STEM

CONNECT EXPLORE ACHIEVE
WITH CAREER READINESS

STEM Education =
Integrating science, technology, engineering and math to solve complex, real-world problems.

Did you know...

Kent ISD has two full time consultants on staff dedicated to creating K-12 STEM lessons you can use in your classroom. These consultants work directly with individual teachers, or teams of teachers, to meet your specific needs.

Did you also know...

Our consultants offer a range of services, including

- supplying existing lesson plans
- working with you to create custom lessons and units
- visiting your classroom to help teach a lesson
- consulting and help integrating STEM throughout your curriculum
- access to cutting-edge technology to engage students

What might that look like?

They can bring a real, operational UAV/drone to your class where students get a chance to actually fly it themselves while learning important concepts like the physics of wave properties, place-based ecology in earth science or geographic analysis.

Or, they can bring a portable 3D printer to help students learn everything from geometry and algebra to spatial analysis and 3D design basics.

They also give you access to the *STEM Thinking* professional learning series and other resources to help you engage students and bring real world relevance to your classroom.

Visit careerreadiness.kentisd.org and click "Educators" for more information. Or contact Rick and Ebiri directly to see how they can help you reach your unique teaching and learning goals.

Contact our STEM Consultants:

Rick Mushing
rickmushing@kentisd.org - 616.365.2326

Ebiri Nkugba
ebirinkugba@kentisd.org - 616.365.2354

STEM

Engage and inspire your students in new ways by bringing exciting projects like these, and many more, to your classroom.

Programming & Geography in Flight

Your students will be excited to learn programming skills and geographic information systems while programming a flight for Kent ISD's Unmanned Aerial Vehicle (UAV – a.k.a. drone). We'll bring the UAV and supply the lesson plan in which students research weather phenomena using real time weather and wind data from the National Oceanic and Atmospheric Administration (NOAA). Then, the students decide whether the conditions meet the UAV manufacturer's flight safety parameters, they program the flight into the UAV and finally, actually fly the aircraft!

3D Printing Design Challenge

Challenge your students with a real world design problem and bring their solutions to life with our 3D printer. In one of our lessons, fifth grade students redesign faulty structural clips for a greenhouse. The problem? The greenhouse's panels fall off in heavy winds. It's up to the students to collect information about the problem and experiment with different design solutions. Then, with the help of our 3D printer, they create and test real-life versions of their solutions on the actual greenhouse and determine the best fix for the problem.

Kent ISD
We Lead Learning

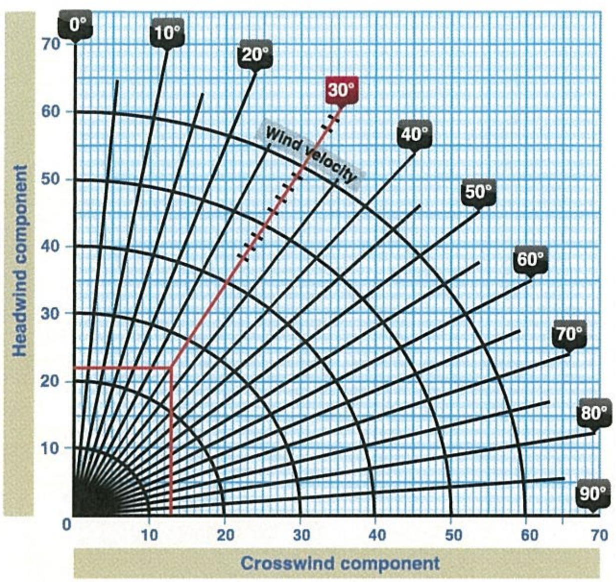


Figure 10-30. *Crosswind component chart.*

the correct wind velocity of 25 knots. From there, draw a line straight down and a line straight across. The headwind component is 22 knots and the crosswind component is 13 knots. This information is important when taking off and landing so that, first of all, the appropriate runway can be picked if more than one exists at a particular airport, but also so that the aircraft is not pushed beyond its tested limits.

Landing Charts

Landing performance is affected by variables similar to those affecting takeoff performance. It is necessary to compensate for differences in density altitude, weight of the airplane, and headwinds. Like takeoff performance charts, landing distance information is available as normal landing information, as well as landing distance over a 50 foot obstacle. As usual, read the associated conditions and notes in order to ascertain the basis of the chart information. Remember, when calculating landing distance that the landing weight will not be the same as the takeoff weight. The weight must be recalculated to compensate for the fuel that was used during the flight.

Sample Problem 11

Pressure Altitude..1,250 feet

Temperature...Standard

Refer to *Figure 10-31.* This example makes use of a landing distance table. Notice that the altitude of 1,250 feet is not on this table. It is, therefore, necessary to interpolate to find the correct landing distance. The pressure altitude of 1,250 is halfway between sea level and 2,500 feet. First, find the column for sea level and the column for 2,500 feet. Take the total distance of 1,075 for sea level and the total distance of 1,135 for 2,500 and add them together. Divide the total by two to obtain the distance for 1,250 feet. The distance is 1,105 feet total landing distance to clear a 50 foot obstacle. Repeat this process to obtain the ground roll distance for the pressure altitude. The ground roll should be 457.5 feet.

Sample Problem 12

OAT.. 57 °F

Pressure Altitude.. 4,000 feet

Landing Weight...2,400 pounds

Headwind.. 6 knots

Obstacle Height.. 50 feet

Using the given conditions and *Figure 10-32,* determine the landing distance for the aircraft. This graph is an example of a combined landing distance graph and allows compensation for temperature, weight, headwinds, tailwinds, and varying obstacle height. Begin by finding the correct OAT on the scale on the left side of the chart. Move up in a straight line to the correct pressure altitude of 4,000 feet. From this intersection, move straight across to the first dark reference line. Follow the lines in the same diagonal fashion until the correct landing weight is reached. At 2,400 pounds, continue in a straight line across to the second dark reference line. Once again, draw a line in a diagonal manner to the correct wind component and then straight across to the third dark

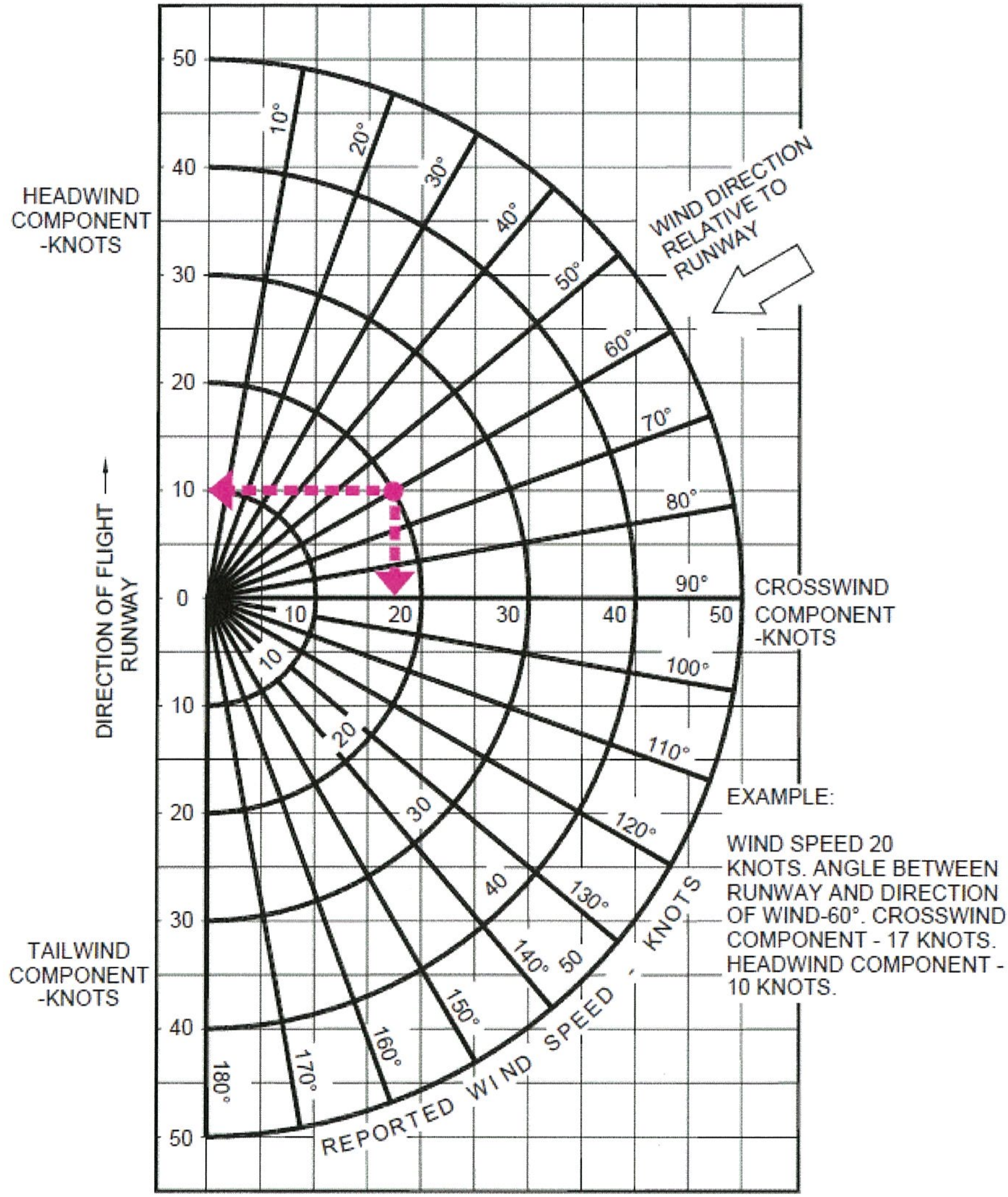
Conditions: Flaps lowered to 40°; Power off; Hard surface runway; Zero wind

LANDING DISTANCE

Gross weight lb	Approach speed IAS, MPH	At sea level & 59 °F		At 2,500 ft & 59 °F		At 5,000 ft & 41 °F		At 7,500 ft & 32 °F	
		Ground roll	Total to clear 50 ft OBS	Ground roll	Total to clear 50 ft OBS	Ground roll	Total to clear 50 ft OBS	Ground roll	Total to clear 50 ft OBS
1,600	60	445	1,075	470	1,135	495	1,195	520	1,255

Note:
1. Decrease the distances shown by 10% for each 4 knots of headwind.
2. Increase the distance by 10% for each 60 °F temperature increase above standard.
3. For operation on a dry, grass runway, increase distances (both "ground roll" and "total to clear 50 ft obstacle") by 20% of the "total to clear 50 ft obstacle" figure.

