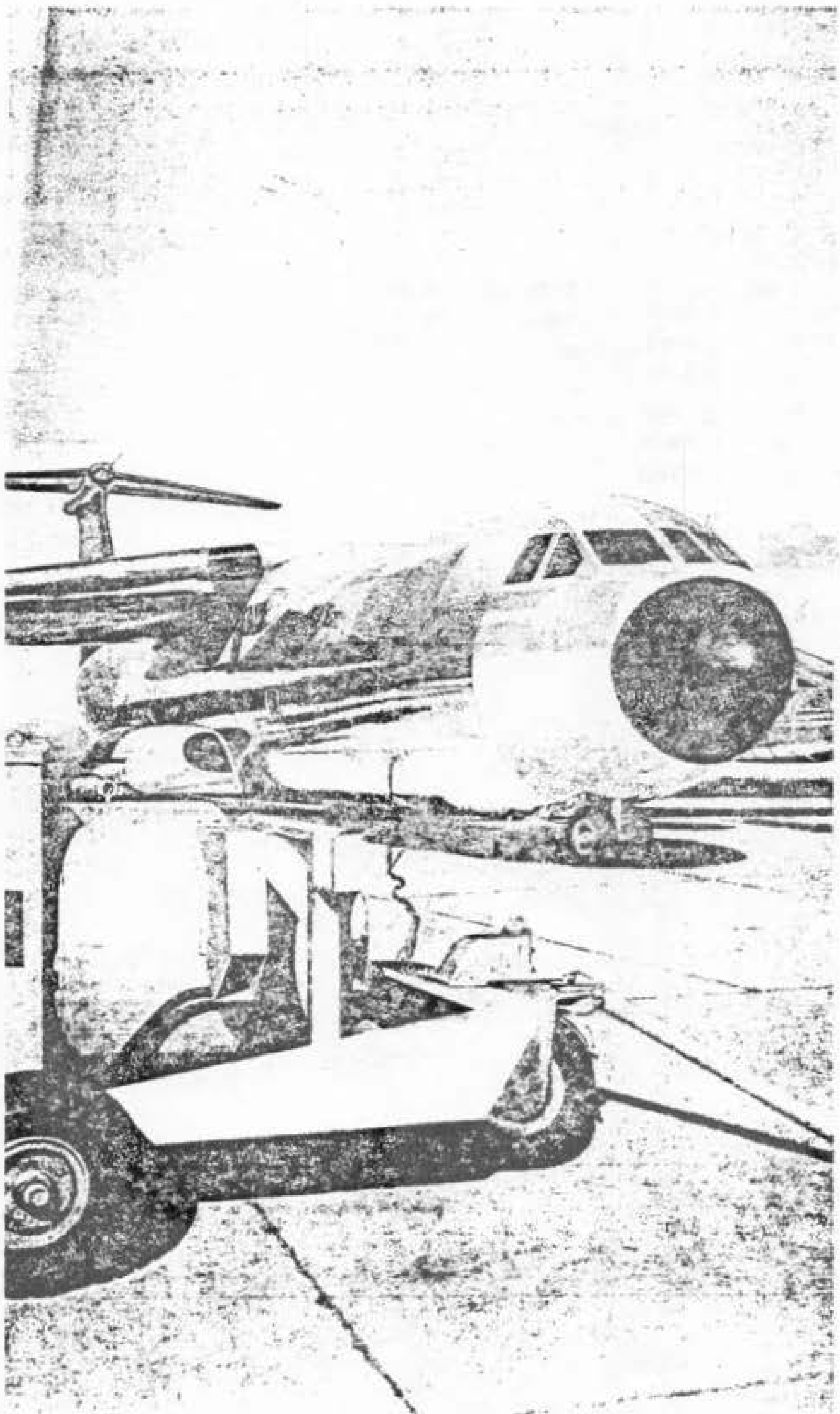
STARLIFTER TRAINING MANUAL • VOLUME III



ELECTRICAL

Customer Training Department • Lockheed - Georgia Company • Marietta, Georgia 30060

STARLIFTER TRAINING MANUAL

VOLUME III

ELECTRICAL

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT)

TABLE OF CONTENTS (CONT)

ABBREVIATIONS, ACRONYMS, AND SYMBOLS*

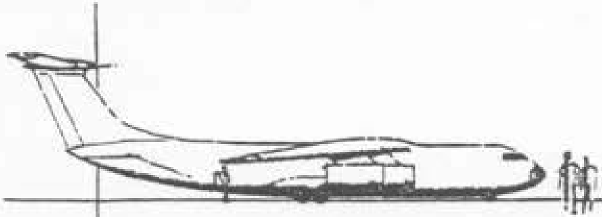
A	Amperes
AC	Alternating Current
AER	Auxiliary External Power Relay
AIL	Aileron
ALD	Automatic Load Disconnect
ALR	Automatic Paralleling Lockout Relay
AMPLS	Amplifier
APA	Automatic Paralleling Auxiliary Relay
APC	Auxiliary Power Contactor
APR	Automatic Paralleling Relay
APU	Auxiliary Power Unit
ASYM	Asymmetrical
AWG	American Wire Gauge
AUX	Auxiliary
BAR	BTC Auxiliary Relay
BAT	Battery
BPD	Bus Power Disconnect
BR	Battery Relay
BTC	Bus Tie Contactor
BTL	Bus Tie Lockout Relay
BTS	Bus Tie Switch
C	Capacity, in farads; Common Relay Contacts
CADC	Central Air Data Computers
CAR	Generator Contactor Auxiliary Relay
CSD	Constant Speed Drive
CT	Current Transformer
CUR	Current
DC	Direct Current (noun)
DEC	Decrease
DET	Detection
DIFF	Differential
DISC	Disconnect
DLR	Differential Lockout Relay (Trip-Reset)
DPCT	Differential Protection Current Transformer
DPR	Differential Protection Relay

* Metric system prefixes are shown on Page 1-1; symbols used on electrical schematics are shown on Page 1-13.

E	Electromotive Force (in volts)
EAR	External Power Auxiliary Relay
EBPR	Emergency Bus Power Relay
EGCR	Emergency Generator Control Relay
ELEC	Electric, Electrical
ELEV	Elevator
EMER, EMERG	Emergency
EMF	Electromotive Force
EMP	Empennage
ENG	Engine, Engineer
Ep	Applied Voltage in Primary of Transformer
EPC	External Power Contactor
EPR	Essential Bus Power Relay
Es	Induced Voltage in Secondary of Transformer
ESS, ESSEN	Essential
ETR	Emergency Power Test Relay
EXT	External
f	Frequency in Hertz (cycles-per-second)
FLT	Flight
FREQ	Frequency (in Hertz)
FSR	Frequency Sensitive Relay
FWD	Forward
GLC	Generator Line Contactor
GCS	Generator Control Relay
GEN	Generator
GLC	Generator Line Contactor
GPU	Ground Power Unit
GRD	Ground
HPT	High Phase Takeover
HI	High
HV	High Voltage
Hz	Hertz (cycles-per-second)
I	Current (in amperes)
IAS	Indicated Air Speed
IBPR	Isolated D-C Bus Power Relay
INC	Increase
IND	Indicator
INOP	Inoperative
INPH	Interphone
INST	Instrument
Ip	Current in Primary of Transformer
IPR	Isolated A-C Bus Power Relay

Is	Current is Secondary of Transformer
ISO L	Isolated
KVA	Kilovolt-Ampere
L	Inductance (in henrys); Left
L-C	Inductance-Capacitance (circuit)
LT	Light
LITS	Lights
LOR	Lockout Relay
LOX	Liquid Oxygen
MAG	Magnetic
MALFUNC	Malfunction
MAX	Maximum
MMF	Magnetomotive Force
MON	Monitor
N	Negative side of Transistors and Diodes (Base)
NBR	Navigation Bus Power Relay
NCR	Neutral Current Relay
N.C.	Normally Closed Relay Contacts
N.O.	Normally Open Relay Contacts
NORM	Normal
Np	Number of Turns in Primary Coil of Transformer
NPN	Type of Transistor
Ns	Number of Turns in Secondary Coil of Transformer
OVHT, OVERHT	Overheat
OXY	Oxygen
P	Power, (in watts); Positive Side of Transistor or Diode (Emitter)
PERM	Permanent
PLR	Power Lockout Relay
PMG	Permanent Magnet Generator
PNP	Type of Transistor
PRESS	Pressure
PREV	Prevention
PROT	Protection
PSR	Phase Sequence Relay
PSS	Power Select Switch
PWR	Power
Q	Charge (in coulombs)
QAD	Quick Attach-Detach

R	Resistance (in ohms); Right
RBC	Reactive Bias Circuit
R-C	Resistance-Capacitance (circuit)
RCCR	Reverse Current Cutout Relay
REC	Recorder
RECT	Rectifier
REG	Regulator
REL	Relay
RET	Retract
REV	Reverse
SBR	Synchronizing Bus Relay Circuit
SCR	Silicon Control Rectifier
SER	Synchronizing Bus Relay
SPLR	Spoiler
STAB	Stabilizer
SW	Switch
SYS	System
T	Time (in seconds)
TDR	Time Delay Relay
TEMP	Temperature
TR	Transformer-Rectifier
UER	Underexcitation Relay
UNDR	Under
USR	Underspeed Relay
USS	Underspeed Switch
UVR	Undervoltage Relay
VAR	Volt-Amperes Reactive
VR	Voltage Regulator
W	Work (in joules); Warning
WARN	Warning
WG	Wing
X_L	Inductive Reactance (in ohms)
X_C	Capacitive Reactance (in ohms)
Z	Impedance (in ohms)
Z_p	Impedance in Primary of Transformer (in ohms)
Z_s	Impedance in Secondary of Transformer (in ohms)



ELECTRICAL FUNDAMENTALS

REVIEW OF FUNDAMENTALS.

The metric system is a convenient system of units for measuring physical quantities. This system is almost universally used in studying electrical circuits.

The quantities that can be measured are length, mass, and time. In the metric system, the fundamental unit for length is the meter, the fundamental unit for mass is the gram, and the fundamental unit for time is the second.

Prefixes indicate the various possible multiples and subdivisions of the fundamental units. The metric system prefixes are as follows:

SYMBOL	PREFIX	MEANING OF PREFIX	SAMPLE USAGE
p	pico	one-trillionth of	picogram
n	nano	one-billionth of	nanogram
u	micro	one-millionth of	microgram
m	milli	one-thousandth of	milligram
c	centi	one-hundredth of	centigram
d	deci	one-tenth	decigram
	-----	--------------	gram
dk	deka	ten times	dekagram
h	hecto	one hundred times	hectogram
k	kilo	one thousand times	kilogram
M	mega	one million times	megagram
G	giga	one billion times	gigagram
T	tera	one trillion times	teragram

The metric system is a decimal system; that is, all multiple units differ from each other by factors of ten. This mathematical relationship helps in writing very large or very small numbers. A special method of expressing these quantities is called scientific number notation. This special method is based upon use of exponents of the number 10. The exponent of a number is called the "power" of that number. Since 10 is the only number concerned here, these exponents are called power of

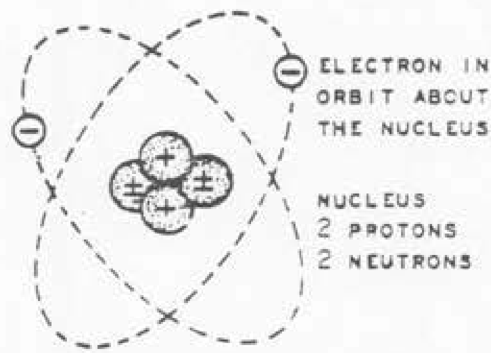
10. Positive and negative powers of 10 are reviewed in this table:

$10^1 = 10$	$10^{-1} = 1/10 = 0.1$
$10^2 = 100$	$10^{-2} = 1/10^2 = 1/100 = 0.01$
$10^3 = 1,000$	$10^{-3} = 1/10^3 = 1/1,000 = 0.001$
$10^4 = 10,000$	$10^{-4} = 1/10^4 = 1/10,000 = 0.0001$
$10^5 = 100,000$	$10^{-5} = 1/10^5 = 1/100,000 = 0.00001$
$10^6 = 1,000,000$	$10^{-6} = 1/10^6 = 1/1,000,000 = 0.000001$

Since 4,000,000 is the same as 4 x 1,000,000, it can be expressed as 4×10^6. Thus 4 megagrams = 4×10^6 grams. When numbers with more than a single digit are used, the decimal point is placed after the first non-zero digit, and the proper power of 10 is used as a multiplier. A decimal point placed here is said to be in "standard position." Examples: ($143,000 = 1.43 \times 10^5$), ($0.00344 = 3.44 \times 10^{-3}$). The number of positions the decimal is moved determines the exponent, and the direction it is moved determines the exponent's sign.

ATOMIC THEORY.

Matter is any substance having weight and occupying space. All matter is made up of basic elements. An element is a substance which cannot be broken down into simpler substances by chemical means. Oxygen, hydrogen, and iron are some of the elements.



HELIUM ATOM

A combination of elements is called a compound. Water is a combination of hydrogen and oxygen. The smallest part of an element is called the atom. When two atoms of hydrogen are combined with one atom of oxygen (H_2O), water is formed. This combination is the smallest part of a compound and is called a molecule.

The basis of all electrical flow goes back to the smallest part of an element, the atom. Each atom has a nucleus (center) which includes protons (charged positively) and neutrons (uncharged). Orbiting the atom's center is the same number of negatively charged electrons as there are protons in the center. In good conductors, these electrons move easily from one atom to another. This movement is called electrical flow.

STATIC ELECTRICITY.

Static electricity is generally associated with insulators or isolated conductors. Whenever an electrical charge is unable to move through or on an object, it is said to be restricted or static, hence the name "static electricity."

CHARGE TRANSFER

One of the general laws of electricity is like charges repel each other while unlike charges attract each other. Other important behavior characteristics of electrical charges follow:

1. The presence of a charged body affects some of the properties of any nearby object.

2. Charges remain on the outer surface conductors.

3. Charges tend to concentrate on surfaces where the curvature is greatest.

4. Charges tend to "leak off" at points.

5. Charges can be transferred from one object to another.

6. Charges can move through certain kinds of materials called conductors and are opposed in insulators.

7. A semiconductor is a material that presents more opposition to current than a conductor but not as much opposition as an insulator.

Charge is transferred through a solid conductor or insulator by movement of electrons. Conductors such as silver, copper, gold, and most other metals allow charge transfer with relative ease. Insulators or dielectrics on the other hand, offer considerable opposition to charge transfer. The best insulating materials are non-metallic substances like glass, rubber, and plastics, The most satisfactory insulators are compounds such as lucite, bakelite, and polyethylene. Common semiconductor materials are silicon, selenium, and germanium.

Charge transfer through semi-conductors is made by electrons and "holes." A hole is considered to be positive; an electron is considered to be negative. Holes are attracted to a negative terminal and electrons are attracted to a positive terminal. Impurity atoms have to be added to materials such as germanium or silicon to make them good semi-conductors. This is due to the fact that germanium and silicon in a pure state are good insulators.

Some liquids, such as water solutions of mineral compounds or chemical solutions of acids, bases, or salts, are excellent conductors of charge. The process of charge transfer is accomplished by the movement of positive and

and negative ions in the liquid solution. A positive ion is an atom which has lost electrons; a negative ion is an atom which has gained electrons.

Charge transfer through gases, such as neon, argon, and mecury vapor, is accomplished by the movement of positive ions, negative ions, and free electrons. Free electrons are electrons which are free to move between the atoms when acted upon by electric forces. The time rate at which a charged particle moves is quite low; however, the speed of an electrical impulse is high. An electrical impulse travels close to the speed of light (1.86×10^5 miles/second) in short straight wires.

ELECTRICAL CURRENT.

Electric charge is measured in coulombs. A coulomb represents an exact, large number of electrons, positive ions, or negative ions. There are approximate 6.28×10^{18} electrons in one coulomb of negative electricity. The time rate of a charge is the number of charges moving past a given point in a circuit in some unit of time. The time rate of a charge is defined as current. The <u>ampere</u> is the basic unit of current, and is one coulomb per second. Expressed as a formula,

$$I \text{ (current)} = \frac{Q\text{(charge)}}{T\text{(time)}} \qquad 1 \text{ ampere} = \frac{1 \text{ coulomb}}{1 \text{ second}}$$

RESISTANCE.

