard Atmospheric Conditions
- Hard Surface Runway — Flaps Full Down

NOTES: 1. This Chart Constructed Using 50% of Reported Headwind and 150% of Reported Tailwind.
2. Landing Distance Equals 60% of Effective Runway Length.

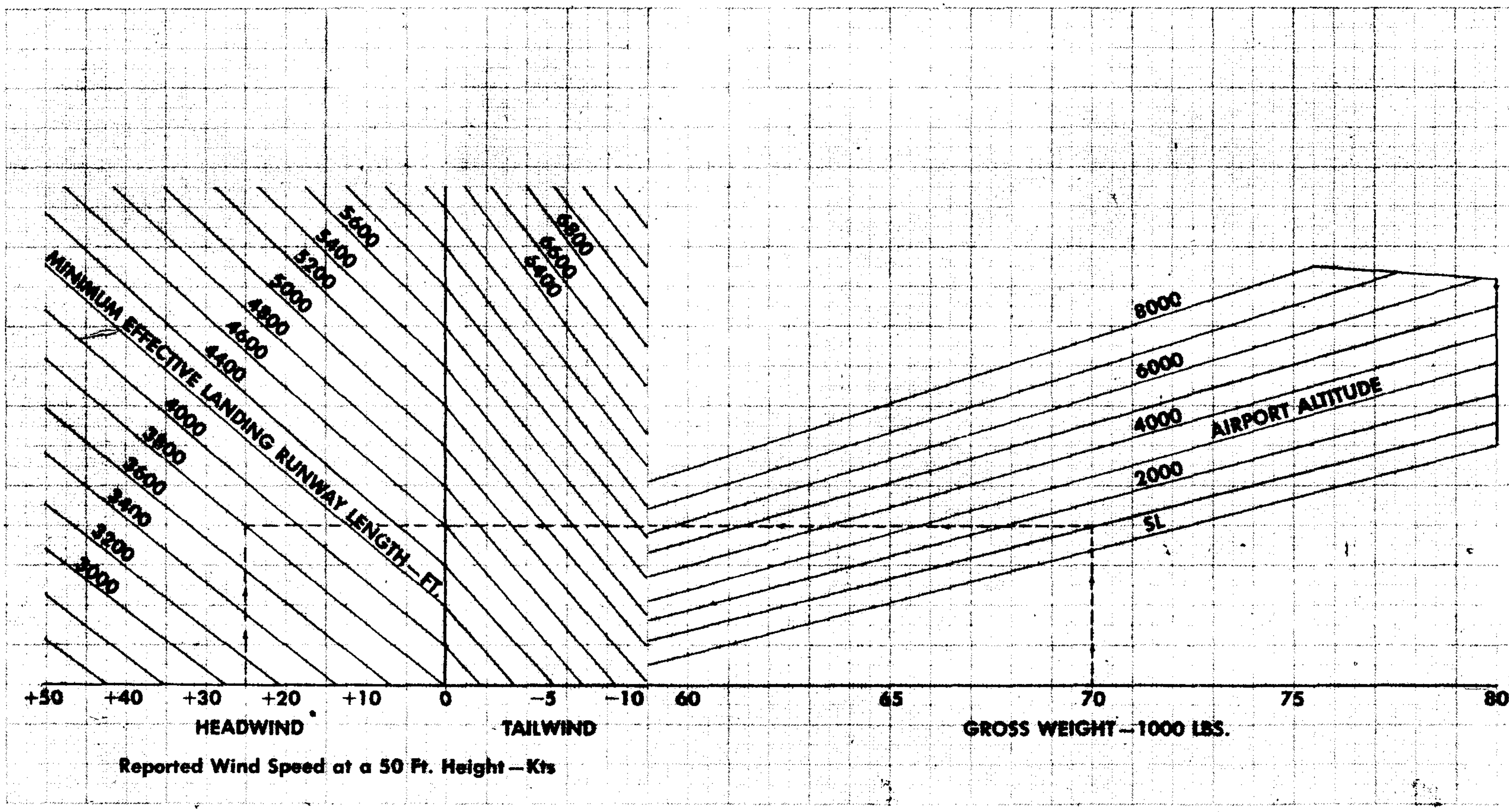


Fig. 11-13—Minimum Effective Landing Runway Length—Destination

Next, proceed horizontally left (from the point at 1,000 feet) to intersect a vertical wind line of +25 knots. Where these lines intersect, read the minimum effective landing runway length of ______________ feet.	*70,000*
The airplane must be capable of landing and stopping within 60% of the effective runway length. 60% of 3,800 feet equals a landing and stopping distance of ______________ feet.	*3,800*
For an alternate airport, the landing and stopping distance is ______________% of the effective runway length.	*2,280*
	70

Tabulated Data

A large amount of information indispensable to the pilot is presented in tabulated form rather than by way of charts and graphs. A current trend emphasizes the use of the tabulated form, and in the future a majority of performance information will probably be presented in this manner. Tabulated material offers the advantages of easy readability and precise computation.

Climb Data

The excerpt from a Climb Data Chart in Figure 11-14 is an example of tabulated material. Data of this type is based on certain assumptions such as:

(1) 2100 BHP for takeoff and 1900 BHP for climb
(2) climbing IAS of 120-130 knots
(3) cowl flaps open +4°
(4) still air conditions
(5) standard temperature

For example, a flight is to be conducted at 9,000 feet at a takeoff gross weight of 90,000 pounds. In order to find performance data for the climb to 9,000 feet, the pilot would reference the Climb Data Chart, (Figure 11-14) and arrive at the figures 16/1010/39. The "16" represents the time in minutes required to climb to 9,000 feet, the "1010" represents the total fuel burned in pounds and the "39" represents the nautical miles covered in the climb from sea level.

CLIMB DATA CHART

11/720/24 = minutes/fuel in pounds/distance						
Pressure Altitude	Takeoff Gross Weight – lbs.					
	95,000	90,000	85,000	80,000	75,000	70,000
5,000	11/720/24	10/640/21	9/570/18	8/520/15	7/480/12	6/440/9
6,000	13/830/29	11/730/25	10/650/21	9/590/19	8/530/15	7/480/12
7,000	15/930/35	13/820/29	11/730/25	10/660/22	9/580/18	8/520/15
8,000	17/1040/40	14/910/34	13/810/29	11/720/25	10/630/21	9/560/18
9,000	18/1160/46	16/1010/39	14/890/33	12/790/29	11/680/24	10/700/21
10,000	20/1270/52	18/1100/44	15/970/37	14/860/32	13/730/27	12/740/25
11,000	22/1390/58	19/1200/49	17/1050/40	15/930/36	14/790/30	13/800/28
12,000	24/1520/65	21/1300/54	18/1130/44	16/1000/39	15/850/33	14/840/31
13,000	26/1640/71	23/1410/60	19/1220/49	17/1070/43	16/910/36	15/890/34
14,000	28/1770/78	25/1520/66	21/1310/53	18/1140/47	17/970/39	16/940/37

Fig. 11-14

Many pilots prefer to use *tabulated* performance data instead of graphs because the tabulated data is easy to ______ and precise ______ can be obtained.	
The example given for use of the Climb Data Chart, Figure 11-14, involves an airplane with a gross weight of 90,000 pounds climbing from sea level to an altitude of 9,000 feet. The table is read horizontally to the right from 9,000 feet and vertically downward from ______ pounds.	*read* *answers* *(data)*
The above problem results in time to climb of ______ minutes, fuel burnout of ______ pounds, and a distance flown of ______ nautical miles.	*90,000*
Here is another example. Use the Climb Data Chart, Figure 11-14, to find the data for a climb from sea level to 12,000 feet at a gross weight of 80,000 pounds. The time to climb is ______ minutes, fuel burnout is ______ pounds, and distance is ______ nautical miles.	*16* *1010* *39*
	16 *1,000* *39*

Long Range Cruise

The table in Figure 11-15 is an excerpt from a typical long range cruise performance table. Airplane manuals contain data of this type for every altitude within the performance capability of the airplane, however only data for the 9,000 and 10,000 foot altitudes is included here. Note that this table contains performance data for four engine operation. Similar charts for two and three engine operation (one engine operation in the case of two engine airplanes) are available and are interpreted in the same manner. Cruise speeds in the long range cruise tables are based on the speed that will afford the best range.

Notice in Figure 11-15 that there is a different long range cruise speed, power setting and fuel flow for each gross weight and altitude combination. The table is based on temperatures that are 10°C. above standard. It is constructed in this manner because average temperatures usually range somewhat above standard in the continental United States.

FOUR ENGINE LONG RANGE CRUISE PERFORMANCE

Pressure Altitude	Gross Weight	95,000 to 90,001	90,000 to 85,001	85,000 to 80,001	80,000 to 75,001	75,000 to 70,001
9,000	(TAS) (IAS) kts.	192 (168)	187 (161)	181 (151)	175 (151)	169 (146)
	BHP	800	760	725	695	660
	Blower	Low	Low	Low	Low	Low
	RPM	2000	1950	1900	1850	1800
	MAP (approx.)	32.5	32.2	32.0	31.8	31.5
	FF lbs./hr./eng.	415	380	345	310	275
	FF lbs./hr./airplane	1,660	1,520	1,380	1,240	1,100
10,000	TAS (IAS) kts.	194 (165)	189 (160)	184 (156)	180 (153)	176 (149)
	BHP	765	730	695	660	630
	Blower	Low	Low	Low	Low	Low
	RPM	2000	1950	1900	1850	1800
	MAP (approx.)	31.7	31.5	31.0	30.5	30.2
	FF lbs./hr./eng.	420	385	350	315	280
	FF lbs./hr./airplane	1,680	1,540	1,400	1,260	1,120

Fig. 11-15

As an example in the use of the table in Figure 11-15, find the power setting recommended for long range cruise at 9,000 feet with a gross weight of 88,000 pounds. Notice the vertical column of information under the heading 90,000 to 85,001 pounds which is opposite to 9,000 foot pressure altitude. Under the stated conditions, the recommended RPM is 1950 and the MAP is 32.2 inches. Under normal operating conditions, this power setting will result in a TAS of 187 knots, an IAS of 161 knots and BHP of 760. The word "low" found next in succession refers to low supercharger (blower) speed. The two headings under the MAP value refer to expected fuel flow in pounds per hour. This is a convenient method of determining expected engine performance, time enroute, and fuel consumption.

In Long Range Cruise Tabulations (Figure 11-15) the speeds shown are those which will result in best long ________ flight.	
There is a specific long range cruise power setting for each gross weight and ________ combination.	*range*
In the text example, Figure 11-15 is used to find the power setting for long range cruise at 9,000 feet with a gross weight of 88,000 pounds. At the intersection of 9,000 feet and 85,001 to 90,000 pounds, the recommended RPM is ________ and the MAP is ________ inches Hg.	*altitude*
To cruise at 10,000 feet with a gross weight of 77,000 pounds, the power setting would be ________ RPM and ________ inches MAP and the fuel flow would be ________ pounds/hour/engine.	*1950* *32.2*
	1850 *30.5* *315*

Cruise Power

The cruise power performance table, Figure 11-16, contains predicted airspeeds based on a given BHP of 900. The table is interpreted in the same manner as the previous table in that airspeed is associated with a given gross weight and flight altitude.

CRUISE POWER PERFORMANCE—900 BRAKE HORSE POWER

198 (176) = TAS (IAS)

Press Altitude-Ft. \ Gross Wt. Lbs.	95,000 to 90,001	90,000 to 85,001	85,000 to 80,001	80,000 to 75,001	75,000 to 70,001	Approximate Fuel Flow lbs./hr.
5,000	192 (171)	198 (176)	202 (181)	206 (185)	209 (188)	1740
6,000	193 (169)	199 (174)	203 (178)	207 (183)	211 (186)	1740
7,000	194 (166)	200 (172)	205 (177)	209 (182)	213 (185)	1740
8,000	195 (164)	201 (170)	207 (176)	211 (180)	215 (183)	1740
9,000	196 (162)	203 (167)	208 (174)	212 (177)	217 (182)	1760
10,000	197 (160)	204 (166)	210 (173)	214 (176)	218 (180)	1760
11,000	197 (158)	205 (164)	211 (171)	216 (174)	220 (178)	1760
12,000	198 (156)	206 (162)	213 (168)	217 (172)	222 (176)	1800
13,000	198 (155)	207 (161)	214 (167)	219 (171)	224 (175)	1800
14,000	199 (152)	208 (159)	215 (166)	221 (170)	226 (174)	1800

Fig. 11-16

The first value found in each column is the expected TAS, and the value in parentheses is the IAS. The extreme right column contains expected fuel flow in pounds per hour at 900 BHP. This table is based on temperatures 10°C. above standard for a given altitude.

According to this table, Figure 11-16, an airplane weighing 74,000 pounds and flying at 6,000 feet could be expected to have a TAS of 211 knots, an IAS of 186 knots and a fuel flow 1,740 pounds per hour. Of course each particular type airplane will require performance figures that apply exclusively to that airplane. Airplane manufacturers supply tables similar to Figure 11-16 for various BHP cruise ratings, all of which are interpreted in the same manner.

In the text example for the Cruise Power Performance Chart, Figure 11-16, for a flight at 6,000 feet, gross weight 74,000 pounds, the indicated airspeed would be ________ knots.	
Using Figure 11-16, in the example flight at 6,000 feet, the fuel flow would be approximately ________ pounds/hour.	*186*
Refer again to Figure 11-16. When flying at 10,000 feet at a gross weight of 87,000 pounds at 900 BHP, the true airspeed would be ________ knots and the approximate fuel flow ________ pounds/hour.	*1740*
Here is another example using Figure 11-16. Gross weight is 73,000 pounds, altitude is 13,000 feet, BHP = 900. In this case fuel flow should be ________ pounds/hour, and indicated airspeed should be ________ knots.	*204* *1760*
	1800 *175*

Fuel Requirements

The table in Figure 11-17 is used as an aid in planning for fuel requirements. Regulations state that when an alternate airport is required, the airplane must have sufficient fuel aboard to fly to the destination, to the alternate and then have enough remaining fuel to fly for an additional 45 minutes. The table in Figure 11-17, provides the pilot with a handy reference regarding expected fuel consumption from the destination to the alternate plus 45 minutes.

If the expected time from the destination to an alternate is 1 hour and 10 minutes, then, using Figure 11-17, the fuel required is 3,420 pounds. Note that this fuel figure includes fuel for the required 45 minutes additional flying time.

Figure 11-17 is based on flight at 10,000 feet at 900 BHP and on speeds from the 900 BHP table.

In fuel planning, when an alternate airport is named, the fuel aboard must be sufficient to fly to the destination, then to the alternate, plus an added reserve of ________ minutes fuel.	
Minimum reserve fuel includes the fuel from the destination to the ________ airport, plus 45 minutes of fuel.	*45*

FUEL TO ALTERNATE PLUS 45 MINUTES

Estimated Flight Time to Alternate		Minimum Reserve Fuel Required – lbs.
Hours	Minutes	
	00	1320
	10	1620
	20	1920
	30	2220
	40	2520
	50	2820
1	00	3120
	10	3420
	20	3720
	30	4020
	40	4320
	50	4620
2	00	4920
	10	5220
	20	5520
	30	5820
	40	6120
	50	6420
3	00	6720
	10	7020
	20	7320
	30	7620
	40	7920
	50	8220
4	00	8520

Fig. 11-17

The tabulation in Figure 11-17 gives total minimum reserve fuel when time from ____________ to alternate airport is known.	*alternate*
If the flight time from destination to the alternate airport is 2 + 30, then using the table, Figure 11-17, ____________ pounds of reserve fuel are required which includes the ____________ minute reserve.	*destination*
In the previous exercise, the reserve fuel would amount to ____________ gallons. *(Note: 1 gallon = 6 pounds)*	*5820* *45*
How many gallons of fuel are required as reserve fuel if the time from destination to alternate is 1 + 50? ____________	*970*
	770 gallons

General Considerations

The previous pages on airplane performance contain a general resume of those charts and graphs which are important to the pilot in commercial air transportation. No attempt has been made to include the entire scope of performance data. However, if the pilot familiarizes himself with the information contained herein, he will be able to interpret the data presented by the various airplane manufacturers.

It should be noted that every manufacturer presents performance data in a unique manner. This presents no problem if the pilot exercises care in following the manufacturer's recommendations accompanying the information. The pilot should also exercise care in selecting the exact chart or graph desired since, in many cases, one particular chart closely resembles another.

Many regulations have been presented in the course of this performance section, however, one must consult the appropriate FAR for complete treatment of existing regulations.

GLOSSARY OF TERMS

1. *CAS—Calibrated Airspeed* is the result of correcting IAS for errors of instrument and errors due to position or location of the installation.
2. *EAS—Equivalent Airspeed* is the result of correcting CAS for compressibility effects.
3. *IAS—Indicated Airspeed* is the actual instrument indication.
4. *TAS—True Airspeed* is the speed of the airplane relative to undisturbed air. TAS results when EAS is corrected for density altitude.
5. V_{FE}—The maximum speed with the wing flaps in a prescribed extended position.
6. V_{MC}—*Minimum Control Speed* is the minimum speed at which a multi-engine airplane is controllable when the critical engine is inoperative with the remaining engines at takeoff power.
7. V_{MO}—*Maximum Operating Limit Speed* shall not be exceeded under normal conditions. This same value may be referred to in terms of Mach number as "Mmo"
8. V_{S1}—*Power Off Stalling Speed* in a specified configuration.
9. V_{S0}—*Power Off Stalling Speed* in the landing configuration.
10. V_X—*Best angle of climb speed.*
11. V_Y—*Best rate of climb speed.*

JET AIRPLANE PERFORMANCE (Transport Category)

The introduction of jet airplanes into the commercial aviation scene has necessitated some changes in the performance standards which heretofore applied only to piston powered airplanes.

Takeoff Speed Requirements

One of the most significant changes incident to jet operation has been in the realm of speed requirements for takeoff. The symbol V_R (Figure 11-18) designates the "rotation speed", or in other words the speed at which the pilot initiates the control movements which will lift the nose wheel off the runway. The V_R speed is predicated on the fact that the airplane must attain the safety takeoff speed (V_2) at or before reaching a height of 35 feet above the runway. The V_R speed must be at least 5 percent greater than the minimum control speed (V_{MC}). This restriction is placed on the operator in order to provide a margin of safety in case of over rotation which would result in a lesser rate of acceleration.

The speed at which the airplane actually lifts off the runway is designated V_{LOF}. After lift off, regulations stipulate that the takeoff safety speed (V_2) must be attained at or prior to reaching a point 35 feet above the runway.

It is readily seen that V_2 does not designate the speed at which the airplane leaves the runway, as it did with reciprocating engine airplanes. However, this change in V_2 requirements in no way changes the definition of the V_2 speed, it simply provides some latitude to higher performance jet airplanes by allowing them to lift off the runway before reaching V_2.

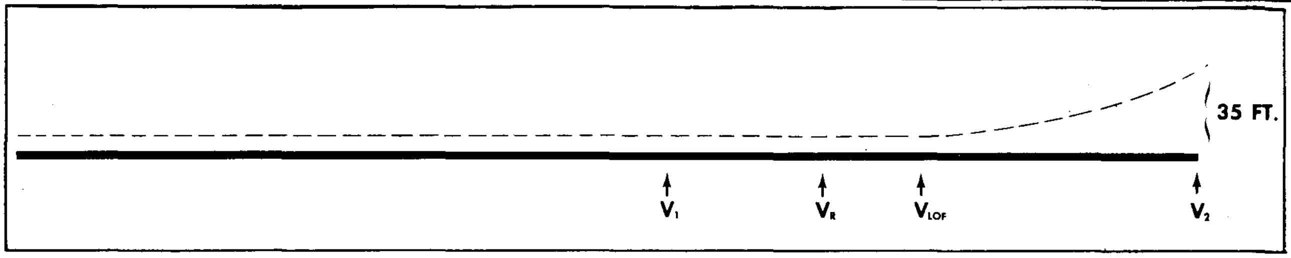


Fig. 11-18—Takeoff Speeds For "T" Category Jet Airplanes

Takeoff Distance

The definition of takeoff distance has been altered for jet airplanes in order to more closely reflect their performance capabilities. The takeoff distance for jet airplanes shall be the longer of the two distances described below:

1. The distance from brake release to a point where a 35 foot height above the surface is reached, assuming the loss of the critical engine at V_1, or
2. 115 percent of the distance from brake release to a point where a 35 foot height above the surface is reached, assuming that all engines are operating normally.

Stopways and Clearways

Stopways and clearways have been introduced to allow operation with high gross weights which are commensurate with the higher operating capabilities of modern airplanes. It is possible to accomplish this while remaining within the bounds of safe operating procedure because of the lengthened stopping distance afforded by the incorporation of stopways.

A *stopway* is an area beyond the runway which may be used to decelerate an airplane in case of an aborted takeoff. A stopway is constructed so that its surface is adequate to support an airplane and prevent any structural damage. It should be noted that stopways are not intended for normal use.

A *clearway* is a space at the end of the runway which is cleared of obstructions so that it provides an additional obstacle free space for climbout. Where a clearway exists, it is considered to start at the end of the runway irrespective of whether a stopway is incorporated or not.

The speed at which the pilot initiates the control movements which lift the nose wheel off the runway, is called the rotation speed. The symbol for this speed is ________.	
The minimum rotation speed must be greater than the minimum control speed by at least ________ percent.	*V_R*
The symbol for the speed at which a jet airplane actually lifts off the runway is ________.	*5*
A jet airplane must attain the V_2 speed at or prior to reaching a point ________ feet above the runway.	*V_{LOF}*
Under the regulations governing jet airplanes. V_2 does not designate the speed at which a jet airplane lifts off the runway. However, V_2 is still considered to be the takeoff safety ________.	*35*

The takeoff distance for a jet airplane, assuming the critical engine has failed, ends at a point where the airplane reaches a height of ____________ feet above the runway.	*speed*
Assuming all engines are operating normally, the takeoff distance is 115 percent of the distance from brake release to a point where the airplane reaches a height of 35 feet above the ____________.	*35*
Stopways and clearways have been incorporated to allow operation at higher gross weights while still remaining within the bounds of ____________.	*surface*
A surfaced area at the end of the runway which may be used in the event of an aborted takeoff is referred to as a ____________.	*safety*
Stopways increase the safety margin by lengthening the distance available in which to ____________.	*stopway*
A stopway is designed and constructed so as to support the weight of an airplane and aid in avoiding structural damage in the event of an aborted ________ ________.	*stop*
A stopway is not intended for normal ____________.	*takeoff*
An obstruction free area at the end of a runway is referred to as a ____________.	*use*
	clearway

Jet Performance Charts

The *Takeoff Distance Chart* in Figure 11-19 is typical of those utilized for jet operations. The following information is given as an example problem in the use of the takeoff distance chart.