Figure 10-31. *Landing distance table.*


HEADWIND COMPONENT -KNOTS
TAILWIND COMPONENT -KNOTS
DIRECTION OF FLIGHT
RUNWAY
CROSSWIND COMPONENT -KNOTS
WIND DIRECTION RELATIVE TO RUNWAY
REPORTED WIND SPEED - KNOTS
10° 20° 30° 40° 50° 60° 70° 80° 90° 100° 110° 120° 130° 140° 150° 160° 170° 180°
50 40 30 20 10 0 10 20 30 40 50
10 20 30 40 50
EXAMPLE:
WIND SPEED 20 KNOTS. ANGLE BETWEEN RUNWAY AND DIRECTION OF WIND-60°. CROSSWIND COMPONENT - 17 KNOTS. HEADWIND COMPONENT - 10 KNOTS.

In full view of the pilot, in the area of the air conditioner control panel when the air conditioner is installed:

"WARNING—AIR CONDITIONER MUST BE OFF TO INSURE NORMAL TAKEOFF CLIMB PERFORMANCE."

Adjacent to upper door latch:

"ENGAGE LATCH BEFORE FLIGHT."

On inside of the baggage compartment door:

"BAGGAGE MAXIMUM 200 LBS"
"UTILITY CATEGORY OPERATION - NO BAGGAGE OR AFT PASSENGERS ALLOWED. NORMAL CATEGORY OPERATION - SEE PILOT'S OPERATING HANDBOOK WEIGHT AND BALANCE SECTION FOR BAGGAGE AND AFT PASSENGER LIMITATIONS."

In full view of the pilot:

"MANEUVERING SPEED 111 KIAS AT 2325 LBS. (SEE P.O.H.)" OR "VA = 111 KIAS AT 2325 #(SEE P.O.H.)"

"UTILITY CATEGORY OPERATION - NO AFT PASSENGERS ALLOWED."

"DEMONSTRATED CROSS WIND COMPONENT - 17 KTS." or "DEMO. X-WIND 17 KTS."

In full view of the pilot when the oil cooler winterization kit is installed:

"OIL COOLER WINTERIZATION PLATE TO BE REMOVED WHEN AMBIENT TEMPERATURE EXCEEDS 50°F."

In full view of the pilot:

"UTILITY CATEGORY OPERATION ONLY."

(1) NO AFT PASSENGERS ALLOWED.
(2) ACROBATIC MANEUVERS ARE LIMITED TO THE FOLLOWING:

	ENTRY SPEED
SPINS PROHIBITED	
STEEP TURNS	111 KIAS
LAZY EIGHTS	111 KIAS
CHANDELLES	111 KIAS

In full view of the pilot:

"WARNING — TURN OFF STROBE LIGHTS WHEN IN CLOSE PROXIMITY TO GROUND OR DURING FLIGHT THROUGH CLOUD, FOG OR HAZE."

VFR FLIGHT PLANNER

packafoma.com/aviation

N	Date	Dist.	GS	Time Off	Fuel
				:	

Wind Dir. / Temp.	Wind Vel.	TAS	TC / ±WCA	TH / ±Var.	MH	Altitude	Check Point	Ident. / Freq.	Route	Dist. Leg / Rem.	GS Est. / Act.	ETE / ATE	ETA / ATA	Fuel Leg / Rem.
									Totals:					

Block In	
Block Out	

Emergency 121.5 Squawk 7700

Radio Contact	Freq.
Flight Service	122.2
Flight Watch	122.0
ATIS	
Apch	
TWR	
GND	
Clear	
UNI	
FSS	

Speed \ Distance	5	10	15	20
80	3:45	7:40	11:15	15:00
90	3:20	6:40	10:00	13:20
100	3:00	6:00	9:00	12:00
110	2:43	5:27	8:10	10:54
120	2:30	5:00	7:30	10:00
130	2:18	4:36	6:55	9:13
140	2:08	4:17	6:25	8:34
150	2:00	4:00	6:00	8:00
160	1:52	3:45	5:37	7:30

Notes

• CLOSE FLIGHT PLAN •

Destination Airport	
Pattern Altitude	
Field Elevation	
RW	RW
RW	RW

VFR FLIGHT PLANNER

packafoma.com/aviation

N	Date

Wind Dir.	Wind Vel. / Temp.	TAS	TC / ±WCA	TH / ±Var.	MH	Altitude	Check Point	Ident. / Freq.	Route	Dist. Leg / Rem.	GS Est. / Act.	Time Off ETE / ATE	ETA / ATA	Fuel Leg / Rem.
												:		
									Totals:					

Block In	
Block Out	

Emergency 121.5 Squawk 7700

Radio Contact	Freq.
Flight Service	122.2
Flight Watch	122.0
ATIS	
Apch	
TWR	
GND	
Clear	
UNI	
FSS	

Distance / Speed

Speed	5	10	15	20
80	3:45	7:40	11:15	15:00
90	3:20	6:40	10:00	13:20
100	3:00	6:00	9:00	12:00
110	2:43	5:27	8:10	10:54
120	2:30	5:00	7:30	10:00
130	2:18	4:36	6:55	9:13
140	2:08	4:17	6:25	8:34
150	2:00	4:00	6:00	8:00
160	1:52	3:45	5:37	7:30

Notes

• CLOSE FLIGHT PLAN •

Destination Airport	
Pattern Altitude	
Field Elevation	
RW	RW
RW	RW

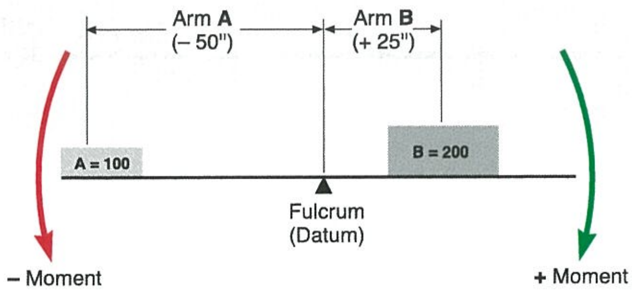


Figure 2-2. *The lever is balanced when the algebraic sum of the moments is zero.*

Consider these facts about the lever in Figure 2-2: The 100-pound weight A is located 50 inches to the left of the fulcrum (the datum, in this instance), and it has a moment of 100 X-50 = -5,000 in-lb. The 200-pound weight B is located 25 inches to the right of the fulcrum, and its moment is 200 x +25 = +5000 in-lb. The sum of the moment is -5000 + 5000 = 0, and the lever is balanced. [Figure 2-3] The forces that try to rotate it clockwise have the same magnitude as those that try to rotate it counterclockwise.

Item	Weight (lb)	Arm (in)	Moment (lb-in)
Weight A	100	–50	–5,000
Weight B	200	+25	+5,000
	300		0

Figure 2-3. *When a lever is in balance, the sum of the moments is zero.*

Determining the CG

One of the easiest ways to understand weight and balance is to consider a board with weights placed at various locations. We can determine the CG of the board and observe the way the CG changes as the weights are moved.

The CG of a board like the one in Figure 2-4 may be determined by using these four steps:

1. Measure the arm of each weight in inches from the datum.
2. Multiply each arm by its weight in pounds to determine the moment in pound-inches of each weight.
3. Determine the total of all weights and of all the moments. Disregard the weight of the board.
4. Divide the total moment by the total weight to determine the CG in inches from the datum.

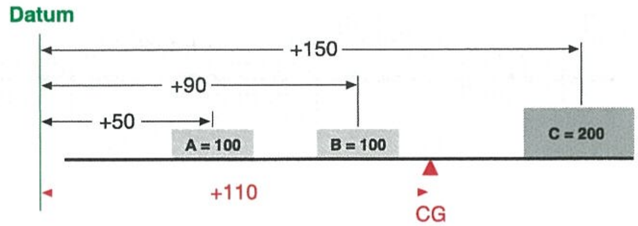


Figure 2-4. *Determining the center of gravity from a datum located off the board.*

In Figure 2-4, the board has three weights, and the datum is located 50 inches to the left of the CG of weight A. Determine the CG by making a chart like the one in Figure 2-5.

Item	Weight	Arm	Moment	CG
Weight A	100	50	5,000	
Weight B	100	90	9,000	
Weight C	200	150	30,000	
	400		44,000	110

Figure 2-5. *Determining the CG of a board with three weights and the datum located off the board.*

As noted in Figure 2-5, A weighs 100 pounds and is 50 inches from the datum: B weighs 100 pounds and is 90 inches from the datum; C weighs 200 pounds and is 150 inches from the datum. Thus the total of the three weights is 400 pounds, and the total moment is 44,000 lb-in.

Determine the CG by dividing the total moment by the total weight.

$$CG = \frac{\text{Total moment}}{\text{Total weight}}$$

$$= \frac{44{,}000}{400}$$

$$= 110 \text{ inches from the datum}$$

To prove this is the correct CG, move the datum to a location 110 to the right of the original datum and determine the arm of each weight from this new datum, as in Figure 2-6. Then make a new chart similar to the one in Figure 2-7. If the CG is correct, the sum of the moments will be zero.

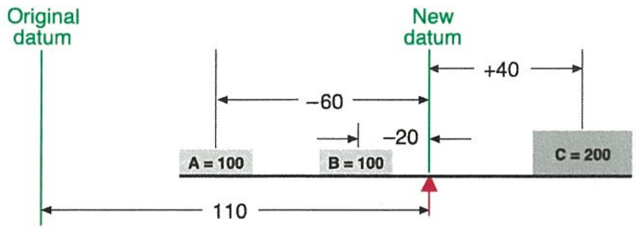


Figure 2-6. *Arms from the datum assigned to the CG.*

The new arm of weight A is 110 - 50 = 60 inches, and since this weight is to the left of the datum, its arm is negative, or -60 inches. The new arm of weight B is 110 - 90 = 20 inches, and it is also to the left of the datum, so it is - 20; the new arm of weight C is 150 - 110 = 40 inches. It is to the right of the datum and is therefore positive.