Resistance is opposition to current. The basic unit of electrical resistance is the ohm (Ω). Good conductors have a low resistance to charge transfer; poor conductors have a high resistance. The resistance of a conductor varies with length, cross-sectional area, and type of material. If the length of a conductor is increased, the resistance increases. If the diameter of a conductor is doubled, the cross-sectional area increases four times, and the resistance of the wire is one-fourth as great. A convenient formula for finding resistance of a wire is <u>$R = rL/A$</u>. <u>R</u> is the total resistance, and <u>r</u> is the resistance per unit length. <u>L</u> is the total lenght, and <u>A</u> is the cross-sectional area. The standard unit of measurement of cross-sectional area is the circular mil.

ELECTRICAL POTENTIAL.

The potential energy possessed by electric charges determines the work which the charge can do. Work can appear in the form of heat, as in resistors, or in the form of motion, as in electric motors. The more potential energy a charge has, the more work it can do. In other words, the potential energy is the ability to do work.

The basic unit of work is the joule, which is the amount of work that would be done by lifting a 0.7-pound weight one foot. The amount of work per unit charge is defined to be electrical potential energy. The <u>volt</u> is the basic unit of electric potential and is one joule per coulomb. Expressed as a formula,

$$E \text{ (volts)} = \frac{W \text{ (work)}}{Q \text{(charge)}} \qquad \text{or} \qquad 1 \text{ volt} = \frac{1 \text{ joule}}{1 \text{ coulomb}}$$

Voltage is sometimes referred to as electromotive force, or EMF. This is the force produced in a generator, battery, or other source of electric energy.

OHM'S LAW.

Ohm's law can be mathematically stated $I = E/R$ where current (I) is measured in amperes, potential (E) in volts, and resistance (R) in ohms. Current varies directly with potential and inversely with resistance. The ohm is electrically defined by its relationship to other electrical quantities. A potential of one volt across a one-ohm resistor will cause a current of one ampere through it. The voltage appearing across a resistor is said to be "dropped" across the resistor.

KIRCHOFF'S LAWS.

Kirchoff's voltage and current laws for D-C circuits can be stated as follows:

1. Current Law: the algebraic sum of the currents at any junction of an electric circuit is zero.

2. Voltage Law: the algebraic sum of the supply voltage and the voltage drops in any continuous path of an electric circuit is zero.

These two laws have to be restated when used in A-C networks. The laws for A-C circuits are stated as follows:

1. Current Law: the vector sum of the currents at any junction of an electric circuit in zero.

2. Voltage Law: the vector sum of the supply voltage and the voltage drops in any continuous path of an electric circuit is zero.

Kirchoff's laws help in handling complex circuits, and particularly those containing more than one source of voltage (EMF).

POWER.

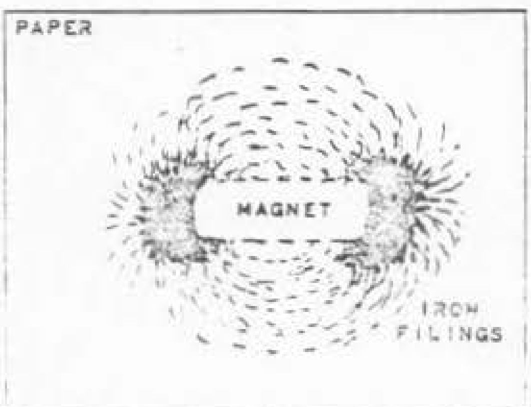
Power is the time rate or energy consumed. The basic unit of power is the watt. One watt is one joule of energy being used in one second. In electrical circuits, the power being dissipated is the product of current and voltage, or $P = EI$. By applying Ohm's Law, power can also be calculated as $P = EI = E^2/R = I^2R$.

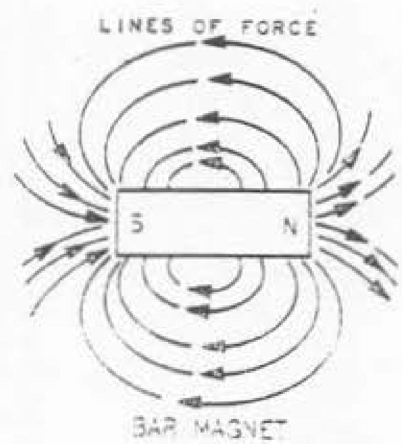
MAGNETISM.

Magnetism is a characteristic property exhibited by electric currents and certain materials. It is an invisible field through which action can be transferred. The field is considered to be made up of lines of force even though such lines do not actually exist. If iron filings are scattered on a surface over a magnetic field, they will appear to arrange themselves along these imaginary lines.

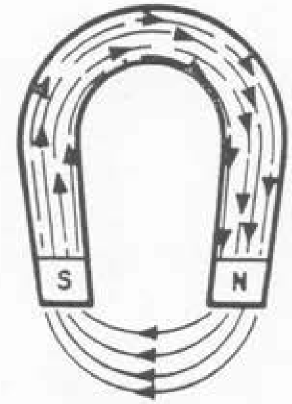
There are two types of man-made magnets: permanent and temporary. Hard steel (alloys of steel) and alnico (an alloy of aluminum, nickel, iron and cobalt) are used to make permanent magnets. Iron and soft steel are used for temporary magnets.

Each magnet has two poles: a north pole and a south pole. It is a fundamental law of magnetism that <u>like poles repel each other while unlike poles attract each other.</u>



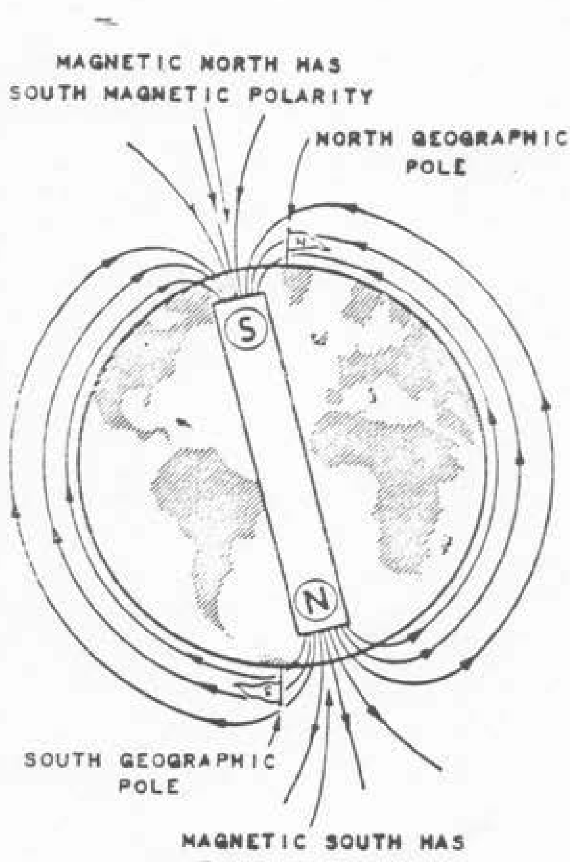


Each magnet has a magnetic field which is represented by "lines of force," or "flux lines." These "lines of force" actually represent the direction which the north pole of a compass would assume if a compass were placed in the field. Thus, the arrows will enter the south pole of a bar magnet, pass through the magnet, leave the north pole, and complete the path around the magnet. Magnetic lines of force are always closed loops, and will never cross one another.



MAGNETIC FIELD
(FLUX LINES)

If two like poles are placed near each other, the lines of force will try to cross one another. Since the lines of force cannot cross one another, the like poles will repel and move away from each other if possible. If two unlike poles are placed near each other, the lines of force will be in the same direction. A force of attraction will result between the two unlike poles, pulling the two together.



The force of attraction or repulsion decreases rapidly as the distance between the two magnets is increased.

If the earth is considered to be a bar magnet, the north pole of the bar magnet is located near the south geographic pole, and the south pole of the bar magnet is located near the north geographic pole. The magnetic poles of the earth are not fixed, but drift slowly with time.

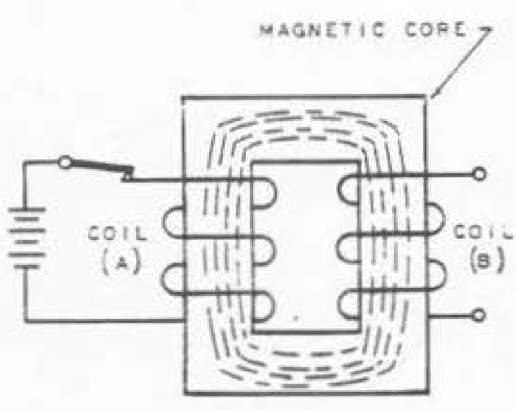
The magnetizing effect which a magnet or coil of current-carrying wire can exert in a circuit is called magnetomotive force, abbreviated MMF. It corresponds to EMF in electrical circuits. The amount of MMF exerted is expressed in ampere turns. One ampere through one turn of a coil constitutes one ampere-turn. The pole of a generator having 30 turns of wire around it with 10 amperes through the wire will exert 300 ampere-turns of MMF.

Magnetic flux may be represented by lines of force which are imagined to exist in the circuit. Flux in a magnetic circuit is similar to current in an electrical circuit. The greater the number of ampere-turns the greater the magnetic flux.

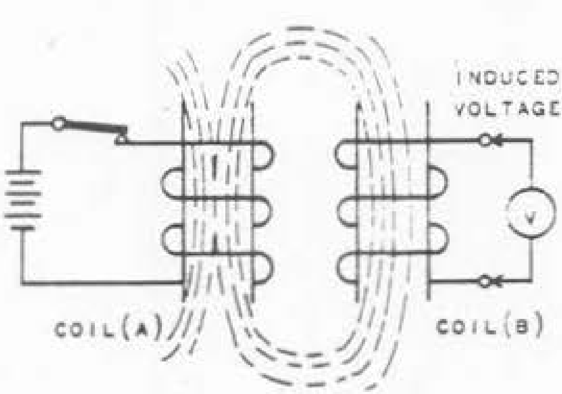
Reluctance in magnetic circuits is similar to resistance in an electrical circuit. Reluctance is opposition to lines of force and determines how much flux will be established by a given MMF. The shorter the length and the greater the cross-section of parts of a magnetic circuit, the lower the reluctance. The unit of reluctance is the oersted. Permeability, the reciprocal of reluctance, is the ratio of the number of flux lines produced by a coil with a core to the number of flux lines produced without a core.

INDUCTION.

Voltage and current can be produced by moving a conductor through magnetic lines of force or by varying the magnetic lines of force surrounding the conductor. Voltage and current obtained this way are produced by electromagnetic induction, or simply induction.

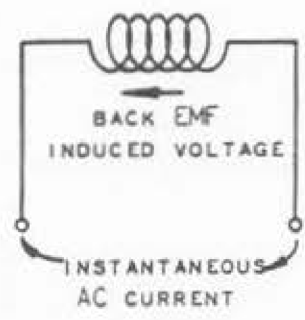


TIGHT COUPLING



LOOSE COUPLING

Induction explains how energy is transferred in magnetic circuits. Producing voltage in a circuit by changing the current in that circuit is called self-induction. Voltage produced in a circuit by the variation of the magnetic field of force in a nearby circuit is called mutual induction. If most of the lines of force from coil (A) are confined to a magnetic core, and are made to link coil (B), the two coils are tightly coupled. If there is no magnetic core, few of the lines of force from coil (A) will cut coil (B) and the two are loosely coupled. Tight coupling is usually most desirable. The amount of voltage induced in an inductor is determined by the rate of current through it and its inductance.



SELF INDUCTION

INDUCTANCE.

Any wire has inductance, but the amount of inductance can be increased by coiling the wire and by using magnetic material for the coil core. The basic unit of inductance is the henry. A coil has an inductance of one henry if a current change of one ampere per second induces one volt across its terminals.

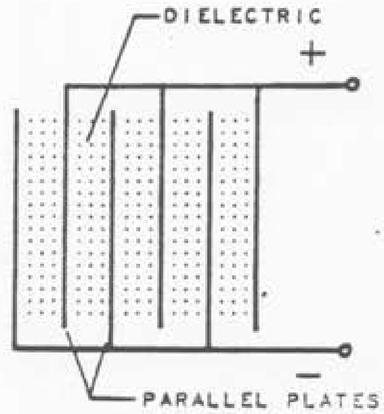
Inductance in a wire or coil opposes any change in current through it. The opposition to changing the current results in a voltage being induced across the coil terminals. Thus, inductance has no effect on pure direct current.

CAPACITANCE.

Capacitors, or condensers, are devices that temporarily store electrical energy. The essential parts of a capacitor are two plates, an insulator (called a dielectric) between the plates, and connecting leads to the circuit. The capacity of a capacitor depends on the area of the plates, the distance between the plates, and the material used as the dielectric. The capacity of a capacitor indicates the amount of electrical energy it can store. The basic unit of capacitance is the farad. A capacitor has a capacity of one farad if one coulomb of charge on the plates will cause a one-volt potential across its terminals. Capacitance opposes any change in voltage across its terminals. The opposition to changing the voltage results in a charging current into the capacitor.

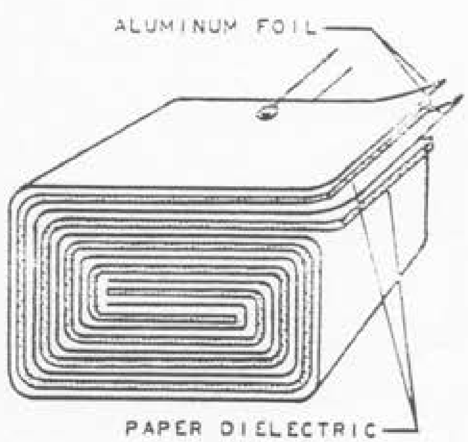
The relationship between the charge stored in a capacitor, its capacity, and its voltage is given by the formula $Q = CE$ where Q is the charge in coulombs, C is the capacity in farads, and E is the EMF in volts.

Conduction current, from free electron movement, does not exist in an ideal capacitor, but does exist as a small leakage current in real units. Normal capacitor current is the result of electron orbit displacement and is called displacement current which cannot exist except when the capacitor is charging or discharging. If DC is connected to a capacitor, a displacement current will exist in its external circuit until it is charged. Then, it acts as an open circuit until it is discharged. Since AC is continuously changing, it will cause a capacitor to charge or discharge continuously which creates an effective current in the external circuit.



STACKED TYPE CAPACITOR

It should be remembered that all electron movement is in the circuits external of the capacitor and not through the dielectric (except for leakage current.) If a capacitor's voltage limitations are exceeded, the dielectric will break down and may render the unit unusable.



ROLLED TYPE CAPACITOR

When sinusoidal alternating current is applied to a pure capacitance, the current leads the voltage by 90 electrical degrees.

WIRING AND CIRCUIT ELEMENTS.

Electrical energy is of little use unless a means to carry it from the source to the using equipment is provided. In most aircraft, single-wire circuits are used. In this type circuit, the metal of the aircraft structure serves as the second conductor. This is called a ground. The ground completes the circuit back to the source. This eliminates the need for a second wire, saving much weight.

The wires which connect electric energy sources to the operating units are of different sizes. Many wires are actually a group of smaller wires, or strands, twisted or braided together. The wires are stranded to make them more flexible. These stranded wires have about the same current carrying capacities as solid wires of the same diameter.

The current rating of a wire is the amount of current which can pass through the wire without overheating it. In choosing a wire or cable for any particular use, the greatest amount of current the wire will have to carry must be considered.

If a long wire is used, the resistance is greater. High resistance can cause improper operation of a unit connected to the wire.

Several types of metal are used to make wire and cable. Probably the most widely used metal is copper. Pure copper is a good conductor because it has very low resistance (many free electrons). Pure copper is not practical to use because it is too soft and has little tensile strength. To make it more usable, various alloys of copper are used. This increases the tensile strength. It also increases the resistance of the wire. Of course, the resistance of the wire is taken into account when the circuit wiring system is designed. Aluminum alloys are often used for large wires in aircraft. Aluminum is a good conductor and is used because it weighs less than copper.

The electrical system in a large aircraft is extensive. A set of electrical drawings, called wiring diagrams, is supplied with each aircraft. They are used as aid in isolating trouble and checking systems.

Each wire is labeled according to its use, location, and size. A typical coding for one of the wires might be

3D 128A20N

This is what the number means:

3 - UNIT NUMBER: It identifies the wiring of a particular unit if there is more than one identical unit on the aircraft.

