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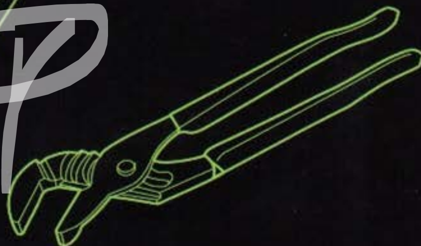
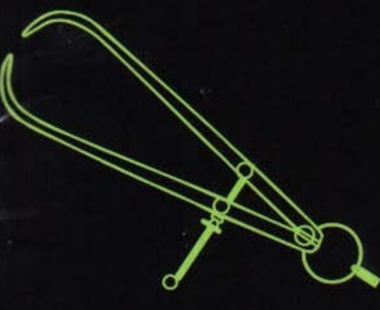
THE Aviation STANDARD

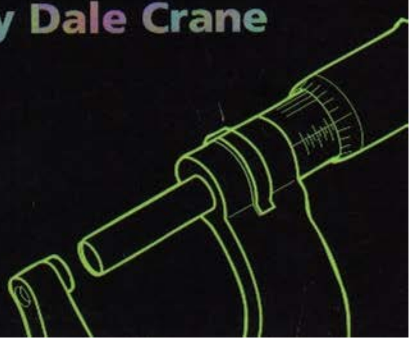


Aviation Mechanic Handbook

Fifth Edition

by Dale Crane





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Aviation Mechanic Handbook

Fifth Edition
by Dale Crane

Aviation Supplies & Academics, Inc.
Newcastle, Washington

Contents

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Section 1: General Information

1.1 Fraction, Decimal, and Metric Equivalents

Fraction	Decimal	MM	Fraction	Decimal	MM
1/64	0.0156	0.397	33/64	0.5156	13.097
1/32	0.0313	0.794	17/32	0.5313	13.494
3/64	0.0469	1.191	35/64	0.5469	13.891
1/16	0.0625	1.588	9/16	0.5625	14.287
5/64	0.0781	1.984	37/64	0.5781	14.684
3/32	0.0938	2.381	19/32	0.5938	15.081
7/64	0.1094	2.n8	39/64	0.6094	15.478
1/8	**0.1250**	**3.175**	**5/8**	**0.6250**	**15.875**
9/64	0.1406	3.572	41/64	0.6406	16.272
5/32	0.1563	3.969	21/32	0.6563	16.669
11/64	0.1719	4.366	43/64	0.6719	17.066
3/16	0.1875	4.762	11/16	0.6875	17.463
13/64	0.2031	5.159	45/64	0.7031	17.860
7/32	0.2188	5.556	23/32	0.7188	18.256
15/64	0.2344	5.953	47/64	0.7344	18.653
1/4	**0.2500**	**6.350**	**3/4**	**0.7500**	**19.049**
17/64	0.2656	6.747	49/64	0.7656	19.447
9/32	0.2813	7.144	25/32	0.7813	19.844
19/64	0.2969	7.541	51/64	0.7968	20.239
5/16	0.3125	7.937	13/16	0.8125	20.638
21/64	0.3281	8.334	53/64	0.8281	21.034
11/32	0.3438	8.731	27/32	0.8438	21.431
23/64	0.3594	9.128	55/64	0.8594	21.828
3/8	**0.3750**	**9.525**	**7/8**	**0.8750**	**22.225**
25/64	0.3906	9.922	57/64	0.8906	22.622
13/32	0.4063	10.319	29/32	0.9063	23.018
27/64	0.4219	10.716	59/64	0.9219	23.416
7/16	0.4375	11.112	15/16	0.9375	23.812
29/64	0.4531	11.509	61/64	0.9531	24.209
15/32	0.4688	11.906	31/32	0.9688	24.606
31/64	0.4844	12.303	63/64	0.9844	25.003
1/2	**0.5000**	**12.700**	1	1.0000	**25.400**

1.2 Conversions

Multiply	By	To Get
acres	43,560	square feet
acres	4,047	square meters
acre feet	3.259×10^5	gallons
amperes/ sq. cm	6452	amperes/ sq. inch
amperes/ sq. inch	0.1550	amperes/ sq. cm.
ampere hours	3,600	coulombs
ampere hours	0.03731	faradays
ampere turns	1.257	gilberts
ampere turns / cm	2.540	ampere turns / Inch
ampere turns/ cm	1.257	gllberts / cm.
ampere turns /inch	0.4950	gllberts / centimeter
ampere turns/ meter	0.01257	gllberts / centimeter
atmospheres	76.0	centimeters of mercury
atmospheres	33.9	feet of water
atmospheres	29.92	inches of mercury
atmospheres	10,332	kilograms/ sq. meter
atmospheres	14.69	pounds/ sq. Inch
barrels of oil	42	gallons
bars	0.9869	atmospheres
bars	106	dynes / sq. centimeter
bars	14.50	pounds/sq.Inch
Btu	1.0550×10^{10}	ergs
Btu	ns.3	foot-pounds
Btu	252.0	gram-calories
Btu	1,054.8	joules
Btu	107.5	kilogram-meters
Btu	2.928 x ,0	kilowatt-hours
Btu/ hour	0.2162	foot-pounds/ second
Btu/ hour	3.929 x 10	horsepower-hours
Btu I hour	0.2931	watts
Btu/ minute	12.96	foot-pounds/ second
Btu/ minute	0.02356	horsepower
Btu/ minute	17.57	watts
bushels	1.2445	cubic feet
bushels	2,150.4	cubic inches
bushels	35.24	liters
bushels	4	pecks
bushels	64	pints (dry)

Multlply	By	To Get
centimeters	3.281 x 10^{-2}	feet
centimeters	0.3937	inches
centimeter-dynes	1.020 x 10^{-3}	centimeter-grams
centimeter-dynes	7.376 x 10^{-a}	pound-feet
centimeter-grams	980.7	centimeter-dynes
centimeter-grams	7.233 x 10^{-5}	pound-feet
cm of mercury	0.01316	atmospheres
cm of mercury	0.4461	feet of water
cm of mercury	136.0	kilOgrams / sq. meter
cm of mercury	27.85	pounds / sq. foot
cm of mercury	0.1934	pounds / sq. inch
cm / second	1.9685	feet / minute
cm/ second	0.03281	feet/ second
cm / second	**0.036**	kilometers/ hour
cm/ second	0.0194	knots
cm/ second/ second	0.03281	feet/ second / second
cm/ second/ second	0.02237	miles/ hour/ second
circular mils	5.067 x 10^{-6}	square centimeters
circular mils	0.7854	square mils
circular mils	7.854 x 10^{-7}	square inches
coulombs	1.036 x 10^{-5}	faradays
cubic centimeters	3.531 x 10^{-5}	cubic feet
cubic centimeters	0.06102	cubic inches
cubic centimeters	10^{-o}	cubic meters
cubic centimeters	1.308 x 10^{s}	cubic yards
cubic centimeters	2.642 x 10" '	gallons (U.S.)
cubic centimeters	0.001	liters
cubic centimeters	2.113 x 10^{-3}	pints (U.S.)
cubic feet	0.8036	bushels
cubic feet	28,320	cubic centimeters
cubic feet	1,728	cubic inches
cubic feet	0.02832	cubic meters
cubic feet	7.48052	gallons (U.S.)
cubic feet	28.32	liters
cubic feet/ minute	0.1247	gallons/ second
cubic feet/ minute	0.4720	liters/ second
cubic feet/ second	448.831	gallons/ minute
cubic inches	16.39	cubic centimeters
cubic inches	5.787 x 10	cubic feet
cubic inches	1.639 x 10^{-5}	cubic meters
cubic inches	2.143 x 10^{-5}	cubic yards
cubic inches	4.329 x 10^{-3}	gallons (U.S.)

Multiply	By	To Get
cubic Inches	0.01639	liters
cubic meters	28.38	bushels
cubic meters	35.31	cubic feet
cubic meters	61,023	cubic inches
cubic meters	1.308	cubic yards
cubic meters	264.2	gallons (U.S.)
cubic yards	27	cubic feet
cubic yards	46,656	cubic inches
cubic yards	0.7646	cubic meters
cubic yards	202	gallons (U.S.)
cubic yards	764.6	liters
cubic yards/ minute	3.367	gallons / second
cubic yards/ minute	12.74	liters/ second
days	24	hours
days	1,440	mlnu1es
days	86,400	seconds
degrees (angular)	60	minutes
degrees (angular)	0.01111	quadrants
degrees (angular)	0.01745	radians
degrees (angular)	3,600	seconds
degrees/ second	0.01745	radians/ second
degrees / second	0.1667	revolutions I minute
degrees/ seoond	2.ns x 1o3	revolutions/ second
drams	1.n1s	grams
drams	0.0625	ounces
dynes	1.020 x 10-3	grams
dynes	10-7	Joules / centimeter
dynes	10-5	Joules/ meter (newtons)
dynes	7.233 X 10^{-5}	poundals
dynes	2.248 x 10^{-6}	pounds
dynes / sq. centimeter	10^{-6}	bars
ergs	9.480 x 10-11	Btu
ergs	1.0	dyne-centimeters
ergs	7.367 x 10^{-8}	foot-pounds
ergs	0.2389 x 10-7	gram-calories
ergs	3.7250 x 10-1	horsepower-hours
ergs	10-7	joules
ergs	o.2ns x 10-13	kilowatt-hours
ergs/ second	5.688 x 10-9	Btu/ minute

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Multiply	By	To Get
ergs / second	1.341×10^{-10}	horsepower
ergs / second	10^{-10}	kilowatts
faradays	26.8	ampere-hours
faradays	9.649×10^{4}	coulombs
fathoms	6	feet
feet	30.48	centimeters
feet	0.3048	meters
feet	$1.645 \times 10^{[illegible]}$	miles (nautical)
feet	$1.894 \times 10^{[illegible]}$	miles (statute)
feet of water	0.02950	atmospheres
feet of water	0.8826	inches of mercury
feet of water	62.43	pounds / square foot
feet / minute	0.5080	centimeters / second
feet / minute	0.01667	feet / second
feet / second	1.097	kilometers / hour
feet / second	0.5921	knots
feet / second	0.6818	miles / hour
feet / second / second	0.6818	miles / hour / second
foot-pounds	1.286×10^{-3}	Btu
foot-pounds	1.356	joules
foot-pounds	$3.24 \times 10^{[illegible]}$	kilogram-calories
foot-pounds	0.1383	kilogram-meters
foot-pounds / minute	3.030×10^{-5}	horsepower
foot-pounds / minute	2.260×10^{-5}	kilowatts
furlongs	660	feet
gallons	3,785	cubic centimeters
gallons	0.1337	cubic feet
gallons	231	cubic inches
gallons	3.785	liters
gallons (Imperial)	1.20095	gallons (U.S.)
gallons (U.S.)	0.83267	gallons (Imperial)
gallons / minute	2.228×10^{-3}	cubic feet / second
gausses	6.452	lines of flux / sq. inch
gausses	10^{-8}	webers / sq. centimeter
gilberts	0.7958	ampere-turns
gilberts / centimeter	2.021	ampere-turns / inch
gills	0.1183	liters
grains (troy)	0.06480	grams
grains (troy)	2.0833×10^{-3}	ounces (avoir.)
grams	980.7	dynes

Multiply	By	To Get
grams	9.807×10^{-5}	joules/ centimeter
grams	0.03527	ounces (avolr.)
grams	0.07093	poundals
grams	2.205×10^{-3}	pounds
grams/ cubic cm	62.43	pounds/ cubic foot
grams/ square cm	2.0481	pounds/ square foot
gram-calories	3.9683×10^{-3}	Btu
gram-calories	4.1868×10^{7}	ergs
gram-calories	3.0880	foot-pounds
gram-calories	1.1630×10	kilowatt-hours
gram-centimeters	9.297×10^{-5}	Btu
gram-centimeters	980.7	ergs
gram-centimeters	9.807×10^{-5}	joules
hectares	2.471	acres
horsepower	42.44	Btu / minute
horsepower	33.000	foot-pounds / minute
horsepower	550	foot-pounds/ second
horsepower (metric)	542.5	foot-pounds / second
horsepower (metric)	0.9863	horsepower
horsepower	10.68	kilogram-calories / min.
horsepower	745.7	watts
hours	3,600	seconds
Inches	2.540	centimeters
Inches	8.333×10^{-2}	feet
inches	2.540×10^{-2}	meters
inches	25.40	millimeters
Inches	1,000	mils
inches of mercury	3.342×10^{-2}	atmospheres
inches of mercury	1.133	feet of water
Inches of mercury	345.3	kilograms / sq. meter
inches of mercury	0.4912	pounds / sq. inch
Inches of mercury	33.864	millibars
inches of water	7.355×10^{-2}	Inches of mercury
Inches of water	3.613×10^{-2}	pounds / sq. Inch
Joules	9.480×10	Btu
Joules	10^{7}	ergs
Joules	0.7376	foot-pounds
joules	2.389×10	kilogram-calories
Joules	0.1020	kilogram-meters

Multiply	By	To Get
joules	2.778×10^{-4}	watt-hours
joules/ centimeter	10^{7}	dynes
joules/ centimeter	723.3	poundals
joules / centimeter	22.48	pounds
kilograms	980,665	dynes
kilograms	9.807	joules/ meter (newtons)
kilograms	70.93	poundals
kilograms	2.205	pounds
kilograms	9.842×10^{4}	tons (long)
kilograms	1.102×10^{-3}	tons (short)
kilograms/ cubic meter	0.06243	pounds / cubic foot
kilograms / sq. meter	9.687×10^{-5}	atmospheres
kilograms/ sq. meter	0.2048	pounds/ square foot
kilogram-calories	3.968	Btu
kilogram-calories	3,088	foot-pounds
kilogram-calories	4,186	joules
kilogram-meters	9.294×10^{-3}	Btu
kllogram·meters	7.233	foot-pounds
kilometers	3,281	feet
kilometers	0.6214	miles
kilometers / hour	0.9113	feet/ second
kilometers/ hour	0.5396	knots
kilometers/ hour	0.6214	miles/ hour
kilowatts	56.92	Btu/ minute
kilowatts	4.426×10^{4}	foot-pounds / minute
kilowatts	1.341	horsepower
kilowatt-hours	3,413	Btu
kilowatt-hours	2.655×10^{6}	foot-pounds
kilowatt-hours	3.6×10^{6}	joules
knots	6,080	feet / hour
knots	1.8532	kilometers/ hour
knots	1.151	miles (statute)/ hour
knots	1.689	feet / second
leagues	3.0	miles
lines of flux/ sq. cm	1.0	gausses
lines of flux/ sq. inch	0.1550	gausses
lines of flux/ sq. inch	1.550×10^{-9}	webers / sq. centimeter
liters	1,000	cubic centimeters
liters	61.02	cubic inches
liters	0.2642	gallons (U.S.)
liters/ minute	5.886×10^{4}	cubic feet / second

Multiply	By	To Get
lumens / sq. foot	1.0	foot-candles
lux	0.0929	foot-candles
maxwells	$10^{\cdot a}$	webers
meters	3.281	feet
meters	39.37	inches
meters	5.396 x 10	miles (nautical)
meters	6.214 x 10°"	miles (statute)
meters	1.094	yards
meters / second	3.6	kilometers/ hour
meters / second	2.237	miles/ hour
meter-kllograms	9.807×10^{7}	centimeter-dynes
meter-kilograms	7.233	pound-feet
miles (nautical)	6,076.103	feet
miles (nautical)	1.852	kilometers
miles (nautical)	1.1508	miles (statute)
miles (statute)	5,280	feet
miles (statute)	1.609	kilometers
miles (statute)	0.8689	miles (nautical)
miles (statute)	1,760	yards
miles/ hour	1.467	feet/ second
miles/ hour	1.609	kilometers/ hour
miles/ hour	0.8684	knots
millimeters	3.281 x 10·3	feet
millimeters	0.03937	Inches
mils	$2.54 \times 10^{\cdot 3}$	centimeters
mils	0.001	inches
minutes (angular)	0.01667	degrees
minutes (angular)	1.852 x 10'''	quadrants
minutes (angular)	$2.909 \times 10^{..c}$	radians
ounces	16.0	drams
ounces	437.5	grains
ounces	28.3495	grams
ounces	0.0625	pounds
ounces (fluid)	1.805	cubic inches
ounces (fluid)	0.02957	liters
ounces (troy)	1.09714	ounces (avoir.)
pint (dry)	33.60	cubic inches
pint (liquid)	0.4732	liters
poundals	13,826	dynes
poundals	14.10	grams

Multiply	By	To Get
poundals	0.1383	joules/ meter (newtons)
poundals	0.01410	kilograms
poundals	0.03108	pounds
pounds	453.5924	grams
pounds	4.448	joules/ meter (newtons)
pounds	0.4536	kilograms
pounds	16	ounces
pounds	32.17	poundals
pounds	0.0005	tons (short)
pounds of water	0.1198	gallons
pounds/ cubic foot	16.02	kilograms/ cubic meter
pounds/ cubic inch	27.68	grams/ cubic centimeter
pounds/ square inch	0.06804	atmospheres
pounds/ square inch	2.307	feet of water
pounds/ square inch	2.036	inches of mercury
quadrants (angular)	90	degrees
quadrants (angular)	5,400	minu1es
quadrants (angular)	1.571	radians
quarts (liquid)	57.75	cubic inches
quarts (liquid)	0.9463	liters
radians	57.30	degrees
radians	3,438	minutes
radians	0.6366	quadrants
radians/ second	9.549	revolutions/ minute
revolutions/ minute	6.0	degrees/ second
revolutions / minute	0.1047	radians/ second
rods	16.5	feet
square centimeters	1.973×10^5	circular mils
square centimeters	0.1550	square inches
square Inches	1.273×10^6	circular mils
square Inches	6.452	square centimeters
square meters	10.76	square feet
square meters	1.196	square yards
square miles	640	acres
square millimeters	1,973	circular mils
square mils	1.273	circular mils
tons (long)	1,016	kilograms
tons (long)	2,240	pounds
tons (metric)	1,000	kilograms
tons (metric)	2,205	pounds

Multiply	By	To Get
tons (short)	907.185	kilograms
tons (short)	2,000	pounds
watts	3.413	Btu/ hour
watts	10^7	ergs/ second
watts	4427	foot-pounds I minute
watts	1.341 x 10^{-3}	horsepower
watt-hours	3.413	Btu
watt-hours	2,656	loot-pounds
watt-hours	367.2	kilogram-meters
webers	10^8	maxwells
webers /sq.inch	1.55 x 10^7	gausses
yards	36	Inches
yards	0.9144	meters

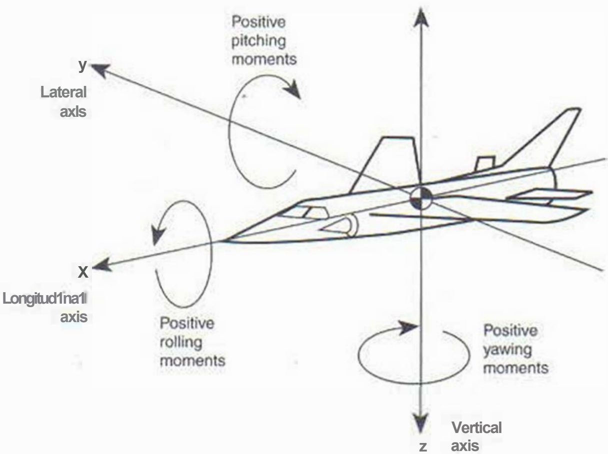
Notes

1.3 Aircraft Nomenclature

I

Axes of an Airplane

An airplane in flight is free to rotate about three axes: horizontal, longitudinal and vertical. Each axis is perpendicular to the others and each passes through the center of gravity.

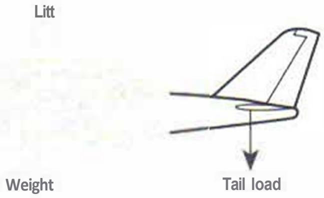


The three axes of an aircraft are mutually perpendicular, and all pass through the center of gravity of the aircraft.

Forces Acting on an Aircraft in Flight

In straight-and-level, unaccelerated flight the forces about the aircraft center of gravity are balanced. Lift acts upward and is opposed by weight and the aerodynamic tail load which act downward. Thrust acting forward is opposed by drag which acts rearward.

In straight-and-level, unaccelerated flight the forces about the center of gravity are balanced.



~~In straight-and-level, unacce~~lerated flight the forces about the center of gravity are balanced.

Types of Aircraft Structure

Tn,ss

A type of structure made up of longitudinal beams and cross braces. Compression loads between the main beams are carried by rigid cross braces called compression struts. Tension loads are carried by stays, or wires, that go from one main beam to the other and cross between the compression struts.

Most fabric-covered wings are constructed with a Pratt truss. The spars are the main beams and the cross braces are the compression struts or compression ribs. The stays are the drag and antldrag wires. The drag wires run from the front spar Inboard to the rear spar outboard, and oppose the drag forces that try to move the wing tips backward. The antldrag wires run from the rear spar inboard to the front spar outboard. They oppose the aerodynamic forces that try to move the wing tips forward.

The Warren truss Is used for the fuselage of most steel tube and fabric aircraft. The main beams are the longerons and the cross braces are steel tube diagonals which carry both compression and tension loads.

Monocoque

A single-shell that carries all of the flight loads in its outer surface. A chicken egg is a perfect example of a nalural monocoque structure.

Metal monocoque aircraft fuselages have a minimum of internal structure, usually with Just formers to provide the shape. Thin sheets of metal (called skins) riveted to the formers provide a rigid, strong, streamlined structure. Dents in the skins destroy the Integrity of a monocoque structure.

Wooden monocoque aircraft structures are similar to those of metal. Thin sheets of aircraft plywood are glued to the formers to provide a strong, lightweight structure.

Modern composite structures are made of resins reinforced with special fabrics and formed in molds or over patterns; these provide a shell sufficiently strong to carry all the flight loads.

Semimonocoque

Most larger metal aircraft have a semimonocoque structure. This differs from the monocoque by having a series of longerons and stringers between the formers to support the skins and provide additional strength.

1.4 ATA-100 System of Identification

System	Sub-system	Title
21		**Air Conditioning**
	00	General
	10	Compression
	20	Distribution
	30	Pressurization Control
	40	Heating
	50	Cooling
	60	Temperature Control
	70	Moisture/Air Contaminant Control
22		**Auto Flight**
	00	General
	10	Auto Pilot
	20	Speed/Attitude Correction
	30	Auto Throttle
	40	System Monitor
23		**Communications**
	00	General
	10	HF
	20	VHF/UHF
	30	Passenger Addressing and Entertainment
	40	Interphone
	50	Audio Integrating
	60	Static Discharging
	70	Audio & Video Monitoring
24		**Electrlal Power**
	00	General
	10	Generator Drive
	20	AC Generation
	30	DC Generation
	40	External Power
	50	Elect. Load Distribution

System	Sub-system	Title
25		**Equipment and Furnishings**
	00	General
	10	Flight Compartment
	20	Passenger Compartment
	30	BuffeVGalley
	40	Lavatories
	50	Cargo Compartment
	60	Emergency
	70	Accessory Compartments
26		**Fire Protection**
	00	General
	10	Detection
	20	Extinguishing
	30	Explosion Suppression
27		Flight Controls
	00	General
	10	Alieron & Tab
	20	Audder/Auddervator & Tab
	30	Elevator & Tab
	40	Horiz. Stablllzer/Stabllator
	50	Flaps
	60	Spoilers, Drag Devices & Variable Aerodynamic Fairings
	70	Gust Lock & Dampener
	80	Lift Augmenting
28		**Fuel**
	00	General
	10	Storage
	20	Distribution/Drain Valves
	30	Dump
	40	Indicating

System	Sub-system	Title
29		**Hydraulic Power**
	00	General
	10	Main
	20	Auxiliary
	30	Indicating
30		**Ice and Rain Protection**
	00	General
	10	Airfoil
	20	Air Intakes
	30	Pilot & Static
	40	Windows & Windshields
	50	Antennas & Aadomes
	60	Propellers & Rotor
	70	Waterlines
	80	Detection
31		**Indicating/Recording Systems**
	00	General
	10	Unassigned
	20	Unassigned
	30	Recorders
	40	Central Computers
	50	Central Warning System
32		**Landing Gear**
	00	General
	10	Main Gear
	20	Nose Gear/fall Gear
	30	Extension & Retraction, Level Switch
	40	Wheels & Brakes
	50	Steering
	60	Position, Warning & Ground Safety Switch
	70	Supplementary Gear/Skis, Floats

System	Sub-system	Title
33		**Lights**
	00	General
	10	Flight Compartment & Annunciator Panel
	20	Passenger Compartments
	30	Cargo & Service Compartment
	40	Exterior Lighting
	50	Emergency Lighting
34		**Navigation**
	00	General
	10	Flight Environment Data
	20	Attitude & Direction
	30	Landing & Taxi Aids
	40	Independent Position Determining
	50	Dependent Position Determining
	60	Position Computing
35		**Oxygen**
	00	General
	10	Crew
	20	Passenger
	30	Portable
36		**Pneumatic**
	00	General
	10	Distribution
	20	Indicating
37		**Vacuum/Pressure**
	00	General
	10	Distribution
	20	Indicating

System	Sub-system	Title
38		**Water/Waste**
	00	General
	10	Potable
	20	Wash
	30	Waste Disposal
	40	Air Supply
39		**Electrical/Electronic Panels and Multi-Purpose Components**
	00	General
	10	Instrument & Control Panels
	20	Electrical & Electronic Equipment Racks
	30	Electrical & Electronic Junction Boxes
	40	Multipurpose Electronic Components
	50	Integrated Circuits
	60	Printed Circuit Card Assemblies
49		**Airborne Auxiliary Power**
	00	General
	10	Power Plant
	20	Engine
	30	Engine Fuel & Control
	40	Ignition/Starting
	50	Air
	60	Engine Controls
	70	Indicating
	80	Exhaust
	90	Oil
51		**Structures**
	00	General

System	Sub-system	Title
52		**Doors**
	00	General
	10	Passenger/Crew
	20	Emergency Exit
	30	Cargo
	40	Service
	50	Fixed Interior
	60	Entrance Stairs
	70	Door Warning
	80	Landing Gear
53		**Fuselage**
	00	General
	10	Main Frame
	20	Auxiliary Structure
	30	Plates/Skin
	40	Attach Fittings
	50	Aerodynamic Fairings
54		**Nacelles/Pylons**
	00	General
	10	Main Frame
	20	Auxiliary Structure
	30	Plates/Skin
	40	Attach Fittings
	50	Fillets/Fairings
55		**Stabilizers**
	00	General
	10	Horizontal Stabilizer/ Stabilator
	20	Elevator/Elevon
	30	Vertical Stabilizer
	40	Rudder/Ruddervator
	50	Attach Fittings

System	Sub-system	Title
56		**Windows**
	00	General
	10	Flight Compartment
	20	Cabin
	30	Door
	40	Inspection & Observation
57		**Wings**
	00	General
	10	Main Frame
	20	Auxiliary Structure
	30	Plates/Skin
	40	Attach Fittings
	50	Flight Surfaces
61		**Propellers**
	00	General
	10	Propeller Assembly
	20	Controlling
	30	Braking
	40	Indicating
65		**Rotors**
	00	General
	10	Main Rotor
	20	Anti-torque Rotor Assembly
	30	Accessory Driving
	40	Controlling
	50	Braking
	60	Indicating
71		**Powerplant**
	00	General
	10	Cowling
	20	Mounts
	30	Fireseals & Shrouds
	40	Attach Fittings
	50	Electrical Harness
	60	Engine Air Intakes
	70	Engine Drains

System	Sub-system	Title
72 (T)		**Engine Turbine/Turboprop**
	00	General
	10	Reduction Gear & Shaft Section
	20	Air Inlet Section
	30	Compressor Section
	40	Combustion Section
	50	Turbine Section
	60	Accessory Drives
	70	By-pass Section
72 (R)		**Engine Reciprocating**
	00	General
	10	Front Section
	20	Power Section
	30	Cylinder Section
	40	Supercharger Section
	50	Lubrication
73		**Engine Fuel and Control**
	00	General
	10	Distribution
	20	Controlling/Governing
	30	Indicating
74		**Ignition**
	00	General
	10	Electrical Power Supply
	20	Distribution
	30	Switching
75		**Bleed Air**
	00	General
	10	Engine Anti-Icing
	20	Engine Cooling
	30	Compressor Control
	40	Indicating

System	Sub-system	Title
76		**Engine Controls**
	00	General
	10	Power Control
	20	Emergency Shutdown
77		**Engine Indicating**
	00	General
	10	Power
	20	Temperature
	30	Analyzers
78		**Engine Exhaust**
	00	General
	10	Collector/Nozzle
	20	Noise Suppressor
	30	Thrust Reverser
	40	Supplementary Air
79		**Engine Oil**
	00	General
	10	Storage (Dry Sump)
	20	Distribution
	30	Indicating

System	Sub-system	Title
80		**Starting**
	00	General
	10	Cranking
81		**Turbines (Reciprocating Engines)**
	00	General
	10	Power Recovery
	20	Turbo-supercharger
82		**Water Injection**
	00	General
	10	Storage
	20	Distribution
	30	Dumping & Purging
	40	Indicating
83		**Remote Gear Boxes (Engine Driven)**
	00	General
	10	Drive Shaft Section
	20	Gearbox Section

1.5 Aircraft Nationality Identification

Mark	Country
AP	Pakistan
A2	Botswana
A3	Tonga
A40	Oman
AS	Bhutan
A6	United Arab Emirates
A7	Qatar
A9C	Bahrain
8	China
C, CF	Canada
CC	Chile
CN	Morocco
CP	Bolivia
CR. CS	Portugal
CU	Cuba
CX	Uruguay
C2	Nauru
CS	Gambia
C6	Bahamas
C9	Mozambique
D	Germany
CQ	Fiji
02	Angola
04	Cape Verde
EC	Spain
EI, EJ	Ireland
EK	Armenia
EL	Liberia
EP	Iran, Islamic Republic of
ER	Republic of Moldova
ES	Estonia
ET	Ethiopia
EW	Belarus
EX	Kyrgyzstan
EV	Tajikistan
EZ	Turkmenistan
E3	Eritrea
F	France
G	United Kingdom

Mark	Country
HA	Hungary
HB plus national emblem	Switzerland
HB plus national emblem	Liechtenstein
HC	Ecuador
HH	Haiti
HI	Dominican Republic
HK	Colombia
HL	Republic of Korea
HP	Panama
HA	Honduras
HS	Thailand
HZ	Saudi Arabia
H4	Solomon Islands
I	Italy
JA	Japan
JU	Mongolia
JV	Jordan
J2	Djibouti
J3	Grenada
JS	Guinea-Bissau
J6	Saint Lucia
J7	Dominica
JS	Saint Vincent and the Grenadines
LN	Norway
LQ, LV	Argentina
LX	Luxembourg
LV	Lithuania
LZ	Bulgaria
N	United States
0 8	Peru
0 0	Lebanon
OE	Austria
OH	Finland
OK	Czech Republic

(continued)

Mark	Country
OM	Slovakia
0 0	Belgium
OY	Denmark
P	Democratic People's Republic of Korea
PH	Netherlands
PJ	Netherlands Antilles
PK	Indonesia
PP.PR, PT, PU	Brazil
PZ	Suriname
P2	Papua New Guinea
P4	Aruba (Netherlands)
RA	Russian Federation
RDPL	Lao People's Democratic Republic
RP	Philippines
SE	Sweden
SP	Poland
ST	Sudan
SU	Egypt
SX	Greece
S2	Bangladesh
S5	Slovenia
S7	Seychelles
S9	Sao Tome and Principe
TC	Turkey
TF	Iceland
TG	Guatemala
TI	Costa Alea
TJ	Cameroon
TL	Central African Republic
TN	Congo
TR	Gabon
TS	Tunisia
T I	Chad
TU	Cote d'Ivoire
TY	Benin
TZ	Mall
T7	San Marino

Mark	Country
T9	Bosnia and Herzegovina
UK	Uzbekistan
UN	Kazakhstan
UR	Ukraine
VH	Australia
VP-A	Anguilla (U.K.)'
VP-B	Bermuda (U.K.)'
VP-C	Cayman Islands (U.K.)'
VP-F	Falkland Islands (Malvinas) (U.K.)"
VP·G	Gibraltar (U.K.)'
VP-L	Virgin Islands (U.K.)*
VP·M	Montserrat (U.K.)'
VQ-H	St.Helena/Ascension (U.K.)'
VQ-T	Turks and Caicos (U.K.)'
VT	India
V2	Antigua and Barbuda
V3	Belize
V4	Saint Kitts and Nevis
VS	Namibia
V6	Micronesia, Federated States of
V7	Marshall Islands
VS	Brunel Darussalam
XA, XB', XC	Mexico
XT	Burkina Faso
XU	Cambodia
XV	Vietnam
XY, XZ	Myanmar
YA	Afghanistan
YI	Iraq
YJ	Vanuatu
YK	Syrian Arab Republic
YL	Latvia
YN	Nicaragua
YR	Romania
YS	El Salvador
YU	Federal Republic of Yugoslavia
YV	Venezuela

Mark	Country
2	Zimbabwe
ZK, ZL, ZM	New Zealand
ZP	Paraguay
ZS, ZT, ZU	South Africa
23	The former Yugoslav Republic of Macedonia
3A	Monaco
38	Mauritius
3C	Equatorial Guinea
30	Swaziland
3X	Guinea
4K	Azerbaijan
4L	Georgia
4R	Sri Lanka
4X	Israel
SA	Libyan Arab Jamahiriya
56	Cyprus
SH	United Republic Tanzania
SN	Nigeria
SR	Madagascar
ST	Mauritania
SU	Niger
s v	Togo
SW	Samoa
SY	Kenya
60	Somalia
6V, 6W	Senegal
6Y	Jamaica
70	Yemen
7P	Lesotho
70Y	Malawi
7T	Algeria
8P	Barbados
80	Maldives
SR	Guyana
9A	Croatia
9G	Ghana
9H	Malta
9J	Zambia
9K	Kuwait
9L	Sierra Leone
9M	Malaysia
9N	Nepal
90	Democratic Republic of the Congo
9U	Burundi
9V	Singapore
9XR	Rwanda
9Y	Trinidad and Tobago

• (United Kingdom)

1.6 Title 14 of the Code of Federal Regulations

The documents in Title 14 of the Code of Federal Regulations (14 CFR), formerly called the Federal Aviation Regulations (FARs), are the actual legal documents that govern civil aircraft operations. Information on the latest regulations is available in Advisory Circular (AC) 00-44 *Status of the Federal Aviation Regulations.* This AC is tree and may be ordered from:

U.S. Department of Transportation
Subsequent Distribution Office, SVC-121.23
Ardmore East Business Center
3341 Q 75th Ave
Landover. MD 20785

Part Title

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1 Definitions and abbreviations

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11 General rulemakIng procedures
13 Investigative and enforcement procedures
14 Rules implementing the Equal Access to Justice Act of 1980
15 Administrative claims under Federal Tort Claims Act
16 Rules of practice for Federally-assisted airport enforcement proceedings

Subchepter C-Afrcreft

21 Certification procedures for products and parts
23 Airworthiness standards: normal, utility, acrobatic, and commuter category airplanes
25 Airworthiness standards: transport category airplanes
27 Airworthiness standards: normal category rotorcraft
29 Airworthiness standards: transport category rotorcraft
31 Airworthiness standards: manned free balloons
33 Airworthiness standards: aircraft engines
34 Fuel venting and exhaust emission requirements for turbine engine powered airplanes
35 Airworthiness standards: propellers
36 Noise standards: aircraft type and airworthiness certification
39 Airworthiness directives
43 Maintenance, preventive maintenance, rebuilding, and alteration

I

45 Identification and registration marking
47 Aircraft registration
49 Recording of aircraft titles and security documents
50-59 [Reserved]

Subchapter D-Airmen

60 [Reserved]
61 Certification: Pilots, flight instructors, and ground instructors
63 Certification: Flight crewmembers other than pilots
65 Certification: Airmen other than flight crewmembers
67 Medical standards and certification

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71 Designation of class A, class B, class C, class D, and class E airspace areas; airways; routes; and reporting points
73 Special use airspace
75 [Reserved)
77 Objects affecting navigable airspace

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91 General operating and flight rules
93 Special air traffic rules and airport traffic patterns
95 IFR altitudes
97 Standard instrument approach procedures
99 Security control of air traffic
101 Moored balloons, kites, unmanned rockets and unmanned free balloons
103 Ultralight vehicles
105 Parachute operations
107 Airport security
108 Airplane operator security
109 Indirect air carrier security

Subchapter G - Air Carriers and Operators for Compensation or Hire: Certification and Operations

119 Certification: Air carriers and commercial operators
121 Operating requirements: Domestic, flag, and supplemental operations
125 Certification and operations: Airplanes having a seating capacity of 20 or more passengers or a maximum payload capacity of 6,000 pounds or more; and rules governing persons on board such aircraft
129 Operations: Foreign air carriers and foreign operators of U.S.-registered aircraft engaged in common carriage

133 Rotorcraft external-load operations
135 Operating requirements: Commuter and on-demand operations and rules governing persons on board such aircraft
137 Agricultural aircraft operations
139 Certification and operations: Land airports serving certain air carriers

Subchapter H-Schools and Other Certificated Agencies

140 [Reserved]
141 Pilot schools
142 Training centers
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145 Repair stations
147 Aviation maintenance technician schools

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150 Airport noise compatibility planning
151 Federal aid to airports
152 Airport aid program
155 Release of airport property from surplus property disposal restrictions
156 State block grant pilot program
157 Notice of construction, alteration, activation, and deactivation of airports
158 Passenger facility charges (PFCs)
161 Notice and approval of airport noise and access restrictions
169 Expenditure of Federal funds for nonmilitary airports or air navigation facilities thereon

Subchapter J-Navigational Facilities

170 Establishment and discontinuance criteria for air traffic control services and navigational facilities
171 Non-Federal navigation facilities

Subchapter K-Administrative Regulations

183 Representatives of the Administrator
185 Testimony by employees and production of records in legal proceedings, and service of legal process and pleadings
187 Fees
189 Use of Federal Aviation Administration communications system
191 Protection of sensitive security Information

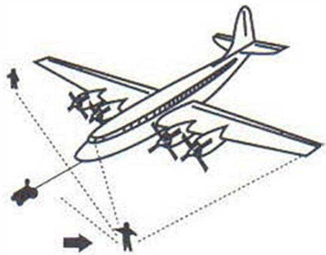
Subchapters L through M [Reserved]

Subchapter N-War Risk Insurance

198 Aviation Insurance

1.7 Standard Taxi Signals

Signalman's position



Signalman directs towing

Flagman directs pilot

Proceed straight ahead

Stop

Cut engines

Start engines

Pull chocks

Insert chocks

Slowdown

All clear (0.K.)

Left turn

Right turn

Night operation

1.8 Cylinder Color Code Identifiers

Painted around cylinder base by the hold down nuts or on fins between push rods:

Gray or unpainted	Standard steel barrels
Orange	Chrome plated cylinder barrels
Blue	Nitride hardened cylinder barrels
Green	Steel cylihder 0.010 oversize
Yellow	Steel cylinder 0.020 oversize
White	Rebarreled cylinder
Platinum	CermiNil" cylinder barrels
Two orange bands	CermlChrome• cylinder barrels

Section 2: Physical and Chemical

I

Periodic Table of Elements

weigh!

Period	Light Metale IA	Light Metale IIA	Heavy Metels 1118	IVB	VB	VIB	IVUB	VID			18	1T	Nonmetals LIA	IV A	VA	VI A	VII A	Inen Gases
1	1 H 1.00797																	2 He 4.0028
2	3 Li 6.941	4 Be 9.0122											B 10.811	6 C 1201115	7 N 14.0067	8 O 15999'	9 F 18.11934	10 Ne 20.179
3	11 Na 229898	12 Mg 24,305											13 Al 26.9815	14 Si 28.066	15 p 30.9736	16 S 32.0&I	17 Cl 35453	18 A, 39.948
4	19 K 39.0983	20 Ca 40.08	21 Sc [illegible]	22 Ti 47.90	23 V 509'2	24 Cr 51996	25 Mn 54 94	26 Fe 55&17	27 Co 58.9332	28 Ni 58.70	29 Cu 63.54	30 Zn 65aB	31 Ga li8.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 7990"	36 Kr 8380
5	37 Rb 85.47	38 Sr 87.62	39 y 88J105	40 Zr 91.22	41 Nb [illegible]	42 Mo [illegible]	43 Tc W 7)	44 Ru 10107	45 Rh 102.9116	46 Pd 1064	47 Ag 107.868	48 Cd It2.41	49 1n 114'82	50 Sn 118.69	51 Sb 121.75	52 Te 127,60	53 I 126.9045	54 Xe 131.30
6	55 Cs 132905	56 Ba 137.34	57* La 138.91	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 196.967	80 Hg 200.59	81 Tl 204 J /	82 Pb 207.19	83 Bi 208.980	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra 22602	89 ·· Ac (227)															

Atomic weights in () are mass numbers of most stable Isotope of that element.

Rare Earth Elements															
	* Lathan1de Series	58 Ce 140.12	59 Pr 140907	60 Nd 144.24	61 Pm (14!')	62 Sm 150.35	63 Eu 15196	64 Gd 1S7.2S	65 Tb 158.925	66 Dy 162.50	67 Ho 164.930	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu 174.97
	** Actinide Senes	90 Th 232038	91 Pa 231.1135S	92 U 238.03	93 Np 237.0482	94 Pu (244)	95 A,n 1243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (254)	100 Fm (257)	101 Md (258)	102 No (2.59)	103 Lr (260)

2.1 Temperature Conversion

To convert between the temperature scales, use these formulas:

Fahrenheit to Celsius:

$$°F = 1.8 \times °C + 32$$

or

$$°F = \frac{(9 \times °C)}{5} + 32$$

Celsius to Fahrenheit:

$$°C = \frac{°F - 32}{1.8}$$

or

$$°C = \frac{5(°F - 32)}{9}$$

For interpolation, 1°C = 1.8°F

°C	← °F | °C →	°F	°C	← °F | °C →	°F
-73.3	-100	-148.0	-23.3	-10	14.0
-70.6	-95	-139.0	-20.6	-5	23.0
-67.8	-90	-130.0	-18.3	-1	30.2
-65.0	-85	-121.0	-17.8	0	32.0
-62.2	-80	-112.0	-17.2	1	33.8
-59.4	-75	-103.0	-16.7	2	35.6
-56.7	-70	-94.0	-16.1	3	37.4
-53.9	-65	-85.0	-15.6	4	39.2
-51.1	-60	-76.0	-15.0	5	41.0
-48.3	-55	-67.0	-14.4	6	42.8
-45.6	-50	-58.0	-13.9	7	44.6
-42.8	-45	-49.0	-13.3	8	46.4
-40.0	-40	-40.0	-12.8	9	48.2
-37.2	-35	-31.0	-12.2	10	50.0
-34.4	-30	-22.0	-11.7	11	51.8
-31.7	-25	-13.0	-11.1	12	53.6
-28.9	-20	-4.0	-10.6	13	55.4
-26.1	-15	5.0	-10.0	14	57.2

°C	← °F °C →	°F	°C	← °F °C →	°F
-9.4	15	59.0	14.4	58	136.4
-8.9	16	60.8	15.0	59	138.2
-8.3	17	62.6	15.6	60	140.0
-7.8	18	64.4	16.1	61	141.8
-7.2	19	66.2	16.7	62	143.6
-6.7	20	68.0	17.2	63	145.4
-6.1	21	69.8	17.8	64	147.2
-5.6	22	71.6	18.3	65	149.0
-5.0	23	73.4	18.9	66	150.8
-4.4	24	75.2	19.4	67	152.6
-3.9	25	77.0	20.0	68	154.4
-3.3	26	78.8	20.6	69	156.2
-2.8	27	80.6	21.1	70	158.0
-2.2	28	82.4	21.7	71	159.8
-1.7	29	84.2	22.2	72	161.6
-1.1	30	86.0	22.8	73	163.4
-0.6	31	87.8	23.3	74	165.2
0.0	32	89.6	23.9	75	167.0
0.6	33	91.4	24.4	76	168.8
1.1	34	93.2	25.0	77	170.6
1.7	35	95.0	25.6	78	172.4
2.2	36	96.8	26.1	79	174.2
2.8	37	98.6	26.7	80	176.0
3.3	38	100.4	27.2	81	177.8
3.9	39	102.2	27.8	82	179.6
4.4	40	104.0	28.3	83	181.4
5.0	41	105.8	28.9	84	183.2
5.6	42	107.6	29.4	85	185.0
6.1	43	109.4	30.0	86	186.8
6.7	44	111.2	30.6	87	188.6
7.2	45	113.0	31.1	88	190.4
7.8	46	114.8	31.7	89	192.2
8.3	47	116.6	32.2	90	194.0
8.9	48	118.4	32.8	91	195.8
9.4	49	120.2	33.3	92	197.6
10.0	50	122.0	33.9	93	199.4
10.6	51	123.8	34.4	94	201.2
11.1	52	125.6	35.0	95	203.0
11.7	53	127.4	35.6	96	204.8
12.2	54	129.2	36.1	97	206.6
12.8	55	131.0	36.7	98	208.4
13.3	56	132.8	37.2	99	210.2
13.9	57	134.6	37.8	100	212.0

°C	← °F | °C →	°F	°C	← °F | °C →	°F
38.3	101	213.8	62.2	144	291.2
38.9	102	215.6	62.8	145	293.0
39.4	103	217.4	63.3	146	294.8
40.0	104	219.2	63.9	147	296.6
40.6	105	221.0	64.4	148	298.4
41.1	106	222.8	65.0	149	300.2
41.7	107	224.6	65.6	150	302.0
42.2	108	226.4	66.1	151	303.8
42.8	109	228.2	66.7	152	305.6
43.3	110	230.0	67.2	153	307.4
43.9	111	231.8	67.8	154	309.2
44.4	112	233.6	68.3	155	311.0
45.0	113	235.4	68.9	156	312.8
45.6	114	237.2	69.4	157	314.6
46.1	115	239.0	70.0	158	316.4
46.7	116	240.8	70.6	159	318.2
47.2	117	242.6	71.1	160	320.0
47.8	118	244.4	71.7	161	321.8
48.3	119	246.2	72.2	162	323.6
48.9	120	248.0	72.8	163	325.4
49.4	121	249.8	73.3	164	327.2
50.0	122	251.6	73.9	165	329.0
50.6	123	253.4	74.4	166	330.8
51.1	124	255.2	75.0	167	332.6
51.7	125	257.0	75.6	168	334.4
52.2	126	258.8	76.1	169	336.2
52.8	127	260.6	76.7	170	338.0
53.3	128	262.4	77.2	171	339.8
53.9	129	264.2	77.8	172	341.6
54.4	130	266.0	78.3	173	343.4
55.0	131	267.8	78.9	174	345.2
55.6	132	269.6	79.4	175	347.0
56.1	133	271.4	80.0	176	348.8
56.7	134	273.2	80.6	177	350.6
57.2	135	275.0	81.1	178	352.4
57.8	136	276.8	81.7	179	354.2
58.3	137	278.6	82.2	180	356.0
58.9	138	280.4	82.8	181	357.8
59.4	139	282.2	83.3	182	359.6
60.0	140	284.0	83.9	183	361.4
60.6	141	285.8	84.4	184	363.2
61.1	142	287.6	85.0	185	365.0
61.7	143	289.4	85.6	186	366.8

°C	°F/°C	°F	°C	°F/°C	°F
86.1	187	368.6	132.2	270	518.0
86.7	188	370.4	135.0	275	527.0
87.2	189	372.2	137.8	280	536.0
87.8	190	374.0	140.6	285	545.0
88.3	191	375.8	143.3	290	554.0
88.9	192	377.6	146.1	295	563.0
89.4	193	379.4	148.9	300	572.0
90.0	194	381.2	154.4	310	590.0
90.6	195	383.0	160.0	320	608.0
91.1	196	384.8	165.6	330	626.0
91.7	197	386.6	171.1	340	644.0
92.2	198	388.4	176.7	350	662.0
92.8	199	390.2	182.2	360	680.0
93.3	200	392.0	187.8	370	698.0
93.9	201	393.8	193.3	380	716.0
94.4	202	395.6	198.9	390	734.0
95.0	203	397.4	204.4	400	752.0
95.6	204	399.2	210.0	410	770.0
96.1	205	401.0	215.6	420	788.0
96.7	206	402.8	221.1	430	806.0
97.2	207	404.6	226.7	440	824.0
97.8	208	406.4	232.2	450	842.0
98.3	209	408.2	237.8	460	860.0
98.9	210	410.0	243.3	470	878.0
99.4	211	411.8	248.9	480	896.0
100.0	212	413.6	254.4	490	914.0
100.6	213	415.4	260.0	500	932.0
101.1	214	417.2	265.6	510	950.0
101.7	215	419.0	271.1	520	968.0
102.2	216	420.8	276.7	530	986.0
102.8	217	422.6	282.2	540	1004.0
103.3	218	424.4	287.8	550	1022.0
103.9	219	426.2	293.3	560	1040.0
104.4	220	428.0	298.9	570	1058.0
107.2	225	437.0	304.4	580	1076.0
110.0	230	446.0	310.0	590	1094.0
112.8	235	455.0	315.6	600	1112.0
115.6	240	464.0	321.1	610	1130.0
118.3	245	473.0	326.7	620	1148.0
121.1	250	482.0	332.2	630	1166.0
123.9	255	491.0	337.8	640	1184.0
126.7	260	500.0	343.3	650	1202.0
129.4	265	509.0	348.9	660	1220.0

°C	← °F/°C →	°F	°C	← °F/°C →	°F
354.4	670	1238.0	648.9	1200	2192.0
360.0	680	1256.0	660.0	1220	2228.0
365.6	690	1274.0	671.1	1240	2264.0
371.1	700	1292.0	682.2	1260	2300.0
376.7	710	1310.0	693.3	1280	2336.0
382.2	720	1328.0	704.4	1300	2372.0
387.8	730	1346.0	715.6	1320	2408.0
393.3	740	1364.0	726.7	1340	2444.0
398.9	750	1382.0	737.8	1360	2480.0
404.4	760	1400.0	748.9	1380	2516.0
410.0	770	1418.0	760.0	1400	2552.0
415.6	780	1436.0	771.1	1420	2588.0
421.1	790	1454.0	782.2	1440	2624.0
426.7	800	1472.0	793.3	1460	2660.0
432.2	810	1490.0	804.4	1480	2696.0
437.8	820	1508.0	815.6	1500	2732.0
443.3	830	1526.0	826.7	1520	2768.0
448.9	840	1544.0	837.8	1540	2804.0
454.4	850	1562.0	848.9	1560	2840.0
460.0	860	1580.0	860.0	1580	2876.0
465.6	870	1598.0	871.1	1600	2912.0
471.1	880	1616.0	882.2	1620	2948.0
476.7	890	1634.0	893.3	1640	2984.0
482.2	900	1652.0	904.4	1660	3020.0
487.8	910	1670.0	915.6	1680	3056.0
493.3	920	1688.0	926.7	1700	3092.0
498.9	930	1706.0	937.8	1720	3128.0
504.4	940	1724.0	948.9	1740	3164.0
510.0	950	1742.0	960.0	1760	3200.0
515.6	960	1760.0	971.1	1780	3236.0
521.1	970	1778.0	982.2	1800	3272.0
526.7	980	1796.0	993.3	1820	3308.0
532.2	990	1814.0	1004.4	1840	3344.0
537.8	1000	1832.0	1015.6	1860	3380.0
548.9	1020	1868.0	1026.7	1880	3416.0
560.0	1040	1904.0	1037.8	1900	3452.0
571.1	1060	1940.0	1048.9	1920	3488.0
582.2	1080	1976.0	1060.0	1940	3524.0
593.3	1100	2012.0	1071.1	1960	3560.0
604.4	1120	2048.0	1082.2	1980	3596.0
615.6	1140	2084.0	1093.3	2000	3632.0
626.7	1160	2120.0	1104.4	2020	3668.0
637.8	1180	2156.0	1115.6	2040	3704.0

°C	°F | °C	°F	°C	°F | °C	°F
1126.7	2060	3740.0	1360.0	2480	4496.0
1137.8	2080	3776.0	1371.1	2500	4532.0
1148.9	2100	3812.0	1382.2	2520	4568.0
1160.0	2120	3848.0	1393.3	2540	4604.0
1171.1	2140	3884.0	1404.4	2560	4640.0
1182.2	2160	3920.0	1415.6	2580	4676.0
1193.3	2180	3956.0	1426.7	2600	4712.0
1204.4	2200	3992.0	1437.8	2620	4748.0
1215.6	2220	4028.0	1448.9	2640	4784.0
1226.7	2240	4064.0	1460.0	2660	4820.0
1237.8	2260	4100.0	1471.1	2680	4856.0
1248.9	2280	4136.0	1482.2	2700	4892.0
1260.0	2300	4172.0	1493.3	2720	4928.0
1271.1	2320	4208.0	1504.4	2740	4964.0
1282.2	2340	4244.0	1515.6	2760	5000.0
1293.3	2360	4280.0	1526.7	2780	5036.0
1304.4	2380	4316.0	1537.8	2800	5072.0
1315.6	2400	4352.0	1565.6	2850	5162.0
1326.7	2420	4388.0	1593.3	2900	5252.0
1337.8	2440	4424.0	1621.1	2950	5342.0
1348.9	2460	4460.0	1648.9	3000	5432.0