Item	Weight	Arm	Moment
Weight A	100	–60	–6,000
Weight B	100	–20	–2,000
Weight C	200	+40	+8,000
			0

Figure 2-7. *The board balances at a point 110 inches to the right of the original datum.*

The board is balanced when the sum of the moments is zero. The location of the datum used for determining the arms of the weights is not important; it can be anywhere. But all of the measurements must be made from the same datum location.

Determining the CG of an airplane is done in the same way as determining the CG of the board in the previous example. [Figure 2-8] Prepare the airplane for weighing (as explained in Chapter 3) and place it on three scales. All tare weight, that is, the weight of any chocks or devices used to hold the aircraft on the scales, is subtracted from the scale reading, and the net weight from each wheel weigh point is entered on the chart like the one in Figure 2-9. The arms of the weighing points are specified in the Type Certificate Data Sheet (TCDS) for the airplane in terms of stations, which are distances in inches from the datum. Tare weight also includes items used to level the aircraft.

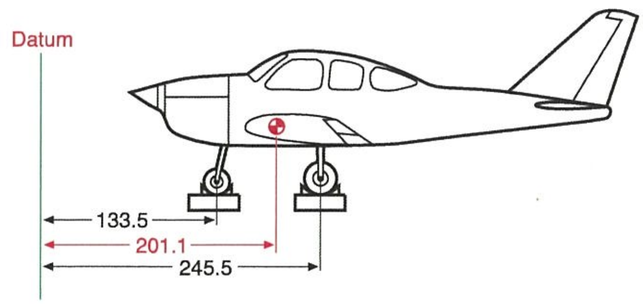


Figure 2-8. *Determining the CG of an airplane whose datum is ahead of the airplane.*

Item	Weight	Arm	Moment	CG
Main wheels	3,540	245.5	869,070	
Nose wheel	2,322	133.5	309,987	
Total	5,862		1,179,057	201.1

Figure 2-9. *Chart for determining the CG of an airplane whose datum is ahead of the airplane.*

The empty weight of this aircraft is 5,862 pounds. Its EWCG, determined by dividing the total moment by the total weight, is located at fuselage station 201.1. This is 201.1 inches behind the datum.

$$CG = \frac{\text{Total moment}}{\text{Total weight}}$$

$$= \frac{1,179,057}{5,862}$$

$$= 201.1 \text{ inches behind the datum}$$

Shifting the CG

One common weight and balance problem involves moving passengers from one seat to another or shifting baggage or cargo from one compartment to another to move the CG to a desired location. This also can be visualized by using a board with three weights and then working out the problem the way it is actually done on an airplane.

Solution by Chart

The CG of a board can be moved by shifting the weights as demonstrated in Figure 2-10. As the board is loaded, it balances at a point 72 inches from the CG of weight A. [Figure 2-11]

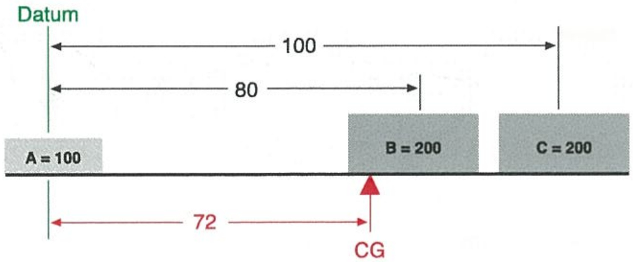


Figure 2-10. *Moving the CG of a board by shifting the weights. This is the original configuration.*

Item	Weight	Arm	Moment	CG
Weight A	100	0	0	
Weight B	200	80	16,000	
Weight C	200	100	20,000	
	500		36,000	72

Figure 2-11. *Shifting the CG of a board by moving one of the weights. This is the original condition of the board.*

To shift weight B so the board will balance about its center, 50 inches from the CG of weight A, first determine the arm of weight B that will produce a moment that causes the total moment of all three weights around this desired balance point to be zero. The combined moment of weights A and C around this new balance point, is 5,000 in-lb, so the moment of weight B will have to be -5,000 lb-in in order for the board to balance. [Figure 2-12]

Item	Weight	Arm	Moment
Weight A	100	–50	–5,000
Weight B			
Weight C	200	+50	+10,000
			+5,000

Figure 2-12. *Determining the combined moment of weights A and C.*

Determine the arm of weight B by dividing its moment, -5,000 lb-in, by its weight of 200 pounds. Its arm is -25 inches.

$$\text{Arm B} = \frac{\text{Moment}}{\text{Weight}}$$

$$= \frac{-5{,}000}{200}$$

$$= -25$$

To balance the board at its center, weight B will have to be placed so its CG is 25 inches to the left of the center of the board, as in Figure 2-13.

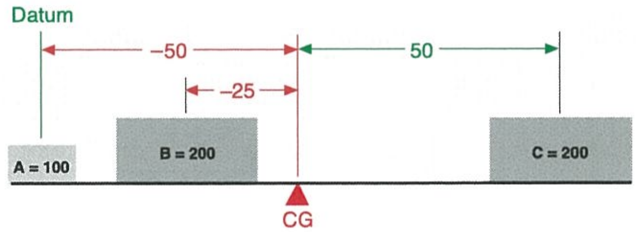


Figure 2-13. *Placement of weight B to cause the board to balance about its center.*

Basic Weight and Balance Equation

$$\frac{\text{Weight to be shifted}}{\text{Total weight}} = \frac{\Delta\text{CG}}{\text{Distance weight is shifted}}$$

This equation can be rearranged to find the distance a weight must be shifted to give a desired change in the CG location:

$$\text{Distance weight is shifted} = \frac{\text{Total weight} \times \Delta\text{CG}}{\text{Weight shifted}}$$

This equation can also be rearranged to find the amount of weight to shift to move the CG to a desired location:

$$\text{Weight shifted} = \frac{\text{Total weight} \times \Delta\text{CG}}{\text{Distance weight is shifted}}$$

It can also be rearranged to find the amount the CG is moved when a given amount of weight is shifted:

$$\Delta\text{CG} = \frac{\text{Weight shifted} \times \text{Distance weight is shifted}}{\text{Total weight}}$$

Finally, this equation can be rearranged to find the total weight that would allow shifting a given amount of weight to move the CG a given distance:

$$\text{Total weight} = \frac{\text{Weight shifted} \times \text{Distance weight is shifted}}{\Delta\text{CG}}$$

Solution by Formula

This same problem can also be solved by using this basic equation:

$$\frac{\text{Weight to be shifted}}{\text{Total weight}} = \frac{\Delta\text{CG}}{\text{Distance weight is shifted}}$$

Rearrange this formula to determine the distance weight B must be shifted:

$$\text{Distance weight B is shifted} = \frac{\text{Total weight} \times \Delta CG}{\text{Weight shifted}}$$

$$= \frac{500 \times -22}{200}$$

$$= -55 \text{ inches}$$

The CG of the board in Figure 2-10 was 72 inches from the datum. This CG can be shifted to the center of the board as in Figure 2-13 by moving weight B. If the 200-pound weight B is moved 55 inches to the left, the CG will shift from 72 inches to 50 inches, a distance of 22 inches. The sum of the moments about the new CG will be zero. [Figure 2-14]

Item	Weight	Arm	Moment
Weight A	100	–50	–5,000
Weight B	200	–25	–5,000
Weight C	200	+50	+10,000
			0

Figure 2-14. *Proof that the board balances at its center. The board is balanced when the sum of the moments is zero.*

When the distance the weight is to be shifted is known, the amount of weight to be shifted to move the CG to any location can be determined by another arrangement of the basic equation. Use the following arrangement of the formula to determine the amount of weight that will have to be shifted from station 80 to station 25, to move the CG from station 72 to station 50.

$$\text{Weight shifted} = \frac{\text{Total weight} \times \Delta CG}{\text{Distance weight is shifted}}$$

$$= \frac{500 \times 22}{55}$$

$$= 200 \text{ pounds}$$

If the 200-pound weight B is shifted from station 80 to station 25, the CG will move from station 72 to station 50.

A third arrangement of this basic equation may be used to determine the amount the CG is shifted when a given amount of weight is moved for a specified distance (as it was done in Figure 2-10). Use this formula to determine the amount the CG will be shifted when 200-pound weight B is moved from +80 to +25.

$$\Delta CG = \frac{\text{Weight shifted} \times \text{Distance it is shifted}}{\text{Total weight}}$$

$$= \frac{200 \times 55}{500}$$

$$= 22 \text{ inches}$$

Moving weight B from +80 to +25 will move the CG 22 inches, from its original location at +72 to its new location at +50 as seen in Figure 2-13.

Shifting the Airplane CG

The same procedures for shifting the CG by moving weights can be used to change the CG of an airplane by rearranging passengers or baggage.

Consider this airplane:

Airplane empty weight and EWCG 1340 lbs @ +37.0
Maximum gross weight .... 2,300 lbs
CG limits .... +35.6 to +43.2
Front seats (2) .... +35
Rear seats (2) .... +72
Fuel .... 40 gal @ +48
Baggage (maximum) .... 60 lbs @ +92

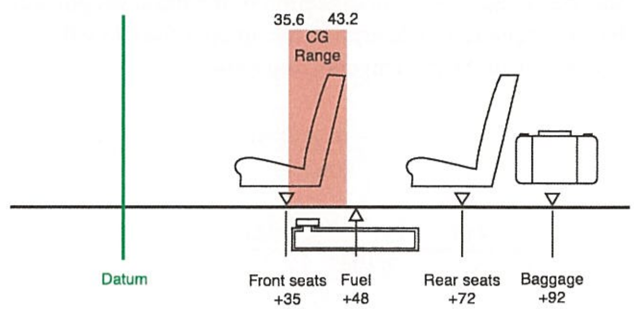


Figure 2-15. *Loading diagram for a typical single-engine airplane.*

The pilot has prepared a chart, Figure 2-16, with certain permanent data filled in and blanks left to be filled in with information on this particular flight.

Item	Weight 2,300 max	Arm	Moment	CG +35.6 to +43.2
Airplane	1,340	37	49,580	
Front Seats		35		
Rear Seats		72		
Fuel		48		
Baggage		92		

Figure 2-16. *Blank loading chart.*

For this flight, the 140-pound pilot and a 115-pound passenger are to occupy the front seats, and a 212-pound and a 97-pound passenger are in the rear seats. There will be 50 pounds of baggage, and the flight is to have maximum range, so maximum fuel is carried. The loading chart, Figure 2-17, is filled in using the information from Figure 2-15.