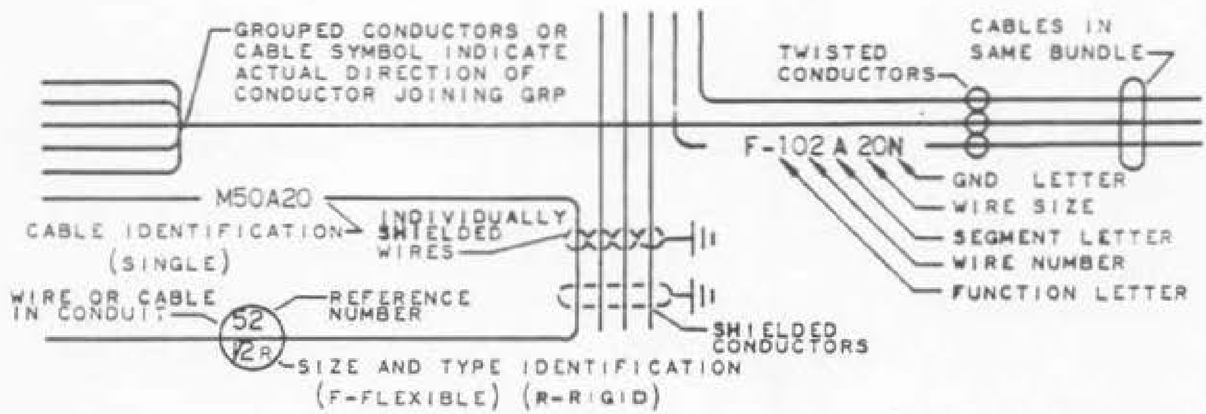
D - FUNCTION LETTER: It identifies the function of the circuit in which the wire is connected. For example, the letter "D" means instruments other than engine or flight instruments.

128 - WIRE NUMBER: A given wire might be a part of a larger system or bundle. This number is used to tell the difference between the wires in a particular system. The wire number may also be used to separate two identical systems.

A - WIRE SEGMENT LETTER: This letter identifies which part of the wire is represented. For example, a given wire may start at some point on the wing and finally end in the fuselage. It might go through several terminal boards and quick disconnects. Therefore, a segment letter is assigned to identify each part of the circuit.

20 - WIRE SIZE NUMBER: This is referred to as wire gauge or American Wire Gauge (AWG). Coaxial or thermocouple wires do not carry sizes. Thermocouples use letters to identify the type wire, such as AL (alumel) and CH (chromel).

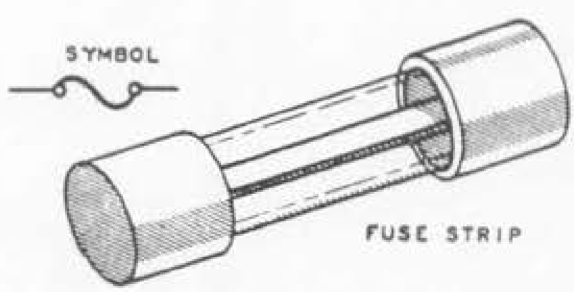
N - GROUND OR PHASE LETTER: This letter is not always included. It is added if the wire is used in a three-phase, A-C system, or if it is the neutral or ground lead in the system. A single-phase system carries the letter "V". The letter A = phase A; B = phase B; and C = phase C in place of the letter N.



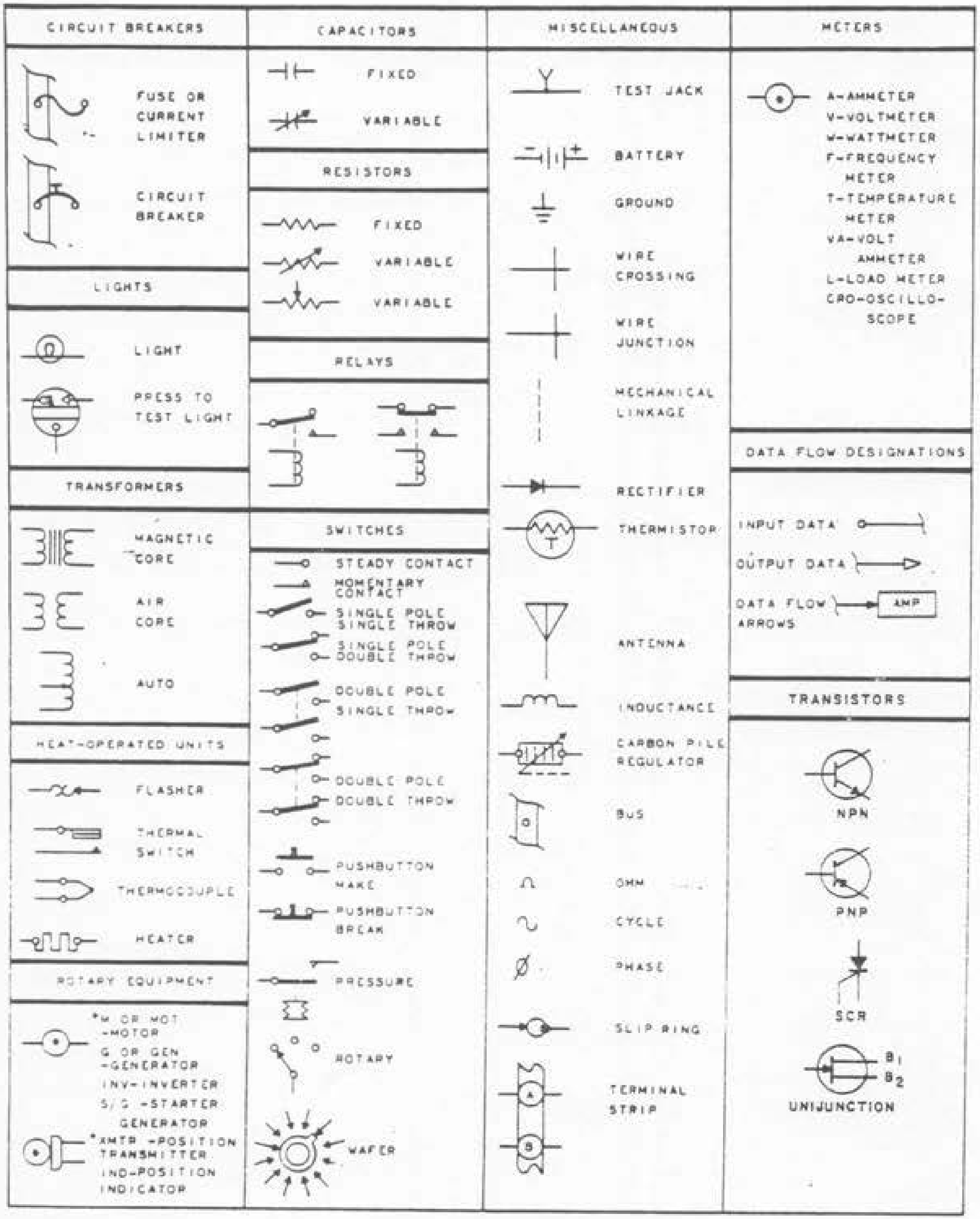
In a schematic diagram or in a wiring diagram different symbols are used to represent the various electrical units. This is often called the electrician's shorthand. The more common symbols are illustrated on the following page.

FUSES.

The primary purpose of a fuse is to protect the electrical wiring in the aircraft. The fuse is put in the line so that if anything goes wrong, it will prevent damage to the aircraft. Charge transfer through a conductor causes heat. The greater the charge flow the hotter the conductor will get. If the current is larger than the fuse is designed to carry, heat operates the fuse. The heat melts the fuse strip. This opens, or breaks, the circuits and stops the charge flow.



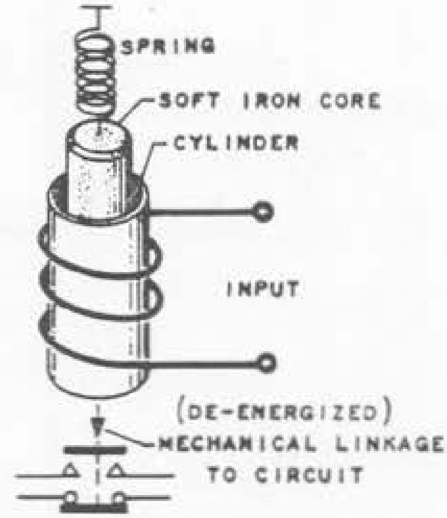
SYMBOLS


CIRCUIT BREAKERS
FUSE OR CURRENT LIMITER
CIRCUIT BREAKER
LIGHTS
LIGHT
PRESS TO TEST LIGHT
TRANSFORMERS
MAGNETIC CORE
AIR CORE
AUTO
HEAT-OPERATED UNITS
FLASHER
THERMAL SWITCH
THERMOCOUPLE
HEATER
ROTARY EQUIPMENT
*M OR MOT -MOTOR
G OR GEN -GENERATOR
INV-INVERTER
S/G -STARTER GENERATOR
*AMTR -POSITION TRANSMITTER
IND-POSITION INDICATOR
CAPACITORS
FIXED
VARIABLE
RESISTORS
FIXED
VARIABLE
VARIABLE
RELAYS
SWITCHES
STEADY CONTACT
MOMENTARY CONTACT
SINGLE POLE SINGLE THROW
SINGLE POLE DOUBLE THROW
DOUBLE POLE SINGLE THROW
DOUBLE POLE DOUBLE THROW
PUSHBUTTON MAKE
PUSHBUTTON BREAK
PRESSURE
ROTARY
WAFER
MISCELLANEOUS
TEST JACK
BATTERY
GROUND
WIRE CROSSING
WIRE JUNCTION
MECHANICAL LINKAGE
RECTIFIER
THERMISTOR
T
ANTENNA
INDUCTANCE
CARBON PILE REGULATOR
BUS
OHM
CYCLE
PHASE
SLIP RING
TERMINAL STRIP
A
B
METERS
A-AMMETER
V-VOLTMETER
W-WATTMETER
F-FREQUENCY METER
T-TEMPERATURE METER
VA-VOLT AMMETER
L-LOAD METER
CRO-OSCILLO-SCOPE
DATA FLOW DESIGNATIONS
INPUT DATA
OUTPUT DATA
DATA FLOW ARROWS
AMP
TRANSISTORS
NPN
PNP
SCR
B1
B2
UNIJUNCTION

SOLENOID.

A solenoid consists of a coil of wire wound about a hollow cylinder. If a movable core of soft iron is placed inside the cylinder, the field of the coil will tend to center the core in the coil when current is turned on.

Solenoids are used to operate various units such as valves and switches. A solenoid-operated switch is usually called a relay.

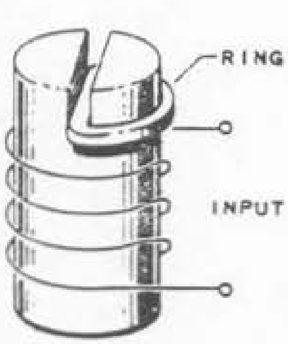


SOLENOID RELAY

RELAYS.

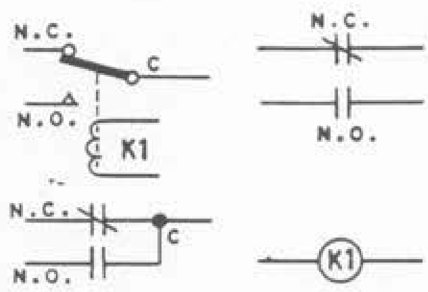
A relay is an electromagnet which positions switch contacts. The magnet can be energized from an A-C or D-C power source, depending on the type of relay. A switch actuator is held in the normal (deenergized) position by a spring. When a power source is connected to the electromagnet, the resulting magnetic field attracts the metal actuator. The relay is energized when the actuator positions the switch contacts in opposition to the spring. Since the field is stronger than the spring, the relay remains energized. When source voltage is removed, the field is collapsed and the spring returns the contacts to normal.

An A-C electromagnet is designed differently than a D-C electromagnet. The D-C electromagnet is energized by a continuous current. The coil is a wire wound around a soft iron core. An A-C electromagnet is energized from an A-C source and must remain energized when the current reverses. A shorted ring is placed in the core to hold the actuator when source current is zero. The collapsing magnetic field induces a current into the ring which keeps the relay energized.



AC ELECTROMAGNET

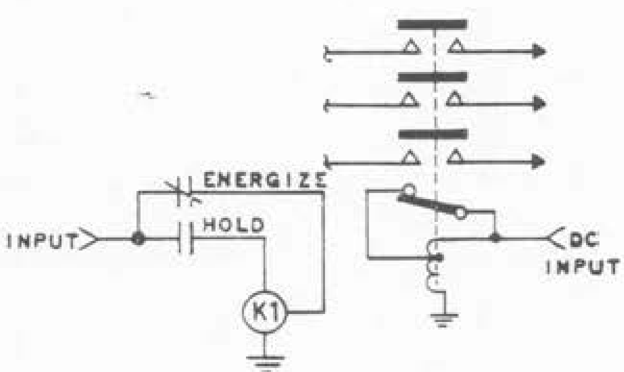
Relay contacts are normally open (N.O.), normally closed (N.C.), or common (C). A schematic symbol for a relay coil is an actual coil mechanically coupled to a switch arm, or a circle representing a coil. The relay is usually identified within the circle. Relay contacts are represented by switch contacts or by two parallel plates. The normally open contact is a triangle symbol indicating momentary and the normally closed contact is a circular contact. With the parallel plate symbol, the normally closed contact has a slanted line between the plates and the normally open does not have a line. When the



relay is energized, the N.O. contacts close and the N.C. contacts open.

A polarized relay is a DC relay which has a permanent magnet as the switch actuator. The magnet holds the contacts in one position or the other but is not strong enough to change the switch positions. The polarity of the power source to the coil determines contact position since the coil field either aids or opposes the permanent magnet field.

A solenoid can be used to actuate relay contacts where many heavy duty and lightweight contacts are required. A relay of this type is a contactor, used in generating and bus distribution systems.



CONTACTOR

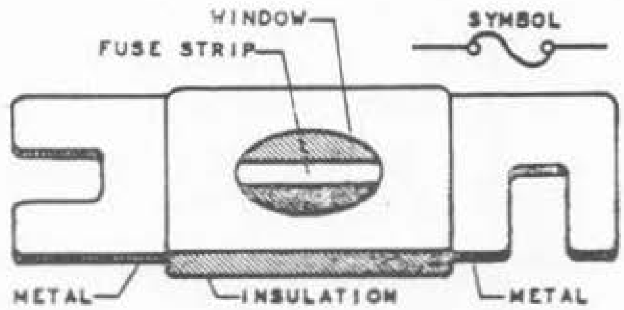
The coil winding of a contactor is usually center tapped. One set of normally closed contacts bypass half the coil winding. The contactor coil is energized by current through half of the winding and held energized by the reduced current through the entire winding.

When the current is below the safe maximum, the fuse lets charge flow to the using equipment. If a short occurs somewhere in the circuit and the current is excessive, the fuse strip melts or "blows." These fuses can be made "blow" at any desired current by choosing the right kind of material for the fuse strip and making it the right size. When the fuse "blows," power is removed from the system.

When a fuse is replaced, use a fuse with the current and voltage rating required by the system.

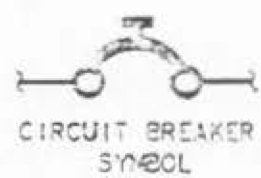
CURRENT LIMITERS.

A current limiter is a special type of fuse used to protect alternators and generators. Alternators and generators can operate up to 50 percent overloads for short to medium intervals of time without excessive overheating or damage. The current limiter is a fuse with a built-in overload delay. This is accomplished by providing a controlled method of heat removal from the fuse element. The heat conduction path is such that too rapid production of heat does not delay the element burnout. If, however, the overload is within the current limiter overload range, the element is cooled by heat conduction into the terminals and case. This conduction can continue only until the case and terminal temperature increases to about the melting point of the element. Then the element melts and the limiter opens the circuit.



CIRCUIT BREAKERS.

Another protective device is a circuit breaker. A circuit breaker acts as a fuse or current limiter, except that it does not melt on overload. It is a spring-loaded switch which opens when too much current exists in a circuit. It can be reset only after the fault is corrected.



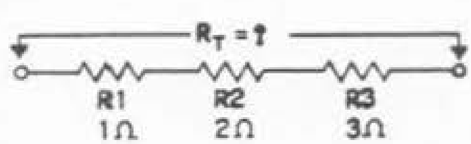
RESISTORS IN SERIES.