Given:
1. Gross Weight — 237,000 pounds
2. Airport Pressure Altitude — 4,000 feet
3. Outside Air Temperature — +10° C.
4. Runway Gradient — −1% (downhill)
5. Wind — 10 knots (headwind)

Required: Takeoff Distance

Solution: Enter the chart at the takeoff gross weight of 237,000 pounds. Follow the dashed line upward until reaching the pressure altitude line of 4,000 feet. From this point go right horizontally until the dashed line intersects the +10°C. temperature line. Project this intersection vertically upward until reaching the −1% gradient line. Then follow the dashed line horizontally to the left until intersecting the +10 knot wind line. Project this intersection downward to arrive at the takeoff distance of 8,900 feet.

Use the chart in Figure 11-19 to calculate the takeoff distance under the following conditions: gross weight 250,000 pounds, airport pressure altitude 2,000 feet, OAT 0°C., gradient +1%, and 0 wind. In this example, the takeoff distance would be ____________ feet.	

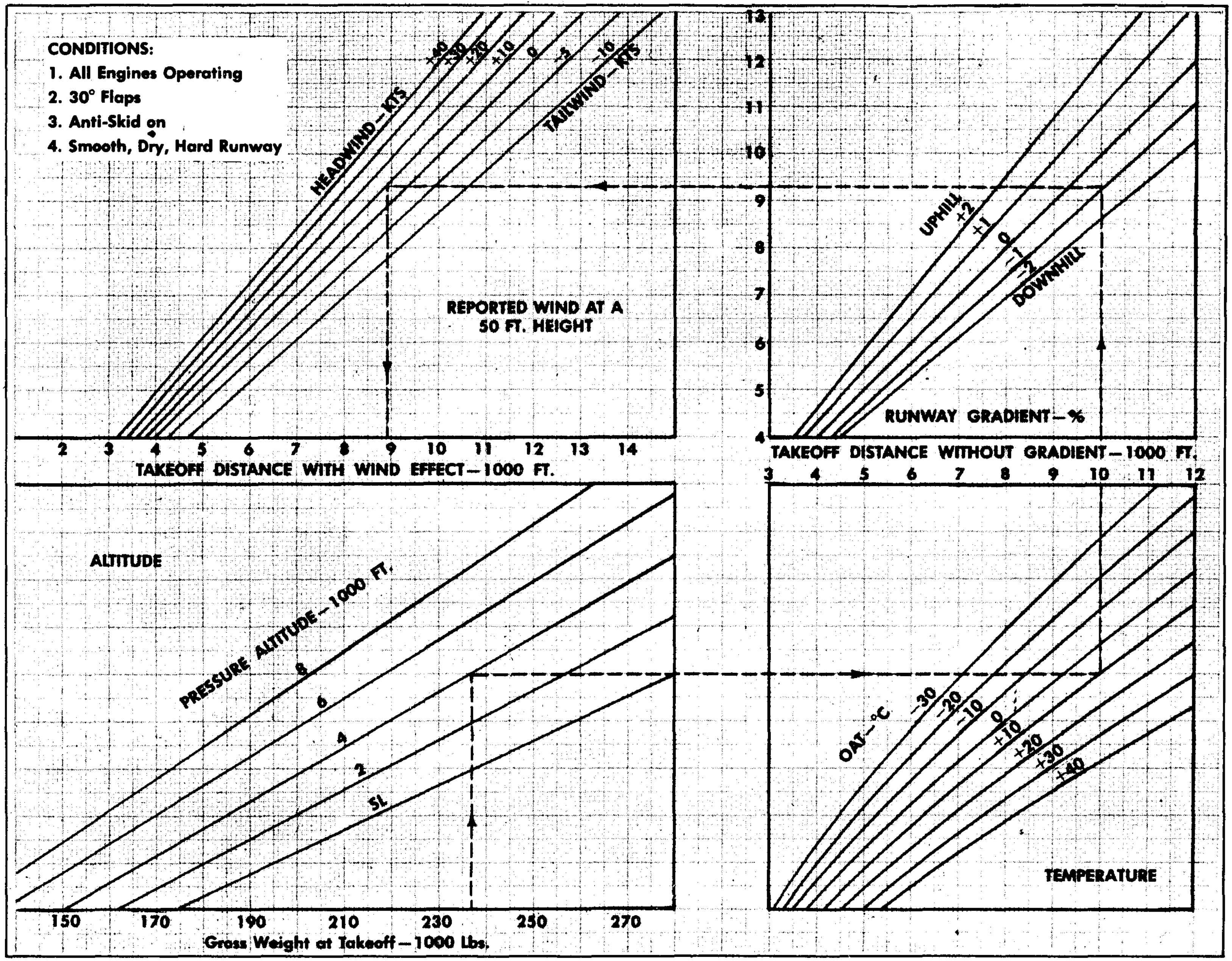


Fig. 11-19—Takeoff Distance

Solve another example problem using the Takeoff Distance Chart in Figure. 11-19. Utilize the same conditions as stated in the previous frame except substitute an airport pressure altitude of 0 feet. Under these conditions, the takeoff distance would be __________ feet.	*9,600*
Use the chart in Figure 11-19 to solve another example problem. Utilize the same conditions stated in frame 154 except substitute an OAT of +20°C. Under these conditions, the takeoff distance would be __________ feet.	*8,200*
	11,500

Climb Gradient

Another factor incident to jet operations, and just as important as the computation of the required runway distance, is the calculation of the climb gradient. Regulations specify a certain minimum climb gradient for each portion of the climb. Since performance varies with gross weight and atmospheric conditions, the climb gradient must be computed prior to each takeoff.

In that portion of the climb between the lift off and landing gear retraction (first climb segment), the following gradients apply:

1. a positive rate of climb for two-engine airplanes
2. not less than 0.3 percent for three-engine airplanes
3. not less than 0.5 percent for four-engine airplanes

During the first climb segment, the airplane must maintain at least a speed equal to V_{LOF} with the critical engine inoperative and the remaining engines at takeoff thrust.

In the second climb segment (extending from landing gear retraction to enroute configuration), the following climb gradients apply:

1. not less than 2.4 percent for two-engine airplanes
2. not less than 2.7 percent for three-engine airplanes
3. not less than 3.0 percent for four-engine airplanes

During the second climb segment, the airplane must maintain at least a speed equal to V_2 with the critical engine inoperative and the remaining engines at takeoff thrust.

In the final climb segment (enroute configuration), the following climb gradients apply:

1. not less than 1.2 percent for two-engine airplanes
2. not less than 1.5 percent for three-engine airplanes
3. not less than 1.7 percent for four-engine airplanes

During the final climb segment, the airplane must maintain at least a speed equal to 125 percent of the stall (V_S) speed with the critical engine inoperative and the remaining engines at maximum continuous thrust.

It must be determined prior to takeoff that the airplane is capable of meeting both the takeoff and climb requirements applicable to the gross weight and prevailing atmospheric conditions.

Regulations governing jet airplane performance, specify for each climb segment, a certain minimum climb __________.	

The minimum gradients which apply to the first climb segment are: 0.5 percent for four-engine airplanes, 0.3 percent for three-engine airplanes and a positive ______ ______ for two-engine airplanes.	*gradient*
A jet airplane must be loaded in such a manner that if the critical engine failed, a speed of at least ______ could be maintained during the first climb segment.	*rate of climb*
The minimum gradients for the second climb segment are: ______ percent for two-engine airplanes, ______ percent for three-engine airplanes and ______ percent for four-engine airplanes.	V_{LOF}
The airplane must be loaded in such a manner that if the critical engine failed, a speed of at least ______ could be maintained during the second climb segment.	*2.4* *2.7* *3.0*
The minimum gradients for the final climb segments are: 1.2 percent for two-engine airplanes, 1.5 percent for three-engine airplanes and ______ percent for four-engine airplanes.	V_2
The airplane must be loaded in such a manner that if the critical engine failed, a speed of at least ______ percent of ______ could be maintained during the final climb segment.	*1.7*
	125 V_S

Climb Gradient Charts

The chart in Figure 11-20 is typical of those charts used to determine the expected climb gradient. This particular chart is designed for a four-engine airplane and applies only to the second climb segment.

It has been determined in the initial example problem associated with the Takeoff Distance Chart that the takeoff distance would be 8,900 feet under the conditions stated in that problem. Now determine that the airplane is capable of the required 3.0 percent climb gradient in the second climb segment under the same gross weight and atmospheric conditions as utilized in the Takeoff Distance Chart. Refer to the Second Segment Climb Chart in Figure 11-20.

Given:

1. OAT — +10°C.
2. Airport Pressure Altitude — 4,000 feet
3. Gross Weight — 237,000 pounds
4. Anti-icing — off

Required: 1. Second climb segment gradient

Solution: Enter the chart at the top left hand corner at +10° C. OAT. Follow the dashed line to the right until intersecting the slanted 4,000 foot pressure altitude line. Project the intersection vertically downward to the "anti-icing off" line. From this point follow the dashed line horizontally to the right to a point which represents a gross weight of 237,000 pounds. Go vertically downward from this point to the climb gradient of 5.0 percent.

DIRECTED STUDY PROGRAM

USFAA EXAMINATION GUIDE

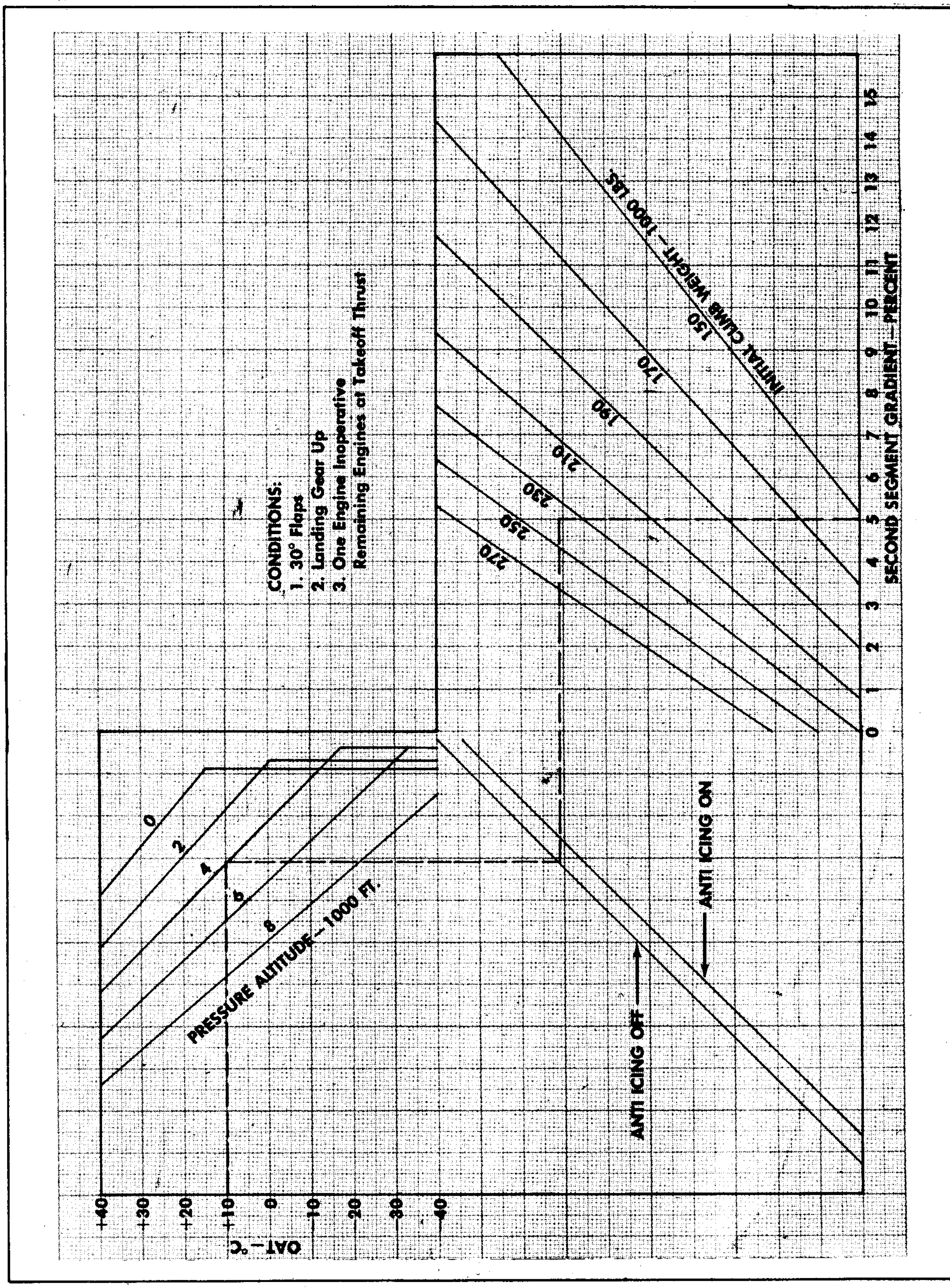


Fig. 11-20—Second Segment Climb

Since 5.0 percent is well over the required 3.0 percent, it can be assumed that the airplane is capable of meeting the second segment climb requirements. Remember that in an actual operation it would also have to be determined that the expected climb performance would meet the requirements for the first and final climb segments. However, experience has demonstrated that in the case of most airplanes, the second segment is the most difficult with which to comply. Thus, usually if the airplane will meet second segment requirements, it is probable that it will equal or exceed the first and final segment requirements.

Use the Second Segment Climb Chart in Figure 11-20 to calculate the climb gradient under the following conditions: OAT 0° C., airport pressure altitude 2,000 feet, anti-icing off, and a gross weight of 230,000 pounds. In this example, the second segment climb gradient would be ______ percent.

Solve another example problem using Figure 11-20. Utilize the same conditions stated in the previous frame except substitute the gross weight of 270,000 pounds. Under these conditions, the climb gradient would be ______ percent.

7.3

Use the chart in Figure 11-20 to solve another example problem utilizing the following conditions: OAT +20° C., airport pressure altitude 2,000 feet, anti-icing on, and a gross weight of 270,000 pounds. In this example, the climb gradient would be ______ percent.

5.0

3.1

Landing Charts

The Landing Field Length Chart in Figure 11-21 is typical of those used to determine the expected landing performance.

The following information is given as an example in the use of the Landing Field Length Chart.

Given:
1. Gross Weight — 156,000 pounds
2. Airport Pressure Altitude — 4,000 feet
3. Wind — 0 knots

Required:
1. Landing Field length

Solution:

Enter the chart at the 156,000 gross weight line. Follow the dashed line to the airport pressure altitude of 4,000 feet. From this point, go vertically downward to the intersection of the dashed line and the 0 wind line. Project this intersection horizontally to the right to arrive at the landing field length of 5,800 feet.

Use the Landing Field Length Chart in Figure 11-21 to calculate the landing field length under the following conditions: landing weight 170,000 pounds, airport pressure altitude 0, and a headwind of 10 knots. In this example, the landing field length would be ______ feet.

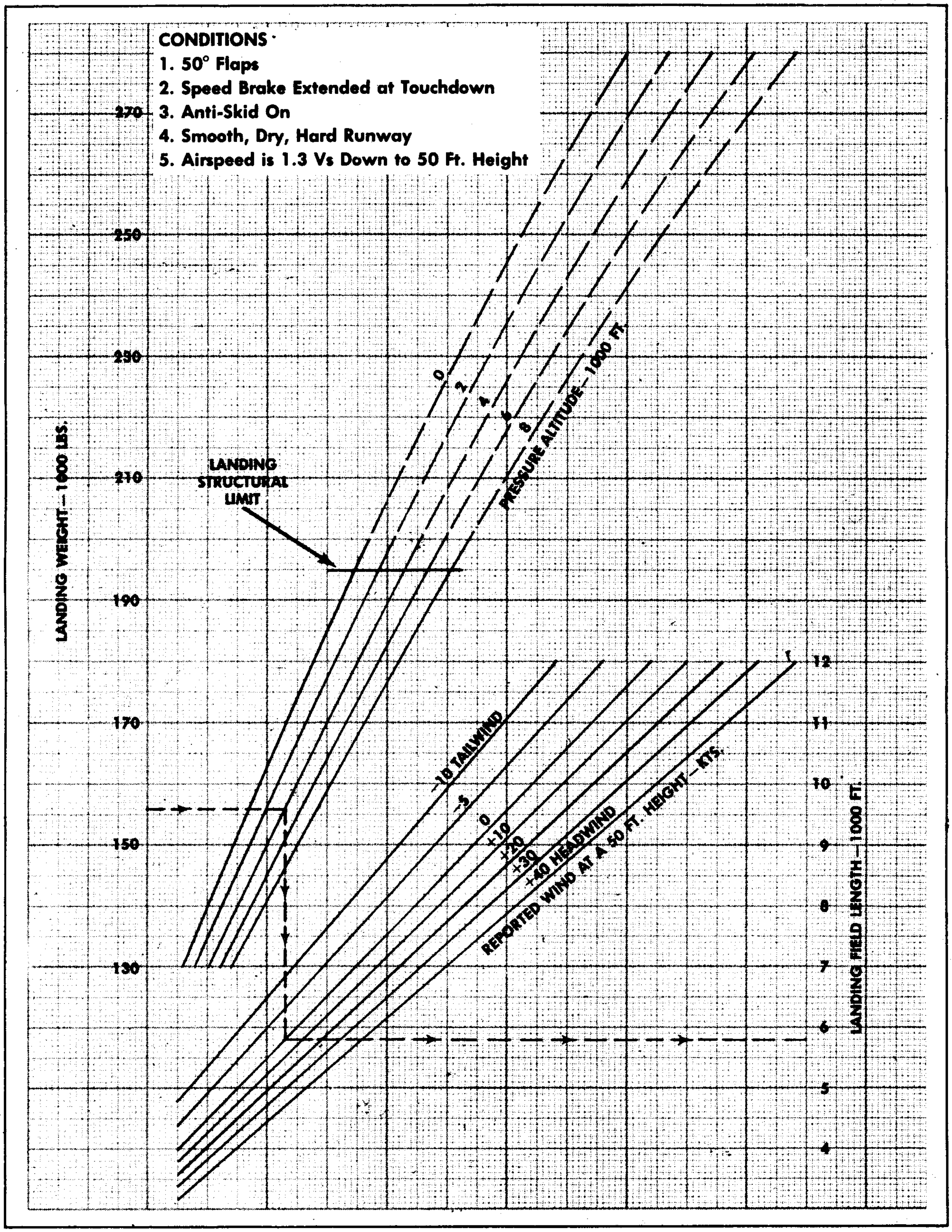


Fig. 11-21 — Landing Field Length At Destination

Solve another example problem using Figure 11-21. Utilize the same conditions stated in the previous frame except substitute a landing weight of 160,000 pounds. Under these conditions the landing field length would be ____________ feet.	*5,500*
Use the chart in Figure 11-21 to solve another example problem. Utilize the same conditions stated in frame 167 except substitute a tailwind of 10 knots. Under these conditions the landing field length would be ____________ feet.	*5,100*
	6,900

General Considerations

The preceeding pages on jet performance are intended to present the reader with a short resume of some of the major considerations incident to jet airplane operation. The student should consult the appropriate Federal Aviation Regulation and Airplane Operating Manual for current and complete information.

THE BASIC LAWS OF THRUST PRODUCTION

The natural laws governing the thrust production in a jet engine are not new to man's knowledge. However, considerable time has elapsed between the discovery of these laws and their practical application in modern jet engines.

In the 18th century, Sir Isaac Newton stated in his Third Law of physics, that each action creates an opposite and equal reaction. To understand how this law applies to jet engines, consider the behavior of a toy balloon. When the balloon is inflated and the neck is closed, the pressure exerted on the inside of the balloon is equal in all directions. This is illustrated in Figure 12-1.

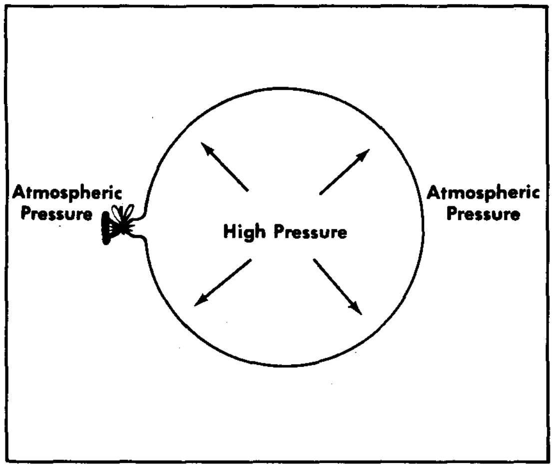


Fig. 12-1 – Balloon Under Static Conditions (Closed Valve)

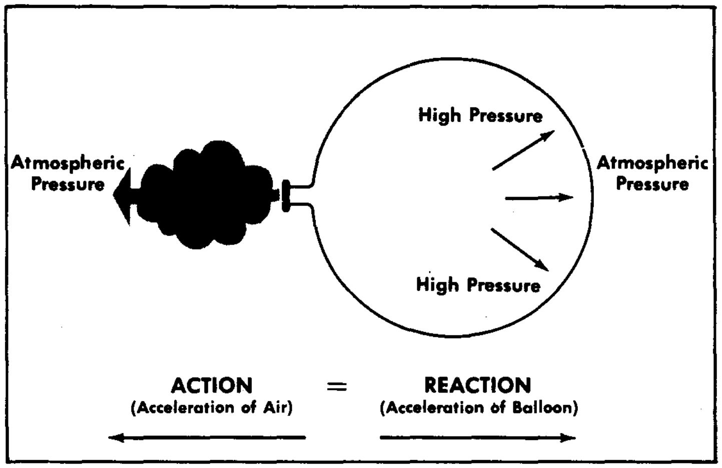


Fig. 12-2 – Balloon Under Accelerated Conditions (Open Valve)

When the neck is opened, the air is accelerated through the valve because the pressure within the balloon is greater than the pressure outside the balloon. This acceleration of air creates an imbalance and a resultant reaction in the opposite direction as shown in Figure 12-2. Stated in other words, the action of the released air produces an equal and opposite reaction that displaces the balloon from its static position. The thrust of the balloon is generated by reaction alone, not by the escaping air pressing against the atmosphere.

The fluttering balloon and the jet engine are governed by the same laws. In fact, it may be said that a jet engine acts as a balloon with a constant air supply. The air inside the balloon is accelerated by differential pressure, and the air inside the jet engine is accelerated by heating the air to form a rapidly expanding gas.

Natural laws govern the production of ____________ in a jet engine.	
Considerable time has elapsed between the discovery of the jet principle and its practical ____________.	*thrust*
Newton's Third Law states that for every action there is an equal and opposite ____________.	*application*
When gas is confined inside a balloon, pressure is exerted equally in all ____________.	*reaction*
No movement of the balloon occurs when the pressures within the balloon are ____________.	*directions*

If the neck of the balloon is opened, the result is an acceleration of air from the balloon due to a difference between inside and outside air ______.	*equalized (equal)*
The acceleration of air from the balloon causes an ______ condition.	*pressure*
The result of the unbalanced condition is a reaction which is opposite to the acceleration of the ______.	*unbalanced*
This reaction, caused by the escaping gases, may be referred to as ______.	*air*
The thrust can be visually noted by observing the movement of the ______.	*thrust*
The accelerated balloon and the jet engine are governed by the same ______.	*balloon*
The air within the balloon is accelerated by differential ______.	*laws (principles)*
The air within the jet engine is accelerated by heating the air to produce a rapidly ______ gas.	*pressure*
	expanding

Jet Engine Operation

The jet engine cycle is essentially the same as that of a reciprocating engine. The sequence of events is intake, compression, combustion and exhaust. Figure 12-3 graphically illustrates the stages of jet engine operation.