Item	Weight 2,300 max	Arm	Moment	CG +35.6 to +43.2
Airplane	1,340	37	49,580	
Front Seats	255	35	8,925	
Rear Seats	309	72	22,248	
Fuel	240	48	11,520	
Baggage	50	92	4,600	
	2,194		96,873	44.1

Figure 2-17. *This completed loading chart shows the weight is within limits, but the CG is too far aft.*

With this loading, the total weight is less than the maximum of 2,300 pounds and is within limits, but the CG is 0.9 inch too far aft.

One possible solution would be to trade places between the 212-pound rear-seat passenger and the 115-pound front-seat passenger. Use a modification of the basic weight and balance equation to determine the amount the CG will change when the passengers swap seats.

$$\Delta CG = \frac{\text{Weight shifted} \times \text{Distance it is shifted}}{\text{Total weight}}$$

$$= \frac{(212 - 115) \times (72 - 35)}{2{,}194}$$

$$= \frac{97 \times 37}{2{,}194}$$

$$= 1.6 \text{ inches}$$

The two passengers changing seats moved the CG forward 1.6 inches, which places it within the operating range. This can be proven correct by making a new chart incorporating the changes. [Figure 2-18]

Item	Weight 2,300 max	Arm	Moment	CG +35.6 to +43.2
Airplane	1,340	37	49,580	
Front Seats	352	35	12,320	
Rear Seats	212	72	15,264	
Fuel	240	48	11,520	
Baggage	50	92	4,600	
	2,194		93,284	42.5

Figure 2-18. *This loading chart, made after the seat changes, shows both the weight and balance are within allowable limits.*

Weight and Balance Documentation

FAA-Furnished Information

Before an aircraft can be properly weighed and its empty-weight center of gravity computed, certain information must be known. This information is furnished by the FAA to anyone for every certificated aircraft in the Type Certificate Data Sheets (TCDS) or Aircraft Specifications and can be accessed via the internet at: www.faa.gov (home page), from that page, select " Regulations and Policies," and at that page, select "Regulatory and Guidance Library." This is the official FAA technical reference library.

When the design of an aircraft is approved by the FAA, an Approved Type Certificate and TCDS are issued. The TCDS includes all of the pertinent specifications for the aircraft, and at each annual or 100-hour inspection, it is the responsibility of the inspecting mechanic or repairman to ensure that the aircraft adheres to them. See pages 2-7 through 2-9, for examples of TCDS excerpts. A note about the TCDS: aircraft certificated before January 1, 1958, were issued Aircraft Specifications under the Civil Air Regulations (CARs), but when the Civil Aeronautical Administration (CAA) was replaced by the FAA, Aircraft Specifications were replaced by the Type Certificate Data Sheets. The weight and balance information on a TCDS includes the following:

Data Pertinent to Individual Models

This type of information is determined in the sections pertinent to each individual model:

CG Range

Normal Category
(+82.0) to (+93.0) at 2,050 pounds.
(+87.4) to (+93.0) at 2,450 pounds.

Utility Category

(+82.0) to (+86.5) at 1,950 pounds.
Straight-line variations between points given.

Introduction

Airplanes are subject to many forces and torques, both on the ground and in the air. According to Federal Aviation Regulation 91.103 each time an airplane flies, there must be a check done to make sure the airplane is balanced. What does "balancing" the airplane mean?

Each airplane has specifications dealing with the center of gravity of the plane. The center of gravity is the point within the airplane where all of the weight is centered. It is like finding the average location of the weight of the airplane. The center of gravity for an object is not necessarily the geometric center. In fact, for an airplane it is NOT the geometric center. Each manufacturer releases tolerances for where the center of gravity should be for each plane. As items are added to the plane (i.e. baggage, passengers, fuel, instruments, antennae, etc.), it is imperative that the center of gravity remain within the limitations (it is also illegal to do otherwise!).

Keeping the center of gravity within the limitations allows the plane to fly normally and for the pilot to keep it under control. If the center of gravity were to shift outside of the limitations, the pilot may end up not being able to steer the airplane correctly. Even more dangerous, the plane might stall at some point and the pilot would not be able to recover!

This principle also applies to helicopters.

There are some terms that you need to know in order to participate in the weighing and balancing of an aircraft.

Weight: the force or weight of the part of the aircraft or object in the aircraft. Measured in pounds (lbs.)

Datum: this is the ***imaginary*** vertical line from which all other distance (lever arm/arm) measurements are taken. The datum may exist somewhere on the aircraft, in front of the aircraft, or even possibly behind it. Each manufacturer will identify the location of the datum. This is **nothing more than** the reference point, or line, for measurements.

Arm: the distance from the datum to the location where a force (weight) is applied. In physics, this is often called the lever arm. The arm can be either positive or negative, depending on its position (in front of or behind) from the datum. The arm is measured in inches (in.).

Moment: this is another way to refer to torque. Torque is the rotational analogy of force. Force causes acceleration, whereas torque causes rotation. It is found by taking the cross product of the force applied and the lever arm. If the lever arm and force are perpendicular, then the two are just multiplied. If there is an angle between the two, multiply the force and lever arm then multiply by the sine of the angle between the two. This will give you the cross product. Using the industry jargon, the moment is found by multiplying the force (weight) and the arm. This is measured in (in.-lbs.)

Center of gravity (C.G.): this is the point in the aircraft where all of the moments from the nose end of the plane are balanced with the moments from the tail end of the plane. This acts as a fulcrum for the balance of the aircraft.

Weights of the aircraft: the aircraft will have different weights, depending on the situation. Is the aircraft empty, is it full of fuel, does it have minimum fuel, etc. The placement and tolerance for the center of gravity varies, depending on the weight. The manufacturer has guidelines for the placement and tolerance of the center of gravity for the different weights.

Weight and Balance Data

One way to make the weight and balance data useful is to place it into a Weight and Balance table. This is often used in industry to streamline calculations. An example of a Weight and Balance table can be found on the next page.

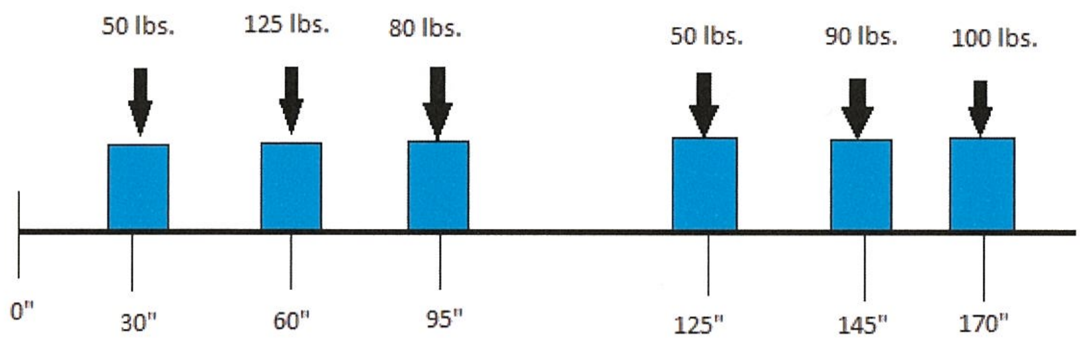


*Diagram above shows distribution of weights throughout the aircraft. 0" is the datum.

Weight and Balance data table based off of diagram.

Item	Weight (lbs.)	Arm (in)	Moment (in-lb)
50 pound weight	50	+30	1,500
125 pound weight	125	+60	7,500
80 pound weight	80	+95	7,600
50 pound weight	50	+125	6,250
90 pound weight	90	+145	13,050
100 pound weight	100	+170	17,000
Total	495	+106.9 (center of gravity)	52,900

The center of gravity then acts as a fulcrum in balancing the plane. Forces on one side of the fulcrum will cause negative torques, whereas forces on the other side of the fulcrum will cause positive torques. Adding these torques together, will result in net torque of zero (a balanced airplane). The lift of the wings is centered at the center of gravity to counteract all other weights from the airplane, causing it to fly. Said differently- the weight and balance of the airplane needs to be such that the C.G. is near the center of lift for the wings.

There is an equation used in industry to find the center of gravity. The equation is

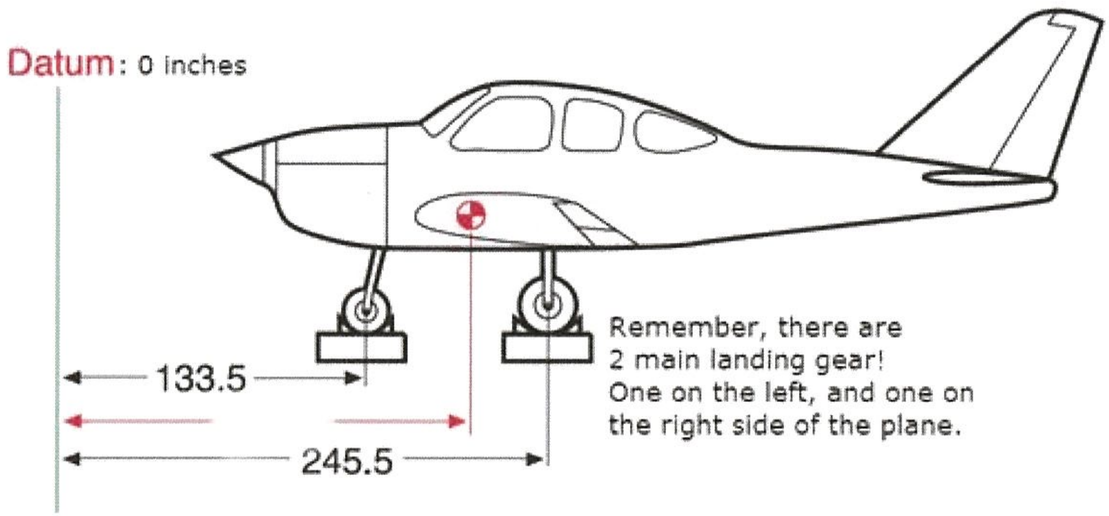
$$\mathbf{C.G. = D - \frac{F(L)}{W}}$$

Where C.G. is the center of gravity
D = the horizontal distance measured from the datum to the main wheel weighing point
F = the weight at the nose weighing point
L = the horizontal distance measured from the main wheel weighing point to the nose weighing point
W = the weight of the airplane at the time of weighing

Objective: Utilize the concepts of torque, force, lever arm, and balance as well as industry procedures and standards to determine the location of a center of gravity.