Absolute Temperature

The Kelvin temperature scale uses the same graduations as are used in the Celsius scale. Zero degrees Kelvin (0°K) is absolute zero, and is equal to -273°C.

$$°K = °C + 273$$

and

$$°C = °K - 273$$

The Rankine temperature scale uses the same graduations as are used in the Fahrenheit scale. Zero degrees Rankine (0°R) is absolute zero, and is equal to -460°F.

$$°R = °F + 460$$

and

$$°F = °R - 460$$

2.2 ICAO Standard Atmosphere

Altitude	Temperature		Pressure	Speed of Sound
Feet	*°F*	*°C*	*In.Hg*	*Knots*
-2,000	66.10	19.0	32.15	666.0
-1,000	62.50	17.0	31.01	663.7
0	59.00	15.0	29.92	661.7
1,000	55.43	13.0	28.86	659.5
2,000	51.87	11.0	27.82	657.2
3,000	48.30	9.1	26.82	654.9
4,000	44.74	7.1	25.84	652.6
5,000	41.17	5.1	24.90	650.3
6,000	37.60	3.1	23.98	647.9
7,000	34.04	1.1	23.09	645.6
8,000	30.47	-0.8	22.23	643.3
9,000	26.90	-2.8	21.39	640.9
10,000	23.34	-4.8	20.58	638.6
15,000	5.51	-14.7	16.89	626.7
20,000	-12.32	-24.6	13.75	614.6
25,000	-30.15	-34.5	11.12	602.2
30,000	-47.90	-44.4	8.885	589.5
35,000	-65.82	-54.2	7.041	576.6
*36,089	-69.70	-56.5	6.683	573.8
40,000	-69.70	-56.5	5.558	573.8
45,000	-69.70	-56.5	4.355	573.8
50,000	-69.70	-56.5	3.425	573.8
55,000	-69.70	-56.5	2.693	573.8
60,000	-69.70	-56.5	2.118	573.8
65,000	-69.70	-56.5	1.665	573.8
70,000	-69.70	-56.5	1.310	573.8
75,000	-69.70	-56.5	1.030	573.8
80,000	-69.70	-56.5	0.810	573.8
85,000	-64.80	-53.8	0.637	577.4
90,000	-56.57	-49.2	0.504	583.4
95,000	-48.34	-44.6	0.400	589.3
100,000	-40.11	-40.1	0.320	595.2

*Geopotential of the tropopause

2.3 Distribution of Electrons in the Chemical Elements

Atomic Number	Element	Symbol	Atomic Weight	Shells k	l	m	n	o	p	q
1	Hydrogen	H	1.00797	1						
2	Helium	He	4.0026	2						
3	Lithium	Li	6.941	2	1					
4	Beryllium	Be	9.0122	2	2					
5	Boron	B	10.811	2	3					
6	Carbon	C	12.01115	2	4					
7	Nitrogen	N	14.0067	2	5					
8	Oxygen	0	15.9994	2	7					
9	Fluorine	F	18.9984	2	7					
10	Neon	Ne	20.179	2	8					
11	Sodium	Na	22.9898	2	8	1				
12	Magnesium	Mg	24.305	2	8	2				
13	Aluminum	Ai	26.9815	2	8	3				
14	Silicon	Si	28.086	2	8	4				
15	Phosphorus	p	30.9736	2	8	5				
16	Sulfur	S	32.064	2	8	6				
17	Chlorine	Cl	35.453	2	8	7				
18	Argon	Ar	39.948	2	8	8				
19	Potassium	K	39.0983	2	8	8	1			
20	Calcium	Ca	40.08	2	8	8	2			
21	Scandium	Sc	44.956	2	8	9	2			
22	Titanium	Ti	47.90	2	8	10	2			
23	Vanadium	V	50.942	2	8	11	2			
24	Chromium	Cr	51.996	2	8	13	1			
25	Manganese	Mn	54.94	2	8	13	2			
26	Iron	Fe	55.847	2	8	14	2			
27	Cobalt	Co	58.9332	2	8	15	2			
28	Nickel	Ni	58.70	2	8	16	2			
29	Copper	Cu	63.54	2	8	18	1			
30	Zinc	Zn	65.38	2	8	18	2			
31	Gallium	Ga	69.72	2	8	18	3			
32	Germanium	Ge	72.59	2	8	18	4			
33	Arsenic	As	74.9216	2	8	18	5			
34	Selenium	Se	78.96	2	8	18	6			
35	Bromine	Br	79.904	2	8	18	7			
36	Krypton	Kr	83.80	2	8	18	8			
37	Rubidium	Rb	85.4678	2	8	18	8	1		
38	Strontium	Sr	87.62	2	8	18	8	2		
39	Yttrium	y	88.905	2	8	18	9	2		

Atomic Number	Element	Symbol	Atomic Weight	Shells k	l	m	n	o	p	q
40	Zirconium	Zr	91.22	2	8	18	10	2		
41	Niobium	Nb	92.906	2	8	18	12	1		
42	Molybdenum	Mo	95.94	2	8	18	13	1		
43	Technetium	Tc	(97)	2	8	18	14	1		
44	Ruthenium	Ru	101.07	2	8	18	15	1		
45	Rhodium	Rh	102.905	2	8	18	16	1		
46	Palladium	Pd	106.4	2	8	18	18	0		
47	Sliver	Ag	107.868	2	8	18	18	1		
48	Cadmium	Cd	112.41	2	8	18	18	2		
49	Indium	In	114.82	2	8	18	18	3		
50	Tin	Sn	118.69	2	8	18	18	4		
51	Antimony	Sb	121.75	2	8	18	18	5		
52	Tellurium	Te	127.60	2	8	18	18	6		
53	Iodine	I	126.9045	2	8	18	18	7		
54	Xenon	Xe	131.30	2	8	18	18	8		
55	Cesium	Cs	132.905	2	8	18	18	8	1	
56	Barium	Ba	137.34	2	8	18	18	8	2	
57	Lanthanum	La	138.91	2	8	18	18	9	2	
58	Cerium	Ce	140.12	2	8	18	20	8	2	
59	Praseodymium	Pr	140.907	2	8	18	21	8	2	
60	Neodymium	Nd	144.24	2	8	18	22	8	2	
61	Promethium	Pm	(145)	2	8	18	23	8	2	
62	Samarium	Sm	150.35	2	8	18	24	8	2	
63	Europium	Eu	151.96	2	8	18	25	8	2	
64	Gadolinium	Gd	157.25	2	8	18	25	9	2	
65	Terbium	Tb	158.925	2	8	18	27	8	2	
66	Dysprosium	Dy	162.50	2	8	18	28	8	2	
67	Holmium	Ho	164.930	2	8	18	29	8	2	
68	Erbium	Er	167.26	2	8	18	30	8	2	
69	Thulium	Tm	168.934	2	8	18	31	8	2	
70	Ytterbium	Yb	173.04	2	8	18	32	8	2	
71	Lutetium	Lu	174.97	2	8	18	32	9	2	
72	Hafnium	Hf	178.49	2	8	18	32	10	2	
73	Tantalum	Ta	180.948	2	8	18	32	11	2	
74	Tungsten	W	183.85	2	8	18	32	12	2	
75	Rhenium	Re	186.2	2	8	18	32	13	2	
76	Osmium	Os	190.2	2	8	18	32	14	2	
77	Iridium	Ir	192.2	2	8	18	32	17	0	
78	Platinum	Pt	195.09	2	8	18	32	17	1	
79	Gold	Au	196.967	2	8	18	32	18	1	
80	Mercury	Hg	200.59	2	8	18	32	18	2	
81	Thallium	Tl	204.37	2	8	18	32	18	3	
82	Lead	Pb	207.19	2	8	18	32	18	4	

Atomic Number	Element	Symbol	Atomic Weight	Shells						
				k	l	m	n	o	p	q
83	Bismuth	Bi	208.980	2	8	18	32	18	5	
84	Polonium	Po	(209)	2	8	18	32	18	6	
85	Astatine	Al	(210)	2	8	18	32	18	7	
86	Radon	Rn	(222)	2	8	18	32	18	8	
87	Francium	Fr	(223)	2	8	18	32	18	8	1
88	Radium	Ra	226.02	2	8	18	32	18	8	2
89	Actinium	Ac	(227)	2	8	18	32	18	9	2
90	Thorium	Th	232.038	2	8	18	32	18	10	2
91	Protactinium	Pa	231.0359	2	8	18	32	20	9	2
92	Uranium	U	238.03	2	8	18	32	21	9	2
93	Neptunium	Np	237.0482	2	8	18	32	22	9	2
94	Plutonium	Pu	(244)	2	8	18	32	23	9	2
95	Americium	Am	(243)	2	8	18	32	24	9	2
96	Curium	Cm	(247)	2	8	18	32	25	9	2
97	Berkelium	Bk	(247)	2	8	18	32	26	9	2
98	Californium	Cf	(251)	2	8	18	32	27	9	2
99	Einsteinium	Es	(254)	2	8	18	32	28	9	2
100	Fermium	Fm	(257)	2	8	18	32	29	9	2
101	Mendelvium	Md	(258)	2	8	18	32	30	9	2
102	Nobelium	No	(259)	2	8	18	32	31	9	2
103	Lawrencium	Lr	(262)	2	8	18	32	32	9	2

Values in parentheses give the atomic mass number of the Isotope of longest half-life.

2.4 Density of Various Solids and Liquids

Substance	Specific Gravity	Pounds/ Cubic Foot	Pounds/ Gallon
Cork	0.22	13.7	
Gasoline	0.72	44.9	6.02
Jp.4	0.79	49.0	6.60
Alcohol (methyl)	0.81	50.5	6.76
JP-5	0.82	51.2	6.84
Kerosine	0.82	51.2	6.84
Oil (Petroleum)	0.89	55.5	7.43
Ice	0.92	57.4	
Oil (Synthetic)	0.93	58.0	7.76
Water (fresh)	1.00	62.4	8.35
Water (sea)	1.03	64.3	8.60
Ethylene Glycol	1.12	69.9	9.35
Sugar	1.59	99.2	
Carbon Tetrachloride	1.60	99.8	13.36
Magnesium	1.74	108.6	
Salt	2.18	136.0	
Aluminum	2.70	168.5	
Zinc	7.10	443.0	
Steel	7.83	488.6	
Iron	7.90	493.0	
Brass	8.65	539.8	
Copper	8.95	558.5	
Lead	11.37	709.5	
Mercury	13.55	845.6	113.14
Gold	19.31	1,204.9	

Density of Various Gases

Gas	Specific Gravity	Pounds/ Cubic Foot
Hydrogen	0.073	0.00561
Helium	0.146	0.01114
Air	1.000	0.07651
Nitrogen	1.020	0.07807
Oxygen	1.166	0.08921
Carbon Dioxide	1.613	0.12341

2.5 Hydraulic Relationships

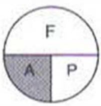
Relationships exist between pressure, area, and volume in a hydraulic actuator that allow us to find the value of any one of them when the other two are known. Circle graphs make it easy for us to visualize the way to find the desired value.

To find the value of the shaded area, multiply the other two if they are both below the horizontal line. Divide if they are separated by the horizontal line.

The amount of force produced by a hydraulic actuator can be found by multiplying the pressure in pounds per square Inch (psi), by the area of the piston in square inches.

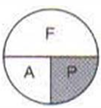
$$F = P \times A$$

The area of a piston needed to produce a given amount of force can be found by dividing the force, in pounds, by the pressure of the hydraulic fluid in psi.



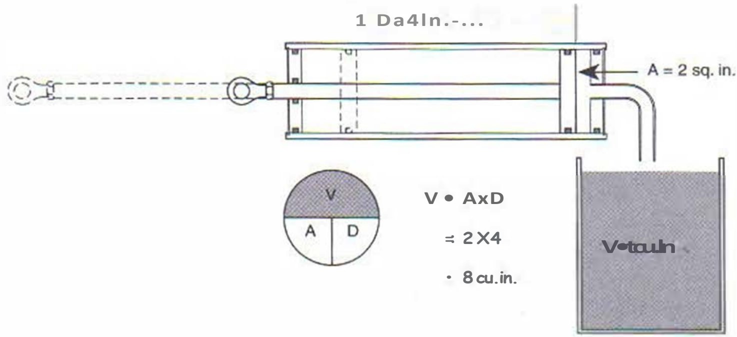
$$A = \frac{F}{P}$$

The amount of pressur needed for a piston having a given area (In square inches) to produce a known force may be found by dividing the amount of force by the area of the piston.



$$P = \frac{F}{A}$$

Relationships exist between the volume of fluid moved by a piston in a cylinder, the area of the piston, and the distance the piston moves. Circle graphs make it easy for us to visualize the way to find the desired value.



The volume of fluid, in cubic inches, moved by a piston is found by multiplying the area of the piston in square inches, by the distance the piston has moved in inches.

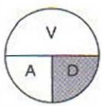
A

=

=4

= 2 sq. in.

The area of a piston needed to move a given quantity of fluid is found by dividing the volume of the fluid by the distance the piston moves.



$$A = \frac{V}{A}$$

$$= \frac{8}{2}$$

= 4 inches

The distance that a piston with a given area must move to displace a given volume of fluid is found by dividing the volume of the fluid by the area of the piston.

2.6 Quantity of Liquid in a Drum

Estimating Quantity of Liquid In a Standard 55-Gallon Drum

Drum Upright

Depth of Liquid (Inches)	Gallons (approx.)
31	54.0
30	52.0
29	50.0
28	48.5
27	47.0
26	45.0
25	43.5
24	41.5
23	40.0
22	38.0
21	36.5
20	34.5
19	33.0
18	31.5
17	29.5
16	27.5
15	26.0
14	24.5
13	22.5
12	21.0
11	19.0
10	17.5
9	15.5
8	14.0
7	12.0
6	10.5
5	8.5
4	7.0
3	5.0
2	3.5
1	2.0

Drum On Its Side

Depth of Liquid (inches)	Gallons (approx.)
20	55.0
19	52.5
18	50.0
17	47.5
16	44.5
15	41.5
14	38.5
13	35.0
12	32.0
11	28.5
10	25.0
9	22.0
8	18.5
7	15.5
6	12.5
5	9.5
4	7.0
3	4.5
2	2.5
1	0.8

Section 3: Mathematics

3.1 Measurement Systems

There are two systems of measurement used in the United States: the U.S. Customary system (U.S.), and the metric system.

The U.S. Customary system was mainly derived from the British Imperial system in which there is no correlation between the units, and the basis of many are arbitrary. However, they have been used for so long that most of us are familiar with them. The metric system, on the other hand, is based upon absolute and repeatable physical factors. The sizes of the units change in multiples of 10.

The metric system had its start in France late in the eighteenth century when the unit of length, the meter, was accepted as being equal to one ten-millionth of the length of the arc from the equator to the North Pole. The unit of mass was the kilogram which was equal to the mass of water contained in a cube whose length, width, and height are one tenth of a meter.

The metric system spread slowly from France to other European countries. In the United States, in July of 1866, legislation was signed into law authorizing, but not mandating the use of the metric system. More than one hundred years later, in 1968, Congress authorized an intensive study to determine the advantages and disadvantages of increased use in the U.S. of the metric system. In 1975 the U.S. Metric Board was established to coordinate the voluntary conversion to the metric system.

The Omnibus Trade Bill passed in 1988 required most federal agencies to convert to metric units in their activities by 1992.

Enthusiastic adoption of the metric system in the U.S. has been slow because of the tremendous amount of machinery and equipment in use that was built to U.S. dimensions. However, the increase in international trade has caused many U.S. manufacturers to include both U.S. and metric dimensions in their service literature. The popularity of foreign automobiles in the U.S. has increased the familiarity of most Americans with metric dimensions. Most professional mechanics and technicians now have two sets of hand tools, one U.S. and the other metric.

The International System of Units (SI)

The International System of Units is founded on seven base units:

length .... meter
mass .... kilogram
time .... second
electrical current .... ampere
temperature .... °Kelvin
amount of substance .... mole
luminous intensity .... candela

These units make up a complete set from which all other units of measurement can be derived.

The Metric System

The metric system is based upon dividing and multiplying the standard units by the powers of 10 and giving each a name indicating its value.

Prefix	Symbol	Power
exa	E	10^{18}
peta	p	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deka	da	10^{1}
UNIT		
deci	d	10^{-1}
centl	C	10^{-2}
mili	m	10^{-3}
micro	m	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}

U.S. - Metric Conversion

The basis of many units in the U.S. system are arbitrary and are not reproducible. But by relating them to one of the units in the SI system, they are traceable back to a reproducible basic unit

length

1 Inch		2.54 centimeters
1 foot	121nches	30.48 centimeters
1 yard	3 feet	0.9144 meter
1 statute mile	5,280feet	1.609 kilometers
1 nautical mile	6,076feet	1.852 kilometers

Weight

1 ounce		28.3495 gram
1 pound	16 ounces	0.4536 kilogram
1 ton	2,000 pounds	907.2 kilograms

Volume

1 cubic inch		16.39 cubic centimeters
1 cubic inch		0.01639 liter
1 U.S. gallon	231 cubic inches	3.785 liters
1 Imperial gallon	1.2 U.S. gallons	4.542 liters

3.2 Mathematical Constants

$\pi = 3.1416$

$\pi^2 = 9.8696$

$\pi^3 = 31.0063$

$\frac{1}{\pi} = 0.3183$

$\frac{1}{\pi^2} = 0.1013$

$\sqrt{\pi} = 1.7725$

$\frac{1}{\sqrt{\pi}} = 0.5642$

$\frac{1}{2\pi} = 0.1592$

$\left[\frac{1}{2\pi}\right]^2 = 0.0253$

$2\pi = 6.2832$

$2\pi^2 = 39.4784$

$4\pi = 12.5664$

$\frac{\pi}{2} = 1.5708$

$\sqrt{\frac{\pi}{2}} = 1.253$

$\sqrt{2} = 1.4142$

$\sqrt{3} = 1.7321$

$\frac{1}{\sqrt{2}} = 0.7071$

$\frac{1}{\sqrt{3}} = 0.5773$

$\log \pi = 0.4971$

$\log \pi^2 = 0.9943$

$\log \sqrt{\pi} = 0.2486$

$\log \frac{\pi}{2} = 1.5708$

3.3 Mathematical Symbols

+	Plus, or positive
–	Minus, or negative
x or·	Multiplied by
+	Divided by
=	Equal to
"	Not equal to
≃	Approximately equal to
.!:	Greater than or equal to
s	Less than or equal to
=	Identical with
>	Greater than
<	Less than
II	Parallel with
.1.	Perpendicular to
±	Plus or minus
00	Infinity
6	Increment
.fa	Square root of a
	Cube root of a
lal	Absolute value of a
L	Angle
∴	Therefore
3	There exists
:	Ratio

3.4 Squares, Square Roots, Cubes, Cube Roots of Numbers

Number	Square	Square Root	Cube	Cube Root
1	1	1.0000	1	1.0000
2	4	1.4142	8	1.2599
3	9	1.7321	27	1.4423
4	16	2.0000	64	1.5874
5	25	2.2361	125	1.7110
6	36	2.4495	216	1.8171
7	49	2.6458	343	1.9129
8	64	2.8284	512	2.0000
9	81	3.0000	729	2.0801
10	100	3.1623	1,000	2.1544
11	121	3.3166	1,331	2.2240
12	144	3.4641	1,728	2.2894
13	169	3.6056	2,197	2.3513
14	196	3.7417	2,744	2.4101
15	225	3.8730	3,375	2.4662
16	256	4.0000	4,096	2.5198
17	289	4.1232	4,913	2.5713
18	324	4.2426	5,832	2.6207
19	361	4.3589	6,859	2.6684
20	400	4.4721	8,000	2.7144
21	441	4.5826	9.261	2.7589
22	484	4.6904	10,648	2.8020
23	529	4.7958	12,167	2.8439
24	576	4.8990	13,824	2.8845
25	625	5.0000	15,625	2.9240
26	676	5.0990	17,576	2.9625
27	729	5.1962	19,683	3.0000
28	784	5.2915	21,952	3.0366
29	841	5.3852	24,389	3.0723
30	900	5.4772	27,000	3.1072
31	961	5.5678	29,791	3.1414
32	1,024	5.6569	32,768	3.1748
33	1,089	5.7446	35,937	3.2075
34	1,156	5.8310	39,304	3.2396
35	1,225	5.9161	42,875	3.2711
36	1,296	6.0000	46,656	3.3019
37	1,369	6.0828	50,653	3.3322
38	1,444	6.1644	54,872	3.3620
39	1,521	6.2450	59,319	3.3912

Number	Square	Square Root	Cube	Cube Root
40	1,600	6.3246	64,000	3.4200
41	1,681	6.4031	68,921	3.4482
42	1,764	6.4807	74,088	3.4760
43	1,849	6.5574	79,507	3.5034
44	1,936	6.6333	85,184	3.5303
45	2,025	6.7082	91,125	3.5569
46	2,116	6.7823	97,336	3.5830
47	2,206	6.8557	103,823	3.6088
48	2,304	6.9282	110,592	3.6342
49	2,401	7.0000	117,649	3.6593
50	2,500	7.0711	125,000	3.6840
51	2,601	7.1414	132,651	3.7084
52	2,704	7.2111	140,608	3.7325
53	2,809	7.2801	148,877	3.7563
54	2,916	7.3485	157,464	3.7798
55	3,025	7.4162	166,375	3.8030
56	3,136	7.4833	175,616	3.8259
57	3,249	7.5498	185,193	3.8485
58	3,364	7.6158	195,112	3.8709
59	3,481	7.6811	205,379	3.8930
60	3,600	7.7460	216,000	3.9149
61	3,721	7.8103	226,981	3.9365
62	3,844	7.8740	238,328	3.9579
63	3,969	7.9373	250,047	3.9791
64	4,096	8.0000	262,144	4.0000
65	4,225	8.0623	274,625	4.0207
66	4,356	8.1240	287,496	4.0412
67	4,489	8.1854	300,763	4.0615
68	4,624	8.2462	314,432	4.0817
69	4,761	8.3066	328,509	4.1016
70	4,900	8.3666	343,000	4.1213
71	5,041	8.4262	357,911	4.1408
72	5,184	8.4853	373,248	4.1602
73	5,329	8.5440	389,017	4.1793
74	5,476	8.6023	405,224	4.1983
75	5,625	8.6603	421,875	4.2172
76	5,776	8.7178	438,976	4.2358
77	5,929	8.7750	456,533	4.2543
78	6,084	8.8318	474,552	4.2727
79	6,241	8.8882	493,039	4.2908
80	6,400	8.9443	512,000	4.3089
81	6,561	9.0000	531,441	4.3267
82	6,724	9.0554	551,368	4.3445
83	6,889	9.1104	571,787	4.3621

I

Number	Square	Square Root	Cube	Cube Root
84	7,056	9.1652	592,704	4.3795
85	7,225	9.2195	614,125	4.3968
86	7,396	9.2736	636,056	4.4140
87	7,569	9.3274	658,503	4.4310
88	7,744	9.3808	681,472	4.4480
89	7,921	9.4340	704,969	4.4647
90	8,100	9.4868	729,000	4.4814
91	8,281	9.5394	753,571	4.4979
92	8,464	9.5917	n8,688	4.5144
93	8,649	9.6437	804,357	4.5307
94	8,836	9.6954	830,584	4.5468
95	9,025	9.7468	857,375	4.5629
96	9,216	9.7980	884,736	4.5789
97	9,409	9.8489	912,673	4.5947
98	9,604	9.8995	941,192	4.6104
99	9,801	9.9499	970,299	4.6261
100	10,000	10.0000	1,000,000	4.6416

3.5 Diameter, Circumference and Area of a Circle

Diameter *Units*	Circumference *Units*	Area *Square Units*
1	3.1416	0.7854
2	6.2832	3.1416
3	9.4248	7.0686
4	12.5664	12.566
5	15.7080	19.635
6	18.8496	28.274
7	21.9911	38.485
8	25.1327	50.265
9	28.2743	63.617
10	31.4159	78.540
11	34.5575	95.033
12	37.6991	113.10
13	40.8407	132.73
14	43.9823	153.94
15	47.1239	176.71
16	50.2655	201.06
17	53.4071	226.98
18	56.5487	254.47
19	59.6903	283.53
20	62.8319	314.16
21	65.9735	346.36
22	69.1150	380.13
23	72.2566	415.48
24	75.3982	452.39
25	78.5398	490.87
26	81.6814	530.93
27	84.8230	572.56
28	87.9646	615.75
29	91.1062	660.52
30	94.2478	706.86
31	97.3894	754.77
32	100.5310	804.25
33	103.6726	855.30
34	106.8142	907.92
35	109.9557	962.11
36	113.0973	1,017.88
37	116.2389	1,075.21
38	119.3805	1,134.12

I

Diameter *Units*	Circumference *Units*	Area *Square Units*
39	122.5221	1,194.59
40	125.6637	1,256.64
41	128.8053	1,320.25
42	131.9469	1,385.44
43	135.0885	1,452.20
44	138.2301	1,520.53
45	141.3717	1,590.43
46	144.5133	1,661.90
47	147.6549	1,734.95
48	150.7964	1,809.56
49	153.9380	1,885.74
50	157.0796	1,963.50
51	160.2212	2,042.82
52	163.3628	2,123.72
53	166.5044	2,206.18
54	169.6460	2,290.22
55	172.7876	2,375.83
56	175.9292	2,463.01
57	179.0708	2,551.76
58	182.2124	2,642.08
59	185.3540	2,733.97
60	188.4956	2,827.43
61	191.6372	2,922.47
62	194.7787	3,019.07
63	197.9203	3,117.25
64	201.0619	3,126.99
65	204.2035	3,318.31
66	207.3451	3,421.19
67	210.4867	3,525.65
68	213.6283	3,631.68
69	216.7699	3,739.28
70	219.9115	3,848.45
71	223.0531	3,959.19
72	226.1947	4,071.50
73	229.3363	4,185.39
74	232.4779	4,300.84
75	235.6194	4,417.87
76	238.7610	4,536.46
77	241.9026	4,656.63
78	245.0442	4,778.36
79	248.1858	4,901.67
80	251.3274	5,026.55
81	254.4690	5,153.00

Diameter *Units*	Circumference *Units*	Area *Square Units*
82	257.6106	5,281.02
83	260.7522	5,410.61
84	263.8938	5,541.77
85	267.0354	5,674.50
86	270.1770	5,808.81
87	273.3186	5,944.68
88	276.4602	6,082.12
89	279.6017	6,221.14
90	282.7433	6,361.73
91	285.8849	6,503.88
92	289.0265	6,647.61
93	292.1681	6,792.91
94	295.3097	6,939.78
95	298.4513	7,088.22
96	301.5929	7,283.23
97	304.7345	7,389.81
98	307.8861	7,542.96
99	311.0177	7,697.69
100	314.1593	7,853.98

3.6 Geometric Formulas

Triangle

A closed, three-sided, plane figure. The sum of the angles in a triangle is always equal to 180 degrees.

Area:

$$A = \frac{b \times a}{2}$$

b = Length of the base
a = Altitude (height)

Square

A closed, four-sided, plane figure. All sides are of equal length and the opposing sides are parallel. All angles are right angles.

Area:

$$A = s^2$$

s = Length of one of the sides

Rectangle

A closed, four-sided, plane figure. The opposing sides are of equal length and are parallel. All angles are right angles.

Area:

$$A = l \times w$$

l = Length of longer side
w = length of shorter side

Parallelogram

A closed, four-sided, plane figure. The opposing sides are of equal lengths and are parallel. None of the angles are right angles.

Area:

$$A = l \times h$$

l = length of longer side
h = Height (perpendicular distance between the two longer sides)

Trapezoid

A closed, four-sided, plane figure. Two of the opposing sides are parallel, but are of unequal length.

Area:

$$A = \frac{(a + b)}{2} \times h$$

a = Length of the longest parallel side
b = Length of the shortest parallel side
h = Height (perpendicular distance between the parallel sides)

Regular Pentagon

A closed, five-sided, plane figure. All sides are of equal length, and all angles are equal.

Area:

$$A = 1.720 \times s^2$$

s = Length of one side

Regular Hexagon

A closed, six-sided, plane figure. All sides are of equal length, and all angles are equal.

Area:

$$A = 2.598 \times s^2$$

s = Length of one side

Regular Octagon

A closed, eight-sided, plane figure. All sides are of equal length, and all angles are equal.

$$A = 4.828 \times s^2$$

s = Length of one side

Circle

A closed, curved, plane figure. Every point on the curve is an equal distance from a point within the curve called the center.

Circumference:

C = i t x d

it = A constant, 3.1416
d = Diameter of a circle

Area:

A = n x r^2

or

$$A = 0.7854 \times d^2$$

it = A constant, 3.1416
r = Radius of a circle
d = Diameter of a circle

Ellipse

A closed, plane curve, generated by a point moving in such a way that the sums of the distances from two fixed points is constant.

Circumference:

C = 2 n j $\overline{a^2 � b^2}$

Area:

A = n a b

rr = A constant, 3.1416
a = Length of one of the semiaxes
b : Length of the other semiaxis

Sphere

A solld object bounded by a surface, all points of which are a constant distance from a point within, called the center.

Surface area:

$$A = 4nr^2$$

Volume:

$$V = \frac{4\pi}{3} \times r^3$$

or

$$V = \frac{\pi}{6} \times d^3$$

n = A constant, **3.1416**
r = Radius of a circle
d = Diameter of a circle

Cube

A regular solld figure having six square sides.

Surface area:

$$A = 6 X s^2$$

Volume:

$$A = s^3$$

s = Length of one of the sides

Rectangular Solld

A solid figure with six rectangular sides.

Surface area:

$$A = 2\,([l x w) + (l\ x\ h] + (w\ x\ h])$$

Volume:

$$V = l \times w \times h$$

l = Length
w = Width
h = Height

Cone

A solld figure with a circular base and sides that taper to a point.

Curved surface area:

$$A = nr\sqrt{r^2 + h^2}$$

Volume:

$$V = \frac{\pi}{3} \times r^2 h$$

n = A constant, **3.1416**
r = Radius of the base
h = Vertical height of the cone

Cyllnder

A solld figure with circular ends and parallel sides.

Surface area:

$$A = n \times d \times h$$

Volume:

$$V = 0.7854 \times d^2 \times h$$

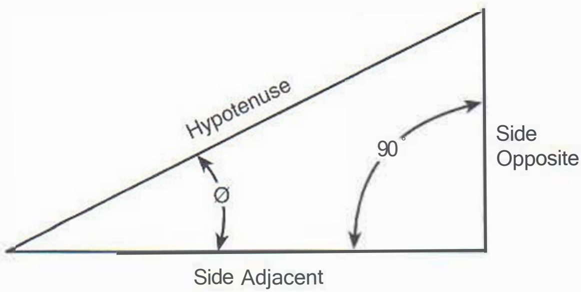
n = A constant, **3.1416**
d = Diameter of the end
h = Height of the cylinder

3.7 Trigonometric Functions

Trigonometry is based on the relationship between the angles and the lengths of the sides of a right triangle (a triangle that contains one 90-degree angle).

Since the sum of the angles in any triangle is always 180 degrees, the sum of the two acute angles in a right triangle is always 90 degrees.

The functions considered are those of one of the acute angles, called angle θ (Theta). The side of the triangle between angle θ and the right angle is the side adjacent, and the side away from angle θ is the side opposite. The side of the triangle joining the two acute angles is called the hypotenuse.



The six basic trigonometric functions, the sine (sin), cosine (cos), tangent (tan), cosecant (csc), secant (sec), and cotangent (cot) are the ratios of the lengths of the three sides of a right triangle.

$$\text{Sine (sin) } \theta = \frac{\text{side opposite}}{\text{hypotenuse}}$$

$$\text{Cosine (cos) } \theta = \frac{\text{side adjacent}}{\text{hypotenuse}}$$

$$\text{Tangent (tan) } \theta = \frac{\text{side opposite}}{\text{side adjacent}}$$

$$\text{Cosecant (csc) } \theta = \frac{1}{\sin\theta} = \frac{\text{hypotenuse}}{\text{side opposite}}$$

$$\text{Secant (sec) } \theta = \frac{1}{\cos\theta} = \frac{\text{hypotenuse}}{\text{side adjacent}}$$

$$\text{Cotangent (cot) } \theta = \frac{1}{\tan\theta} = \frac{\text{side adjacent}}{\text{side opposite}}$$

Degrees		Sines	Cosines	Tangents	Cotangents		
0°	00'	0.0000	1.0000	0.0000		90°	00'
	30'	0.0087	0.9999	0.0087	114.59		30'
1·	00'	0.0175	0.9998	0.0175	57.290	89°	00'
	30'	0.0262	0.9997	0.0262	38.188		30'
2•	00'	0.0349	0.9994	0.0349	28.636	ss·	00'
	30'	0.0436	0.9990	0.0437	22.904		30'
3•	00'	0.0523	0.9986	0.0524	19.081	87°	00'
	30'	0.0610	0.9981	0.0612	16.350		30'
4•	00'	0.0698	0.9976	0.0699	14.301	86°	00'
	30'	0.0785	0.9969	0.0787	12.706		30'
5•	00'	0.0872	0.9962	0.0875	11.430	s5•	00'
	30'	0.0958	0.9954	0.0963	10.385		30'
5•	00'	0.1045	0.9945	0.1051	9.5144	84°	00'
	30'	0.1132	0.9936	0.1139	s.n69		30'
7•	00'	0.1219	0.9925	0.1228	8.1443	83°	00'
	30'	0.1305	0.9914	0.1317	7.5958		30'
s•	00'	0.1392	0.9903	0.1405	7.1154	s2°	00'
	30'	0.1478	0.9890	0.1495	6.6912		30'
90	00'	0.1564	0.9877	0.1584	6.3138	s1°	00'
	30'	0.1650	0.9863	0.1673	5.9758		30'
10°	00'	0.1736	0.9848	0.1763	5.6713	so·	00'
	30'	0.1822	0.9833	0.1853	5.3955		30'
11°	00'	0.1908	0.9816	0.1944	5.1446	79°	00'
	30'	0.1994	0.9799	0.2035	4.9152		30'
12°	00'	0.2079	0.9781	0.2126	4.7046	78°	00'
	30'	0.2164	0.9763	0.2217	4.5107		30'
13°	00'	0.2250	0.9744	0.2309	4.3315	77°	00'
	30'	0.2334	0.9724	0.2401	4.1653		30'
14°	00'	0.2419	0.9703	0.2493	4.0108	76°	00'
	30'	0.2504	0.9681	0.2586	3.8667		30'
15°	00'	0.2588	0.9659	0.2679	3.7321	75°	00'
	30'	0.2672	0.9636	0.2773	3.6059		30'
16°	00'	0.2756	0.9613	0.2867	3.4874	74°	00'
	30'	0.2840	0.9588	0.2962	3.3759		30'
17°	00'	0.2924	0.9563	0.3057	3.2709	73°	00'
	30'	0.3007	0.9537	0.3153	3.1716		30'
18°	00'	0.3090	0.9511	0.3249	*3.01n*	72°	00'
	30'	0.3173	0.9483	0.3346	2.9887		30'
19°	00'	0.3256	0.9455	0.3443	2.9042	71•	00'
	30'	0.3338	0.9426	0.3541	2.8239		30'
20°	00'	0.3420	0.9397	0.3640	2.7475	70°	00'
	30'	0.3502	0.9367	0.3739	2.6746		30'
21°	00'	0.3584	0.9336	0.3839	2.6051	69°	00'
		Cosines	Sines	Cotangents	Tangents	Degrees	

Degrees		Sines	Cosines	Tangents	Cotangents		
	30'	0.3665	0.9304	0.3939	2.5386		30'
22°	00'	0.3746	0.9272	0.4040	2.4751	68°	00'
	30'	0.3827	0.9239	0.4142	2.4142		30'
23°	00'	0.3907	0.9205	0.4245	2.3559	67°	00'
	30'	0.3987	0.9171	0.4348	2.2998		30'
24°	00'	0.4067	0.9135	0.4452	2.2460	66°	00'
	30'	0.4147	0.9100	0.4557	2.1943		30'
25°	00'	0.4226	0.9063	0.4663	2.1445	65°	00'
	30'	0.4305	0.9026	0.4770	2.0965		30'
26°	00'	0.4384	0.8988	0.4877	2.0503	64°	00'
	30'	0.4462	0.8949	0.4986	2.0057		30'
27°	00'	0.4540	0.8910	0.5095	1.9626	63°	00'
	30'	0.4617	0.8870	0.5206	1.9210		30'
28°	00'	0.4695	0.8829	0.5317	1.8807	s2°	00'
	30'	0.4772	0.8788	0.5430	1.8418		30'
29°	00'	0.4848	0.8746	0.5543	1.8040	s1°	00'
	30'	0.4924	0.8704	0.5658	1.7675		30'
30°	00'	0.5000	0.8660	0.5774	1.7321	so°	00'
	30'	0.5075	0.8616	0.5890	1.6977		30'
31°	00'	0.5150	0.8572	0.6009	1.6643	59°	00'
	30'	0.5225	0.8526	0.6128	1.6319		30'
32°	00'	0.5299	0.8480	0.6249	1.6003	58°	00'
	30'	0.5373	0.8434	0.6371	1.5697		30'
33°	00'	0.5446	0.8387	0.6494	1.5399	57°	00'
	30'	0.5519	0.8339	0.6619	1.5108		30'
34°	00'	0.5592	0.8290	0.6745	1.4826	56°	00'
	30'	0.5664	0.8241	0.6873	1.4550		30'
35°	00'	0.5736	0.8192	0.7002	1.4281	55°	00'
	30'	0.5807	0.8141	0.7133	1.4019		30'
36°	00'	0.5878	0.8090	0.7265	1.3764	54°	00'
	30'	0.5948	0.8039	0.7400	1.3514		30'
37°	00'	0.6018	0.7986	0.7536	1.3270	53°	00'
	30'	0.6088	0.7934	0.7673	1.3032		30'
38°	00'	0.6157	0.7880	0.7813	1.2799	52°	00'
	30'	0.6225	0.7826	0.7954	1.2572		30'
39°	00'	0.6293	0.7771	0.8098	1.2349	51°	00'
	30'	0.6361	0.7716	0.8243	1.2131		30'
40°	00'	0.6428	0.7660	0.8391	1.1918	SO•	00'
	30'	0.6494	0.7604	0.8541	1.1708		30'
41°	00'	0.6561	0.7547	0.8693	1.1504	49°	00'
	30'	0.6626	0.7490	0.8847	1.1303		30'
42°	00'	0.6691	0.7431	0.9004	1.1106	48°	00'
	30'	0.6756	0.7373	0.9163	1.0913		30'
		Cosines	Sines	Cotangents	Tangents	Degrees	

Degrees		Sines	Cosines	Tangents	Cotangents		
43°	00'	0.6820	0.7314	0.9325	1.0724	47°	00'
	30'	0.6884	0.7254	0.9490	1.0538		30'
44°	00'	0.6947	0.7193	0.9657	1.0355	46°	00'
	30'	0.7009	0.7133	0.9827	1.0176		30'
45°	00'	0.7071	0.7071	1.0000	1.0000	45°	00'
		Cosines	Sines	Cotangents	Tangents	Degrees	

3.8 Powers of Ten

Numbers larger than one:

Move the decimal to the left until you have a number between one and ten. Multiply this number by ten raised to the power equal to the number of places you moved the decimal.

$$1 = 1 \times 10^{0}$$
$$10 = 1 \times 10^{1}$$
$$100 = 1 \times 10^{2}$$
$$1{,}000 = 1 \times 10^{3}$$
$$10{,}000 = 1 \times 10^{4}$$
$$100{,}000 = 1 \times 10^{5}$$
$$1{,}000{,}000 = 1 \times 10^{6}$$
$$10{,}000{,}000 = 1 \times 10^{7}$$
$$100{,}000{,}000 = 1 \times 10^{8}$$
$$1{,}000{,}000{,}000 = 1 \times 10^{9}$$
$$10{,}000{,}000{,}000 = 1 \times 10^{10}$$
$$100{,}000{,}000{,}000 = 1 \times 10^{11}$$
$$1{,}000{,}000{,}000{,}000 = 1 \times 10^{12}$$

Numbers smaller than one:

Move the decimal to the right until you have a number between one and ten. Multiply this number by ten raised to the negative power equal to the number of places you moved the decimal.

$$0.1 = 1 \times 10^{-1}$$
$$0.01 = 1 \times 10^{-2}$$
$$0.001 = 1 \times 10^{-3}$$
$$0.000\ 1 = 1 \times 10^{-4}$$
$$0.000\ 01 = 1 \times 10^{-5}$$
$$0.000\ 001 = 1 \times 10^{-6}$$
$$0.0000001 = 1 \times 10^{-7}$$
$$0.000\ 000\ 01 = 1 \times 10^{-8}$$
$$0.000\ 000\ 001 = 1 \times 10^{-9}$$
$$0.000\ 000\ 000\ 1 = 1 \times 10^{-10}$$
$$0.000\ 000\ 000\ 01 = 1 \times 10^{-11}$$
$$0.000\ 000\ 000\ 001 = 1 \times 10^{-12}$$

Addition of numbers using powers of ten:

1. Change all the numbers so they will have the same power of ten.
2. Add the numbers.
3. The answer will have the same power of ten.

Add: 356 + 1,254

$356 = 3.56 \times 10^2$

$1{,}254 = 1.254 \times 10^3$

Change 1.254×10^3 to 12.54×10^2, and add:

$3.56 \times 10^2 + 12.54 \times 10^2 : 16.1 \times 10^2 : 1{,}610$

Subtraction of numbers using powers of ten:

1. Change all the numbers so they will have the same power of ten.
2. Subtract the smaller number from the larger.
3. The answer will have the same power of ten.

Subtract: 1,254 - 356

$1{,}254 : 1.254 \times 1o^3$

$356 = 3.56 \times 10^2$

Change 1.254×10^3 10 12.54×10^2, and subtract:

$12.54 \times 10^2 - 3.56 \times 10^2 = 8.98 \times 10^2 : 898$

Multiplication of numbers using powers of ten:

1. Change all the numbers Into powers of ten.
2. Multiply the numbers.
3. Add the powers of ten and use this as !he power of ten for the answer.

Multiply: 0.356 x 1,254

$0.356 = 3.56 \times 10{\cdot}1$

$1{,}254 : 1.254 \times 10^1$

$3.56 \times 10{\cdot}1 \times 1.254 \times 10^3 : 4.464 \times 10^2 : 446{,}4$

Division of numbers using powers of ten:

1. Change all of the numbers into powers of ten.
2. Divide the numbers.
3. Subtract the power of ten of the denominator from the power of ten of the numerator and use this as the power of ten for the answer.

Divide: 1,254 by 356

$1{,}254 : 1.254 \times 10^{3}$

$356 = 3.56 \text{ X } 10^{2}$

$1.254 \times 10^{3} + 3.56 \times 10^{2} : 0.352 \times 10^{1} : 3.52$

3.9 Number Systems

Binary Equivalent of Decimal

Decimal	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111

Octal Equivalent of Decimal

Decimal	Octal
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	10
9	11
10	12

Binary Equivalent of Octal

Octal	Binary
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

Hexadecimal Number System

Decimal	Hex	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111

Binary Coded Decimal Equivalent of Decimal

Decimal	BCD
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

The Gray Code

The gray code is used for optical or mechanical shaft-position encoders because of its speed. Only one bit changes between each successive word.

Decimal	Gray	Binary
0	0000	0000
1	0001	0001
2	0011	0010
3	0010	0011
4	0110	0100
5	0111	0101
6	0101	0110
7	0100	0111
8	1100	1000
9	1101	1001
10	1111	1010
11	1110	1011
12	1010	1100
13	1011	1101
14	1001	1110
15	1000	1111

American Standard Code for Information Interchange (ASCII)

ASCII	Decimal	Octal	Hex
NUL	0	000	00
SOH	1	001	01
STX	2	002	02
ETX	3	003	03
EQT	4	004	04
ENO	5	005	05
ACK	6	006	06
BEL	7	007	07
BS	8	010	08
HT	9	011	09
LF	10	012	0A
VT	11	013	0B
FF	12	014	0C
CR	13	015	0D
SO	14	016	0E
SI	15	017	0F
OLE	16	020	10
DC1	17	021	11
DC2	18	022	12
DC3	19	023	13
DC4	20	024	14
NAK	21	025	15
SYN	22	026	16
ETB	23	027	17
CAN	24	030	18
EM	25	031	19
SUB	26	032	1A
ESC	27	033	18
FS	28	034	1C
GS	29	035	10
RS	30	036	1E
US	31	037	1F
SP	32	040	20
!	33	041	21
"	34	042	22
#	35	043	23
$	36	044	24
%	37	045	25
&	38	046	26
'	39	047	27
(	40	050	28

ASCII	Decimal	Octal	Hex	ASCII	Decimal	Octal	Hex
)	41	051	29	u	85	125	55
*	42	052	2A	V	86	126	56
+	43	053	28	W	87	127	57
,	44	054	2C	X	88	130	58
-	45	055	2D	y	89	131	59
.	46	056	2E	Z	90	132	SA
/	47	057	2F	[	91	133	58
0	48	060	30	\	92	134	SC
1	49	061	31	|	93	135	50
2	50	062	32	^	94	136	SE
3	51	063	33	—	95	137	SF
4	52	064	34	`	96	140	60
5	53	065	35	a	97	141	61
6	54	066	36	b	98	142	62
7	55	067	37	c	99	143	63
8	56	070	38	d	100	144	64
9	57	071	39	e	101	145	65
:	58	072	3A	f	102	146	66
;	59	073	38	g	103	147	67
<	60	074	3C	h	104	150	68
=	61	075	30	I	105	151	69
>	62	076	3E	]	106	152	6A
?	63	077	3F	k	107	153	68
@	64	100	40	l	108	154	6C
A	65	101	41	m	109	155	60
8	66	102	42	n	110	156	6E
C	67	103	43	o	111	157	6F
0	68	104	44	p	112	160	70
E	69	105	45	q	113	161	71
F	70	106	46	r	114	162	72
G	71	107	47	s	115	163	73
H	72	110	48	I	116	164	74
I	73	111	49	u	117	165	75
J	74	112	4A	v	118	166	76
K	75	113	48	w	119	167	77
L	76	114	4C	x	120	170	78
M	77	115	40	y	121	171	79
N	78	116	4E	z	122	172	7A
O	79	117	4F	{	123	173	76
p	80	120	50	l	124	174	7C
Q	81	121	51	}	125	175	70
A	82	122	52	~	126	176	7E
S	83	123	53	DEL	127	177	7F
T	84	124	54				

Special Control Functions Used in ASCII:

NUL	Null
SOH	Start of Heading
STX	Start of Text
ETX	End of Text
EOT	End of Transmission
ENQ	Enquiry
ACK	Acknowledge
BEL	Bell (audible signal)
BS	Backspace
HT	Horizontal Tabulation
LF	Line Feed
VT	Vertical Tabulation
FF	Form Feed
CR	Carriage Return
SO	Shift Out
SI	Shift In
SP	Space
OLE	Data Link Escape
DC1	Device Control 1
DC2	Device Control 2
DC3	Device Control 3
DC4	Device Control 4
[illegible]	[illegible]
ETB	End of Transmission Block
CAN	Cancel
EM	End of Message
SUB	Substitute
ESC	Escape
FS	File Separator
GS	Group Separator
RS	Record Separator
US	Unit Separator
DEL	Delete

Section 4: Aircraft Drawings

4.1 Types of Aircraft Drawings

There are a number of types of drawings used in aircraft manufacture and maintenance. Each type of drawing has a definite function and purpose.

Sketches

These are rough drawings made without the use of instruments. They are used to convey only a specific bit of information and include the minimum amount of detail needed to manufacture the part.

Detail Drawings

Detail drawings are made with the use of instruments, or on a computer. They include all of the information needed to fabricate a part, including dimensions.

Assembly Drawings

An assembly drawing shows all of the components in an assembly. The components are shown in exploded view to display the way they are assembled. A parts list is included showing the reference number, part number, description, quantity per assembly, and model usage for each component.

Installation Drawings

These drawings show the location of the parts and assemblies on the completed aircraft and identifies all of the detail parts used in the installation.

Sectional Drawings

These show the way a component would appear if it were cut through the middle. Different types of sectional lines and cross-hatching show the different types of materials used in the component.

A half-sectional drawing shows a part as it would appear with only one half a sectional view and the other half a plain view.

Cutaway Drawing

A cutaway drawing shows the outside of a component with part of it cut away to show the parts on the inside.

Exploded-View Drawing

Exploded-view drawings are similar to assembly drawings. All of the parts in a component are spread out to show what each looks like and their relationship to other parts.

Schematic Diagram

A schematic diagram shows the relative location of all of the parts in a system but does not give the physical location in the aircraft. Schematic diagrams are extremely useful in troubleshooting a system.

Block Diagram

Block diagrams show the various functions of a system but do not Include any details. Lines connecting the blocks show the direction of flow of signals or other forms of information. Block diagrams help explain the way a complex system works, and they are often used in troubleshooting.

Repair Drawings

These are drawings used to show the way a repair is made. They are used h aircraft manufacturer's maintenance and repair manuals to Illustrate typical repairs. No dimensions are given. but enough information is provided thal an experienced technician can use the drawing as a guide to make an airworthy repair.

Wiring Diagrams

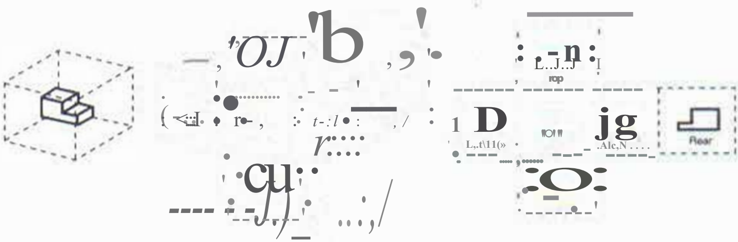
Wiring diagrams show all of the wires h a particular section of an aircraft electrical system, The parts list accompanying the drawing provides the wire size, wire number, and the part number of the terminals on each end of each wire.

Pictorial Diagrams

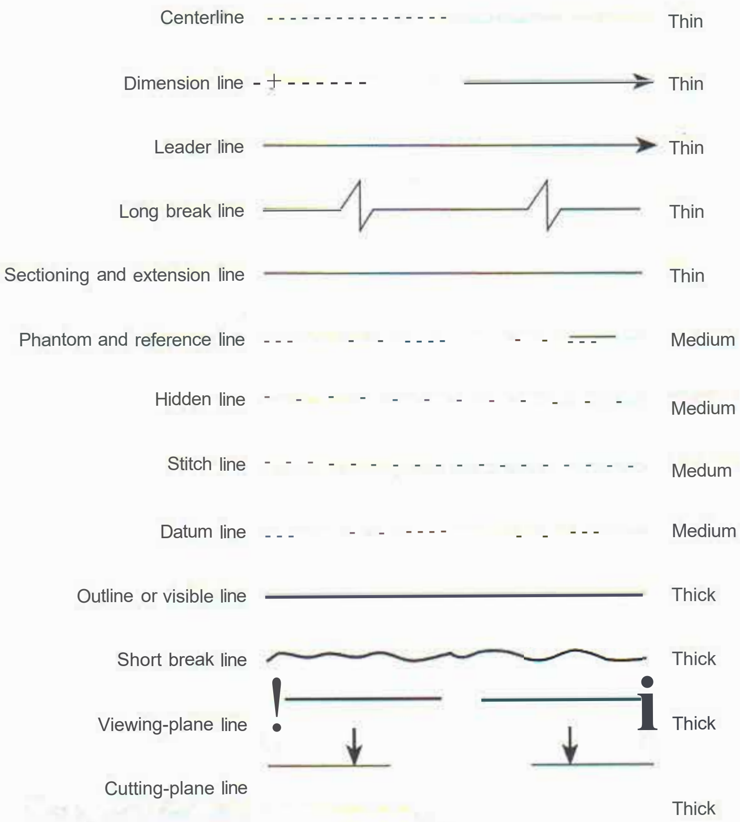
Pictorial diagrams show the components as they.actually appear, rather than using conventional symbols. Pictorial diagrams are often used for electrical systems h Pilot's Operating Handbooks.

Orthographic Projections

There are six possible views h an orthographic projection:

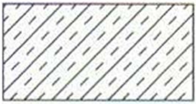


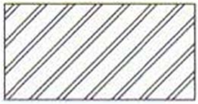
4.2 Meaning of Lines

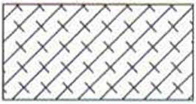


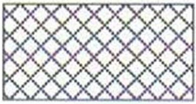
4.3 Material Symbols


Cast iron

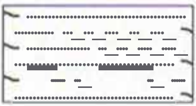

Copper, brass, and copper alloys


Steel and wrought iron

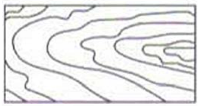

Aluminum, magnesium and their alloys

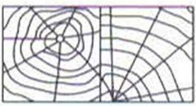

Babbit, lead, zinc and their alloys

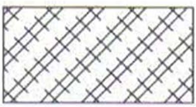

Rubber, plastic, electrical Insulation

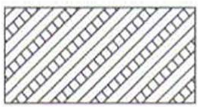

Fabric and flexible materials


Electrical windings


Wood, with the grain


Wood, across the grain


Titanium


Beryllium

4.4 Location Identification

Fuselage Stations

Locations along the length of a fuselage are identified by fuselage station (FS) numbers which represent the distance in inches from FS-O, a point chosen by the aircraft manufacturer from which all longitudinal measurements are made. For example, FS-199 is 199 inches aft of FS-0.