The basic components of the jet engine are the compressor, the combustion chamber and the turbine wheel. The air is directed to the compressor by the air intake. The compressor actually draws in and compresses large quantities of air. As is seen by reference to the velocity, pressure and temperature charts in Figure 12-3, the condition of the air is radically changed in the compression cycle. As the air is pressurized, it increases in both temperature and velocity.

The air under great pressure and heated by the compression action is forced into the combustion chamber by the compressor. In the combustion chamber, fuel is mixed with the air and ignited. The mixture is burned in a continuous ignition process which further heats and accelerates the air mass. As the hot, highly pressurized gas passes out of the combustion chamber, it is forced through the blades of the turbine wheel. The action of the gas on the turbine wheel causes the wheel to rotate at high speeds, thus driving the compressor to which it is connected. As the air passes through the turbine, the pressure decreases because the hot gas is allowed to expand. The pressure drop is accompanied by a decrease in temperature and a great increase in velocity. The action of the heated air mass being discharged at a very high velocity results in a reaction which propels the airplane forward.

The jet engine cycle consists of four stages, intake, compression, combustion and ______.	

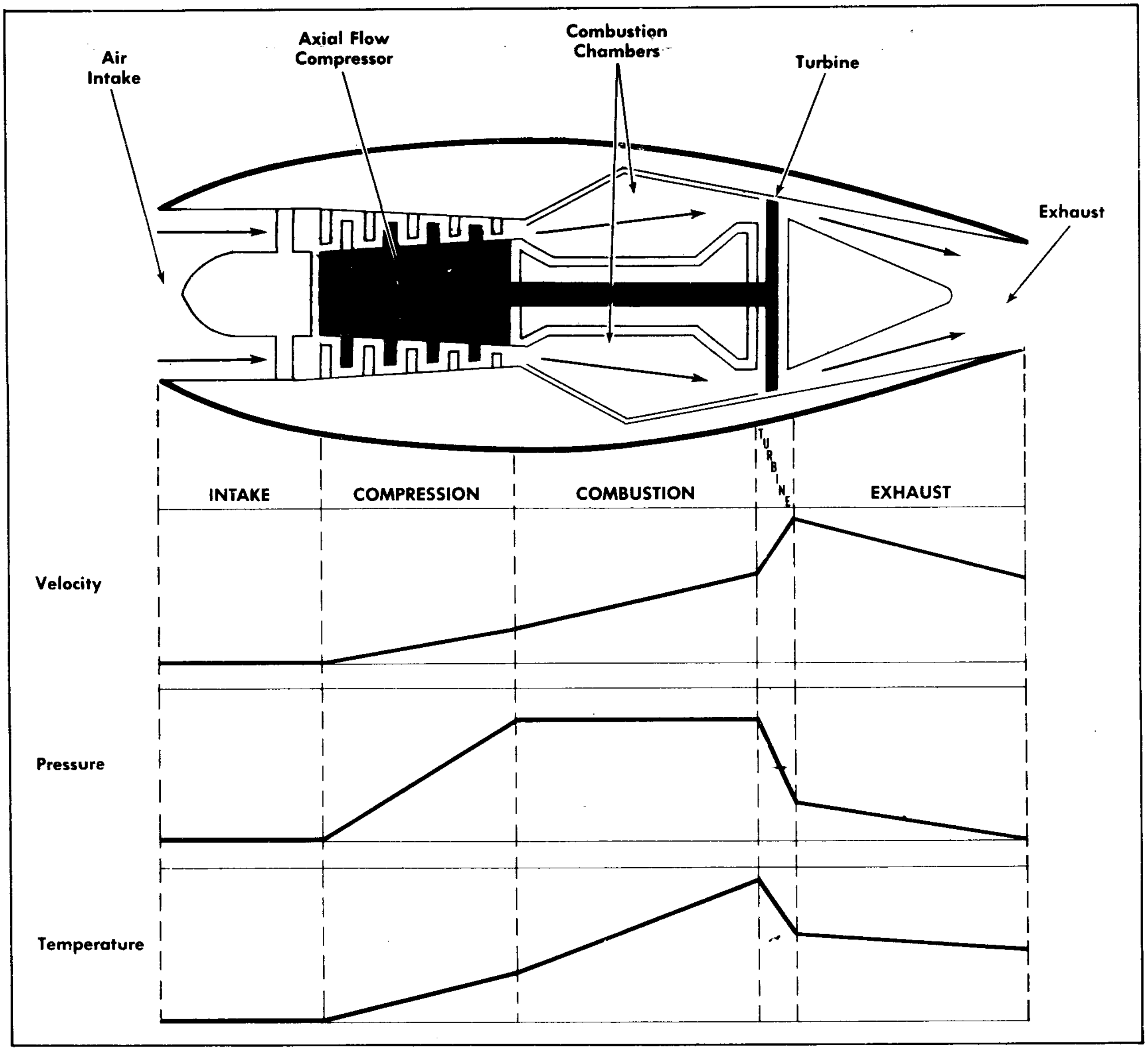


Fig. 12-3 – Jet Air Stages

The basic components of the jet engine are the compressor, the combustion chamber and the ________________ wheel.	*exhaust*
The function of the compressor is to draw in and compress ________________.	*turbine*
In the jet engine, air temperature and velocity increase as the air moves through the ________________.	*air*
The compressor forces heated, compressed air into the ________________ chamber.	*compressor*
In the combustion chamber, fuel is mixed with ________________ and ignited.	*combustion*

In the jet engine, the ignition process is __________.	*air*
As the hot, highly pressurized gas passes out of the combustion chamber, it is forced through the blades of the __________ __________.	*continuous*
The turbine wheel is connected to the __________.	*turbine wheel*
The impact of the gas on the turbine blades causes the turbine wheel and compressor to rotate at high __________.	*compressor*
The heated air mass being ejected at high velocity produces a reaction which causes the airplane to __________ forward.	*speed*
	move

Compressors

The demand for increased efficiency and speed has led to constant modification and improvement in turbojet engines. Early models, and to some extent, small modern engines utilize *centrifugal compressors.* In this type of engine, air enters through the guide vanes and strikes the center of a rapidly rotating impeller Figure 12-4) which compresses the air by centrifugal force. The compressed air is then passed on to the combustion chambers.

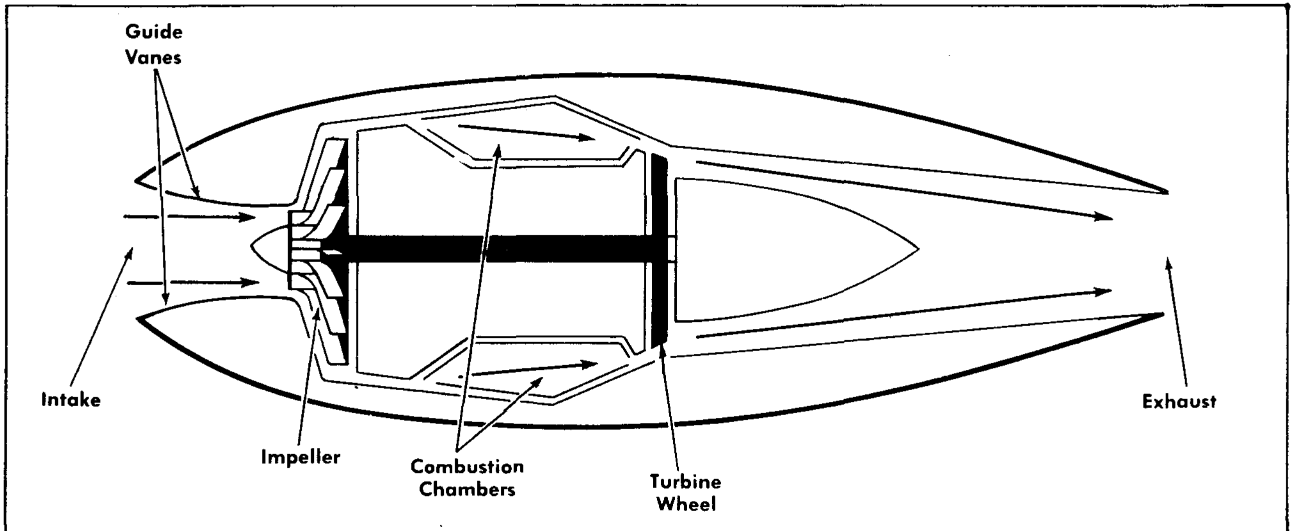


Fig. 12-4—Centrifugal Type Jet Engine

The *axial flow* compressor (Figure 12-5) is a later development and is currently utilized in large jet engines. This compressor consists of several rows of alternating stationary and rotating blades. Air is compressed to a greater degree by each succeeding stage as it passes through the compressor. Each row of rotating "rotor" blades is preceeded by a row of stationary "stator" blades for the purpose of properly directing the air through the engine.

In response to the demand for small, high compression axial-flow jet engines, the "dual rotor" or "twin-spool" compressor was developed (Figure 12-6). This engine incorporates a high and a low pressure compressor, each driven by an associated turbine wheel or wheels. This arrangement is accomplished by

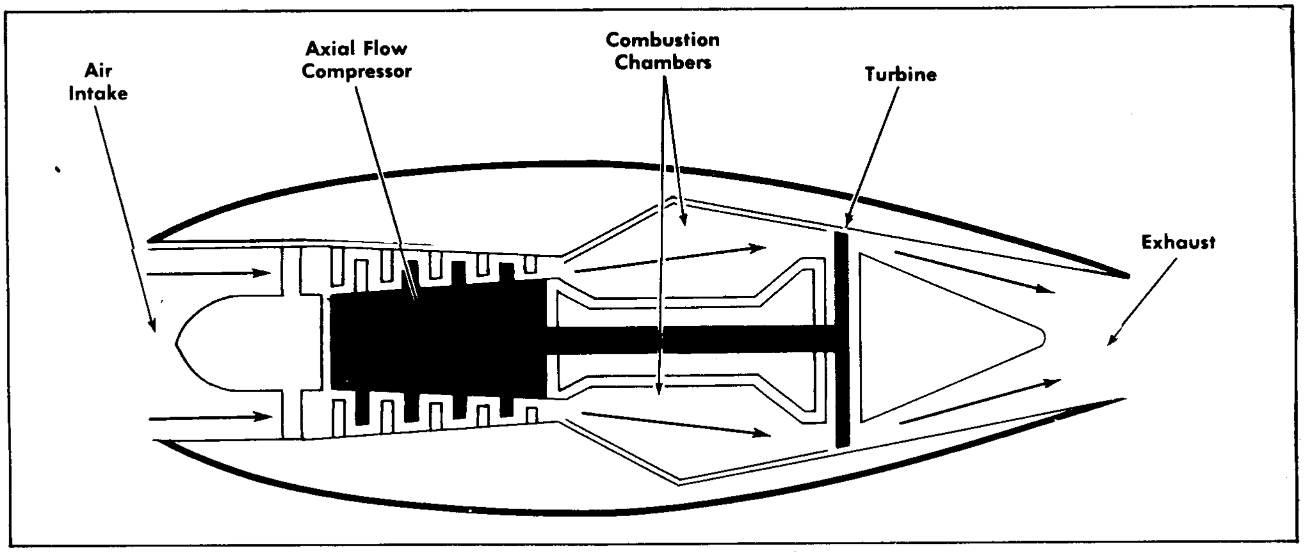


Fig. 12-5—Axial Flow Type Engine

placing the front compressor shaft inside the hollow rear compressor shaft, thus allowing the compressors to operate independently and at different speeds.

An outstanding advantage of the axial flow type engine is its small diameter. As can be seen in Figure 12-6, many compression stages can be added to this type compressor without increasing its diameter.

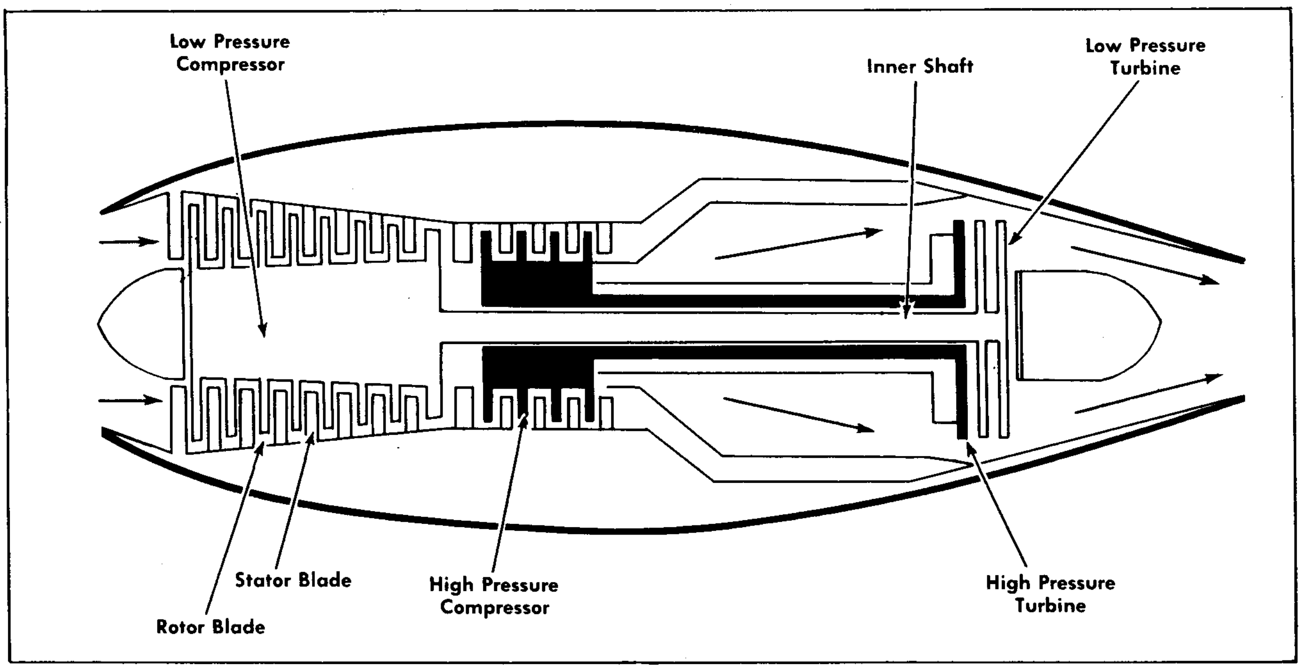


Fig. 12-6—Dual Rotor Axial Flow Type Engine

Early jet engines and a limited number of modern types utilize the ________________ compressor.

In the centrifugal type compressor, air is pressurized by means of a rapidly rotating ________________ — *centrifugal*

The impeller compresses air by means of ______ force.	*impeller*
Many large airplanes utilize the more versatile and later developed axial ______ compressor.	*centrifugal*
The axial flow compressor consists of several rows of alternating stationary and ______ blades.	*flow*
In this type of compressor, the degree of air compression increases with each succeeding ______.	*rotating*
The axial flow compressor utilizes movable ______ blades and stationary ______ blades.	*stage*
The function of the stator blades is to properly direct the flow of ______ through the engine.	*rotor* *stator*
The dual rotor axial flow engine incorporates both ______ pressure and ______ pressure compressors.	*air*
The dual rotor engine is sometimes referred to as a "______ spool" engine.	*high* *low*
This type of engine utilizes a separate turbine wheel(s) for both the high and low pressure ______.	*twin*
The high and low pressure compressors operate independently of each other and at different ______.	*compressors*
Axial flow engines in general have the advantage of being small in ______.	*speeds*
Many stages may be added to the axial flow compressor without ______ its diameter.	*diameter*
	increasing

The Turboprop Engine

The turboprop engine (Figure 12-7) incorporates many of the advantages of both the turbojet and the propeller type engines. This engine is similar to a turbojet except that most of the power is used to drive one or more large turbines, which in turn rotate a propeller. A reduction gear is placed between the propeller and the turbine shaft in order to maintain the propeller RPM within established limits.

The turboprop engine incorporates many of the advantages of both the turbojet and ______ type engines.	
Most of the power developed in a turboprop engine is used to drive one or more turbines which in turn, through gearing, rotate a ______.	*propeller*

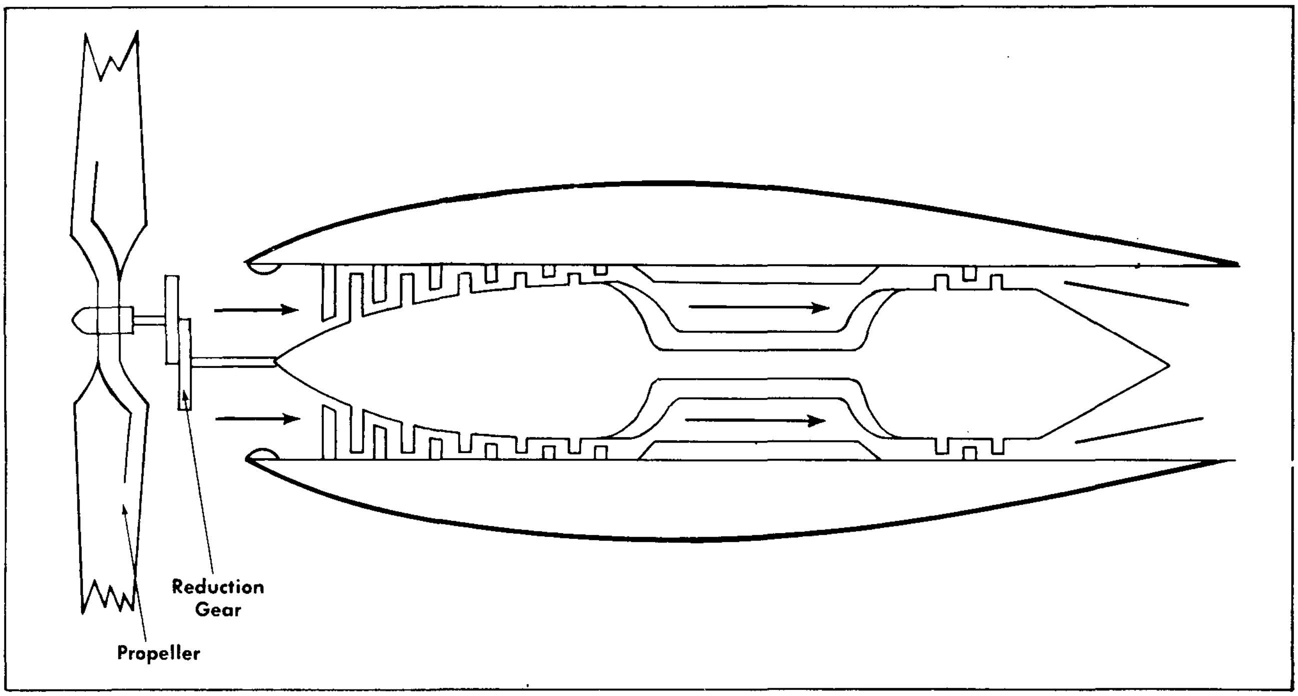


Fig. 12-7 – Turboprop Engine

In this type of engine, a reduction gear is utilized to maintain propeller RPM within established ______________. | *propeller*

limits

The Comparative Merits of the Jet Engine

Now that the basic operation of the jet engine has been explained, consider its relative merits as compared to the reciprocating engine.

Speed and high altitude performance are among the most apparent advantages of a jet engine. Jet engines also afford less vibration, reduced interior noise and a lower weight to power ratio. (Turbine engines will develop about four times as much thrust per pound of weight as reciprocating engines.) Due to the design of the jet engine, it is possible to use fuels that are not highly refined, thus reducing the cost and the fire hazard. Also because there are fewer moving parts in the jet engine, oil consumption is reduced.

On the other side of the scale, turbine engine fuel consumption is much greater than that of a reciprocating engine, especially at low altitudes. Initial costs of jet engines are still much higher than piston engines. There is also the ever present problem of jet noise in and around terminal areas.

As the jet age progresses, we are sure to see improvements and innovations that will help solve today's problems, but at the same time, will pose new challenges for the future.

Speed and high altitude performance are among the most apparent ______________ of the jet engine.

When compared to reciprocating engines, jet engines afford less vibration, reduced interior noise and have a lower ______________ to ______________ ratio. | *advantages*

	weight *power*
Jet engines do not require highly refined__________________.	*fuels*
Because there are comparatively few moving parts within a jet engine, __________________ consumption is reduced.	*oil*
When compared to reciprocating engines, jet engine fuel consumption is comparatively (high) (low) __________________.	*high*
Initial costs of jet engines are comparatively (high) (low) __________________.	*high*

High Speed Aerodynamics

The jet engine has propelled us into a new realm in which such terms as Mach number, shock wave and compressibility have come into popular usage in aviation circles. A few years ago transport aircraft pilots were not concerned with high speed aerodynamics, but today knowledge in this area is necessary. Until recently, all airplanes operated in the subsonic range which extends from 0 to 500 knots (Mach .75). As aircraft entered the transonic range, (approximately Mach .75 to 1.2) they encountered hitherto unknown and mysterious effects. As velocities neared the speed of sound (Mach 1.0) air compression caused shock waves which radically altered the behavior of an aircraft.

Just what causes a shock wave and how is it formed? Lift is created when the air pressure on the underside of the wing exceeds the pressure on the top of the wing. Conventional aircraft wings are so constructed that air accelerates across the top of the wing causing a low pressure area resulting in lift. Assume that the wing cross section depicted in Figure 12-8 is attached to a transport airplane flying at Mach 0.8. Air is being accelerated over that section of the wing labeled "A". As the air flow reaches section B it is accelerated to sonic speeds. When the sonic air flow reaches section C it has generated so much energy that it is impossible for it to make the transition back to subsonic flow without a great energy loss. This energy loss is called a shock wave.

To understand what occurs when a shock wave is encountered, the air velocity and air pressure acting on the wing surface must be studied. The curved line on the *air velocity graph* in Figure 12-8 depicts the speed of the air over the top wing surface from the leading edge to the trailing edge. The wing has a relative velocity to the air mass equal to the true airspeed of the airplane. Notice that the air velocity over the top of the wing is accelerated beyond the true airspeed of the airplane to a supersonic speed. This acceleration, caused by the aerodynamic shape of the wing, is indicated by the ascending line in sections A and B. In section C, the smooth air flow is disrupted by a shock wave and a resultant rapid deceleration in air velocity occurs. The air velocity further decelerates in section D until it is returned to its original condition behind the trailing edge of the wing. The actual effects that a pilot experiences resulting from this sudden deceleration in air flow will be discussed later in this section.