Procedure:

At an airport facility there would be a number of steps listed in an aircraft manual to jack up the plane and place appropriate weighing devices under it. For our purposes, refer to this diagram:



Part 1 Data:

(Don't forget the units!)

Item	Weight (lbs)	Arm (cm)	Moment (lb-cm)
Nose gear scale	411		
Main gear scale 1	365		
Main gear scale 2	395		

Weights

Nose gear scale	411 lbs
Main gear scale 1	365 lbs
Main gear scale 2	395 lbs

Industry range for center of gravity: 200 in – 205 in aft of datum

Part 1 Calculations

1. Calculate the moment due to each weight by multiplying the weight and arm.

2. Using the equation $C.G. = D - \frac{F(L)}{W}$, find the center of gravity for the airplane.

Calculated location of center of gravity ______________

Will the airplane fly? ________________________

How do you know?

____

____

____

Part 3

Weight and balance of a chair and object.

- Arrange a chair on top of four (4) household scales.
- Choose a datum position (your choice) on the ground in front of the chair. Mark this location with tape and draw a line on the tape to be precise
- Load some weight onto the chair
    - A person would need to sit quite still (and be OK with being weighed)
    - An inanimate object would work also.
- Take measurements for arm lengths
- Record weight(s)
- Calculate weight and balance C.G. location for the chair and object
- Mark the location of the C.G. on the floor with tape and a pencil mark
- Learn more- ***move your datum location for your chair and object***
    - Recalculate the weight and balance
    - Is the location of the C.G. the same or not? Why?
    - If you used a person sitting in the chair, what impact did/would them not sitting still have on the calculations?

Analysis Question:

Fuel tanks are typically located in the wings. Give an explanation for the location of the fuel tanks based on your understanding of center of gravity. Keep in mind that fuel is ***<u>used</u>*** during flight.

2. Determine the distance between the CG and the datum by adding the CG in inches aft of LEMAC to the distance from the datum to LEMAC:

$$\text{CG (in. from datum)} = \text{CG in. aft of LEMAC} + \text{datum to LEMAC}$$
$$= 31.84 + 549.13$$
$$= 580.97 \text{ inches}$$

3. Determine the moment/1,000 for the original weight:

$$\text{Moment/1,000} = \frac{\text{Weight} \times \text{Arm}}{1{,}000}$$
$$= \frac{90{,}000 \times 580.97}{1{,}000}$$
$$= 52{,}287.30$$

4. Determine the new weight and new CG by first determining the moment/1,000 of the removed weight.

   Multiply the amount of weight removed (-2,500 pounds) by the centroid of the forward cargo hold (352.1 inches), and then divide this by 1,000.

$$\text{Moment/1,000} = \frac{\text{Weight} \times \text{Arm}}{1{,}000}$$
$$= \frac{-2{,}500 \times 352.1}{1{,}000}$$
$$= -880.25$$

5. Subtract the removed weight and its moment/1,000 from the original weight and moment/1,000.

Item	Weight	Moment/1000
Original weight	90,000	52,287.30
Δ Weight	– 2,500	– 880.25
New weight & moment	87,500	51,407.05

6. Determine the location of the new CG by dividing the total moment/1,000 by the total weight and multiplying this by the reduction factor 1,000.

$$\text{CG} = \left(\frac{\text{Total moment/1,000}}{\text{Total weight}}\right) \times 1{,}000$$
$$= \left(\frac{51{,}407}{87{,}500}\right) \times 1{,}000$$
$$= 587.5 \text{ inches behind the datum}$$

7. Convert the new CG location to % MAC. First, determine the distance between the CG location and LEMAC:

$$\text{CG (in. aft of LEMAC)} = \text{CG (in. from datum)} - \text{LEMAC}$$
$$= 587.5 - 549.13$$
$$= 38.37 \text{ inches}$$

8. Then, determine new CG in % MAC:

$$\text{CG \% MAC} = \left(\frac{\text{Distance CG to LEMAC}}{\text{MAC}}\right) \times 100$$
$$= \left(\frac{38.37}{141.5}\right) \times 100$$
$$= 27.1\% \text{ MAC}$$

Offloading 2,500 pounds of cargo from the forward cargo hold moves the CG from 22.5% MAC to 27.1% MAC.

Effects of Onloading Cargo

The previous example showed the way the weight and CG changed when cargo was offloaded. This example shows the way both parameters change when cargo is onloaded.

The same basic airplane is used in the following example, but 3,000 pounds of cargo is onloaded in the forward cargo hold.

Weight before cargo is loaded....... 87,500 lbs
CG before cargo is loaded .... 27.1% MAC
Weight change............................+ 3,000 lbs
Fwd. cargo hold centroid .... station 352.1
MAC ....141.5 in
LEMAC .... station 549.13

1. Determine the CG location in inches from the datum before the cargo is onloaded. Do this by first determining the distance of the CG aft of the LEMAC:

$$\text{CG (inches aft of LEMAC)} = \left(\frac{\text{CG in \% MAC}}{100}\right) \times \text{MAC}$$
$$= \left(\frac{27.1}{100}\right) \times 141.5$$
$$= 38.35 \text{ inches}$$

2. Determine the distance between the CG and the datum by adding the CG in inches aft of LEMAC to the distance from the datum to LEMAC:

$$\text{CG (in. from datum)} = \text{CG in. aft of LEMAC} + \text{datum to LEMAC}$$
$$= 38.35 + 549.13$$
$$= 587.48 \text{ inches}$$

3. Determine the moment/1,000 for the original weight:

$$\text{Moment/1,000} = \frac{\text{Weight} \times \text{Arm}}{1{,}000}$$
$$= \frac{87{,}500 \times 587.48}{1{,}000}$$
$$= 51{,}404.5$$

4. Determine the new weight and new CG by first determining the moment/1,000 of the added weight. Multiply the amount of weight added (3,000 pounds) by the centroid of the forward cargo hold (352.1 inches), and then divide this by 1,000.

$$\text{Moment/1,000} = \frac{\text{Weight} \times \text{Arm}}{1{,}000} = \frac{3{,}000 \times 352.1}{1{,}000} = 1{,}056.3$$

5. Add the onloaded cargo weight and its moment/1,000 to the original weight and moment/1,000.

	Weight	Moment/1000	CG in/datum	CG % MAC
Original weight and CG	87,500	51,404.5	587.48	27.1
Δ Weight	+ 3,000	1,056.3		
New weight and CG	90,500	52,460.8	579.68	21.59

6. Determine the location of the new CG by dividing the total moment/1,000 by the total weight and multiplying this by the reduction factor of 1,000.

$$\text{CG} = \frac{\text{Total moment/1,000}}{\text{Total weight}} \times 1{,}000 = \frac{52{,}460.8}{90{,}500} \times 1{,}000 = 579.68 \text{ inches behind the datum}$$

7. Convert the new CG location to % MAC. First, determine the distance between the CG location and LEMAC:

$$\text{CG (in. aft of LEMAC)} = \text{CG (in. from datum)} - \text{LEMAC} = 579.68 - 549.13 = 30.55 \text{ inches}$$

8. Then, determine new CG in % MAC:

$$\text{CG \% MAC} = \left(\frac{\text{Distance CG to LEMA}}{\text{MAC}}\right) \times 100 = \left(\frac{30.55}{141.5}\right) \times 100 = 21.59\% \text{ MAC}$$

Onloading 3,000 pounds of cargo into the forward cargo hold moves the CG forward 5.51 inches, from 27.1% MAC to 21.59% MAC.

Effects of Shifting Cargo from One Hold to Another

When cargo is shifted from one cargo hold to another, the CG changes, but the total weight of the aircraft remains the same.

As an example, use this data:

Loaded weight.......................... 90,000 lbs
Loaded CG.......................... station 580.97
(which is 22.5% MAC)
Fwd. cargo hold centroid .... station 352
Aft cargo hold centroid .... station 724.9
MAC.. 141.5 in
LEMAC................................... station 549

To determine the change in CG, or __CG, caused by shifting 2,500 pounds of cargo from the forward cargo hold to the aft cargo hold, use this formula:

$$\Delta\text{CG} = \frac{\text{Weight shifted} \times \text{Distance shifted}}{\text{Total weight}} = \frac{2{,}500 \times (227.9 + 144.9)}{90{,}000} = \frac{2{,}500 \times 372.8}{90{,}000} = 10.36 \text{ inches}$$

Since the weight was shifted aft, the CG moved aft, and the CG change is positive. If the shift were forward, the CG change would be negative.

Before the cargo was shifted, the CG was located at station 580.97, which is 22.5% MAC. The CG moved aft 10.36 inches, so the new CG is:

$$\text{New CG} = \text{Old CG} \pm \Delta\text{CG} = 580.97 + 10.36 = 591.33 \text{ inches}$$

Convert the location of the CG in inches aft of the datum to % MAC by using this formula:

$$\Delta CG\ \%\ MAC = \left(\frac{\Delta CG\ inches}{MAC}\right) \times 100$$
$$= \left(\frac{10.36}{141.5}\right) \times 100$$
$$= 7.32\%\ MAC$$

The new CG in % MAC caused by shifting the cargo is the sum of the old CG plus the change in CG:

$$New\ CG\ \%\ MAC = Old\ CG \pm \Delta CG$$
$$= 22.5\% + 7.32\%$$
$$= 29.82\%\ MAC$$

Some aircraft AFMs locate the CG relative to an index point rather than the datum or the MAC. An index point is a location specified by the aircraft manufacturer from which arms used in weight and balance computations are measured. Arms measured from the index point are called index arms, and objects ahead of the index point have negative index arms, while those behind the index point have positive index arms.

Use the same data as in the previous example, except for these changes:

Loaded CG........index arm of 0.97, which is 22.5% MAC
Index point ....fuselage station 580.0
Fwd. cargo hold centroid ....-227.9 index arm
Aft cargo hold centroid ....+144.9 index arm
MAC...141.5 in
LEMAC...-30.87 index arm

The weight was shifted 372.8 inches (-227.9 to +144.9 = 372.8).