Water Lines

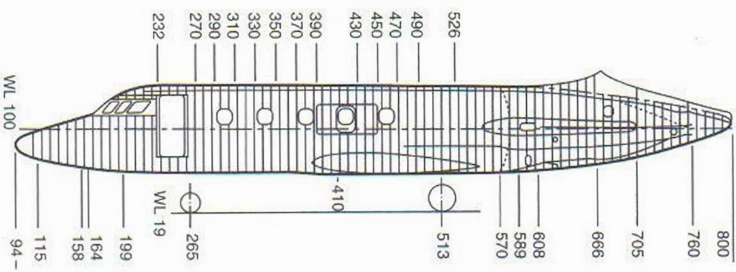
Vertical locations are identified by water lines (WL). Water line zero (WL-0) is a line chosen by the aircraft manufacturer as a vertical reference line. Locations above WL-0 are positive and those below are negative. WL+20 is a plane 20 inches above WL-0.

Butt Lines

Lateral locations are identified by butt lines (BL, or buttock lines) that are distances to the left or right in inches from BL-O, a vertical plane through the center of the fuselage. BL-36R is a vertical plane 36 inches to the right (when facing forward) from BL-0.

Wing and Horizontal Stabilizer Stations

These stations are locations in inches left or right, along the wing or stabilizer span measured from the center line of the fuselage, BL-0.



Fuselage stations and water lines

Section 5: Aircraft Electrical Systerrys

5.1 Electrical Symbols

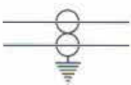
Conductors

 Conductors, crossing but not connected

 Conductors, crossing and connected

 Spare conductor with end insulated

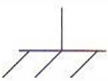
 Shielded conductor

 Shielded double conductor

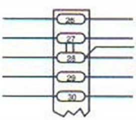
 Shielded and twisted double conductor

 Coaxial conductor

 Ground connection (earth ground)

 Chassis ground connection (not necessarily at ground potential)

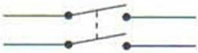
 Terminal strip



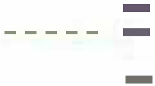
Terminal strip

Switches

Single-pole, single-throw switch



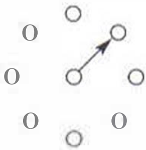
Double-pole, single-throw switch



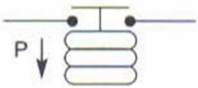
Single-pole, double-throw switch

Double-pole, double-throw switch

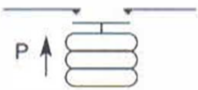
Single-pole, double-throw switch - normally closed, momentarily open



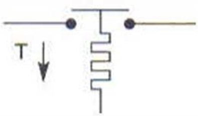
Eight-position rotary switch



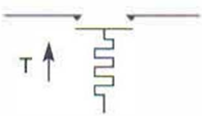
Pressure-actuated switch-closes on decreasing pressure



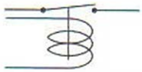
Pressure-actuated switch-closes on Increasing pressure



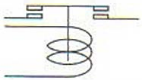
Temperature-actuated switch-closes on decreasing temperature



Temperature-actuated switch-closes on increasing temperature



Relay switch



Solenoid switch

Power Sources

Battery

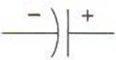
Generator

Thermocouple

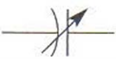
Piezoelectric crystal

Capacitors

Fixed, nonelectrolytic capacitor



Electrolytic capacitor



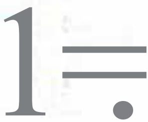
Variable capacitor

Inductors

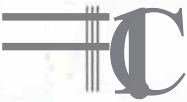
Air-core inductor

Iron-core inductor

Variable Inductor



Autotransformer



Iron-core transformer

Air-core transformer

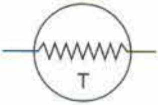
Resistors

Fixed resistor

Variable resistor-rheostat

Variable resistor-potentiometer

Tapped resistor

1 W	Resistor installed external to LAU (line replaceable unit)
	Temperature-sensitive resistor
—.ru1J1–	Heater element resistor

Indicators

-0-	Voltmeter
--0-	Ammeter
--0---	Wattmeter
-0--	Ohmmeter
-----e-	Milliammeter
-e-	Microammeter

Semiconductor Devices

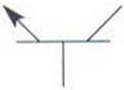
Diode

Zener diode

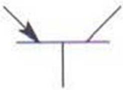
Light emitting diode

Light sensing diode

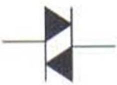
Silicon controlled rectifier



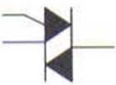
NPN bipolar transistor



PNP bipolar transistor

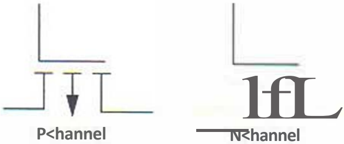


Diac



Triac

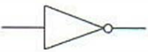
Junction field effect transistor



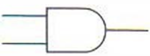
Insulated gate field effect transistor

Logic Devices

Buffer or amplifier



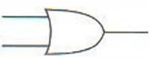
Inverter



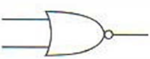
AND gate

NANO gate

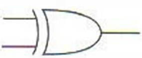
AND gate with one input having an active low



OR gate

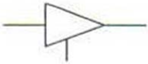


NOR gate

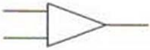


EXCLUSIVE OR (XOR} gate

OR gate with one input having an active low



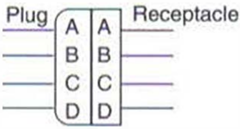
Three-state buffer



Operational amplifier

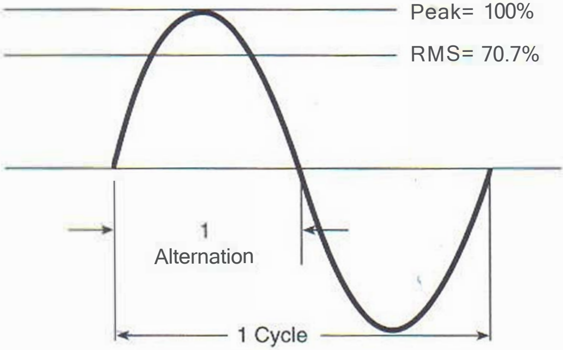
Connectors

Wire splice



Quick-disconnect connector

5.2 Alternating Current Terms and Values



Peak value: The maximum amplitude of current or voltage in one alternation.

Peak-to-peak value: The voltage or current measured from a positive peak to a negative peak.

rms value: Root mean square, or effective value. This is 0.707 times peak value. One amp rms of sine wave AC produces the same amount of heat as one amp of DC. One amp rms of sine wave AC has a peak value of 1.414 amp.

Cycle: One complete series of values of alternating current in which the voltage or current starts from zero, rises to a positive peak, drops back through zero to a negative peak, and then returns to zero.

Alternation: One half cycle of alternating current.

Period: The time required for one cycle of alternating current.

Frequency: The number of cycles of alternating current that occur in one second.

Phase: The angular relationship between the current and voltage in an AC circuit. Inductance and capacitance in a circuit cause the current to either lag or lead the voltage.

Power: Power in an AC circuit is determined by the voltage and the amount of current that is in phase with the voltage.

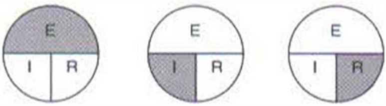
Power factor: The percentage of current in an AC circuit that is in phase with the voltage.

5.3 Ohm's Law Relationships

Ohm's law gives us the relationship between voltage, current, resistance, and power in an electrical circuit. When we know any two values, we can find either of the others by using the appropriate formula.

E = Voltage (volts)
I = Current (amps)
A= Resistance (ohms)
P= Power (watts)

To visualize the relationships, use these circles. The shaded value is the product or the quotient of the unshaded values.



To Find	Known Values	Formula
E	I & R	E:=IxR
E	P & I	$E = \frac{p}{T}$
E	P & R	$E = \sqrt{P \times R}$
I	E & R	$I = \frac{E}{R}$
I	P & E	$I = \frac{P}{E}$
I	P & R	I - P

To Find	Known Values	Formula
R	E & I	$R = \frac{E}{I}$
R	E & P	$R = \frac{E^2}{P}$
R	P & I	$R = \frac{P}{I^2}$
P	I & E	$P = I \times E$
P	I & R	$P = I^2 \times R$
P	E & R	$P = \frac{E^2}{R}$

5.4 Electrical Formulas

Formulas Involving Resistance

Resistors in series:

$$Ar = R, + R_2 + R_3 + \ldots$$

Ar = Total resistance
R_1, R_2, R_3 = Value of individual resistances

Resistors of the same value in parallel:

$$Rr = \frac{R}{n}$$

R_1 = Total resistance
R = Value of a single resistor
n = Number of resistors

Two resistors of different value in parallel:

$$Rr = \frac{R1 \times R2}{R, + R_2}$$

Rr = Total resistance
R_1 = Value of first resistor
R_2 = Value of second resistor

To find the value of one resistor in a parallel combination when the total resistance and the value of lhe other resistor are known:

$$R, = \frac{\cdot Ar \times R2}{Rr - A_2}$$

Ar = Total resistance
$A,$ = Value of first resistor
R_2 = Value of second resistor

More than two resistors of different values in parallel:

$$R_T = \cfrac{1}{\cfrac{1}{R_1} + \cfrac{1}{R_2} + \cfrac{1}{R_3} + \cfrac{1}{R_4}}$$

Rr = Total resistance
R_1, R_2, R_3, R_4 = Value of each resistor

The total resistance of any number of resistors connected in parallel may be found by using a calculator with a reciprocal (1/x) key.

Enter the problem in this sequence:

(Ar) (1/x) + (R_2) (1/x) + (R_3) (1/x) + (R_4) (1/x) = (1/x)

The number displayed after the (1/x) key is pressed the last time is the value of the total resistance.

Formulas Involving Capacitance

Capacity of a capacitor:

$$C = 0.2235\ (\ t\ )\ (\ N - 1\ )$$

C = Capacity in picofarads
K = Dielectric constant
A = Area of plates in square inches
D = Thickness of dielectric in inches
N = Number of plates

Capacitors in parallel:

$$C_T = C_1 + C_2 + C_3 + \cdots$$

C r = Total capacitance
C_1, C_2, C_3 = Value of individual capacitors

Capacitors of the same value in series:

$$C_T = \frac{C}{n}$$

C_T = Total capacitance
C = Value of a single capacitor
n = Number of capacitors

Two capacitors of different values in series:

$$C_T = \frac{C_1 \times C_2}{C_1 + C_2}$$

C_T = Total capacitance
C_1 = Value of one capacitor
C_2 = Value of other capacitor

More than two capacitors of different values in series:

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4}}$$

C_T = Total capacitance
C_1, C_2, C_3, C_4 = Value of Individual capacitors

The total capacitance of any number of capacitors connected in series may be found by using a calculator with a reciprocal (1/x) key.

Enter the problem in this sequence:

(C_1) (1/x) + (C_2) (1/x) + (C_3) (1/x) + (C_4) (1/x) = (1/x)

The number displayed after the (1/x) key is pressed the last time is the value of the total capacitance.

Charge stored in a capacitor:

$$Q = C \times E$$

Q = Charge in coulombs
C = Capacitance in farads
E = Voltage across the capacitor in volts

Energy stored in a capacitor:

$$W = \frac{(C \times E^2)}{2}$$

W = Stored energy in joules (watt-seconds)
C = Capacitance in farads
E = Applied voltage in volts

Capacitive reactance:

$$Xe = \frac{1}{2itEC}$$

Xe = Capacitive reactance in ohms
2;i; = A constant, 6.2832
F = Frequency in hertz
C = Capacitance in farads

Because there are constants in both the numerator and the denominator, this formula can be changed to:

$$X_C = \frac{159{,}200}{Fe}$$

Xe = Capacitive reactance in ohms
159,200 = A constant (1,000,000 + 2it)
F = Frequency in hertz
C = Capacitance in microfarads

Formulas Involving Inductance

Inductors in series with no mutual inductance:

$$Lr = L1 + L2 + L3 + \cdots$$

Lr = Total inductance
L_1, L_2, L3 = Value of each inductor

Two inductors of different size in parallel with no mutual inductance:

$$Lr = \frac{L_1 \times L2}{L_1 + L_2}$$

Lr = Total inductance
L_1, L_2 = Value of individual inductors

More than two inductors of different size in parallel with no mutual inductance:

$$L_T = \cfrac{1}{\cfrac{1}{L_1} + \cfrac{1}{L_2} + \cfrac{1}{L_3} + \cfrac{1}{L_4}}$$

L_T = Total inductance
L_1, L_2, L_3, L_4 = Value of individual inductors

The total Inductance of any number of inductors connected in parallel with no mutual inductance may be found by using a calculator with a reciprocal (1/x) key.

Enter the problem in this sequence:

$(L_T)\ (1/x) + (L_2)\ (1/x) + (L_3)\ (1/x) + (L_4)\ (1/x) = (1/x)$

The number displayed after the (1/x) key is pressed the last time is the total Inductance.

Mutual Inductance or two coils:

$$L_M = \frac{L_A - L_O}{4}$$

L_M = Mutual inductance in the same units as that or the Individual Inductances
L_A = Total inductance of the two coils with their fields aiding
L_0 = Total Inductance of the two coils with their fields opposing

Mutual inductance of two inductors connected in series with fields aiding:

$$L_T = L_1 + L_2 + 2M$$

L_T = Total inductance
L_1 = Inductance of the first inductor
L_2 = Inductance of the second inductor
M = Mutual inductance

Total inductance of two inductors connected in series with fields opposing:

$$L_T = L_1 + L_2 - 2M$$

L_T = Total inductance
L_1 = Inductance of the first inductor
L_2 = Inductance of the second inductor
M = Mutual inductance

Coefficient of coupling:

$$K = \frac{M}{\sqrt{L_1 \times L_2}}$$

K = Coefficient of coupling
M = Mutual inductance
L_1 = Inductance of first inductor
L_2 = Inductance of second inductor

Energy stored in an inductor:

$$W = \frac{L \times I^2}{2}$$

W = Stored energy in joules (watt-seconds)
L = Inductance in henries
I = Current in amperes

Inductive reactance:

$$X_L = 2\pi FL$$

X_L = Inductive reactance in ohms
2π = A constant, 6.2832
L = Inductance in henries
F = Frequency in hertz

Formulas Involving Both Capacitance and Inductance

Resonant *Frequency*

The resonant frequency of an AC circuit is that frequency which causes the capacitive reactance and the inductive reactance to be the same. It may be found by the formula:

$$F_R = \frac{1}{2\pi\sqrt{LC}}$$

F_R = Resonant frequency in hertz
2π = A constant, 6.2832
L = Inductance in henries
C = Capacitance in farads

Total Reactance

Current in a purely capacitive circuit leads the voltage by 90 degrees, and current in a purely Inductive circuit lags 90 degrees behind the voltage.

Capacitive reactance and inductive reactance are 180 degrees out of phase with each other, and they cancel. Total reactance is the difference between the two reactances and is the type or the greater reaclance.

$$X_T = X_C - X_L \quad \text{or} \quad X_T = X_L - X_C$$

Impedance

Impedance is the total opposition to the flow of alternating current, and it is the vector sum of capacitive reactance, inductive reactance, and resistance. It is found by the following formulas.

Impedance in a series circuit:

$$Z = \sqrt{R^2 + X^2}$$

Z = Impedance in ohms
R = Total resistance in ohms
X = Total reactance in ohms

Impedance in a parallel circuit:

$$Z = \frac{R \times X}{\sqrt{R^2 + X^2}}$$

Z = Impedance in ohms
R = Total resistance in ohms
X = Total reactance in ohms

5.5 Electrical System Installation

Selection of Wire Size

Aircraft electrical wire is measured in American Wire Gage (AWG) units. The larger the number, the smaller the diameter of the wire. The actual American wire gage, shown in Figure 5.5.1, is a circular piece of steel with notches cut in its periphery. The width of each notch is the diameter of the wire whose gage number is beside the notch.

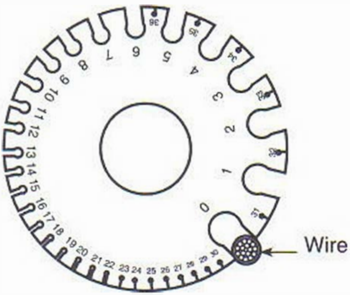


***Figure** 5.5.1. An American wire gage is used to determine the size of an aircraft electrical wire.*

When selecting the proper gage of wire, consider both the current-carrying capability of the wire and the voltage drop caused by it. The charts in Figure 5.5.2 give the current-carrying capability of copper wire in sizes 20 through 0000, and aluminum wire in sizes 6 through 0000. When wires are routed in bundles, the maximum current is less than when the **wire** is routed by itself in free air. Wires in a bundle cannot readily dissipate heat.

Nominal system voltage	Allowable voltage drop	
	Continuous load	Intermittent load
14	0.5	1.0
28	1.0	2.0
115	4.0	8.0
200	7.0	14.0

***Figure** 5.5.2. Allowable voltage drop in an aircraft electrical system*

The allowable voltage drop in an aircraft electrical system is determined by both the nominal system voltage and whether the component is operating continuously or intermittently. The chart in Figure 5.5.3 gives the allowable voltage drops for the most commonly used aircraft electrical systems.

To find the correct size copper wire for a continuous load, use the chart in Figure 5.5.3.

For example: Find the size wire needed to supply 30 amps continuously to a component in a 28-volt electrical system. The wire must be 60 feet long.

1. Follow the 30-amp diagonal line down until it crosses the horizontal line for 60 feet in the 28-vott column.
2. These lines cross between the vertical lines for 6-gage and 8-gage wires. Always use the larger wire, so choose a 6-gage wire. Thirty amps of current will not produce more than the allowable 1-volt drop when it flows through 60 leet of 6-gage wire.
3. The intersection of these two lines is above curve 1, which means that a 6-gage wire carrying 30 amps of current can be routed in a bundle without causing excessive heat. This can be proved by the chart in Figure 5.5.4, which shows that a 6-gage copper wire in a bundle can carry 60 amps.

To find the correct size copper wire for an intermittent load, use the chart in Figure 5.5.5.

For example: Find the size wire needed to supply 200 amps to a landing gear motor in a 28-volt electrical system. The wire must be 1Ofeet long.

1. In this example, the current-carrying capability of the wire is the limiting factor, rather than the voltage drop. Assume the wire will be routed by Itself in free air. The chart in Figure 5.5.4 shows that at least a 1-gage wire must be used. This size wire will carry 211 amps in free air.
2. Follow the 200-amp diagonal line down until it intersects the vertical line for a 1-gage wire. This intersection is about the location of a horizontal line for 67 feet in the 28-volt column. This means that it would take 67 feet of 1-gage wire to cause a 2-volt drop (the voltage drop allowed for an Intermittent load in a 28-volt system). The wire is only 10 feet long, so there will be much less than the allowable voltage drop.

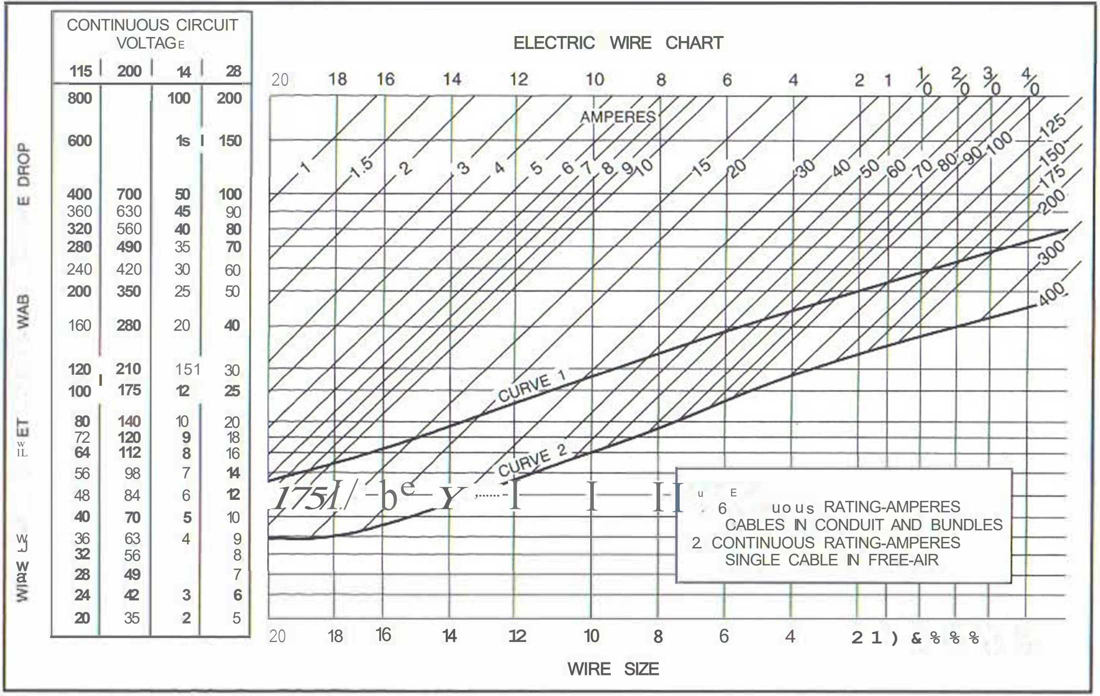


Figure 5.5.3. Wire selection chart for continuous loads

Copper wire current-carrying capability		
Wire size (gage)	Max. amps single wire in free air	Max. amps wire in bundle or conduit
AN-20	11	7.5
AN-18	16	10
AN-16	22	13
AN-14	32	17
AN-12	41	23
AN-10	55	33
AN-8	73	46
AN-6	101	60
AN-4	135	80
AN-2	181	100
AN-1	211	125
AN-0	245	150
AN-00	283	175
AN-000	328	200
AN-0000	380	225

Aluminum wire current-carrying capability		
Wire size (gage)	Max. amps single wire in free air	Max. amps wire in bundle or conduit
AL-6	83	50
AL-4	108	66
AL-2	152	90
AL-0	202	123
AL-00	235	145
AL-000	266	162
AL-0000	303	190

Figure 5.5.4. Current-carrying capability of copper and aluminum wire

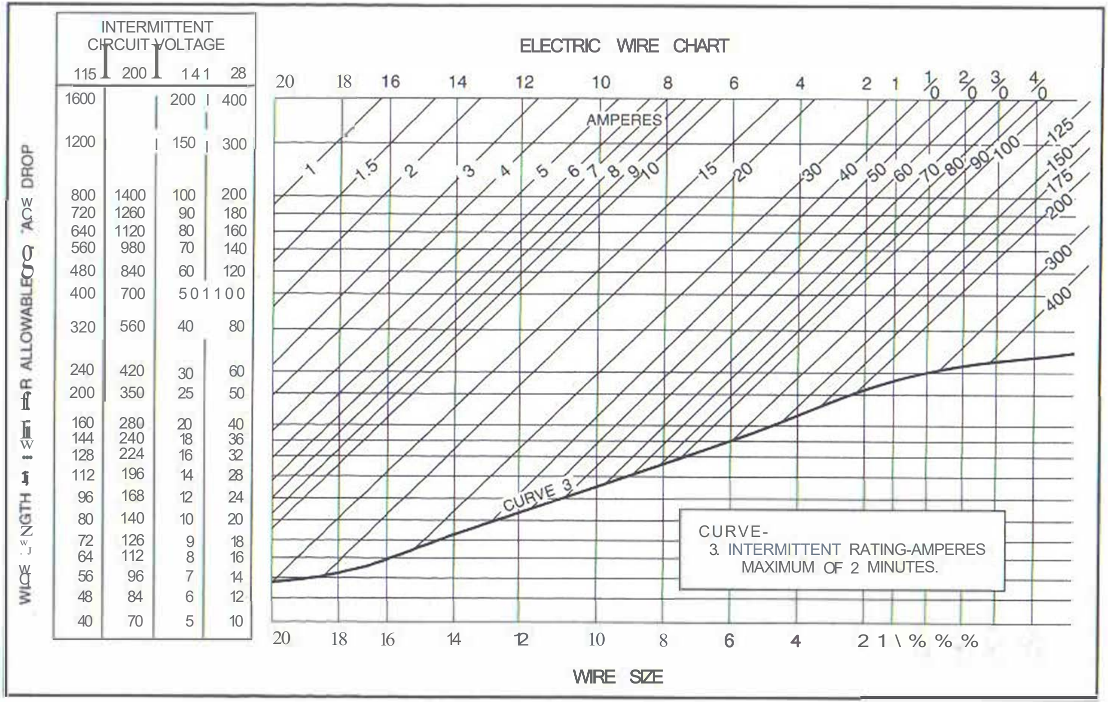
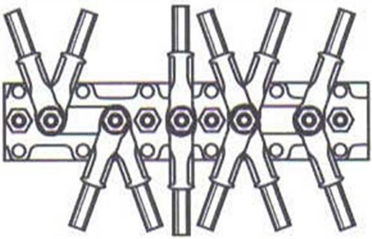


Figure 5.5.5. *Wire selection chart for intermittent loads*

Notes on Wire Installation

1. All wires should be marked along their entire length with the wire identification number specified by the aircraft manufacturer.
2. Wires should have a 6-inch diameter loop near their connection to the component to which they are connected, in order to accommodate any wire tensions that result from aircraft structural deformations during a crash.
3. Electrical wire bundles should be routed along the strongest aircraft structural members, and should not cross areas where there is likely to be severe structural deformation during a crash.
4. When electrical wire bundles pass through a structural member, the holes shOuld be 8 to 12 times the diameter of the bundle. The edges of the hole should be protected with grommets, and the wire bundle should be securely clamped to the structure.
5. If a wire bundle is routed parallel to a fluid line, the wire bundle should be above the fluid line and should not be secured to the line.
6. No more than four wire terminals should be secured to any single stud in a terminal strip. If more wires must be connected at a single point. use more than one stud, and connect the studs with metal bus bars.



*Flgu,.. **5.5.6.** Never insts/1 more thsn four wire terminals on any single terminal-strip lug. If more wires should be connected, Join two adjacent lugs with a connector strip.*

7. All bonding jumpers should be as short as possible and must not have more than 0.003-ohm resistance. The jumper must not interfere with the free movement of the component that is being bonded.
8. When a ground connection is made to an anodized aluminum alloy component, the oxide film must be removed at the location where the connection is made. After the connection is made, the area must be protected against corrosion.

9. When wire bundles must be routed through areas where they can likely be damaged, they should be protected by routing them through a flexible or rigid conduit.
   a. The conduit must not be installed in such a way that it can be used as a step or a hand hold.
   b. The inside diameter of the conduit must be large enough that the wire bundle does not fill more than 80% of the conduit area.
   c. Drain holes must be provided at the lowest point in a conduit run.
   d. Rigid conduit must not be flattened in the bends enough to decrease its minimum diameter to less than 75 percent of the original diameter.
   e. All burrs must be removed from the ends of the conduit and from any drain holes.
   f. Do not use a smaller bend radius for rigid conduit than is allowed by the chart in Figure 5.5.7.
   g. Do not use a smaller bend radius for flexible aluminum or brass conduit than is allowed by the chart in Figure 5.5.8.

Bend radii allowed for rigid conduit	
Nominal tube O.D. (inches)	Minimum bend radius (inches)
1/8	3/8
3/16	7/16
1/4	9/16
3/8	15/16
1/2	1-1/4
5/8	1-1/2
3/4	1-3/4
1	3
1-1/4	3-3/4
1-1/2	5
1·3/4	7
2	8

Figure 5.5.7. Minimum bend radius for rigid electrical conduit

I

Bend radii allowed for flexible aluminum or brass conduit	
Nominal I.D. of conduit (inches)	Minimum bend radius (inches)
3/16	2-1/4
1/4	2-3/4
3/8	3-3/4
1/2	3-3/4
5/8	3-3/4
3/4	4-1/4
1	5-3/4
1-1/4	8
1-1/2	8-1/4
1-3/4	9
2	9-3/4
2-1/2	10

Figure 5.5.8. Minimum bend radius for flexible electrical conduit

10. Securely attach all wire bundles to the aircraft structure with cushioned clamps. There should be no more slack between supports than that which will allow a 1/2-inch deflection.

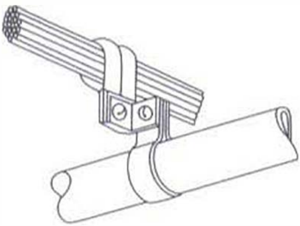


Figure 5.5.9. Support wire bundles from aircraft tubing with clamps. The clamp around the wire should be cushioned.

11. Wrap the cord twice around wire bundles secured with individual ties, and secure them with a clove hitch and a square knot.

Switch Derating Factors

Incandescent lamps, motors, relays, and heaters all allow a large amount of current to flow when the switch is first closed. Soon after the current begins to flow, its value drops off to a nominal value. Because of this high inrush, switches in these circuits must be derated. The chart in Figure 5.5.10 shows the derating factors to be used.

Nominal system DC voltage	Type of load	Derating factor
24 volts	Lamp	8
24 volts	Inductive	4
24 volts	Resistive	2
24 volts	Motor	3
12 volts	Lamp	5
12 volts	Inductive	2
12 volts	Resistive	1
12 volts	Motor	2

Example: A switch installed in a 24-volt circuit to control a 100-watt incandescent lamp must have a current rating of more than 33.3 amps.

Figure 5.5.10. *Switch derating factors*

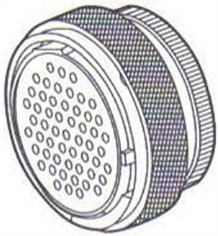
Wire and Circuit Protectors

Fuses and circuit breakers are installed in an aircraft to protect the wiring from overheating due to excessive current. The chart in Figure 5.5.11 shows the size circuit protectors that should be used with the various gage wires.

AN copper wire (gage)	Circuit breaker (amps)	Fuse (amps)
22	5	5
20	7.5	5
18	10	10
16	15	10
14	20	15
12	25	(30) 20
10	35	(40) 30
8	50	50
6	80	70
4	100	70
2	125	100
1		150
0		150

Values in parentheses may be substituted when the indicated ratings are not available.

Figure 5.5.11. *Wire and circuit protector chart*



MS27480 F 10 A 6 P B

MIL SPECIFICATION

CLASS

SHELL SIZE

POLARIZATION

CONTACT STYLE

INSERT ARRANGEMENT

FINISH

MS27472	WALL MOUNT RECEPTACLE
MS27473	STRAIGHT PLUG
MS27474	JAM NUT RECEPTACLE
MS27475	HERMETIC WALL MOUNT RECEPTACLE
MS27478	HERMETIC BOX MOUNT RECEPTACLE
MS274n	HERMETIC JAM NUT RECEPTACLE
MS27478	HERMETIC SOLDER MOUNT RECEPTACLE
MS27479	WALL MOUNT RECEPTACLE (NOTE i)
MS27480	STRAIGHT PLUG (NOTE 1)
MS27481	JAM NUT RECEPTACLE (NOTE 1)
MS27482	HERMETIC WALL MOUNT RECEPTACLE (NOTE 1)
MS27483	HERMETIC JAM NUT RECEPTACLE (NOTE 1)
MS27484	STRAIGHT PLUG, EMI GROUNDING
MS27497	WALL RECEPTACLE. BACK PANEL MOUNTING
MS27499	BOX MOUNTING RECEPTACLE
MS27500	90' PLUG (NOTE 1)
MS27S03	HERMETIC SOLDER MOUNT RECEPTACLE (NOTE 1)
MS27504	BOX MOUNT RECEPTACLE (NOTE 1)
MS27S08	BOX MOUNT RECEPTACLE, BACK PANEL MOUNTING
MS27513	BOX MOUNT RECEPTACLE, LONG GROMMET
MS27664	WALL MOUNT RECEPTACLE, BACK PANEL MOUNTING (NOTE 1)
MS27667	THAU-BULKHEAD RECEPTACLE

Figure 5.5. 12. MS Electrical Connector Information

NOTE

1.ACTIVE	SUPERSEDES
MS27472	MS27479
MS27473	MS27480
MS27474	MS27481
MS27475	MS27482
MS27477	MS27483
MS27473 WITH MS27507 ELBOW	MS27500
MS27478	MS27503
MS27499	MS27504
MS27497	MS27664

CLASS

E	ENVIRONMENT RESISTING-BOX AND THAU-BULKHEAD MOUNTING TYPES ONLY (SEE CLASS T)
P	POTTING-INCLUDES POTTING FORM AND SHORT REAR GROMMET
T	ENVIRONMENT RESISTING-WALL AND JAM-NUT MOUNTING RECEPTACLE AND PLUG TYPES: THREAD AND TEETH FOR ACCESSORY ATTACHMENT
Y	HERMETICALLY SEALED

FINISH

A	SILVER TO LIGHT IRIDESCENT YELLOW COLOR CADMIUM PLATE OVER NICKEL (CONDUCTIVE), -65'C TO +150'C (INACTIVE FOR NEW DESIGN)
B	OLIVE DRAB CADMIUM PLATE OVER SUITABLE UNDERPLATE (CONDUCTIVE), ·65'C TO +175'C
C	ANODIC (NONCONDUCTIVE), -65'C TO +175'C
D	FUSED TIN, CARBON STEEL (CONDUCTIVE), ·65"C TO 150'C
E	CORROSION RESISTANT STEEL (CRES), PASSIVATED (CONDUCTIVE), ·65°C TO +200'C
F	ELECTROLESS NICKEL COATING (CONDUCTIVE), -65'C TO +200"C
N	HERMETIC SEAL OR ENVIRONMENT RESISTING CRES (CONDUCTIVE PLATING). ·65'C T0+200'C

CONTACT STYLE

A	WITHOUT PIN CONTACTS
B	WITHOUT SOCKET CONTACTS
C	FEED THROUGH
P	PIN CONTACTS-INCLUDING HERMETICS WITH SOLDER CUPS
S	SOCKET CONTACTS-INCLUDING HERMETICS WITH SOLDER CUPS
X	PIN CONTACTS WITH EYELET (HERMETIC)
Z	SOCKET CONTACTS WITH EYELET (HERMETIC)

POLARIZATION

A, B C, OR D	NORMAL-NO LETTER REQUIRED

Figure 5.5. 12. MS Electrical Connector Information (continued)

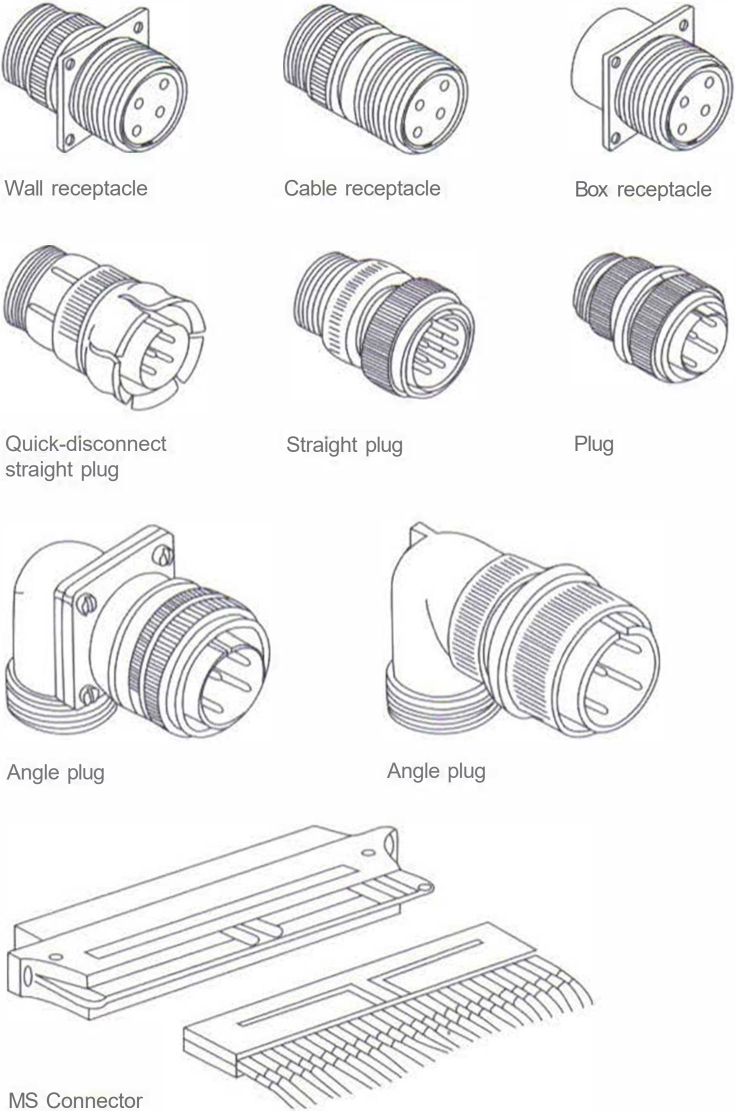
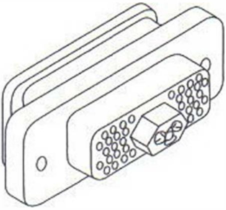
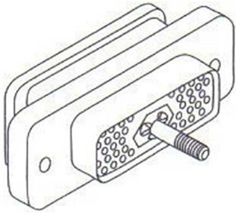


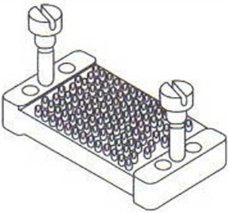
Figure 5.5.13. Typical MS Electrical Connectors



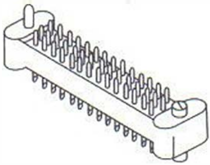
Receptacle



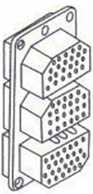
Facing view plug



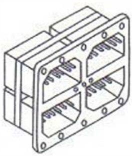
Receptacle



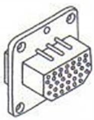
Plug



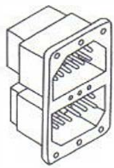
Triple
insert plug



Quadruple
insert receptacle



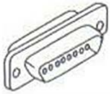
Single
insert plug



Double insert
receptacle

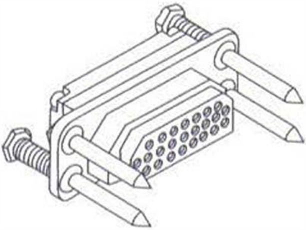
Figure *5.5.13. Typical MS Electrical Connectors (continued)*

Receptacle

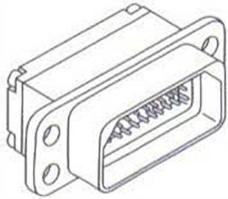


Plug

Typical rack and panel connectors



Plug



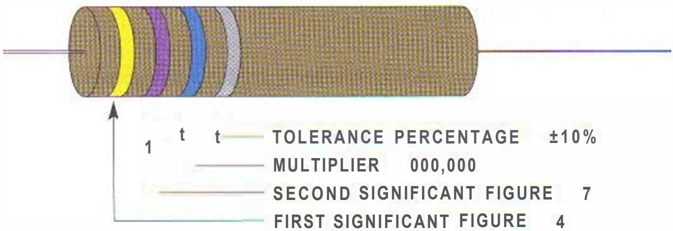
Receptacle

F/9u,.. 5.5.13. Typical MS Electrics/ Connectors (continued)

Resistor Color Code

The resistance ,n ohms of a composition resistor is deslgnaled by a series of colored bands around one end, as shown h Figure 5.5.14.

- The first colored band (nearest the end) represents the first significant figure in the resistance.
- The second band represents the second slgnilicanl llgure.
- The third band represents the multiplier, or the number of zeros to add to the two significant figures. If this band is gold, the resistance ls less than ten ohms, and the multiplier is 0.1. If It is silver, the resistance ls less than one ohm and the multiplier ls 0.01.
- The fourth band from the end shows the tolerance of the resistor h a plus or minus percentage.



Resistance is 47,000,000 ohms± 10%

Colors for the first and second significant figure (first and second band), and multiplier (third band):

Black	0	Green	5
Brown	1	Blue	6
Red	2	Violet	7
Orange	3	Gray	8
Yellow	4	White	9

Colors for the fractional multiplier (third band):

Gold	0.1	Silver	0.01

Colors for tolerance in percentage (fourth band):

Gold	±5%	Silver	±10%
No band	±20%		

Examples:

A resistor marked red, red, orange, silver has a resistance of 22,000 ohms± 10%.

A resistor marked brown, green, brown has a resistance of 150 ohms ±20%.

A resistor marked yellow, violet, gold has a resistance of 4.7 ohms.

Aircraft Storage Batteries

Lead-Acid Batteries

To prevent a lead-acid battery from overheating, limit the charging voltage to 2.35 volts per cell unless the battery manufacturer specifies a different voltage for the specific battery.

The freezing temperature of the electrolyte in a lead-acid battery 1s determined by its specific gravity as indicated h Figure 5.5.15.

Specific gravity	Freezing point	
	°C	°F
1.300	-70	.95
1.275	-62	-80
1.250	-52	-62
1.225	.37	·35
1.200	-26	-16
1.175	·20	-4
1.150	-15	+5
1.125	-10	+13
1.100	-8	+19

FI9ure 5.5.15. The freezing temperature of the electrolyte ,n a lead-acid battery Is determmod by 1/s specific gravity.

When measuring the specific gravity of the electrolyte, a correction must be applied 1f Its temperature is different from the standard of 80°. If the temperature is greater than 80"F, add four points to the specific gravity for each ten degrees. If the temperature 1s lower than 80°F, subtract four points for each ten degrees. The correct10n is shown in the chart in Figure 5.5.16.

Other cautions for lead-acid batteries are:

- Neutralize any spilled electrolyte with bicarbonate of soda and water.
- Remove all traces of corros10n and treat any bare metal in the battery box or adjacent structure with an acid-proof paint.
- Be sure the banery box drain is open and if a sump Jar is used, be sure the pad 1s saturated with a solution of bicarbonate of soda and water.
- If electrolyte 1s to be mixed, always pour the acid into the water. DO NOT pour water into the acid.
- Do not service lead-acid batteries in the same area as is used for servicing nickel-cadmium batteries.

Electrolyte temperature		Points to be subtracted or added to specific gravity reading
°C	°F	
60	140	+24
55	130	+20
49	120	+16
43	110	+12
38	100	+8
33	90	+4
27	80	0
23	70	-4
15	60	-8
10	50	-12
5	40	-16
-2	30	-20
-7	20	-24
-13	10	-28
-18	0	-32
-23	-10	-36
-28	-20	-40
-35	-30	-44

Figure 5.5.16. *Correction for nonstandard temperature of the electrolyte of a lead-acid battery.*

Nickel.Cadmium Batteries

Be sure the top of the battery is clean, and that all of the cell connectors are free from corrosion and are properly torqued.

The electrolyte level varies with the state of charge of the battery. Never add electrolyte to the battery while it is installed in the aircraft. Remove the battery, clean and inspect it, and add distilled or demineralized water according to the battery manufacturer's recommendation.

Other cautions for nickel-cadmium batteries are:

- Neutralize spilled electrolyte with a solution of 3 percent acetic acid, vinegar, or lemon juice, and wash the area with fresh water.
- Do not service nickel-cadmium batteries in the same area used for lead-acid batteries.

Alejandra

Section 6: Aircraft Materials

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6.1 Composition of Wrought Aluminum Alloys

Percent of alloying elements; aluminum and normal impurities constitute remainder of metal.

Alloy Number	Silicon	Copper	Manganese	Magnesium	Chromium	Zinc
1100	-99.00% aluminum minimum-					
2017		4.0	0.5	0.5		
2024		4.5	0.6	1.5		
2117		2.5		0.3		
3003			1.2			
5052				2.5	0.25	
5056			0.10	5.2	0.10	
6061	0.6	0.25		1.0	0.25	
7075		1.6		2.5	0.30	5.6

6.2 Four-Digit Designation System for Wrought Aluminum Alloys

First digit: Principal alloying element
Second digit: A measure of the limits for impurities
Third and fourth digits: The amount of the alloying element in the metal

Type of Alloy	**Number Group**
Aluminum 99% or greater	1xxx
Copper	2xxx
Manganese	3xxx
Silicon	4xxx
Magnesium	5xxx
Magnesium and silicon	6xxx
Zinc	7xxx
Other elements	Sxxx
Unused series	9xxx

Pure aluminum is the softest and most corrosion-resistant form of aluminum, but it is not generally used in aircraft construction or maintenance. 1100 is the most widely used form of commercially pure aluminum used in aircraft maintenance. It can only be used in nonstructural applications, such as fairings.

Copper is alloyed with aluminum to increase its strength and make it heat-treatable, but this makes it susceptible to corrosion. 2024 is the most widely used alloy in this series. To make a 2024 sheet more corrosion-resistant, a thin layer of pure aluminum is rolled onto its surface when the sheet metal is made. This process is called "cladding." Most of the rivets used in sheet metal construction are made of 2117, 2017, or 2024.

Manganese makes the aluminum stronger and easier to weld. 3003 is the most widely used alloy in this series because it is soft and easy to form. It is used for cowling, propeller spinners, and wheel pants.

Magnesium adds strength to the aluminum, which makes it more difficult to form. 5052 is widely used for fluid lines; in its sheet form it is used for fuel tanks because it is weldable and reasonably corrosion-resistant. 5052 is not heat-treatable.

Magnesium and silicon give aluminum strength, malleability, and weldability. 6061 is used in applications in which heat treatability, ease of forming, medium strength and corrosion-resistance are important.

Zinc gives aluminum high strength, but makes it expensive and difficult to form. 7075 is the alloy used in modern aircraft where high strength and light weight are the primary considerations.

6.3 Mechanical Properties of Aluminum Alloys

Alloy and temper•	Tensile strength, psi Ultimate	Yield	Brinell hardness 500 kg load, 10 mm ball
1100-0	13,000	5,000	23
1100-H18	24,000	22,000	44
2017-0	26,000	10,000	45
2017-T4	62,000	40,000	105
2024-0	27,000	11,000	47
2024-T36	72,000	57,000	130
2024-T4	68,000	47,000	120
Alclad 2024-0	26,000	11,000	na
Alclad 2024-T36	67,000	53,000	na
3003-0	16,000	6,000	40
3003-H18	29,000	27,000	10
5052-0	28,000	13,000	47
5052-H38	42,000	37,000	77
6061-0	18,000	8,000	30
6061-T6	45,000	40,000	95
7075-0	33,000	15,000	60
7075-T6	83,000	73,000	150
Alclad 7075-0	32,000	14,000	na
Alclad 7075-T6	76,000	67,000	na

• *See* Section 6.4, "Temper Designations"

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6.4 Temper Designations for Aluminum Alloys

Heat-Treatable Alloys

-0 .... Annealed temper of wrought alloys

·F .... As-fabricated condition for wrought alloys and as-cast for casting alloys

-T2 .... Annealed temper of casting alloys

-T3 .... Solution heat-treated followed by strain hardening; a second digit, if used, Indicates the amount of strain hardening

·T4 .... Solution heat-treated followed by natural aging at room temperature

-TS .... Artificially aged at an elevated temperature

·T6 .... Solution heat-treated followed by artificial aging

-n .... Solution heat-treated followed by stabilization

·TS .... Solution heat-treated followed by strain hardening, then artificial aging

-T9 .... Solution heat-treated followed by artificial aging, then strain hardening

Non-Heat-Treatable Alloys

-0 .... Annealed

-H1 ...... Strain hardened by cold-working; a second digit indicates the degree of strain hardening

-H12 .... 1/4 hard

-H14 .... 1/2 hard

-H18 .... Full hard

-H19 .... Extra hard

·H2 ...... Strain hardened by cold-working, then partially annealed

-H3 ...... Strain hardened and stabilized

6.5 Temperatures for Heat Treatment of Aluminum Alloys

Alloy	Annealing temp. °F	Annealing time hours	Solution temp. °F	Heat treat. temper	Precip. temp. °F	Heat treat. time hours	Heat treat. temper
1100	650	2-3					
2017	775	2-3	940	·T4			
2024	775	2-3	920	-T4	375	7-9	-T86
2117	775	2-3	940	-T4			
3003	775	2-3					
5052	650	2-3					
6061	775	2-3	970	·T4	320	16-20	-TS
7075	775	2-3	870	-W	250	24-28	-T6

6.6 Bearing Strength (in pounds) of Aluminum Alloy Sheet

Sheet thickness (inches)	Diameter of rivet (Inches)							
	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
0.014	71	107	143	179	215	287	358	430
0.016	82	123	164	204	246	328	410	492
OQ18	92	138	184	230	276	369	461	553
0.020	102	153	205	256	307	410	512	615
0.025	128	192	256	320	284	512	640	768
0.032	164	245	328	409	492	656	820	984
0.036	184	276	369	461	553	738	922	1,107
0.040	205	307	410	512	615	820	1,025	1,230
0.045	230	345	461	576	691	922	1,153	1,383
0.051	261	391	522	653	784	1,045	1,306	1,568
0.064		492	656	820	984	1,312	1,640	1,968
0.072		553	738	922	1,107	1,476	1,845	2,214
0.081		622	830	1,037	1,245	1,660	2,075	2,490
0.091		699	932	1,167	1,398	1,864	2,330	2,796
0.102		784	1,046	1,307	1,569	2,092	2,615	3,138
0.125		961	1,281	1,602	1,922	2,563	3,203	3,844
0.156		1,198	1,598	1,997	2,397	3,196	3,995	4,794
0.188		1,445	1,927	2,409	2,891	3,854	4,818	5,781
0.250		1,921	2,562	3,202	3,843	5,125	6,405	7,686
0.313		2,405	3,208	4,009	4,811	6,417	7,568	9,623
0.375		2,882	3,843	4,803	5,765	7,688	9,068	11,529
0.500		3,842	5,124	6,404	7,686	10,250	12,090	15,372

6.7 Shear Strength of Aluminum Alloy Rivets

Single-Shear Strength (In pounds) of Aluminum-Alloy Rivets

Rivet comp. (alloy)	Strength of rivet (psi)	Diameter of rivet (Inches)							
		1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
2117-T	27,000	83	186	331	518	745	1,325	2,071	2,981
2017-T	30,000	92	206	368	573	828	1,472	2,300	3,313
2024-T	35,000	107	241	429	670	966	1,718	2,684	3,865

Double-Shear Strength (in pounds) of Aluminum-Alloy Rivets

Rivet comp. (alloy)	Strength of rivet (psi)	Diameter of rivet (Inches)							
		1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
2117-T	27,000	166	372	662	1,036	1,490	2,650	4,142	5,962
2017-T	30,000	184	412	736	1,146	1,656	2,944	4,600	6,626
2024-T	35,000	214	482	858	1,340	1,932	3,436	5,368	7,730

6.8 SAE Classification of Steel

Type of steel	Identification number
Carbon steels	1xxx
Plain carbon steel	10xx
Free cutting steel	11xx
Manganese steels (Manganese 1.60 to 1.90%)	13xx
Nickel steels	2xxx
3.50% nickel	23xx
5.00% nickel	25xx
Nickel chromium steels	3xxx
9.7% nickel, 0.07% chromium	30xx
1.25% nickel, 0.60% chromium	31xx
1.75% nickel, 1.00% chromium	32xx
3.50% nickel, 1.50% chromium	33xx
Corrosion and heat resisting	30xxx
Molybdenum steels	40xx
Chromium molybdenum steels	41xx
Nickel chromium molybdenum steels	43xx
Nickel molybdenum steels	
1.75% nickel, 0.25% molybdenum	46xx
3.50% nickel, 0.25% molybdenum	48xx
Chromium steels	Sxxx
Low chromium	51xx
Medium chromium	52xxx
Corrosion and heat resisting	51xxx
Chromium vanadium steels	6xxx
1.00% chromium	61xx
National emergency steels	8xxx
Silicon manganese steels	9xxx
2.00% silicon	92xx

6.9 Strength of Steel Related to its Hardness

Rockwell C-Scale hardness number	Brinell hardness number	Tensile strength 1,000 psi	Rockwell C-Scale hardness number	Brinell hardness number	Tensile strength 1,000 psi
52	500	262	30	286	142
51	487	253	29	279	138
50	475	245	28	271	134
49	464	239	27	264	131
48	451	232	26	258	127
47	442	225	25	253	124
46	432	219	24	247	121
45	421	212	23	243	118
44	409	206	22	237	115
43	400	201	21	231	113
42	390	196	20	226	110
41	381	191	(18)	219	106
40	371	186	(16)	212	102
39	362	181	(14)	203	98
38	353	176	(12)	194	94
37	344	172	(10)	187	90
36	336	168	(8)	179	87
35	327	163	(6)	171	84
34	319	159	(4)	165	80
33	311	154	(2)	158	n
32	301	150	(0)	152	75
31	294	146			

Numbers in parentheses ( ) are beyond the normal range of the Rockwell C-Scale.