Now consider the air pressure distribution on the hypothetical airfoil. Remember that the wing is still at Mach 0.8 and that the velocity and pressure values are affecting the wing simultaneously. Notice that the *air pressure graph* in Figure 12-8 contains two curved lines. One line depicts the air pressure on the bottom of the wing, and the other depicts the air pressure on the top of the wing. Note the high pressure indicated by both lines in the first portion of section A. This is the result of the wing's leading edge. This pressure zone exists until the air begins to be accelerated by the rounded surfaces

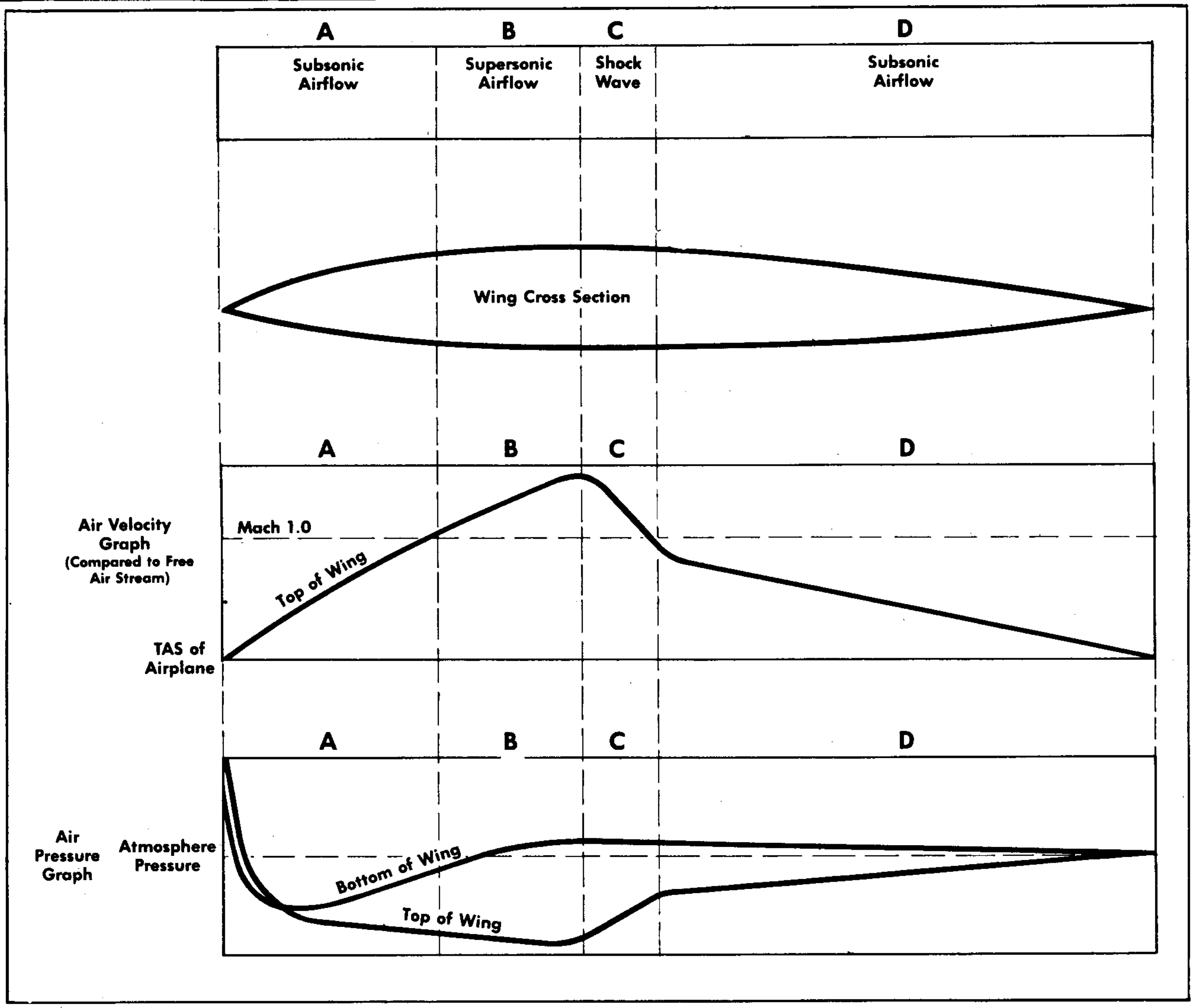


Fig. 12-8 – Air Velocity and Pressure on Wing Surface at Transonic Speeds

of the wing. By reference to sections A and B, one may easily see that the pressure on the top of the wing continues to decrease until the shock wave is encountered. At this point, pressure increases rapidly through the shock wave then increases at a slower rate until passing over the trailing edge of the wing. The pressure on the bottom of the wing is not affected by a shock wave since the local air velocity is not accelerated to sonic speeds.

The subsonic range is generally considered to extend from ______ to ______ knots.	
The transonic range is generally considered to extend from Mach ______ to 1.2 (500 to 790 knots).	*0–500*
The performance of an airplane may be radically altered as it enters the ______ speed range.	*.75*

Lift is created when air pressure on the underside of the wing exceeds pressure on the ______________ surface of the wing.	*transonic*
Acceleration of air across the top of a conventional airfoil creates a (high) (low) ______________ pressure area.	*top (upper)*
The low pressure area on the top of the airfoil is caused by the ______________ of air.	*low*
As an airplane enters the transonic range, airflow over the lift producing portions of the airplane may reach ______________ speeds.	*acceleration*
When air suddenly transitions from sonic to subsonic speeds, a ______________ wave is formed.	*sonic (supersonic)*
The speed of an airplane relative to the air mass through which it is flying is equal to the ______________ ______________ ______________ of the airplane.	*shock*
In flight at transonic speeds, the speed of the airplane plus the speed of the accelerated air over the airfoils may result in ______________ speeds.	*true air speed*
As the velocity of the air over the top of the wing nears sonic speeds, the pressure is decreased until a ______________ ______________ is formed.	*sonic (supersonic)*
The rapid deceleration of the air behind the shock wave results in an increase in air ______________	*shock wave*
When a shock wave occurs, the smooth airflow over the wing is ______________.	*pressure*
	disrupted

The effects of the varying pressure and velocity associated with a shock wave can be immediately understood when they are evaluated in terms of lift and drag. When a shock wave occurs, lift is immediately decreased because the net pressure on the wing rises. Drag is greatly increased because the deceleration of air causes a rise in static pressure. This creates an area of airflow separation behind the shock wave similar to that experienced when an airfoil is stalled. This separation is depicted in Figure 12-9.

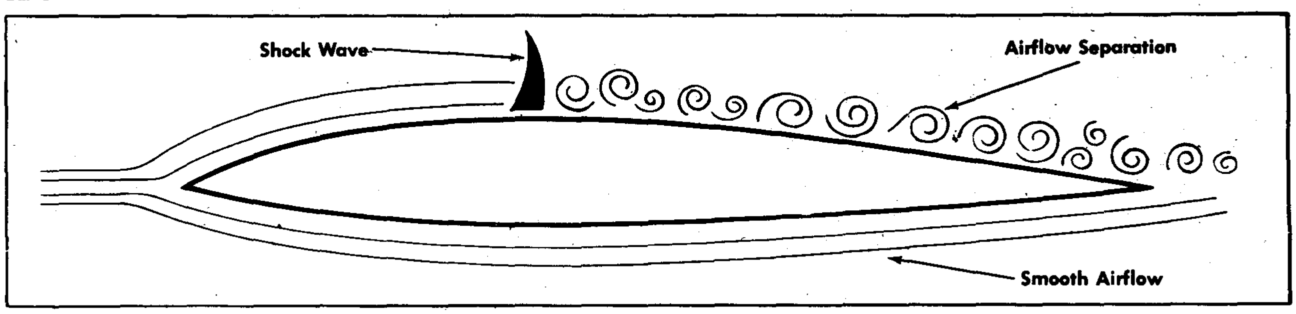


Fig. 12-9—Airflow Separation in Connection with a Shock Wave

In the above explanation, shock waves have been associated with aircraft velocities below the speed of sound. This is possible because the conventional airfoil is constructed so as to produce an acceleration in airflow. Thus the air velocity over the lift-producing portions of the aircraft is faster than the actual velocity of the aircraft. This phenomenon produces supersonic airflow before the aircraft velocity reaches Mach 1.0.

Each aircraft will react in its own characteristic manner in transonic flight. Characteristics vary from violent reactions to almost imperceptible tremors, depending of course, on the design of the aircraft. In any case, the pilot should be acquainted with the high speed characteristics of his own aircraft and should have great respect for its never exceed speed.

A shock wave causes a decrease in lift because the net pressure on the wing (increases) (decreases) ________.	
A shock wave causes an increase in drag because the deceleration of air results in a rise in ________ pressure.	*increases*
The static pressure accompanying a shock wave causes ________ separation.	*static*
Shock wave formation on airplanes traveling below the speed of sound (is) (is not) ________ possible.	*airflow*
Shock wave formation at subsonic speeds is possible because the speed of the airplane may be exceeded by the relative velocity of the ________.	*is*
Air velocity over the lift producing portions of an airplane is faster than the actual ________ of the airplane.	*air*
Transonic flight will have a varying effect on each different type of ________.	*speed*
In order that the structural limits of an airplane may not be exceeded, the pilot should be acutely aware of the ________ ________ speed of his aircraft.	*airplane*
	never exceed

Wing Sweepback

Wing sweepback is incorporated into many high performance airplanes to permit the attainment of greater speeds before encountering shock wave formation. On a straight wing airplane, the air is encountered by the airfoil at an angle of approximately 90 degrees. On a swept wing airplane this angle is reduced, thus changing the air pressure distribution on the airfoil. This results in the capability of greater speeds prior to the onset of shock wave effects.

Many high performance airplanes incorporate a wing characteristic referred to as ________.	

On a straight-wing airplane, the wing encounters the air at an angle of approximately ______________ degrees.	*sweepback*
Sweepback in a high performance airplane changes the distribution of air ______________ on the wing.	*90*
Sweepback results in the capability of greater speed without the effects of ______________ ______________ formation.	*pressure*
	shock wave

GLOSSARY OF TERMS

Compressibility. The compressing together of the molecules of air by an object moving faster than the molecules can move out of the way; the result of compressibility is to increase the density of the air in the immediate vicinity of the object.

Drag Rise. The rapid increase in parasite drag encountered by an airplane as it approaches the speed of sound.

Hypersonic Speed. Pertaining to the speed of aircraft or other objects moving at a speed of Mach 5.0 or greater.

Local Velocity. The velocity of air at some specific point on a moving body, as distinguished from the velocity of the moving body.

Mach Number. A number expressing the ratio of the speed of a moving body to the speed of sound in air.

$$\text{Mach Number} = \frac{\text{True Airspeed}}{\text{Speed of Sound at Flight Temperature}}$$

Shock Wave. A line across which a flow of air, relative to a body passing through the air, changes in pressure, velocity, density, temperature and energy within an infinitesimal period of time.

Speed Ranges. Subsonic – Mach numbers below 0.75
Transonic – Mach numbers from 0.75 to 1.20
Supersonic – Mach numbers from 1.20 to 5.00
Hypersonic – Mach numbers above 5.00

Note: Since all aircraft will have some aerodynamic shape and will be developing lift, there will be local velocities on the surfaces which are greater than the flight speed. With the possibility of having both subsonic and supersonic flow on the same aircraft, it is convenient to establish approximate speed ranges as shown above.

Speed of Sound. The speed at which sound waves travel through a medium. At standard sea level conditions, the speed of sound in air is 661 knots or 761 miles per hour.

Subsonic Speed. A speed less than the speed of sound in the surrounding fluid.

Transonic Speed. A speed at which an aircraft moves relative to the surrounding fluid when one or more points on the aircraft is subsonic and at the same time one or more points is sonic or supersonic.

DIRECTED STUDY PROGRAM

USFAA EXAMINATION GUIDE

DATE: 1 June, 1966

REF: 2000 - 1

The Job Performance section concerns the information which is necessary for the airline transport pilot and the aircraft dispatcher. This section is intended as a review prior to taking the FAA type examination and the Regular FAA Written Examination. Should you find yourself deficient in any area, you should review the appropriate section prior to taking the FAA type exam included herein.

You will need the following charts to complete this section: Low Altitude Enroute Chart(11/12); Denver, Colorado, ILS Approach Chart(11-1); Denver, Colorado, VOR Approach Chart(13-1); Denver, Colorado, Low Altitude Area Chart; Pueblo, Colorado, VOR Approach Chart.

When Charts are needed order from DOTD, TPE.

The frames concerning Federal Aviation Regulations are not designed to be exhaustive in that area, however they are intended to serve as a guide to effective study.

To comply with takeoff limitations which provide for failure of the critical engine after the V_1 speed is exceeded, a reciprocating engine aircraft must be capable of climbing to a height of ________ feet by the end of the runway.	
An air carrier aircraft shall not be taken off in excess of that weight which would permit the airplane to be brought to a stop (assuming normal fuel burnout) at the planned destination in ________ percent of the effective runway length.	*50*
The materials used for the construction of aircraft cabin interiors shall be no less than ________ resistant.	*60*
All transport category aircraft shall be equipped with at least (one) (two) ________ crash axe(s).	*flash*
When the light system which illuminates the emergency exits requires arming to function automatically, the system shall be armed prior to each ________ and ________.	*one*
Supplemental oxygen shall be used by each member of the "on duty" crew when operating above ________ feet.	*takeoff* *landing*
Supplemental oxygen, for each passenger for the entire flight, shall be provided when operating at altitudes above ________ feet.	*10,000*
For a turbine powered airplane operating at a cabin pressure altitude of 15,000 feet, supplemental oxygen will be provided for the entire flight for ________ percent of the passengers carried.	*15,000*
When a flight recorder is required in an airplane, it will be operated continuously from the beginning of the takeoff roll to completion of the ________ roll.	*30*

DIRECTED STUDY PROGRAM

USFAA EXAMINATION GUIDE

DATE: 1 June, 1966

REF: 2000 - 1

Prior to serving as pilot in command on a scheduled flight, a pilot must have had, in the particular type airplane on which he is to serve, at least three takeoffs and three landings within the preceeding ______ days.	*landing*
A pilot must successfully accomplish a line check prior to serving as pilot in command and at least once every ______ months thereafter.	*90*
The pilot proficiency check for a pilot in command must be accomplished each ______ months.	*twelve*
To be utilized as pilot in command on a specific route, a pilot must have made at least one flight over the specified route as a crew member within the preceeding ______ months.	*six*
The pilot proficiency check for second in command must be accomplished every ______ months.	*twelve*
In any one month, a pilot may not be scheduled for more than ______ hours of commercial flying.	*twelve*
If a pilot has been on flight duty in excess of eight hours in a twenty-four hour period, he must be given at least ______ hours rest.	*100*
An airport cannot be specified in the dispatch release as an alternate airport unless the appropriate weather reports and forecasts indicate that at the estimated time of arrival of the flight, the ceiling and visibility will be at or above the alternate minimums as specified in the air carrier's operations specifications for that specific ______.	*sixteen*
A scheduled air carrier flight must carry enough fuel to fly to the destination, then on to the most distant alternate and thereafter for an additional ______ minutes at normal fuel consumption.	*airport*
Protective breathing equipment for crew member use shall be installed if the airplane contains class A, B or ______ cargo compartments.	*45*
According to FAR part 4b, an air carrier airplane with a passenger capacity of 55 is required to be equipped to (two) (three) ______ fire extinguishers.	*E*
For the purposes of fire protection, cargo compartments are divided into (four) (five) ______ classes.	*three*
The maximum indicated airspeed for propeller driven aircraft in the holding pattern is ______ knots.	*five*
An automatic bearing indicator is incorporated into the VOR equipment of a particular aircraft. When the receiver is tuned to a VOT, the bearing indicator will indicate ______ degrees.	*175*

A flashing green signal from the tower portable traffic control light while a pilot is on the ground indicates that the pilot is cleared to ______________.	*180*
When a pilot is cleared for an ascent, he should climb as rapidly as practicable to 1,000 feet below the assigned altitude, then transion to a ______________ foot per minute rate of climb.	*taxi*
The phrase "via flight planned route" when used in a clearance indicates to the pilot that he (is) (is not) ______________ cleared to climb to the requested altitude.	*500*
The symbol used to indicate the maximum speed with the flaps in landing position is ______________.	*is not*
The inbound course of a particular standard holding pattern is 150°. For an aircraft entering holding on a heading of 190°, the initial turn to enter the pattern would be (right) (left) ______________.	*V*
A "VFR on top" flight is considered to be an (VFR) (IFR) ______________ operation.	*right*
Assuming an engine failure at V_1, a transport category aircraft must be capable of attaining a height of 50 feet before passing over the end of the runway and thereafter, clear all obstacles by at least 50 feet vertically and ______________ feet horizontally within the airport boundaries.	*IFR*
The pilot of an air carrier aircraft who has requested an instrument route clearance, may expect to be given a SID at the discretion of ______________.	*200*
For operations requiring an airline transport pilot certificate, the first class medical certificate must be renewed every ______________ months.	*ATC*
Regulations classify fires according to the extinguishing agent which should be used. Electrical fires are in class ______________.	*six*
	C

The hypothetical flight for this exercise will be from Oklahoma City to Denver at a planned pressure altitude of 14,000 feet. Pueblo will be used as the alternate and the leg from Denver to Pueblo will be planned at 11,000 feet. In this exercise, assume that pressure and indicated altitude are identical.

The exact route to be planned is as follows: Will Rogers Airport direct to Oklahoma City VOR, Victor 17 to Goodland and Victor 4 to Denver. The route to the alternate, Pueblo, will be Victor 81.

The flight is scheduled to depart Oklahoma City at 0700 CST.

Figures referred to in the following frames can be found at the end of this section.

Referring to the 0500 CST surface weather map (Figure 13-1), the high clouds over Denver are ______________.	
The barometric pressure at Goodland, Kansas, at 0500 CST is (increasing) (decreasing) ______________.	*cirrus*
The surface weather over Denver at 0500 CST includes precipitation in the form of ______________.	*decreasing*
According to the 0600 CST Weather Report, (Figure 13-2), the wind at Denver is approximately ______________ degrees at ______________ knots.	*rain*
Referring again to the 0600 CST Weather Report, the obstruction to vision at North Platte is ______________ snow.	*280* *10*
According to the winds aloft forecast (Figure 13-2), the wind over Dodge City at 14,000 feet is ______________ degrees at ______________ knots.	*light*
According to the Denver Area Forecast, (Figure 13-3), there will be scattered thunderstorms in Colorado east of the mountains in the ______________ and ______________.	*278* *48*
The 700 MB chart is associated with an altitude of approximately ______________ feet.	*afternoon* *evening*
	10,000

Flight Planning Particulars

A. For the OKC to GAG leg, use the average of the winds and temperatures given for those two cities on the Winds Aloft Forecast. For the GAG to GLD leg, use the winds aloft forecast for Dodge City. For the GLD to DEN leg, use the average winds and temperatures aloft given for DEN and GLD. Use an average of the winds and temperatures between DEN and PUB, for the alternate leg. Note that one must interpolate between the 10,000 and 15,000 foot levels to arrive at the correct wind for the desired altitude.

B. Assume the calibrated airspeed (CAS) is 190 knots throughout the flight, unless instructed to the contrary. The true airspeed (TAS) can be computed from the CAS when the outside air temperature (OAT) and pressure altitude are known.

C. The fuel consumption values are listed on the flight planning sheet. Assume that the airplane is off the ground at Oklahoma City with a total of 3200 gallons.

D. It will be to the student's advantage to complete all the information required on the flight planning sheet (Figure 13-4), prior to continuing with this section.