The change in CG can be calculated by using this formula:

$$\Delta CG = \frac{Weight\ shifted \times Distance\ shifted}{Total\ weight}$$
$$= \frac{2{,}500 \times (724.9 - 352)}{90{,}000}$$
$$= \frac{2{,}500 \times 372.9}{90{,}000}$$
$$= 10.36\ inches$$

Since the weight was shifted aft, the CG moved aft, and the CG change is positive. If the shift were forward, the CG change would be negative.

Before the cargo was shifted, the CG was located at 0.97 index arm, which is 22.5% MAC. The CG moved aft 10.36 inches, and the new CG is:

$$New\ CG = Old\ CG \pm \Delta CG$$
$$= 0.97 + 10.36$$
$$= 11.33\ index\ arm$$

The change in the CG in % MAC is determined by using this formula:

$$New\ CG\ \%\ MAC = Old\ CG \pm \Delta CG$$
$$= 22.5\% + 7.32\%$$
$$= 29.82\%\ MAC$$

The new CG in % MAC is the sum of the old CG plus the change in CG:

$$\Delta CG\ \%\ MAC = \left(\frac{\Delta CG\ inches}{MAC}\right) \times 100$$
$$= \left(\frac{10.36}{141.5}\right) \times 100$$
$$= 7.32\%\ MAC$$

Notice that the new CG is in the same location whether the distances are measured from the datum or from the index point.

Determining Cargo Pallet Loads with Regard to Floor Loading Limits

Each cargo hold has a structural floor loading limit based on the weight of the load and the area over which this weight is distributed. To determine the maximum weight of a loaded cargo pallet that can be carried in a cargo hold, divide its total weight, which includes the weight of the empty pallet and its tiedown devices, by its area in square feet. This load per square foot must be equal to or less than the floor load limit.

In this example, determine the maximum load that can be placed on this pallet without exceeding the floor load limit.

Pallet dimensions ....36 by 48 in
Empty pallet weight ....47 lbs
Tiedown devices...33 lbs
Floor load limit .... 169 pounds per square foot

The pallet has an area of 36 inches (3 feet) by 48 inches (4 feet). This is equal to 12 square feet. The floor has a load limit of 169 pounds per square foot; therefore, the total weight of the loaded pallet can be 169 x 12 = 2,028 pounds.

Subtracting the weight of the pallet and the tiedown devices gives an allowable load of 1,948 pounds (2,028 - [47 + 33]).

applications where they are subjected to excessive vibration, repeated bending, or frequent disconnection from screw termination. *[Figure 9-116]*

Current Carrying Capacity

In some instances, the wire may be capable of carrying more current than is recommended for the contacts of the related connector. In this instance, it is the contact rating that dictates the maximum current to be carried by a wire. Wires of larger gauge may need to be used to fit within the crimp range of connector contacts that are adequately rated for the current being carried. *Figure 9-117* gives a family of curves whereby the bundle derating factor may be obtained.

Maximum Operating Temperature

The current that causes a temperature steady state condition equal to the rated temperature of the wire should not be exceeded. Rated temperature of the wire may be based upon the ability of either the conductor or the insulation to withstand continuous operation without degradation.

1. Single Wire in Free Air

Determining a wiring system's current-carrying capacity begins with determining the maximum current that a given-sized wire can carry without exceeding the allowable temperature difference (wire rating minus ambient °C). The curves are based upon a single copper wire in free air. *[Figure 9-117]*

2. Wires in a Harness

When wires are bundled into harnesses, the current derived for a single wire must be reduced, as shown in *Figure 9-118*. The amount of current derating is a function of the number of wires in the bundle and the percentage of the total wire bundle capacity that is being used.

3. Harness at Altitude

Since heat loss from the bundle is reduced with increased altitude, the amount of current should be derated. *Figure 9-119* gives a curve whereby the altitude-derating factor may be obtained.

4. Aluminum Conductor Wire

When aluminum conductor wire is used, sizes should be selected on the basis of current ratings shown in *Figure 9-120*. The use of sizes smaller than #8 is discouraged. Aluminum wire should not be attached to engine mounted accessories or used in areas having corrosive fumes, severe vibration, mechanical stresses, or where there is a need for frequent disconnection. Use of aluminum wire is also discouraged for runs of less than 3 feet. Termination hardware should be of the type specifically designed for use with aluminum conductor wiring.

Computing Current Carrying Capacity

The following section presents some examples on how to calculate the load carrying capacity of aircraft electrical wire. The calculation is a step by step approach and several graphs are used to obtain information to compute the current carrying capacity of a particular wire.

Example 1

Assume a harness (open or braided) consisting of 10 wires, size 20, 200 °C rated copper, and 25 wires size 22, 200 °C rated copper, is installed in an area where the ambient temperature is 60 °C and the aircraft is capable of operating at a 35,000 foot altitude. Circuit analysis reveals that 7 of the 35 wires in the bundle ($^7/_{35}$ = 20 percent) are carrying power currents near or up to capacity.

Step 1—Refer to the single wire in free air curves in *Figure 9-117*. Determine the change of temperature of the wire to determine free air ratings. Since the wire is in an ambient temperature of 60 °C and rated at 200 °C, the change of the temperature is 200 °C – 60 °C = 140 °C. Follow the 140 °C temperature difference horizontally until it intersects with wire size line on *Figure 9-117*. The free air rating for size 20 is 21.5 amps, and the free air rating for size 22 is 16.2 amps.

Step 2—Refer to the bundle derating curves in *Figure 9-118*. The 20 percent curve is selected since circuit analysis indicate that 20 percent or less of the wire in the harness would be carrying power currents and less than 20 percent of the bundle capacity would be used. Find 35 (on the horizontal axis), since there are 35 wires in the bundle, and determine a derating factor of 0.52 (on the vertical axis) from the 20 percent curve.

Step 3—Derate the size 22 free air rating by multiplying 16.2 by 0.52 to get 8.4 amps in harness rating. Derate the size 20 free air rating by multiplying 21.5 by 0.52 to get 11.2 amps in-harness rating.

Step 4—Refer to the altitude derating curve of *Figure 9-119*. Look for 35,000 feet (on the horizontal axis) since that is the altitude at which the aircraft is operating. Note that the wire must be derated by a factor of 0.86 (found on the vertical axis). Derate the size 22 harness rating by multiplying 8.4 amps by 0.86 to get 7.2 amps. Derate the size 20 harness rating by multiplying 11.2 amps by 0.86 to get 9.6 amps.

Step 5—To find the total harness capacity, multiply the total number of size 22 wires by the derated capacity (25 × 7.2 = 180.0 amps) and add to that the number of size 20 wires multiplied by the derated capacity (10 × 9.6 = 96.8 amps) and multiply the sum by the 20 percent harness capacity factor. Thus, the total harness capacity is (180.0 + 96.0) × 0.20 = 55.2 amps. It has been determined that the total harness

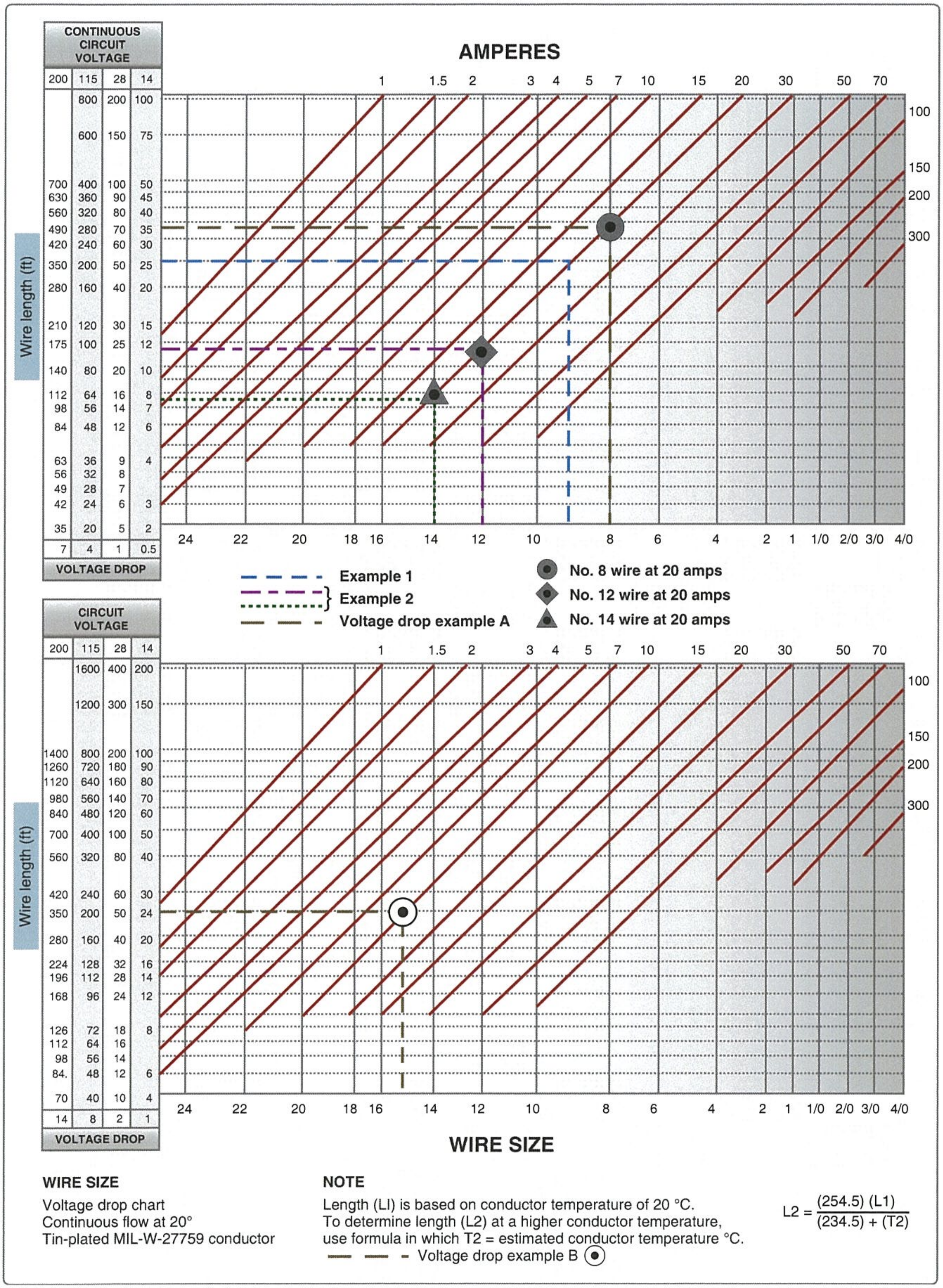


Figure 9-116. *Conductor chart, continuous (top) and intermittent flow (bottom).*