6.10 Color of Steel for Various Temperatures

	Temperature of steel	
Color of steel	°F	°C
Faint red	900	482
Blood red	1,050	566
Dark cherry	1,075	579
Medium cherry	1,250	677
Cherry (full red)	1,375	746
Bright red	1,550	843
Salmon	1,650	899
Orange	1,725	941
Lemon	1,825	996
Light yellow	1,975	1,079
White	2,200	1,204
Dazzling white	2,350	1,288

6.11 Color of Oxides on Steel at Various Tempering Temperatures

Oxide color	Temperature °F	Temperature °C
Pale yellow	428	220
Straw	446	230
Golden yellow	469	243
Brown	491	255
Brown with purple spots	509	265
Purple	531	277
Dark blue	550	288
Bright blue	567	297
Pale blue	610	321

To temper a small tool, first harden it by heating it until it is cherry red, and then quench it in oil or water. Polish the hardened tool and then reheat it until the correct color oxide forms on the polished surface. The first oxides to form are pale yellow, and they progress through darker yellows, brown, purple and shades of blue. When the correct color oxide forms, quench the tool again.

The correct color of oxides for tempering small tools are:

Tool	Oxide Color
Scribers, scrapers and hammer faces	Pale yellow
Center punches and drills	Golden yellow
Cold chisels and drifts	Brown
Screwdrivers	Purple

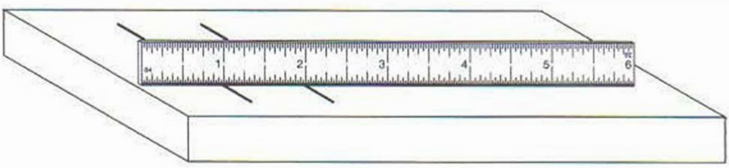
Section 7: Tools for Aircraft Maintenance

I

7.1 Measuring and Layout Tools

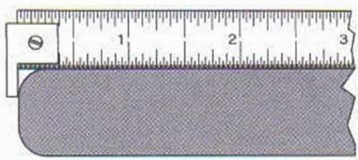
St-I Rule

For greater accuracy, when making a measurement with a steel rule do not use the end of the rule, but measure the distance between two marks away from the end.



Hook Rule

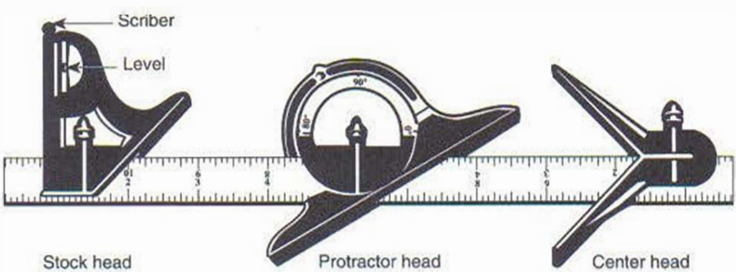
Hook rules are a special type of steel rule that are usually stiff and have a hook on one end accurately aligned with the end of the rule, for measuring from the edge of an object where a radius is involved.

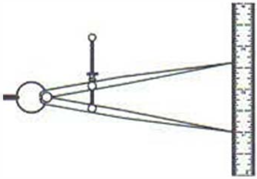


7.1

Combination Set

A combination set consists of a 12-inch steel rule with three heads held onto the rule by clamps. The stock head converts the rule into a square to measure 90° and 45° angles. The protractor head can be set to measure any angle between the rule and the bottom of the head. When the two arms of the center head are held against a circular object, the edge of the rule passes across its center.





Dividers

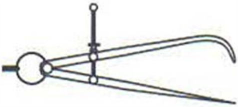
Dividers are used to transfer distances from a steel rule to a piece of sheet metal that is being laid out. They are also used for dividing a line into equal increments.

Outside Calipers

On outside calipers, the ends of the legs are pointed inward so that the outside of an object can be measured. Adjust the legs so the ends are exactly the same distance apart as the outside of the object, and then measure the distance between the ends with a steel rule.

Inside Calipers

Adjust the legs of inside calipers so the ends exactly fit into the object being measured, and then measure the distance between the ends with a steel rule.



Hermaphrodite Calipers

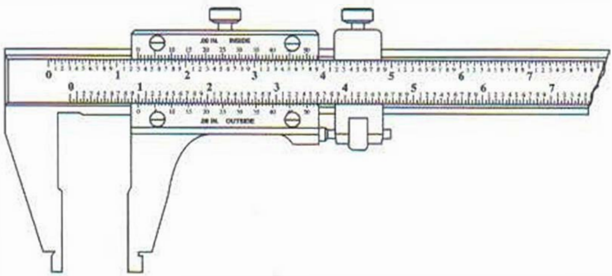
Hermaphrodite calipers are used to scribe a line along a piece of material a specific distance from the edge.

Scriber

Scribers have a needle-sharp point used to mark very fine lines on the surface of a piece of metal to be cut. Scribed lines on highly stressed metal can cause stress risers.

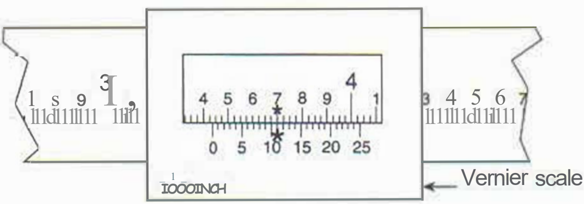
Vernier Calipers

Vernier calipers are used to make rapid and accurate inside and outside measurements over a greater range than that of a micrometer caliper. Each inch on the main scale is divided Into 10 numbered increments, each representing 1/10 inch (0.1 inch). One inch on the vernier scale is divided into 25 increments, with each increment representing 1/25 inch or 0.040 inch.

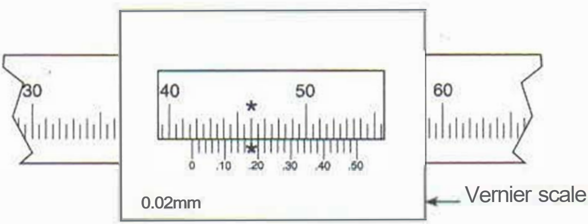


How to Read the Vemler Scale

The vernier scale's "zero" is beyond the main scale's 3-inch mark (3.000). It is also past the 4/10-inch mark (0.400), and past one of the 1/40-inch marks (0.025). Only one mark on the vernier scale aligns with a mark on the main scale: the "11" mark (see asterisk in figure). Add 0.011 to the total: 3.000 + 0.400 + 0.025 + 0.011 = 3.436 inches.

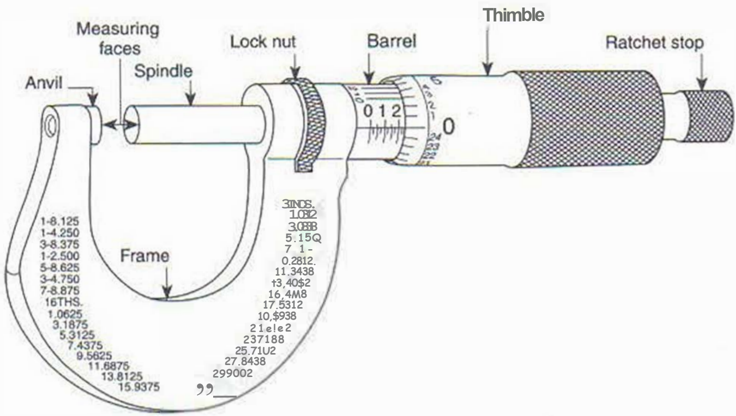


The vernier scale's "zero" is beyond the main scale's 41.5-mm mark. Only one mark on the vernier scale aligns with one of the marks on the main scale: the ".18" mark (see asterisk in figure). Add 0.18 to 41.5 to get a total reading of 41.68 mm.



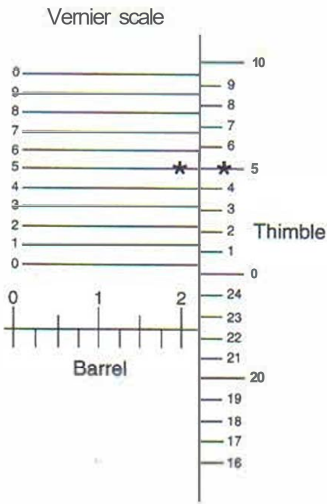
Micrometer Caliper

Micrometer calipers are available as inside and outside calipers, with ranges from Oto 1 inch, to special calipers that measure up to 60 inches. Standard micrometer calipers can be read to 0.001 inch (one one thousandth of an inch) and vernier micrometer calipers can be read to 0.0001 inch (one ten thousandth of an inch).

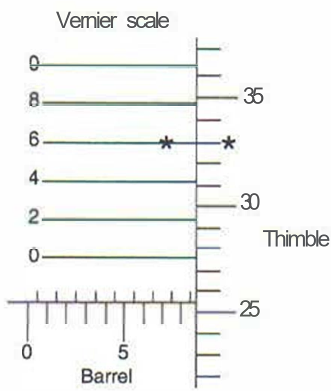


How to Read the Vernier Micrometer Scale

In the figure shown, the thimble was screwed out more than eight complete turns, which moved the spindle out two tenths of an inch (0.200); then it stopped, before another turn, with the reference line on the barrel between the 22 and 23 thousandth-inch marks on the thimble. The measuring faces are between 0.222· and 0.223-inch apart. The "5" mark on the vernier scale lines up with one of the marks on the thimble. This means that the spindle moved out five ten thousandths of an inch beyond 0.222. The total separation of the measuring faces is 0.2225 inch.

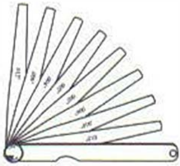


In the metric example, the thImble moved out more than 8.5 mm, and then more than 25 graduations, or 0.25 mm, beyond the reference mark. The vernier mark representing 6 divisions is aligned with one of the marks on the thimble, indicating the spindle moved 0.006 mm beyond 0.25. The total separation of the measuring faces is therefore 8.5 + 0.25 + 0.006 = 8.756 millimeters.



Dial Indicator

Dial indicators are used to measure end-play in shaft installations, gear backlash, bevel gear preload, and shaft out-of-round or runout.

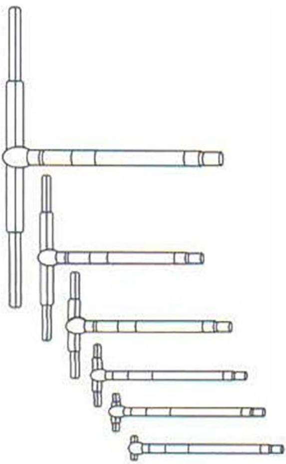


Feeler Gages

Feeler gages are used for measuring clearances in valve trains and breaker points, gear backlash, piston ring end-gap and side clearance, and the flatness of objects when used with a precision surface plate.

Small-Hole Gages

Small holes, up to approximately 1/2-inch in diameter, may be accurately measured with small-hole gages. Place a ball-type small-hole gage into the hole to be measured and twist the knurled end of the handle to expand the ball end until it exactly fits in the hole. Remove the gage and measure its diameter with a vernier micrometer caliper.



Telescoping Gages

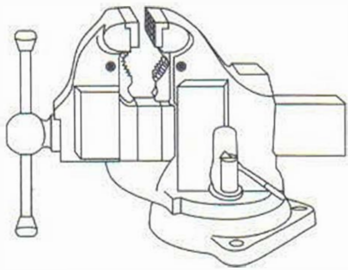
Select the gage with the proper range and place it in the hole. Loosen the knurled end of the handle to release the hardened steel plungers in the telescoping head. This allows an internal spring to force the plungers out against the walls of the cylinder bore. Hold the gage so the T-head is perpendicular to the inside wall of the bore and tighten the end of the handle. Remove the gage and measure the distance between the ends of the plungers with a vernier micrometer caliper.

7.2 Holding Tools

Vises

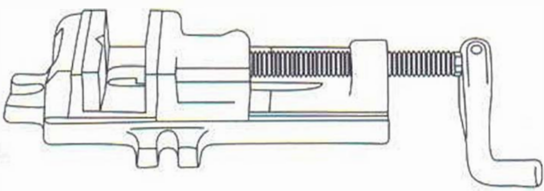
Bench Vise

Bench vises normally have replace·able serrated Jaws to hold the material without slipping and are mounted on a swiveling base. The size of a vise is indicated by the width of the jaws, which normally range from 3-1/2 to 6 inches.



Drill Press *Vise*

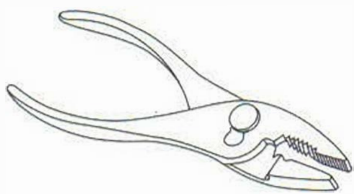
Drill-press vises have a flat bottom with slots which allow them to be bolted to the table of a drill press.



Pliers

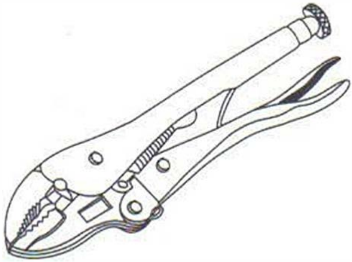
Combination/Slip Joint Pliers

Standard pliers that have serrated jaws for gripping round objects and flat jaws for holding flat materials. When the jaws are open wide, the handle pivot may be slipped from one pivot hole to the other, allowing the jaws to open wider to hold larger objects.



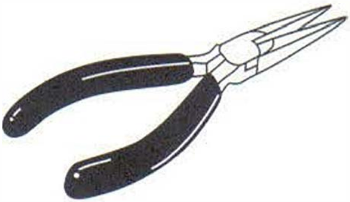
Water Pump *Pliers*

Also called adjustable-joint pliers. The long handles are for applying force to the jaws and torque to the object being turned. Available with a slip-joint adjustment or a tongue and groove type of adjustment that cannot slip, in lengths from 4-1/2 inches with parallel jaws that open to 1/2 inch, to 16 inches with jaws that open to more than 4 inches.



Vise-Grip® Pliers

These patented locking pliers have a knurled knob in the handle that adjusts the opening of the jaws. When the handles are squeezed together, a compound-lever action applies a tremendous force to the jaws, and an over-center feature holds them tightly locked on the object between the jaws.



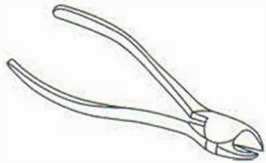
Needle-Nose *Pliers*

Used to hold wires or small objects and to make loops or bends in electrical wires. Some have straight jaws and others are bent to reach into obstructed areas; available in lengths from 4-1 /2 to more than 10 inches.

7.3 Safety Wiring Tools

Diagonal Cutting Pliers

Diagonal cutters, or "dikes," are used to cut safety wire and cotter pins. The name of these pliers is derived from the shape of the jaws that have an angled cutting edge.



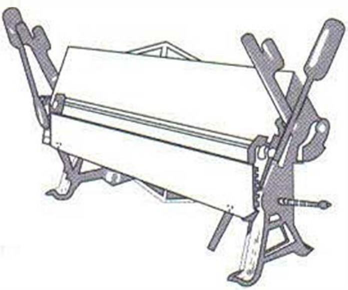
Duckbill Pliers

Duckbill pliers have long handles and wide serrated jaws that hold safety wire firmly while it is being twisted.

Safety Wire Twisting Tool

This safety-wiring tool grips wire securely, and the jaws lock on the wire; when the knob in the handle is pulled out, the tool twists the safety wire with a uniform twist. Can be used to give wire a left-hand or right-hand twist.

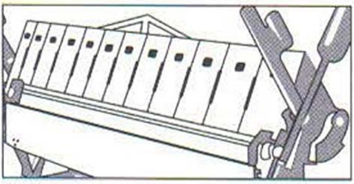
7.4 Bending and Forming Tools



Tools for Making Straight Bends and Curves

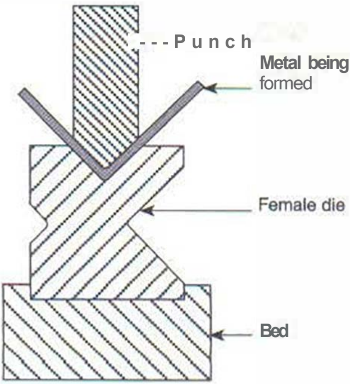
Comice Bralce

The cornice, or leaf brake is a heavy shop tool used to make straight bends across a piece of sheet metal. The bend radius appropriate for the thickness and temper of the metal can be chosen by using the appropriate radius block on the upper jaw of the brake.



Box Bralce

A box, or finger brake is similar to a cornice brake, except the upper jaw is made up of a number of heavy steel fingers so all four sides of a box can be folded up.

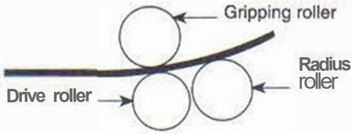


Press *Bralce*

A press brake is used when a large number of duplicate pieces of material must be made with exactly the same amount of bend. The metal is placed over the female die whose inside radius is the same as the outside radius of the finished bend. A matching male die, or punch, with the correct radius forces the material into the die with energy stored in a large flywheel or with hydraulic pressure. Angles and channels are formed on press brakes.

Slip Roll Former

Used for making large radius bends across a piece of sheet metal. The metal is clamped between the drive roller and the gripping roller, and the handle is turned to pull the metal through the machine against the radius roller, which is adjusted to control the radius of the bend.



Forming Compound Curves in Sheet Metal

English Wheel

Aluminum alloy sheets are formed by stretching them, which is initially done with a soft mallet and a sandbag, resulting in a rough surface that must be smoothed out. The smoothing is done by moving the stretched aluminum sheet back and forth between the two rollers in an English wheel. The upper roller is a large cast-iron wheel with a highly polished and very slightly concave surface. A smaller, lower wheel is adjustable so it can be moved closer to or further from the upper wheel. The lower wheel has a convex surface, and there are a number of wheels available with differing radii to vary the radius of the metal being formed. The metal being worked is moved back and forth between the two wheels to smooth and form it.

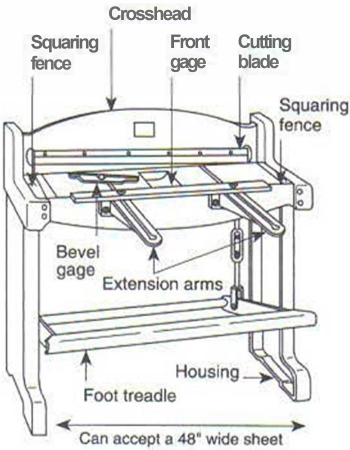
I

7.5 Cutting Tools

Shears

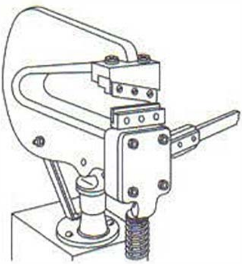
Throatless Shears

Throatless shears have two short cutting blades that cut much like a pair of scissors. The lower blade is fixed to the base and the upper blade is operated by a long handle,



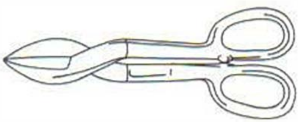
Squaring Shears

Foot-treadle-operated shears can make a straight cut across aluminum alloy sheets up to approximately 0.051-inch thickness and mild steel of 22-gage or thinner. Power-operated shears that use a small electric motor to store a large amount of energy in a heavy flywheel can cut much thicker sheets. Place the metal to be cut on the bed and square it by holding it against the squaring fence. Lock the hold-down clamp in place to hold the metal tight on the table and keep your fingers out of the way of the'blade. The blade is angled so that it slices its way through the sheet when the foot-treadle is pressed or when the energy stored in the flywheel forces the blade down.



Scroll Shears

Used to pierce a piece of sheet metal and cut irregular curves on the iMSide of the sheet without having to cut through to the edge. The upper blade has a sharp point for piercing the metal and is fixed to the frame of the shears; the lower blade is raised against the upper by the compound action of a hand-operated handle.



Hand Shears

Tin Snips

Used to cut sheets of aluminum alloy up to about 0.032-inch thick to roughly the size needed to fabricate a part. Final cutting and trimming is done with other tools.

Compound Shears

Also known as aviation shears or Dutchman shears. They have short serrated blades, actuated by a com-pound action from the handles. There are three shapes of blades, one designed to cut to the left, one to cut to the right, and one to make straight cuts. The serrated blades leave a rough edge that must be filed off to prevent stress risers. The handles of these shears are often color coded. Shears with red handles cut to the left, green han-dles cut to the right, and yellow handles cut straight.

Cuts left-red handle

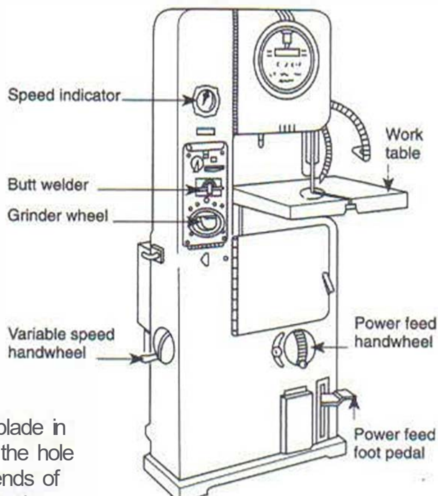
Cuts straight-yellow handle

Cuts right—green handle

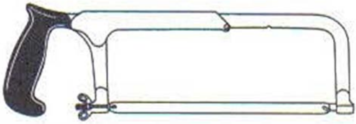
Saws

Band Saw

This contour band saw has a work table adjusted for tilt, and a variable-speed drive that allows the cutting speed of the blade to be adjusted to meet the requirements for the material being cut. It also has a cutter, welder, and grinder that allows the saw to be used for cutting inside a piece of sheet material without cutting through to the edge. Drill or punch a hole in the area to be sawed and remove the blade from the wheels of the saw. Cut the blade in two and place one end through the hole in the material. Clamp the two ends of the blade in the butt welder. Electric current flows through them, and heats them enough to melt the ends so they flow together. Shut the current off and allow the joint to cool, then grind it smooth. Reinstall the blade over the wheels, and cut the Inside of the material.



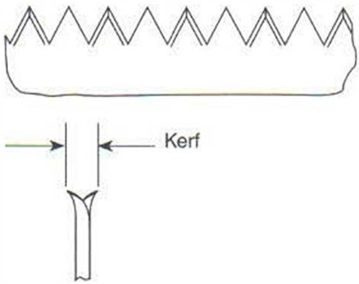
Hacksaw



A hacksaw uses a narrow replaceable blade held under tension in a steel frame. The blades are available in 10 and 12-inch lengths and from 14 to 32 teeth per inch. A blade should be chosen that will allow at least two teeth to be on the material at all times. When cutting, pressure should be applied on the forward stroke and relaxed on the return stroke.

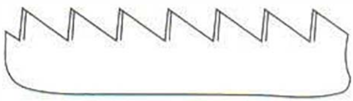
Wood Saws

Crosscut Saw



A crosscut saw is a handsaw used for cutting across the grain of wood. The teeth, or points, are filed so they have a knife-like cutting edge on the same side of each alternate tooth. The teeth are set by bending every other tooth to one side and the alternate teeth to the opposite side. The set of the teeth results in a cut that is wider than the saw blade. This widened cut, called the kerf, keeps the blade from binding in the cut.

Ripsaw

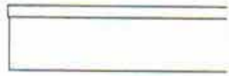


Ripsaws are similar to crosscut saws except for the shape and number of the teeth. They have fewer teeth per inch than a crosscut saw and the teeth are shaped to act as chisels and dig into the wood fibers.

Compass, or Keyhole Saw

A compass, or keyhole saw is a small saw with teeth similar to those of a crosscut saw. The blade is thin and tapered so it can enter a drilled hole and cut curves or circles.

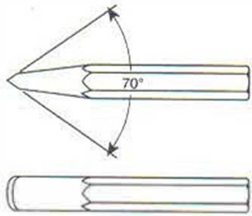
Bacl<saw



Backsaws have teeth similar to crosscut saws, but much smaller with more teeth per inch and less set. The blade has a stiffener across its back to keep it from bending. Backsaws produce a smooth cut across the grain for wood stringers or capstrips *and* they are often used with a miter box.

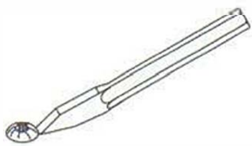
Chisels

Flat Chisel



Made of a piece of hardened steel that is ground with a cutting angle of 70°. The cutting edge is ground to a convex shape to concentrate the force of the hammer blows at the point the cut is being made.

Cape *Chisel*



Cape chisels have a narrow cutting edge used to remove the head of a solid rivet after the head has been drilled through.

Diamond Point Chisel

These are *forged* to a sharp-cornered square, *and* the end is ground to an acute angle to form a sharp pointed cutting edge. They are used for cutting V-shaped grooves, and for cutting the sharp corners in square or rectangular grooves.

Round Nose *Chisel*

These chisels look much like diamond-point chisels except the cutting edge is ground to a circular point. They are used for cutting radii in the bottom of grooves.

Files

Flat file: Rectangular cross-section, tapered toward point in both width and thickness.

Hand file: Rectangular cross-section, sides parallel, tapers in thickness. One edge is safe (there are no teeth cut on it). Used for finishing flat surfaces.

Half-round file: Flat side and rounded side. Tapers in both width and thickness. Used to file the inside of large radius curves.

Triangular, or three-square file: double-cut with triangular cross-section, tapered. Used to file acute internal angles and to restore damaged threads.

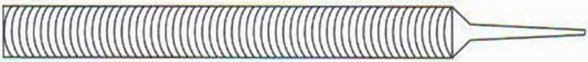
Round file: Commonly called a rattail file. Circular cross-section, tapered in length. Used to file the inside of circular openings and curved surfaces.

Knife file: Tapered in both width and thickness, cross-sectional shape much like a knife blade. Used for filing work with acute angles.

Vixen file: Curved teeth across file; used for removing large amounts of soft metal.

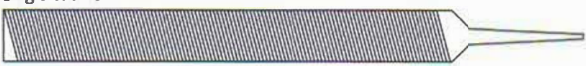
Wood rasp: Resembles file, except teeth formed in rows of individual round-point chisels. Used to remove large amounts of wood; they do not leave a smooth surface.

Vixen file



Double-cut file

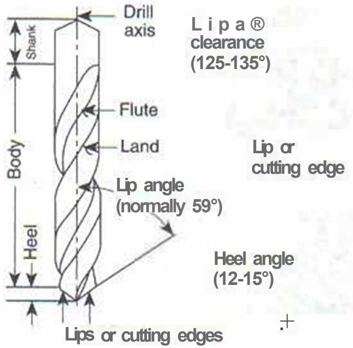
Single-cut file



7.6 Hole Cutting Tools

Twist Drills

Twist drills are available in two materials, carbon steel and high-speed steel. Carbon drills cost less and have a shorter life than high-speed drills and therefore they have limited use. High-speed drills are made of alloy steel and maintain their sharpness even when they are hot. They are available in three groups of sizes: number, letter, and fraction.



Twist Drill Sizes

Number or Letter	Fraction	Decimal Equivalent
80		0.0135
79		0.0145
78		0.0160
	1/64	0.0156
77		0.0180
76		0.0200
75		0.0210
74		0.0225
73		0.0240
72		0.0250
71		0.0260
70		0.0280
69		0.0290
68		0.0310
	1/32	0.0313
67		0.0320
66		0.0330
65		0.0350
64		0.0360
63		0.0370
62		0.0380
61		0.0390
60		0.0400
59		0.0410
58		0.0420
57		0.0430

I

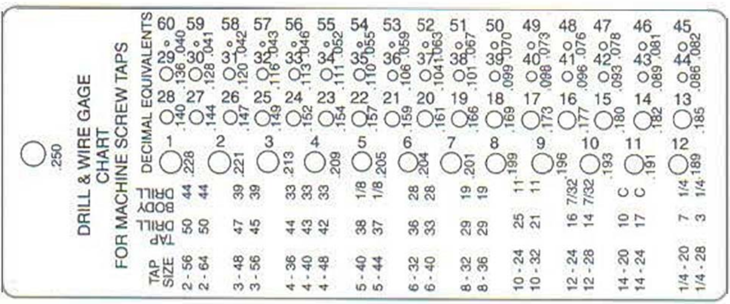
Number or Letter	Fraction	Decimal Equivalent
56		0.0465
	3/64	0.0469
55		0.0520
54		0.0550
53		0.0595
	1/16	0.0625
52		0.0635
51		0.0670
50		0.0700
49		0.0730
48		0.0760
	5/64	0.0781
47		0.0785
46		0.0810
45		0.0820
44		0.0860
43		0.0890
42		0.0935
	3/32	0.0937
41		0.0960
40		0.0980
39		0.0995
38		0.1015
37		0.1040
36		0.1065
	7/64	0.1094
35		0.1100
34		0.1110
33		0.1130
32		0.1160
31		0.1200
	1/8	0.1250
30		0.1285
29		0.1360
28		0.1405
	9/64	0.1406
27		0.1440
26		0.1470
25		0.1495
24		0.1520
23		0.1540
	5/32	0.1562
22		0.1570
21		0.1590
20		0.1610
19		0.1660
18		0.1695
	11/64	0.1719

Number or Letter	Fraction	Decimal Equivalent
17		0.1730
16		o.1no
15		0.1800
14		0.1820
13		0.1850
	3/16	0.1875
12		0.1890
11		0.1910
10		0.1935
9		0.1960
8		0.1990
7		0.2010
	13/64	0.2031
6		0.2040
5		0.2055
4		0.2090
3		0.2130
	7/32	0.2187
2		0.2210
1		0.2280
A		0.2340
	15/64	0.2344
B		0.2380
C		0.2420
D		0.2460
E	1/4	0.2500
F		0.2570
G		0.2610
	17/64	0.2656
H		0.2660
I		0.2720
J		o.2no
K		0.2810
	9/32	0.2812
L		0.2900
M		0.2950
	19/64	0.2969
N		0.3020
	5/16	0.3125
O		0.3160
p		0.3230
	21/64	0.3281
Q		0.3320
A		0.3390
	11/32	0.3438
S		0.3480
T		0.3580
	23/64	0.3594

Number or Letter	Fraction	Decimal Equivalent
U		0.3680
	3/8	0.3750
V		0.3770
W		0.3860
	25/64	0.3906
X		0.3970
y		0.4040
	13/32	0.4062
Z		0.4130
	27/64	0.4219
	7/16	0.4375
	29/64	0.4331
	15/32	0.4688
	31/64	0.4844
	1/2	0.5000

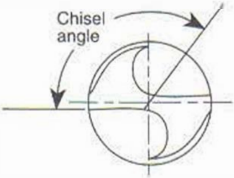
Drill Gage

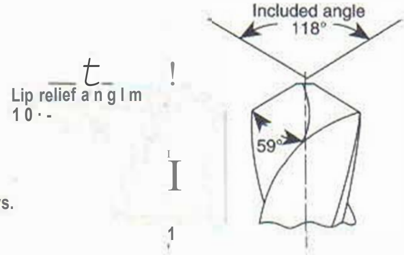
To identify the size of the drill, find the hole that exactly fits the drill; the number beside the hole is the size of the drill.



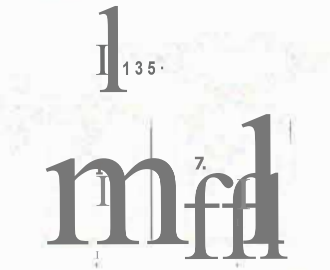
Twist Drill Sharpening

Twist drills are perhaps the simplest cutting tool used by an AMT but it is important that they be properly sharpened for the material they are used on. The point angles shown here are for aluminum alloys and brass. hard and tough metals, and transparent plastics and wood. When sharpening a drill, be sure that the lengths of the lips, *or* cutting edges, are the same, and the included angle and lip relief angle are correct for the material to be drilled.

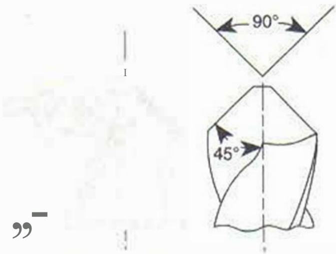




General purpose point for aluminum alloys. brass. and laminated plastics. The chisel angle should be between 125° and 135°.



Point ground for hard and tough metals. Thechisel angle should be between 115° and 125°.

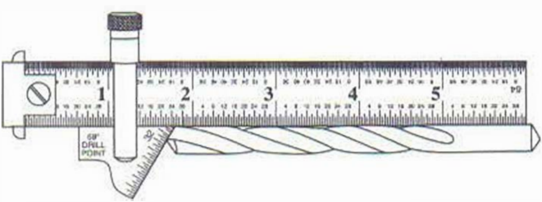


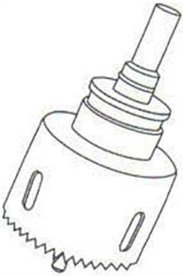
Point ground for transparent plastics and wood. The chisel angle should be between 125• and 135°.

Material	Included angle	Lip relief angle
Aluminum, mild steel, brass	11s•	10· -1s•
Hard and tough materials	135°	6° - 9°
Plastics, wood	90•	12• - 15°

Drill Point Gage

Because the points of most drills used in routine aviation maintenance are ground to an included angle of 118°, or 59° either side of center, a handy drill point gage is available to determine that the angle is proper and the lips are of the same lengths.

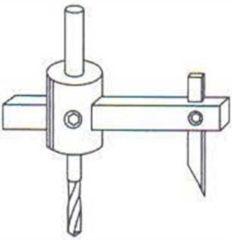




Large Hole Cutters

Hole Saws

Used to cut large-diameter holes in thin sheet metal or wood. Different diameter saws can be installed, available from 9/19-inch up to more than 4 inches. A shank fits into a drill press or a hand drill motor, and the pilot drill has a short section of flutes with a longer smooth shank. This allows the drill to cut the pilot hole, then when the saw reaches the material, the shank of the pilot drill is in the hole and therefore does not enlarge the hole, yet holds the saw centered.

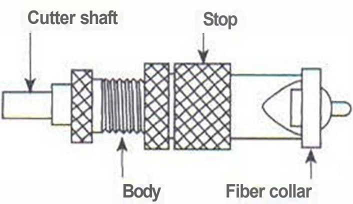


Fly Cutter

Used to cut large holes in thin sheet metal, but not limited to specific size holes. A cutting tool is mounted in the arm of the fly cutter, and the arm is adjusted so the tip of the cutter is exactly the radius of the desired hole from the center of the pilot drill. The shank of the fly cutter is chucked in a drill press, and the pilot drill cuts the guide hole.

Operate the drill press at a slow speed, and feed the cutter into the work very slowly and carefully so it cuts rather than grabs.

WARNING: It is important when cutting holes in thin sheet metal to support the metal on a piece of scrap plywood and clamp the metal and plywood firmly to the drill press table. This prevents the metal from becoming a lethal spinning knife if the cutter should dig into it.

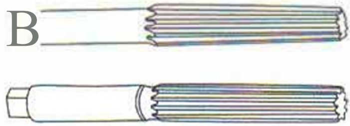


Countersink

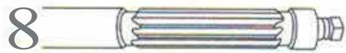
A stop countersink cuts a countersink to the correct depth. Place the proper cutter in the tool and adjust the fiber collar so it contacts the skin when the countersink hole is the correct depth. To determine the correct adjustment of the skirt, make some test countersinks in scrap material until the recess is just deep enough so the top of the fastener is flush with the metal surface.

Reamers

A special cutting tool with sharp knife-edge blades, or flutes, cut into its periphery that are extremely hard and easily chipped. When preparing a hole for a close-tolerance bolt, drill the hole about one to three thousandths of an inch (0.001 to 0.003 inch) smaller than the outside diameter of the reamer. Be sure that the reamer is perfectly aligned with the hole and turn it steadily in its proper cutting direction to prevent it from chattering. Never turn the reamer backward after it has begun to cut as this will dull the reamer. Fixed-diameter reamers enlarge the hole to the most accurate dimensions, but expansion reamers may be used to ream a hole slightly larger than a fixed reamer. The hex on the end of the cutter is turned to increase the diameter of the cutters which can be measured with a vernier micrometer caliper.



Fixed-diameter reamers

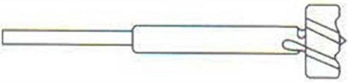


Expansion reamer

Drills for Wood and Composite Materials

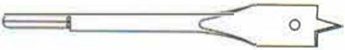
Auger Bits

Auger bits are turned with a bow-type brace. The feed screw in the end of the bit screws into the wood and pulls the bit in. Sharp cutting edges parallel with the axis of the bit cut a circle in the wood and the cutting edge perpendicular to the axis of the bit cuts the chips from within the circle. The chips travel up the spiral flutes and out of the hole.



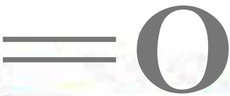
Forstner *Bits*

Mounted in a drill press and used for boring flat-bottom hOles h wood. The vertical cutting edge cuts a circle the size of the hole being bored and the horizontal edge cuts the chips from the area within the circle.



Flat Wood-Boring Bits

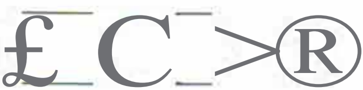
Available in sizes from 1/4-inch to more than one inch. These bits are chucked into an electric or pneumatic drill motor. The pointed pilot keeps the bit centered in the hole as the cutting edge of the bit cuts the chips and moves them out of the hole.



Side view End view

Brad-Point Drllls

Brad-point drills **are** used for cutting Kevlar reinforced material. The drill is chucked into a high-speed electric or pneumatic drill motor and pressed into the material with little pressure. The cutting edges cut the fibers and produce a fuzz-free hole.



Side view End view

SpadeDrlll

Used to drill graphite materials, these provide ample space for the graphite dust to leave so it will not enlarge the hole. Spade drills are turned at a high speed h an electric or pneumatic drill motor, using very little pressure.

7.7 Threads and Threading Tools

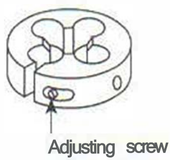
Unified and American Standard Thread Form

There are a number of forms of threads used on bolts and screws, but the Unified and American Standard Thread form has been accepted as the standard for most aircraft hardware. This thread form is available in both fine (UNF) and coarse (UNC) threads.

	Threads/Inch	
Screw size	**UNF**	**UNC**
#0	80	
#2	64	56
#4	48	40
#6	40	32
#8	36	32
#10	32	24
#12	28	24
Bolt size		
3/16	32	24
1/4	28	20
5/16	24	18
3/8	24	16
7/16	20	14
1/2	20	13
9/16	18	12
5/8	18	11
3/4	16	10
7/8	14	9
1	14	8

Thread-Cutting Tools

Cut threads are formed with a die as shown at right. The adjusting screw is screwed in to spread the split in the die in order to shallow the threads being cut. The die is put in the die stock, and the four set screws are tightened to hold the die in place. The die is then placed over the end of the rod to be threaded and turned to cut the threads. The depth of the threads can be increased by screwing out on the adjusting screw.



Taper tap

Plug tap

Bottoming lap

Taps

Threads are cut inside a hole using a series of taps. **A** taper tap is used to start the threads as the flrst several threads **are** ground back so the tap will enter the hole and easily begin to cut the threads. For thick material, a plug tap is used to follow the taper tap. If the threads are to extend all the *way* to the bottom of a blind hole, a bottoming tap is used to follow the plug tap. The threads on a bottoming tap are full depth all the way to the end. Taps are held in a tap wrench which is turned with both hands to ensure that the tap is perpendicular to the material as threads are cut.

Body and Tap Drill Sizes

For UNF threads				
Size and threads	**Body diameter**	**Bodydrlll**	**Preferred hole diameter**	**Tap drill**
0-80	0.060	52	0.0472	3/64
1-72	0.073	47	0.0591	53
2-64	0.056	42	0.7000	50
3-56	0.099	37	0.0810	46
4·48	0.112	31	0.0911	42
5.44	0.125	29	0.1024	38
6-40	0.138	27	0.1130	33
8-36	0.164	18	0.1360	29
10-32	0.190	10	0.1590	21
12-28	0.216	2	0.1800	15
1/4-28	0.250	F	0.2130	3
5/16-24	0.3125	5/16	0.2703	I
3/8-24	0.375	3/8	0.3320	a
7/16·20	0.4375	7/16	0.3860	W
1/2-20	0.500	1/2	0.4490	7/16
9/16-18	0.5625	9/16	0.5060	1/2
5/8-18	0.625	5/8	0.5680	9/16
3/4-16	0.750	314	0.6688	11/16
7/8-14	0.875	7/8	0.7822	51/64
1"-14	1.000	1'	0.9072	59/64

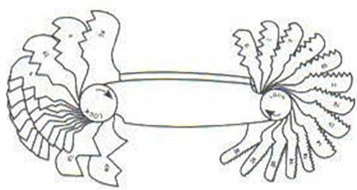
For UNC threads				
Size and threads	Body diameter	Body drill	Preferred hole diameter	Tap drill
1-64	0.073	47	0.0575	53
2-56	0.086	42	0.0682	51
3-48	0.099	37	0.078	5164
4-40	0.122	31	0.0866	44
5-40	0.125	29	0.0995	39
6-32	0.138	27	0.1063	36
8-32	0.164	18	0.1324	29
10-24	0.190	10	0.1476	26
12-24	0.216	2	0.1732	17
1/4-20	0.250	1/4	0.1990	8
5/16-18	0.3125	5/16	0.2559	F
3/8-16	0.375	3/8	0.3110	5/16
7/16-14	0.4375	7/16	0.3642	U
1/2-13	0.500	1/2	0.4219	27/64
9/16-12	0.5625	9/16	o.4n6	31/64
5/8-11	0.625	5/8	0.5315	17/32
3/4-10	0.750	3/4	0.6480	41/64
7/8-9	0.875	7/8	0.7307	49/64
1'-8	1.000	1'	0.8376	7/8

For National Taper Pipe Serles			
Nominal pipe size {Inch)	Threads per inch	Root diameter of pipe	Tap drill
1/8	27	0.3339	a
1/4	18	0.4329	7/16
3/8	18	0.5676	9/16
1/2	14	0.7013	45/64
3/4	14	0.9105	29/32

For metric threads	
Metric threads	Metric tap drlll
M2.5 x0.45	2.05
MB X0.5	2.5
M3.5x0.6	2.9
M4x0.7	3.3
MS x 0.8	4.2
M6.3x 1	5.3
MBx 1.25	6.8
M10x 1.5	8.5
M12x 1.75	10.2
M14X2	12.0
M16x2	14.0
M20x2.5	17.5
M24x3	21.0

Screw Pitch Gage

Screw pitch gages help to identify the thread type and size on a bolt or nut. Each leaf in the gage has teeth that correspond to bolt or nut threads, with the number of threads per inch stamped on it. To find the number of threads per inch on a bolt or nut, select the leaf with an exact fit to the threads and note the number stamped on the leaf.

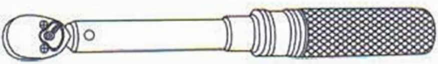


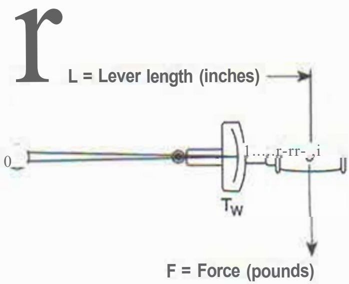
7.8 Torque and Torque Wrenches

> **NOTE:** The strongest threaded joint is one in which the load applied to the fastener when it is installed is greater than the maximum load that will be applied to the joint in service. If a threaded fastener does not fail when it is being properly torqued, it will not fail in service.

Click-Type Torque Wrench

Twist the handle until a reference mark aligns with a graduation on the shaft of the wrench indicates the desired torque. Place the correct socket on the wrench and put it on the fastener to be torqued. With the wrench perfectly square to the fastener, apply a smooth pull on the wrench until it clicks. Click-type torque wrenches do not limit the amount of torque that can be applied; rather, they indicate the set amount of torque being applied when they click. Stop the pull as soon as the wrench clicks.

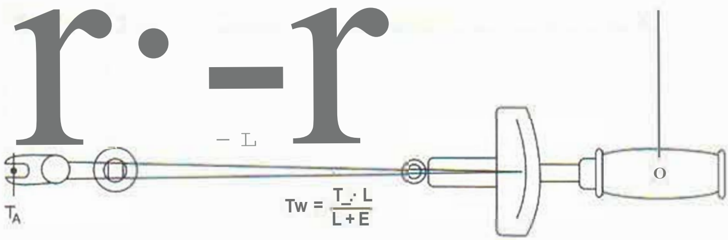




Deflecting-Beam Torque Wrench

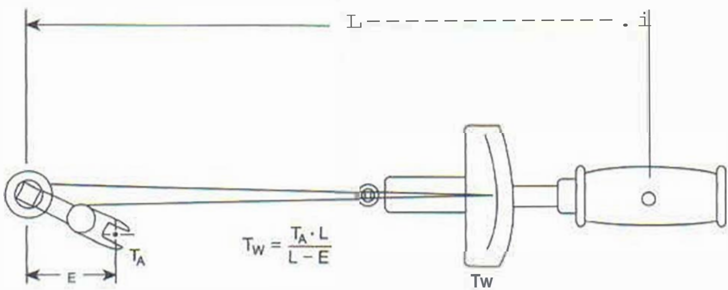
It is important that the socket is square on the fitting and the force applied to the wrench is concentrated at the pivot point on the handle. The torque read on the wrench (T_W) measured in inch-pounds is the product of the lever length (L) in inches and the force (F) in pounds.

When using an adapter on a torque wrench that adds to the lever length, you must use the formula below to determine the torque reading on the wrench T_W in order to attain the required amount of torque applied to the fastener by the adapter T_A.



Tw = Torque Indicated on the wrench
T_A = Torque applied at the adapter
L = Lever length of torque wrench
E = Arm of the adapter

When the extension subtracts from the lever length of the wrench, use this formula.



Tw = Torque Indicated on the wrench
T_A = Torque applied at the adapter
L = Lever length of torque wrench
E = Arm of the adapter

Torque Conversions

Inch grams	Inch ouncea	Inch pounds	Foot pounds	Centimeter kilogram,	Meter kilograms
7.09	0.25				
14.17	0.5				
21.26	0.75				
28.35	1.0				
113.40	4.0	0.25			
226.80	8.0	0.50			
453.59	16.0	1.00	0.08	1.11	
	96.0	6.00	0.50	6.92	
	192.0	12.00	1.00	13.83	0.138
	384.0	24.00	2.00	27.66	0.277
	576.0	36.00	3.00	41.49	0.415
	768.0	48.00	4.00	55.32	0.553
	960.0	60.00	5.00	69.15	0.692
		72.00	6.00	82.98	0.830
		84.00	7.00	96.81	0.968
		96.00	8.00	110.64	1.106
		108.00	9.00	124.47	1.245
		120.00	10.00	138.31	1.383

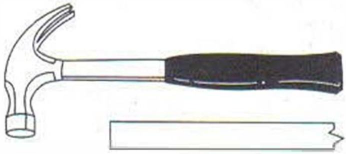
Recommended Torque Values

Recommended Torque Val • for Fln&-Thread-Serlea Steel Fasteners								
	Standard AN and MS eteel bolts In tension				High strength MS end NAS iteel bolta ht tension			
Nut-Bolt size	Nute tension torque llmlta (ln.-lbs.)		Nut ahear torque llmlta (ln.·lbs.)		Nuts tension torque llmlta (ln.-lbe.)		Nut shear torque llmlts (ln.-lbs.)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
8-36	12	15	7	a				
10-32	20	25	12	15	25	30	15	20
1/4-28	SO	70	30	40	80	100	50	60
5/16-24	100	140	60	85	120	145	70	90
3/8-24	160	190	95	110	200	250	120	150
7/16-20	450	500	270	300	520	630	300	400
1/2-20	480	690	290	410	770	950	450	550
9/16-18	800	1,000	480	600	.1,100	1,300	650	800
5/8-18	1,100	1,300	660	780	1,250	1,550	750	950
3/4-16	2,300	2,500	1,300	1,500'	2,650	3,200	1,600	1,900
7/8-14	2,500	3,000	1,500	1,800	3,550	4,350	2,100	2,600
1-14	3,700	4,500	2,200	3,300	4,500	5,500	2,700	3,300
1-1/8-12	5,000	7,000	3,000	4,200	6,000	7,300	3,600	4,400
1·1/4·12	9,000	11,000	5,400	6,600	11,000	13,400	6,600	8,000

Recommended Torque Values for Coa,... Thread•Serlea Steel Fastener•				
Nut-Bolt size	Standard AN and MS ateel bolts In tension			
	Nute tension torque Ilmlte (In.-lbe.)		Nuts shear torque Ilmlt11 (In.-lbt.)	
	Min.	Max.	Min.	Max.
8·32	12	15	7	9
10-24	20	25	12	15
1/4·20	40	50	25	30
5/16-18	80	90	48	55
3/8·16	160	185	95	110
7/16·14	235	255	140	155
1/2·13	400	480	240	290
9/16-12	500	700	300	420
5/8·11	700	900	420	540
3/4·10	1,150	1,600	700	950
7/8·9	2,200	3,000	1,300	1,800
1-8	3,700	5,000	2,200	3,000
1-1/8·8	5,500	6,500	3,300	4,000
1-1/4·8	6,500	8,000	4,000	5,000

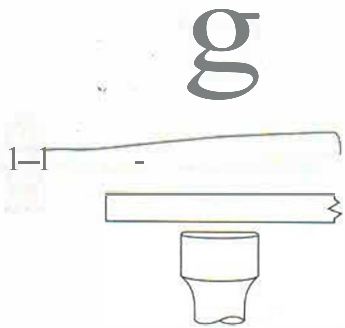
Recommended Torque Valuee for Fine-Thread-Sarles Aluminum Alloy Fasteners				
Nut-Bolt size	Aluminum bolts In tension			
	Nuts tension torque Ilmlts {In.-lbs.)		Nute shear torque Ilmlts (In.-lbs.)	
	Min.	Max.	Min.	Max.
8-36	5	10	3	6
10-32	10	15	5	10
1/4-28	30	45	15	30
5/16-24	40	65	25	40
3/S-24	75	110	45	70
7/16-20	180	280	110	170
1/2-20	280	410	160	260

7.9 Pounding Tools



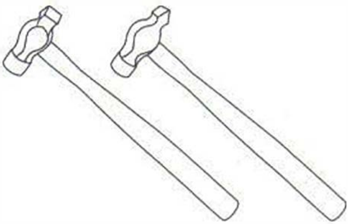
Carpenter's Claw Hammer

This hammer is used for driving and removing nails, but is seldom used when working on an aircraft. It is not designed for use in metal working because its face is slightly crowned to concentrate the force when driving nails.



Ball Peen Hammer

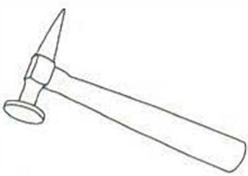
This is the most widely used hammer for general aviation maintenance; available with head weights from a few ounces to several pounds. The face of the hammer is flat with slightly rounded edges, and the opposite end of the head is rounded like a ball.



Metalworking Hammers

Straight* Peen *and Cross* Peen *Hammers

These are similar to the ball peen except the peen end is in the form of a wedge. The wedge on a straight peen hammer is parallel to the handle; the wedge on a cross peen hammer is across the handle.



Body, or Planishing Hammer

To form compound curves in sheet aluminum, the metal may be stretched by hammering it into a sandbag, then smoothed out by hammering it over a smooth steel dolly block with a planishing, or body hammer, a lightweight hammer with a large-area smooth face.

Mallets and Soft-Face Hammers

Sheet aluminum is formed by first stretching it, then smoothing it so the stretched metal forms the desired curves. The initial stretching is done by pounding the metal into a sandbag or around a form with a soft-face hammer, or mallet. These hammers may have replaceable faces of soft metal, resilient plastic, or coils of rawhide. Some hammer faces are domed to better stretch the metal; some are flat for the initial smoothing.

Sledge Hammers

Sledge hammers are long-handled, heavy-head hammers that have two parallel flat faces. They are wielded with two hands and used for heavy pounding work, or for driving stakes in the ground.

7.10 Punches

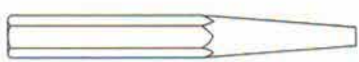
Prick Punch

Has a sharp point; used to mark the exact location for drilling a hole in a piece of sheet metal. The point of the prick punch is placed at this location, and the punch is tapped with a lightweight hammer, leaving a small indentation at the location for the hole.

Center Punch

Similar to a prick punch, but its point is more blunt. It is ground to an angle of approximately 60°, which is correct for starting a properly ground twist drill to cut. The point is placed in the indentation formed by the prick punch. and the punch is hit with a hammer to create a depression for holding the drill as it begins to cut.

Drift, or Starting Punch

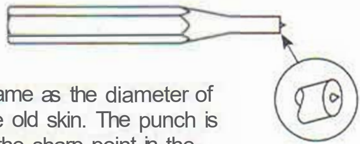


Has a tapered shank; used to drive bolts from their holes and to align parts for assembly. Especially useful when installing wings or other large airplane components. The wing is put in place, and a drift punch is used to align the holes in the wing spars and the fuselage before the bolts are put in place.

Pin Punch

Used to remove rivets after the manufactured head has been drilled through. A punch of the proper size is placed in the drilled hole, and the rivet head is broken off. The punch is then tapped with a lightweight hammer to punch the rivet shank from the hole. Also used to align components being assembled.