The total planned flight time to Denver is ______________.	
The total fuel required, including fuel to the destination and alternate plus the reserve fuel, is ______________ gallons.	*2 + 25*

The planned fuel remaining in the aircraft upon reaching the Denver VOR is ______________ gallons.	*1145*
The planned groundspeed between Gage and Garden City is ______________ knots.	*2406*
According to the data in the flight planning sheet, the magnetic heading between Thurman and Denver is ______________ degrees.	*203*
Assume: (1) the takeoff gross weight of the airplane is 88,800 pounds, (2) standard atmospheric conditions exist at Oklahoma City, (3) a 20 knot headwind exists, (4) and the takeoff runway has an uphill gradient of one (1) percent. According to Figures 13-5 and 13-6, the minimum takeoff runway length would be ______________ feet.	*279*
By reference to the Airman's Guide, (Figure 13-7) it is determined that the ground control frequency at Colorado Springs is ______________ mc.	*5,525*
The maximum weight authorized for an airplane, excluding disposable fuel and oil, is called the ______________ weight.	*121.7*
In weight and balance computations, total moment divided by total weight equals the distance from the datum line to the ______________.	*zero fuel*
Assume an airplane has a total weight of 106,000 pounds and the fore and aft CG limits are at 421 inches and 478 inches respectively. The CG is located at 436 inches. If 10 passengers, weighing 165 pounds each, are moved from station 561 to station 395, the new CG would be located at ______________ inches. NOTE: $1650 = \frac{X\ 106{,}000}{166}$	*CG*
If the MAC for the above problem is from 395 inches to 587 inches, the CG location expressed in terms of % of MAC is ______________%.	*433.4*
After route and takeoff clearance is received, the takeoff is accomplished and the pilot is advised that he will be given a radar vector to the Calumet Intersection. While under radar control (assume no non-radar separation), the pilot can expect a minimum aircraft separation of (three) (two) ______________ miles.	*20*
Assuming that the pilot received clearance to 14,000 feet, he may legally climb unrestricted to an altitude of ______________ feet.	*three*
While in the climb-out, the pilot should anticipate the fact that control of his flight will be transferred to an ARTCC. The Center which would most likely be concerned would be ______________.	*13,000*

The airplane is level at 14,000 feet (pressure altitude) over Omega Intersection at 0717 CST. At 0732, over Camargo Intersection the pilot computes the wind: Given: Magnetic heading 297° OAT −17°C Required: Wind direction and velocity = __________. *NOTE: Wind is usually computed using the following values: TAS, TH, GS, TC.*	*Fort Worth*
The pilot reports Gage at 0742 and is requested by ATC to arrive at Meade Intersection not before 0805. On the basis of the wind calculated in the preceeding frame, the true airspeed necessary for this leg will be __________ knots. *NOTE: Find TAS by using wind (347/49), true course (337°) and desired groundspeed (154 kts.).*	*347/49*
Assuming a temperature of −17°C, what calibrated airspeed must be maintained to arrive at Meade at 0805? __________ knots.	*203*
Assume a flight is at a pressure altitude of 14,000 feet in an area of standard atmospheric conditions. In this situation, with a true airspeed of 215 knots, the calibrated airspeed would be __________ knots.	*165*
As the flight passes Garden City, Kansas City Center requests that Denver Center be contacted passing the 231° radial of Hill City VOR. Assume the pilot has tuned Hill City VOR and has selected 231° on the OBS. If the flight is 45 miles southeast of Goodland on V-17, the course deviation indicator will be to the (right) (left) __________ of center.	*173*
VOR radials are oriented to (true) (magnetic) __________ North.	*right*
Denver Center requests the flight to climb to 16,000 feet (pressure altitude) prior to reaching Goodland. At 16,000 feet the pilot computes the TAS from the following information: Indicated airspeed 155 knots Airspeed position and instrument correction +3 knots Indicated Outside Air temperature −20° C Temperature Correction 4° C Compressibility Correction 2 knots The TAS is __________ knots. *NOTE: Remember, compressibility causes an erroneously high airspeed indication and friction causes an erroneously high air temperature indication.*	*magnetic*
The Mach number for the TAS computed in the preceeding frame is __________.	*.198*
Mach number is the ratio of true airspeed to the speed of __________.	*.32*
The true airspeed of a Mach number varies directly with the __________.	*sound*

When flying from a low pressure area to a high pressure area, the altimeter will indicate (higher) (lower) ________ than the true altitude. *NOTE: Remember the old adage—"When flying from high to low, (hot to cold) watch out below".*	*temperature*
Jet stream activity is much greater in the (winter) (summer) ________.	*lower*
Clear air turbulence associated with the jet stream is most likely to occur on the (north) (south) ________ side of the jet stream.	*winter*
The Polar Jet Stream over the United States occurs near the break between the Polar and Sub-tropical tropopauses. This is normally at an altitude of approximately ________ feet.	*north*
When a pilot is affected by hypoxia, his pulse and respiration rate are likely to be (increased) (decreased) ________.	*34,000*
Maximum night vision requires dark adaption. The average person becomes fully dark adapted after being in darkness for about ________ minutes.	*increased*
Over Goodland, the pilot accepts a radar vector south of course in order to avoid severe weather. After flying on a compass heading of 265° for 7 minutes, the pilot sees the Burlington Airport below. The pilot is cleared from his present position direct to Thurman. In this case, the compass heading to Thurman would be ________ degrees. *NOTE: Consult computer instruction manual on "off course corrections".*	*30*
The pilot is instructed to enter a standard holding pattern upon reaching Thurman. The initial turn over the holding fix will be to the (left) (right) ________.	*295*
Nearing Denver, the pilot checks the approach chart for the Stapleton ILS approach to runway 26L. The Watkins Intersection is 21.4 miles out on the 320° radial of the ________ (Kiowa) VORTAC.	*right*
The safe altitude within a 20 nautical mile radius of Stapleton Airport is ________ feet.	*IOC*
Watkins Intersection is 9.4 miles from the ________.	*11,000*
The weather minimums for a scheduled air carrier prop aircraft executing an ILS approach to runway 26L are, 200-½ or an RVR of ________ feet.	*outer marker*
Referring to the preceeding frame, if the pilot receives no glide slope indication, he may descend to a minimum of ________ feet.	*2400*

If the groundspeed on final approach is 120 knots, the time from the outer marker to the field is ______.	5731
The middle marker is ______ miles from the runway.	2:45
For a three engine jet landing on runway 26L, the RVR minimum is ______ feet.	0.6
When on glide slope for a VASI approach, the downwind lights will be (white) (red) ______.	4000
Consult Figure 13-8 to find the landing distance from a 50 foot height at Stapleton Airport in Denver, Colorado. Assume standard atmospheric conditions, a 10 knot headwind and a landing gross weight of 68,000 pounds. Under this configuration, the landing distance is ______ feet.	*white*
Effective runway length is established by an obstruction clearance line which has a slope of ______ to 1.	2800
If obstructions exist in the flight path area, the actual runway length may be longer than the ______ runway length.	20
The planned landing distance at the alternate airport may be no more than ______ percent of the effective length of the runway.	*effective*
The symbol for the maximum operating limit speed when given in terms of Mach number, is ______.	70
An obstruction free area at the end of a runway is referred to as a ______.	*Mmo*
Shock wave formation caused by aircraft traveling at subsonic speeds is possible because the speed of the airplane may be exceeded by the relative velocity of the ______.	*clearway*
The word subsonic, when referring to the speed ranges of aircraft, refers to speeds less than Mach ______.	*air*
The symbol for the speed at which a jet airplane actually lifts off the runway is ______.	.75
The minimum climb gradient necessary for a four engine jet airplane in the second segment of climb, is ______ percent.	V_{lof}
Runway Visual Range equipment provides the pilot with a value which represents the visibility at the ______ of the runway.	3.0
On a VASI approach, the pilot sees red over pink lights. He should know from this information, that he is (low) (high) ______ on the glide path.	*threshold*

Referring to Figure 13-9, determine the takeoff distance under the following conditions: GIVEN: 1. Gross weight 240,000 lbs. 2. Pressure altitude 500 ft. 3. Temperature 0°C 4. Runway gradient +2% 5. Wind +10 kts. REQUIRED: 1. Takeoff distance ________.	*low*
By reference to Figure 13-10, determine the second segment climb gradient under the following conditions: GIVEN: 1. Outside air temperature +15° C 2. Pressure altitude 2000 ft. 3. Anti icing ON 4. Initial climb weight 220,000 lbs. REQUIRED: 1. Second Segment Gradient ________ percent.	*8100*
	6.3

NOTE: Figure 13-11 is a completed flight planning sheet for the exercise discussed in this section.

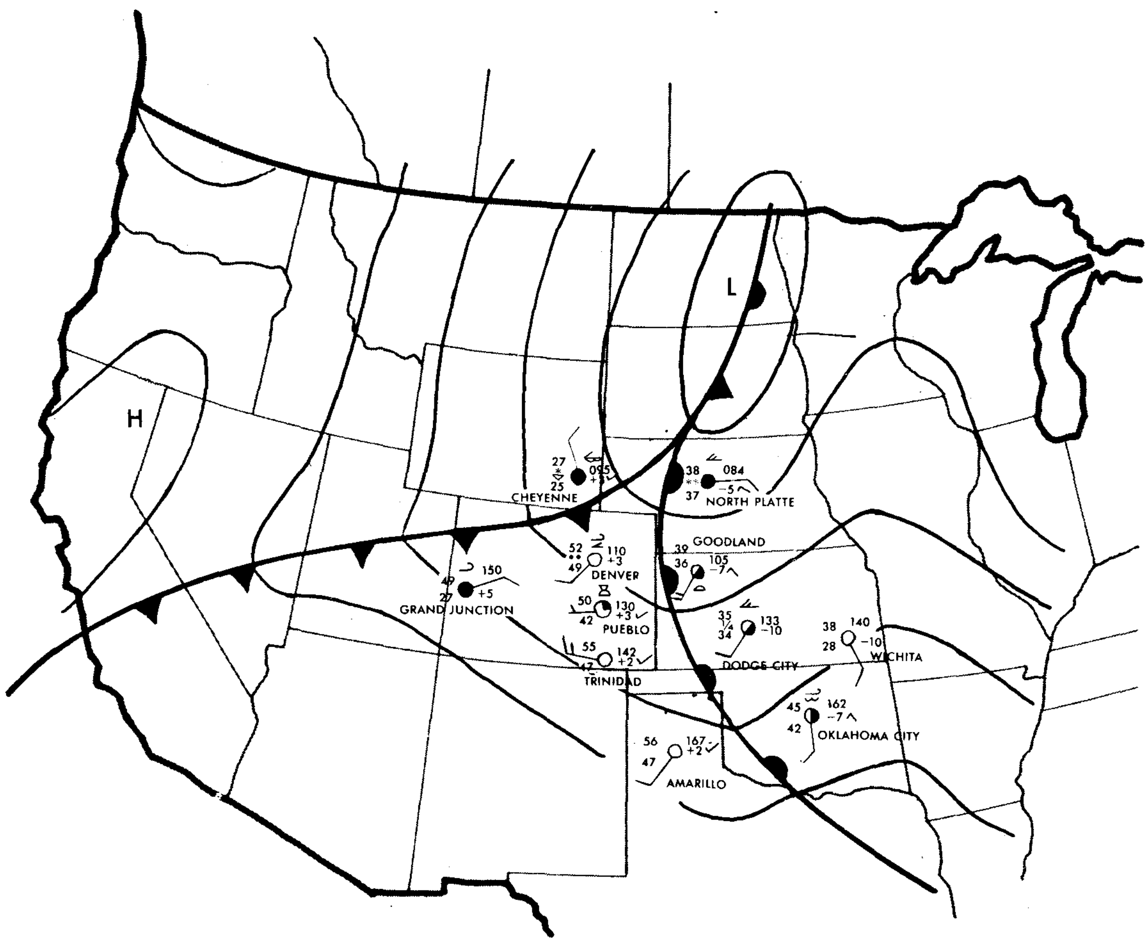


Fig. 13-1 — 0500 C Surface Weather Map

TELETYPE WEATHER REPORTS

0500C - GLD (Goodland) 2⊕2S- 105/39/36/2015/984
LBF (N. Platte) 3⊕S+ 084/38/37/0810/978
GCK (Garden City) 20⦶25⊕4 133/35/34/2010/992
DEN (Denver) 20⊕2S 110/52/49/2110/985

0600C - GLD M10 ⊕ 102/42/38/1920/983
LBF M2⊕2S- 083/34/32/1515/977
GCK 25⦶M50⊕10 131/37/35/992
GAG (Gage) M20⊕4R-H 148/54/53/2615/997
DEN 30⊕2S+ 118/36/34/2810/988

WINDS ALOFT FORECAST

LVL	3000	5000FT	10000FT	15000FT	20000FT	25000FT
OKC	1910+4	2220-1	2545-9	2750-19	2655-26	2660-33
GAG	1615-2	1825-5	2435-13	2645-23	2550-29	2655-36
DDC		2535-1	2740-12	2850-22	2660-30	2565-38
GLD		3625-3	3450-13	3355-23	3160-29	2765-39
DEN			3560-2	3260-14	2765-25	2670-36
PUB			3545-1	3250-13	2760-25	2670-35

TERMINAL FORECAST

FT 110600 C
DEN C15⊕6S- 3620. 0700C C20⊕8S- 3620
0900C C25⊕8S- 3625
PUB C25 ⊕ 3620. 0800C 30⦶C80⊕ 3625
1000C 30⦶C80 ⊕ 3625

Fig. 13-2

DENVER AREA FORECAST

FA DEN 141245

6M-18M SAT

COLO WYO NEB PHNDL

CLDS AND WX. WARM FRONT CNTL NEB E KAN WITH INVERTED TROF NNWD THRU NE WYO. FRONT AND TROF MOVG EWD ABT 12 TO 15 KT. ALG TROF THRU NEB PHNDL PTCHY GND FOG AND ST LCLY C6⊕4F TIL 8M LFTG AND DSPTG BFR NOON WITH CU DECK DVLPG ARND 40 TO 50 AGL AFTN SCTD SHWRS AND TSTMS. ALG AND 50 TO 100 MIS FLWG TROF NE AND N-CNTRL WYO C10 -18⦷35⊕ OCNL RW- PSBL ISLTD OVRNG TSTM. MTS GEN OBSCD. CIGS STDLY IMPROVG THRU MRNG WITH GEN C40 -60⦷ AGL AFTN. FQT TSTMS AFTN WITH CDNS LCLY C25⊕4 TRW+A-. SW WYO SCCU GEN C25⦷50⦷ LFTG STDLY BCMG MSTLY 60⦶C+ 100⦷ AFTN WITH ISLTD TSTMS. COLO CU DVLPG THRU MRNG WITH ISLTD AFTN TSTMS W DVD AND SCTD TSTMS E MTNS AFTN AND EVE. TSTM BASES GEN 110 -120 MSL E MTNS

ICG. NONE OF CONSEQUENCE OUTSIDE TSTMS. FRZG. LVL 60 MSL WYO NEB PHNDL NRN COLO SLPG TO 80 MSL SRN COLO

TURBC. NONE OF CONSEQUENCE OUTSIDE TSTMS

OTLK. 18M SAT-6M SUN. TSTM ACTVTY DCRG RPDLY MTNS AND W AFTR SNST AND AFTR 22M ERN COLO ERN WYO NEB PHNDL. PTCHY ACAS GEN BASED 160 -180 MSL WYO NEB PHNDL EXTRM NRN COLO CLRG RMNDR COLO

Fig. 13-3

ROUTE		Cruise Alt.	Average True Course	Wind Dir/Vel Knots	Average Drift Corr.	Average TAS Knots	Average GS Kts.	Dist. NM	Time	Fuel
FROM	TO									
WILL ROGERS	OKC	↗						9	3	
OKC	OMEGA	↗						33	12	
OMEGA	GAG	14,000								
GAG	GCK									
GCK	GLD									
GLD	TXC									
TXC	DEN									
							TOTALS:			
				ALTERNATE						
DEN	COS	11,000								
COS	PUB									
							TOTALS:			

FUEL PLANNING

	Time	Gal.
Climb		
Cruise		
Alternate		
Reserve		
Extra		
Total		

Fuel Consumption Values

Climb: 405 GAL/HOUR

Cruise: 320 GAL/HOUR
(Destination/Alternate/Reserve)

Extra: 290 GAL/HOUR

Fig. 13-4—Flight Planning Sheet

CONDITIONS:

- Wing Flap Setting 17°
- Hard Surface Runway
- No Runway Slope
- Standard Atmospheric Conditions

NOTE:
1. If the Critical Engine Fails at V_1, the Distance to Stop is Equal to the Distance to Climb to 50 Ft.
2. 150% of Reported Tailwind and 50% of Reported Headwind used in Construction of this Chart.

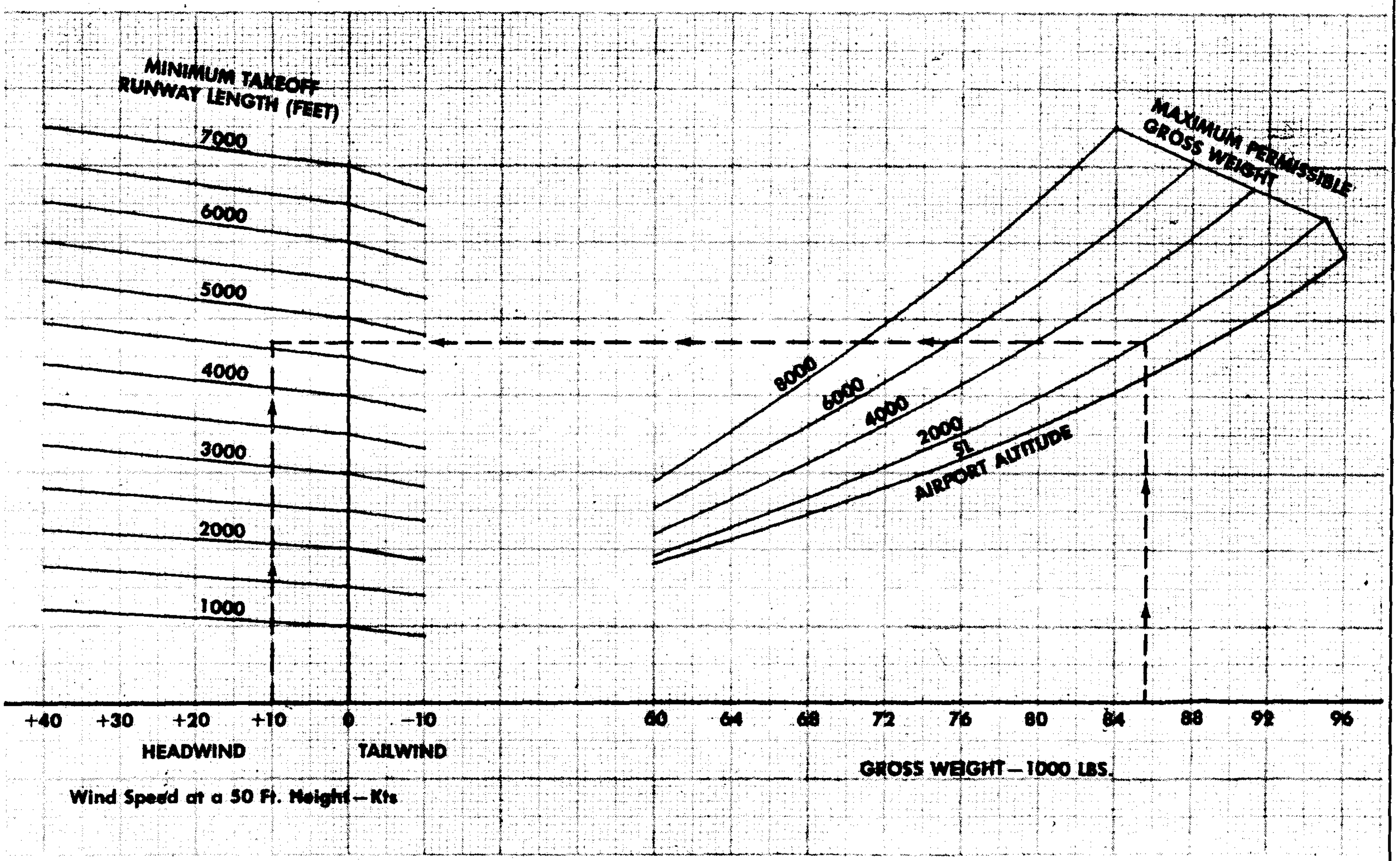


Fig. 13-5 – Minimum Takeoff Runway Length Chart

CONDITIONS:
- Flap Setting 17°
- No Obstacle at End of Runway
- Hard Surface Runway
- Standard Atmospheric Conditions

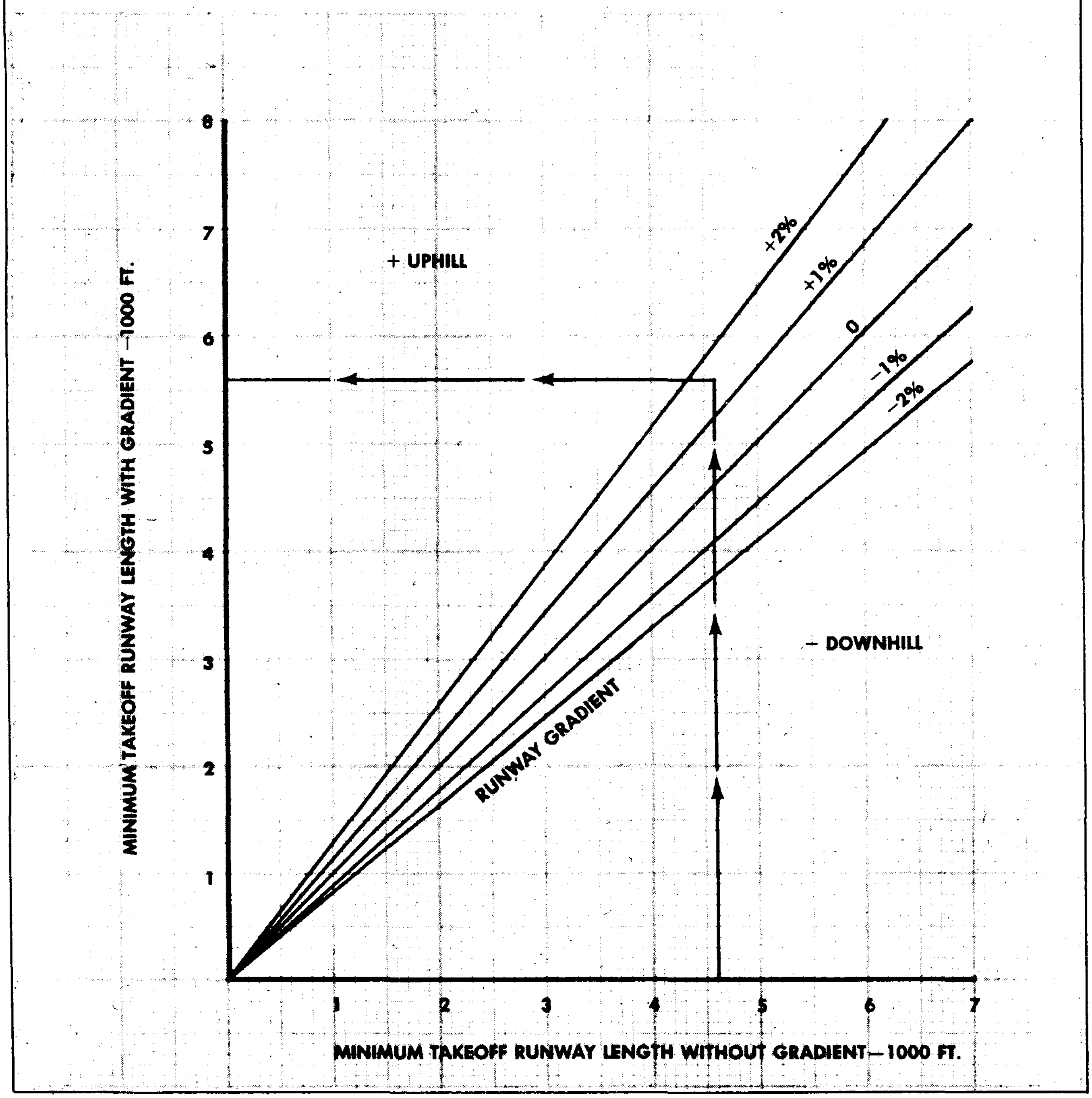


Fig. 13-6 — Effect Of Runway Gradient On The Minimum Takeoff Runway Length

AIR NAVIGATION RADIO AIDS—*Continued*

CALIFORNIA—*Continued*

LOCATION	CLASS	IDENT	FREQUENCIES TRANSMITS	FREQUENCIES RECEIVES	REMARKS
San Francisco Gap	MHWZ	SFG	332		
San Jose [1]	L-VOR	SJC	108.2		
San Jose Mun	C(g.7)		227 120.7 243.0 381.6	(1) ◆ 122.4	
San Jose Mun	VHF/DF			120.1 121.3 123.7 122.4 (req 100–155)	Moffett apch ctl
San Jose Mun	UHF/DF			322.0 346.0 350.8 (req 225.0–399.9)	Moffett apch ctl
San Luis Obispo [1]	M-BVORTAC	SBP	112.4	122.1	Paso Robles FSS
San Nicholas (N)	MHW	NSI	203		
Santa Ana, El Toro MCAS	H	NZJ	410 142.74 243.0	(1) ◆	
Santa Ana, El Toro MCAS	M- VOR	NZJ	111.0		
Santa Ana, Orange Co	L-VOR	SNA	108.8		
Santa Ana, Orange Co	C(g.7)		326 119.9 243.0 257.8 269.3	◆ 122.5	(0600–2400)
SANTA BARBARA [1]	H-BVORTAC	SBA	114.9 V 243.0 255.4 272.7	(3) —3023.5 req◆	
Santa Barbara	AC(g. 7)		338 119. 7 125. 4 243. 0 269. 2 353. 9	◆ 122. 7	
Santa Catalina [1]	L-BVOR	SXC	111.6		Los Angeles FSS
Santa Maria [1]	L-·VOR	SMX	109.0	122.1	Ctld Vandenberg AFB
Santa Monica (P)	L-*VORW	SMO	110.8		
Santa Monica Mun	C(g)		201 120.3 126.2 243.0 257.8	(1) ◆ 122.6	(0700–2300)
Santa Rosa, Sonoma Co	C(g)		206 118.5 243.0 348.6 363.0	◆ 122.5	(0600–2200)
Sausalito [1]	L-BVORTAC	SAU	110.4		Oakland FSS
STOCKTON [1]	H-BVORTAC	SCK	116.0 V 243.0 255.4 272.7	(3) —3023.5 req◆	
Stockton Metro	AC(g)		299 120.3 126.2 243.0 257.8 363.2	(2) ◆	
THERMAL (AAS) [1]	H-BVORTAC	TRM	116.7 V 243.0 255.4 272.7	(3) —3023.5 req◆	
Torrance Mun	C(g)		221 118.1 243.0 319.8	◆ 122.5	(0600–2200)
Twenty Nine Palms [1]	M-BVORTAC	TNP	114.2		Ctld Thermal FSS
UKIAH (AAS)[1]	M-BVORTAC	UKI	112.3 V 243.0 255.4 272.7	(3) —3023.5 req◆	
Ukiah	BJ	UKI	278		
Van Nuys	C(g.7)		281 120.1 126.2 243.0 383.1	(2) ◆	
Van Nuys	UHF/DF			243.0 257.8 383.1	
Ventura [1]	L-BVOR	VTU	108.2		Santa Barbara FSS
Victorville, George AFB	L-VOR	VCV	108.6		
Victorville, George AFB	HW	VCV	376		
Whitmore	MRLWZ	NIT	353		01A 91N 181A 271N
Williams [1]	M-*BVORTAC	ILA	114.4 V 243.0 255.4 272.7	(3) —3023.5◆	Marysville FSS
Woodside [1]	L-BVOR-DME	OSI	111.4		Oakland FSS