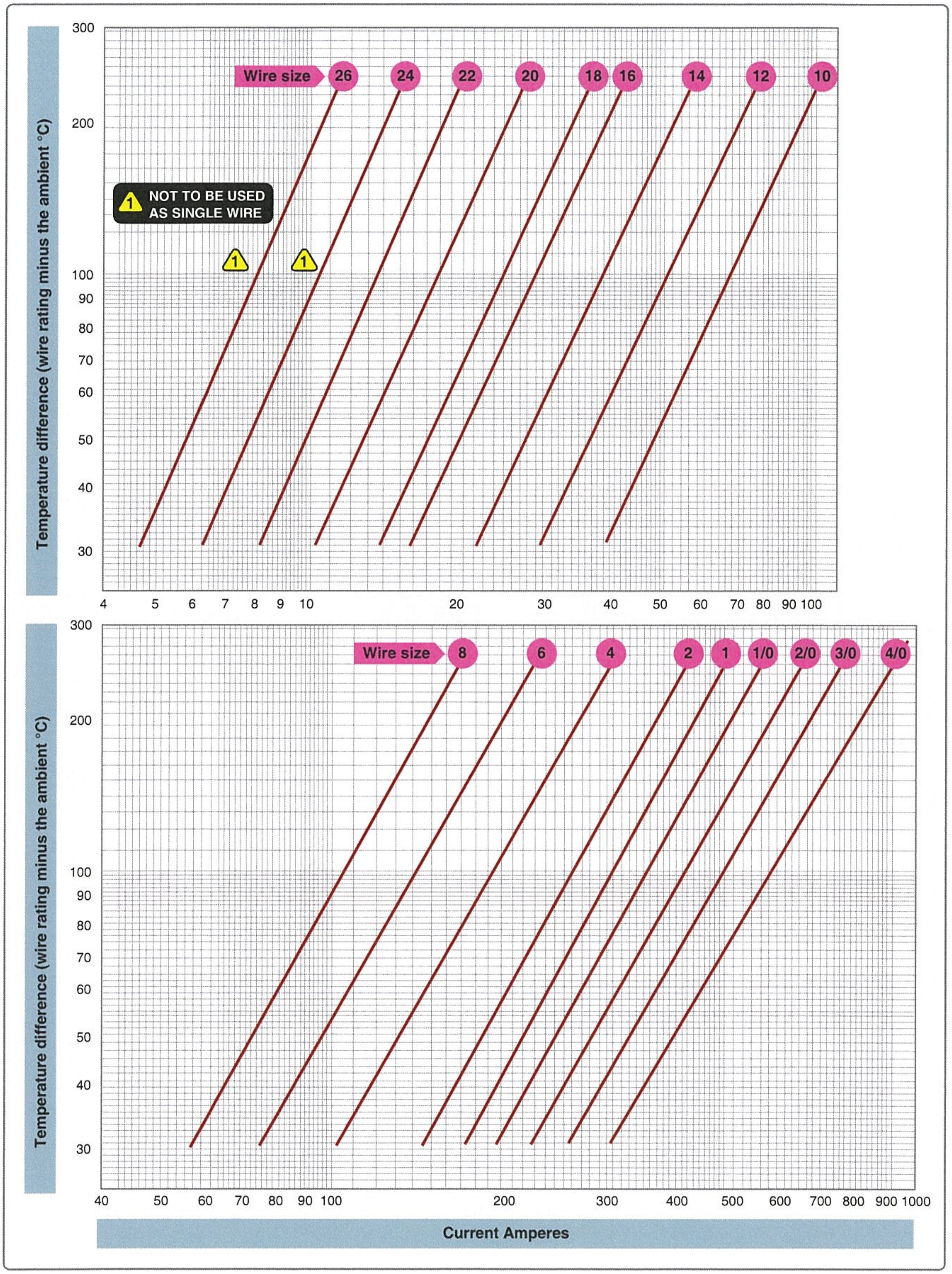


Figure 9-117. *Single copper wire in free air.*

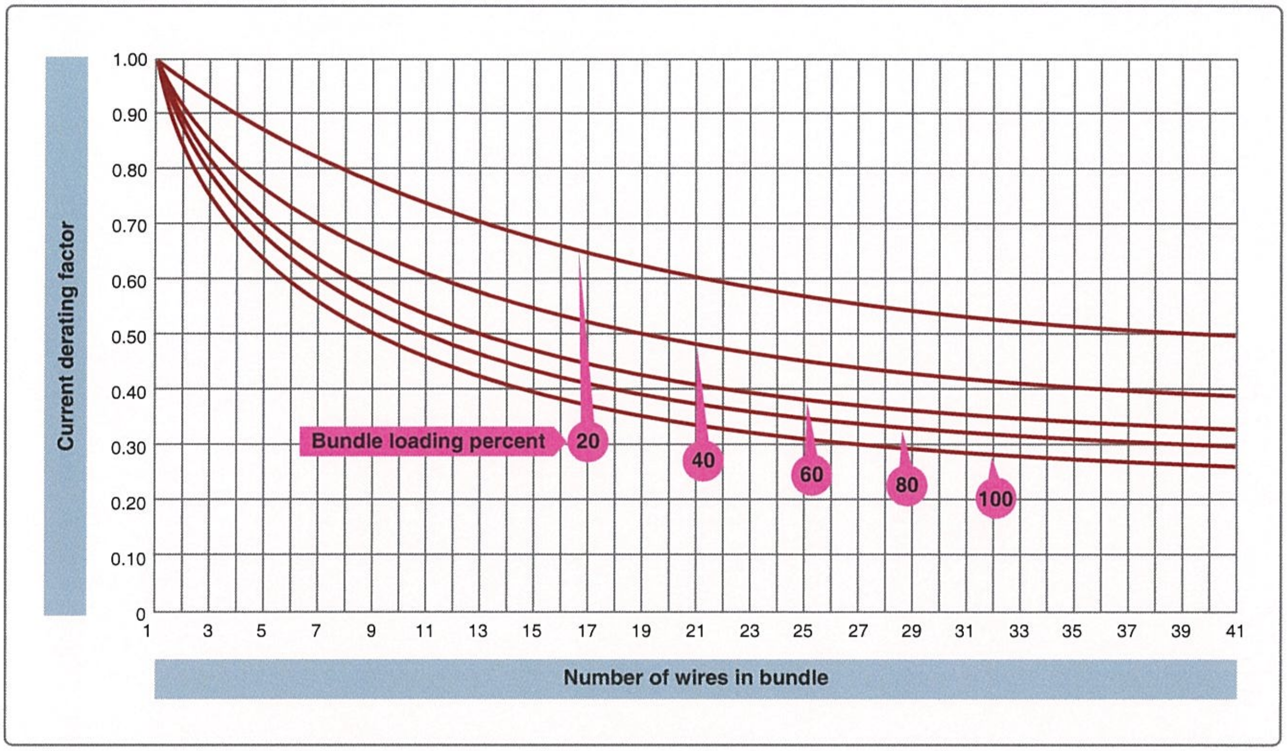


Figure 9-118. *Bundle derating curve.*

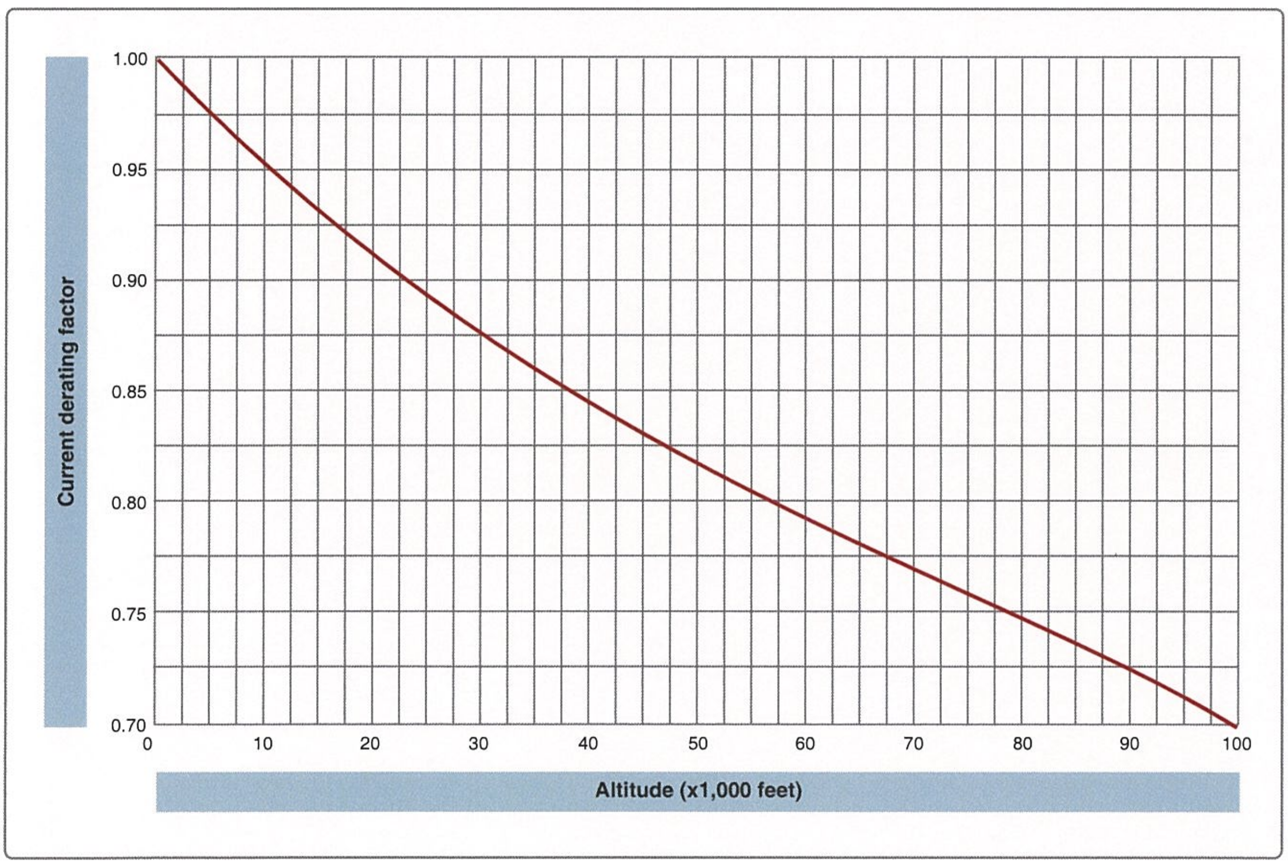


Figure 9-119. *Altitude derating curve.*

Voltage drop	Run lengths (feet)	Circuit current (amps)	Wire size from chart	Check calculated voltage drop (VD) = (resistance/feet) (length) (current)
1	107	20	No. 6	VD = (0.00044 ohms/feet) (107 x 20) = 0.942
0.5	90	20	No. 4	VD = (0.00028 ohms/feet) (90 x 20) = 0.504
4	88	20	No. 12	VD = (0.00202 ohms/feet) (88 x 20) = 3.60
7	100	20	No. 14	VD = (0.00306 ohms/feet) (100 x 20) = 6.12