Transfer Punch



Used to locate rivet holes when making a new aircraft skin using the old skin as a pattern. A transfer punch whose outside diameter is the same as the diameter of the rivet hole is placed in the hole in the old skin. The punch is tapped with a lightweight hammer and the sharp point in the center of the flat end makes a small indentation; this transfers a location for a center punch to the new skin.

Automatic Center Punch

Used when a large number of holes must be marked. A spring inside the handle is adjusted by twisting the handle. Place the point in the Indentation made by a prick punch and press the punch into the metal. As you press, the spring is compressed, and when the proper compression is reached, the spring automatically releases and drives the point into the metal.

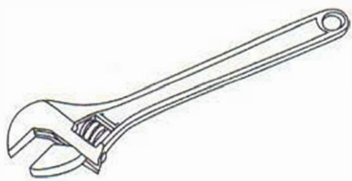
7.11 Wrenches

Open End Wrench

Open end wrenches have parallel jaws on each end. These jaws are angled 15° to the axis of the wrench to allow the wrench to be flipped over to get a new grip on the fastener when turning it in a confined space. Most have different-sized openings on the ends.

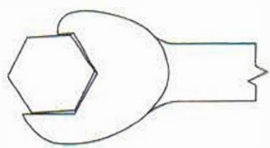
U.S.wrench sizes (Inches)	Metric wrench alzea(mm)
1/4 - 5-16	6 - 8
3/8 - 7/16	7 . 9
1/2 - 9/16	10-11
518 -3/4	12-14
11/16 • 13/16	13 -15
3/4 - 7/8	16 · 18
25/32 • 13/16	17 · 19
15/16 • 1	20-22
1-1/16· 1-1/8	21 · 23
1-1/4 - 1-5/16	24-26

Adjustable* Open *End Wrench



Adjustable end wrenches have one fixed jaw and one jaw that slides in a groove and moves by a worm gear that is rotated by the user. Important: Place the wrench on the fastener so the pull is away from the fixed jaw. When the wrench is held in this way, the strain is placed on the tip of the fixed jaw and at the base of the movable jaw where it is the strongest.

Ratcheting* Open *End Wrench



A ratcheting open end wrench allows a fastener to be turned down or removed without having to lift the wrench at each turn. It looks like an ordinary open end wrench except one of the jaws is much shorter than the other. When you pull the wrench toward you the pressure is applied near the end of the long jaw and the root of the short jaw. When the direction of wrench movement is reversed the short jaw moves around to the next flat.

I

Box End Wrench

Much more torque can be applied with a box end wrench than with an open end, as they cannot be sprung open. Available in both 6-point and 12-point ends, with gripping surfaces offset so the wrench can be flipped over to get a new grip on the fastener while working in close quarters. The handles of some box end wrenches are offset so they extend upward, for clearance, when the box of the wrench is flat.

Ratcheting BoIC Wrench

These have two thin 6- or 12-point open sockets mounted in the ends, in the same way as the box ends of a standard box end wrench. The outside of the sockets have ratchet teeth cut in them, and the ratchet pawls are inside the wrench handle-to get a new grip on the fastener, just ratchet the handle for a new grip each time the pawl slips over a ratchet tooth. To reverse the wrench, remove it and flip it over. Made with both straight and offset handles.

Combination Wrench

This wrench has a box end and an open end of the same size handy for removing tight fasteners. The box end is used to apply maximum torque for breaking the fastener loose, then the open end is used as it is much quicker to get a new grip with an open end than with a box end.

Flare Nut Wrench

Flare nut wrenches resemble a straight box end wrench that has a portion of the box removed so the wrench will slip over the fluid line to loosen or tighten the fitting. These are weaker than box end wrenches and should not be used in place of a box end wrench for general nut lightening or loosening.

Socket Wrenches

Socket Wrench Handles

The ratchet-type allows a socket to be placed on a fastener, and by moving the handle back and forth, it is possible to tighten or loosen the fastener without removing the socket. The break-over handle, or breaker bar, is a long handle with the socket drive mounted on a pin that allows its angle relative to the handle to be varied. Break-over handles can apply the maximum torque to a fastener to tighten or loosen it. Speed handles, or speeders, resemble a crank that allows a fastener to be rapidly spun into place. Very little torque can be applied with a speed handle.

Ratchet handle

Breakover handle

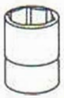
Speed handle

Hand Impact Tool

Used to break loose nuts and screws that have been corroded or rusted to the extent that an ordinary socket or screwdriver cannot budge them. Especially useful when fitted with a screwdriver bit to loosen structural screws in stressed inspection plates. The recess in the screw is cleaned out, and the screwdriver bit is installed on the driver and placed in the recess. The end of the driver is struck with a ball peen hammer; the blow rotates the screwdriver bit and at the same time prevents it from jumping out of the recess.

Typical Socket Wrenches

Available in 6- and 12-point openings, and in U.S. and metric sizes. Varieties are shallow sockets, semi-deep sockets, and deep sockets. Sockets with universal joints are available, as well as universal joints that can be placed between a normal socket and a drive. Crowfoot wrenches with an open end or a flare-nut end can be mounted on an extension to reach fasteners that cannot be reached by any other type of wrench.



Shallow socket

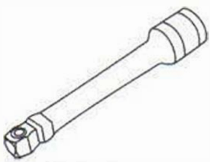
Deep socket

Crowfoot

Universal socket

Extension and Adapters

Straight extensions are available from less than 2 inches long to more than 36 inches. Some extensions are made of double-wrapped steel wire and are flexible so the socket can be oriented at any angle relative to the drive handle. Universal joints allow any socket to be used as a universal socket. Ratchet adapters can be installed between a handle and a socket, or an extension and a socket, so the socket can be ratcheted.



Straight axtensJon

Universal joint

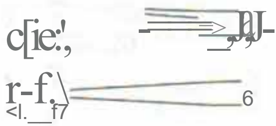
Ratchet adapter

Allen Wrenches

Allen wrenches are made of hardened tool steel with a hexagonal cross section, in the shape of the letter L with a long and a short leg. They normally come in sets and have dimensions across their flats of from 1/16 inch to 5/8 inch.

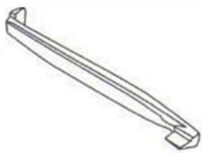
7.12 Screwdrivers

Slot Screwdrivers



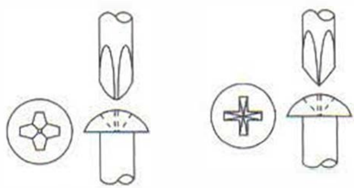
Slot-head screws have limited use in aircraft because they cannot be installed or removed with power screwdrivers-the blade slips out of the screw slot and can damage the component. Mostly they have been replaced with recessed-head screws. The blade of a slot screwdriver must be properly sharpened to prevent damage to the screw or the component in which the screw is installed. The sides of the lip should be ground parallel with the shank, and the edges should be sharp to grip the screw at the bottom of the slot.

Offset Screwdriver



Used to turn screws in locations that a straight screwdriver cannot reach.

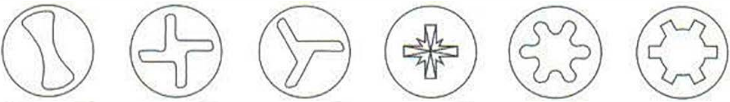
Recessed-Head Screwdrivers



Power screwdrivers require a screw head that will not allow the bit to slip out. Two types of recessed-head, or cross point screws have been used in aviation maintenance for decades: the Phillips and the Reed & Prince. The point of the Phillips screwdriver is blunt, and the sides of the point have a double taper. The Reed & Prince has a sharp point and a single taper.

Screw Heads for Special Structural Screws

The airlines and the military use screws with other types of recessed heads that hold the point of the screwdriver bit more tightly to prevent its slipping out when used with a power screwdriver. Screwdriver bits are made to fit all of these special screws. The Pozidriv screwdriver tips are an improvement on the Phillips because the tip is not as tapered, with wedges that ensure a tight fit in the screw head. Phillips screwdriver bits should not be used on Pozidriv screws as they will ride up out of the recess and round the corners of both the screw head and the screwdriver bit.



HI-Torque•　Torq-Set[1]　**Tri-Wing•**　Pozidriv'9　Tone•　**Spline**

Section 8: Aircraft Hardware

8.1 Standards

In the past, most manufacturers used standard aircraft parts that had been engineered and approved by the Army and Navy, with their specifications issued as AN standards. AN standard parts were easy to identify and their numbering system was relatively simple. But with the introduction of the turbine engine and high-speed, high-performance aircraft, aircraft hardware has become a much more complex and critical field. AN standards were replaced by Air Force-Navy standards; then other standards were developed-some of the more Important standards are listed below:

AN-Air Force/ Navy Standards
NAS-National Aerospace Standards
MS-Military Standards
AMS-Aeronautical Material Specifications
SAE-Society of Automotive Engineers
MIL-Military Specifications

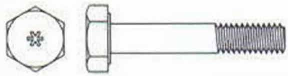
The task of looking at markings on a part and measuring it to determine its part number is now a thing of the past. Many parts look alike, but their materials or tolerances can be quite different. **Any replacement hardware must be the part number specified In the aircraft or engine parts manual, and each piece of hardware must be purchased from a source known to be reputable.** Look-alike parts that might be of Inferior strength can jeopardize the safety of an aircraft. The most commonly used parts and pertinent facts about their proper use are listed in this Section. AMTs should become familiar with the parts manuals for the aircraft and engines he or she is working on to find the correct part number for each piece of hardware used.

8.2 Threaded Fasteners

Bolts

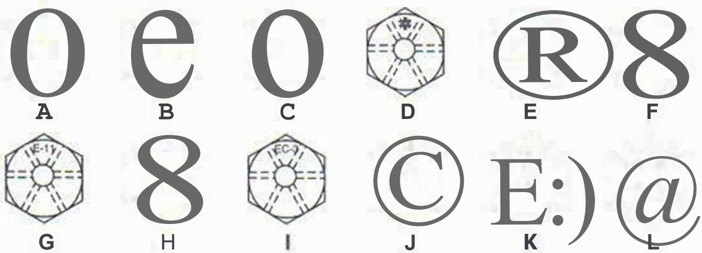
The most common type of threaded fastener, available in a number of materials such as nickel steel, aluminum alloy, corrosion-resistant steel, and titanium. Different types of heads for special purposes and different thread pitches adapt them to special functions.

Hex-Head Bolts



The standard bolt used in airframe and powerplant construction, designed for both tensile and shear loads. They depend on the proper application of torque for the strength of the joint. Available with both UNC and UNF threads, made of SAE 2330 nickel steel, 2024 aluminum alloy, corrosion resistant steel, and titanium. Most have a medium (class 3) fit and most of the steel bolts are cadmium-plated. Also available with holes drilled through the head for safety wire, and/or with a hole through the shank for a cotter pin. The material or bolt type is identified by marks on the head. Close-tolerance bolts, identified by a triangle, are ground to a fit of ±0.0005 inch and the ground surface is not plated, but is protected from rust with grease.

Bolt Head Identification Marks



A AN3-AN20-Standard alloy steel hex-head aircraft bolt

B AN3DD-AN20DD-Standard aluminum alloy hex-head aircraft bolt

C AN3C-AN20C-Standard corrosion resistant steel hex-head aircraft bolt

D AN73-AN81-Drilled-head aircraft bolt

E AN173-AN182-Close-tolerance bolt

F AN101001-AN103600-Alloy steel hex-head aircraft bolt

G AN103701-AN104600-Drilled-head aircraft bolt

H AN104601-AN105500-Corrosion resistant steel drilled-head aircraft bolt

I AN107301·AN108200-Corrosion resistant steel drilled-head aircraft bolt

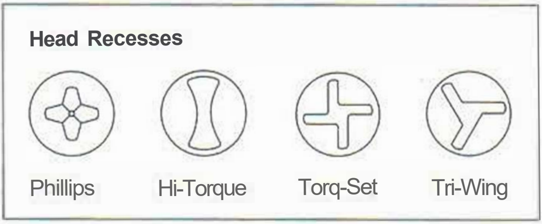
J NAS464-Close-tolerance bolt

K NAS501-Corrosion resistant steel hex-head aircraft bolt

L NAS1103-NAS1112-Alloy steel hex-head aircraft bolt

Flush-Head Bolts

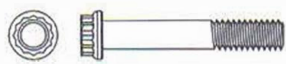
Many modern aircraft applications require high-strength bolts with heads that can be flush with the outside skin of the aircraft. Most bolts in the NAS and MS series have a 100° head, but some have an 82° head. These high-strength bolts are made of alloy steel and titanium and some have self-locking inserts in the threads.



Drilled-Head Bolts

Drilled-head airframe bolts are used in locations where a high tensile strength is required and where the bolt is safetied with safety wire. There is no hole in the shank for a cotter pin.

Twelve-Point, Washer-Head Bolts



Designed for special high-strength and high-temperature airframe and powerplant applications; available in both NAS and MS series. The heads of many of these bolts are drilled for safety wire.

Internal Wrenching *Bolts*

NAS144, MS2004

These are the typical high-strength alloy steel bolts used in special airframe applications where severe loads are imposed on the structure. They have a radius between the shank and the head, and a special chamfered, heat-treated steel washer (such as the NAS 143C) is used under the head to provide a bearing surface. Turned with a hex wrench which fits into the socket in the head.

Clevis Bolts

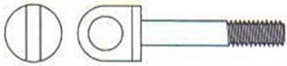
Designed for shear loads only. To prevent them from being used for tensile loads, the head is shallow and has a slot or recess for turning with a screwdriver. The threads are short to take a thin nut, and there is a notch between the threads and the shank. Most have a drilled shank so a cotter pin can be used to prevent the nut from backing off. A typical application is the attachment of a cable to a control horn: the bolt is installed and the nut is tightened just enough that the cable terminal is free to move on the horn.

AN21 to AN36 series

Eye Bolts

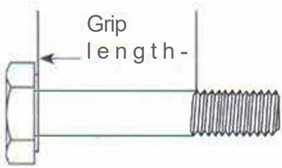
Used to attach wires and cables to aircraft structure; made of alloy steel, cadmium-plated, and available with or without drilled shanks.

AN42 to AN49 series



Bolt Installation

Almost all hex-head bolts have a round, smooth, washer-like bearing surface just below the head. This surface prevents the edges of the head from damaging the surface of the component into which the bolt is installed. If there is no such surface, a washer should be placed under the head. Also, always place a washer under the nut to provide a good bearing surface and prevent damage to lhe component as the nut is tightened.



The bolt length should be chosen so that the grip length (the length of the unthreaded shank) is the same as the thickness of the materials being joined. The nut must never be screwed down against the last thread on the bolt. If the grip length is too long, use plain washers to act as shims to prevent the nut reaching the last thread. **Bolts must be Installed In exactly the way the aircraft or engine maintenance manual specifies.** If there is no information of this nature, bolts should be installed with the head upward. forward, or inboard. These orientations normally aid in preventing the bolt from falling out if the nut were not screwed on.

Some bolts have holes drilled in the threaded portion of the shank for cotter pins to secure a castellated nut. If a self-locking nut is to be used on a drilled shank bolt, be sure that the edges of the hole are chamfered to prevent the sharp edges from cutting threads in the nut insert.

Bolt Fits

If there is any looseness or play in a threaded joint, vibration can prOduce a cyclic stress that can further loosen the fastener and lead to destruction. Aircraft design engineers calculate the stresses that will affect ***every*** joint, and the fasteners are designed to prOduce a stress within the joint greater than any anticipated applied stress. This bolt stress is determined by the fit of the bolt in the bolt hole, and by the torque applied (*see* Pages 162-165). The maintenance manual usually specifies the drill size for all bolt holes. If no drill size is specified, it is normally satisfactory to use the next larger number drill (smaller number) than the shank diameter of the bolt being installed. Example: a #12 drill (0.1890) can be used for a 3/16-inch (0.1875) bolt. Some manuals specify a type of drive fit for the bolt in which the hole is drilled slightly undersize and reamed to the diameter that will provide the desired fit (*see* table below):

Type of fit	How to drill/ream hole
Loose fit	Use a drill number one size larger than the diameter of bolt. Hole is 0.002 to 0.005 inch larger than bolt shank.
Push fit	Reamed fit-allows bolt to be forced into the hole by hard, steady push against bolt head.
Tight-drive fit	Requires bolt to be driven into the hole with sharp blows from a 12- or 14-ounce hammer.
Interference fit	Bolt diameter is larger than reamed diameter of hole. The component with the hole must be heated to expand the hole-the bolt is chilled with dry ice to shrink it. When bolt is installed, and the component and the bolt reach the same temperature, the bolt cannot be ***moved.***

Screws

Normally differ from a bolt because they have a slot or recess in the head so they can be turned with a screwdriver rather than a wrench, and their threads extend all of the way to the head. However, this distinction has been blurred: a number of high-strength bolts also exist with flush heads so they can be installed on the outside of an aircraft structure and not cause wind resistance.

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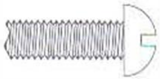
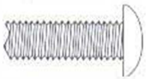
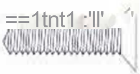
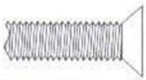
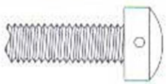
Aircraft Screw Heads

	Round **head** Normally used for nonstructural applications and are made in steel and brass. Most have a class **2** fit; available with both coarse and fine threads. Slot heads and Phillips recessed heads are the most common.
	**Pan head** Flatter than round heads, used to replace round heads for new designs. Available with slot or Phillips recessed heads.
	100° Flush head Used for applications where high strength and a smooth surface are necessary. Available in both NAS and MS series; may have Phillips, Hi-Torque, or Torq-Set heads.
	**82°** Flush **head** Found on some of AN screws; used for a flush installation where high strength is not necessary.
	**Fillister head** Used where surface smoothness is not necessary. Often drilled for safety wire.

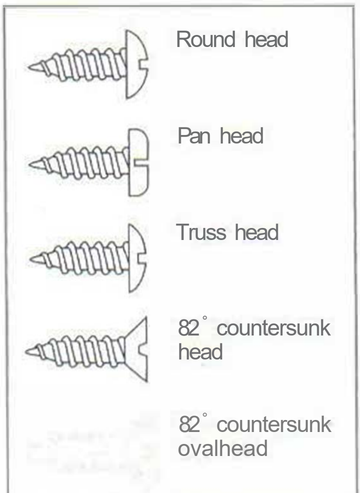
	**Slot**		**Tri-wing" recess** (Registered trademark of Phillips Screw Company)
	**Hi-Torque recess**		**Phillips recess**
	**Torq-Set recess**		

Set Screws

A special type of headless screw used for such applications as securing wheels or pulleys to shafts, or indexing a wheel on a splined shaft. The cup and cone points bite into the shaft for a tight grip. The full dog and half dog points are used to ride in a spline to allow lengthwise movement while preventing rotation.

Self-Tapping Sheet-Metal Screws

Used in the installation of cowling and inspection plates for some lighter aircraft. Often called PK screws because the first ones to become popular were made by the Parker-Kaylon company. Available in the AN, MS, and NAS series. They may have either a sharp point (Type A) or a blunt end (Type B), and are made with either a slot or a Phillips recessed head in sizes 4, 6, 8, and 10.



All of the screws shown are Type A, having a sharp point.

Nuts

These components have internal threads that screw down over a bolt to provide the clamping action that holds all the components in a bolted joint tightly together.

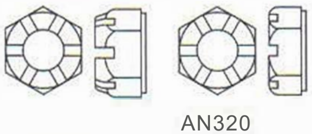
Nonloclclng Nuts

- No built-in provision for automatically locking them to the bolt.
- Must use a cotter pin, safety wire, or a check nut to prevent them from turning.

AN310 and AN320

- Secured to bolts by cotter pins passed through bolt holes and slots in the nuts.
- AN310-thick nut used for tensile loads
- AN320-thin nut used only for shear loads.
- Available in cadmium-plated nickel steel, aluminum alloy, and corrosion resistant steel.

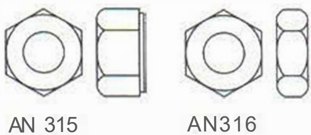
Castellated, or Castle Airframe Nuts



AN315 and AN316

- AN315-used on a bolt with no cotter pin hole: thick, for tensile loads.
- AN316-check nut used to lock the AN315 to a bolt.
- The AN315 nut is screwed down on the bolt and tightened with the proper torque, then the AN316 nut is screwed down on top of it and tightened.

Plain Airframe Nuts

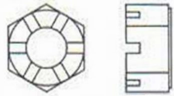


- Tightening the AN316 applies a tensile stress to the bolt which holds the nuts tightly together, preventing vibration from loosening the joint.

AN355

- Slotted nut; locked onto bolt or stud with a cotter pin or safety wire through the slots and through a bolt or stud hole.
- Designed for use on engines; not approved for use on aircraft structures.
- Being replaced with AN121551 through AN121600 series nuts.

Slotted Engine Nut

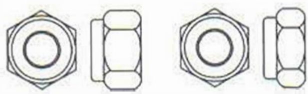


AN 355

Seit-Locking Nuts

Vibration is an ever-present problem in aircraft operation, and some method must be used to prevent nuts from loosening on bolts or studs. This is often done with cotter pins or safety wire through holes in the bolt or stud and slots in the nuts. Self-locking nuts were devised to save the time needed to safety these nuts. These are classified by the temperature they are designed to withstand. Low-temperature nuts should not be used where temperatures exceed 250° F, but high-temperature nuts are good to temperatures as high as 1,400° F.

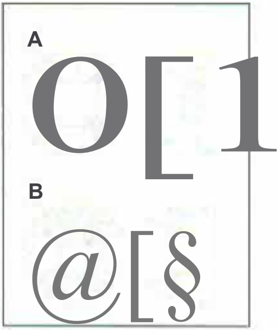
Low-temperature locking nuts:



MS20365 (AN365)   MS20364 (AN364)

1. Has a fiber or nylon insert tocked into the end of the nut, with a hole slightly smaller than the major diameter of the bolt used.
2. Screws down freely until the insert is reached, then a wrench is required to turn it further.
3. The bolt does not cut threads in the insert, rather it distorts the insert causing it to grip the bolt threads. This gripping action plus the opposition to turning caused by the Insert produces a force between the nut and bolt threads which prevents the nut from loosening.
4. Self-locking nuts should not be used in any application where the nut and bolt are subject to rotation (such as in attaching a control cable to a control horn).
5. A self-locking nut can be reused as long as a wrench is required to turn it on the bolt.
6. To ensure that the insert grips all of the bolt threads, the complete chamfer on the end of the bolt must stick out beyond the insert; if the bolt is not chamfered, at least one complete thread should show beyond the insert.

High-temperature loclclng nuts:



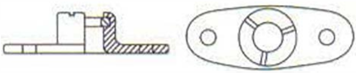
- The fiber or nylon insert cannot tolerate high temperatures, therefore several methods have been devised to lock all-metal nuts to the bolt-two of the most popular methods are distorting the pitch of the threads, and compressing the end of the nut.
- Some nuts, such as the 12-point nut in view A, have a thinned section near the end that is compressed enough to distort the pitch of the threads. As the nut is screwed down on the bolt, it turns easily until the bolt threads encounter the distorted area, then a wrench is needed to turn it further. This type of nut is widely used in aircraft engine and missile applications and is suitable for applications to temperatures as high as 1,400°F.
- The nut in view B is made of relatively thin steel, with the end of the nut formed into an elliptical shape. As it screws down on the bolt threads the ellipse rounds out, and the spring action of the nut grips the bolt threads.

Not all nuts used in aviation construction are of the hex or 12-point configuration. There are many types of nuts that are fixed to the structure that do not require a wrench for installation with screws or bolts.

Wing Nuts

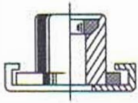
1. For special aircraft applications that require a nut that can be turned without the use of any tools.
2. Not normally required to produce a great deal of force, so they do not need much torque for installation.
3. Used to secure objects that must be frequently removed.

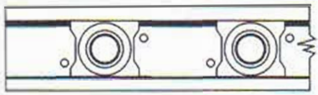
Anchor Nuts



1. For use on inspection plates that are retained with screws from the outside of the aircraft, with no access to the nuts on the inside.
2. Available in both low- and high-temperature styles.
3. Riveted around the screw hole in the aircraft structure so that the inspection plate screws can be screwed into the anchor nut without having to hold the nut with a wrench.

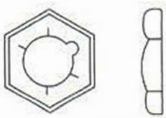
Channel Nuts





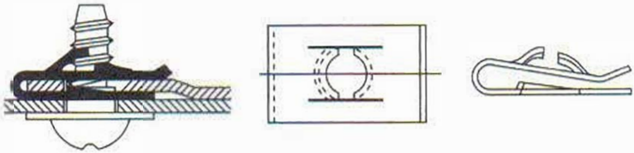
1. A form of anchor nut used when it is necessary to have a number of nuts inside the aircraft structure for attaching components such as access panels.
2. The channel is riveted to the structure, and the nuts ride loosely inside the channel; this looseness allows for slight movement to align the nut with the screw.
3. The body of the nut is square so it will not turn as the screw is driven into it.
4. The ESNA (Elastic Stop Nut series) nuts use fiber or nylon inserts to grip the screws and prevent them from loosening.
5. On the Boots series nuts, the pitch of the last threads at the nut end is distorted with respect to the nut threads in the body. The difference in the thread pitch grips the screw tightly so they will not loosen.

Pressed-Steel Nuts



1. Saves cost and weight in aircraft construction.
2. The best example is the Pal nut, a thin nut used primarily on engines as a check nut to prevent a plain nut from loosening.
3. The plain nut is tightened to the proper torque, then the Pal nut is installed over it and tightened only snugly.
4. The thin steel of the nut rides in the threads of the bolt, and as the nut is tightened it exerts a force on the threads that holds the nut so tight against the plain nut, that normal vibration cannot loosen it.

Tinnerman Type U Speed Nut

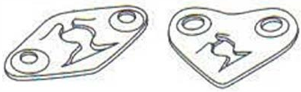


8.2

5. The Type U Speed nut is a popular pressed-steel nut for cowling and other applications on light aircraft. It is slipped over a screw hole in the fixed portion of the cowling, and a self-tapping sheet metal screw is passed through the mating hole in the removable part. As the screw is tightened, it forces down the edge of the spring steel nut and holds the screw tight so vibration will not loosen it. Prevents the hole in the soft sheet aluminum of the cowling from being enlarged by repeated installation and removal of the screws.

6. Anchor nuts are available in pressed-steel-two of the more popular configurations are the plain type and the corner type, both available for round-head and flat-head screws. Anchor nuts for flat-head screws are dimpled so the dimpled hole of the inspection plate will nest in it.

Pressed Steel Anchor Nuts

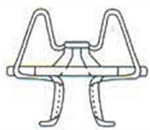


Instrument *Nuts*

1. This nut can be slipped into the mounting holes and will receive the screw and not turn when the nut is tightened.

2. For mounting instruments on the front side of the panel, the same type of nut is available with the legs just long enough to go through the panel metal.

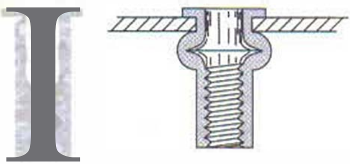
Pressed-Steel Instrument Mounting Nut



Rivnuts

1. Developed to attlich rubber deicer boots to the thin metal of aircraft wings and empennage leading edge surfaces.

2. Special tubular nuts are screwed onto a mandrel in the puller, and inserted in the hole in the aircraft skin.



3. The handles of the puller are squeezed together and the, Rivnut tube is collapsed, tightly gripping the skin.

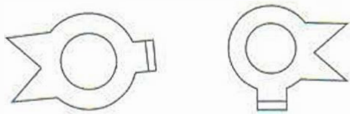
4. The mandrel of the puller is screwed out, then the machine screw used to attach the boot can be screwed in.

5. Many Rivnuts have a key under the head that fits Into a notch cut into the edge of the hole in the skin to prevent the Rivnut from turning when the screw is inserted or removed.

Threaded Fastener Safetying

All threaded fasteners with the exception of self-locking nuts are secured with some form of safety device.

locking Washers

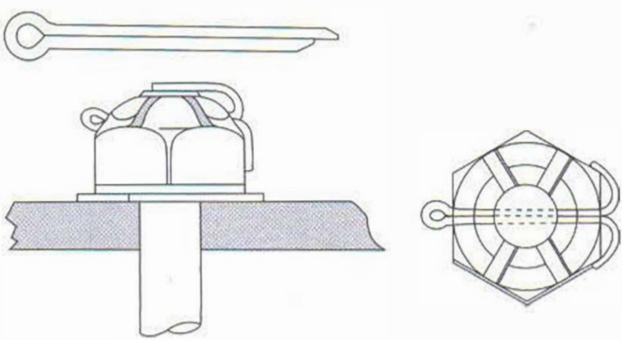


- Flt over the bolt or stud.
- Tab fits into a hole or slot in the body of the component.
- Plain nut installed and torqued; the triangular-shaped tabs are bent up against the flats of the nut.
- Nut cannot back off of the stud, stud cannot back out of the component.

Corter Pins

- Castellated nuts are safetied on bolts with cotter pins passed through the castellations and the hole in the shank of the bolt.
- Available as AN380 in low-carbon steel, and AN381 in corrosion-resistant steel.
- Be sure to check the airframe or engine maintenance or parts manual to get the correct part number for the correct pin.

Cotter Pin Installation

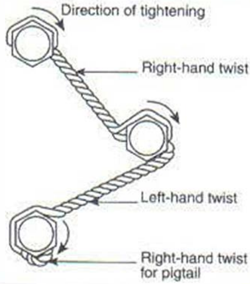


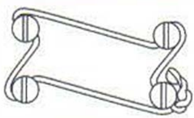
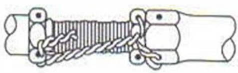
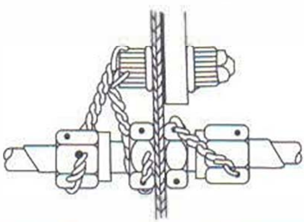
Installation:

1. First check the alignment of the slots in the nut with the hole in the bolt at the minimum recommended torque. If they are not aligned, continue to tighten. This normally ensures the hole and slots will align within the allowable torque range. If there is no alignment by the time maximum torque is reached, remove the nut and install a different thickness plain washer under the nut and retorque. It is not recommended that maximum torque be exceeded for alignment.
2. When the nut is properly torqued, slip the correct cotter pin through the slots in the nut and the hole in the bolt shank.
3. Spread the pin and pull the head tightly into the slot of the nut.
4. Fold one of the legs back against the end of the bolt shank and cut it off with a pair of diagonal cutters so it does not extend past the edge of the bolt shank.
5. Cut the other leg of the pin so it does not extend beyond the edge of the nut and fold it securely down against the flat of the nut.
6. As a final check, be sure that the cotter pin is tight, with no looseness or play, and that the ends of the pin are tight against the bolt and nut (so they cannot cut you if you rub your hand over them).
7. If it is important that the cotter pin not protrude beyond the end of the bolt shank, the pin may be inserted with the split vertical and the ends folded back against the flats of the nut. The pin should be tight in the slot and the ends cut off so they leave no sharp edges.

Safety *Wire and* Safety Wire *Twisting*

- Safety wire is available in copper, brass, stainless steel, and galvanized or tinned steel.
- Sizes in diameters from 0.020 to 0.051 inch.
- Be sure to use the size and material wire specified by the equipment manufacturer, and safety as specified in the appropriate maintenance manual.
- Safety wire twisting can be done with a pair of duckbill pliers, but one of the reversible safety wire twisting tools makes the job much faster and more uniform.

<table>
<tr><th colspan="2">Some tips for twisting safety wire:</th></tr>
<tr><td>
</td><td>• Safety wire should be twisted in a direction that will hold the loop of wire down along the side of the fastener.

• Bolt heads are safetied in such a way that the loosening tendency of one will pull on the wire in a tightening direction on the other.</td></tr>
<tr><td></td><td>• When there is a clearance problem, safety wire may be passed over the end of the stud rather than around the nut.</td></tr>
<tr><td></td><td>• Fillister-head screws may be safetied with a single wire.</td></tr>
<tr><td></td><td>• To safety the adjustment of a control rod: after the length of the rod is adjusted, the socket end of the rod is safetied to the check nut, and then to the holes in the hex of the male end of the rod.</td></tr>
<tr><td></td><td>• Safety a coupling nut on a flexible line to a straight connector brazed on a rigid tube, as shown.</td></tr>
<tr><td></td><td>• Safety coupling nuts to a bulkhead fitting as shown: the coupling nut on the right is safetied to the hex on the bulkhead fitting. The bulkhead nut is tightened against the bulkhead and is safetied to a fixed point with the safety wire pulling on the nut in the direction of tightening. The coupling nut is safetied to the same fixed point.</td></tr>
</table>

There are many different applications for safety wiring in modern aircraft and engines, and some basic principles apply to all installations:

1. Before safety wiring a fastener, be sure that it is properly torqued.
2. Be sure to use the method of safety wiring specified in the airframe or engine maintenance manual.
3. Install the wire so that it always pulls the fastener in the direction of tightening. This will prevent the fastener from backing off if it should loosen.
4. Loop the wire around the outside of the fastener so that it is routed under the wire protruding from the hole. This causes the loop to stay down and prevents slackening. The direction of twist should reverse from run to run, and from run to pigtail. This reversal is done to hold the loop of wire down around the fastener.
5. Be sure that the twists are tight and even, and the twisted wire between the fasteners is taut but not too tight. The recommended number of twists per inch depends upon the diameter of wire.

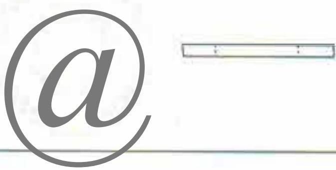
Wire diameter	Twists per inch
0.020 - 0.025	**8 - 14**
0.032 - 0.041	**6 - 11**
0.051 - 0.060	4 - 9

6. Be sure that the pigtail at the end of the wire is no more than 3/4 inch long and has a minimum of 4 twists. Double the pigtail back, cut the end off, and bend it under so it will not snag or cut anything that rubs across it.

8.3 Washers

Plain washers, (examples of}	Uses	Description
AN960	• Provides smooth bearing surface for nut. • Serves as shim for bolt grip purposes. • Prevents sharp edges under lock washers from damaging material clamped.	•Steel or aluminum alloy • Hole with plain edges
AN 143C	• Used under the heads of high-strength internal-wrenching bolts such as NAS 144 (because of the radius between the head and shank).	•Steel •Hole has chamfered edges
AN 970	• When bolting wood structures together: spreads force applied by bolt and nut over larger area of the wood.	• Large area (outside diameter larger than AN 960)

AN 960 Plain Washer



Lock Washers, Types	Uses	Description
Split lock washer	• Prevent vibration from loosening nut by producing a stress between the nut and the material being clamped. • Not to be used on aircraft structure where failure of washer might result in damage or danger to aircraft or personnel. • Primarily used under large nuts.	• Heavy spring steel • Cut and twisted
Shakeproof lock washer	• Teeth are twisted to produce the needed stress. • Primarily used with machine screws.	• Thin spring steel with internal or external teeth

Lock Washers

Split   Internal shakeproof   External shakeproof

Ball Socket and Seat Washers	Uses	Description
AN950 AN955	Used together as a pair to help clamp when it is impossible to get perfect alignment between the bolt and material.	• Ball socket • Seat washer

AN 950 and AN 955 ball socket and seat washers

8.4 Special Rivets

Solid rivets, the most widely used fasteners in aircraft construction, and their identification are covered in Section 9 *Metal Aircraft Fabrication.* Other types of rivets for special uses in aircraft materials and construction are listed below.

Blind Rivets

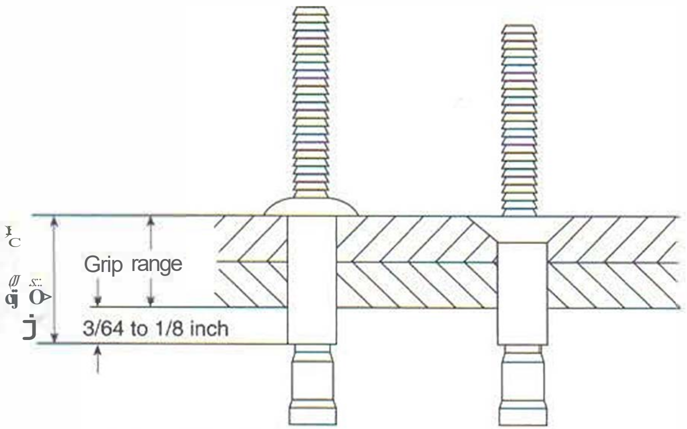
Often it is necessary to install rivets where there is access to only one side of the material, as opposed to solid rivets which require access to both sides for driving. There are a number of rivets that meet this need. such as the blind rivet types listed below.

> NOTE: When using a blind rivet in a repair, it must be the rivet specified in the maintenance manual for the specific repair. The common pull-type Pop rivets such as those found in most hardware stores are not approved for use on certificated aircraft.

Friction-Loci< Rivets

- Made by the Townsend Division of Textron, approved for aircraft structure.
- May be used to replace a solid rivet in some instances, but normally must have a diameter one size larger than the rivet it replaces_

Seit-Plugging, Friction-Lock Cherry Rivets



To install a friction-tock rivet:

1. Insert it in the prepared hole, then grip and pull the serrated stem with a special tool.
2. This pulls the tapered plug up into the hollow shank and swells it to form the upset head inside the structure.
3. Continued pulling snaps the stem off and leaves the plug inside the shank.
4. Cut off the broken-off stem and file it flush with the rivet head.

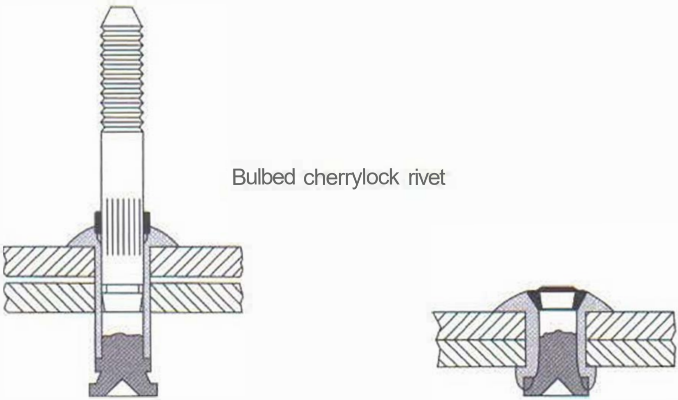
> **NOTE:** Plug is held in the shank only with friction-it is possible that vibration can shake it out and weaken the joint.

5. To remove friction-lock rivets, punch the stem out of the rivet. Using a drill the diameter of the rivet shank, drill the head and tap the shank out of the skin with a properly fitting pin punch.

Mechanlcal-Lock Rivets

- Normally approved to replace solid rivets on a size-for-size basis because the stem is locked into the hollow rivet shank and it cannot vibrate out.
- As strong or stronger than a solid rivet of the same diameter.
- Available with both universal heads and 100° countersunk heads.
- Standard and oversize diameters.
- Lengths measured in increments of 1/16 inch.

Mechanical-locked rivets



(Before stem is pulled out)

(After stem is pulled out)

Installed in the same way as the friction-lock rivet:

1. As the stem is pulled, the head is forced firmly against the skin and the skins are pulled tightly together.
2. The shear ring on the bottom of the stem upsets the shank, forms the blind head inside the structure and swells the shank to completely fill the rivet hole.
3. Continued pulling of the stem shears off the shear ring and pulls the end of the stem up to form the bulbed head.
4. The locking collar is forced into the groove in the stem, holding it tight, preventing it vibrating loose.
5. The stem then breaks off flush with the rivet head.

CherryMax *Rivets, Olympic-Lok Rivets, Huck* Rfvets

- Mechanical-locking blind rivets that are approved for use in aircraft structure.
- All function on the same principle as that described for the Bulbed Cherrytock rivet.

To remove mechanical-locked rivets:

1. File the head to weaken the locking ring.
2. Tap the stern out with a properly fitting pin punch.
3. Drill through the head of the rivet and tap the shank out of the hole with a pin punch.

High-Strength Pin Rivets

Pin rivets are a group of fasteners that have the strength of a bolted joint but are lighter weight and easier to install than a bolt, and are installed in locations where they are not likely to need to be removed.

HI-Shear Rivet

- Has a heat-treated alloy steel pin equivalent or superior in strength to the AN bolt that it is approved to replace.

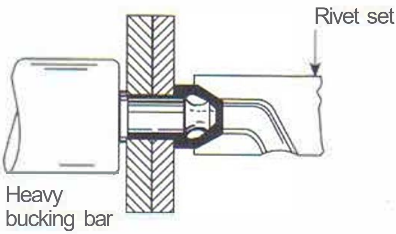
To install a Hi-Shear rivet:

1. Tap pin into a hole that has been drilled and reamed to an interference fit.
2. The grip length of the pin must be such that no more than 1/16-inch protrudes from the material.
3. A collar is placed over the end of the pin and special rivet set in a rivet gun swages the collar down into the groove of the pin.

- Hi-Shear pin rivets are removed by splitting the collar with a small, sharp chisel and tapping the pin from the hole.

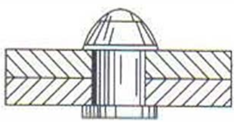
Hi-Shear Pin Rivet

Installation:

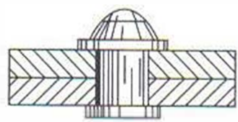


Inspection:

Proper Installation

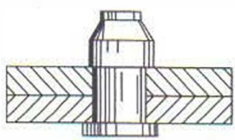


Correctly-driven pin rivet.

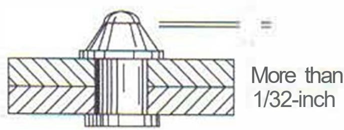


0.032-inch steel washer may be used to adjust grip length of pin.

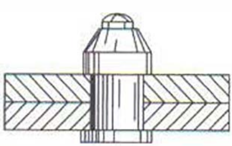
Improper Installation



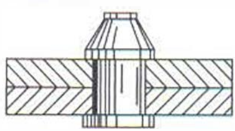
Collar is underdriven. It may be driven more.



Collar is overdriven. If there is more than 1/32-inch between shearing edge of pin and top of collar, collar should be removed and a new one installed.



Pin is too long. Remove collar, install washer, or use shorter pin.

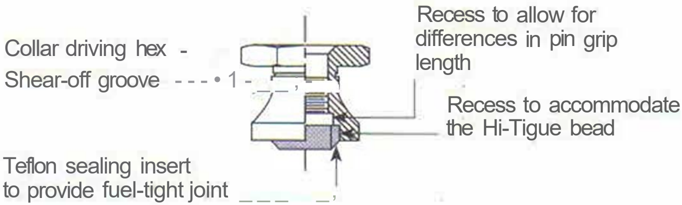


Pin is too short. Remove collar and use longer pin.

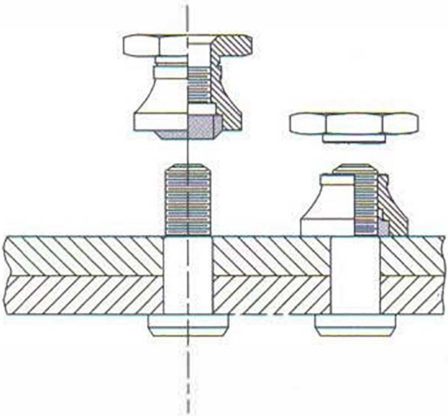
Hi-Lok Fasteners

- Hi-Lok/Hi-Tigue fasteners are a product of the Hi-Shear Corporation; they are an improvement of the Hi-Shear piri rivet.
- Consists of a special precision-threaded pin, with either a flush or protruding head and a special collar.
- The pin is inserted in a reamed hole to provide a slight (up to 0.002-inch) interference fit.
- Of the two counterbores in the collar, the smaller and deeper one compensates for differences of material thickness by providing space for the threads when the grip length is long. The larger counterbore accommodates the bead of the Hi-Tigue pin.
- A Teflon insert forms a fluid-tight seal between the pin and the collar, allowing use in fuel tanks without the need for any sealant.

HI-Lok/HI-Tigue Fastener



Installation of a protruding-head HI-Lok Fastener

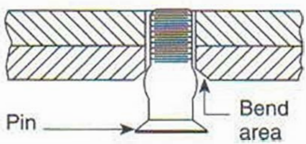


Installation:

1. The collar is started on the pin by hand, then continued by an electric or pneumatic driving tool. The tool has a hex wrench tip that fits into a hexagonal hole in the end of the pin to hold it and prevent its turning while the collar is being driven.
2. A socket that exactly fits the collar driving hex turns it; as the collar contacts the surface of the material being joined, it pulls the pin up tightly and clamps the structural parts together.
3. Continued turning of the driving hex breaks it off at the shear-off groove, ensuring that the minimum-weight fastener is properly torqued without the need of an accurately-calibrated torque wrench.

Hi-Tigue Fasteners

HI-Tigue Fastener



- Similar to the Hi-Lok, except the pin has a slightly enlarged bead near the threaded area of the pin.
- The hole should be drilled and reamed so the bead area will have between a 0.002 and 0.004-inch interference fit.
- The pin is driven into the prepared hole with a conventional rivet gun and the opposite side of the material is supported by a draw bar whose hole just fits over the pin.
- The interference fit holds the pin while the collar is driven and therefore does not need to be held with a hex wrench (as is done with the Hi-Lok pin).

Both the Hi-Lok and Hi-Tigue fasteners can be driven with an open end or box wrench, and the Hi-Lok pin can be held with an Allen wrench. Both fasteners may be removed by unscrewing the collar using a pair of vise-grip pliers or cutting away the collar with a hollow mill-type cutter. The pin may be reused if it is not damaged.

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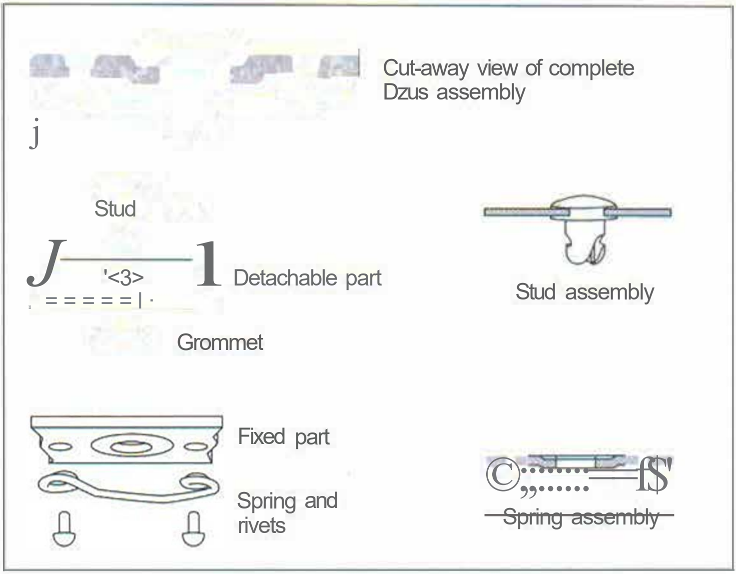
8.5 Cowling Fasteners

Aircraft cowling require fasteners that allow the pilot to open the cowling for preflight inspection without requiring special tools. Some fasteners hold the cowling tightly in place, yet allow it be opened with a quarter of a turn with a screwdriver, or even with a coin. The Dzus (pronounced zoos) fastener is one of the oldest and most popular cowling fastener.

Other fasteners, notably the Camloc and Airloc, are different physically but operate on the same principle as the Dzus, and are used for the same applications. Both of these fasteners turn a cross pin in the stud into a cam-shaped receptacle. In the Camlok fastener, the pin is spring loaded, and in the Airloc, the receptacle is made of spring steel.



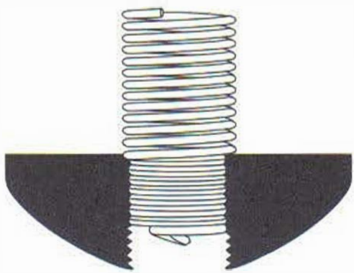
- A wire spring is riveted across the hole in the fixed part of the cowling and a notched stud is assembled in the detachable part.
- The stud is held in its hole with an aluminum grommet that is swaged into the hole so it fills the notch just under the head of the stud, allowing it to turn but preventing it from falling out.

- When the cowling is closed, the stud fits through the hole in the fixed part and the notch straddles the spring.
- A clockwise quarter tum forces the cam-shaped notch to pull the spring up and hold the detachable part of the cowling tight against the fixed structure.

8.6 Thread Repair Hardware

There are a number of aluminum castings in an aircraft, particularly in the engine. These castings are relatively soft and the threads are easy to strip out, so provisions are made to repair the damage rather than replace the expensive component.

Helicoil Insert



One of the handiest and most useful thread repair tools is the Helicoil insert. Damaged threads are drilled out with a special drill and new threads are tapped in using a special Heiicoil tap.

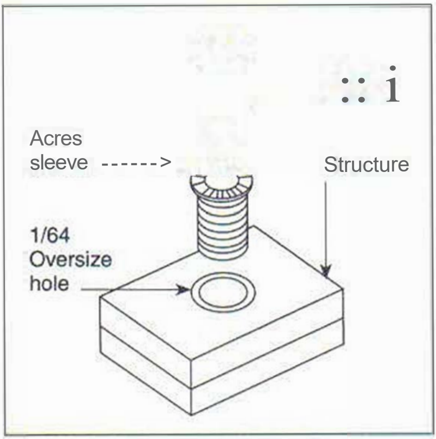
Helicoil inserts are used not only in repair work, but some engine manufacturers use them rather than bushings for the threads in the spark plug holes. The inserts give more durable threads than the cast aluminum cylinder head and may be replaced if they are ever damaged.

1. The insert, a coil of stainless steel wire with a diamond-shaped cross-section, is placed on the insertion tool with the slot in the end of the tool straddling a driving tang at the end of the Insert.
2. As the insert is screwed into the new threads, it is wound tighter and its outside diameter decreases enough that it can screw in easily.
3. When the insert is screwed in all the way, the tool is reversed, the driving tang breaks off and the spring force of the insert expands it outward, holding it tightly in the threads.
4. The inside of the insert now acts as the new threads into which the bolt can be screwed.

Acres Sleeves

Corrosion often damages the threaded area in aluminum alloy castings; these can be repaired with Acres sleeves.

1. The damaged hole is drilled out 1/64-inch oversize to clean up the damage or corrosion.
2. A bonding agent is applied to the outside of the insert and it is pressed into the hole.
3. When the bonding agent cures the threads on the inside, the sleeve allows the original fastener to be installed.
4. Grooves around the outside of an Acres sleeve allows it to be broken off to a length correct for the material into which it is inserted and to hold the bonding agent.



Section 9: Metal Aircraft Fabrication

I

9.1 Sheet Metal Layout and Forming

Definitions

bend radius (BR)-The radius of the *inside* of the bend.

bend allowance-The actual amount of metal used in the bend.

setback(SB)-The distance between the bend tangent line and the mold line.

K-A multiplfer used to find the bend allowance for bends of angles other than 90°.

neutral line-The line through a material that has no stresses imposed by a bend; material along the neutral axis neither shrinks nor stretches when the material is bent.

mold line-The extension of the flat side of an object beyond the radius.

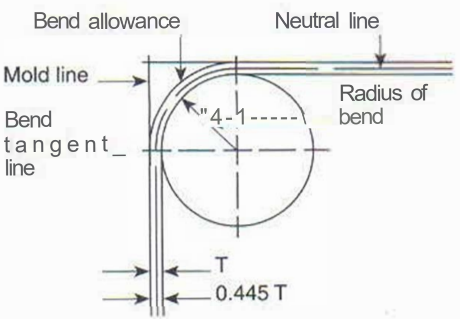
sight line-A line drawn on a sheet metal layout that is placed directly below the nose of the radius bar in a leaf brake.

open angle-A bend in which the metal is bent less than 90°.

closed angle-A bend in which the metal is bent more than 90°.

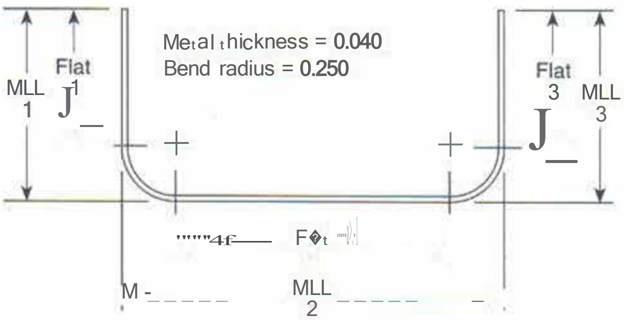
bend tangent line-The line in a sheet metal layout that marks the end of a flat surface and the beginning of the bend.

Bend Nomenclature



Layout Procedure

Bend Dimensions



Example

MLL 1 = 1.00 inch
MLL 2 = 2.00 inch
MLL 3 = 1.00 inch

BR = 0.25 inch
Thickness = 0.040 inch

1. Find the setback by adding the bend radius and the metal thickness.

   SB = (BR + MD X K

   : (0.250 + 0.040) X 1

   = 0.290 inch

   The value of the constant K can be found in the chart on Pages 212 through 214.