Resistors can be connected in series. This means that they are connected end-to-end so that any current in the circuit must pass through each of them. When resistors, or resistive loads, are connected in series, the total resistance of the circuit is simply the sum, or total, of all resistors in series. The total resistance of the resistors in the illustration would be:

$R_t = R_1 + R_2 + R_3$

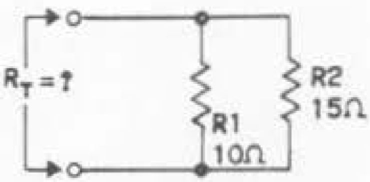
$R_t = 1 + 2 + 3$

$R_t = 6$ ohms



RESISTORS IN PARALLEL.

Another way resistors can be connected is in parallel; that is, connected across each other. In a parallel connection, the total resistance is found in a completely different way than in the series circuit.



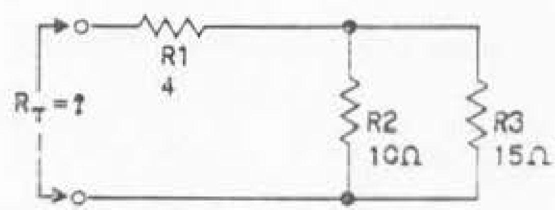
Here the resistors add as reciprocals:

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_1 + R_2}{R_1 \times R_2} \qquad R_t = \frac{1}{\dfrac{R_1 + R_2}{R_1 \times R_2}}$$

$$R_t = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{10 \times 15}{10 + 15} = \frac{150}{25} = 6 \text{ ohms}$$

RESISTORS IN SERIES-PARALLEL.

Series and parallel resistors can be combined to form a series-parallel circuit. If three resistors are connected as shown in the diagram, both principles from the two separate methods must be applied.



$$R_t = R_1 + \frac{R_2 \times R_3}{R_2 + R_3} = 4 + \frac{10 \times 15}{10 + 15}$$

$$R_t = 4 + \frac{150}{25} = 4 + 6$$

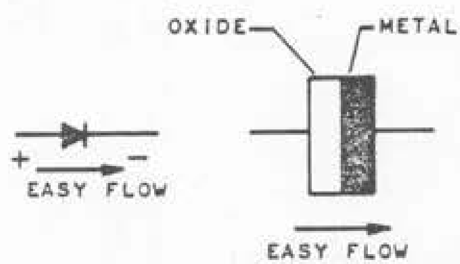
$$R_t = 10 \text{ ohms}$$

In actual practice, most circuits are combinations of series-parallel connections.

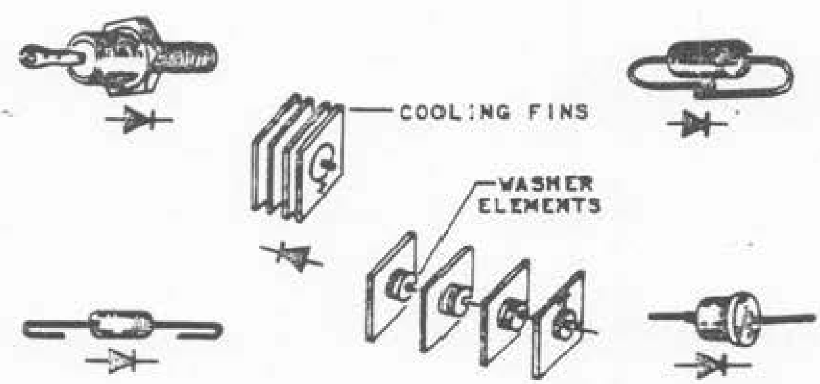
RECTIFIERS.

A rectifier is a device which will allow charge to flow in one direction only. It is often a metal washer with an oxide coating on one side. Because of barrier properties which exist between the metal and the oxide, charge can flow easily from the oxide through the metal. Charge cannot flow easily in the other direction.

In use, the oxide is connected (by wire or terminal) to one point in a circuit. The metal is connected to another. In this illustration, the assumed direction of charge flow is determined by the conventional current theory.



Shown here is the symbol for a rectifier. Physically, a rectifier assembly might look somewhat like the units in this illustration. They are made in many sizes and various other shapes. Rectifiers will be used in later explanations of circuits.



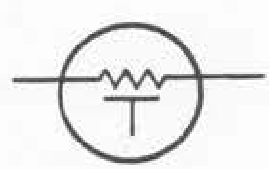
TYPICAL RECTIFIERS

THERMISTORS.

Thermistors (or thermal resistors) are heat-sensitive resistors that are used to sense temperature variations. They are made of materials selected for their temperature coefficients to enable electrical circuits (such as a wheatstone bridge) to detect temperature changes. This information can be used as visual indications or as controlling signals. If the thermal resistor used has a negative temperature coefficient, the resistance decreases as the temperature around it increases. The opposite is true for one with a positive temperature coefficient.

INDUCTORS.

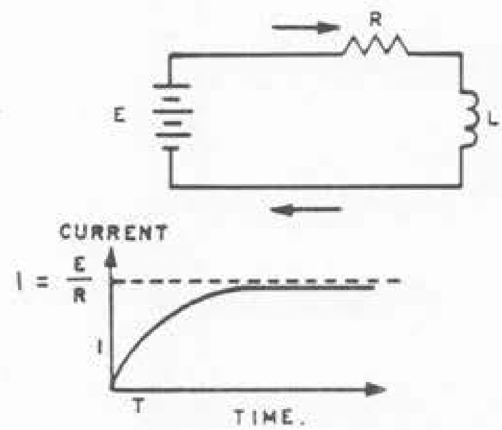
An inductor is a coil, with or without an iron core. Inductors oppose current changes. This is due to self-inductance. If a coil is connected across a battery as shown in the illus-



THERMISTOR

tration below, the charge flow through the coil will follow the graph shown. It will build up slowly and finally reach a maximum value of $I = E \div R$. R is the D-C resistance of the windings of the coil. The reason the current builds up slowly is due to the characteristics of a coil.

At the instant the coil is connected to the battery, the current is zero. As the current increases, the magnetic field around the loops of the coil also increases. As the field around the loops of the coil changes, it induces a voltage in the coil.



Due to the direction of the changing field, this induced voltage is of opposite polarity to the battery. That is, it will buck the applied voltage of the battery and tend to reduce the charge flow through the coil. This bucking effect, or voltage, is known as the back EMF (electromotive force).

As the current approaches its greatest value, its rate of change decreases. This, in turn, decreases the change in the magnetic field. The process continues until the current is no longer changing. When the current stops changing, the field stops changing and the back EMF disappears. The current assumes a constant value which is determined by the voltage of the battery and the D-C resistance of the coil.

If the coil is connected across an A-C source, the back EMF will have quite an effect on the charge flow. Because the current is constantly changing, a constantly changing magnetic field will be created. In this case, the back EMF never completely disappears.

The back EMF factor of the coil inpedance is known as its reactance. Since the reactance is brought about by the changing magnetic field which is dependent on changing current, it follows that the reactance will be dependent on the rate of change of the current. This means that it will be dependent on the frequency. As the frequency goes up, the back EMF, and hence the reactance, goes up. This type reactance, which is called "inductive", is given the symbol "X_L." It may be expressed in a mathematical formula as:

$$X_L = 2\pi fL \qquad (2\pi = 6.28)$$

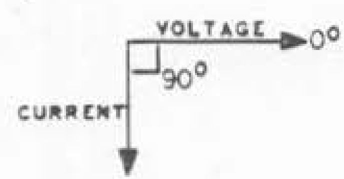
where "f" is the frequency and "L" is the inductance of the coil.

The inductance of the coil is determined mainly by the number of turns, their spacing, and the type core used. As previously stated, the basic unit of inductance is the henry.

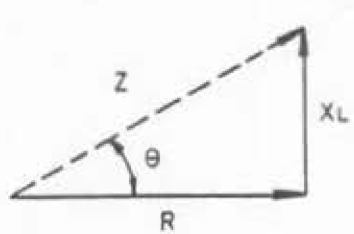
The back EMF factor, or reactance, introduces a new concept. This new concept is phase. In the graph showing the current rise in a coil which is connected to a D-C source, the current lags the voltage across the coil. This is due to induced back EMF retarding the current.

As the current tries to rise, it creates the back EMF which tries to furnish a current in opposition to the original current. This opposition makes the current rise slow down and take longer to reach its maximum.

This same lag of the current behind the voltage takes place in AC. The voltage and current can be shown by the vector diagram. The length of a vector represents the size, or magnitude. Its arrow indicates the direction. For the time being, the coil is considered as having no resistance. In this case, the current lags the voltage by 90 degrees if the AC is a sine wave. In vector diagrams, the applied voltage (and anything in phase or at the same angle with it) is usually shown as being the reference or zero-degree point.



It is the combination of two factors, the resistance of the winding and the back EMF, that determine the impedance of the coil. Impedance in an A-C circuit is the total opposition to a current. In this respect, it is like resistance in a D-C circuit.



The actual coil has both resistance and reactance. The impedance of the coil is the vector sum of the two. Since the resistance has zero degrees phase (the same as voltage), it is drawn horizontally. Since the inductive reactance causes a lag in current, it is drawn 90 degrees ahead of the resistance vector.

Impedance, given the symbol Z, is the slanted line connecting the end of the two (resistance and reactance) vectors. Because of the relationship between the side of the right triangle, $Z = \sqrt{R^2 + X^2}$. The angle that the impedance vector makes with the resistance vector is called the <u>phase angle.</u> It is usually given the symbol Θ (the Greek letter theta).

If a coil with a known inductance is given, its reactance at any frequency can be calculated. The equation $X_L = 2\pi fL$ is used. Then, knowing the <u>reactance</u> and the <u>resistance</u>, the <u>impedance</u> at that frequency can be found. For this, the equation $Z = \sqrt{R^2 + X_L^2}$ is used. Impedance is expressed in ohms.

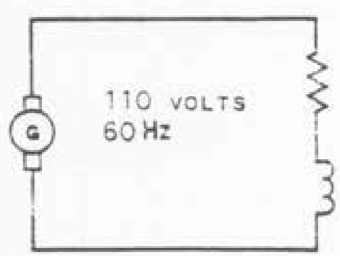
Example: Compute the impedance of a coil having an inductance of 10 henrys and a resistance of 1,000 ohms at a frequency of 60 Hertz (cycles per second).

Step 1: $X_L = 2\pi fL = 2 \times 3.14 \times 60 \times 10$

$X_L = 3{,}768$ ohms

Step 2: $Z = \sqrt{R^2 + X_L^2} = \sqrt{(1{,}000)^2 + (3{,}768)^2}$

$Z = 3{,}900$ ohms



Impedance can be used in a form of Ohm's law to solve A-C circuit problems. The equation is written $I = E/Z$.

The coil is now connected across an A-C source as shown. Its resistance and reactance are shown as separate quantities, even though they are both actually within the coil itself.

To compute the current in the coil, simply apply OHM's law and use impedance instead of resistance.

$I = E \div Z = 110 \div 3{,}900$ $I = 0.0282$ amperes on 28.2 milliamperes

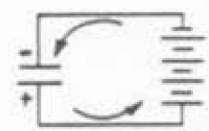
The phase angle in degrees is equal to the cosine of R/Z in the trigonometric table.

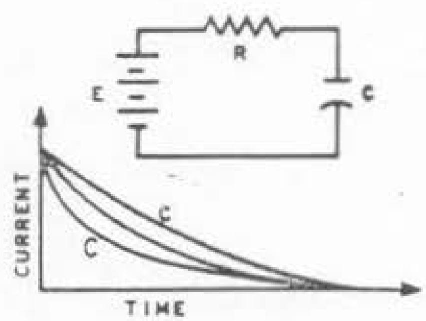
$$\frac{R}{Z} = \frac{1000}{3900} = 0.256$$

The cosine of 0.256 is 75.1°. Circuit current lags voltage by 75.1°.

CAPACITORS.

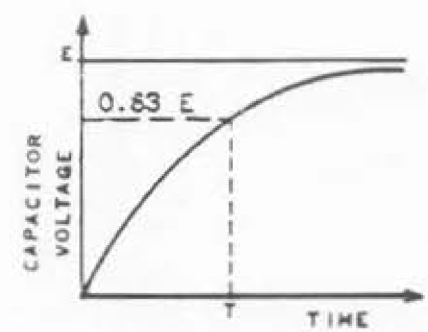
The term capacitor is another name for an electrical condenser. A capacitor is capable of storing electrical energy. When a capacitor is connected across a battery as shown, there is an initial surge of current that charges the capacitor until the charge equals the battery voltage. When this occurs there is no further flow of charge from the battery. When the capacitor is disconnected from the battery, the charge will gradually leak off and neutralize the capacitor. The capacitor can be discharged rapidly by connecting a wire to both plates.





The capacitor is connected to a battery through a resistor. At the instant the connection is made, there is a high surge of current. This is due to the charging of the capacitor. As the capacitor nears full charge, the current decreases until, for all practical purposes, it is zero. When the charge stops flowing in the circuit, the full voltage of the battery will be across the capacitor. This is true because there is no more current to cause a voltage drop across the resistor.

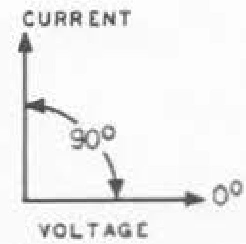
If an R-C circuit is connected to a battery, the voltage across the capacitor terminals will rise as shown. The length of time required for the capacitor to charge to 0.63E or 63% of its final voltage, is the <u>time constant</u> for that R-C circuit. The relationship between the time constant T (in sec), the capacitance C (in farads), and the resistance R (in ohms) is



$$T = RC$$

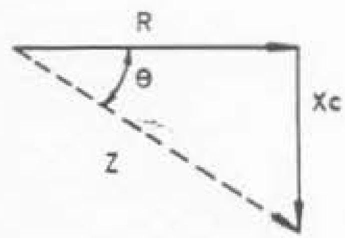
Time constants in electrical circuits are sometimes very important because the operating time of relays is affected. The time constant can be used to provide a desired delay in the operation of a circuit.

The phase relationship graph for a capacitor is shown here. It is the exact opposite of the graph for an inductance. This means that the current through the capacitor leads the voltage. So, the same type of vector diagram, as before, can be drawn except that now the current lead the voltage. It would not lead it by 90 degrees if there were any resistance involved.



This leads to the formula for the reactance of the capacitor,

$$X_C = \frac{1}{2\pi fC} = \frac{0.159}{fC}$$



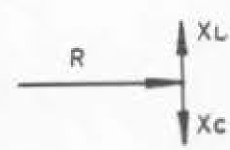
This time, as the frequency goes up the reactance goes down. To represent the impedace of a capacitor, the vector diagram would be just like the one for the coil except that now the reactance vector points down. As far as any calculations go, they are the same for both, with one exception. The phase angle for the impedance of the capacitor is negative.

Once the reactance or impedance has been calculated, it can be treated the same as resistance, except for the phase angle. Reactances or impedances in parallel add like resistors in parallel. Reactances or impedance in series add like resistors in series. The main difference is that the reactance or impedances vary with frequency.

A capacitive reactance is cancelled by an equal inductive reactance due to the phase angle. (Example: X_C of $10 = -90^\circ$ is cancelled by an X_L of $10 = 90^\circ$ which results in a pure resistive circuit). Capacitors in series act the same as resistors in parallel and capacitors in parallel act the same as resistors in series.

RESONANCE.

Resonance occurs at the frequency at which a given coil and capacitor have the same reactance (equal in number but opposite in sign). There are only two ways a coil and capacitor can be connected: in series or in parallel. Either way, this point can be shown with another vector diagram. When $X_C = X_L$,



the two 90-degree components cancel each other since they are opposite in sign. The resistance of the coil and capacitor is neglected in the following discussion.