Figure 9-122. *Determining required tin-plated copper wire size and checking voltage drop.*

Maximum Voltage drop	Wire size	Circuit current (amps)	Maximum wire run length (feet)	Check calculated voltage drop (VD) = (resistance/feet) (length) (current)
1	No. 10	20	39	VD = (0.00126 ohms/feet) (39 x 20) = 0.98
0.5	---		19.5	VD = (0.00126 ohms/feet) (19.5 x 20) = 0.366
4	---		156	VD = (0.00126 ohms/feet) (156 x 20) = 3.93
7	---		273	VD = (0.00126 ohms/feet) (273 x 20) = 6.88

Figure 9-123. *Determining maximum tin-plated copper wire length and checking voltage drop.*

The following formula can be used to check the voltage drop. The resistance/ft can be found in *Figures 9-122* and *9-123* for the wire size.

Calculated Voltage drop (VD) = resistance/ft × length × current

Electric Wire Chart Instructions

To select the correct size of electrical wire, two major requirements must be met:

1. The wire size should be sufficient to prevent an excessive voltage drop while carrying the required current over the required distance. *[Figure 9-121]*
2. The size should be sufficient to prevent overheating of the wire carrying the required current. (See Maximum Operating Temperature earlier in this chapter for computing current carrying capacity methods.)

To meet the two requirements for selecting the correct wire size using *Figure 9-116*, the following must be known:

1. The wire length in feet.
2. The number of amperes of current to be carried.
3. The allowable voltage drop permitted.
4. The required continuous or intermittent current.
5. The estimated or measured conductor temperature.
6. Is the wire to be installed in conduit and/or bundle?
7. Is the wire to be installed as a single wire in free air?

Example A.

Find the wire size in *Figure 9-116* using the following known information:

1. The wire run is 50 feet long, including the ground wire.
2. Current load is 20 amps.
3. The voltage source is 28 volts from bus to equipment.
4. The circuit has continuous operation.
5. Estimated conductor temperature is 20 °C or less. The scale on the left of the chart represents maximum wire length in feet to prevent an excessive voltage drop for a specified voltage source system (e.g., 14V, 28V, 115V, 200V). This voltage is identified at the top of scale and the corresponding voltage drop limit for continuous operation at the bottom. The scale (slant lines) on top of the chart represents amperes. The scale at the bottom of the chart represents wire gauge.

Step 1—From the left scale, find the wire length 50 feet under the 28V source column.

Step 2—Follow the corresponding horizontal line to the right until it intersects the slanted line for the 20-amp load.

Step 3—At this point, drop vertically to the bottom of the chart. The value falls between No. 8 and No. 10. Select the next larger size wire to the right, in this case No. 8. This is the smallest size wire that can be used without exceeding the voltage drop limit expressed at the bottom of the left scale. This example is plotted on the wire chart in *Figure 9-116*. Use *Figure 9-116 (top)* for continuous flow and *Figure 9-116 (bottom)* for intermittent flow.

Example B.

Find the wire size in *Figure 9-116* using the following known information:

1. The wire run is 200 feet long, including the ground wire.

2. Current load is 10 amps.
3. The voltage source is 115 volts from bus to equipment.
4. The circuit has intermittent operation.

Step 1—From the left scale, find the wire length of 200 feet under the 115V source column.

Step 2—Follow the corresponding horizontal line to the right until it intersects the slanted line for the 10 amp load.

Step 3—At this point, drop vertically to the bottom of the chart. The value falls between No. 16 and No. 14. Select the next larger size wire to the right—in this case, No. 14. This is the smallest size wire that can be used without exceeding the voltage drop limit expressed at the bottom of the left scale.

Wire Identification

The proper identification of electrical wires and cables with their circuits and voltages is necessary to provide safety of operation, safety to maintenance personnel, and ease of maintenance. All wire used on aircraft must have its type identification imprinted along its length. It is common practice to follow this part number with the five digit/letter Commercial and Government Entity (CAGE) code identifying the wire manufacturer. You can identify the performance capabilities of existing installed wire you need to replace, and avoid the inadvertent use of a lower performance and unsuitable replacement wire.

Placement of Identification Markings

Identification markings should be placed at each end of the wire and at 15-inch maximum intervals along the length of the wire. Wires less than 3 inches in length need not be identified. Wires 3 to 7 inches in length should be identified approximately at the center. Added identification marker sleeves should be located so that ties, clamps, or supporting devices need not be removed to read the identification. The wire identification code must be printed to read horizontally (from left to right) or vertically (from top to bottom). The two methods of marking wire or cable are as follows:

1. Direct marking is accomplished by printing the cable's outer covering. *[Figure 9-124B]*
2. Indirect marking is accomplished by printing a heat-shrinkable sleeve and installing the printed sleeve on the wire or cables outer covering. Indirectly-marked wire or cable should be identified with printed sleeves at each end and at intervals not longer than 6 feet. *[Figure 9-125]* The individual wires inside a cable should be identified within 3 inches of their termination. *[Figure 9-124A]*

Types of Wire Markings

The preferred method is to mark directly on the wire without causing insulation degradation. Teflon-coated wires, shielded wiring, multiconductor cable, and thermocouple wires usually require special sleeves to carry identification marks. There are some special wire marking machines available that can be used to stamp directly on the type wires mentioned above. Whatever method of marking is used, the marking should be legible and the color should contrast with the wire insulation or sleeve.

Several different methods can be used to mark directly on the wire: hot stamp marking, ink jet printers, and laser jet printers. *[Figure 9-126]* The hot stamp method can damage the insulation of a newer type of wire that utilizes thin

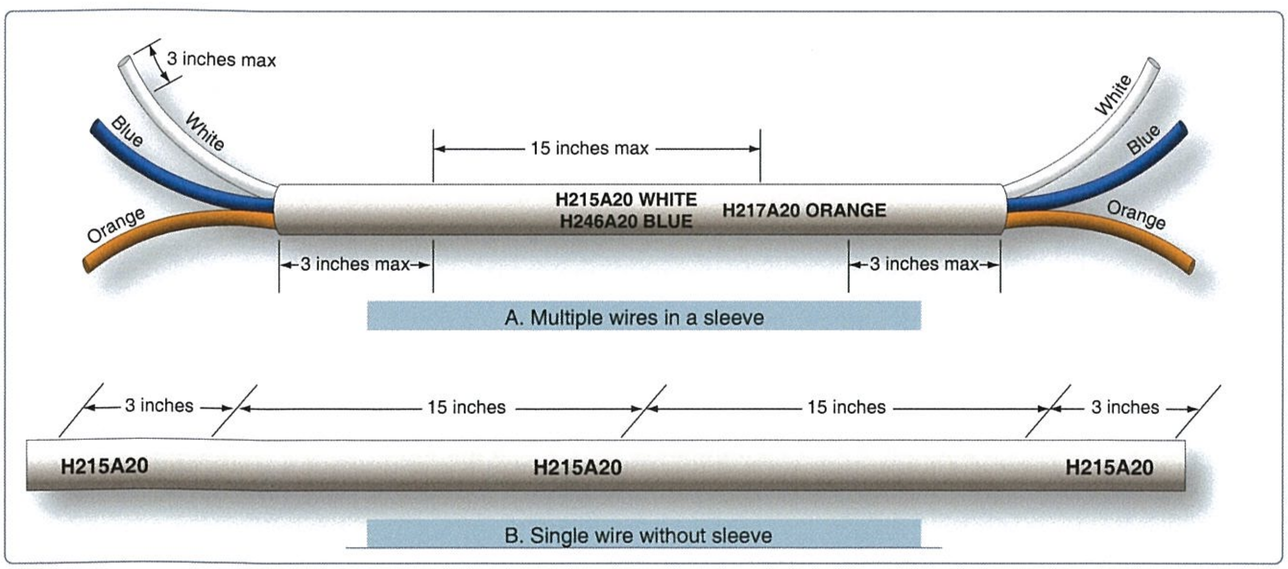


Figure 9-124. *Wire markings for single wire without sleeve.*

Name:______________________________ Session:______________________________

Aircraft Wiring Worksheet 3

- Using the charts in the text, calculate three things:
  - Maximum total harness current capacity:_________________________
  - Individual wire current capacity for the #20 AWG in the harness:_______________________
  - Individual wire current capacity for the #22 AWG in the harness:_______________________

  Assume a harness (open or braided) consisting of 10 wires, size 20, 200 °C rated copper, and 25 wires size 22, 200 °C rated copper, is installed in an area where the ambient temperature is 60 °C and the aircraft is capable of operating at a 35,000 foot altitude. Circuit analysis reveals that 7 of the 35 wires in the bundle (7/35 = 20 percent) are carrying power currents near or up to capacity.
- Using the charts in the text, calculate three things:
  - Maximum total harness current capacity:_________________________
  - Individual wire current capacity for the #20 AWG in the harness:_______________________
  - Individual wire current capacity for the #22 AWG in the harness:_______________________

  Assume a harness (open or braided) consisting of 12 wires, size 20, 200 °C rated copper, and 28 wires size 22, 200 °C rated copper, is installed in an area where the ambient temperature is 50 °C and the aircraft is capable of operating at a 40,000 foot altitude. Circuit analysis reveals that 12 of the 40 wires in the bundle (12/40 = 30 percent) are carrying power currents near or up to capacity.