   For a 90° bend, K = 1

2. Find the length of flat 1 by subtracting the setback from mold line length 1.

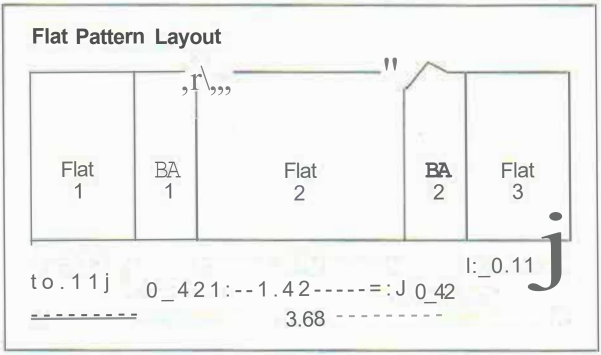
   Flat 1= MLL 1 - setback

   = 1.00 - 0.290

   = 0.710

3. Find the bend allowance by using the chart on Pages 215 through 217.

Follow the 0.040 metal thickness row across to the column for 1/4-inch bend radius. The top number is the amount of bend allowance for a 90° bend, and the bottom number is the amount of material used for each degree of bend. In the example, a 90° bend in a piece of 0.040 sheet metal using a 1/4-inch bend radius requires 0.421 inch of metal.



4. Find the length of flat 2 by subtracting two setbacks from mold line length 2.

   Flat 2 = MLL 2 - 2 setbacks

   = 2.00 - 2(0.290)

   = 1.42 inch

5. Bend allowance 2 is the same as bend allowance 1.

   BA 2 = 0.421 inch

6. Find the length of flat 3 by subtracting the setback from mold line length 3.

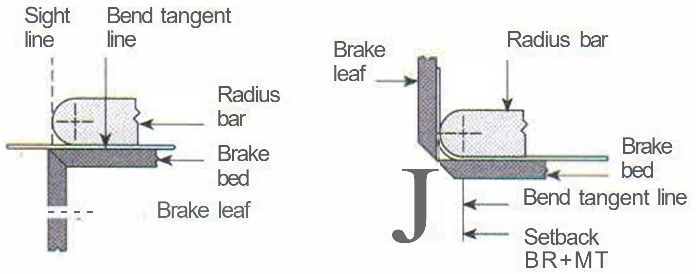
   Flat 3 = MLL 3 - Setback

   = 1.00 - 0.290

   = 0.710 inch

7. Cut the material 3.68 inches wide and as long as needed. Mark the bend tangent lines with a sharp-pointed soft lead pencil.

Correct placement of metal in the brake



1. Clamp the metal in the brake with the bend tangent lines even with the beginning of the radius of the radius bar.
2. You can determine this position by drawing a sight line inside the bend allowance material. Draw this line one bend radius from the bend tangent line.
3. Position the material so this sight line is directly below the edge of the radius block when viewing it perpendicular to the surface of the metal.
4. When the brake leaf is raised, the metal will form smoothly around the radius bar.

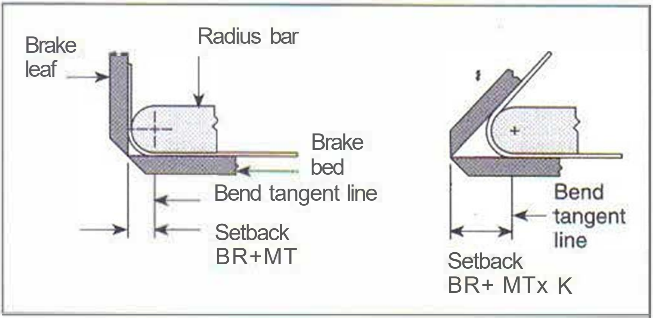
9.2 Minimum Bend Radii for 90° Bends in Aluminum Alloys

Alloy and Temper	Sheet Thickness							
	0.020	0.025	0.032	0.040	0.050	0.063	0.071	0.080
2024-0 [1]	1/32	1/16	1/16	1/16	1/16	3/32	1/8	1/8
2024-T4 [1,2]	1/16	1/16	3/32	3/32	1/8	5/32	7/32	1/4
5052-0	1/32	1/32	1/16	1/16	1/16	1/16	1/8	1/8
5052-H34	1/32	1/16	1/16	1/16	3/32	3/32	1/8	1/8
6061-0	1/32	1/32	1/32	1/16	1/16	1/16	3/32	3/32
6061-T4	1/32	1/32	1/32	1/16	1/16	3/32	5/32	5/32
6061-T6	1/16	1/16	1/16	3/32	3/32	1/8	3/16	3/16
7075-0	1/16	1/16	1/16	1/16	3/32	3/32	5/32	3/16
7075-W	3/32	3/32	1/8	5/32	3/16	1/4	9/32	5/16
7075-T61	1/8	1/8	1/8	3/16	1/4	5/16	3/8	7/16

[1] Clad sheet may be bent over a slightly smaller radii than the corresponding tempers of bare alloy sheets.

[2] Immediately after quenching, this alloy may be formed over appreciably smaller radii.

9.3 Setback



Setback for a 90° bend is the bend radius plus the metal thickness (BR+ MT). For any angle other than 90°, the sum of the bend radius and the metal thickness must be multiplied by the value of "K" found in the setback (K) chart below.

Setback (K) Chart

Degrees	K	Degrees	K
1	0.00873	18	0.15838
2	0.01745	19	0.16734
3	0.02618	20	0.17633
4	0.03492	21	0.18534
5	0.04366	22	0.19438
6	0.05241	23	0.20345
7	0.06116	24	0.21256
8	0.06993	25	0.22169
9	0.07870	26	0.23087
10	0.08749	27	0.24008
11	0.09629	28	0.24933
12	0.10510	29	0.25862
13	0.11393	30	0.26795
14	0.12278	31	0.27732
15	0.13165	32	0.28674
16	0.14054	33	0.29621
17	0.14945	34	0.30573

Degrees	K
35	0.31530
36	0.32492
37	0.33459
38	0.34433
39	0.35412
40	0.36397
41	0.37388
42	0.38386
43	0.39391
44	0.40403
45	0.41421
46	0.42447
47	0.43481
48	0.44523
49	0.45573
50	0.46631
51	0.47697
52	0.48773
53	0.49858
54	0.50952
55	0.52057
56	0.53171
57	0.54295
58	0.55431
59	0.56577
60	0.57735
61	0.58904
62	0.60086
63	0.61280
64	0.62487
65	0.63707
66	0.64941
67	0.66188
68	0.67451
69	0.68728
70	0.70021
71	0.71329
72	0.72654
73	0.73996
74	0.75355
75	0.76733
76	0.78128
77	0.79543
78	0.80978

Degrees	K
79	0.82434
80	0.83910
81	0.85408
82	0.86929
83	0.88472
84	0.90040
85	0.91633
86	0.93251
87	0.80978
88	0.96569
89	0.9827
90	1.0000
91	1.0176
92	1.0355
93	1.0538
94	1.0724
95	1.0913
96	1.1106
97	1.1303
98	1.1504
99	1.1708
100	1.1917
101	1.2131
102	1.2349
103	1.2572
104	1.2799
105	1.3032
106	1.3270
107	1.3514
108	1.3764
109	1.4019
110	1.4281
111	1.4550
112	1.4826
113	1.5108
114	1.5399
115	1.5697
116	1.6003
117	1.6318
118	1.6643
119	1.6977
120	1.7320
121	1.7675
122	1.8040

Degrees	K	Degrees	K
123	1.8418	152	4.0108
124	1.8807	153	4.1653
125	1.9210	154	4.3315
126	1.9626	155	4.5107
127	2.0057	156	4.7046
128	2.0503	157	4.9151
129	2.0965	158	5.1455
130	2.1445	159	5.3995
131	2.1943	160	5.6713
132	2.2460	161	5.9758
133	2.2998	162	6.3137
134	2.3558	163	6.6911
135	2.4142	164	7.1154
136	2.4751	165	7.5957
137	2.5386	166	8.1443
138	2.6051	167	8.7769
139	2.6746	168	9.5144
140	2.7475	169	10.385
141	2.8239	170	11.430
142	2.9042	171	12.706
143	2.9887	172	14.301
144	3.0777	173	16.350
145	3.1716	174	19.081
146	3.2708	175	22.904
147	3.3759	176	26.636
148	3.4874	177	38.188
149	3.6059	178	57.290
150	3.7320	179	114.590
151	3.8667	180	Infinite

9.4 Bend Allowance Chart

The top number in each group of numbers (at the intersections of the metal thickness rows and bend radius columns) is the bend allowance for a 90° bend. The bottom number is the bend allowance for each degree of bend.

Metal thickness	Radius of bend (inches) 1/32	1/16	3/32	1/8	5132	3/16	7/32
0.020	.062	.113	.161	.210	.259	.309	.358
	.000693	.001251	.001792	.002333	.002874	.003433	.0039n
0.025	.066	.116	.165	.214	.263	.313	.362
	.000736	.001294	.001835	.002376	.002917	.003476	.004017
0.028	.068	.119	.167	.216	.265	.315	.364
	.000759	.001318	.001859	.002400	.002941	.003499	.004040
0.032	.071	.121	.170	.218	.267	.317	.366
	.000787	.001345	.001886	.002427	.002968	.003526	.004067
0.038	.075	.126	.174	.223	.272	.322	.371
	.000837	.001396	.001937	.002478	.003019	.003577	.004118
0.040	.077	.127	.176	.224	.273	.323	.372
	.000853	.001411	.001952	.002493	.003034	.003593	.004134
0.051		.134	.183	.232	.280	.331	.379
		.001413	.002034	.002575	.003116	.003675	.004215
0.064		.144	.192	.241	.290	.340	.389
		.001595	.002136	.002676	.003218	.003776	.004317
0.072			.198	.247	.296	.346	.394
			.002202	.002743	.003284	.003842	.004283
0.078			.202	.251	.300	.350	.399
			.002249	.002790	.003331	.003889	.004430
0.081			.204	.253	.302	.352	.401
			.002272	.002813	.003354	.003912	.004453
0.091			.212	.260	.309	.359	.408
			.002350	.002891	.003432	.003990	.004531
0.094			.214	.262	.311	.361	.410
			.002374	.002914	.003455	.004014	.004555
0.102				.268	.317	.367	.416
				.002977	.003518	.004076	.004617

Metal thickness	Radius of bend (Inches) 1/32	1/16	3/32	1/8	5/32	3/16	7/32
0.109				.273	.321	.372	.420
				.003031	.003572	.004131	.004672
0.125				.284	.333	.383	.432
				.003156	.003697	.004256	.004797
0.156					.355	.405	.453
					.003939	.004497	.005038
0.188						.417	.476
						.004747	.005288

Metal thickness	Radius of bend (Inches) 1/4	9/32	5/16	11/32	3/8	7/16	1/2
0.020	.406	.455	.505	.554	.603	.702	.799
	.004515	.005056	.005614	.006155	.006695	.007795	.008877
0.025	.410	.459	.509	.558	.607	.705	.803
	.004558	.005098	.005657	.006198	.006739	.007838	.008920
0.028	.412	.461	.511	.560	.609	.708	.805
	.004581	.005122	.005680	.006221	.006762	.007862	.008944
0.032	.415	.463	.514	.562	.611	.710	.807
	.004608	.005149	.005708	.006249	.006789	.007889	.008971
0.040	.421	.469	.520	.568	.617	.716	.813
	.004675	.005215	.005774	.006315	.006856	.007955	.009037
0.051	.428	.477	.527	.576	.624	.723	.821
	.004756	.005297	.005855	.006397	.006934	.008037	.009119
0.064	.437	.486	.536	.585	.634	.732	.830
	.004858	.005399	.005957	.006498	.007039	.008138	.009220
0.072	.443	.492	.542	.591	.639	.738	.836
	.004924	.005465	.006023	.006564	.007105	.008205	.009287
0.078	.447	.496	.546	.595	.644	.745	.840
	.004963	.005512	.006070	.006611	.007152	.008252	.009333
0.081	.449	.498	.548	.598	.646	.745	.842
	.004969	.005535	.006094	.006635	.007176	.008275	.009357
0.091	.456	.505	.555	.604	.653	.752	.849
	.005072	.005613	.006172	.006713	.007254	.008353	.009435
0.094	.459	.507	.558	.606	.655	.754	.851
	.005096	.005637	.006195	.006736	.007277	.008376	.009458

Metal thickness	Radius of bend (Inches) 1/4	9/32	5/16	11/32	3/8	7/16	1/2
0.102	.464	.513	.563	.612	.661	.760	.857
	.005158	.005699	.006257	.006798	.007339	.008439	.009521
0.109	.469	.518	.568	.617	.665	.764	.862
	.005213	.005754	.006312	.006853	.007394	.008493	.009575
0.125	.480	.529	.579	.628	.677	.776	.873
	.005338	.005878	.006437	.006978	.007519	.008618	.009700
0.156	.502	.551	.601	.650	.698	.797	.895
	.005579	.006120	.006679	.007220	.007761	.008860	.009942
0.188	.525	.573	.624	.672	.721	.820	.917
	.005829	.006370	.006928	.007469	.008010	.009109	.010191
0.250	.568	.617	.667	.716	.764	.863	.961
	.006313	.006853	.007412	.007953	.008494	.009593	.010675

The empirical formula for bend allowance for each degree of bend Is:

Bend Allowance= (0.01743 A) + (0.0078 T)
A = Bend Radius
T = Metal Thickness

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9.5 Rivets and Riveting

Solid rivets are the most widely-used fastening devices for sheet metal aircraft construction.

Alternatives to Riveting

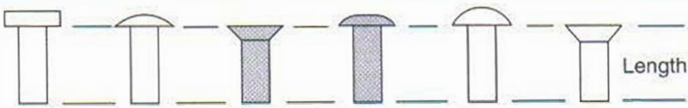
- Milled skins reduce the number of stringers and stiffeners, and eliminate the need for many rivets.
- Composite structure is bonded and does not require rivets.
- Welding has not proven to be a viable alternative because of the nature of sheet aluminum alloy.

Aircraft Solid Rivets

Most of the rivets used in aircraft structure range in diameter from 3/32-inch to 1/4-inch and most are made of an aluminum alloy. They are available with either a protruding head or a flush head.

Rivet Head Shapes

After WW II, aircraft manufactures adopted the universal head rivet to replace all protruding head rivets, and the 100° countersunk head rivet to be used for almost all flush riveting requirements.



AN 441 Flat head	AN456 Brazier head	MS20426 100· Counter-sunk head	MS20470 Universal head	AN 430 Round head	AN425 1s· Counter-sunk head

- AN 441 - Used in internal structure
- AN 456 - Replaced with MS20470
- MS20426 - Most widely-used flush rivet
- MS20470 - Most widely used protruding head rivet
- AN 430 - Replaced with MS20470
- AN 425 - Replaced with MS20426

Rivet Material

- Nonstructural applications of 1100 or 3003 aluminum may be riveted with the soft 1100 (A) rivet.
- Bare or clad 2024-T4 aluminum alloy is generally riveted with 2117 (AD) rivets. AD rivets may be driven as they are received from the manufacturer without additional heat treatment.
- When greater strength is needed than can be provided by an AD rivet, a 2017 (D) or 2024 (DD) rivet may be used. Both O and DD rivets require heat treatment before they are driven. These rivets are soft enough to drive immediately after they are removed from the quench bath, but will begin to harden within 10 minutes if left at room temperature. The hardening can be delayed for several days if they are immediately stored in a sub-zero refrigerator.
- Magnesium structural parts may be joined with 5056 aluminum alloy (8) rivets. B rivets may be driven as received from the manufacturer.
- High-strength aluminum alloy with zinc as its chief alloying agent must be riveted with 7050-T73 and 7075-T73 rivets.
- Titanium structure must be riveted with titanium rivets.

Rivet Diameter

- Diameter chosen must allow a riveted joint to fail by the rivets shearing rather than the sheet metal tearing at the rivet holes.
- A general rule of thumb is for the rivet diameter to be three times the thickness of the thickest sheet being joined.
- Refer to the charts on Pages 212-215 to select the diameter and number of rivets to use in a repair.
- The columns in these charts represent the rivet diameter, and the rows the metal thickness. The numbers represent the number of rivets per inch for a single lap splice.
- One number In each column is under1ined. A riveted joint using rivets listed below the underlined number will fail by the rivets shearing, and those above this under1ine will fail by tearing out of the rivet holes.

Rivet head markings identity the metal of which the rivet Is made.

Head Mark	Alloy	Code
Plain O	1100	A
Recessed dot O	2117T	AO
Raised dot O	2017T	D
Raised double dash 8	2024 T	DD
Raised cross EB	5056H	B
Three raised dashes	7075T73	
Raised circle @	7050T73	E
Recessed large and small dots @	Titanium	
Recessed dash e	Corrosion resistant steel	F
Recessed triangle @	Carbon steel	

Number of Rivets or Bolts Required for Single-Lap Splices In Bare 2017, Clad 2017, Clad 202 T3 Sheet, and 202 T3 Plate, Bar, Rod, Tube and Extrusions						
Thickness of metal (inches)	Number of AD protruding head rivets needed per inch width 'W'					No.of Bolts
	Rivet Diameter					
	3/32	**1/8**	**5/32**	**3/16**	**1/4**	**AN-3**
0.016	6.5	4.9				
0.020	**6.5**	4.9	3.9			
0.025	6.9	**4.9**	3.9			
0.032	8.9	4.9	3.9	3.3		
0.036	10.0	5.6	**3.9**	3.3	2.4	
0.040	11.1	6.2	4.0	**3.3**	2.4	
0.051		7.9	5.1	3.6	**2.4**	3.3
0.064		9.9	6.5	4.5	2.5	3.3
0.081		12.5	8.1	5.7	3.1	3.3
0.091			9.1	6.3	3.5	3.3
0.102			10.3	7.1	3.9	**3.3**
0.128			12.9	8.9	4.9	3.3

NOTES:

1. For stringers in the upper surface of a wing, or in a fuselage, 80% of the number of rivets shown may be used.
2. For intermediate frames, 60% of the number of rivets shown may be used.
3. For single-lap sheet Joints, 75% of the number shown may be used.

Number of Rivets or Bolts Required for Single-Lap Splices in 5052 (All Hardness) Sheet						
Thickness of metal (inches)	Number of AO protruding head rivets needed per inch width "W"					No.of Bolts
	Rivet Diameter					
	3/32	1/8	5/32	3/16	1/4	AN-3
0.016	6.3	4.7				
0.020	6.3	4.7	3.8			
0.025	6.3	4.7	3.8			
0.032	<u>6.3</u>	4.7	3.8	3.2		
0.036	7.1	4.7	3.8	3.2	2.4	
0.040	7.9	<u>4.7</u>	3.8	3.2	2.4	
0.051	10.1	5.6	<u>3.8</u>	3.2	2.4	
0.064	12.7	7.0	4.6	<u>3.2</u>	2.4	
0.081		8.9	5.8	4.0	<u>2.4</u>	3.2
0.091		10.0	6.5	4.5	2.5	3.2
0.102		11.2	7.3	5.1	2.8	<u>3.2</u>
0.128			9.2	6.4	3.5	3.2

NOTES:

1. For stringers in the upper surface of a wing, or in a fuselage, 80% of the number of rivets shown may be used.
2. For intermediate frames, 60% of the number of rivets shown may be used.
3. For single-lap sheet joints, 75% of the number shown may be used.

Examples ol Rivet Selection

- Use the chart on Page 221 to find the minimum number of rivets needed to make a splice on an intermediate frame using a single-lap joint, 2024 clad sheet aluminum 0.040-inch thick, with 1/8-inch 2117-AD rivets.

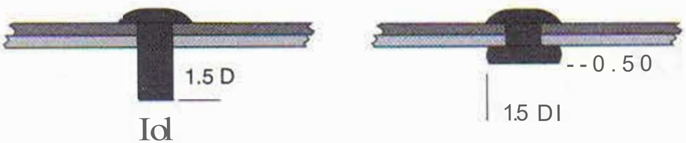
1. At the intersection of the 1/8-inch rivet column and the 0.040-inch metal thickness row, notice that 6.2 rivets per inch are needed for full strength. This choice is below the underlined number h this column, indicating the joint will fail by the rivets shearing, as it should, rather than the rivet holes tearing out.
2. According to NOTE 2, an intermediate frame requires only 60% of this number, therefore 3.72 rivets per inch is required for the splice.

- Use the chart on Page 222 to find the minimum number of rivets needed to make a single-lap joint in 5052-H36 sheet aluminum 0.064-inch thick, with 5/32-inch 2117-AD rivets.

1. At the Intersection of the 5/32-inch rivet column and the 0.064-inch metal thickness row, notice that 4.6 rivets per inch are needed for full strength. This choice is below the line in this column, indicating the joint will fail by the rivets shearing, as it should, rather than the rivet holes tearing out.
2. A single-lap sheet joint requires only 75% of this number, therefore 3.45 rivets per inch is required for the joint.

Rivet Length

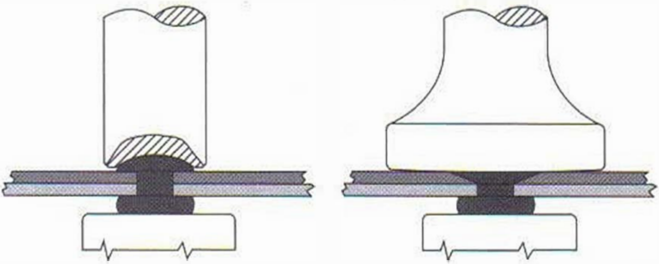
Determining the length of a rivet for a properly formed shop head



- The shop head on a rivet should have a diameter of one and one-half times the diameter of the shank, and its thickness should be one-half of the shank diameter.
- To get this size head, the shank should stick through the material by a distance of one and one-half times the shank diameter.

Riveting Tools

Rivet Sets



- Rivet sets fit over the manufactured head of a rivet and are driven by the rivet gun.
- For protruding-head rivets, the cup in the rivet set should have a slightly larger radius than the head of the rivet.
- The rivet set for driving flush rivets is slightly crowned and highly polished so it will not mark the skin.

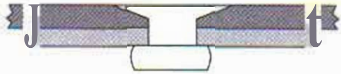
Bucking Bars

Bucking bar selection	
Rivet Diameter (Inch)	**Bucking Bar Weight (pounds)**
3/32	2 to 3
1/8	3 to 4
5/32	3.5 to 4.5
3/16	4 to 5
1/4	5 to 6.5

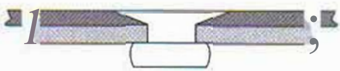
- The rivet set is held tightly against the manufactured head of the rivet, and a bucking bar of hardened and polished steel is held squarely against the end of the rivet shank. The blows from the rivet gun cause the bucking bar to bounce on the end of the rivet shank and flatten it.
- The shape of a bucking bar must be chosen so it can fit squarely on the end of the rivet, and the weight of the bar must be compatible with the rivet diameter.

Installing Flush Rivets

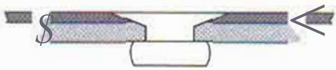
- If the top skin is thicker than the head of the rivet, it should be countersunk to a depth that will cause the top of the rivet to be flush with the skin.



- It is permissible, but not recommended, to countersink the top skin if its thickness is the same as the thickness of the rivet head.



- If the top skin is thinner than the rivet head, the skin should be dimpled either by coin or radius dimpling.



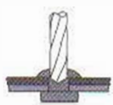
Blind Rivet Code

When team riveting, with the gunner unable to see or hear the bucker, this code serves for communications:

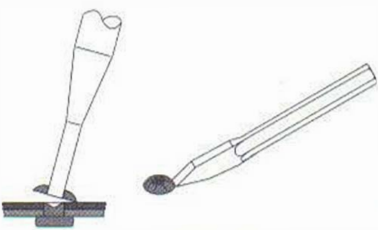
One Tap - Start riveting
Two Taps - Rivet OK
Three Taps - Bad rivet, mark it and move to next one.

Removal of Damaged Rivets

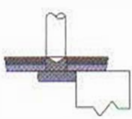
Make center punch mark in center of manufactured head.



Drill through head with drill one size smaller than used for rivet.

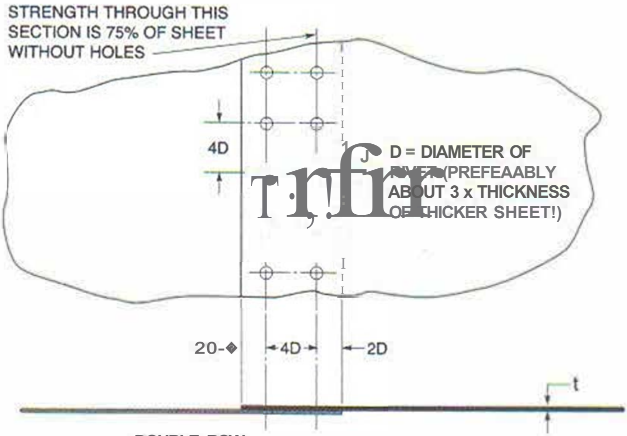


Use pin punch the size of the hole. pry the head off rivet or use cape chisel to cut head off.

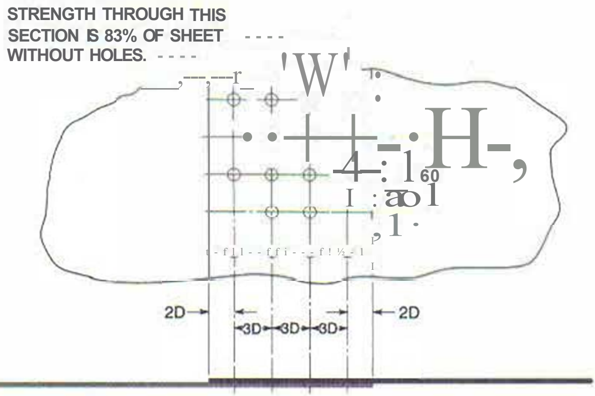


Buck up metal with bucking bar beside shop head and use pin punch to drive shank from the metal.

Minimum Rivet Spacing and Edge Distance



DOUBLE ROW



TRIPLE OR MULTIPLE ROWS

You must determine that the repaired structure will be at least as strong and rigid as the original, and If the repair is made to an external skin it must have no adverse effect on the airflow. To obtain proper strength from a riveted Joint, the rivet spacing and edge distance shown here must be observed. If a rivet hole has been damaged when a ***rivet*** is being replaced, the next size larger rivet may be used provided the rivet spacing and edge distance are within the limits shown here.

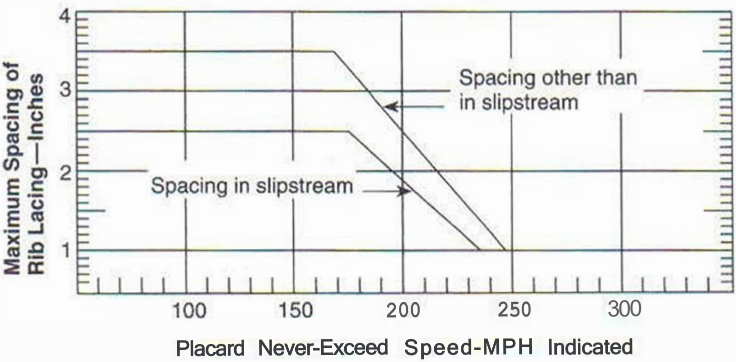
Section 10: Aircraft Fabric Covering

Almost all modern aircraft are of either all-metal or composite construction. Fabric covering is used only on older airplanes and some modem ultralight aircraft.

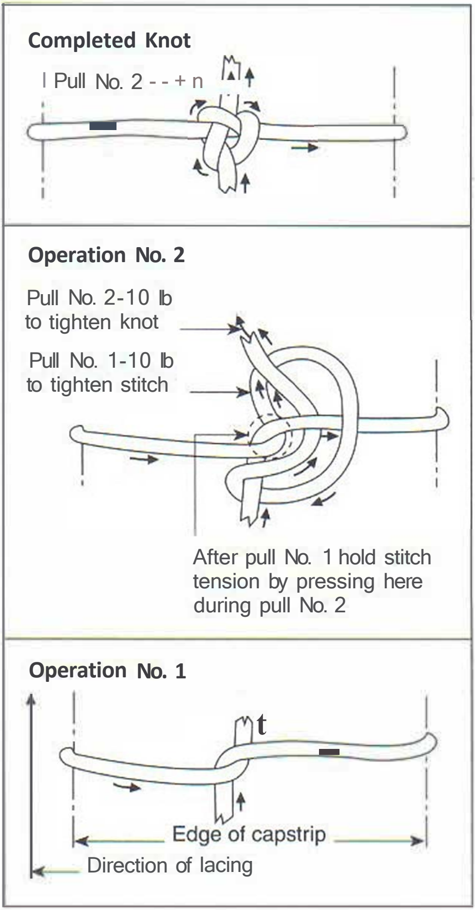
When a fabric-covered aircraft is being recovered, the type of materials crafted in its original manufacture must be used. One of the modern materials (much stronger and of longer-life) may be used if it has been approved as an alteration for the particular aircraft. This approval is normally accomplished with a Supplemental Type Certificate obtained by the manufacturer of the covering system.

10.1 Rib Stitch Spacing

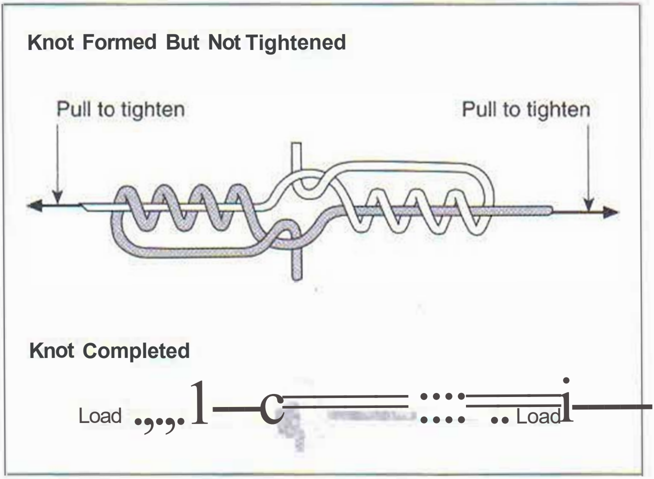
If for any reason the original rib stitch spacing cannot be determined, use the spacing indicated by the chart below. For the purpose of this chart the slipstream is the diameter of the propeller plus one rib on each side.



10.2 Rib Stitch Knots



A modified seine knot is used to tie the rib stitch cord around each rib.



A splice knot is used to Join two pieces of waxed rib stitch cord.

Section 11: Corrosion Detection and Control

11.1 Types of Corrosion

There are several types of corrosion that attack aircraft. Some types, like iron rust, continue to eat the metal until It is all gone; but others, like aluminum oxidization, form a dense film that prevents oxygen from reaching the metal, and the corrosive action almost stops.

Appearance of CorTOsion on Various Metals

Alloy	Type of Attack To Which Alloy is Susceptible	Appearance of Corrosion Product
Magnesium	Highly susceptible to pitting	White, powdery, snowlike mounds and white spots on the surface
Low alloy steel	Surface oxidation and pitting, surface, and intergranular	Reddish-brown oxide (rust)
Aluminum	Surface pitting, intergranular, exfoliation, stress-ccrrosion and fatigue cracking, and fretting	White to gray powder
Titanium	Highly corrosion resistant; extended or repeated contact with chlorinated solvents may result in degradation of the metal's structural properties at high temperature	No visible corrosion products at low temperature. Colored surface oxides develop above 700°F (370°C)
Cadmium	Uniform surface corrosion; used as sacrificial plating to protect steel	From white powdery deposit to brown or black mottling of the surface

(continued)

Appearance of Corrosion on Various Metals		
Alloy	**Type of Attack To Which Alloy Is Susceptible**	**Appearance of Corrosion Product**
Stainless Steels (30D-400 series)	Crevice corrosion; some pitting in marine environments; corrosion cracking; intergranular corrosion (300 series); surface corrosion (400 series)	Rough surface; sometimes a uniform red, brown stain
Nickel-base (Inconel, Monel)	Generally has good corrosion-resistant qualities; susceptible to pitting in sea water	Green powdery deposit
Copper-base brass, bronze	Surface and intergranular corrosion	Blue or blue-green powdery deposit
Chromium (plate)	Pitting (promotes rusting of steel where pits occur in plating)	No visible corrosion products; blistering of plating due to rusting and lifting
Silver	Will tarnish in the presence of sulfur	Brown to black film
Gold	Highly corrosion-resistant	Deposits cause darkening of reflective surfaces
Tin	Subject to whisker growth	Whisker-like deposits

11. 2 Oxidation

Type	Reaction Upon Exposure to Air	Protect Against
Aluminum Oxidation	• When pure aluminum is exposed to the air, a chemical reaction takes place between the metal and the oxygen. • Aluminum oxide forms on the surface and produces a dull, rough appearance. • Once the oxide forms, it insulates the surface from the air and any further reaction continues at a greatly reduced rate, or almost stops.	• Protect aluminum alloys from oxidation by electrolytically or chemically forming a hard oxide film on its surface.
Iron Oxidation	• When any metal containing iron is exposed to the air, iron oxide (or, rust) forms. Iron oxide is porous. and the iron will continue to react rust until it is completely destroyed.	Protect metals containing iron from rust: • *temporarily* by covering the surface with oil or grease, or • *permanently* by plating it with cadmium or chromium, or by covering it with paint.

I

11. 3 Surface and Pitting Corrosion

When unprotected metal is exposed to an atmosphere containing industrial contaminants, exhaust or battery fumes, corrosion will form on the surface giving it a dull appearance.

Reaction	Results	Appearance
• Contaminants react with the metal, changing microscopic amounts of it into the salts of corrosion.	• If these deposits are not removed and the surface protected, pits of corrosion will form at localized anodic areas. Corrosion will continue in these pits, changing the metal into salts.	• Pitting corrosion shows up as small blisters on the surface of the metal. • Blisters are full of white powder.

11.4 Intergranular Corrosion

Aluminum alloys are made of tiny grains of aluminum and the various alloying elements.

- Heating the metal causes the alloying elements to go into a solid solution with the aluminum.
- Quenching the metal in cold water locks the alloying elements and the aluminum together into the tiny grains.

Reactions	1. As the metal cools, the grains enlarge. A delay in quenching for even a few seconds will allow the grains to become large enough to produce anodic and cathodic areas that allow intergranular corrosion to form.
Results	2. Corrosion started on the surface can reach the boundaries of some enlarged grains, and continue inside the metal. Electrolyte travels from the surface through the porous salts and along the grain boundaries.
Appearance	3. Intergranular corrosion is difficult to detect because it is inside the metal. It sometimes, but not always, shows up as a blister on the surface.
Detection	4. Intergranular corrosion can be detected by ultrasonic or X-ray inspection; once it is detected, the only sure fix is the replacement of the part.

Exfoliation Corrosion

- An extreme form of intergranular corrosion.
- Occurs chiefly in extruded materials such as channels or angles where the grain structure is layer-like, or laminar.
- Occurs along the grain boundaries, and causes the material to separate or delaminate. By the time it shows up on the surface, the strength of the metal has been destroyed.

11.5 Stress Corrosion

A type of intergranular corrosion that forms in a metal subjected to a tensile stress in the presence of a corrosive environment.

1. Stresses may come from improper quenching after heat treatment, from a fitting or bushing that has been pressed into a structural part with an interference fit, or from tapered pipe fittings.
2. Cracks caused by stress corrosion grow rapidly as the corrosive attack concentrates at the end of the crack, rather than along its sides as it does in other types of intergranular corrosion.
3. Visual inspection may indicate the presence of stress corrosion; but to determine the extent of the damage, dye penetrant, eddy current, or ultrasonic inspection must be used.

11.6 Galvanic Corrosion

Occurs any time two dissimilar metals are in electrical contact in the presence of an electrolyte. The rate at which corrosion occurs depends on the galvanic groups of the two metals. The greater the difference between the groups, the more active the corrosion.

Galvanic Grouping of Metals	
Group I	Magnesium and magnesium alloys
Group II	Aluminum, aluminum alloys, zinc, cadmium, and cadmium-titanium plate
Group III	Iron, steel (except stainless steel), lead, tin and their alloys
Group IV	Copper, brass, bronze, copper-beryllium, copper-nickel, chromium, nickel, nickel-base alloys, cobalt-base alloys, graphite, stainless steels, titanium, and titanium alloys

Galvanic Corrosion	
Cause	• Forms where dissimilar metal skins are riveted together, and where aluminum alloy inspection plates are attached with steel screws.
Results	• The material in the lower number group is the anode, and is the one corroded. When a steel screw (Group III) is used in 2024 aluminum alloy (Group II) the aluminum alloy will become the anode and is corroded. • When a sheet of 2024-T3 aluminum alloy (Group II) is riveted to a piece of magnesium alloy (Group I) the magnesium will corrode.

11.7 Concentration Cell Corrosion

Two types of concentration cell corrosion affect aircraft structure:

1. Low oxygen concentration cell corrosion attacks areas where oxygen is excluded from the surface. These areas are in the faying surface of riveted joints where skins overlap, under the ferrules on aluminum alloy tubing, and under nameplates and decals on aluminum alloy components.
2. High metal-Ion concentration cell corrosion attacks areas in the open along the edges of tap Joints in aircraft skins. Most generally, both types of corrosion occur at the same time in the same general areas of an aircraft structure.

11.8 Fretting Corrosion

Fretting corrosion forms between two surfaces that fit tightly together, but can move slightly relative to one another. These surfaces are not normally close enough together to shut out oxygen, so the protective oxide coatings can form on the surfaces. However, this coating is destroyed by the continued rubbing action.

- When the movement between the two surfaces is small, the debris between them does not have an opportunity to escape, and it acts as an abrasive further eroding the surfaces. Fretting corrosion around rivets in a skin is indicated by dark deposits streaming out behind the rivet heads.
- By the time fretting corrosion appears on the surface, enough damage is usually done that the parts must be replaced.

11.9 Filiform Corrosion

Filiform corrosion consists of threadlike filaments of corrosion on the surface of metals that are coated with organic substances such as paint films.

- Does not require light, electrochemical differences within the metal, or bacteria, but takes place only in relatively high humidity, between 65% and 95%.
- The threadlike filaments are visible under clear lacquers and varnishes, but also occur under opaque paint films such as polyurethane enamels, especially when an improperly cured wash !I(imer has left some acid on the surface beneath the enamel.

11.10 Corrosion Control

The thin, highly reactive aircraft structural metals make them especially vulnerable to corrosion. Once corrosion has started in a structure, it opens the way for more, and the corrosion spreads until the structure is destroyed.

Corrosion cannot be prevented, but it can be controlled by eliminating one or more of the basic requirements for its formation:

1. Prevent the electrical potential difference within the metal.
2. Insulate the conductive path between areas of potential difference.
3. Eliminate any electrolyte that could form a conductive path on the surface of the metal.

Corrosion itself is highly complex, but its control is mainly a matter of good housekeeping:

1. Keep the structure clean and dry, and immediately repair any breaks in the finish.
2. Promptly remove any corrosion that is found, and treat the surface from which the corrosion was removed in order to neutralize any residue and inhibit further corrosion formation.

> **NOTE:** Modem surface treatments, sealers, and finishes are complex, and they will not tolerate any improper procedures in mixing or application. It is imperative that the specific instructions from the manufacturer of these products be followed in detail.

Section 12: Nondestructive Inspection

12.1 Visual Inspection

NDI

The complexity, high cost, and long life of modern aircraft and engines have made nondestructive Inspection, or NOi, an extremely important aspect of aviation maintenance.

Visual Inspection

Visual inspection, the least expensive and most widely used inspection method, is an important adjunct to all other types of inspection. There are two basic types: surface inspection and internal inspection.

Surface *Visual Inspection*

- Requires a strong flashlight, a 2X to a 10X magnifying glass, and a mirror, preferably one with a ball joint.
- Flashlights used in an explosive environment such as in fuel tanks must be explosion proof. Flashlights with krypton and halogen bulbs give out far more light than standard incandescent bulbs.
- Cracks and deformations show up most clearly when the light is shined on the surface toward the viewer at a low angle to the surface.
- Any suspect area must be clean and free of all paint-and if warranted, inspected with some other NOi method such as a penetrant or eddy current inspection.

Intemal Visual Inspection

Borescopes have made internal visual inspection practical as it is no longer necessary to disassemble an engine or a piece of airframe structure to see inside of it. Three types of internal visual inspection Instruments are commonly used in aircraft maintenance shops:

1. **A rigid-tube borescope** has a controllable power source to regulate the intensity of the light produced by a lamp in the end of the scope tube. An orbital scan control on the body of the instrument allows different areas within the component to be scanned.
   a) Insert the tube into the appropriate inspection port and adjust the light.
   b) Aim the instrument at the area to be inspected and focus it to get the sharpest image.

2. **Flexible fiber-optic scopes** consist of a light guide and an image guide made of bundles of transparent fibers enclosed inside a protective sheath. A power supply with a controllable light source is connected to the light guide, and an eyepiece lens allows the user to view the area at the end of the image guide. Bending and focusing controls guide the probe inside the component and focus the lens to get the clearest image of the area.
3. **Borescopes with video-imaging capabllity** have a sensor in the tip of the probe which acts as a miniature video camera. The image is digitized, enhanced, and displayed on a video monitor. Then it is recorded on video tape or a disk to provide a permanent record of the interior of the component.

12.2 Tap Test

A quick nondestructive test of composite structure to determine the presence of delaminations:

- Tap the area to be inspected with the edge of a coin.
  - If there is no delamination, the coin will produce a clear ringing sound.
  - If there is delamination, the sound will be a dull thud.
- The coin tap procedure is not a quantitative test, but it gives an indication when further investigation is needed.

12.3 Penetrant Inspection

Fluorescent and visible-dye penetrant inspection can be used on nonporous metallic or nonmetallic materials to detect faults that extend to the surface and are too small to be seen with normal visual inspection.

1. Part being inspected must be thoroughly clean and dry so the penetrant can get into any surface faults.
2. Penetrant must remain on the surface long enough to completely fill any existing fault. This is called the dwell time and it depends upon:
   a) The size of the anticipated fault
   b) The temperature of the part being inspected
3. Allow the appropriate dwell time, then wash the penetrant off the surface, taking care to not wash it out of any possible faults.

3 types of penetrants:	
Oil base (with additives)	- with a fluorescent dye and an emulsifier added, to make the penetrant removable with a hot water bath.
Oil base	- does not contain the emulsifier, so a separate emulsifier must be used.
Solvent-removable penetrant	- not removable with water, must be cleaned from the surface with a solvent. Solvent-removable penetrant can seep into smaller faults than the other two types.

4. After the penetrant has been removed from the surface, cover the area being inspected with a developer that acts as a blotter to draw some of the penetrant from hidden flaws. This developer may be:
   a) A dry powder
   b) A quick-drying spray that leaves a white chalky surface.
5. If the dye is fluorescent, inspect the part with an ultraviolet, or black light. Any penetrant drawn from a fault shows up as a bright line, usually yellow-green, against a dark background.
6. If the dye is visible under ordinary light, a fault will show up as a highly visible red mark on the white background.
7. As soon as the inspection is completed, remove all traces of the inspection materials, clean and dry the surface.

12.4 Magnetic Particle Inspection

Surface and subsurface faults in a ferromagnetic part can be detected with magnetic particle inspection.

1. Magnetize the part to be inspected. Any flaw or fault within the component interrupts the magnetic lines of flux and forms a north and south pole.
2. Cover the area being inspected with very fine iron oxide particles.
3. The iron oxide is attracted to the magnetic poles where it forms a visible indication of the fault.
4. There are two ways of magnetizing a part. Overhaul manuals specify the way a part must be magnetized and the amount of current to be used for the magnetization:

Circular magnetization- by passing DC through the part.	• Lines of magnetic flux encircle the part at right angles to the flow of current. • Used for detecting faults that are parallel to the length of the part.
Longitudinal magnetization - by holding the part inside a coil of wire carrying DC.	• Lines of flux et end lengthwise through the part at right angles to the coil. • Used for detecting faults that are perpendicular to the length of the part.

5. The iron oxide used to detect the fault contains a fluorescent dye. It may be applied as a dry powder, or as a suspension in a light oil such as kerosine.
6. The powder is dusted over the part, or the suspension is flowed over the surface being inspected. The oxide particles that are attracted to the poles created by the fault show up as a green mark when viewed under a black light.
7. Two types of magnetic particle inspection:
   - Continuous: the magnetizing current flows all the time the part is being inspected.
   - Residual: the part is magnetized and removed from the magnetic field, then inspected.

8. After inspection is completed, thoroughly demagnetize the part, in either of two ways:
   a) Place the part in an AC magnetic field and slowly remove it from the field.
   b) Place the part in a magnetic field made by pulses of DC of reversing polarity that is programmed to decrease its intensity.
      - The *reversing polarity of the field* causes the magnetic domains within the material to continually change their orientation.
      - The *decreasing field strength* allows them to remain in a disoriented condition.

12.5 Eddy Current Inspection

Eddy current inspection checks for faults inside a metal by detecting a change in its conductivity caused by the presence of a fault. This method is especially suited for detecting intergranular corrosion.

How it works

A test probe containing an AC excited coil induces an eddy current into the material being tested.

1. Excite the coil with the proper frequency of AC.
2. Place the probe on the surface being inspected so it can Induce a changing magnetic field in the metal.
3. The changing magnetic field induces eddy currents in the metal. The amount of current is determined by four things:
   a) the conductivity of the metal which is a function of its alloy type, grain size, degree of heat treatment, and tensile strength.
   b) the permeability of the metal.
   c) the mass of the material.
   d) the presence of any faults or voids.

I

What it is suited for

1. Identifying metals by comparison of their alloy type, degree of heat treatment, and tensile strength.
2. Detection of cracks or hidden faults. This is an ideal way to check aircraft wheels for cracks in the bead seat area. These cracks close up when the stress is off the wheel and are almost impossible to detect visually, but show up with eddy current inspection.

Method

1. Place the test probe on a piece of metal (known to be good) of the type being inspected, and zero the indicator.
2. Place the probe on the metal being inspected.

   - If there are no internal faults, the indicator will again zero.

   - If there are any faults within the metal, a different amount of current will be induced and the indicator will show the difference.

Detection of corrosion

The mass of sound material changes when corrosion is present, either internally or on the opposite side of a skin being inspected.

1. Hold the eddy current probe against a part of the skin that is known to be free of corrosion and zero the meter.
2. Move the probe over the area being inspected. If corrosion is present, the meter will move off zero.
3. To inspect for corrosion around fastener holes, insert the small probe into a hole known to be free of corrosion and zero the indicator. When the probe is inserted into a hole where there is corrosion, the indicator will move off zero.

12.6 Ultrasonic Inspection

Ultrasonic waves are vibrations at frequencies between about 200 kilohertz (200,000 hertz) and 25 megahertz (25,000,000 hertz). In this frequency range, these waves are not perceptible to the human ear, but in all other ways they behave the same as vibrations we can hear.

1. A piezoelectric crystal transducer excited at the proper frequency of AC is held against the structure being inspected.
2. The crystal vibrates and sends pulses of energy into the structure. The pulses travel until they reach the back surface of the material or until they strike a fault; then they reflect back to the transducer.
3. A cathode ray tube (CRT) with a horizontal base line is used as the indicator. The pulse entering the test specimen produces a pip along the base line representing the front surface, and a second pip representing the back surface.
4. Any fault within the material reflects some of the energy before it reaches the back surface and forms a third pip between the other two.

12.7 Radiography

Radiographic inspection is useful for checking the inside of an aircraft structure, as it does not require major disassembly. It is not recommended as an exploratory type of inspection, but is most appropriate for examining an area for a type of damage with known characteristics. There are two types of radiographic inspection: X-rays and gamma rays.

X•Rays

X-rays are a form of high-energy, short-wavelength, electromagnetic radiation.

1. An electron is emitted from the cathode in an X-ray tube and aocelerated to a high speed. When this electron strikes a target containing many electrons, it collides and some of its energy is converted into X-rays.
2. Because X-rays have such high frequency they are able to pass through many materials that are opaque to visible light. As they pass through, they are absorbed in an amount proportional to the density of the material.

3. After passing through a material, the X-rays still have enough energy to expose a piece of photographic film.
4. The amount of current used to drive the electrons from the cathode determines the intensity of the X-ray beam and its ability to expose the film.
5. The voltage supplied to the anode of the X-ray tube determines the amount of energy the beam contains. The higher the voltage, the more energy, and the deeper the X-rays will penetrate the material being inspected.
6. Low-powered X-rays are called soft X-rays, and those that are produced by high voltage are called hard X-rays.
7. Soft X-rays are used to inspect for corrosion.

Gamma Rays

Gamma rays are composed of high-energy photons emitted by the nucleus of certain chemical isotopes such as those of Cobalt, Cesium, Iridium, and Thulium that are in the process of disintegration.

1. Unlike X-rays, gamma rays cannot be shut Off or controlled; therefore the source of these rays must be kept in a radiation-proof container shielded with lead.
2. When gamma rays are needed for an inspection, the equipment is set up and the active isotopes are exposed.

Inspection - Steps

1. The penetrating energy of X-rays and gamma rays passing through the material being inspected exposes a sheet of photographic film or causes a fluorescent screen to glow.
2. Discontinuities or faults within the material alter its density and thus the amount of radiation allowed to pass. The more dense the material, the less radiation passes through, and the less the film is exposed. Areas of low penetration appear on the film as light areas.
3. After a sheet of film is exposed to the radiation, it is developed and fixed as with any other photographic film, and its indication is interpreted by an experienced inspector. Damage and faults are detected by comparing the image on the developed film with the indication of a sound structure.

Considerations

1. Radiographic inspection:

   - is more costly,

   - requires more elaborate equipment, and

   - requires more safety considerations than other types of nondestructive inspection, but

   - it can be used to inspect the inside of complex assemblies without disassembling them.

2. The factors of radiographic exposure are so interdependent that it is necessary to consider all of them for any particular inspection. These factors include, but are not limited to:

   - Material thickness and density
   - Shape and size of the object
   - Type of defect to be detected
   - Characteristics of X-ray machine used
   - The exposure distance
   - The exposure angle
   - Film characteristics
   - Type of intensifying screen, if one is used

Safety

Radiation from X-rays and radioisotope sources produce changes in living tissue when they pass through it. Personnel must keep outside the high energy beam at all times.

1. When radiation strikes the molecules of the body, the effect may be no more than to dislodge a few electrons; however, an excess of these changes can cause irreparable harm.

2. The degree of damage depends on which body cells have been changed. This is determined by the amount of radiation received and by the percentage of the total body exposed.

3. Protection for working with radiation equipment:

   - wear a radiation-monitor film badge, which is developed at the end of a given period to determine the amount of radiation absorbed

   - have periodic blood-count tests.

Section 13: Aircraft Control Systems

13.1 Types of Control Systems

Torque Tubes

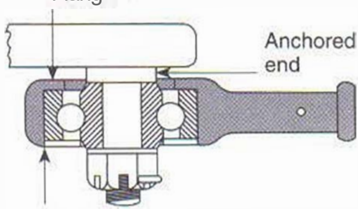
The control in the cockpit is connected to the control surface with a hollow aluminum alloy torque tube. Rotation of the tube transmits a torque force to the surface. Wing flaps are often moved with torque tubes.

Push-Pull Rods

Elevators, some ailerons and flaps, and helicopter rotor controls are operated by rigid push-pull rods. These are hollow aluminum alloy tubes with rod-end bearings or clevises at the ends.

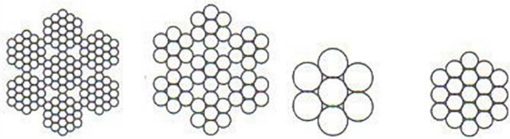
Push-pull rod assembly

- Install rod-end bearings with the flanged side of the bearing housing next to the structure to which it is attached.
- Rod-end bearings have a "witness hole" to indicate when the rod is screwed in far enough to supply full strength. If the rod is screwed in sufficiently far, the threads will cover the hole.



Proper rod-end bearing attachment

13. 2 Control Cables



Extra flexible   Flexible   Non-flexible   Non-flexible

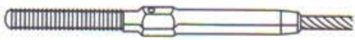
Type of Cable	Strands/ Wires	Material	Application
Extra flexible	7 X 19	Stainless steel Galv. carbon steel	Cables that pass over pulleys
Flexible	7 x 7	Stainless steel Galv. carbon steel	Straight cable runs Slight change in direction allowed
Non-flexible	1 X 19 1 X 7	Stainless steel Galv. carbon steel	Straight cable runs No change in direction allowed

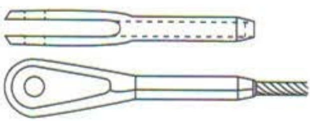
13.3 Control Cable Terminals

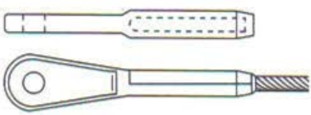
Swaged terminals are made of stainless steel and have a tubular end into which the cable fits. The cable is slipped into the tube and the assembly is swaged, forcing the metal of the tube into the cable so it grips the strands of wire. A "go-no go" gage or a micrometer caliper is used to determine when the terminal has been properly swaged. The swaging process should reduce the diameter of the tubular end to a dimension specified by the terminal manufacturer. When properly swaged, the cable will break before it pulls out of the terminal.