If a coil and capacitor are connected in series as shown here, the circuit offers the least reactance or impedance to current at the frequency when $X_C = X_L$. This is called the resonant frequency. The relationship between the inductance, capacitance, and resonant frequency are found as follows:

$$X_C = X_L$$

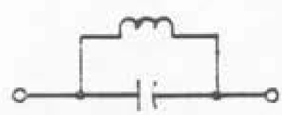
$$\frac{1}{2\pi fC} = 2\pi fL$$

or

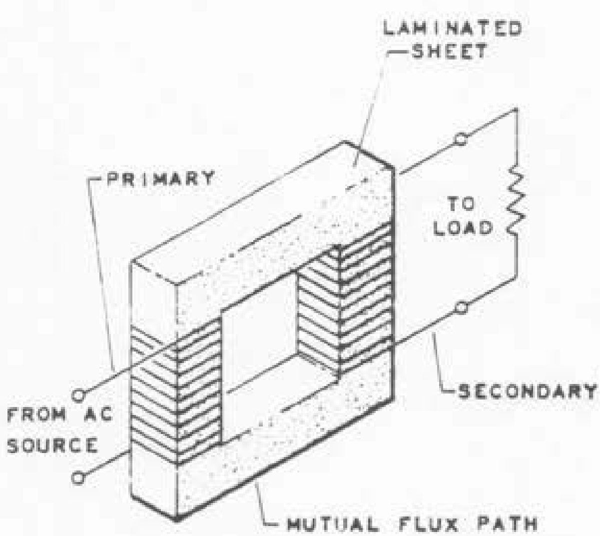
$$f = \frac{1}{2\pi\sqrt{LC}}$$

PARALLEL RESONANCE.

A coil and a capacitor can also be in parallel, as shown. This gives a resonant frequency which is generally the same as for the series circuit. The resonant frequency for the parallel circuit is calculated as if the circuit were a series circuit. In a parallel L-C circuit, the impedance is maximum and circuit frequency is minimum at resonance.



PARALLEL RESONANCE



TRANSFORMERS.

A transformer transfers A-C electric energy from one electrical circuit to another. It does this without a frequency change. The principle used is electromagnetic induction, where electrical circuits are linked by a common magnetic circuit.

This illustration shows the basic construction of a transformer. The primary coil is connected to an A-C source, causing the current and resulting flux to periodically change magnitude and direction. The flux variation is concentrated in the laminated steel core. The varying flux induces an EMF in the secondary coil. If the secondary coil terminals are connected to a load, a charge flows through the load. Thus, electrical energy is transferred from one electrical circuit to another by means of mutual inductance. The action that created the EMF in the secondary is known as transformer action. The EMF is referred to as transformer voltage.

If all lines of flux link both the primary and secondary of a transformer, several useful relationships between the turns, voltage, and current ratios can be found. The primary coil is supplied from an A-C source. The voltage read at the secondary coil is the same as the source voltage (neglecting transformer losses) if both coils have the same number of turns. If the secondary contains more turns than the primary, the secondary voltage is higher than the primary voltage. If the secondary contains fewer turns than the primary, the secondary voltage is lower than the primary voltage. The formula for voltage and turns ration is

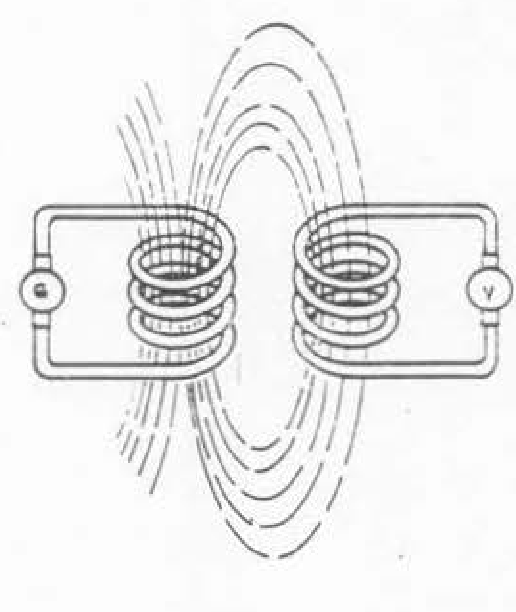
$\frac{Ep}{Es} = \frac{Np}{Ns}$ where:

Np = number of primary turns
Ns = number of secondary turns
Ep = applied voltage in primary
Es = induced voltage in secondary

Transformers are normally used to increase or decrease a voltage. If the voltage is increased, it is called a step-up transformer. The current ration of a transformer is inversely proportional to the voltage ratio

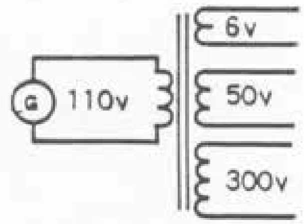
$\frac{Np}{Ns} = \frac{Ep}{Es} = \frac{Is}{Ip} = \sqrt{\frac{Zp}{Zs}}$ where

Is = the current in the secondary
Ip = the current in the primary
Zp = the primary inpedance
Zs = the secondary impedance



POWER TRANSFORMER.

Electronic equipment frequently requires more than one A-C voltage. Power transformers are normally designed

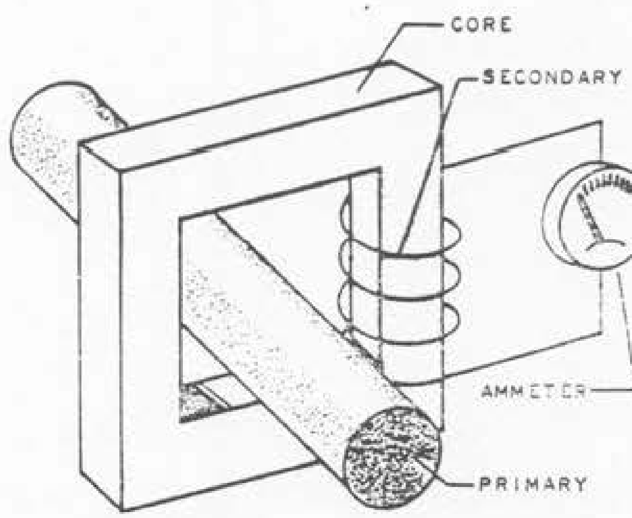


with more than one secondary winding wound on the same core. This illustration shows a typical power transformer. It has a 6-volt winding, a 50-volt winding, and a 300-volt winding.

CURRENT TRANSFORMERS.

Current transformers are used to measure alternating current in a line without breaking the circuit. The current-carrying conductor passes through the core and acts as a single-turn primary. The secondary is made of many turns of fine wire. The voltage in the secondary is stepped up because the secondary contains more turns than the primary. The current is stepped down in the same ratio that the voltage is stepped up. An ammeter rated at five amperes full-scale deflection is normally used. Thus, if the current transformer has a ratio of 100:5, full scale deflection on the 5-ampere meter scale indicates that there is 100 amperes flowing in the primary.

AUTOTRANSFORMERS.

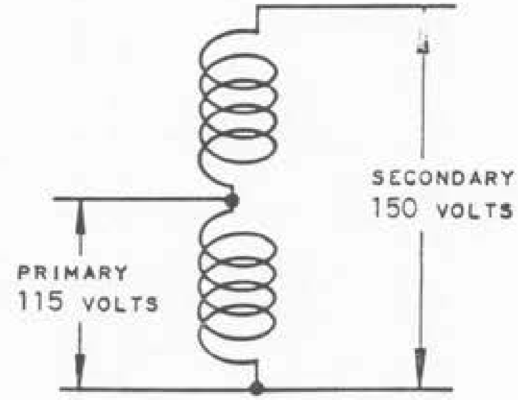


CURRENT TRANSFORMER

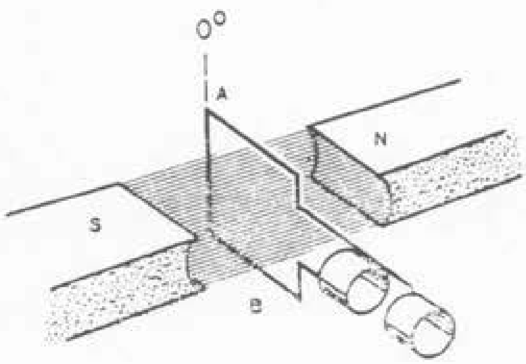
The autotransformer differs from the conventional two-winding transformer in the way in which the primary and secondary are constructed. In the conventional transformer, the primary and secondary winding are completely insulated from each other but are magnetically linked by a common core. In the autotransformer, the two windings, primary and secondary, are both electrically and magnetically connected. The autotransformer may be constructed in either of two ways. In one arrangement there is a single, continuous winding with taps brought out at convenient points. The position of the tap is determined by the desired secondary voltages. In the other arrangement, there are two or more coils which are electrically connected to form a continuous winding. In either case, the same laws governing conventional two-winding transformers also apply to autotransformers.

GENERATOR PRINCIPLES.

When electrons pass through a magnetic field, a force is exerted upon them. If these electrons are in a wire, and if the wire is moved in a magnetic field, the force is still exerted on them. When the force acts on the electrons, the electrons move within the wire. This causes a current or voltage to be induced within the wire by its movement in the field. In other words, when magnetic lines of force are "cut" by, or when they "cut" across, a conductor such as a wire, a current or voltage is produced in the conductor. The amount of this voltage is dependent on the rate or speed at which the lines are "cut," the number of lines "cut", and the number of turns on the generator.

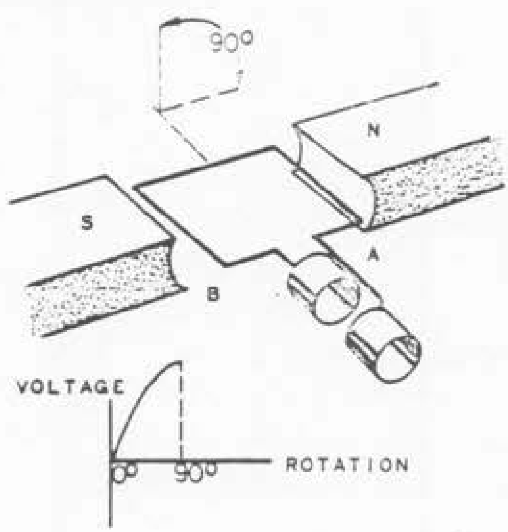


AUTOTRANSFORMER

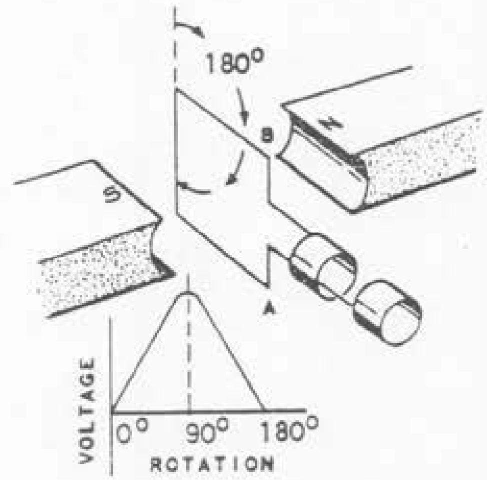


A simple generator can be made by turning a loop of wire in a magnetic field. The ends of the loop can be connected to "slip rings". This allows the generated voltage to be used while the loop is turning. The largest number of lines of force is found between the opposite poles of a permanent magnet. With the loop in the position shown no voltage is induced in the first position, because the sides of the loop are moving parallel to the lines of force. In other words, they are not cutting across them.

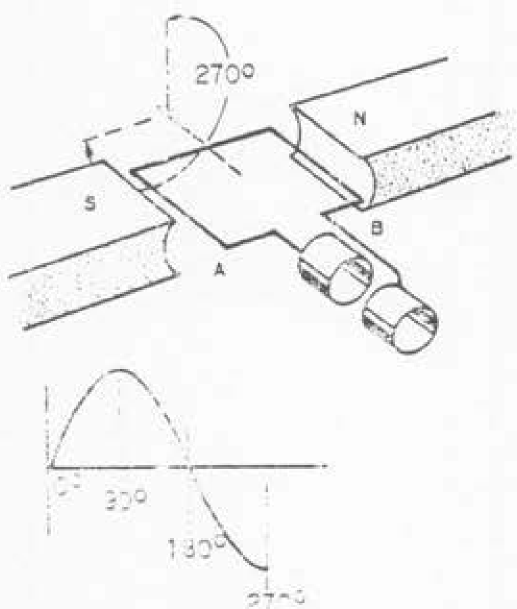
Start the turning at this point, which will be called 0 degrees. As the loop is turned clockwise (to the right), it reaches the 90-degree position. At this point the loop is cutting directly across, or at right angles to, the lines of force, and the greatest voltage is induced in the loop. A graph is made of this voltage against the angular rotation of the loop. The voltage is zero when the rotation is zero, and increases to its maximum at 90 degrees.



As the rotation continues to 180 degrees, the sides of the loop again travel parallel to the lines of force. The induced voltage is again zero.

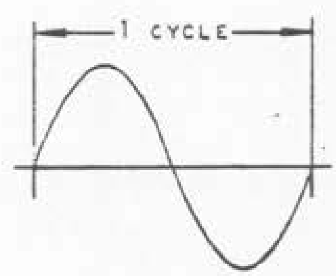


The rise and fall of this voltage is not a straight line. Rather, it is curved since it is a function of the angle of rotation, or turning. In trigonometry this is known as the function of the sine of the angle of rotation.

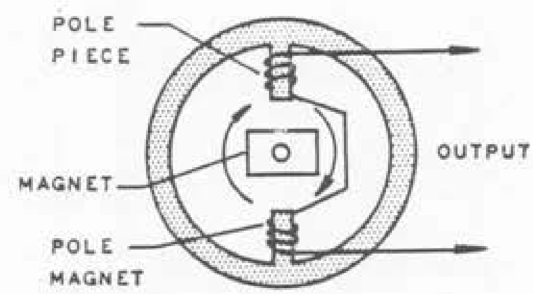


As the rotation continues to 270 degrees, the voltage is again at a maximum. This maximum voltage is reversed in polarity, however, from that produced when the coil was at 90 degrees. This is true because the sides of the loop are now moving in the opposite direction. The graph now shows the other half or the negative swing of the voltage. Then, as the rotation is completed back to 0 degrees, the voltage again is zero.

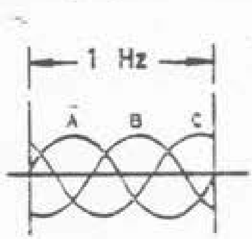
So, for one complete rotation of the loop, the generator produces a voltage which varies both in sign (polarity) and magnitude (amount). This is known as A-C (alternating current) voltage. If the rotation of the loop is continued, this varying voltage can be produced over and over again. Each rotation of the loop produces one "cycle" of the voltage. The number of cycles per second, called a "Hertz" (Hz) is known as the frequency of the voltage. The frequency produced, then, depends on how fast the loop is rotated. The arrangement shown and described is a simple A-C generator, or alternator.



Another form, in which an A-C generator may be represented, is shown in the adjacent illustration. When the rotating magnet is in the position shown, the voltage produced in the stator, or stationary windings, will be at a minimum. As the magnet turns, the magnetic lines "cut" across the stator windings and produce an A-C voltage. Frequency of the produced voltage depends on how fast the magnet is rotated. The output of this, and the previous simple generator, is called "single-phase" A-C voltage.

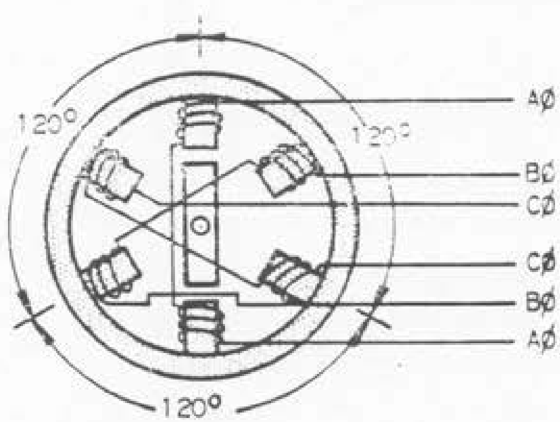


Alternators are often wound to produce a different type of AC. This type is called "three-phase" A-C voltage. Three-phase A-C means that three different voltages are developed at once, with the peaks of the voltages occurring at different times. Each voltage is called a "phase" and each one is lettered A, B, or C. The graph shown here indicates how these three voltages vary with respect to each other. Equipment which uses three-phase power will receive three times as many pulses of voltage per second as single-phase equipment. Three-phase equipment can be made smaller and lighter than single-phase equipment of the same power rating.