COLORADO

LOCATION	CLASS	IDENT	FREQUENCIES TRANSMITS	FREQUENCIES RECEIVES	REMARKS
AKRON (AAS)	SBMRAZ	AK	388 V 243.0 255.4 272.7	(3) —3023.5 req◆	64A 154N 230A 334N
Akron [1]	M-BVOR	AKO	114.4		
Alamosa [1]	H-BVORTAC	ALS	113.9	122.1	Trinidad FSS
Aurora	HW	AUR	281		
Colorado Springs	MHW	CO	407		
Colorado Springs [1]	M-BVORTAC	COS	112.5	122.1	Pueblo FSS
Colorado Springs, Peterson	L-VORW	PEF	109.0		
Colorado Springs, Peterson Fld	AC(g.7)		215 118.5 119.9 120.2 126.2 243.0 269.1 348.6 360.6 362.3 383.1	◆ 122.5	
Colorado Springs, Peterson Fld	VHF/DF			118.5 119.9 120.2 122.1 122.5 125.9 126.2 126.6 126.7	
DENVER	SABMRAZ	DN	379 V 243.0 255.4 272.7	(3) —3023.5 req◆	59N 168A 239N 335A
Denver [1]	M-BVORTAC	DEN	116.3		
Denver, Stapleton Airfld	AC(g)		335 118.3 119.5 119.8 120.5 124.8 126.2 137.65 243.0 257.8 269.3 271.3 284.0 307.0	◆ 122. 5	
Denver	Center		See page 50 for center frequencies		
Denver, Stapleton Airfld	VHF/DF			118.1 118.3 119.3 119.5 120.5 120.9 122.1 122.5 126.2 135.9 137.65	
Dove Creek [1]	M-BVORTAC	DVC	114.4		Farmington NM FSS
Durango (P)	L-VOR	DRO	108.2	122.1	(0500–2200)
●EAGLE (AAS)		EGE	V 243.0 255.4	(3) —3023.5 req◆	
Eagle	BJ	EGE	391		
Ellicott	MHW	ELL	347		
Gill [1]	M-BVOR	GLL	108.8		Denver FSS
GRAND JUNCTION [1]	H-BVORTAC	GJT	112.4 V 243.0 255.4 272.7	(3) —3023.5 req◆	
Grand Junction	MHW	GJT	396		
Grand Junction, Walker Fld	AC(g)		278 118.1 119.7 243.0 257.8 335.5 385.6	◆ 122.5	
Gunnison [1]	M-BVORTAC	GUC	114.9		Grand Jct FSS
Hanover	MHW	HNR	356		
Hugo [1]	M-BVOR	HGO	108.4	122.1	La Junta FSS

V=122.2, 126.7, 135.9 mc transmitted. ◆=Guards same VHF and UHF freqs facility transmits except 122.2 mc. (1)=3023.5 kc guarded. (2)=3023.5 kc 122.5 mc. (3)=3023.5 kc; 122.1, 126.7, 135.9 mc., e.g. (3)-135.9 guards every frequency in group (3) except 135.9 mc. (g)=Tower equipped with 121.9 mc or (g.7)=Tower equipped with 121.7 mc for control of ground traffic. EMERGENCY FREQUENCY (121.5 mc) transmits and guards at all FSS, Towers (FAA and Military). Centers and DF Stations; this frequency is not tabulated in the list above. *=Automatic voice identification. NOTE: FIRST FREQUENCY LISTED IS THE NAVIGATIONAL AID CHANNEL; OTHERS ARE COMMUNICATIONS CHANNELS LISTED IN NUMERICAL ORDER WITHOUT REGARD FOR ASSIGNMENT. See Legend Page (Radar/Rdo-1) for VOR Monitoring Classification and Radio Class Designations.

Fig. 13-7 – Excerpt – For Training Purposes Only

CONDITIONS:

- **No Runway Slope—Standard Atmospheric Conditions**
- **Hard Surface Runway—Flaps Full Down**

NOTE: This Chart Constructed Using 50% of Reported Headwind and 150% of Reported Tailwind.

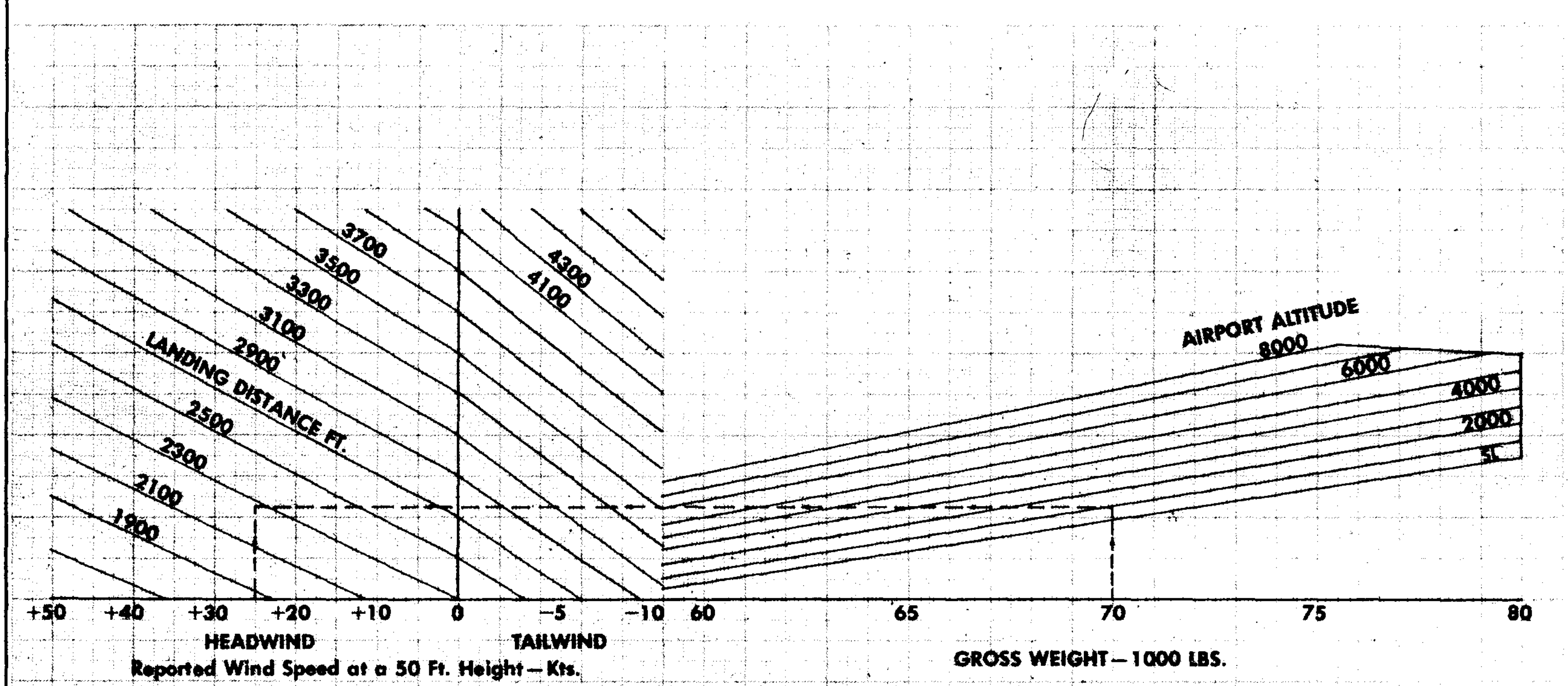


Fig. 13-8—Landing Distance From a 50 Ft. Height

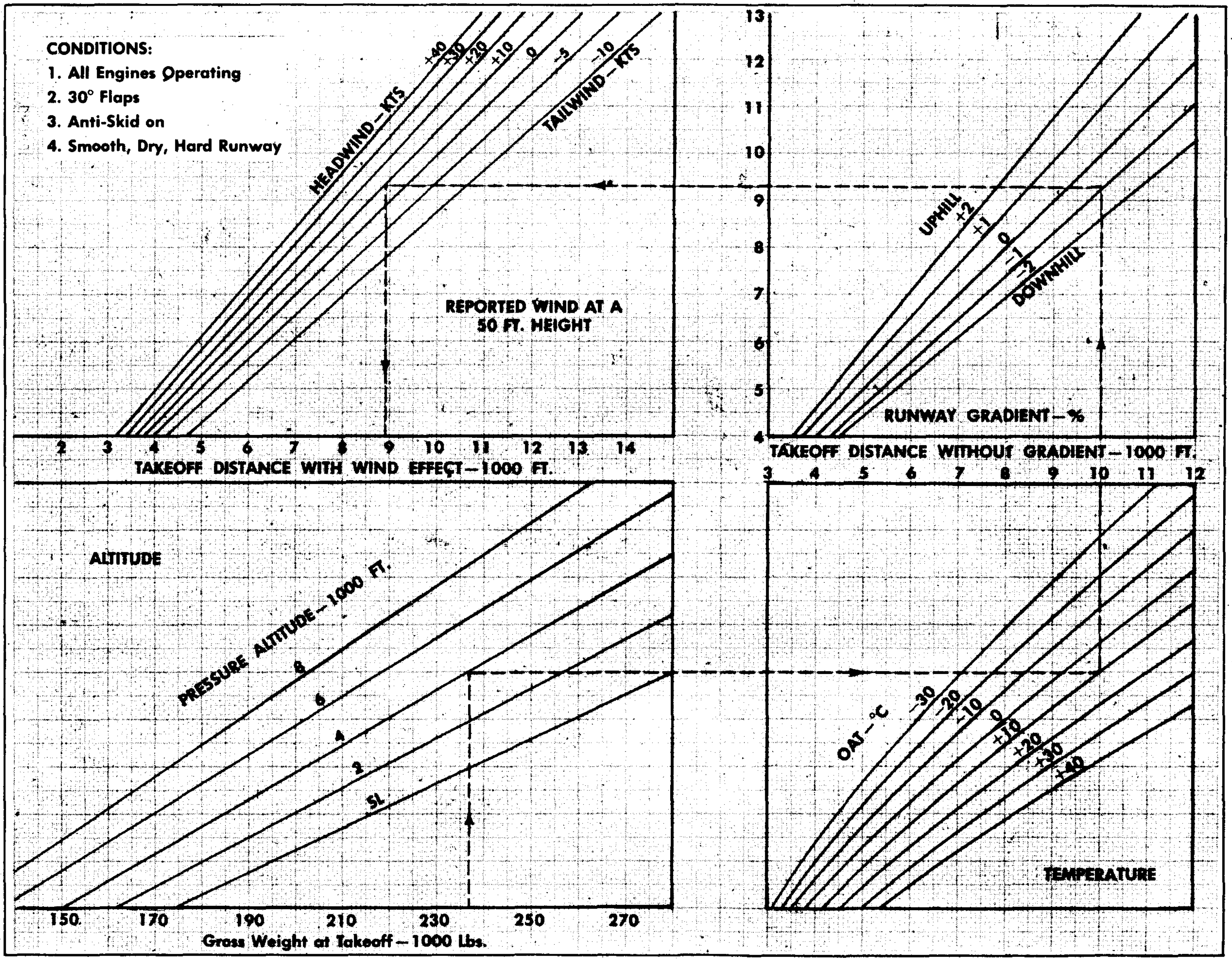


Fig. 13-9—Takeoff Distance

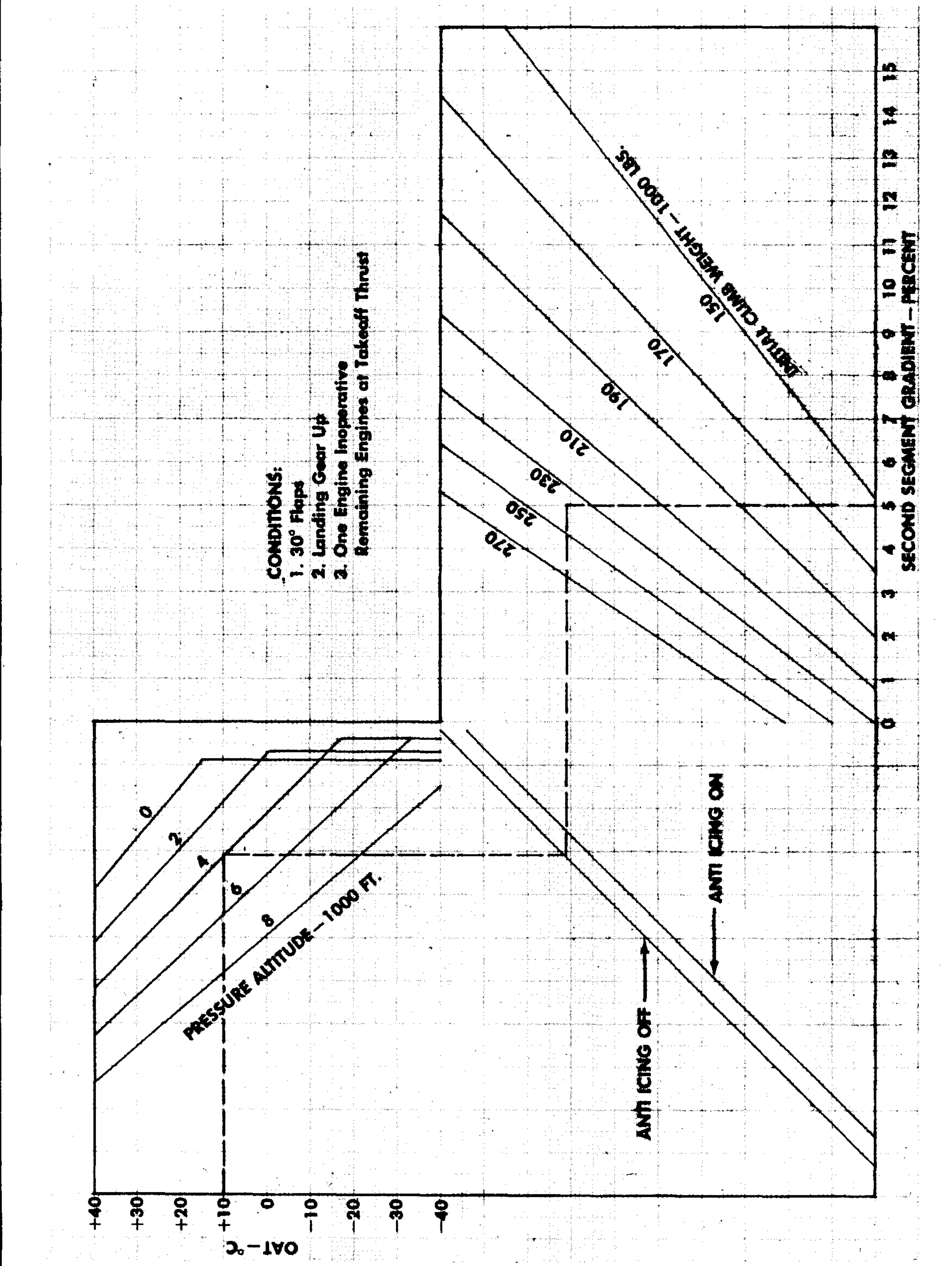


Fig. 13-10 – Second Segment Climb

ROUTE FROM	ROUTE TO	Cruise Alt.	Average True Course	Wind Dir/Vel Knots	Average Drift Corr.	Average TAS Knots	Average GS Kts.	Dist. NM	Time	Fuel
WILL ROGERS	OKC	↗						9	3	20
OKC	OMEGA	↗	298	261/46 (-19)				33	12	81
OMEGA	GAG	14,000	298	261/46 (-19)	7°L	233	196	83	25 ½	136
GAG	GCK	14,000	337	278/48 (-20)	10°L	232	203	103	30 ½	163
GCK	GLD	14,000	334	278/48 (-20)	10°L	232	203	99	29 ½	157
GLD	TXC	14,000	282	329/57 (-16)	10°R	235	194	71	22	117
TXC	DEN	14,000	282	329/57 (-16)	10°R	235	194	73	22 ½	120
							TOTALS:	471	2+25	794
ALTERNATE										
DEN	COS	11,000	174	344/53 (-3)	2°R	226	278	56	12	64
COS	PUB	11,000	167	344/53 (-3)	0°	226	280	40	9	48
							TOTALS:	96	21	112

FUEL PLANNING

	Time	Gal.
Climb	15	101
Cruise	130	692
Alternate	21	112
Reserve	45	240
Extra	—	—
Total		1145

Fuel Consumption Values

Climb: 405 GAL/HOUR

Cruise: 320 GAL/HOUR
(Destination/Alternate/Reserve)

Extra: 290 GAL/HOUR

Fig. 13-11 — Completed Flight Planning Sheet

General Hints About Examinations

The items listed below are important areas of consideration before and during any examination.

1. Be fully prepared to take the examination. Review difficult subject areas if you have doubts about your knowledge. Be ready!
2. Have all equipment required: paper, pencils, plotter, computer, graph paper, as needed.
3. Read very carefully instructions and reference material included with the exam.
4. Read (study) each question carefully. Read it again! Many students fail exams because they do not read the complete question.
5. Carefully select the choice which best answers the question and mark the correct answer accurately.
   - A. If the answer requires filling in a space with pencil, make the marks heavy and black. Some exams are graded by an electronic device which scores by detecting where the graphite (pencil) mark occurs.
   - B. If an answer is changed, completely erase the original answer or the "machine" will detect it, In machine grading, if two choices to a question are detected by the machine, the question will be scored as incorrect.
6. If the exam is "timed", bypass the most difficult and troublesome questions and complete the others. Follow this procedure throughout the examination. When you have completed all of the questions which you can readily answer, then return and work on the more difficult ones.
7. If time is available, re-check doubtful answers.
8. If several items of information are given, such as speed, temperature, distance, etc., list the given items in an organized manner on your "worksheet" where they will be available for immediate reference. Also list the "to find" items. This will reduce the possibility of omitting or forgetting necessary information. Solve the problem and derive the answer. Correctly mark the answer sheet.
9. When you actually start the examination, budget your time. Answer all questions possible in the allotted time.

Before Taking the FAA Written Examination

Note: Read this section again after taking the Final Exam and before taking the FAA Written Exam.

If you have properly studied and completed the Directed Study Program and have answered every frame correctly by actually writing the response, you should have no difficulty in satisfactorily completing the FAA Written Exam. This course should give you more than adequate knowledge.

Other factors to think about are:

1. Before taking the FAA Written Exam, ask the FAA representative how much time is allowed. In any case, start early in the morning to allow sufficient time.

2. When you take the FAA Written Exam, you will need a computer and plotter, the remainder of the required material will be provided.
3. Remember, read each question carefully and completely before you attempt to answer it, then follow a logical and analytical process and answer each question completely.
4. Listing the items known and items required, helps in solving problems.
5. Be certain all factors in a problem are in the same units. For example: all nautical miles or all statute miles. Also be certain items are in the correct value for use on the computer, Example: temperatures in centigrade.

Final Examination (FAA Type)

The first 30 questions are concerned with Federal Aviation Regulations.