AN663 Double shank ball end


AN664 Single shank ball end

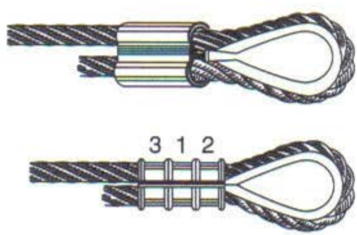

AN666 Threaded cable terminal


AN667 Fork end cable terminal


AN668 Eye end cable terminal

Nicopress sleeves are installed on cables in some lighter aircraft. A properly installed Nicopress terminal provides the full strength of the cable.

1. Slip a copper Nicopress sleeve over the cable and loop the free end around a bushing or a thimble eye and slip it into the opposite side of the sleeve.
2. Make three crimps with a special Nicopress tool. The first crimp is in the center of the sleeve, the next is at the end nearest the eye, and the last crimp is near the opposite end.
3. Use a "go-no go" gage to determine that the sleeve has been sufficiently crimped.



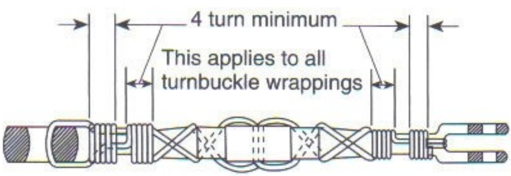
Nicopress sleeve for terminating an aircraft control cable. The lower illustration shows the proper sequence for crimping the sleeve onto the cable.

13.4 Turnbuckles

- Control cable tension is adjusted with turnbuckles that are installed in at least one cable in each run.
- A turnbuckle consists of a bronze barrel and terminals that screw into each end. The threads in one end of the barrel are left-hand and those in the other end are right-hand. The end having the left-hand threads is normally identified with a groove around its end.
- A turnbuckle will produce its full strength only when the threads on the terminal are sufficiently engaged. No more than three threads on the terminals should be exposed. If the cable tension is too high when more than three threads are exposed, a longer barrel should be used.

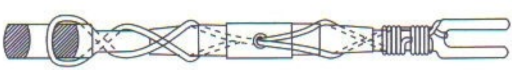
Turnbuckle Safetying

It is important that turnbuckles be properly safetied to prevent them from becoming unscrewed and changing the control cable tension.

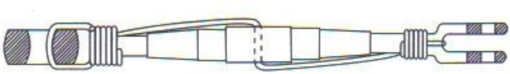


Double wrap (spiral)

Double wrap



Single wrap (spiral)

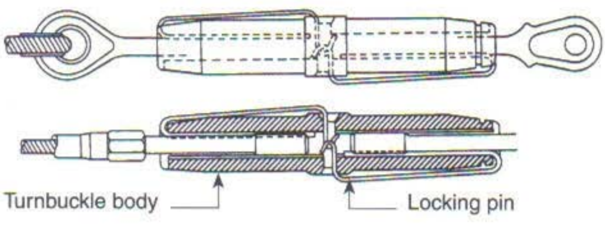


Single wrap

Methods of safetying turnbuckles

Turnbuckle Safetying Guide			
Cable size	**Type of wrap**	**Diameter of safety wire**	**Material (annealed)**
1/16	Single	0.040	Copper, brass
3/32	Single	0.040	Copper, brass
1/8	Single	0.040	Stainless steel, monel and K monel
1/8	Double	0.040	Copper, brass
1/8	Single	0.057 min.	Copper, brass
5/32 and greater	Double	0.040	Stainless steel, monel and K monel
5/32 and greater	Single	0.057 min.	Stainless steel, monel and K monel
5/32 and greater	Double	0.0512	Copper, brass

Clip-Locking Turnbuckles



There is a slot in the threads of the terminal and one in each end of the barrel.

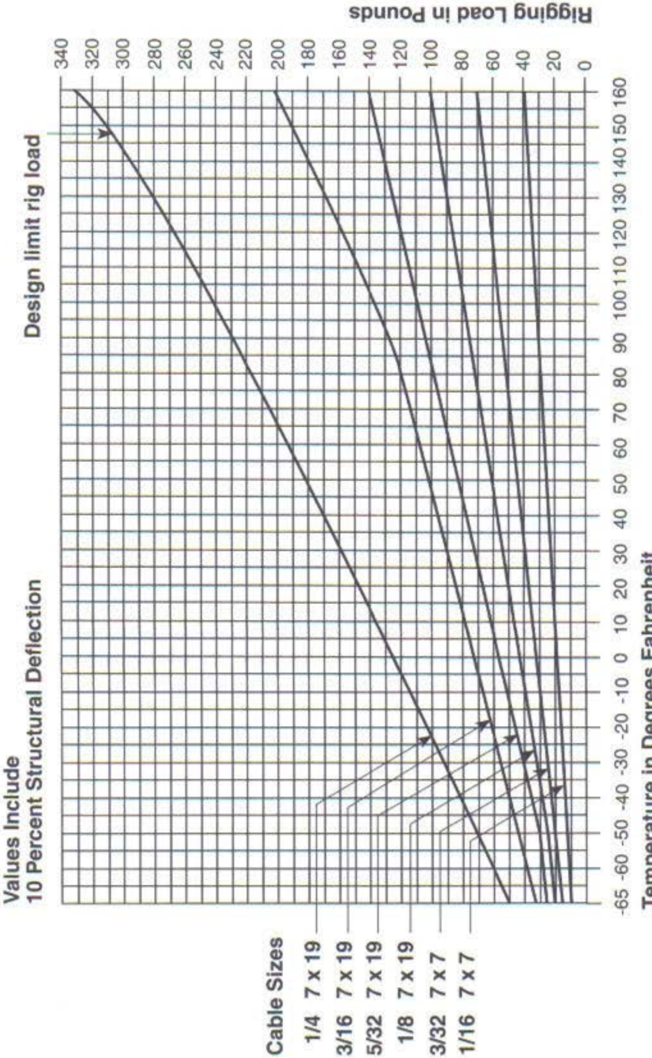
1. After the cable tension has been adjusted, align the slots in the turnbuckle body and the swaged terminal.
2. Insert the straight end of the locking clips into the slots in each end of the barrel.
3. Insert the hooked ends of the clips into the hole in the side of the barrel and press them in until the ends of the hook seat on the edge of the hole.

13.5 Control Cable Tension

1. It is important that control cable tension be within the range specified in the aircraft maintenance manual. If the tension is too high, the controls will be stiff and the pulleys will wear excessively. If the tension is too low, there is danger of the cable getting out of the pulley groove and becoming fouled.
2. Large all-metal aircraft contract as they cold soak at high altitude where the air is extremely cold. The control cables do not change their dimensions as much as the airframe does, so automatic tension adjusters are used to maintain a constant cable tension as temperature changes.
3. Small aircraft do not have automatic adjusters but rely on the cables being properly adjusted to the proper tension determined by the aircraft manufacturer.

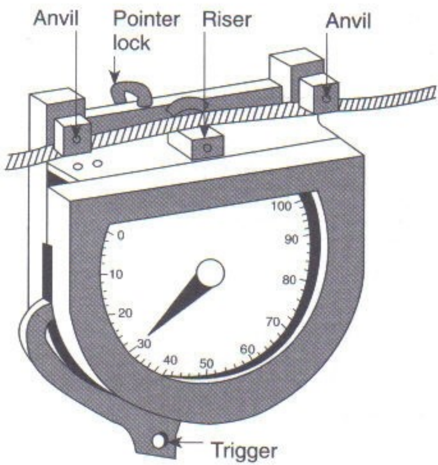
To find the correct rigging load for a 1/8 inch 7x19 cable at 90°F:

1. Follow the vertical line for 90°F upward until it intersects the curve for 1/8 inch 7x19 cable (the third curve up).
2. From this point of intersection, draw a horizontal line to the right to the Rigging Load scale. This shows that the correct rigging load for this temperature is 75 pounds.



Control cable tension chart

13.5



Cable tension is measured with a tensiometer:

1. Install the correct riser for the size of cable being checked, and clamp the tensiometer over the cable.
2. Use the chart furnished with the tensiometer to relate the indication on the tensiometer scale to the diameter of the cable, in order to find the cable tension in pounds.

Section 14: Aircraft Fluid Lines

Fuel, hydraulic fluid, compressed air, lubricating oil, and other fluids are carried in an aircraft and all must be routed through the proper size and type of fluid line. There are two basic types of fluid lines: rigid and flexible.

14.1 Rigid Fluid Lines

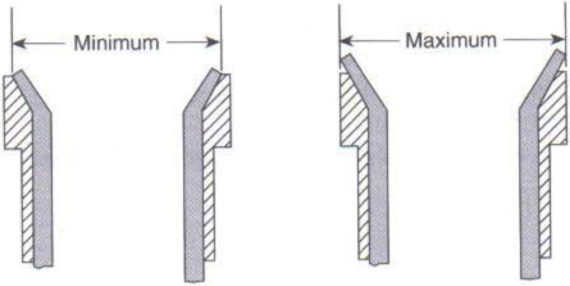
Materials recommended for rigid fluid lines

Application	Material
Low pressure	1100- and 3003-half hard aluminum alloy
High pressure	2024-T and 5052-O aluminum alloy
Oxygen systems	Corrosion resistant steel Fittings are brazed or silver soldered to lines

- Rigid fluid lines

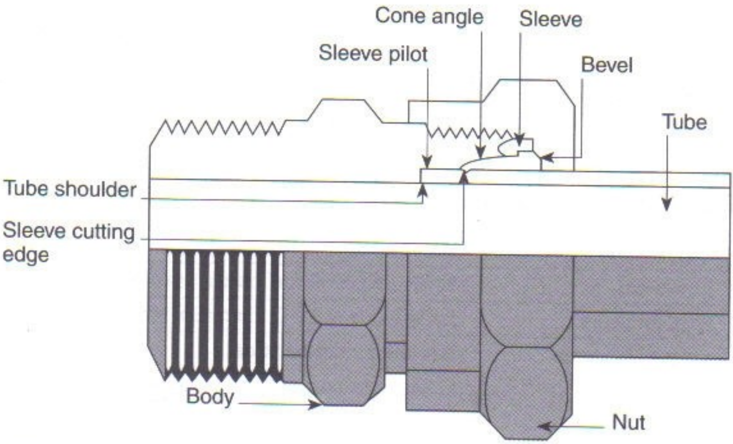
  —are measured by their outside diameter in increments of 1/16-inch. For example, number 8 tubing has an outside diameter of 8/16- or 1/2-inch.

  —are connected to fittings with either a flared or a flareless fitting. Flared fittings have a flare angle of 37°; they must not be mixed with automotive fittings which have a flare angle of 45°.



When a piece of tubing is flared, the minimum diameter of the outside of the flare should be no less than the inside diameter of the flare in the sleeve, and the outside diameter should be no greater than the outside of the sleeve.

- Tubing made of 5052-O and 6061-T aluminum alloy in sizes between 1/8- and 3/8-inch may be double flared.



MS flareless fittings—popular for use in high-pressure hydraulic and pneumatic lines

To assemble an MS flareless fitting:

1. Slide the nut and sleeve onto the tube.
2. Place the tube into a presetting tool and tighten the nut as specified by the tubing manufacturer. (The pressure produced by the nut distorts the sleeve so that it bites into the tube.)
3. Remove the tube from the presetting tool and screw it onto the fitting.
4. Tighten the nut finger tight, then turn it with a wrench for 1/6- to 1/3-turn (one hex to two hexes).
5. Do not overtighten the fitting as it may be damaged and the joint will leak.

14.2 Flexible Fluid Lines

- Flexible fluid lines must be able to carry all of the volume of fluid without an excessive pressure drop. They must withstand the pressure and the vibration they will encounter.
- When a particular hose is specified in an aircraft parts list or service manual, only that hose or an approved substitute may be used when the hose is replaced.
- The size of a flexible hose is approximately its inside diameter in 1/16-inch increments. This dimension refers to the outside diameter of a rigid tube that has equivalent flow characteristics. For example, a -8 hose has flow characteristics equivalent to the same length of -8, or 1/2-inch (8/16) rigid tubing.
- Flexible fluid lines have a linear stripe, called a lay line, running along their length. Its purpose is to help prevent twisting the hose during installation. If this line spirals around the hose, the hose has been twisted.

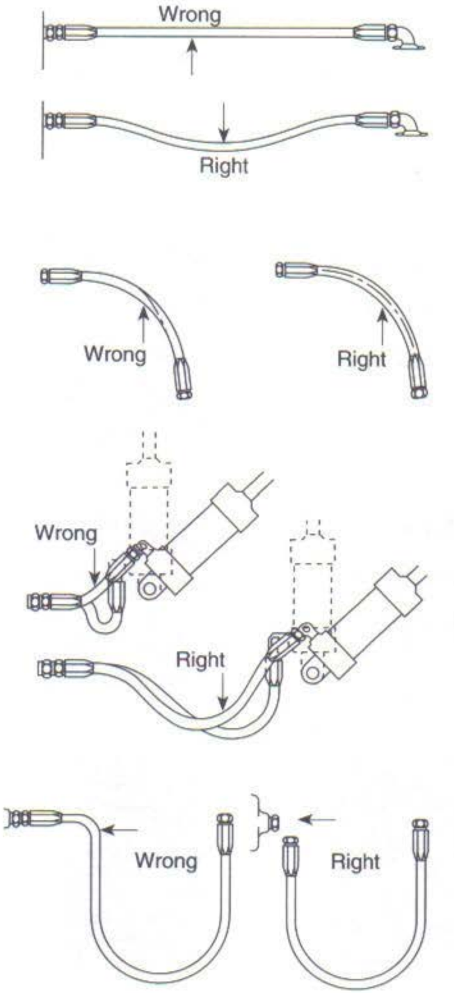
Types of Flexible Fluid Lines

Type/Name	Description and Identification	Approved for use/ Suitability
Low-pressure hose MIL-H-5593	• Synthetic rubber inner liner, a cotton braid, ribbed synthetic rubber outer cover. • Broken yellow lay line, letters "LP," manufacturer's code/date marking	• Approved for pressures up to 300 psi • Primarily used in instrument installations.
Medium-pressure hose MIL-H-8794	• Seamless synthetic rubber inner liner, synthetic-rubber-impregnated cotton braid reinforcement, steel-wire braid reinforcement. • Encased in a rough synthetic-rubber-impregnated cotton braid.	• Suitable for carrying fluids under pressure of up to 1,500 psi.

(continued)

Type/Name	Description and Identification	Approved for use/ Suitability
High-pressure hose MIL-H-8788	• Seamless synthetic rubber inner tube, either two or three carbon-steel wire-braid reinforcements. • Smooth synthetic rubber cover	• Suitable for operating with pressures up to 3,000 psi.
Extra-High-Pressure Hose	• Reinforced with layers of spiral wound stainless steel wire • Encased in a special synthetic rubber outer layer.	• Suitable for use with pressures between 3,000 and 6,000 psi and temperatures up to 400°F.
Teflon Hose Tetrafluoethylene, TFE	• Chemically resistant TFE inner liner, braided stainless steel outer covering.	• Unaffected by any fuel, petroleum or synthetic base oils, alcohol, coolants, or solvents commonly used in aircraft and it retains these characteristics even at elevated temperatures.

14.3 Installation of Flexible Hose



Flexible hose should be approximately 5% to 8% longer than the distance between the fittings. This slack allows for contraction as the line expands its diameter and shortens its length when pressurized.

Flexible hose should be installed with no twists. The lay line spirals around the hose if it is twisted.

Flexible hose should be installed on a movable actuator in such a way that the hose is not crimped in any position of the actuator.

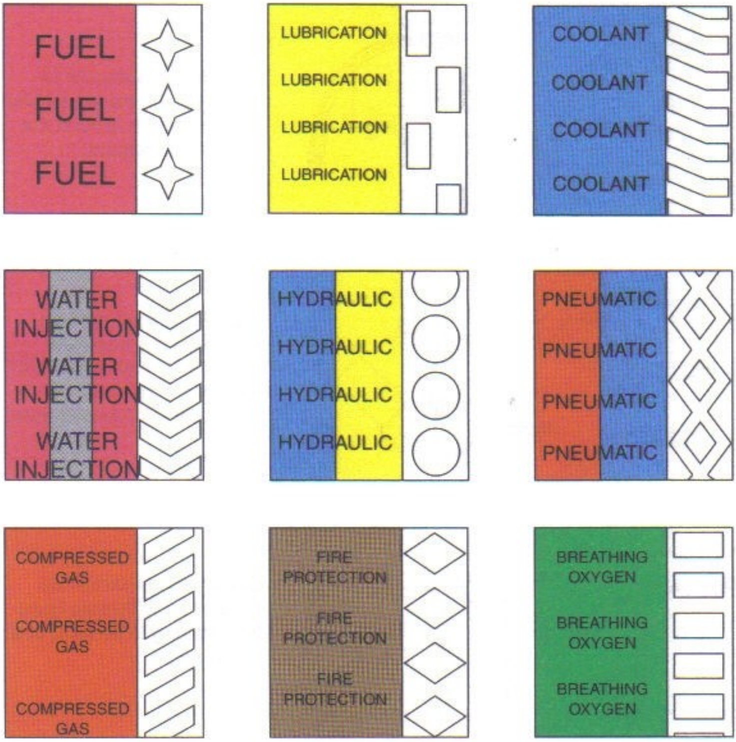
Elbow fittings should be used to keep flexible hose from having to be bent at a sharp angle.

Improper, and proper installation of flexible hose

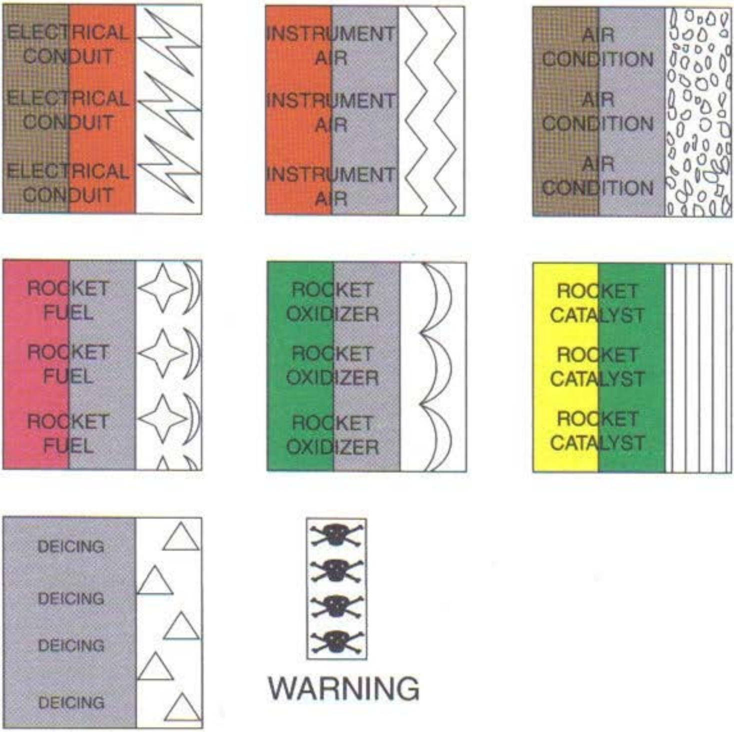
14.4 Fluid Line Identification

- Fluid-carrying lines in an aircraft are identified with a series of colored and coded bands.
- One or two colors identify the fluid in the lines, and the name of the fluid is written in the colored area.
- To aid color-blind technicians, a coded stripe also identifies the fluid.

Fluid Line Identification



Fluid Line Identification (continued)



Section 15: Oxygen System Servicing

15.1 Oxygen System Servicing

1. Be sure to use **no** petroleum lubricants on oxygen system components.
2. Service aircraft oxygen systems only with oxygen approved for use in aircraft.
3. When servicing an oxygen system from a cascade-type servicing cart, charge the system from the cylinder having the lowest pressure first. When the pressure stabilizes, record the pressure on the cylinder, shut it off and open the valve on the cylinder having the next lowest pressure. Continue this process until you have the desired pressure in the system. Use the chart below to determine the final charging pressure, based on the ambient temperature.
4. Do not allow installed oxygen cylinders to become completely empty. When there is no oxygen in a cylinder, air containing water vapor can enter.

Filling Pressure for 1,850 PSI Oxygen Cylinders

Ambient temperature and the heat of compression affect the pressure of oxygen in a cylinder. To end up with 1,850 psi in the cylinder after the oxygen has cooled from the filling process, the following filling pressures should be used:

Ambient Temperature (°F)	Filling Pressure (psi)
0	1,650
10	1,700
20	1,725
30	1,775
40	1,825
50	1,875
60	1,925
70	1,975
80	2,000
90	2,050
100	2,100
110	2,150
120	2,200
130	2,250

Section 16: Aircraft Weight and Balance

16

16.1 Locating the Center of Gravity

- Position the airplane on the scales with the parking brake off.
- Place chocks around the wheels to keep the airplane from rolling.
- Subtract the weight of the chocks (called tare weight) from the scale reading to determine the net weight at each weighing point.

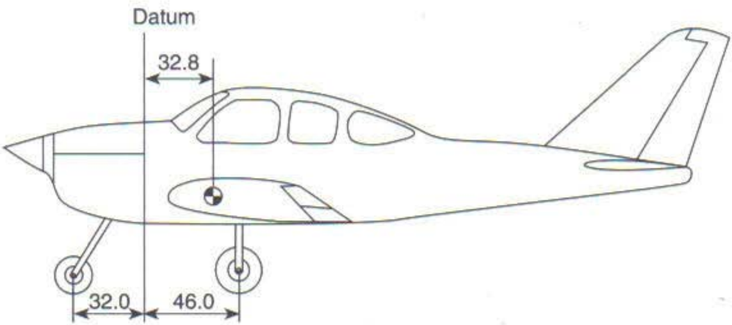


Figure 16.1. *The datum is at the engine firewall.*

- Determine the arm of each weighing point by measuring its distance from the datum.
- Find the moment of each weighing point by multiplying its net weight by its arm.

Nose wheel net weight = 340 pounds
Arm of the nose wheel = -32 inches
Moment of the nose wheel = -10,880 pound-inches

Main wheel net weight = 1,666 pounds
Arm of the main wheels = 46 inches
Moment of the main wheels = 76,636 pound-inches

Total weight = 2,006 pounds
Total moment = 65,756 pound-inches

Find the CG by adding the weight and moment of each weighing point to find the total weight and total moment. Then divide the total moment by the total weight to find the CG relative to the weighing points.

$$
\begin{aligned}
CG &= \frac{\text{Total Moment}}{\text{Total Weight}} \\
&= \frac{65{,}756}{2{,}006} \\
&= 32.8 \text{ inches aft of the datum}
\end{aligned}
$$

The CG is 32.8 inches aft of the datum or 13.2 inches ahead of the main-wheel weighing points.

16.2 Datum Forward of the Airplane—Nose Wheel Landing Gear

In Figure 16.2, the datum is considered to be 100 inches ahead of the leading edge of the wing. The distance (D) between the main-wheel weighing points and the datum is +128 inches. The weight of the nose wheel (F) is 340 pounds, the distance (L) between the main wheel and the nose-wheel weighing points is 78.0 inches, and the total weight (W) is 2,006 pounds.

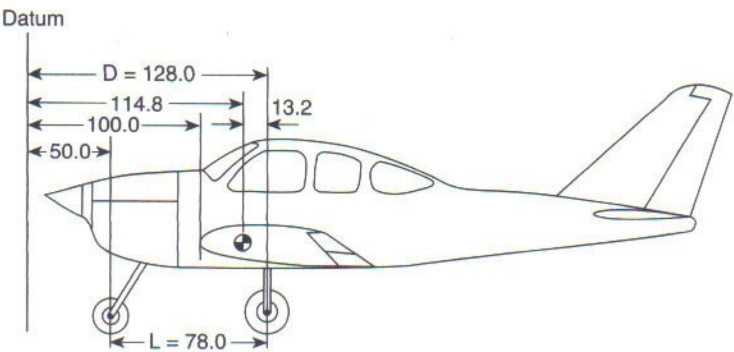


Figure 16.2. *The datum is ahead of the airplane.*

To locate the CG of an airplane relative to the datum that is 100 inches ahead of the wing leading edge, use the formula:

$$CG = D - \left(\frac{F \times L}{W}\right)$$

$$= 128.0 - \left(\frac{340 \times 78}{2{,}006}\right)$$

$$= 114.8 \text{ inches aft of datum}$$

The CG is 114.8 inches aft of the datum, which is 13.2 inches ahead of the main-wheel weighing points. This proves that the location of the datum has no effect on the location of the CG, as long as all measurements are made from the same location.

16.3 Datum Aft of the Main Wheels—Nose Wheel Landing Gear

In Figure 16.3, the datum is at the trailing edge of the wing at the wing root. The distance (D) between the main-wheel weighing points and the datum is +75 inches. The weight of the nose wheel (F) is 340 pounds, the distance (L) between the main wheel and the nose wheel weighing points is 78.0 inches, and the total weight (W) is 2,006 pounds.

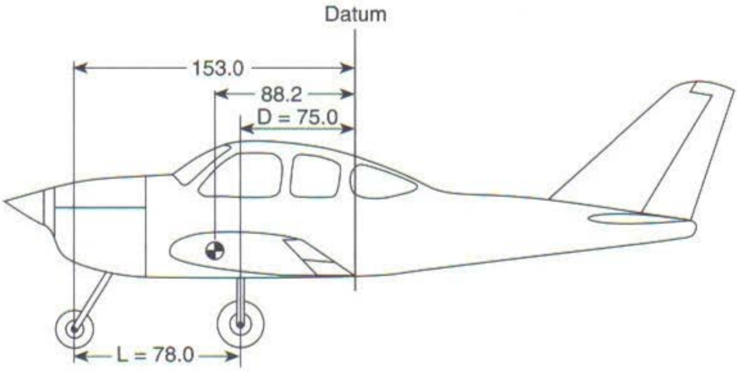


Figure 16.3. *The datum is aft of the main wheels at the intersection of the wing trailing edge and the fuselage.*

$$CG = -\left(D + \frac{F \times L}{W}\right)$$

$$= -\left(75 + \frac{340 \times 78}{2{,}006}\right)$$

$$= -88.2 \text{ inches ahead of the datum}$$

The CG is 88.2 inches ahead of the datum, which is 13.2 inches ahead of the main-wheel weighing points.

16.4 Datum Forward of the Main Wheels—Tail Wheel Landing Gear

In Figure 16.4, the datum is at the leading edge of the wing at the wing root. The distance (D) between the main-wheel weighing points and the datum is +7.5 inches. The weight of the tail wheel (R) is 67 pounds, the distance (L) between the main wheel and the tail-wheel weighing points is 222.0 inches, and the total weight (W) is 1,218 pounds.

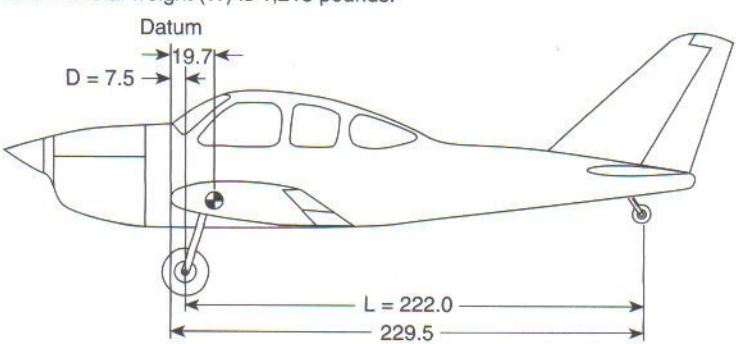


Figure 16.4. *The datum is the leading edge of the wing at the wing root.*

$$CG = D + \left(\frac{R \times L}{W}\right)$$

$$= 7.5 + \left(\frac{67 \times 222}{1{,}218}\right)$$

$$= 19.7 \text{ inches aft of the datum}$$

The CG is 19.7 inches behind the datum, which places it 12.2 inches behind the main-wheel weighing points.

16.5 Datum Aft of the Main Wheels—Tail Wheel Landing Gear

In Figure 16.5, the datum is at the trailing edge of the wing at the wing root. The distance (D) between the main-wheel weighing points and the datum is 80 inches. The weight of the tail wheel (R) is 67 pounds, the distance (L) between the main wheel and the tail-wheel weighing points is 222.0 inches, and the total weight (W) is 1,218 pounds.

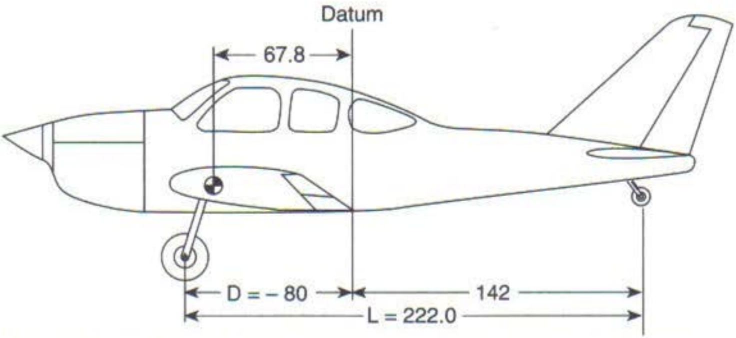


Figure 15.5. *The datum is the trailing edge of the wing at the wing root.*

$$CG = -D + \left(\frac{R \times L}{W}\right)$$

$$= -80 + \left(\frac{67 \times 222}{1{,}218}\right)$$

$$= 67.8 \text{ inches ahead of the datum}$$

The CG is 67.8 inches ahead of the datum, which is 80 inches behind the main-wheel weighing points. The CG is 12.2 inches behind the main-wheel weighing point.

16.6 Location of CG with Respect to the Mean Aerodynamic Chord

Knowing the location of the CG relative to the datum is important to the technician, because it is easy to locate physically. But the pilot and flight engineer are more concerned with location of the CG relative to the aerodynamic characteristics of the wing. The reference for this location is in percentage of the wing chord.

The chord of a tapered wing airplane is not easy to determine; therefore the mean aerodynamic chord (MAC) is used, and the allowable CG range is expressed as percentages of the MAC.

The MAC is the chord of an imaginary airfoil that has all of the aerodynamic characteristics of the actual airfoil. It can also be thought of as the chord drawn through the geographic center of the plan area of the wing. (*see* Figure 16.6)

For example, the aircraft weight and balance data states that the leading edge of MAC (LEMAC) is at station 1022, and the trailing edge of MAC (TEMAC) is at station 1198. A weight and balance computation determines that the CG is located at station 1070, the location expressed in percentage of MAC is found using this formula:

$$\text{CG in \%MAC} = \frac{\text{Distance aft of LEMAC} \times 100}{\text{MAC}}$$

$$= \frac{48 \times 100}{176}$$

$$= 27.3\% \text{ MAC}$$

The CG of the airplane is located at 27.3% MAC.

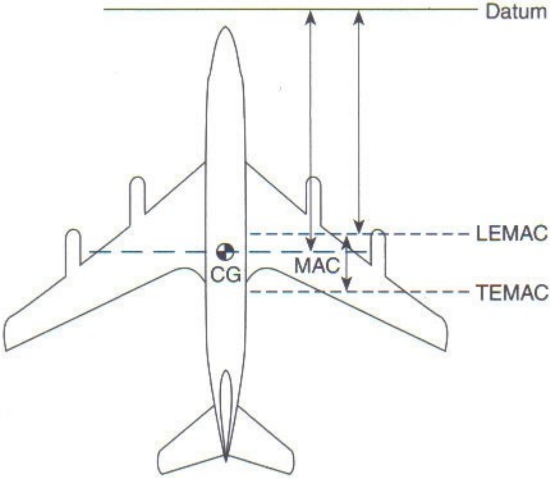


Figure 16.6. *The MAC is the chord drawn through the geographic center of the plan area of the wing.*

Section 17: Composites

17.1 Resin Systems—Typical Properties

Each resin system has its own combination of features or properties, which determine their suitability for a given purpose, e.g. maximum service temperature, smoke properties, adhesive properties, etc. The following is a list of the major resin families and general description of their properties.

Polyester resin	Cured by *polymerization* Environmentally resistant Inexpensive Poor adhesive properties High styrene emissions Poor smoke properties
Vinyl ester resin	Cured by *polymerization* Modified polyester resin Better adhesive properties than polyester High styrene emissions Poor smoke properties
Epoxy resin	Cured by *cross-linking* Excellent strength and adhesive properties Good environmental resistance Wide variety of formulations and properties Most common in aerospace applications Poor smoke properties
Phenolic resin	Cured by *cross-linking* Good chemical and electrical properties Poor adhesive properties Good smoke properties Fairly brittle
Bismaleimide resin	Cured by *cross-linking* Often referred to as BMI Good hot/wet performance High service temperature Process similar to epoxy

(continued)

Cyanate ester resin	Cured by *cross-linking* High service temperature (after post-cure) Minimal micro cracking Expensive
Polyimide resin	Cured by *cross-linking* High service temperature Good smoke properties Difficult to process Expensive

Polymerization begins in polyester and vinyl ester resins at the time of manufacture. An inhibitor is added to the material to keep it in a liquid state until it is ready for use. When the user adds a small quantity of an initiator (catalyst) such as MEKP, it counteracts the effect of the inhibitor and allows the resin to cure and become solid.

Cross-linking occurs in most other thermoset resin systems. It is a one-time chemical reaction in which liquid resin molecules (component A) form links to hardener molecules (component B). As these links form, the resin gels, cures, and ultimately becomes a solid.

WARNING: These curing processes generate heat. If sufficient amounts are left in a container for too long there is a substantial risk of an uncontrolled exothermic reaction. Such reactions can generate large amounts of toxic smoke or possibly start a fire. Always consult the manufacturers data sheet and material safety data sheet (MSDS) for details.

17.2 Resin Mix Ratios

In order for any resin system to develop its full strength after it is cured it must first be mixed properly. The amount of hardener that should be added to a resin system is usually measured by weight, not volume, and is expressed as a ratio (e.g. 100:30). Assuming the unit of measurement is grams, this means to 100 grams of resin, add 30 grams of hardener for a total of 130 grams of mixed material.

For example, if a total of 210 grams of mixed resin is needed and the mix ratio is 100:42, the amount of components A and B to be weighed out may be determined using the following formula:

$$\text{Part A} = \frac{210 \text{ grams}}{100 + 42} \text{ X } 100 = 148 \text{ grams}$$

$$\text{Part B} = \frac{210 \text{ grams}}{100 + 42} \text{ X } 42 = 62 \text{ grams}$$

Therefore, 148 grams of component A added to 62 grams of component B will result in 210 grams of mixed resin with the proper mix ratio.

The importance of understanding mix ratios cannot be stressed enough. Most high performance resin systems will tolerate mix ratio errors up to 3 percent. Errors beyond 3 percent may dramatically reduce a resin's ability to perform properly in service.

17.3 Fiber/Resin Ratio Formulas

Optimum strengths are derived from composite materials when fiber reinforcements (glass, aramid, carbon, etc.) are combined with a particular amount of matrix material (resin). Too much resin makes the laminate heavier and stiffer than it should be; not enough resin causes its physical properties to suffer tremendously. When designing composite parts engineers often use "fiber volume" as a means to express how much fiber and resin make up a component. This works fine for engineering, but is of little use to mechanics conducting repairs in the field.

Since most mechanics have access to a scale, a more practical method is to use the relative weight of the fiber and its associated resin. The relationship of the weight of the fibers to the weight of the resin can then be expressed as a ratio. For example, a 60:40 fiber/resin ratio indicates that 60% of the weight of the laminate is attributed to the reinforcing fibers and 40% is attributed to the resin. Understanding the relationship between fiber and resin weights can aid in developing optimum strength properties in wet lay-up repairs. Below are common fiber/resin ratio ranges for various fiber types.

	Fiberglass	Carbon/Graphite	Aramid
Resin lean	70:30	48:52	39:61
Resin rich	60:40	42:58	33:67

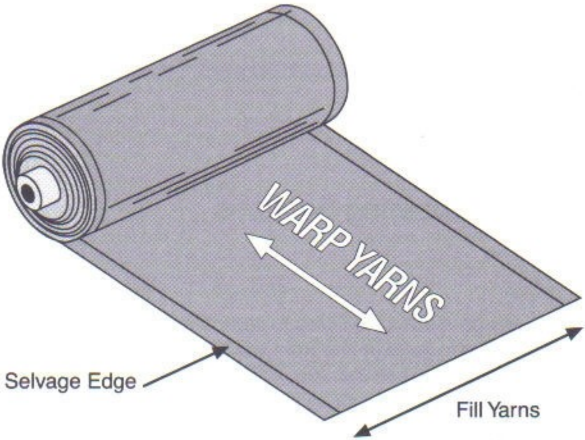
17.4 Reinforcing Fibers

The most common advanced composite fibers used in the aerospace industry today are carbon and graphite fibers, fiberglass, and aramid, or Kevlar® fiber. Each of these has certain properties that make the material unique and particularly well suited for certain applications.

Carbon/Graphite	High modulus (stiffness) Broad range of strength and modulus combinations Electrically conductive
Aramid (Kevlar®)	Light weight High tensile strength Impact / abrasion resistant
Fiberglass	Excellent physical properties Readily available Inexpensive Variety of chemistries available for different purposes

17.5 Textile and Fiber Terminology

Roll of Fabric or Prepreg



Filaments

The smallest element of composite fibers, typically 3 to 25 microns in diameter depending on the type of fiber.

Strands

An intermediate step used in the production of fiberglass yarns only. Filaments are twisted into strands, which are then twisted into yarns.

Yarns/tows

Bundles of filaments numbering from 25 to 24,000. Yarns are twisted to aid in the manufacture of woven cloth (see 17.6 "Yarn Part Numbering Systems"). Tows are often laid flat and parallel to manufacture carbon, aramid, or fiberglass unidirectional tape.

Warp yarns

Yarns running the length of a roll of fabric. Always used when referencing ply orientation.

Fill yarns

Transverse yarns on a roll of fabric.

Selvage edge

Stitching along the long edge of a roll of fabric to keep it from fraying.

Warp face

Harness satin weaves only. The face of a fabric on which one sees primarily warp yarns.

Fill face

Harness satin weaves only. The face of a fabric on which one sees primarily fill yarns.

17.6 Yarn Part Numbering Systems

Composite structures rely on reinforcing fibers to carry the majority of the loads imposed on them. In structures made from woven materials, the fibers are usually gathered into yarns. Since the size, construction, and number of the yarns is critical to the structure's ability to conduct a load properly, it is important to understand how these yarns are described. Each of the major fiber types—fiberglass, carbon, and aramid (Kevlar®)—have their own part numbering system for yarns.

Carbon

A number suffixed by the letter "K" (thousand) is used to indicate how many thousands of filaments make up the yarn. For instance, a 6K yarn is made up of six thousand filaments.

Aramid (Kevlar®)

Aramid yarns are described by their denier weight, which appears as a number suffixed by "de." The denier weight is the weight, in grams, of nine thousand meters of the yarn, the lower the denier, the finer the yarn. For example, a yarn designated as 1140 de indicates that nine thousand meters of that yarn weighs 1,140 grams.

Fiberglass

Given the wide variety of fiberglass materials produced, a more exact system for identifying yarns is required. An example of a fiberglass yarn part number is given below followed by descriptions of each of its components.

For example, **ECG 150 2/3**

First letter—Characterizes the chemical composition of the glass, e.g. E-glass (electrical), C-glass (chemical resistant), S-glass (structural), etc.

Second letter—Describes the filament type. "C" indicates a continuous filament as opposed to a staple filament (S), or a texturized continuous filament (T).

Third letter—A letter code representing the individual filament diameter. "G" indicates an individual filament diameter range of .00035 to .000399 inches. Contact fiberglass manufacturer for additional letter codes.

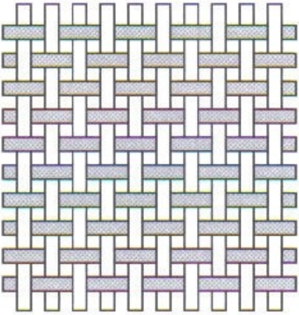
First number—The number of yards, divided by one hundred, required to net one pound of the basic yarn strand. In the example, multiplying 150 by one hundred equals 15,000 yards of strand in one pound.

Second number—The "2/3" shows the number of basic strands in the yarn. The first digit represents the original number of twisted strands. The second digit shows how many of these are twisted together to make one yarn. To find the total number of strands in a yarn, multiply the two digits together (a zero is always multiplied as a one).

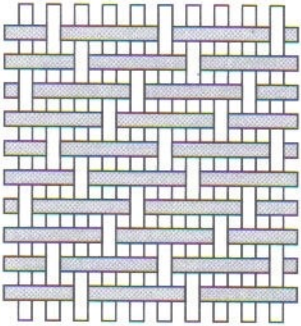
17.7 Fabric Weave Styles

Plain weave

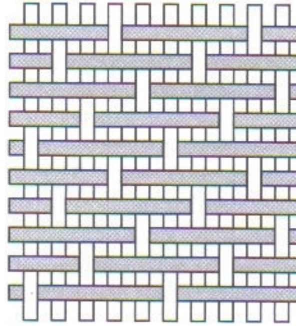
The simplest, most basic of the weave styles. Warp and fill yarns are interlaced over and under each other in an alternating pattern. These fabrics are stable and lightweight, but typically have poor drape properties.



Plain weave



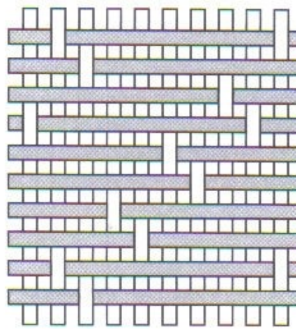
Four-harness



Five-harness

Harness satin weaves

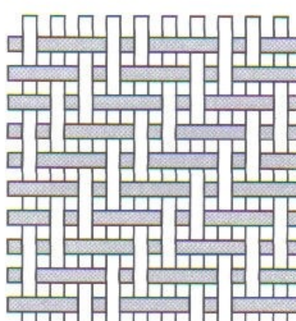
A warp or fill yarn "floats" over a number of yarn intersections before interlacing under just one yarn. This creates the appearance of all the yarns on one side of the fabric "traveling" in a single direction, and the yarns on the opposite side "traveling" 90 degrees out (*see* 17.4, "warp face" and "fill face"). Harness satins have excellent drape and are characterized by the number of yarns a yarn "floats" over, plus the yarn it goes under. Common weave styles include four-harness satin (over three yarns, under one), five-harness satin (over four yarns, under one), and eight-harness satin (over seven yarns, under one).



Eight-harness satin

Twill weave

These relatively stable fabrics offer increased drape properties over plain weaves. The weave pattern is characterized by the appearance of a diagonal rib caused by warp yarns floating over two fill yarns (2x2 twill) and then, under two. A 4x4 twill has a similar appearance and better drape properties.



Twill weave

17.8 Common Weave Style Numbers and Features

It is important to remember that the weave style number is meaningless without knowing the fiber type. For instance, 120 style aramid is in no way similar to 120 style fiberglass. The aramid is a plain weave and the fiberglass is a four harness satin.

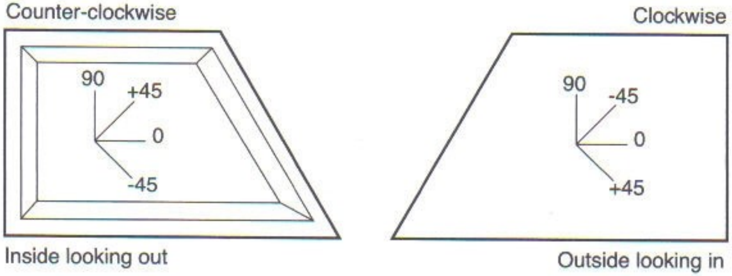
Fiberglass Style number	Characteristics Weave style - Weight - Yarn count (W x F)
120	4 harness satin - 3.1 oz. - 60 x 58
1581	8 harness satin - 8.7 oz. - 57 x 54
7500	plain weave - 9.3 oz. - 56 x 54
7781	8 harness satin - 8.7 oz. - 16 x 14
Aramid Style number*	Characteristics Weave style - Weight - Yarn count (W x F)
348 (181)	8 harness satin - 4.9 oz. - 50 x 50
350 (120)	plain weave - 1.7 oz. - 34 x 34
352 (281)	plain weave - 5.0 oz. - 17 x 17
353 (285)	4 harness satin - 5.0 oz. - 17 x 17
Carbon Style number	Characteristics Weave style - Weight - Yarn count (W x F)
130	plain weave - 3.74 oz. - 24 x 24
282	plain weave - 5.8 oz. - 12 x 12
286	4 harness satin - 5.8 oz. - 12 x 12
433	5 harness satin - 8.4 oz. - 18 x 18
584	8 harness satin - 11.0 oz. - 24 x 24
IM7 Graphite	
SGP193-P	plain weave - 5.7 oz. - 11 x 11
SGP203-CS	4 harness satin - 6.0 oz. - 12 x 12
SGP370-8H	8 harness satin - 11.0 oz. - 21 x 21

* Numbers in parentheses are older style numbers

17.9 Ply Orientation Conventions

Ply orientation convention symbols are used in manufacturers structural repair manuals to coordinate the drawing of the component to the ply tables, which list ply orientations.

There are two types of convention symbols, clockwise and counter-clockwise. The counter-clockwise warp clock is drawn from the manufacturer's standpoint where the plies are viewed from the inside looking out, toward the tool surface. The clockwise warp clock is drawn from the repair standpoint where the plies are viewed from the outside, or tool surface, looking in.

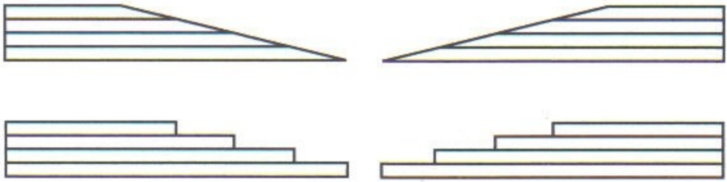


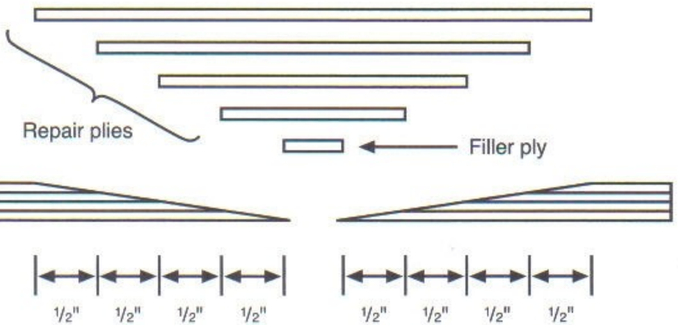
17.10 Damage Removal–Scarfing and Stepping

Once the damaged area of a laminate has been removed, it must be prepared in such a way that allows the repair plies to conduct loads much like the original structure did. Like sheet metal repairs, composite repairs rarely restore a structure to 100% of its original strength, but poorly prepared areas can yield composite repairs that perform well below acceptable standards. Always consult the manufacturer's SRM or other acceptable data for repair specifics.

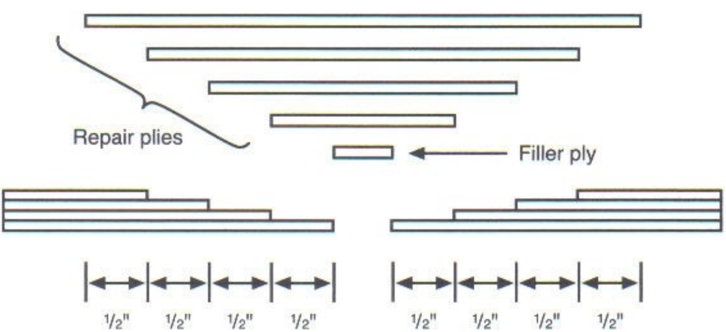
While scarfed, or taper-sanded repairs have been demonstrated to conduct loads more effectively, step-sanded repairs are still found in many aircraft SRMs. Usually, they are both expressed as a specific dimension per ply, e.g. scarf 1/2 inch per ply. On some newer aircraft taper sanding is expressed as a scarf ratio.

In a scarf ratio of 40:1 for example, the "1" represents the thickness of the laminate and the "40" represents the distance the scarf will cover, in this case 40 times the thickness of the laminate.





Typical scarf repair



Typical step repair

17.11 Core Materials

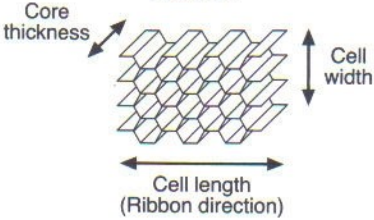
Core materials for composite applications can generally be divided into two categories, foam core and honeycomb core. Foam core materials generally have good properties at a relatively low cost, they are easy to machine, and their closed cell construction offers excellent resistance to water and fluid ingress. While there are many foam chemistries, the three most common are Polyvinylchloride (PVC), Polyurethane, and Polymethacrylimide (PMI). Available densities range from less than 2 pounds per cubic foot (pcf) to 60 pcf.

Honeycomb core is used extensively on modern aircraft due to its exceptional physical properties and light weight. Fabrics are used to make carbon and fiberglass honeycomb, while Nomex® and Kevlar® cores are made from a pressed, paper-like form of the materials. The three most common core cell configurations are; hex core (hexagonal), for flat or nearly flat panels; O.X. core (over-expanded) for simple curves; and flex-core for complex geometries. When honeycomb is specified, the following information needs to be provided:

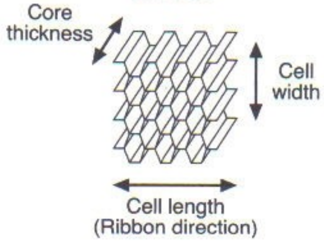
- Material
- Cell shape (Hex-core, O.X. core, Flex-core, etc.)
- Cell size

Core Cell Configurations

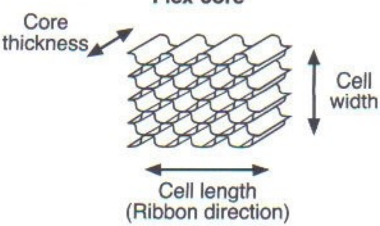
Hex core



O.X. core



Flex-core



Core illustrations courtesy of Hexcel

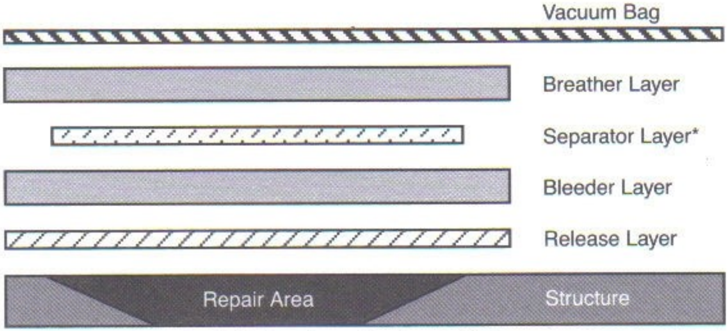
- Density
- Wall thickness and alloy (for aluminum core)

Cell sizes range from 1/16" to 1", with 1/8", 3/16", 1/4", with 3/8" being the most common. Honeycomb densities range from 1.0 lb/ft^3 to 55 lb/ft^3.

17.12 Bleeder Schedules

Bleeder schedules are used in conjunction with vacuum bag processing to remove resin that is in excess of the desired fiber/resin ratio (*see* 17.3) and to remove air and volatiles from the resin system as it cures. There are many types of materials available to perform the various functions in a bleeder schedule, so the potential combinations are infinite. However, a typical bleeder schedule might contain the following elements:

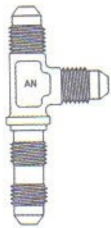
- Release layer—Allows resin and gasses to pass through and releases from the cured part/repair.
- Bleeder material—Absorbent material to hold resin.
- Separator layer—Prevents resin from saturating breather materials. A separator may not be necessary depending on resin quantity and flow characteristics.
- Breather material—Provides gas path for extraction of air and volatiles.
- Vacuum bag—Used with sealant tape to achieve vacuum.



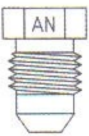
*Separator layer, if used, should allow breather and bleeder materials to make contact beyond the edge of the repair to allow air and volatiles to escape.