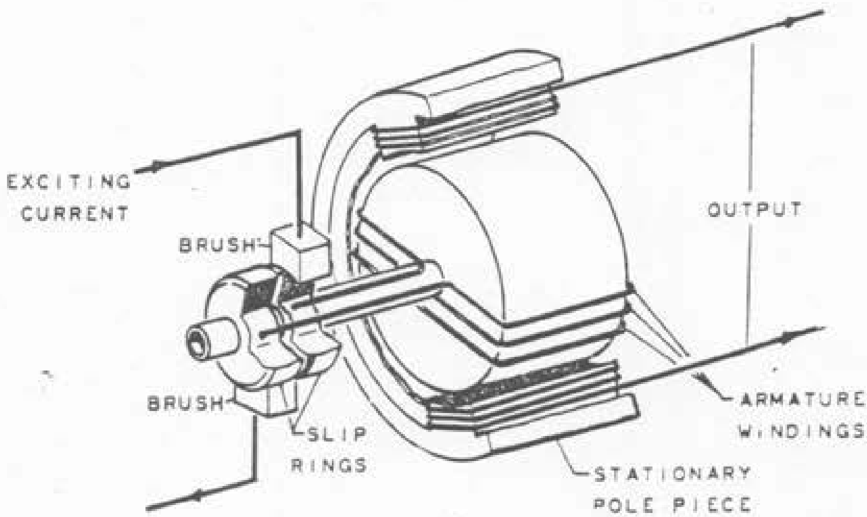


Some changes in the simplified generator must be made to produce three-phase A-C voltage. Instead of just one stator winding, three are wound on pole pieces which are evenly spaced around the generator. The winding are 120 degrees apart.

The phase difference of the voltages produced will be the same as the difference of spacing between the pole pieces, or 120 degrees. As shown, the magnet rotates from pole A to pole B to pole C. This causes coils A, then B, then C to produce voltages. Therefore, the phase "rotation is ABC.

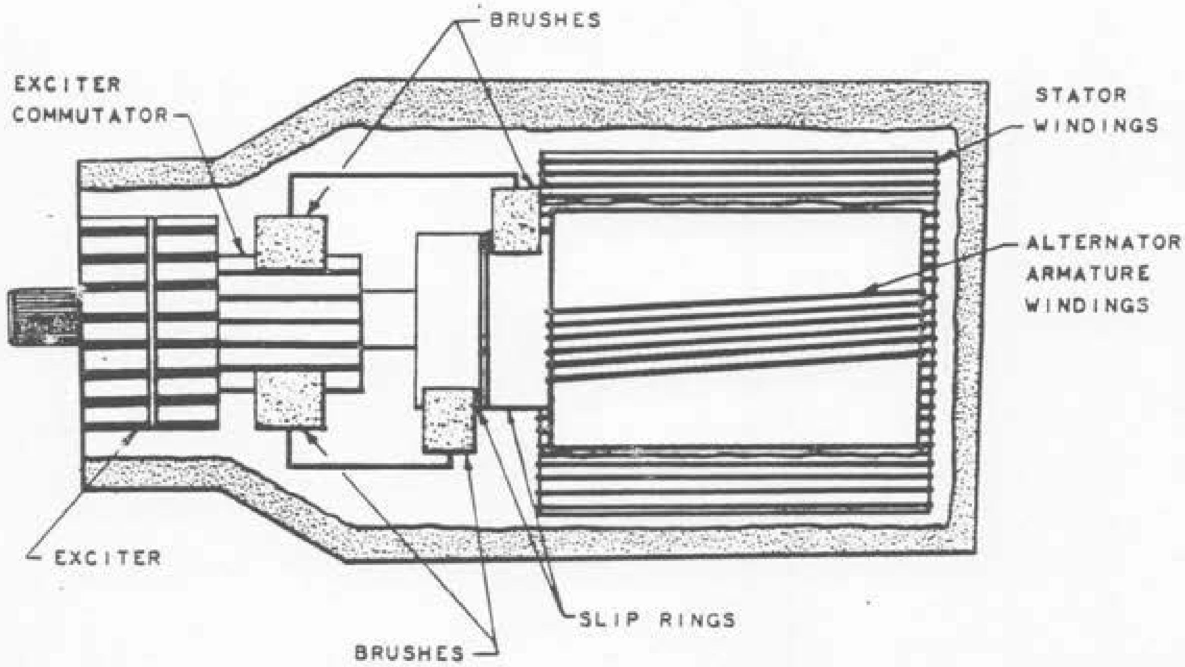


Now take the principles of the simplified generator and see how they are used in actual alternators. So far, a permanent magnet has been used as a source for the magnetic field. Because of regulation, some other means of creating the magnetic field in the actual alternator is needed. An electromagnet is used for this purpose. The electromagnet in this case is a rotating coil, or winding, which has an "exciting" current flowing through it. The coil, or armature, set up a magnetic field. As it rotates, the lines of force of the magnetic field cut across the stator winding which are wound on the stationary pole pieces. This induces a voltage in the stator windings that is the output.



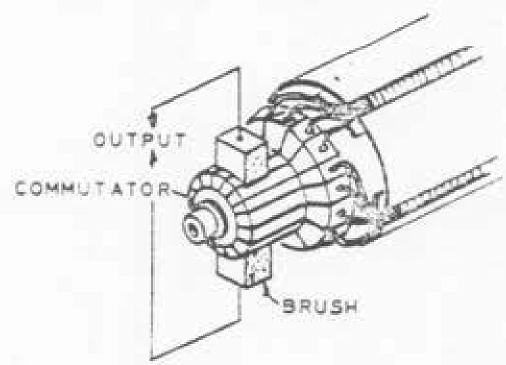
The "brushes" shown in the previous illustration are small blocks (usually made of carbon) with one end curved to fit the metal "slip rings." These brushes are held against the slip rings by springs to provide good electrical contact between the two. Exciting current is applied to the brushes. It flows through the slip rings to the armature assembly rotates but the brushes ride on them and maintain electrical contact at all times.

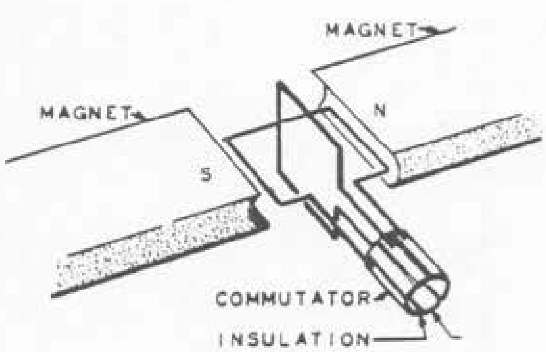
The source of exciting current has not been discussed. In order to have a self-contained generating unit some further additions must be made. These will cause the alternator to supply its own exciting current once it wtarts developing voltage. It will then be a self-excited A-C generator. To produce the exciting current, a D-C generator is built on the same shaft as the alternator armature. When the shaft turns, the D-C generator produces a voltage which is applied to the slip rings on the armature shaft. Direct current then flows through the armature win winding of the A-C generator and develops a magnetic field. As the shaft turns, the magnetic field rotates, cutting across the windings of the alternator and producing the three-phase A-C output voltage. The entire unit is built into one



housing to provide a complete, self-excited, alternator. The D-C generator is the exciter unit. A D-C generator can be made by refining the simplified A-C generator described earlier. Two or more loops of wire for the armature can be used.

Each end of a loop connects to a metal commutator segment. The metal commutator segments are separated by insulation. The segments form a slotted cylinder that makes contact with the brushes. Contact is made in such a way that the output of the generator is rectified DC, or a pulsating D-C voltage.

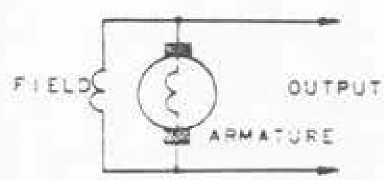




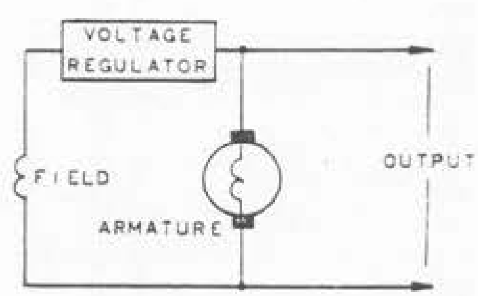
The amplitude of the pulses can be reduced by using more loops in the generator. Of course, with more loops more metal commutator segments are needed. The output of a D-C generator with several loops is shown in the adjacent illustration.

The D-C generator's magnetic field is set up by an electromagnet. As in the simplified A-C generator with the rotating magnet, the "field" winding of the generator is wound on stationary pole pieces.

In order to produce the necessary magnetic field, charge must flow in the field winding. If the field winding is connected to the armature brushes so the generator furnishes its own field current, it is a self-excited D-C generator. Some magnetic field is necessary to start the build-up of armature voltage. The voltage build-up may result from residual magnetism, or it may result from the magnetic field created by a momentary current from an external source. When a generator is first used, a momentary current from an external source is needed to created a magnetic field so that the generator will have an output. Once the generator is used, there is generally enough residual magnetism to start the voltage build-up.



In this illustration, the field is connected directly across the output of the generator. The output voltage causes a current through the field winding which creates the magnetic field needed for operation of the generator. As the output voltage goes up, the field current increases. In turn, the output voltage increases because the magnetic field is stronger. Of course, this process must be controlled in order to get the desired voltage. Usually, a "voltage regulator" of some type is connected so that the field current regulates the generator output to the desired voltage.



The A-C output voltage of the A-C generator alternator described earlier depends on the strength of the rotating magnetic field. The strength of this field depends upon the voltage output of the D-C exciter. So, in practice, the voltage regulator mentioned above "measures" the A-C voltage. If this is too high, the regulator causes the exciter output voltage to decrease. In this way, the alternator output is kept at the desired voltage value.

INVERTED CONVERTER.

A converter is used to change alternating current to direct current. The A-C input causes the machine to operate as a synchronous motor at a constant speed, regardless of field excitation or load. A generator attached to the motor then generates DC.

A converter can also be used to change DC to AC. When used in this manner, it is called an inverted converter, but is more commonly referred to as an inverter. It does not operate at an absolutely constant speed, as does a synchronous motor. Because the motor operates as a D-C motor, its load and field strength both determine its speed. This type of machine is equipped with voltage and frequency regulating devices. In practice, the speed is usually held nearly constant in order to generate a desired frequency.

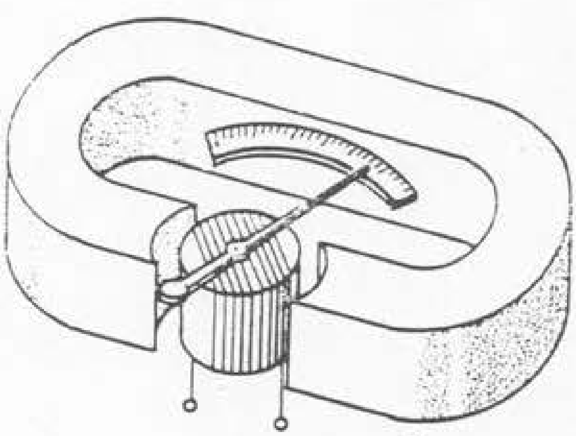
MEASURING INSTRUMENTS.

In the inspection, maintenance, and operation of any electrical system the voltage, current, and resistance must often be measured. Many types of meters are used for this purpose.

GALVANOMETER.

A galvanometer is a very sensitive meter which measures very small currents. The most common type of galvanometer uses a D'Arsonval meter movement. In the D'Arsonval movement, a coil rotates within a magnetic field.

As illustrated, the coil is mounted on a "drum." The "drum" is mounted on nearly friction-free pivot points. It is spring-loaded to return the pointer to the zero position. The coil is placed between the poles of a permanent magnet. If a current exists in the coil, it will produce a magnetic field. This field will act against the field of the magnet. The action results in a force on the coil. Since it is mounted on pivots, it will turn and extend the spring until the spring tension exactly counteracts the force.



The coil will stay in this position as long as the current through it remains constant. It follows that the amount of deflection, or movement, of the coil depends on the amount of current through it. An indicator or needle can be attached to the drum. It then shows the angular deflection of the coil.

The D'Arsonval movement forms the basic meter inside most instruments used today. The magnet, coil, and spring can be designed so that the full-scale deflection represents a particular current. Due to the delicate spring and balance, however, the amount of current that can be sent through the coil is limited.

It may seem strange that this type of meter is so widely used when its range is so limited. But its accuracy, small size, and ruggedness more than make up for its limited range. The range limitation can be overcome with the use of external resistors.

AMMETERS.

The ammeter is a meter that measures current.

Most modern ammeters are basically D'Arsonval movements. These meters come in various ranges. One of the most common has a maximum current-carrying capacity, or full-scale deflection, of 0.01 ampere, or 10 milliamperes. (A milliampere is 0.001 ampere.)

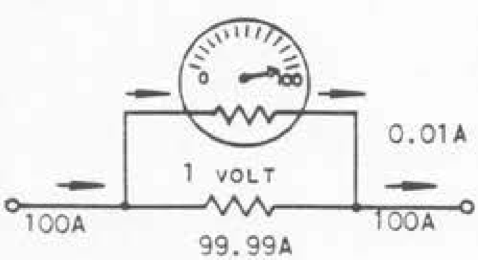
The internal resistance of its coil may vary but is usually around 100 ohms. For an illustration, use a meter with 100 ohms internal resistance and a full-scale deflection of 0.01 ampere (10 milliamperes). From Ohm's law, the voltage across the meter at full scale deflection is

$$E = I \times R$$

$$E = 0.01 \times 100$$

$$E = 1 \text{ volt}$$

Suppose this meter is to be used as a meter capable of measuring up to 100 amperes at full scale. Since the meter itself can carry only 0.01 ampere, another path for the current must be provided for the 99.99 amperes remaining. A current of 0.01 ampere through the meter, together with the 99.99 amperes, make a total of 100 amperes. The additional path is provided by connecting a resistor across the meter terminals. The value of this resistor has to be calculated so that it will conduct 99.99 amperes of current when a voltage of 1 volt (the voltage across the meter at full scale) is impressed across



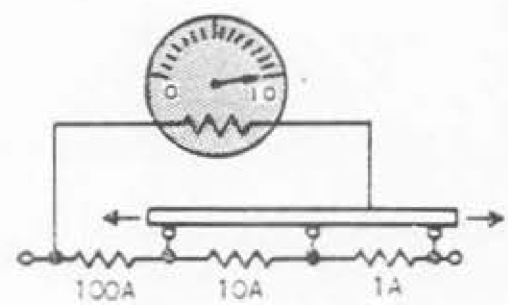
it. To make this calculation, again use Ohm's law and find

$$R = \frac{E}{I} = \frac{1}{99.99}$$

$$R = 0.010001 \text{ ohm}$$

This, of course, is a very small resistance. It would have to be made of a metal bar of some sort. If the meter is to be accurate, the value of the resistor must be accurate. A resistor paralleled across the meter in this manner is usually referred to as as ammeter shunt. The meter gives an accurate measurement of 100 amperes although only 0.01 ampere flows through the meter. If the values are accurate, any amount of current in the line will be measured proportionately by the meter.

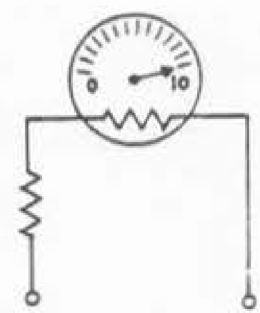
This same type of calculation can be made to convert any basic meter to almost any desired scale. However, its internal resistance and full scale deflection must be known. Most commercial test meters are made with more than one scale by using several shunts. Each shunt is designed to give a particular full scale reading on the meter. A switching arrangement can be used so that the proper shunt is selected to give a desired range.



Extreme care must be used in connecting an ammeter in a circuit. Polarity must be correct when using D-C meters. The terminals must be connected so that the meter pointer will move up scale. Improper terminal connection will cause the pointer, or indicator, of the meter to be driven backwards against its peg. A meter can be very easily damaged in this way. Since it measures current, an ammeter must be connected in series with the line in which the current is to be measured.

VOLTMETERS.

As was the case with ammeters, nearly all voltmeters use the basic D'Arsonval movement. Take the same basic meter that was converted to a high-scale ammeter and make it a voltmeter. It had a full scale deflection of 10 milliamperes with an internal resistance of 100 ohms. By Ohm's law it was shown that a voltage of one volt would deflect it full scale. In the case of the ammeter, most of the current had to be shunted. For the voltmeter, all but one volt of the applied voltage must be dropped across a series resistor, which is called a multiplier. Ohm's law can be used to determine the value of the multiplier.