1. Assume that a flight which has just taken off into instrument conditions, is proceeding outbound under radar control. If radio communication with ATC is lost, the pilot should:
   (1) proceed back to the airport of origin by the most direct route possible
   (2) assume that this is an emergency situation and immediately start flying triangular patterns with left turns and one minute legs
   (3) proceed in accordance with the last clearance received from ATC
   (4) proceed via the flight plan route to the destination approach fix and hold until the expected approach clearance time
2. If a medical certificate, for a person serving as pilot in command for a scheduled air carrier, is issued on the 23rd day of October, it will expire on the next:
   (1) April 23
   (2) October 23
   (3) April 1
   (4) April 30

3. A pilot in command serving an air carrier has had a total of 85 hours in the particular airplane type in which he is presently flying. Under this condition, the destination ceiling and visibility landing minimums prescribed in the air carrier's operations specifications must be increased by:
   (1) 100 feet and $\frac{1}{2}$ mile
   (2) 100 feet and $\frac{1}{4}$ mile
   (3) 150 feet and $\frac{1}{4}$ mile
   (4) 200 feet and $\frac{1}{2}$ mile

4. Regulations state that each air carrier must maintain current records of each crew member and aircraft dispatcher. The disposition of any crew member or dispatcher released from the employ of the air carrier must be registered in these records which shall be retained for at least:
   (1) 60 days
   (2) 3 months
   (3) 6 months
   (4) 1 year

5. An instrument approach cannot be initiated by an air carrier flight when the weather is reported to be less than minimums for the airport, unless the following conditions exist:

   (1) the airport is served by ILS and ASR
   (2) the airport is served by ILS and PAR and the pilot utilizes both facilities
   (3) the airport is served by ILS and the pilot makes use of this facility
   (4) an approach can never be initiated when the weather is below minimums

6. No alternate is required for an air carrier flight when the ceiling and visibility, two hours before and after ETA at the destination are forecast to be at least:

   (1) 1000 feet and 3 miles
   (2) 5000 feet and 5 miles
   (3) 1000 feet above the applicable minimum initial approach altitude and 3 miles
   (4) 2000 feet above the applicable MEA and 3 miles

7. When an air carrier pilot encounters weather, the knowledge of which he considers to be essential to the safety of other flights, he shall report the condition:

   (1) to an aircraft dispatch office immediately
   (2) at the next enroute stop
   (3) to an appropriate ground radio station as soon as practicable
   (4) to ATC no later than 30 minutes after encountering the unforecast weather

8. The Air Traffic Control Radar Beacon System is used to readily identify aircraft. A pilot in any emergency situation should utilize code:

   (1) 64
   (2) 10
   (3) 11
   (4) 77

9. A pilot must always advise ATC when:

   A. a previously reported ETA is in error by more than plus or minus 10 minutes
   B. leaving the approach fix inbound on final approach
   C. the actual TAS varies by plus or minus 10 knots from the planned TAS
   D. departing a VOR station
   E. arriving at a newly assigned altitude
   F. The pilot has deviated from an ATC clearance in an emergency situation

   (1) A B F
   (2) A C D
   (3) A E F
   (4) B C F

10. If a pilot is cleared by ATC to descend from 18,000 feet to 15,000 feet, the descent may be considered to be unrestricted to an altitude of:

   (1) 15,000 feet
   (2) 15,500 feet

(3) the descent is not restricted
(4) 16,000 feet

11. According to part 4b of CAR's, an air carrier airplane with a passenger capacity of 90 and an actual passenger load of 56, must have at least:

    (1) 4 hand fire extinguishers
    (2) 3 hand fire extinguishers
    (3) 2 hand fire extinguishers
    (4) 1 hand fire extinguisher

12. Scheduled air carriers must consider any gradient which might exist in the runway used for takeoff. There must also be a correction for any existing wind. To allow for wind effect, takeoff data based on still air may be corrected by not more than:

    (1) 50% of the reported tailwind and not less than 100% of the reported headwind
    (2) 150% of the reported tailwind and not less than 50% of the reported headwind
    (3) 50% of the reported headwind and not less than 150% of the reported tailwind
    (4) 150% of the reported tailwind and not less than 50% of the reported headwind

13. CAM 4b classifies cargo and baggage compartments into either A, B, C, D or E, for fire protection purposes. The compartment, which is designed so as to completely confine a fire without endangering the airplane or occupants, is:

    (1) A
    (2) B
    (3) C
    (4) D

14. According to FAR 61, an airline transport pilot may log:

    (1) 50% of the total time while acting as copilot
    (2) 100% of the total time while acting as copilot
    (3) over-the-top flying as instrument flight time
    (4) none of the 3 answers above are correct

15. The pilot in command and the aircraft dispatcher are jointly responsible for:

    (1) having the appropriate aeronautical charts aboard the airplane
    (2) providing each crew member with a flashlight in good working order
    (3) any preflight planning delay
    (4) the safety of the airplane while in flight

16. While flying under radar control, when standard non-radar separation is not known to exist, a pilot would expect to have:

    (1) 5 miles aircraft separation when flying within 40 miles of the radar antenna site
    (2) at least 5 miles aircraft separation at all times
    (3) no less than 5 miles aircraft separation when beyond 40 miles from the radar antenna site

(4) no less than 4 miles separation at any time

17. Assume that a pilot is flying a reciprocating-engine-powered airplane which is not pressurized. For a two hour flight at 13,000 feet, the amount of supplemental oxygen which must be provided for passengers is:

    (1) a 30 minute supply of oxygen for 10% of the passengers
    (2) a 30 minute supply of oxygen for 30% of the passengers
    (3) sufficient oxygen for 30% of the passengers for the entire flight
    (4) sufficient oxygen for all of the passengers for the entire flight

18. When a jet airplane is operated at a cabin pressure altitude of 13,000 feet, there must be supplemental oxygen provided for:

    (1) the duration of the flight in excess of 30 minutes for 10% of the passengers
    (2) all of the crew members for the entire flight
    (3) and used by all the crew members on flight deck duty for the entire flight
    (4) all three of the above answers are correct

19. For all scheduled air carrier operations, a load manifest must be prepared which shall include:

    (1) the number of passengers aboard
    (2) the number of crew aboard
    (3) the total weight of fuel and oil
    (4) all three of the above

20. Copies of the load manifest, dispatch release form and the flight plan shall be:

    (1) retained in the possession of the dispatcher at the airport of origin.
    (2) retained in the possession of the dispatcher at the airport of destination for a period of 4 months
    (3) in the possession of the pilot in command and shall be carried in the airplane to the destination airport
    (4) retained for a period of 12 months

21. An air carrier shall not schedule a crew member for duty aloft if his total flight time will exceed:

    (1) 30 hours in any seven consecutive days
    (2) 36 hours in any seven consecutive days
    (3) 30 hours of commercial flying in any seven consecutive days
    (4) 90 hours of commercial flying in any month

22. Assume that a pilot has completed a 10 hour flight. In this situation he may not be scheduled to fly again until he has had a rest period of at least:

    (1) 8 hours
    (2) 16 hours
    (3) 20 hours
    (4) 24 hours

23. A copilot cannot be scheduled to serve as such in scheduled air transporatation unless he has accomplished at least three landings and takeoffs within the preceding:
    (1) 30 days
    (2) 120 days
    (3) 90 days
    (4) there is no restriction of this nature for copilots

24. Assume that a pilot in command received his last line check on November 5th. The last day on which the next succeeding line check may be given is:
    (1) the last day of May
    (2) the last day of December
    (3) November 5
    (4) the last day of November

25. If a pilot observes a flashing red signal from the tower, his action should be to:
    (1) not land because the airport is unsafe
    (2) stop
    (3) give way to other aircraft and continue circling
    (4) exercise extreme caution

26. According to FAR 91, the components of the basic ILS include:
    A. outer marker
    B. middle marker
    C. approach lights
    D. compass locator
    E. localizer
    F. glide slope
    G. DME
    (1) A B E F G
    (2) A B C E F
    (3) A C D E F
    (4) C D E F G

27. The radar approach in which the pilot is supplied with recommended altitude information each mile on final approach in addition to azimuth information, is referred to as a:
    (1) ASR approach
    (2) SAR approach
    (3) PAR approach
    (4) VAR approach

28. When a VOR receiver is tuned to a VOT, the TO-FROM indicator will always indicate:
    (1) TO-when the course selector is set to 360°
    (2) FROM-when the course selector is set to 360°
    (3) FROM-when the course selector is set to 090°
    (4) FROM-when the course selector is set to 180°

29. According to regulation, a fire which could be most easily extinguished by the use of water would be in class:

    (1) A
    (2) B
    (3) C
    (4) D

30. Aircraft are considered to be in the holding pattern upon arrival over the holding fix. For this reason, aircraft are expected to have a speed equal to the maximum holding pattern airspeed or less:

    (1) on the first outbound leg of the holding pattern
    (2) by the first outbound turn
    (3) at the time of arrival over the fix
    (4) three minutes prior to arrival over the fix

Preflight Information

A. The hypothetical flight in this examination is to be planned from Tulsa, Oklahoma International Airport to Denver, Colorado. The route is: direct to Stebbins Intersection, V-74 to Garden City, V-10 to Pueblo, and V-81 to Denver. The planned alternate will be Pueblo and the route from Denver to Pueblo will be via V-81. The planned altitude to the destination will be 16,000 feet and the planned altitude to the alternate will be 13,000 feet. For the purpose of this exam, assume that pressure and indicated altitude are identical.
B. Use a calibrated airspeed of 175 knots in cruise throughout the exam unless otherwise instructed.
C. Assume a total fuel load at takeoff of 2500 gallons. Fuel consumption values can be found on the Flight Planning Sheet at the end of the examination.
D. The flight is scheduled to depart at 1030 CST. Assume throughout the remainder of this exam that the flight is being conducted under Instrument Flight Rules.
E. Several of the frames in the following pages refer the reader to figures in the Job Performance Section of the Airline Transport Pilot and Aircraft Dispatcher Course.

Weather Information
Teletype Weather Reports

0900C - AMA 80⊕10 169/57/49/2310/300
DDC M30⊕3S 131/36/33/2210/991
GLD 8⊕E25⊕2S 110/35/27/2405/984
DEN 90M15⊕1½EW 130/37/32/3210/990/VR60
CYS 110⊕10 105/26/23/2710/983

1000C - AMA 85⊕11 170/59/49/2515/002
DDC M35⊕6 128/39/32/2105/990
GLD E40⊕8 112/41/36/2305/986
DEN M25⊕3 131/33/28/3515/991
CYS 115⊕12 115/26/24/2805/986

Winds Aloft Forecast

LVL	3000	5000 FT.	10000 FT.	15000 FT.	20000 FT.	25000 FT.
OKC	1804+6	2214+1	2440-6	2745-19	2655-25	2662-33
ICT	1709+4	1815-3	2330-12	2640-22	2551-29	2650-34
DDC		2732-2	2732-11	2652-20	2660-27	2565-37
PUB			3544-1	3353-12	3062-23	2771-35
DEN			3556-2	3360-12	3065-25	2670-36

Terminal Forecast

FT 110800 C

CYS 120⊕2710G.0900C 130⊕2715G.1000C⊕2820G.

DEN C20⊕2½S-2615. 0900C C45⊕5 2710. 1000C C60⊕2815.

PUB C15⊕3S 2610. 0900C C35⊕4 2615. 1000C C50⊕ 2710.

Reference 1

31. The types of fronts which are included on the 0500C surface weather map (Figure 13-1 Job Performance Section) are:
    (1) warm, cold and stationary
    (2) warm, cold and occluded
    (3) warm, cold and upper warm
    (4) cold, stationary and occluded

32. According to the surface weather map, the dew point at Denver at 0500C is:
    (1) 49°C.
    (2) 52°F.
    (3) 52°C.
    (4) 49°F.

33. Referring to the surface weather map again, the middle clouds over Oklahoma City are:
    (1) thin altocumulus,
    (2) cirrocumulus
    (3) fractocumulus
    (4) Oklahoma City reports only low and high clouds

34. According to the 0900C teletype weather report (Reference 1, FAA Type Examination Section), the precipitation at Denver is:
    (1) freezing rain
    (2) snow showers
    (3) freezing drizzle
    (4) sleet showers

35. Referring again to the 0900C teletype weather report, the runway visual range at Denver is:
    (1) 600 feet
    (2) 6000 feet

(3) $1\frac{1}{2}$ miles
(4) not reported

36. According to the 0900C teletype weather report for Dodge City, the corrected field barometric pressure is:

(1) 29.91 millibars
(2) 29.31 inches Hg.
(3) 1013.3 millibars
(4) 1013.1 millibars

37. According to latest available terminal forecast for Cheyenne (Reference 1, Final Exam Section), the weather includes:

(1) calm winds
(2) a 1000 foot ceiling
(3) ground fog
(4) gusty winds

NOTE: When flight planning, use the Wichita winds aloft for the TUL to DDC leg; use an average of the Dodge City and Pueblo winds aloft for the DDC to PUB leg; and an average of the Pueblo and Denver winds aloft for the PUB to DEN leg and the alternate leg.

Complete the flight planning sheet located at the end of this exam prior to attempting to answer the following questions.

38. The total fuel required for this planned flight, including fuel to the destination, alternate and reserve, is (assume 1 gallon of fuel weighs 6 pounds):

(1) 1306 gallons
(2) 1341 gallons
(3) 7962 pounds
(4) 7752 pounds

39. The planned wind correction angle between Lamar and Pueblo is:

(1) 9°right
(2) 9°left
(3) 5°left
(4) 4°right

40. The planned groundspeed between Anthony and Dodge City is:

(1) 197 knots
(2) 189 knots
(3) 181 knots
(4) 205 knots

41. The total mileage from the Tulsa International Airport to Denver is:

(1) 531 miles
(2) 534 miles
(3) 626 miles
(4) 536 miles

42. The wind which should be entered on the flight planning sheet for the leg between Dodge City and Garden City is:

    (1) 292/55
    (2) 260/54
    (3) 330/52
    (4) 298/56

43. The planned flight time from the destination to the alternate is:

    (1) 21½ minutes
    (2) 26 minutes
    (3) 16 minutes
    (4) 29½ minutes

NOTE: Aircraft weight and balance information is shown below.

1. The datum line is at the nose of the aircraft.
2. LEMAC and TEMAC (trailing edge of MAC) are at 425 inches and 565 inches respectively.
3. Landing gear stations and wheel weights are:
    (a) The nose gear is at station 115 and has a wheel weight of 9,600 pounds.
    (b) The right main gear is at station 525 and has a wheel weight of 23,300 pounds.
    (c) The left main gear is at station 525 and has a wheel weight of 23,100 pounds.
4. The fore and aft CG limits are 13% and 35% respectively.

44. According to the preceding data, the empty weight center of gravity is located at:

    (1) 451 inches from datum
    (2) 21.4% MAC
    (3) 24.0% MAC
    (4) 463 inches from datum

45. Assume that after the aircraft is loaded to a gross weight of 88,600 pounds, the center of gravity is found to be two inches aft of the aft CG limit. The minimum weight which would have to be added at station 340 in order to bring the CG within tolerance is:

    (1) 1322 pounds
    (2) 148 pounds
    (3) 2492 pounds
    (4) 1403 pounds

46. Referring to the preceding question, assume the pilot decided to shift weight instead of add weight in order to bring the CG within limits. How many inches would the CG be moved if 800 pounds of cargo was shifted from station 630 to station 340?

    (1) 4.8 inches
    (2) 2.6 inches

(3) 3.2 inches
(4) 1.9 inches

47. Assume that the zero fuel weight of a particular aircraft is 82,800 pounds, the operating weight is 55,000 pounds and the maximum gross takeoff weight is 101,000 pounds. Under these conditions, if the aircraft is carrying a capacity cargo load, what is its maximum fuel load (assume 1 gallon equals 6 pounds)?

(1) 18,000 pounds
(2) 27,600 pounds
(3) 4,633 gallons
(4) 3,033 gallons

48. Utilizing Figures 13-5 and 13-6 in the Job Performance Section, find the minimum takeoff runway length at Tulsa under the following conditions:

Gross Weight	88,800 pounds
Wind	+15 knots
Gradient	$-\frac{1}{2}$ percent
Standard Atmospheric Conditions	

(1) 4600
(2) 4850
(3) 4750
(4) 4450

49. According to Figure 13-7 of the Job Performance Section, which one of the following frequencies is received by the Peterson Field in Colorado Springs:

(1) 120.2 mc
(2) 109.0 mc
(3) 112.5 mc
(4) 118.9 mc

50. Before takeoff from Tulsa, the tower advises the pilot that the surface temperature is 13°C. Assuming a standard lapse rate, the pilot should anticipate reaching the freezing level at approximately:

(1) 7000 feet MSL
(2) 6500 feet MSL
(3) 7000 feet AGL
(4) 7500 feet AGL

51. At 1035C the pilot receives the following clearance: "ATC clears Trans Global Two Niner to the Denver VOR, via direct Stebbins, Victor 74 Garden City, Flight Planned Route. Climb to and maintain 16,000. Cross Manion at or above 14,000". After the takeoff is accomplished at 1040, the pilot computes a Manion ETA of 1055. The minimum rate of climb to Manion would be approximately:

(1) 930 feet per minute
(2) 890 feet per minute
(3) 850 feet per minute
(4) 880 feet per minute

52. Over Ponca City the pilot transmits a position report to an ARTCC. The position report:

    A. Must include the type of flight plan under which the flight is being conducted
    B. Must include an estimate to Anthony
    C. Will include Lamar
    D. Need not include the altitude if the flight is level at the assigned altitude
    E. Would probably be given to Kansas City Center
    F. Must include the altitude because the flight is not operating on a VFR on-top clearance

    (1) A C E
    (2) B E F
    (3) C D E
    (4) C E F

53. The altimeter within a particular airplane indicates lower than the true altitude. A possible reason for this might be that the airplane has been flown from an area of:

    (1) low pressure to high pressure or cold air to warm air
    (2) low pressure to high pressure or warm air to cold air
    (3) high pressure to low pressure or warm air to cold air
    (4) high pressure to low pressure or cold air to warm air

54. Assume that the pilot reported Ponca City at 1106C and is over Anthony at 1124C at an altitude of 16,000 feet. If the magnetic heading between Ponca City and Anthony is 294° and the true outside air temperature is -28°C, the actual wind is most nearly:

    (1) 331/43
    (2) 294/55
    (3) 344/25
    (4) 225/63

55. On the basis of the information provided in the previous problem, the ETA (Mountain Standard Time) at Lamar would be:

    (1) 1137 MST
    (2) 1141 MST
    (3) 1131 MST
    (4) 1148 MST

56. Assume that ATC has requested the pilot to report the Salt Intersection. Just prior to reaching Salt, the course deviation indicator is slightly to the left of center. Under this condition, the VOR frequency selector is set to:

    (1) 116.8 mc and the OBS is set to 214°
    (2) 115.6 mc and the OBS is set to 032°
    (3) 115.6 mc and the OBS is set to 212°
    (4) 110.1 mc and the OBS is set to 034°

57. After passing Garden City, the pilot is instructed to descend to 12,000 feet. At this altitude he calculates the new true airspeed with the following information:

Indicated airspeed	177 knots
Airspeed position and instrument correction	-2 knots
Indicated outside air temperature	-15°C
Temperature correction	4°C
Compressibility correction	2 knots

The TAS is:
(1) 207 knots
(2) 204 knots
(3) 213 knots
(4) 210 knots

58. Suppose that the pilot is a short way west of the Lamar VOR in a four-engine airplane when an engine failure is experienced. By regulation, the pilot should:

A. land at the nearest airport
B. proceed to the airport of his selection if he considers this action to be as safe as landing at the nearest suitable airport
C. proceed to the destination by the most direct route
D. immediately advise the proper ground radio station
E. notify the appropriate air carrier operations immediately
F. submit a written report to his operations manager at the conclusion of the trip if he did not land at the nearest suitable airport in point of time

(1) A B D
(2) B D F
(3) C D F
(4) D E F

59. A pilot should take which of the following actions after having experienced communication failure:

A. if cleared to a radio fix short of the destination approach fix with holding instructions and a time to expect approach clearance, the pilot should depart the holding fix at the specified time
B. if no expected approach clearance time is received, the pilot should start the descent from altitude upon arrival over the approach fix or at the ETA as indicated on the flight plan, whichever time occurs first
C. if cleared to a fix short of the destination fix without holding clearance, the pilot should not hold, but should proceed via the last ATC clearance received
D. fly at least three triangles consisting of two minute legs and ½ standard rate turns
E. if assigned an altitude in the highest route structure requested, maintain the assigned altitude or the MEA, whichever is higher
F. if arriving over the destination approach fix after the ETA as given ATC, without having received an expected approach clearance time, the approach may be started at the time of arrival

(1) A C E
(2) B C F
(3) D E F
(4) C E F

60. Assume the pilot has 150 hours as pilot in command of the four-engine prop airplane which he is now flying. The weather minimums to which he would have to adhere on an ILS approach to runway 26L at Stapleton Airport are (do not consider RVR):

(1) 200-½
(2) 400-1
(3) 200-¾
(4) 300-1

61. After reporting the outer marker inbound on an ILS final approach, the pilot is informed that the weather is below minimums. The pilot:

(1) must execute an immediate missed approach
(2) may continue the approach to minimums
(3) may continue the approach only if PAR or ASR is operative for the appropriate runway
(4) may not land

62. Assume the pilot decides to initiate a missed approach after having executed an ILS approach to 26L at Stapleton Airport. The pilot should:

(1) have the VOR receiver tuned to frequency 116.3 mc
(2) climb outbound on the 345° bearing from the LCM
(3) climb to an altitude of 7000 feet above ground level
(4) contact the tower immediately for instructions

63. After the missed approach, the flight is southbound on V-81 proceeding toward the alternate at 13,000 feet when the pilot receives the following clearance from ATC. "Trans Global Two Niner, hold southeast of the Colorado Springs VOR on the 130° radial. Expect further clearance at 1910 Zulu". The pilot's action should be to:

A. Make an initial left turn over Colorado Springs to enter the holding pattern
B. fly the first outbound leg for 1½ minutes
C. slow to 170 knots within three minutes prior to the ETA over Colorado Springs
D. report the time and altitude to ATC upon reaching the holding fix
E. leave the holding pattern immediately and proceed via the flight plan route if a loss of communications is experienced
F. report to ATC when leaving the holding fix

(1) A B D
(2) A D
(3) C E F
(4) A D F

64. After leaving the holding pattern and approaching Pueblo, the pilot studies the Pueblo VOR approach. The pilot should note that:

    (1) the Ordway Intersection is on the 260° radial of the Pueblo VOR
    (2) the procedure turn altitude is 5400 feet MSL
    (3) if the ILS is to be used as a back up approach in the event the weather does not permit a VOR approach, the radio compass should be tuned to 302 kc.
    (4) the approach control frequency normally used by civil aircraft is 290.5

65. In the absence of a winds aloft report, the pilot would probably resort to the:

    (1) 850 mb chart for the winds at 20,000 feet
    (2) 850 mb chart for the winds at 5000 feet
    (3) weather map
    (4) sequence reports

66. Assume that a pilot desires to conduct a time distance check. After starting the check with a GS of 190 knots and with the bearing indicator at a wing tip position, the pilot observes a bearing change of 10 degrees in two minutes. From this information the pilot knows that the aircraft is approximately:

    (1) 10 minutes from the station
    (2) 38 miles from the station
    (3) 23 miles from the station
    (4) 15 minutes from the station

67. When flying from an area of warm air to an area of cooler air, the pilot should anticipate:

    (1) less power output from the engines
    (2) the altimeter indicating a value lower than the true altitude
    (3) greater power output from the engines
    (4) none of the above are correct

68. Aircraft speeds are often expressed in symbols. For instance, the power off stalling speed in specified configuration could be written as:

    (1) Vf
    (2) Vmc
    (3) Vsl
    (4) Vso

69. Assume that a particular four-engine aircraft, which is operating at 1850 BHP is consuming a total of 365 gallons per hour. The specific fuel consumption in this configuration is (assume 1 gallon = 6 pounds):

    (1) .305
    (2) .296
    (3) .289
    (4) .264

70. The jet stream:
    (1) usually precedes the surface front
    (2) wind velocities usually decrease at the fastest rate to the north side of the jet core
    (3) of most concern to pilots in the United States is the Sub-Tropical Jet
    (4) is characterized by strong winds above the tropopause

71. Concerning the jet stream:
    (1) the greatest turbulence will normally be found to the south side of the jet core
    (2) the greatest rate of change in temperature will normally occur to the south of jet core
    (3) the level of maximum winds is usually slightly above the jet core
    (4) isotachs are usually grouped very close together on the north side of the jet core

72. Assume that an aircraft is 9 miles to the left of the desired course after flying 34 miles from the departure point on a compass heading of 342° . What compass heading must be flown to arrive at the destination if it is 194 miles from the present position of the aircraft?
    (1) 360°
    (2) 324°
    (3) 355°
    (4) 335°

73. On a VASI approach, the pilot sees red over white lights. From this information he would know that the aircraft is:
    (1) below the glide slope
    (2) above the glide slope
    (3) on glide slope
    (4) displaced from the runway centerline