Appendices

Appendix 1: Hydraulic Fittings

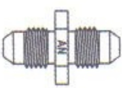


AN804
Bulkhead Tee,
Bulkhead on run



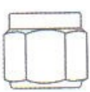
AN806
Pressure Plug

AN814
Bleeder Plug

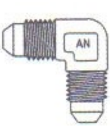


AN815
Union

AN816
Pipe to 37° Flare,
Straight



AN818
Tube Nut

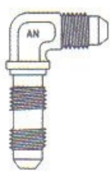


AN821
90° Elbow

AN824
Tee

AN827
Cross

AN832
Bulkhead
Straight

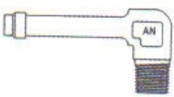


AN833
Bulkhead 90°

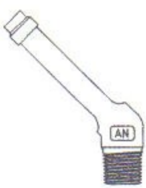
AN834
Bulkhead Tee,
Bulkhead on
side

AN837
Bulkhead 45°

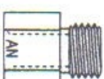
AN840
Straight Nipple



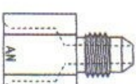
AN842
90° Nipple



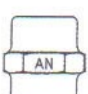
AN844
45° Nipple



AN893
Female
Straight to Male
Straight



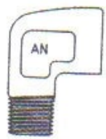
AN894
Female
Straight to
Male 37°



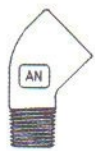
AN910
Female
Straight

AN911
Male Straight

AN912
Pipe to Pipe
Bushing

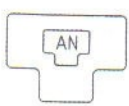


AN914
Male to Female 90°

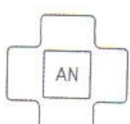


AN915
Male to Female 45°

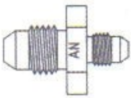
AN916
Female 90°



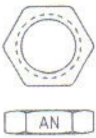
AN917
Female Tee



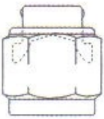
AN918
Female Cross



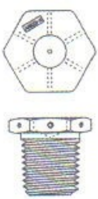
AN919
Male to Male,
37° Flare



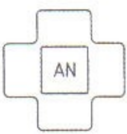
AN924
Bulkhead Nut



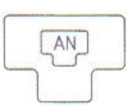
AN929
Pressure Cap



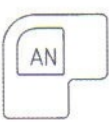
AN933
External Hex Plug



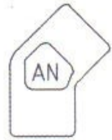
AN937
Straight Thread
Cross



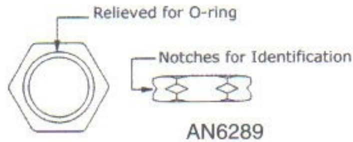
AN938
Straight Thread
Tee



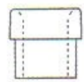
AN939
Straight Thread
90° Elbow



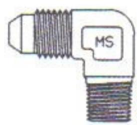
AN941
Straight Thread
45° Elbow



AN6289
Bulkhead Nut



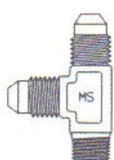
MS20819
Sleeve



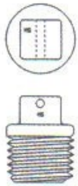
MS20822
Pipe to 37°
Flare, 90°

MS20823
Pipe to 37°
Flare, 45°

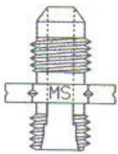
MS20825
Tee, Pipe on
Side



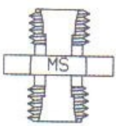
MS20826
Tee, Pipe on
Run



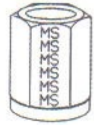
MS20913
Square Plug,
replaces AN913



MS21900
37° Flare to Flareless

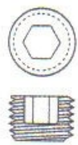


MS21902
Flarelelss Union

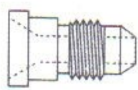


MS21921
Flareless Nut

MS21922
Flareless Sleeve



MS27769
Hex Plug, replaces
AN932



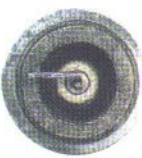
NAS1564
Female 37° to
Male 37°

Appendix 2: Engines

Fine-Wire Spark Plugs

Normal: Indicates short service time and correct heat range. Clean, regap and test before reinstalling.

Worn Out—Normal: Indicates normal service life, electrodes show normal erosion, ground electrodes about half original thickness. Install new spark plugs.



Worn Out—Severe: Extensively eroded center and ground electrodes indicate abnormal engine power operation or plugs long overdue for replacement. Install new spark plugs.

Lead Fouled: Hard, cinder-like deposits from poor fuel vaporization, high T.E.L. content in fuel or engine operating too cold. Clean, regap, test and reinstall.

Carbon Fouled: Black, sooty deposits from excessive ground idling, idle mixture too rich or plug type too cold. If heat range is correct, clean, regap, test and reinstall.

Oil Fouled: Wet, oily deposits may be caused by broken or worn piston rings, excessive valve guide clearances, leaking impeller seal or engine still in break-in period. Repair engine as required. Clean, regap, test and reinstall plugs.

Massive Electrode Plugs

Normal: Indicates short service time and correct heat range. Clean, regap and test before reinstalling.

Worn Out—Normal: Indicates normal service life, electrodes show normal erosion, ground electrodes about half original thickness. Install new spark plugs.

Worn Out—Severe: Excessively eroded center and ground electrodes indicate abnormal engine power operation. Check fuel metering. Install new spark plugs.

Lead Fouled: Hard, cinder-like deposits from poor fuel vaporization, high T.E.L. content in fuel or engine operating too cold. Install new spark plugs.

Carbon Fouled: Black, sooty deposits from excessive ground idling, idle mixture too rich or plug type too cold. If heat range is correct, clean, regap, test and reinstall.

Oil Fouled: Wet, oily deposits may be caused by broken or worn piston rings, excessive valve guide clearances, leaking impeller seal or engine still in break-in period. Repair engine as required. Clean, regap, test and reinstall plugs.

Courtesy Champion Aviation Products

Spark Plug Color Identifier

Painted between spark plug hole and rocker box.

Gray or unpainted	Short reach spark plug
Yellow	Long reach spark plug

Appendix 3: Aircraft Lead Acid Battery Theory

Adapted from "Concorde Aircraft Battery Owner/Operator Manual," courtesy Concorde Battery Corporation

Simplified lead acid electrochemical reaction.	
Discharge >	< Charge

$$PbO_2 + Pb + 2H_2SO_4 \longleftrightarrow 2PbSO_4 + 2H_2O + 2E$$

Chemical Reactions

A chemical reaction takes place when a battery is being charged or discharged, as represented by the above equation.

On discharge, lead dioxide (PbO_2) of the positive electrode and sponge lead (Pb) of the negative electrode are both converted to lead sulfate ($PbSO_4$) freeing two electrons. On charge, the lead sulfate in the positive electrode is converted to lead dioxide (PbO_2) (with oxygen evolution on charge) and the lead sulfate in the negative electrode is converted to sponge lead (with hydrogen evolution on charge). The electrolyte, sulfuric acid (H_2SO_4), is an active component in the reaction at both electrodes.

When flooded (vented) batteries are on charge, the oxygen generated at the positive plates escapes from the cell. Concurrently, at the negative plates, hydrogen is generated from water and escapes from the cell. The overall result is the gassing of the cells and water loss. Therefore, flooded cells require periodic water replenishment.

When valve regulated Recombinant Gas (RG®) batteries are on charge, oxygen combines chemically with the lead at the negative plates in the presence of H_2SO_4 to form lead sulfate and water. This oxygen recombination suppresses the generation of hydrogen at the negative plates. Overall, there is no water loss during charging. A very small quantity of water may be lost as a result of self-discharge reactions; however, such loss is so small that no provision need be made for water replenishment. The battery cells have a pressure relief safety valve that may vent if the battery is overcharged.

> **NOTE: DO NOT** remove the pressure relief valves on an RG® battery and **DO NOT** add water or electrolyte. The Recombinant Gas design eliminates the need to replenish water and electrolyte. Removing the pressure relief valve voids the warranty.

Battery Construction

An aircraft storage battery consists of 6 or 12 lead acid cells connected in series. The open circuit voltage of the 6-cell battery is approximately 12 volts, and the open circuit voltage of the 12-cell battery is approximately 24 volts. Open circuit voltage is the voltage of the battery when it is not connected to a load.

Cell Construction

The lead acid cell used in aircraft batteries consists of positive plates made of lead dioxide (PbO_2); negative plates of pure spongy lead (Pb); and a liquid known as electrolyte, consisting of a mixture of sulfuric acid (H_2SO_4) and water (H_2O). The sulfuric acid and water are mixed so the solution has a specific gravity (S.G.) of 1.275 to 1.300 in a fully charged battery.

The specific gravity of a substance is defined as the ratio of the weight of a given volume of the substance to the weight of an equal volume of pure water at 80°F/27°C.

The plates are sandwiched between layers of microfiber glass mat. Electrolyte is absorbed and held in place by the capillary potential of the fluid and the absorbent glass mat (AGM) fibers.

Grids and Plates

Each cell of a storage battery has positive and negative plates arranged alternately, insulated from each other by separators. Each plate consists of a framework, called the **grid**, and a lead paste compound called **active material**.

The grid is cast from a lead alloy. The heavy outside frame adds strength to the plate. The small horizontal and vertical wires support the active material. These wires also act as conductors for the current.

The lead paste compound (active material) is applied to the grid in much the same manner as plaster is applied to a lath wall. A different paste formula is used for the positive and negative plates.

In compounding the negative plate paste (active material), a substance is added known as an **expander**. This substance is relatively inert and makes up less than one percent of the mixture. Its purpose is to prevent the loss of porosity of the negative material during the life of the battery. Without the use of an expander, the negative material contracts until it becomes quite dense, thus limiting the surface area available for reaction.

Plate Groups

Plate groups are made by joining a number of similar plates to a common terminal post by means of a plate strap. The capacity of a battery is determined by the number and size of plates in a group. Each plate is made with a lug at the top which is fused to the strap. A positive group consists of a number of positive plates connected to a plate strap and a negative group consists of a number of negative plates connected in the same manner. The two groups meshed together with separators between the positive and negative plates constitute a **cell element**.

Separators

The separators used in aircraft batteries are made of micro-porous polypropylene material. Their purpose is to keep the plates separated and thus prevent an internal short circuit. In the RG® Series batteries a second separator made from microfiber absorbent glass mat (AGM) is also used.

The separator material must be extremely porous so that it will offer a minimum of resistance to the ions passing through them. The material must also resist chemical attack from the electrolyte.

The AGM, by design, is approximately 92% saturated with electrolyte. The remainder is filled with gas. This void space provides the channels by which oxygen travels from the positive to the negative plate during charging. The freshly generated gases, which are in their atomic state and very reactive, recombine rapidly and safely.

The recombination passivates the negative slightly, reducing electrolysis and ultimately eliminating the need to add water. Because of the compressed construction, the RG® batteries have a much lower internal resistance and thus provide greater starting power and faster recharging, particularly at cold temperatures, than comparable flooded batteries. Additionally, the AGM provides a much higher degree of support against shock and vibration than in the older flooded (vented) batteries. The RG® batteries provide electrical performance comparable to nickel cadmium aircraft batteries without the requirement of a temperature or current monitoring system.

Cell Containers

When the cell elements are assembled, they are placed in the **cell container** which is made of plastic. Usually cell containers are made up in a monobloc with as many compartments as there are cells in the battery. The plastic used is selected for its resistance to sulfuric acid, low permeability and impact strength.

Cell Covers, Vent Valves and Vent Caps

The assembled cell has a cover made of material similar to that of the cell container. The cell or monobloc cover has holes through which the terminal posts extend and a retention hole for vent cap or valve attachment. When the cover is placed on the cell(s), it is sealed to the container or case with a special sealing compound to prevent leakage and loss of electrolyte.

Precautions

There are several precautions that must be observed when handling storage batteries and especially when charging.

When a flooded (vented) storage battery is being charged, it generates a substantial amount of hydrogen and oxygen. The vent caps should be left in place and no open flames, sparks or other means of ignition should be allowed in the vicinity.

Recombinant Gas (RG®) storage batteries generally do not vent when being charged UNLESS they are being overcharged. Always turn off the power before connecting or disconnecting a storage battery from a charging source.

The electrolyte contains sulfuric acid. Sulfuric acid is very corrosive. Avoid contact with flesh, cloth or wood. Be very careful not to spill the electrolyte. If it is spilled, immediately rinse with water and neutralize it with a solution of water and bicarbonate soda or a mild ammonia and water solution.

There should be adequate ventilation of the area where storage batteries are being charged in order to dissipate the gasses and acid fumes.

Separate facilities for storing and/or servicing flooded electrolyte lead acid and nickel cadmium batteries must be maintained. Introduction of acid electrolyte into alkaline electrolyte will cause permanent damage to vented (flooded electrolyte) nickel-cadmium batteries and vice versa. However, batteries that are sealed can be charged and capacity checked in the same area. Because the electrolyte in a valve regulated lead acid battery is absorbed in the separators and porous plates, **it cannot contaminate a nickel cadmium battery even when they are serviced in the same area.**

Caution: Aircraft are certified with batteries that have reserve or essential capacity for emergency operation. Never "Jump start" an aircraft that has a "Dead" or discharged battery. It takes approximately three hours to fully recharge a discharged battery with the aircraft generating system.

> **NOTE:** With flooded (vented) batteries, unless the battery electrolyte was accidently spilled, you should only add demineralized water in normal service. Water consumption varies with the operating temperature of the battery and the charging voltage.

1) The electrolyte level should be checked at the end of charge and filled to the bottom of the level indicator with water when charging flooded (vented) batteries. Do not allow the reserve electrolyte level to go below the top of the plates or the battery performance and life will be reduced.

2) The capacity of flooded (vented) and Recombinant Gas (RG®) batteries should be checked annually or as often as the Regional Airworthiness Authority Regulations require.

3) Discharged batteries exposed to cold temperatures are subject to plate and separator damage due to freezing. To prevent freezing damage to a lead acid battery, maintain the batteries in a charge state.

Activation of Dry Charged Batteries

Caution:

1) **Do not remove the sealing tape on the cell vents until you are ready to fill the battery with electrolyte. Aircraft Batteries require a pure diluted sulfuric acid electrolyte of 1.285 specific gravity at 80°F or 27°C. Check the specific gravity of the electrolyte before filling the cells of the battery to be sure it is the correct type and specific gravity.**

2) **Use a clean hydrometer to determine the specific gravity of the battery electrolyte.**

3) **If it should become necessary to dilute concentrated sulfuric acid to a lower specific gravity, ALWAYS POUR THE ACID INTO THE WATER. NEVER POUR WATER INTO ACID, a dangerous "spattering" of the liquid will result caused by the extreme heat which is generated when strong acid is mixed with water. Stir liquid continuously while acid is being added.**

4) **When working with acid, always wear a face shield and protective clothing. Sulfuric acid can destroy clothing and burn skin. If electrolyte is spilled or splashed on clothing or on the body, it must be neutralized immediately with a solution of baking soda and water and rinsed with clean water.**

5) **If electrolyte is splashed into the eyes, force the eyes open and flood with cool clean water for approximately five minutes. Call a physician and get medical attention immediately.**

6) **If electrolyte is taken internally, drink large quantities of water or milk, followed with milk of magnesia, beaten egg or vegetable oil. Call a physician immediately.**

7) **Do not place battery acid within the reach of children.**

Caution: Hydrogen and oxygen gases are produced during normal battery operation. Explosive gases may continue to be present in and around the battery for several hours after it has been charged. Keep

sparks, flames, burning cigarettes and other sources of ignition away at all times.

Mixing of Electrolyte

Electrolyte of a given specific gravity can be purchased; however, it is sometimes more convenient to mix it at the shop or hangar. The following table gives the proper amount of demineralized water to be mixed with a given amount of acid to obtain the desired specific gravity.

The container in which electrolyte is mixed should be made of glass, glazed earthenware or other material which will not be attacked by the acid.

Caution: When mixing acid with water, always pour the acid into the water. Never pour water into the acid. The heat generated may cause the acid to spatter on the operator. Severe burns may result.

After the electrolyte is mixed, it may be tested for specific gravity. If the specific gravity is not as desired, it can easily be adjusted by the addition of acid or water. Be sure to correct the specific gravity reading for temperature. (See temperature correction of S.G. reading.)

When purchasing acid or electrolyte for battery use, "commercial" grade acid should not be used. Use "battery" grade sulfuric acid which is free of impurities that may contaminate a battery. It is not as expensive as the chemically pure grade, commonly called "Reagent Grade."

Battery Testing

Hydrometer Test

The most common instrument used for the testing of flooded electrolyte batteries is the **hydrometer**. Concorde recommends the FR-1 Aircraft Battery Hydrometer. The specific gravity of the electrolyte in a battery cell is a good index of the state of charge in the cell. This is due to the fact that as the battery is discharged, the acid in the electrolyte is used in the chemical reaction. This means the acid has broken down, part of it combining with the lead of the plates to form lead sulfate and part of it combining with oxygen to form water. Since the weight of the acid is much greater than that of the water, the reduction of acid and the increase of water will cause the specific gravity of the electrolyte to decrease.

A hydrometer is used to determine the specific gravity of the electrolyte and it generally consists of a glass barrel with a rubber hose on one end and a soft rubber bulb on the other. Inside the glass barrel is a glass float with calibrated graduations. The bulb is squeezed and the rubber hose is inserted into the electrolyte in the battery cell. When the bulb is released electrolyte is drawn into the glass barrel. At eye level and when the float has stabilized, the specific gravity is read at the point on the calibrated float where the surface of the electrolyte crosses the float markings. The specific gravity range is usually 1.100 to 1.300. After the reading is taken, the rubber bulb is squeezed to release the electrolyte back into the battery cell.

It is important to make sure the float is not sticking to the side of the glass barrel and that the electrolyte can be seen between the bottom of the float and the bottom of the glass barrel. If irregular readings are obtained, examine the glass float closely for hairline cracks. It is a good idea to have more than one hydrometer on hand so that one can be checked against the other. The hydrometer must be kept clean. Accumulation of dry acid can cause the float to read inaccurately. The hydrometer should be taken apart and washed occasionally.

A specific gravity reading from 1.275 to 1.300 usually indicates a fully charged cell. If the reading is from 1.200 to 1.240 the charge is considered low. This does not mean that the cell is nearly discharged, but it indicates that it may not be able to furnish power sufficient for heavy loads such as starting engines. A reading of 1.260 in a battery indicates a state of charge sufficient for normal operation, even though it is not fully charged.

It must be pointed out that the specific gravity reading is not always an indication of the state of charge in a cell. If the electrolyte is removed from a discharged cell and replaced with an electrolyte of a high specific gravity, the cell will still be in a discharged condition even though the hydrometer test shows a full charge reading.

Normally, electrolyte should never be added or removed from a cell. The addition of water is necessary periodically to replace the amount lost through electrolytic action and evaporation. Acid should never be added unless electrolyte has been lost by spillage because acid does not evaporate. When it is necessary to add acid, the battery should be fully charged, on charge and gassing freely. Then, by means of a rubber syringe or hydrometer, the electrolyte is drawn off and replaced with electrolyte having a specific gravity of 1.285. The charge should be continued for one hour before making another test.

Batteries are considered fully charged when the temperature corrected specific gravity reading is 1.285 ±0.005. A 1/3 discharged battery reads about 1.240 and a 2/3 discharged battery will show a specific gravity reading of about 1.200 when tested with a hydrometer. However, to determine precise specific gravity readings, temperature corrections shown in the table above should be applied.

The corrections in the table should be added or subtracted from the hydrometer reading. For example, if the temperature of the electrolyte is 10 degrees Fahrenheit, and the hydrometer reading is 1.250, the corrected reading will be 1,250 minus .028 equals 1.222. Notice that the correction points are in thousandths.

Charging Methods

> **NOTE: For specific charging instructions** see Concorde Battery Corporation's *Instructions for Continued Air Worthiness Maintenance Manual Supplement for Concorde Flooded Lead Acid Main Battery* (Drawing: 5-0144); *Instructions for Continued Air Worthiness Maintenance Manual Supplement for Concorde Valve Regulated Lead Acid Main Battery* (Drawing: 5-0142); *Instructions for Continued Air Worthiness Maintenance Manual Supplement for Concorde Valve Regulated Lead Acid Emergency Battery Packs* (Drawing: 5-0143). See our website: www.concordebattery.com for the latest revision.

Storage batteries are charged by passing a direct current through them in a direction opposite to that of the discharge current. The power supply must be connected to the battery, positive to positive and negative to negative. Various sources of direct current may be used, but the most commonly used devices are either rectifiers or direct current generators. The manner in which batteries are connected to the power source will vary. This is usually determined by the type and the voltage of the batteries being charged. When batteries of different voltages must be charged by the same power supply, they are usually charged by the constant current method (CI). Another method used is the constant potential (CP) (voltage) method. This system is usually used on aircraft, where an engine driven generator is continually charging the battery according to its requirements.

Battery charging methods may also be classified as "manually cycled" and "system governed" methods. Usually, where batteries are charged in the hanger or shop, the manually cycled method is employed. This means simply that the voltage or current is controlled by an operator according to the requirements of the batteries being charged. In the system governed method, the voltage of the power supply is automatically controlled by a carefully adjusted voltage regulator.

Constant Voltage Charging (CP)

The battery charging system in an airplane is of the constant voltage type. An engine driven generator, capable of supplying the required voltage, is connected through the aircraft electrical system directly to the battery. A battery switch is incorporated in the system so that the battery may be disconnected when the airplane is not in operation. The voltage of the generator is accurately controlled by means of a voltage regulator connected in the field circuit of the generator.

For a 12-volt system, the voltage of the generator is adjusted to approximately 14.25. On 24-volt systems, the adjustment should be between 28 and 28.5 volts. When these conditions exist, the initial charging current through the battery will be high. As the state of charge increases the battery voltage also increases, causing the current to taper down.

When the battery is fully charged, its voltage will be almost equal to the generator voltage, and very little current will flow into the battery. When the charging current is low, the battery may remain connected to the generator without damage.

At extremely low battery temperatures a setting of 28.5 volts does not supply enough current to charge a battery adequately. At battery temperatures in excess of 90°F the current input at 28.5 volts tends to over charge the battery.

When using a constant voltage system in a battery shop, a voltage regulator that automatically maintains a constant voltage is incorporated in the system. A higher capacity battery (e.g. 42 Ah) has a lower resistance than a lower capacity battery (e.g. 33 Ah). Hence a high capacity battery will draw a higher charging current than a low capacity battery when both are in the same state of charge and when the charging voltages are equal.

Constant Current Charging (CI)

Constant current charging is the most convenient for charging batteries outside the airplane because several batteries of varying voltages may be charged at once on the same system. A constant current system usually consists of a rectifier to change the normal alternating current supply to direct current. A transformer is used to reduce the available 110 volt or 220 volt alternating current supply to the desired level before it is passed through the rectifier.

If a constant current system is used, multiple batteries may be connected in series, provided that the charging current is kept at such a level that the battery does not overheat or gas excessively.

Conditioning After Deep Discharge, see applicable Instructions for Continued Airworthiness (ICA) (See our website: www.concordebattery.com for the latest revision).

Capacity Test

For test procedures and instructions, see Concorde's Instructions for Continued Airworthiness (ICA) (available on our website: www.concordebattery.com).

Batteries that have a capacity greater than 80% of the C1 rated capacity may be considered airworthy. To insure a safety margin, Concorde recommends that batteries have an actual capacity of greater than 85% of the C1 rated capacity for installation in an aircraft.

Capacity testing devices for aircraft storage batteries have been developed and these give an accurate indication of the condition of a battery. A **capacity tester** generally incorporates load resistance, a voltmeter and a time clock. Some models show the percentage of capacity or ampere hours. A fully charged battery is connected to a measured load until the voltage, as indicated on the voltmeter, drops to a predetermined figure. At this time the reading on the clock is noted. The reading gives the capacity of the battery tested.

After this test, the battery should be recharged by either the constant current or constant voltage method described in the applicable ICA. For discharging or charging batteries, it is best to have a disconnect switch on the discharge apparatus or on the charging panel. The closing and opening of the battery circuit by use of spring clips on the battery terminals should be avoided as the resulting arc may cause an explosion of the battery gasses.

The discharge voltage of a healthy battery does not decrease with age although it will be found that an older battery may not have as high of an open circuit voltage when fully charged.

Battery State of Charge (S.O.C.)

S.O.C.	**12 volt O.C.V.**	**24 volt O.C.V.**	**S.G.**
100%	12.9	25.8	1.300
75%	12.7	25.4	1.270
50%	12.4	24.8	1.220
25%	12.0	24.0	1.140
0%	11.7	23.4	1.090

Battery State of Health

A battery's state of health must be determined by verifying its ability to provide sufficient stored energy for essential power requirements. The amount of stored energy (battery capacity) required to start a reciprocating engine is generally less than 3%, while a turbine engine start requires approximately 10% of the rated capacity. Good starting performance is not necessarily a safe indication of the battery's state of health. An airworthy battery must be able to provide essential power in the event of a failure of the generating system. Therefore, a periodic capacity check of the battery at the C1 rate (one hour) is recommended.

Cold Weather Operation

Temperature is a vital factor in the operation and life of a storage battery. Chemical reactions take place more rapidly with heat than with cold. For this reason, a battery will give much better performance in temperate or tropical climates than in cold climates. On the other hand, the battery will deteriorate faster in warm climates. In some cases, a lower specific gravity electrolyte is specified for warm climate operation in order to add to the life of the battery because chemical reactions are more rapid in warmer climates.

In cold climates, the state of charge in a storage battery should be kept at a maximum. A fully charged battery will not freeze even under the most severe weather conditions, but a discharged battery will freeze very easily. When adding water to a battery in extremely cold weather, the battery must be charged at once. If this is not done, the water will not mix with the acid and will freeze.

The following table gives the freezing points of electrolyte for various states of charge. These are the approximate points at which ice crystals start to form. The electrolyte does not freeze solid until a lower temperature is

Specific Gravity	Freezing Point	
	°C	°F
1.300	–70	–95
1.275	–62	–80
1.250	–52	–62
1.225	–37	–35
1.200	–26	–16
1.175	–20	– 4
1.150	–15	+ 5
1.125	–10	+13
1.100	– 7	+19

reached. Solid freezing of electrolyte in a discharged battery will damage the plates and may rupture the container.

Capacity Loss Due to Low Temperatures

Operating a storage battery in cold weather is equivalent to using a battery of lower capacity. For example, a fully charged battery at 80°F may be capable of starting an engine twenty times. At 0°F the same battery may start the engine only three times.

Low temperature greatly increases the time necessary for charging a battery. A battery which could be recharged in an hour at 80°F while flying may require approximately five hours for charging when the temperature is 0°F.

During cold weather, keep batteries fully charged. Make every effort to conserve battery power.

Ventilating Systems

Modern airplanes are equipped with battery ventilating systems. The ventilating system provides for the removal of gasses and acid fumes from the battery in order to reduce fire hazard and to eliminate damage to airframe parts. Air is carried from a scoop outside the airplane through a vent tube to the interior of the battery case. After passing over the top of the battery, air, battery gasses and acid fumes are carried through another tube to the battery sump.

This sump is a glass or plastic jar of at least one pint capacity. In the jar is a felt pad about 1 inch thick saturated with a 5% solution of bicarbonate of soda and water. The tube carrying fumes to the sump extends into the jar to within about 1/4 inch of the felt pad.

An overboard discharge tube leads from the top of the sump jar to a point outside the airplane. The outlet for this tube is designed so there is negative pressure on the tube whenever the airplane is in flight. This helps to insure a continuous flow of air across the top of the battery, through the sump and outside the airplane. The acid fumes going into the sump are neutralized by the action of the soda solution, thus preventing corrosion of the aircraft's metal skin or damage to a fabric surface.

Inspection and Service

See applicable ICA.

Storage

See applicable ICA.

Battery Terminology

Active material: Electrode material which produces electricity during its chemical conversion.

AGM: Absorbent glass mat.

Ampere: Unit of electrical current.

Ampere hour (Ah): The capacity of a storage battery is measured in **ampere hours**. One ampere hour is defined as a current flow of one ampere for a period of one hour. Five ampere hours means a current flow of one ampere for five hours, a current flow of 2-1/2 amperes for 2 hours, or any multiple of current and time that will give multiples of five. This relationship can be expressed as follows: Capacity (in ampere hours) = I X T, when I is the current (in amperes) and T is the time (in hours). The capacity of a storage battery is usually based on a given discharge rate, since the capacity will vary with the rate of discharge. The capacity of an aircraft battery is generally based on **1 hour discharge rate (C1)**. A 17 ampere hour battery will supply a current of approximately 17 amperes for a period of 1 hour. A 34 ampere hour battery will deliver twice that amount of current for the same period of time. If a very heavy load is applied to the battery, it may become discharged in a few minutes.

Battery: A combination of two or more chemical cells electrically connected together to produce electric energy. Common usage permits this designation to be applied also to a single cell used independently.

Boost charge: A charge applied to a battery which is already near a state of full charge. Usually a charge of short duration.

C1 rate: The one hour discharge or current rate in amperes that is numerically equal to rated capacity of a cell or battery in ampere hours.

Capacity: The quantity of electricity delivered by a battery under specified conditions, usually expressed in ampere hours.

Capacity, rated: *See* **nominal capacity**.

Cell: An electrochemical device composed of positive and negative plates, separator and electrolyte which is capable of storing electrical energy.

Cell reversal: Reversing of polarity within a cell in a multicell battery due to over discharge.

Charge: The conversion of electrical energy from an external source into chemical energy within a cell or battery.

Charge rate: The rate at which current is applied to a secondary cell or battery to restore its capacity.

Charge retention: The tendency of a charged cell or battery to resist self-discharge.

Concavo/concave: RG® batteries have one-way cell vent valves designed to relieve excess positive internal pressure. Occasionally, when the atmospheric pressure is greater than the internal pressure of the battery (caused by a rapid decrease in altitude), the battery case may become temporarily concave.

Constant potential (CP) charge: Charging technique where the output voltage of the charge source is held constant and the current is limited only by the resistance of the battery.

Constant current (CI) charge: Charging technique where the output current of the charge source is held constant and the voltage is not regulated.

Counter EMF: Voltage of a cell or battery opposing the voltage of the charging source. When the electromotive force (EMF) of the source is greater than the EMF of the battery, the current flows in the reverse direction.

Current: The rate of flow of electricity. The movement of electrons along a conductor. It is comparable to the flow of a stream of water. The unit of measurement is an ampere.

Cut off voltage: Battery voltage reached at the termination of a discharge. Also known as end point voltage (EPV or VEP).

Deep discharge: Withdrawal of 50% or more of the rated capacity of a cell or battery.

Deionized water: Water which has been freed of ions by treatment with ion exchange resins. Deionized and distilled are not the same.

Depth of discharge: The portion of the nominal capacity from a cell or battery taken out during each discharge cycle, expressed in a percentage. Shallow depth of discharge is considered as 10% or less, deep depth of discharge is considered as 50% or more.

Discharge: The conversion of the chemical energy of a cell or battery into electrical energy and withdrawal of the electrical energy into a load.

Discharge rate: The rate of current flow from a cell or battery.

Distilled water: Water that has been freed of minerals or metallic impurities by a process of vaporization and subsequent condensation. Deionized and distilled are not the same.

Dry charge: Process by which the electrodes are formed and assembled in a charged state without electrolyte. The cell or battery is activated when the electrolyte is added.

Effective internal resistance (Re): The apparent opposition to current within a battery that manifests itself as a drop in battery voltage proportional to the discharge current. Its value is dependent upon battery design, state of charge, temperature and age.

Electrolyte: In a lead acid battery, the electrolyte is sulfuric acid diluted with water. It is a conductor and is also a supplier of hydrogen and sulfate ions for the reaction.

Electromotive force (EMF): Potential causing electricity to flow in a closed circuit.

Electron: That part of an atom having a negative charge.

End of discharge voltage: The voltage of the battery at the termination of a discharge test but before the discharge is stopped. See cut off voltage and End point voltage (EPV).

End of life: The stage at which the battery or cell meets specific failure criteria.

End point voltage (EPV): Cell or battery voltage at which point the rated discharge capacity had been delivered at a specified rate of discharge. Also used to specify the cell or battery voltage below which the connected equipment will not operate or below which operation is not recommended. Sometimes called cutoff voltage or voltage end point.

Entrainment: The process whereby gasses generated in the cell carry electrolyte through the vent cap.

Fast charging: Rapid return of energy to a battery at the C rate or more.

Float charge: A method of maintaining a cell or battery in a charged condition by continuous, long term constant voltage charging at a level sufficient to balance self discharge.

Flooded cell: Concorde's cell design with a removable vent cap that allows the user to service the cell (e.g. check electrolyte levels, specific gravity, etc.). Also called a **vented cell**.

Gassing: The evolution of gas from one or more of the electrodes in a cell. Gassing commonly results from local action (self discharge) or from the electrolysis of water in the electrolyte during charging.

Ground: In aircraft use, the result of attaching one battery cable to the body or airframe which is used as a path for completing a circuit in lieu of a direct wire from a component.

Hydrometer: A float type instrument used to determine the state of charge of a battery by measuring the specific gravity of the electrolyte (i.e. the amount of sulfuric acid in the electrolyte).

Instructions for Continued Airworthiness: ICA

Internal impedance: The opposition to the flow of an alternating current at a particular frequency in a cell or battery at a specified state of charge and temperature.

Internal resistance: The opposition or resistance to the flow of a direct electric current within a cell or battery; the sum of the ionic and electronic resistance of the cell components. Its value may vary with the current, state of charge, age and temperature. With an extremely heavy load, such as an engine starter, the cell voltage may drop to approximately 1.6 volts. This voltage drop is due to the internal resistance of the cell. A cell that is partly discharged has a higher internal resistance than a fully charged cell, hence it will have a greater voltage drop under the same load. This internal resistance is due to the accumulation of lead sulfate on the plates. The lead sulfate reduces the amount of active material exposed to the electrolyte, hence it deters the chemical action and interferes with the current flow.

Ion: Molecule or group of atoms, positively or negatively charged, which transports electricity through the electrolyte.

Joules: Unit of energy, equal to a watt second (a newton meter).

Lead acid: Term used in conjunction with a cell or battery that utilizes lead and lead dioxide as the active plate materials in a diluted electrolyte solution of sulfuric acid and water. Nominal cell voltage about 2.1 volts.

Lead dioxide: A higher oxide of lead present in charge positive plates and frequently referred to as lead peroxide.

Lead sulfate: A lead salt formed by the action of sulfuric acid on lead oxide during paste mixing and formation. It is also formed electrochemically when a battery is discharged.

Load tester: An instrument which measures the battery voltage with an electrical load on the battery to determine its overall condition and its ability to perform under engine starting conditions or essential power requirements.

Nominal capacity: A designation by the battery manufacturer that helps identify a particular cell model and also provides an approximation of capacity; usually expressed in ampere hours at a given discharge current.

Nominal voltage: Voltage of a fully charged cell or battery when delivering rated capacity at a specified discharge rate.

Open circuit voltage (O.C.V.): The voltage of a battery when it is not delivering or receiving power.

Overcharge: The forcing of current through a cell after all the active material has been converted to the charged state. In other words, charging continued after 100% state of charge is achieved. The result will be the decomposition of water in the electrolyte into hydrogen and oxygen gas.

Oxygen recombination: The process by which oxygen generated at the positive plate during charge reacts with the pure lead material of the negative plate and in the presence of sulfuric acid reforms water.

Parallel connection: A circuit in which battery poles of like polarity are connected to a common conductor; i.e., higher capacity while voltage remains the same.

Polarity: The electrical term used to denote the voltage relationship to a reference potential. (+ or -)

Power: Rate at which energy is released or consumed (expressed in watts).

Rated capacity: The number of ampere hours a battery can deliver under specific conditions (rate of discharge, end voltage, temperature).

Re: *See* **Effective internal resistance**.

Recombination: State in which the hydrogen and oxygen gases normally formed within the battery cell during charging are recombined to form water.

Resealable: In a cell, pertains to a safety vent valve, which is capable of closing after each pressure release, in contrast to the non-resealable vent cap.

Sealed cell: Cells that are free from routine maintenance and cannot be serviced by the user. Concorde batteries can be installed and operated without regard to position of the battery.

Self discharge: The decrease in the state of charge of a cell or a battery, over a period of time, due to internal electro chemical losses, effected by environmental temperatures.

Separator: A porous, insulating material placed between plates of opposite polarities to prevent internal short circuits.

Specific gravity (S.G.): The weight of the electrolyte is compared to the weight of an equal volume of pure water, used to measure the strength or percentage of sulfuric acid in the electrolyte.

Starved cell: A cell containing little or no free fluid electrolyte solution. This enables gases to reach electrode surfaces readily, and permits relative high rates of gas recombination.

State of charge (S.O.C.): The available ampere hours in a battery at any given time. State of charge is determined by the amount of sulfuric acid remaining in the electrolyte (specific gravity) at the time of testing or by the stabilized open circuit voltage (O.C.V.).

Sulfation: In its common usage, the term refers to the formation of lead sulfate with physical properties that are extremely difficult, if not impossible, to reconvert it to active material.

Swelling: RG® battery cases swell or bulge when the cell vent valves maintain an internal pressure that is greater than the outer (atmospheric) pressure.

Trickle charge: A continuous, low rate charge, the rate being just about sufficient to compensate for self-discharge losses.

Vent valve: A normally sealed mechanism which allows the controlled escape of gases from within a cell.

Vent cap: The plug on top of a cell. It can be removed to allow for electrolyte level adjustment on flooded (vented) batteries.

Vented cell: *See* **Flooded cell**.

Venting: A release of gas either controlled (through a vent) or accidental.

Volt: Unit of electromotive force, voltage or potential. The volt is the voltage between two points of a conductor carrying a constant current of one ampere, when the power dissipated between these points is one watt.

Appendix 4: Aircraft Tires

Aircraft Tire Construction

Tread

The area of the tire that is actually in contact with the ground. The tread of most modern aircraft tires contain circumferential grooves to channel water from between the tire and the runway surface.

Undertread

The layer of rubber designed to enhance the bonding between the carcass body and the tread reinforcing plies in bias tires or the protector plies in radial tires.

Carcass Ply

Fabric cords (generally nylon), sandwiched between two layers of rubber and anchored by wrapping them around the bead wires.

Bead

A bundle of steel wires embedded in rubber and wrapped with rubber-coated fabric, used to anchor the tire to the wheel.

Chafer Strips

Strips of protective fabric or rubber laid over the outer carcass plies in the bead area of the tire to protect the carcass plies from damage when mounting or demounting the tire, and to reduce the effects of wear and chafing between the wheel and the tire bead.

Liner

In a tubeless tire, this is a layer of specially compounded rubber extending from bead to bead to resist the permeation of nitrogen and moisture through to the carcass. With a tube-type tire, a thinner liner material is used to protect the carcass plies from moisture and the tube from chafing. The liner of a tube-type tire is generally insufficient for air retention.

Sidewall

A layer of rubber covering the outside of the carcass plies.

Bias-Ply Tires

The carcass plies laid at angles between 30° and 60° to the centerline of the tire. The succeeding plies are laid with the cord at angles that are opposite to each other. Most modern aircraft tires are bias-ply tires.

Tread Reinforcing Ply

This consists of single or multiple layers of a special nylon fabric and rubber laid midway beneath the tread grooves and top carcass ply to help reduce tread distortion under load.

Radial Tires

Each carcass ply is laid at an angle of approximately 90° to the centerline of the tire. Radial tires have fewer plies than bias tires of the same size because the cord direction is aligned with the burst pressure radial force.

Protector Ply

A ply found in retreadable tires in the crown area just under the tread rubber that provides cut resistance to the underlying belts and carcass plies.

Belt Plies

Plies laid between the tread area and the top carcass ply to restrain the outer diameter of the tire giving the tread surface greater resistance to squirm and wear.

Chine

A deflector molded into the sidewall of a nose-wheel tire to deflect water and slush to the side and away from aft-fuselage mounted engines.

Safety

Aircraft tire and wheel assemblies contain high pressures to support the loads placed on them. All maintenance should be conducted according to the recommendations of the tire, wheel, and aircraft manufacturers.

Before mounting any tire, visually examine the tire and the wheel for any indication of damage.

After a tire has been mounted, inflate it to the recommended inflation pressure. Most aircraft tires rated for over 190 MPH are inflated with nitrogen.

- When inflating tires, be sure to use a suitable inflation cage.
- Keep pressure hose and fittings used for inflation in good condition.
- Allow the tire to remain in the inflation cage for several minutes after reaching its full inflation pressure.

In service, tires should also be treated with care so as to avoid conditions that would damage the tire and wheel assembly or create a dangerous situation for those around the assembly or aircraft.

- Never approach, or allow anyone else to approach, a tire and wheel assembly mounted on an aircraft that has obvious damage until that assembly has been allowed to cool to ambient temperature. This generally takes at least three hours.
- Always approach a tire and wheel assembly from an oblique angle, in the direction of the tire's shoulder.
- Deflate tires before removing the assembly from the aircraft unless it will be immediately remounted (for example, in the case of a brake inspection).
- Always deflate the tires before attempting to dismount the tire from the wheel or disassembling any wheel component.
- Use extreme caution when removing valve cores as they can be propelled from the valve stem at a high rate of speed.
- When tire and wheel assemblies are found with one or more tie bolt nuts damaged or missing, remove the assembly from service.
- While serviceable tires may be shipped fully pressurized in the cargo area of an aircraft, it is preferred to reduce pressure to 25% of their operating pressure.

Tire Care Basics

Storage

Aircraft tires and tubes should always be stored in a dry environment, free from sunlight and ozone-producing appliances such as air compressors and florescent or mercury vapor lights. Tires should always be stored vertically, on their tread. Stacking tires on their sidewall can cause the beads to collapse, making the mounting process difficult.

Inflation Pressure

It is most important that the aircraft's tires be properly inflated at all times. Tire pressure should be checked before each day of flying, always maintaining the operating pressure specified by the airframe manufacturer.

Properly Inflating Tube-Type Tires

Air is usually trapped between the tire and the tube during mounting. Although initial readings show proper pressure, the trapped air will seep out around the valve stem hole in the wheel, and under the tire beads. Within a few days the tube will expand to fill the void left by the trapped air, and the tire may become severely underinflated. Check tire pressure before each flight for several days after installation, adjusting as necessary, until the tire maintains proper pressure.

Tire Growth

During the first 12 hours after mounting and initial inflation, the nylon plies of aircraft tires will generally grow and the inflation pressure of the tire will drop about 6–10%. Adjust as necessary.

Mounting

Wheels

When mounting a tire on a wheel, follow the recommendations and procedures of the wheel manufacturer.

Special care should be given to the following:

- Ensure that the bead seating area of the wheel is clean.
- Mating surfaces of the wheel halves should be free of nicks, burrs, small dents, or other damage. Painted or coated surfaces should be in good condition.
- Be sure fuse plugs, inflation valves, and wheel plugs are in good condition and properly sealed against pressure loss.
- Check O-ring grooves in the wheel halves for damage or debris.
- Check to see that the O-rings have the proper part number.

Tires

Before mounting any tire, check that the tire markings are correct for the required application (size, ply rating, speed rating, part number, and TSO marking).

Visually inspect the outside of the tire for:

- Damage caused by improper shipping or handling.
- Cuts, tears, or other foreign objects penetrating the rubber.
- Permanent deformations.
- Debris or cuts on the bead seating surfaces.
- Bead distortions.
- Cracking that reaches the cords.
- Contamination from foreign substances (oil, grease, brake fluid, etc.) which can cause surface damage.

Inspect the inside of the tire for:

- Foreign material.
- Wrinkles in or damage to the inner liner.

Initial Pressure Retention Check

The initial pressure retention check requires about 15 hours and it should be conducted as follows:

- Inflate the newly mounted tire to specified operating pressure and store it for 3 hours.
- Check the inflation pressure (be sure that the ambient temperature has not changed more than 5°F—a drop of 5°F will reduce inflation pressure by 1%). If the inflation pressure has dropped to less than 90% of the original value, use a soap solution on tire beads, valves, fuse plugs, etc. to find the leakage. Make appropriate repairs and repeat the test.
- After a 12-hour storage period, check the inflation pressure. If the inflation pressure has dropped to less than 95% of the original value, the tire is defective and it must be rejected.

On-Aircraft Tire Inspection

Inflation Pressure

Tire pressure should be checked before the first flight of the day. If this is not possible, wait at least 3 hours after landing to allow the tire to cool to ambient temperature. Never bleed pressure from a hot tire.

Effects of Underinflation

Underinflated tires can creep or slip on the wheel under stress or when brakes are applied. Valve stems can be damaged or sheared off and the tire, tube, or complete wheel assembly can be damaged. Excessive shoulder wear may also be seen. Underinflation can allow the sidewalls of the tire to be crushed, causing bead damage. Severe underinflation may cause ply separation and carcass degradation. This can also cause inner-tube chafing and a resultant blowout.

Effects of Overinflation

Overinflated tires are more susceptible to bruising, cuts, and shock damage, and the ride quality and operating life are reduced. Extremely high inflation pressures may cause the aircraft wheel or tire to explode, or burst. Never operate aircraft tires above rated inflation pressure.

Wear

Removal Criteria

In the absence of specific instructions from the airframe manufacturer, a tire should be removed from service for wear using this criteria based on the fastest wearing location. (*See* illustration at right.)

- When the wear level reaches the bottom of any groove along more than 1/8 of the circumference on any part of the tread, or
- If either the protector ply (radial) or the reinforcing ply (bias) is exposed for more than 1/8 of the circumference at a given location.
- Operating a tire at a higher pressure than required will cause increased wear at the center of the tread. This will make the tire more susceptible to bruises, cutting, and shock damage.
- When a tire is consistently operated underinflated, shoulder wear will result. Severe underinflation may cause ply separations and carcass heat build-up, which can lead to thrown treads and sidewall fatigue.
- If a tire is worn into the carcass/body plies, the strength of the tire will be reduced. This may cause the tire to burst or explode.
- Flat spotting is a result of the tire skidding without rotating, and is usually caused by brake lock-up or a large steer angle.
- Asymmetrical wear is a result of the tire operating under prolonged yaw and/or camber.
- Any time an aircraft has made a particularly rough landing or an aborted takeoff, the tire, tube, and wheel should be checked.

Limits for Tire Damages

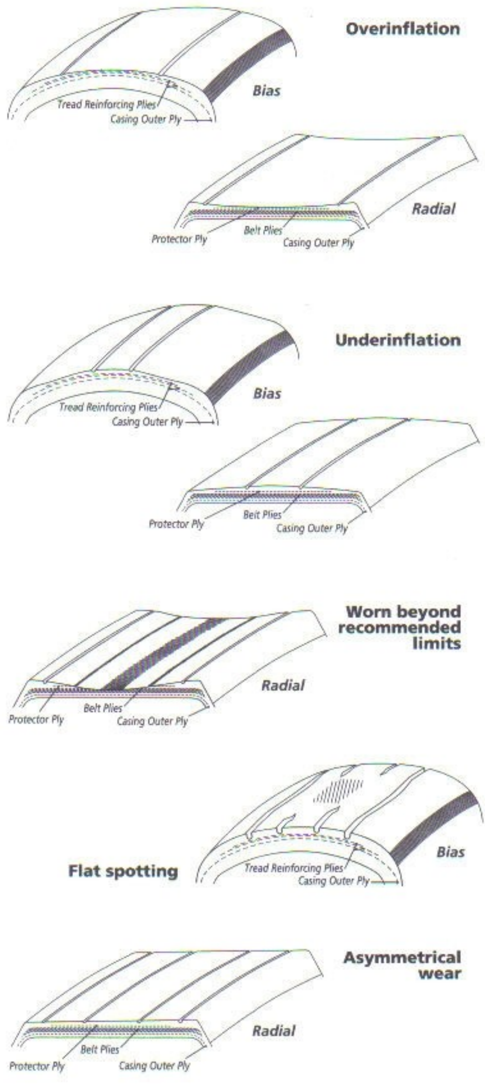
Tread Cuts

In the absence of specific cut-removal instructions from the airframe manufacturer, tires should be removed when:

- Cuts, embedded objects, or other injuries expose or penetrate the carcass plies (bias) or tread belt layers (radial).
- A cut or injury severs or extends across a tread rib.
- Undercutting at the base of any tread rib cut.
- Round foreign object damage greater than .375" in diameter.

Bulges or Separations

Any bulge or separation is cause for immediate removal of the tire from service.

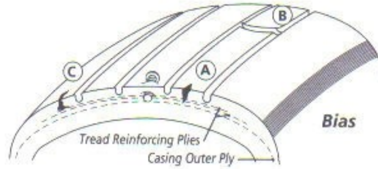


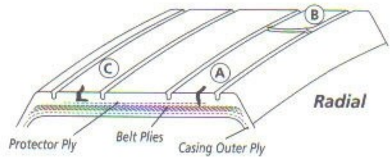
Common tire wear conditions

Courtesy Michelin Aircraft Tire

Chevron Cutting

Remove a tire from service if chevron cutting or any other action results in tread chunking which extends to and exposes the reinforcing or protector ply more than one square inch.





Remove tire from service when:

A. Depth of cut exposes the casing outer ply (bias) or outer belt layer (radial).

B. A tread rib has been severed.

C. Undercutting occurs at the base of any cut.

Peeled Rib

Remove the tire from service if the reinforcing ply or protector ply is exposed.

Groove Cracking

Remove the tire from service if groove cracking exposes the reinforcing ply or protector ply for more than 1/4" in length.

Contamination From Hydrocarbons

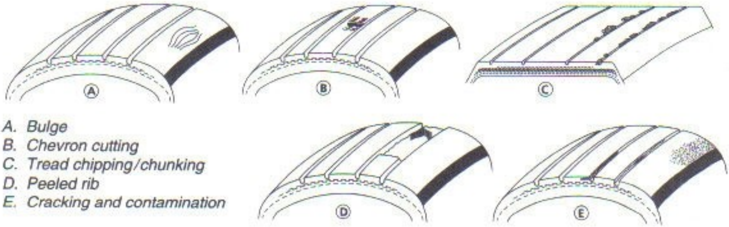
Oil, grease, brake fluids, solvents, etc., can soften or deteriorate rubber components. If a tire comes in contact with any of these, immediately wash the contaminated area with denatured alcohol, then with a soap and water solution. If the contaminated area is soft and spongy compared to an unaffected area of the tire, remove the tire from service.

Sidewall Cuts

If sidewall cords are exposed or damaged, remove the tire from service. Cuts in the rubber that do not reach the cord plies are not detrimental to tire performance and the tire may remain in service.

Weather/Ozone Cracking

Remove the tire from service only if weather or ozone cracks extend to the cord plies.



Common damage conditions

Courtesy Michelin Aircraft Tire

Dismounting

Be sure to follow the instructions and precautions published by the wheel manufacturer.

- Before deflating, use colored chalk to mark any damaged or bulge areas.
- Completely deflate the tire or tube before dismounting.
- Use a bead breaker to loosen tire beads from both wheel-half flanges.
  1. Apply bead breaker pressure slowly, or in a series of jogs, to allow time for the tire's beads to slide on the wheel.
  2. If the tire has become fixed to the wheel:
     a. Release bead-breaker pressure and apply a soap solution to the tire/wheel interface.
     b. Allow several minutes for the solution to penetrate between the tire and wheel.
     c. Reapply a reduced breaker pressure to the tire.
     d. Repeat several times if necessary.
  3. If the tire still remains stuck:
     a. Remove the tire/wheel assembly from the bead breaker.
     b. Reinflate the tire in a cage until the bead moves back to its correct position.
     c. Deflate the tire.
  4. Continue the dismounting procedure:
- Remove tie bolts and slide out both parts of the wheel from the tire.
- For tube-type tires, remove the tube.

Off-Aircraft Inspection with Tire Dismounted

Follow this procedure:

- Inspect the tread area.
- Inspect both sidewall areas.
- Inspect the bead areas for chafing or damage.
- Inspect the innerliner. Tires with loose, frayed or broken cords or wrinkles should be discarded. Liner blisters, especially in tubeless tires, should be left undisturbed.
- Inspect the inner tube, if applicable. Tubes with leaks, severe wrinkles or creases, or chafing should be discarded.
- Inspect for wheel damage according to the wheel manufacturer's recommendations.

Vibration and Balance

Vibration, shimmy, and other similar conditions are usually caused by improper tire balance but there are a number of other conditions that can cause or contribute to aircraft vibration.

The following inspections will help identify and/or prevent vibration problems:

- Check the tire for proper inflation pressure.
- Assure that the tire has reached full growth before it is installed on the aircraft.
- Check to see that the tire beads are properly seated.
- Check the tire for flat spotting or uneven wear.
- Verify that the tires are properly mounted.
- Check for air trapped between the tire and tube.
- Check for wrinkles in the tube.
- Check the wheel for an imbalance due to improper assembly.
- Check to see that the wheel has not been bent.
- Check for a loose wheel bearing caused by an improperly torqued axle nut.
- Check for poor gear alignment as evidenced by uneven wear.
- Check for worn or loose landing gear components.

Adapted from the Michelin Aircraft Tire Care and Service Guide, courtesy Michelin Aircraft Tire.

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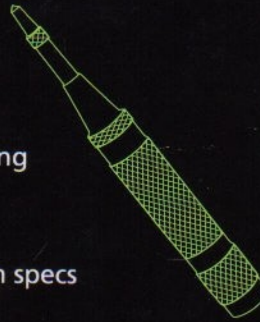
TODAS LAS MUJERES
DEBEN APRENDER ESTA
LECCION EN ALGUN
MOMENTO:
"Ser quien eres
tiene un costo"
(AVECES MUY ALTO)

Aviation Mechanic Handbook by Dale Crane

Fifth Edition



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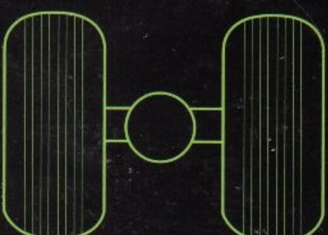

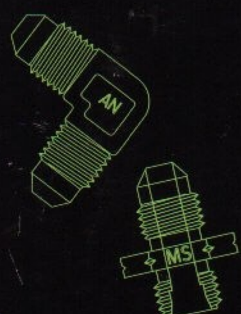

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