Now, convert the meter to measure up to 100 volts. The meter takes 1 volt at full scale. Calculate the value of the multiplying resistor needed to develop 99 volts at a current of 10 milliamperes. For this,

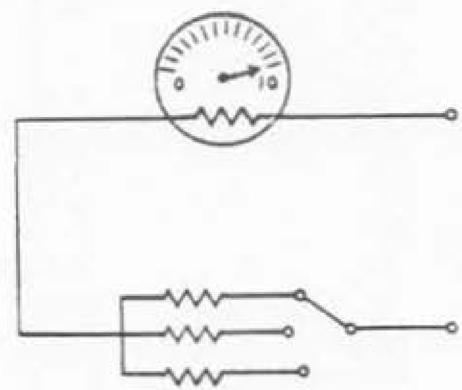
$$R = \frac{E}{I}$$

$$R = \frac{99}{0.01}$$

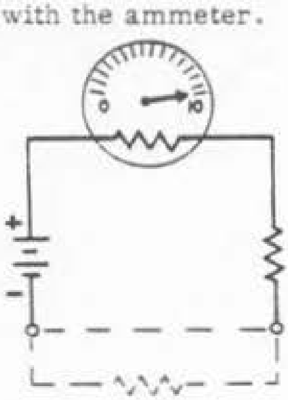
$$R = 9,900 \text{ ohms}$$

Unlike an ammeter, a voltmeter is connected <u>across</u> a voltage source. Its high resistance (including the multiplying resistor) prevents most damage to the meter if it is connected in series. However, this high resistance in the line will prevent the using equipment from operating properly.

The voltmeter can also be made as a multi-range meter. To do so, use several multiplier resistors and a selector switch as illustrated. The values of these resistors can be calculated for the desired scales and connected as shown.



The voltmeter has very definite polarity, which must be observed just as with the ammeter.



OHMMETERS.

As its name implies, an ohmmeter measures resistance. An ohmmeter can be built from the same basic D'Arsonval movement. When a multiplying resistor and a battery are connected in series with the meter as shown, the circuit is a series ohmmeter. Suppose a 3-volt battery is chosen. First, the value of the multiplying resistor must be found. To do this, short, or connect, the two terminals together as shown. Find the value of total resistance (multiplier plus internal) that will allow exactly 0.01 ampere from the battery. Therefore:

$$R + 100 = \frac{E}{I} = \frac{3}{0.01}$$

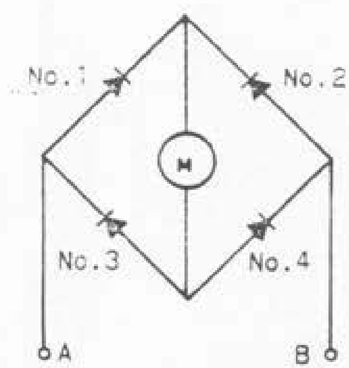
$$R + 100 = 300$$

$$R = 200 \text{ ohms}$$

Now, with a 200-ohm multiplying resistor, <u>the meter reads full scale when the measured resistance is zero</u> (the terminals are shorted). It is important to note that most commercial ohmmeters read zero resistance at full scale deflection of the meter. The meter can now be calibrated. Suppose an unknown resistance will be measured when the meter reads 0.005, or half-scale deflection. Since the internal resistance is 300 ohms, 300 more ohms to be measured would give a half-scale reading. Using Ohm's law, the meter can be calibrated at points all along the scale. The ohmmeter scale is non-linear, which differs from both the voltmeter and the ammeter whose scales are linear.

A-C METERS.

All the meters that have been described have been D-C meters. To make an A-C meter, the meter is built exactly the same as for DC, with one addition. A rectifier circuit is necessary since <u>current must pass in only one direction through the meter</u>.



The arrangement of rectifiers, shown here, will let current pass in only one direction through the meter. When point (A) is positive and point (B) is negative, current passes through rectifier No. 1. It cannot pass through No. 3 or No. 2, but it passes through the meter, through Rectifier No. 4, and back to point (B) .

Now consider the other half of the A-C cycle: when point (B) is positive and point (A) negative, current passes from point (B) through No. 2. Since it cannot pass through No. 4, it passes <u>through the meter</u>. Since it cannot pass through No. 1, it passes through No. 3 and back to point (A) . Either way it always passes in the same direction through the meter. A shunt or multiplying resistor can be connected with this rectifier-meter circuit and make either an A-C ammeter or voltmeter.

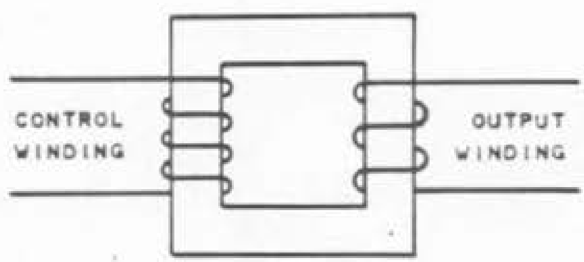
MAGNETIC AMPLIFIERS.

GENERAL. Because of its long life, excellent reliability, and high efficiency, the magnetic amplifier is widely used on modern aircraft. Neither shock nor vibration affect its operation.

The magnetic amplifier permits one electric circuit to magnetically control another. Developed from the saturable reactor, the basic unit is a combination saturable reactor and rectifying diode.

THE SATURABLE REACTOR.

The basic saturable reactor consists of two coils wound on a high permeability iron core. Essentially, this is a transformer whose primary is called the control winding and whose secondary is the output winding.



The control winding has a larger number of turns than the output winding. The control winding is connected to a D-C source. The output winding is connected in series with an A-C source and its load. The control winding creates flux lines in only one direction in the iron core.

The output winding creates an alternating set of fluxlines that add to the control-winding flux lines for one-half cycle. During the following one-half cycle, the two oppose and cancel. When the flux forces add, saturation of the core occurs. When the core becomes saturated, the permeability of the core drops, and the inductance of the output winding drops. With a smaller inductance, the inductive reactance of the output winding is smaller. Thus, when the core saturates, the load current increases. The relationship between core saturation, inductance, and inductive reactance of the control winding, and the load current are summarized as follows:

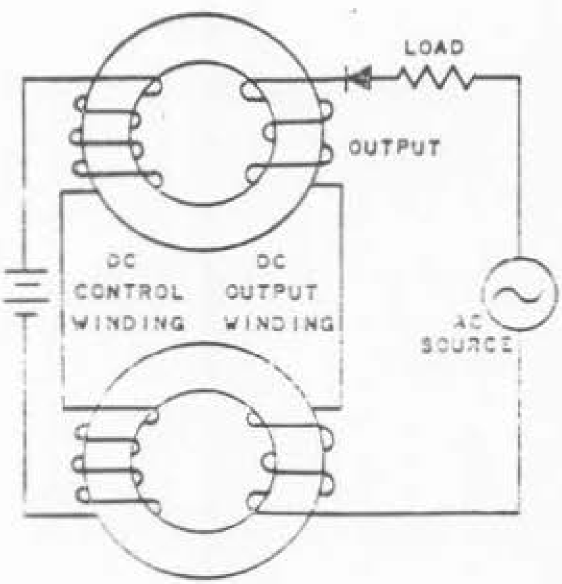
CORE SATURATION	OUTPUT WINDING		
	INDUCTANCE	REACTANCE	CURRENT
Unsaturated	High	High	Low
Saturated	Low	Low	High

Core saturation can be produced by a small direct current in the control winding. Very small control currents saturate the core only when the A-C source voltage is close to its peak. This produces small pulses of current in the load. Increasing the control current causes the core to saturate at a lower instantaneous value of the A-C cource voltage. Saturation thus occurs earlier in the cycle and continues longer. The amplitude of the pulses in the load also increase. Further increases in control current causes further increases in the duration of the saturation period until the core saturates for an entire one-half cycle.

The basic saturable reactor has four serious disadvantages:

1. Transformer action between input and output windings
2. Core losses due to saturation and desaturation
3. Quiescent current (load current even though the control current is zero)
4. No polarization

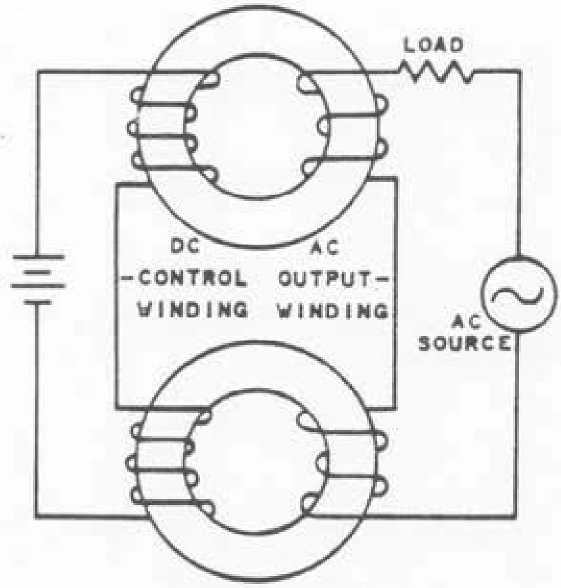
Transformer action can be best cancelled by using two saturable reactors connected in a series opposing arrangement.



HALF-WAVE MAGNETIC AMPLIFIER

If the saturable reactors illustrated are alike, then the control windings are connected so that the A-C voltage induced in the two winding will oppose and cancel. The control flux lines will still saturate the core and thereby control the load current. The doughnut shaped or toroidal core has fewer losses, and is preferred over rectangular cores. Other arrangements can be used to eliminate the high voltage induced in the control winding by the output winding. In any case, the final results make operation of the control loop independent of output loop operation.

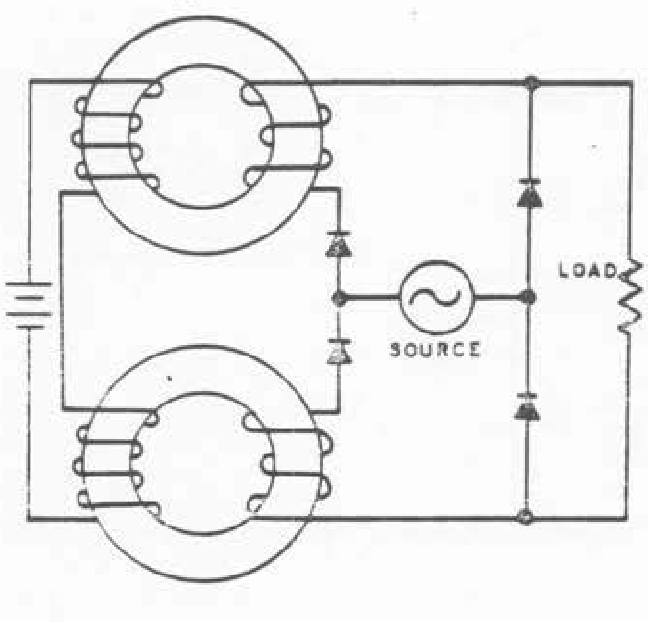
The desaturation of the cores is eliminated by permitting current in only one direction in the output winding. By placing a diode in series with the output loop, no reverse current can exist. Core losses decrease sharply, and the overall circuit operation is improved.



SATURABLE REACTORS

MAGNETIC AMPLIFIERS.

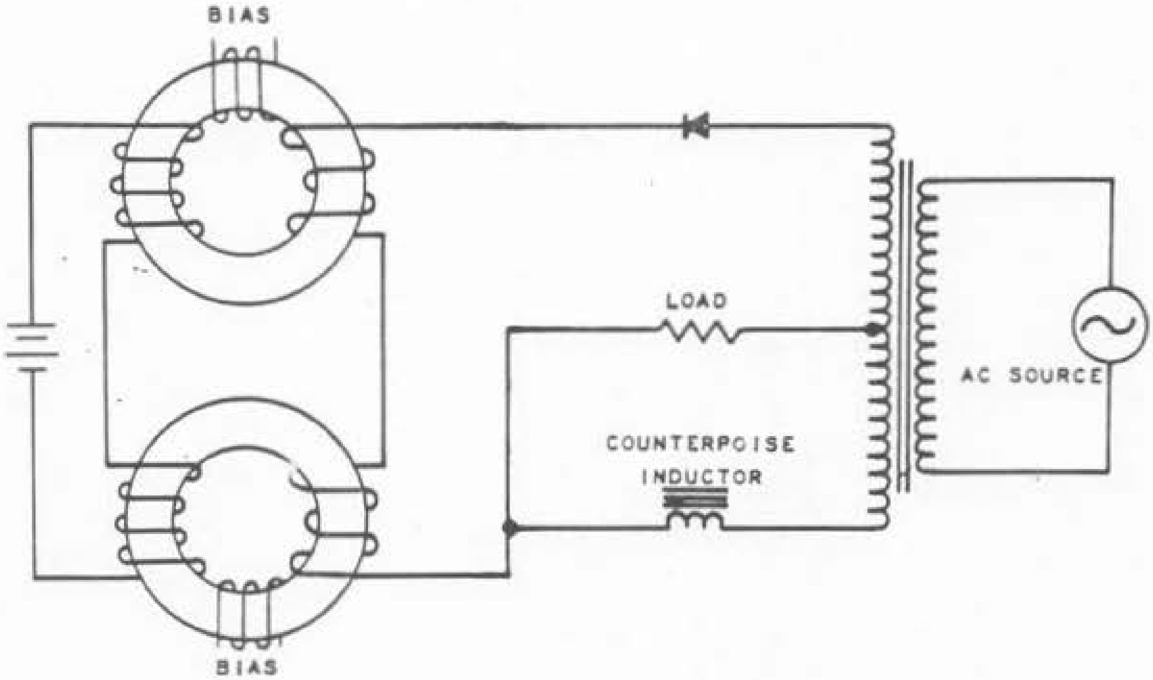
The addition of the diode to the two saturable reactors makes the circuit a basic half-wave magnetic amplifier.



FULL-WAVE MAGNETIC AMPLIFIER

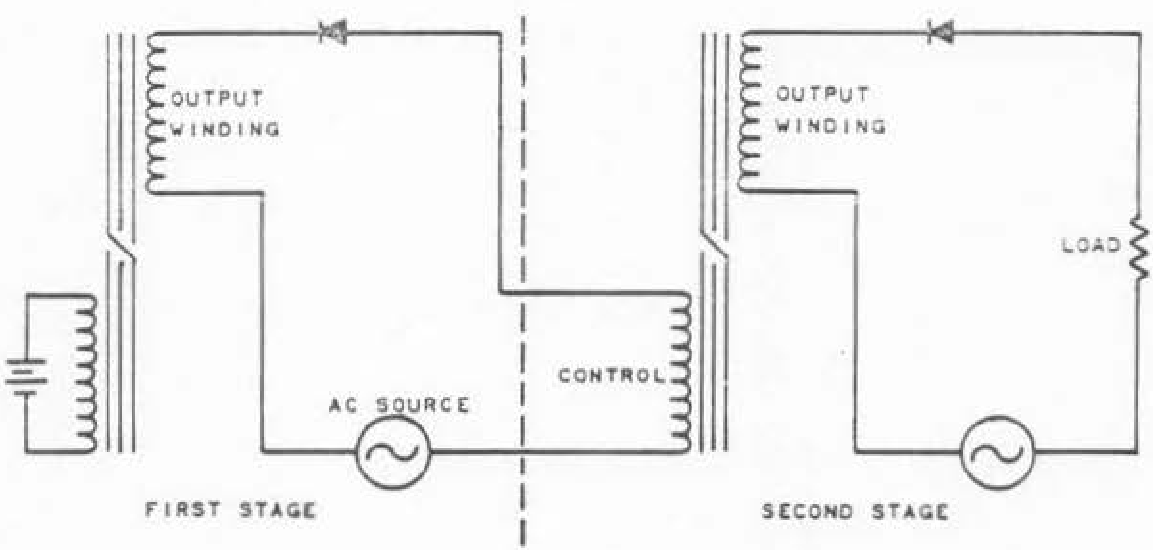
A slight rearrangement of the circuit and the addition of three diodes makes the circuit a full-wave magnetic amplifier.

In all the circuits shown, there is a quiescent current. The quiescent current is the current in the load loop when control current is zero. If more than two stages of magnetic amplifiers are to be used, the quiescent current is undesirable. To eliminate this current, a counterpoise inductor and a center-tapped transformer can be used. The counterpoise inductor cancels quiescent current, but does not appreciably affect circuit operation.