74. Mach number can be described as:
    (1) varying directly with the altitude
    (2) varying inversely with the temperature
    (3) the ratio of the CAS of an airplane to the speed of sound in air
    (4) the ratio of the TAS of an airplane to the speed of sound in air

75. Assume the following figures for a particular flight:

True outside air temperature	-45°C
CAS	256 knots
Altitude	34,000 feet

The TAS of this aircraft would be:
    (1) 456 knots
    (2) 459 knots
    (3) 453 knots
    (4) 462 knots

76. The Mach number for the TAS in the previous question is (do not correct for compressibility):
    (1) .78
    (2) .82
    (3) .76
    (4) .80

77. According to the following weather report, which one of the choices is correct?

    NKT S 10⊕M35⊕1L-H 160/33/34/1709/001/VR50

    (1) the station is experiencing light haze
    (2) the ceiling is at 1000 feet above the ground
    (3) the station pressure corrected to sea level is 1000.1 millibars
    (4) the wind is from a true direction of 170° at 9 knots

78. Regulations specify procedures for checking the accuracy of the VOR receiver when a VOT is not available. The maximum permissible bearing error is:
    (1) ±4° when using a designated airborne check point
    (2) ±2° when using a designated check point on an airport surface
    (3) ±6° when using a designated airborne check point
    (4) ±8° when using a designated airborne check point

79. Utilizing Figure 13-9 in the Job Performance Section, calculate the takeoff distance under the following conditions:

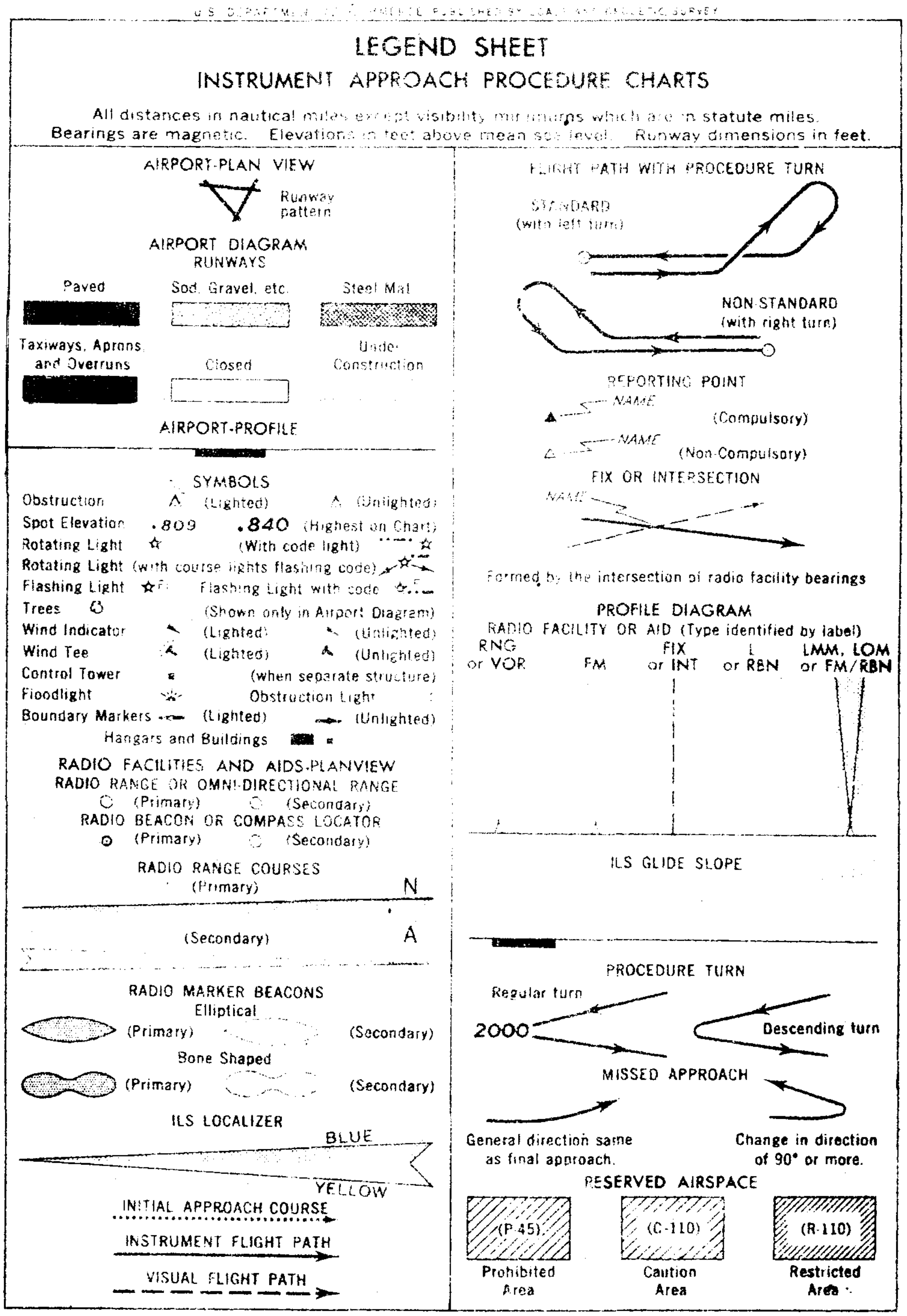
Gross weight	180,000 pounds
Pressure altitude	2000 feet
Temperature	+10°C
Runway gradient	-2%
Wind	+20 knots

    (1) 4250 feet
    (2) 4400 feet
    (3) 4100 feet
    (4) 4000 feet

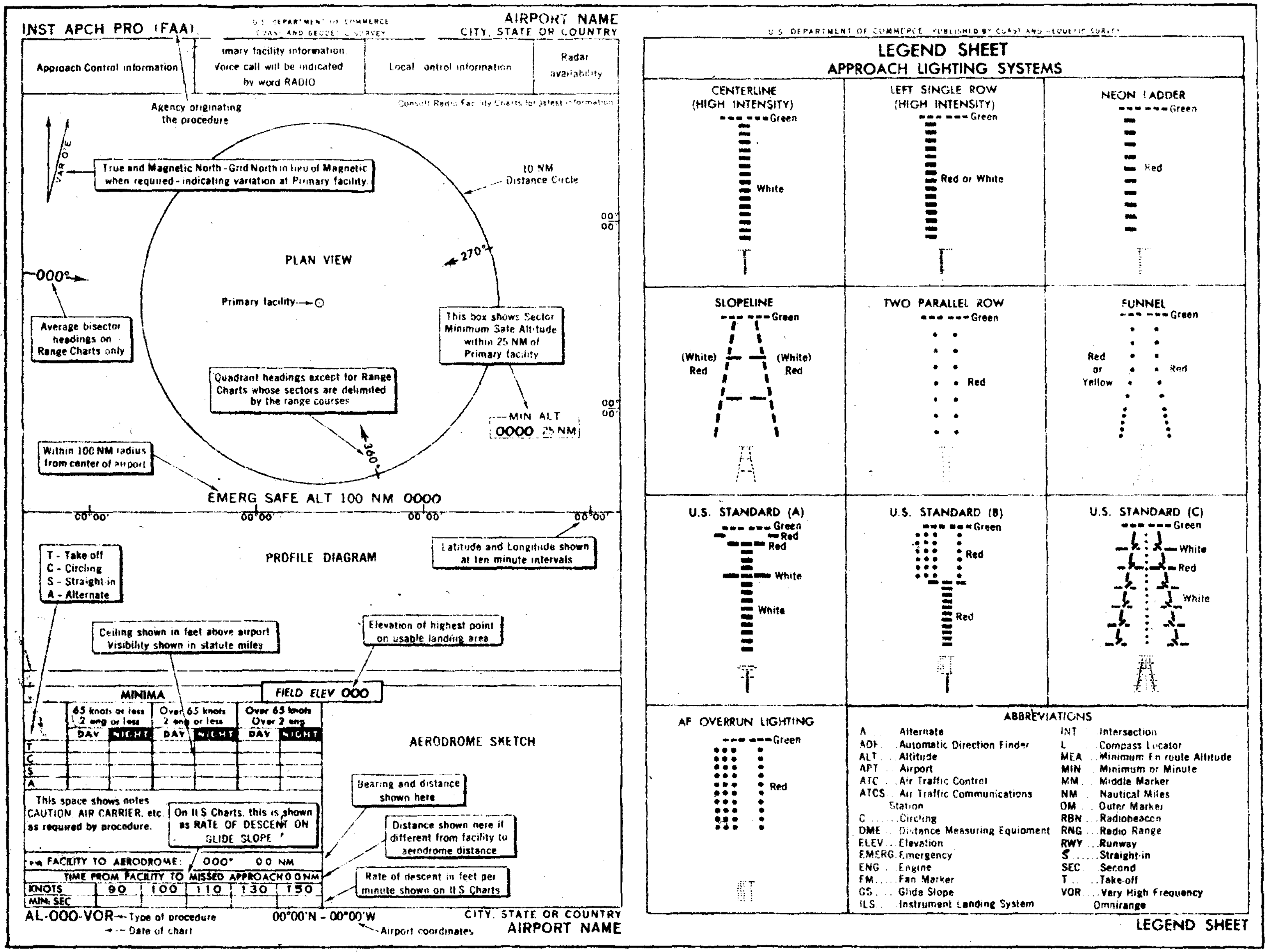
80. Using Figure 13-10 in the Job Performance Section, determine the percent of climb in the second segment under the following conditions:

Temperature	+20°C
Pressure altitude	1000 feet
Anti icing	ON
Initial climb weight	250,000 pounds

    (1) 4.6 percent
    (2) 4.7 percent
    (3) 4.8 percent
    (4) 4.5 percent



Sample Coast and Geodetic Survey Approach Plate Legend (Excerpt for Training Purposes Only)



Sample Coast and eodetic Survey
Approach Pla · Legend
(Excerpt for Training urposes Only)

LEGEND

AERODROMES

Aerodromes/Seadromes shown in BLUE have an approved USAF/USN Low and or/High Altitude Instrument Approach procedure published.

Aerodromes/Seadromes shown in BROWN do not have a published USAF/USN Instrument Approach procedure

LAND — SEA

Military

Joint Military-Civil

Civil

Heliport

RELATED FACILITIES

Pilot to forecaster Service (PFSV)

Continuous Operation

Less Than Continuous

Weather Radar (WXR)

PFSV and WXR Combined

ILS Availability

1. Aerodrome elevation given in feet above mean sea level.
2. Length of longest runway given to nearest 100 feet with 70 feet as the dividing point (Add 00). Sterilized portion not included.
3. Aerodrome symbol may be off-set for enroute navigation aids.

Runway Lighting Capability Asterisk indicates Lighting on prior request.

Name

213*L 97

ASR/PAR

Radar Capability

Aerodrome Elev.

Runway Length

(Name)

216 — 75s

No Runway Lighting Capability

Indicates Soft Surface

RADIO AIDS TO NAVIGATION AND COMMUNICATION BOXES

NAVIGATION AIDS

VHF/UHF Aids are depicted in BLUE

LF/MF Aids are depicted in BROWN

COMPASS ROSE Oriented to Magnetic North

VOR TACAN VORTAC

LF/MF Range with simultaneous Voice signal Capability. Solid tip in "N" Quadrant.

LF/MF Range without simultaneous Voice Signal Capability.

LF/MF Range Course. Feathered Edge indicates "A" Quadrant.

LF/MF Non-directional Radio Beacon or Marine Radio Beacon.

VHF/UHF Non-directional Radio Beacon.

Marker Beacon

Fan (FM) Bone (BM)

Either Symbol Solid indicates Radio Interference.

RADIO AIDS TO NAVIGATION DATA BOXES

Abnormal Status Underprint for Affected Data, e.g.: NOT COMSN. SHUTDOWN, TEST ONLY.

Frequency Protection Classification (See Radio Class Code).

SHUTDOWN

NAME

NAM ≡ 000.0(H)

Chan 00(H)

MN ≡ 000

Half solid, half dashed bottom line indicates same name— LF MF-VHF UHF radio data.

TACAN channels are without voice but are not underlined.

AO/A2

NAME

NAM ≡ *000

Operates Less Than Continuous - See Supplement. Underline indicates No Voice Transmitted on this frequency.

Continuous dashed line indicates only LF/MF info. in box.

AFRS NAME 000 — Armed Forces Radio Station

NAME 000 — Commercial Broadcast Station

AIR/GROUND COMMUNICATION BOXES

VHF/UHF LF/MF

Shaded box: Enroute Air/Ground Freqs 255.4 and 135.9 available.

Plain box: See Supplement for available Enroute A/G Frequencies.

W:No Enroute A/G Communication

[NAME]

Controlling Enroute A/G station when different from name in box. See Supp. for available frequencies.

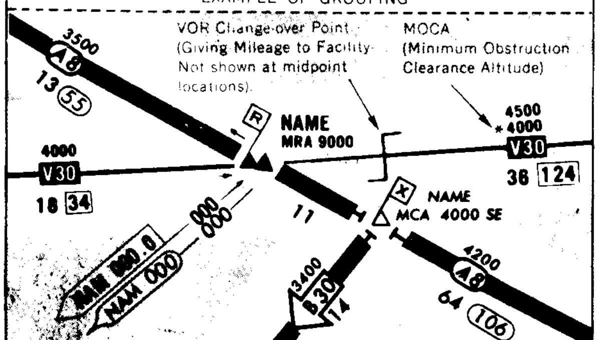
AIR TRAFFIC SERVICES

Type of area traffic service

CTA		TCA
NAME		NAME
FL 200	Vertical limits of control	FL 200
GND		1000 AGL
CON		CON
120.5		124.8

FIR		UIR
NAME		NAME
FL 200	A G Voice call and Frequency	UNLTD
GND		FL 200
CON		CON
120.5		120.5

EXAMPLE OF GROUPING



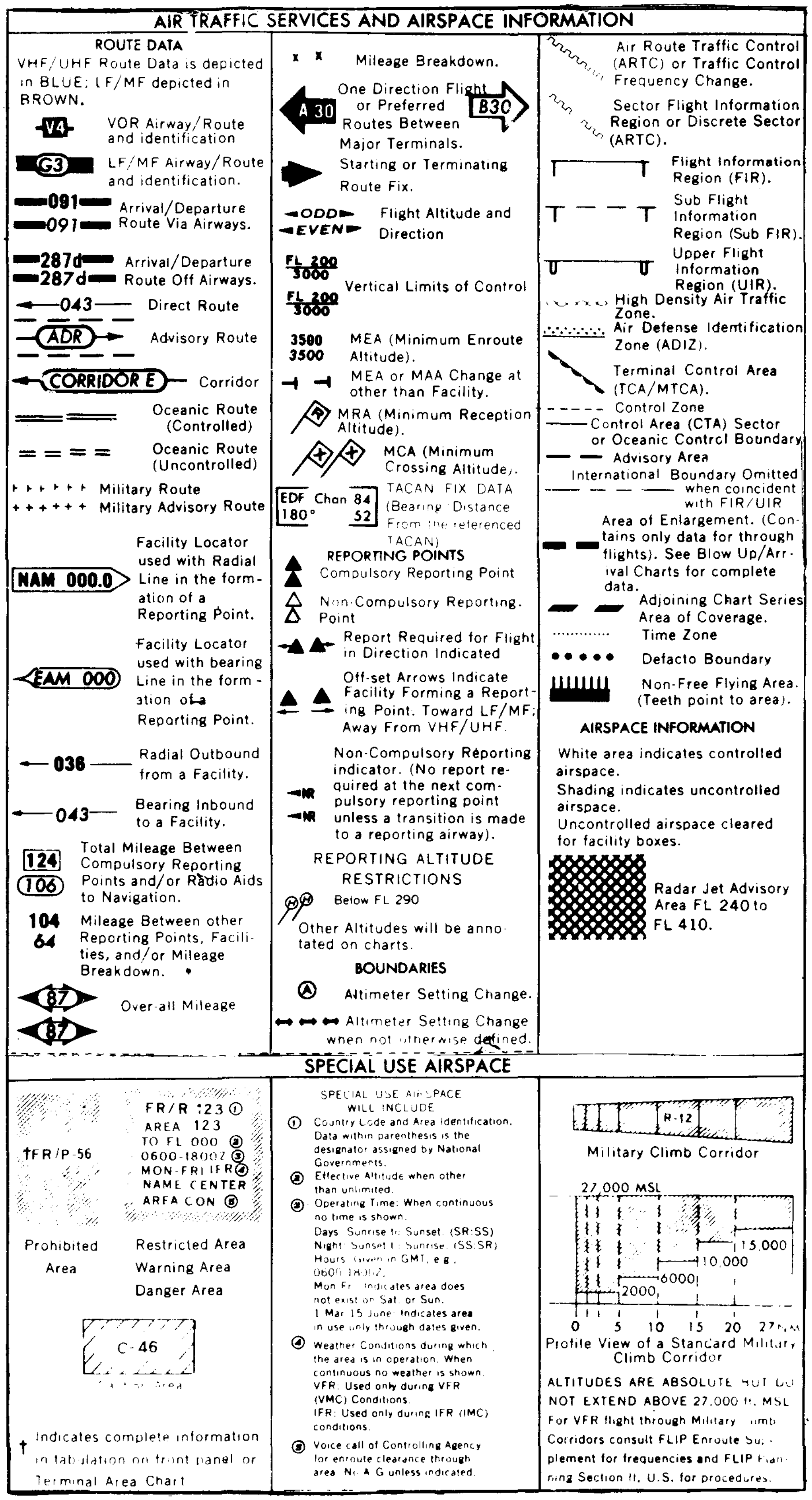
MISCELLANEOUS

13°E — Isogonic Line and Value.

Holding Pattern (Standard)

Coordinates are to the nearest minute with 29" as the dividing point.

ALL MILEAGES ARE NAUTICAL UNLESS OTHERWISE NOTED.
ALL RADIALS AND BEARINGS ARE MAGNETIC to the nearest full degree.



AIR TRAFFIC SERVICES AND AIRSPACE INFORMATION
ROUTE DATA
VHF/UHF Route Data is depicted in BLUE; LF/MF depicted in BROWN.
V4
VOR Airway/Route and identification.
G3
LF/MF Airway/Route and identification.
091
Arrival/Departure Route Via Airways.
287d
Arrival/Departure Route Off Airways.
043
Direct Route
ADR
Advisory Route
CORRIDOR E
Corridor
Oceanic Route (Controlled)
Oceanic Route (Uncontrolled)
Military Route
Military Advisory Route
NAM 000.0
Facility Locator used with Radial Line in the formation of a Reporting Point.
EAM 000
Facility Locator used with bearing Line in the formation of a Reporting Point.
036
Radial Outbound from a Facility.
043
Bearing Inbound to a Facility.
124
106
Total Mileage Between Compulsory Reporting Points and/or Radio Aids to Navigation.
104
64
Mileage Between other Reporting Points, Facilities, and/or Mileage Breakdown.
87
Over-all Mileage
Mileage Breakdown.
A 30
B30
One Direction Flight or Preferred Routes Between Major Terminals.
Starting or Terminating Route Fix.
ODD
EVEN
Flight Altitude and Direction
FL 200
3000
Vertical Limits of Control
3500
MEA (Minimum Enroute Altitude).
MEA or MAA Change at other than Facility.
MRA (Minimum Reception Altitude).
MCA (Minimum Crossing Altitude).
EDF 180°
Chan 84
52
TACAN FIX DATA (Bearing Distance From the referenced TACAN)
REPORTING POINTS
Compulsory Reporting Point
Non-Compulsory Reporting Point
Report Required for Flight in Direction Indicated
Off-set Arrows Indicate Facility Forming a Reporting Point. Toward LF/MF; Away From VHF/UHF.
NR
Non-Compulsory Reporting indicator. (No report required at the next compulsory reporting point unless a transition is made to a reporting airway).
REPORTING ALTITUDE RESTRICTIONS
Below FL 290
Other Altitudes will be annotated on charts.
BOUNDARIES
A
Altimeter Setting Change.
Altimeter Setting Change when not otherwise defined.
Air Route Traffic Control (ARTC) or Traffic Control Frequency Change.
Sector Flight Information Region or Discrete Sector (ARTC).
Flight Information Region (FIR).
Sub Flight Information Region (Sub FIR).
Upper Flight Information Region (UIR).
High Density Air Traffic Zone.
Air Defense Identification Zone (ADIZ).
Terminal Control Area (TCA/MTCA).
Control Zone
Control Area (CTA) Sector or Oceanic Control Boundary
Advisory Area
International Boundary Omitted when coincident with FIR/UIR
Area of Enlargement. (Contains only data for through flights). See Blow Up/Arrival Charts for complete data.
Adjoining Chart Series Area of Coverage.
Time Zone
Defacto Boundary
Non-Free Flying Area. (Teeth point to area).
AIRSPACE INFORMATION
White area indicates controlled airspace.
Shading indicates uncontrolled airspace.
Uncontrolled airspace cleared for facility boxes.
Radar Jet Advisory Area FL 240 to FL 410.
SPECIAL USE AIRSPACE
†FR/P-56
FR/R 123
AREA 123
TO FL 000
0600-1800Z
MON-FRI IFR
NAME CENTER
AREA CON
Prohibited Area
Restricted Area
Warning Area
Danger Area
C-46
† Indicates complete information in tabulation on front panel or Terminal Area Chart
SPECIAL USE AIRSPACE WILL INCLUDE
1 Country Code and Area Identification. Data within parenthesis is the designator assigned by National Governments.
2 Effective Altitude when other than unlimited.
3 Operating Time: When continuous no time is shown.
Days: Sunrise to Sunset (SR-SS)
Night: Sunset to Sunrise (SS-SR)
4 Weather Conditions during which the area is in operation. When continuous no weather is shown.
VFR: Used only during VFR (VMC) Conditions.
IFR: Used only during IFR (IMC) conditions.
5 Voice call of Controlling Agency for enroute clearance through area.
R-12
Military Climb Corridor
27,000 MSL
15,000
10,000
6000
2000
0
5
10
15
20
Profile View of a Standard Military Climb Corridor
ALTITUDES ARE ABSOLUTE
NOT EXTEND ABOVE 27,000 ft. MSL
For VFR flight through Military Climb Corridors consult FLIP Enroute Supplement for frequencies and FLIP Planning Section II, U.S. for procedures.

ROUTE FROM	ROUTE TO	Cruise Alt.	Average True Course	Wind Dir/Vel Knots	Average Drift Corr.	Average TAS Knots	Average GS Kts.	Dist. NM	Time	Fuel
TULSA INTL	STEBBINS	→	307	230/16 -10		150				
STEBBINS	MANION	→	297	230/15 -10		150				
MANION	PNC	16,000								
							TOTALS:			

ALTERNATE

							TOTALS:			

FUEL PLANNING

	Time	Gal.
Climb		
Cruise		
Alternate		
Reserve		
Extra		
Total		

Fuel Consumption Values

Climb 390 GAL/HOUR

Cruise 315 GAL/HOUR
(Destination/Alternate/Reserve)

Extra 285 GAL/HOUR

Flight Planning Sheet