The saturable reactor and the magnetic amplifier can be polarized by the addition of a bias winding. The bias winding is a second control winding. When a saturable reactor has more than one control winding, the additional windings are named for the function they perform. The additional control windings can be used for bias, feedback, reference, or stabilization.

A complete magnetic amplifier may consist of more than one stage in order to get more amplification. In the two-stage amplifier shown, the output of the first stage is used as the control current for the second. Bias and other windings are omitted for simplicity.

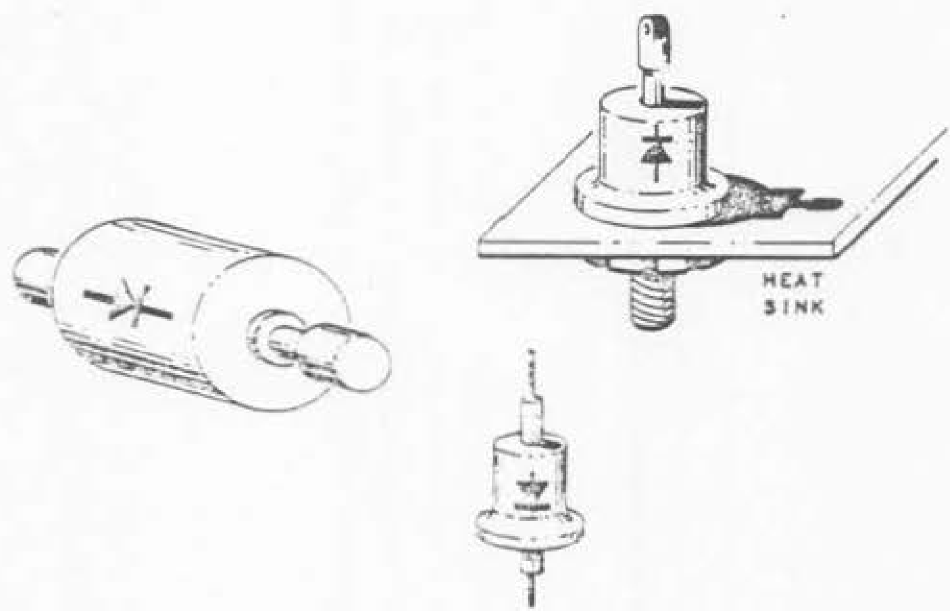


SEMI-CONDUCTORS

A semi-conductor is an element such as silicon, selenium, or germanium, which has resistance. Semi-conductors are not conductors or insulators but have a resistance value somewhere between that of conductors and insulators. Semi-conductor materials are used in the design of solid state devices, such as diodes and transistors. Impurities are added to the semi-conductor materials to form P (positive) and N (negative) type crystals. The type impurity determines the type crystal. The crystals are combined to form diodes and transistors.

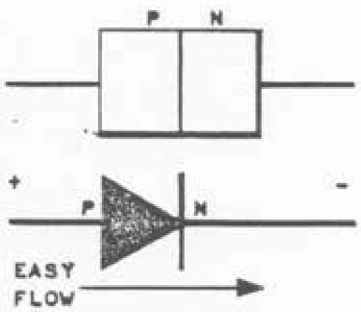
DIODES

A diode is a two-terminal device which allows current to pass in one direction and opposes the flow of current in the reverse direction. Diodes are frequently used for D-C circuit isolation between several control circuits and a load and for rectification in power supplies. A rectifier changes AC to pulsating DC.



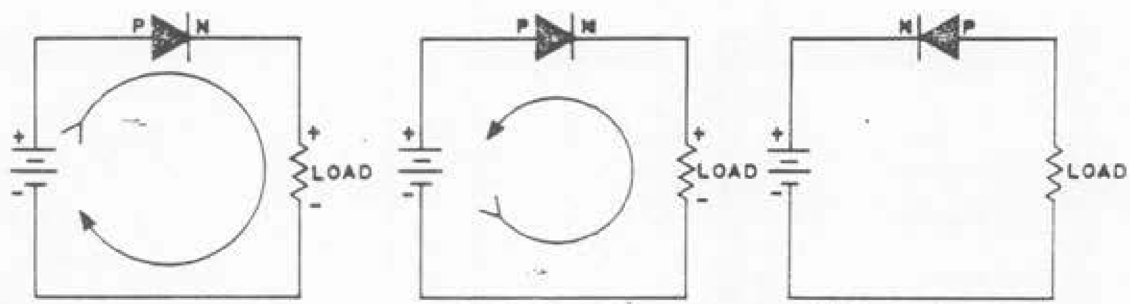
DIODES

Many types of diodes exist which can be used for these purposes. The most common diodes are made of selenium, germanium or silicon. In aircraft systems the silicon diode is most often used due to small physical size, high current rating, temperature characteristics, and reliability.



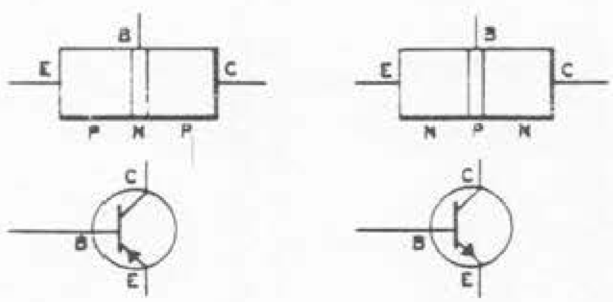
The arrow symbol used for a diode indicates the direction of conventional current (+ to - flow) through the diode. Electron flow is opposite to the arrow (- to + flow).

The junction diode is contructed of P and N crystals. When the crystals are joined, a diode is formed.



CONVENTIONAL CURRENT (MAXIMUM) | ELECTRON FLOW (MAXIMUM) | MINIMUM CURRENT (REVERSE BIAS)

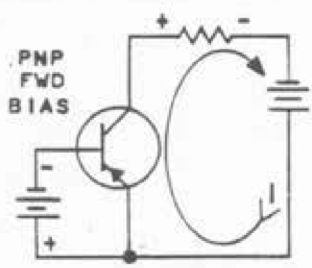
If a D-C source is connected across the silicon diode with the positive potential to the arrowhead (forward bias), the diode conducts, allowing maximum current. If the source is reversed, current would be minimum.



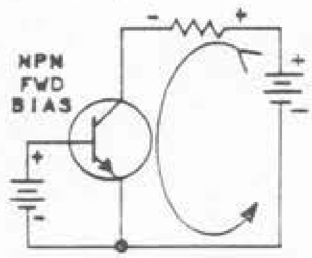
PNP NPN

TRANSISTORS

The transistor is a further development of the junction diode. A transistor is a three-element device, either PNP or NPN combination. A transistor can be used as a current amplifier, voltage amplifier, electronic switch, or gate. The elements are emitter (arrow), base (center), and collector. The emitter and collector are made of the same type material. The base is a thin layer of crystal sandwiched between emitter and base. A transistor must be forward-biased into conduction. The emitter base junction is forward-biased, the same as a diode. If the junction is PN (emitter P, base N), a negative on the base in respect to emitter allows conduction. Reverse bias prevents conduction.



An NP material type must be forward-biased by a positive voltage on the base in respect to emitter. The collector is reverse biased in both type transistors, and base-emitter bias determines collector current. The majority of current in a transistor is between emitter and collector.

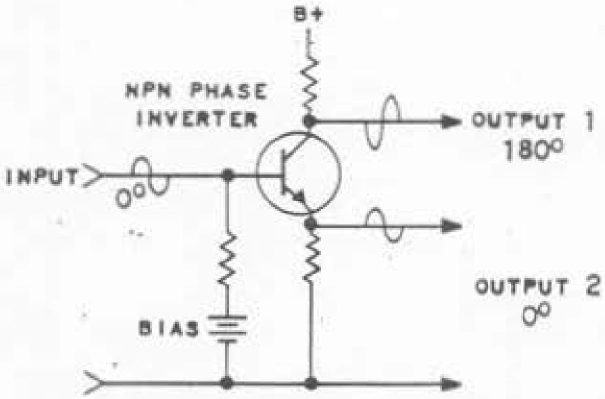


On a schematic, the direction of the emitter arrowhead indicates the type transistor (NPN or PNP). The arrow also indicates the direction of conventional current in the circuit. Electron flow is reversed to the arrow and the flow is between emitter and collector.

An emitter arrow pointing into the transistor indicates a PNP transistor, and the arrow pointing out indicates an NPN transistor. In most cases, the type transistor can be determined by the bias voltages.

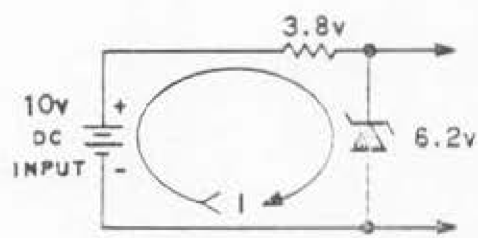
In transistor amplifiers, the input signal is normally applied to the base, and outputs are taken from the collector or emitter. When the signal polarity is forward biased, collector current increases; the reverse signal decreases collector current.

An output signal from the collector is phase reversed 180 degrees in respect to the base input signal. An output from the emitter is in phase with the base signal. The input signal can also be applied to the emitter and the output taken from the collector. In this case, input and output voltages are in phase.

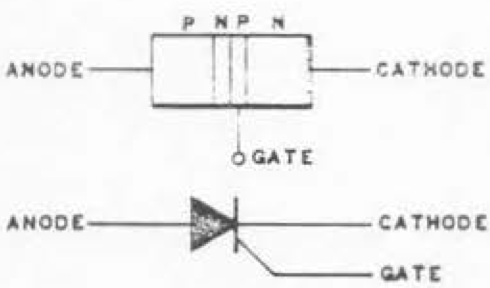


A phase inverter is an amplifier with an input on the base and outputs from the emitter and collector. The outputs are 180 degrees out of phase. Phase inverters are used in servo-loop indicating systems. When properly biased, the NPN or PNP transistor can be used to accomplish the desired result.

SPECIAL PURPOSE DIODES

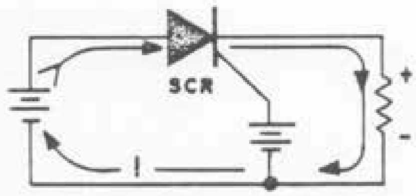


A zener diode is a PN junction used as a voltage regulator. When the diode is reverse-biased sufficiently to breakdown the junction, the diode conducts and maintains a constant voltage across the terminals. Until breakdown, the diode functions as a normal reverse biased diode (minimum current). At breakdown, reverse current is limited by a series resistor to prevent damage to the diode. Zener diodes are designed for use as low-voltage regulators and may be combined in series to obtain high voltages.

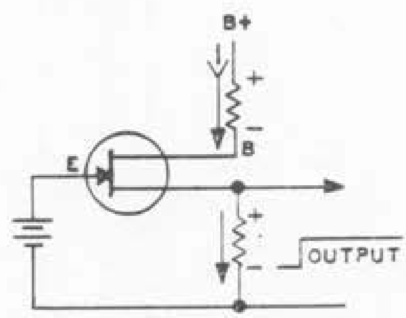


SCR

A silicon-controlled rectifier (SCR) is a gated diode used as a controlled switch. The SCR is a four-layer, three-terminal device consisting of PNPN junctions. An SCR conducts as a normal diode when forward biased and a positive gate potential is applied. Once the diode is conducting, the gate has no effect and can be removed. The SCR continues to conduct until the forward bias is removed. If reverse bias is applied, the diode functions as a normal diode (minimum current).



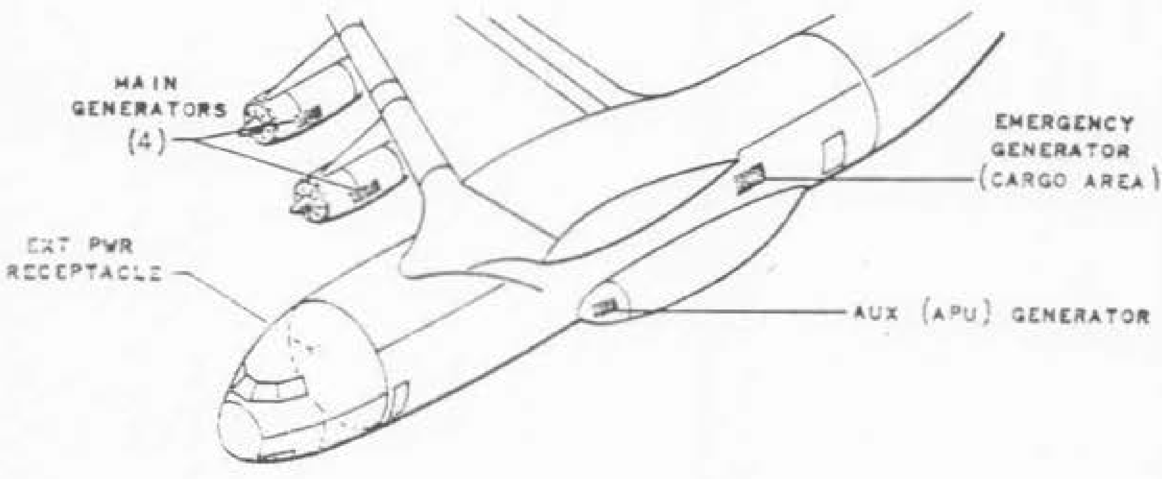
A unijunction transistor is a diode with three terminals. An emitter junction controls current between the two base junctions. When the emitter potential is large enough to overcome the base potential, the transistor conducts. Current between the bases produces a switched high amplitude DC output. When emitter voltage is removed, the base current decreases to zero.



ELECTRICAL POWER SYSTEM

GENERAL.

The electrical power required by the StarLifter systems is normally supplied by four main, engine-driven, brushless A-C generators (alternators). Each generator is a 40/50 KVA unit which supplies 115/200-volt AC to the systems. The main generators are driven by the engines through hydro-mechanical Constant Speed Drives (CSD) to provide an output of three-phase, 400-Hertz (Hz) AC.



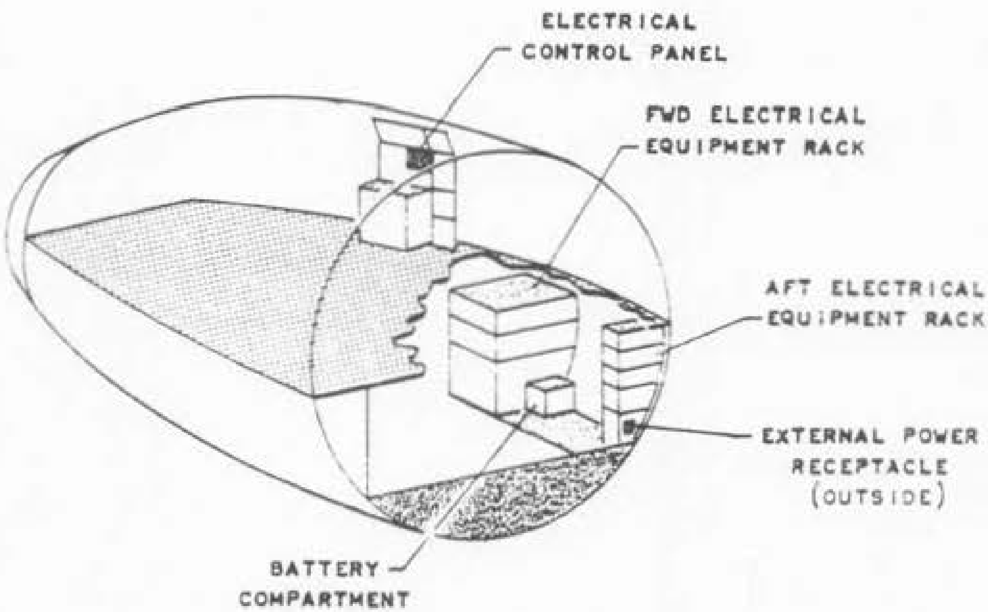
GENERATOR LOCATIONS

Auxiliary A-C power is supplied by a fifth generator, identical to the main generators. The auxiliary generator is driven directly by the Auxiliary Power Unit (APU) in the left main wheel well fairing. The APU and its generator are used only during ground checkout of the aircraft systems.

An emergency generator provides A-C and D-C power as necessary to prevent a total loss of electrical power. The generator is rated at 2 KVA, 115/200-volt AC, at 400 Hertz and 28-volt DC at 20 amperes. The emergency generator is a hydraulic motor-generator unit which is located in the No. 2 hydraulic service center in the cargo area.

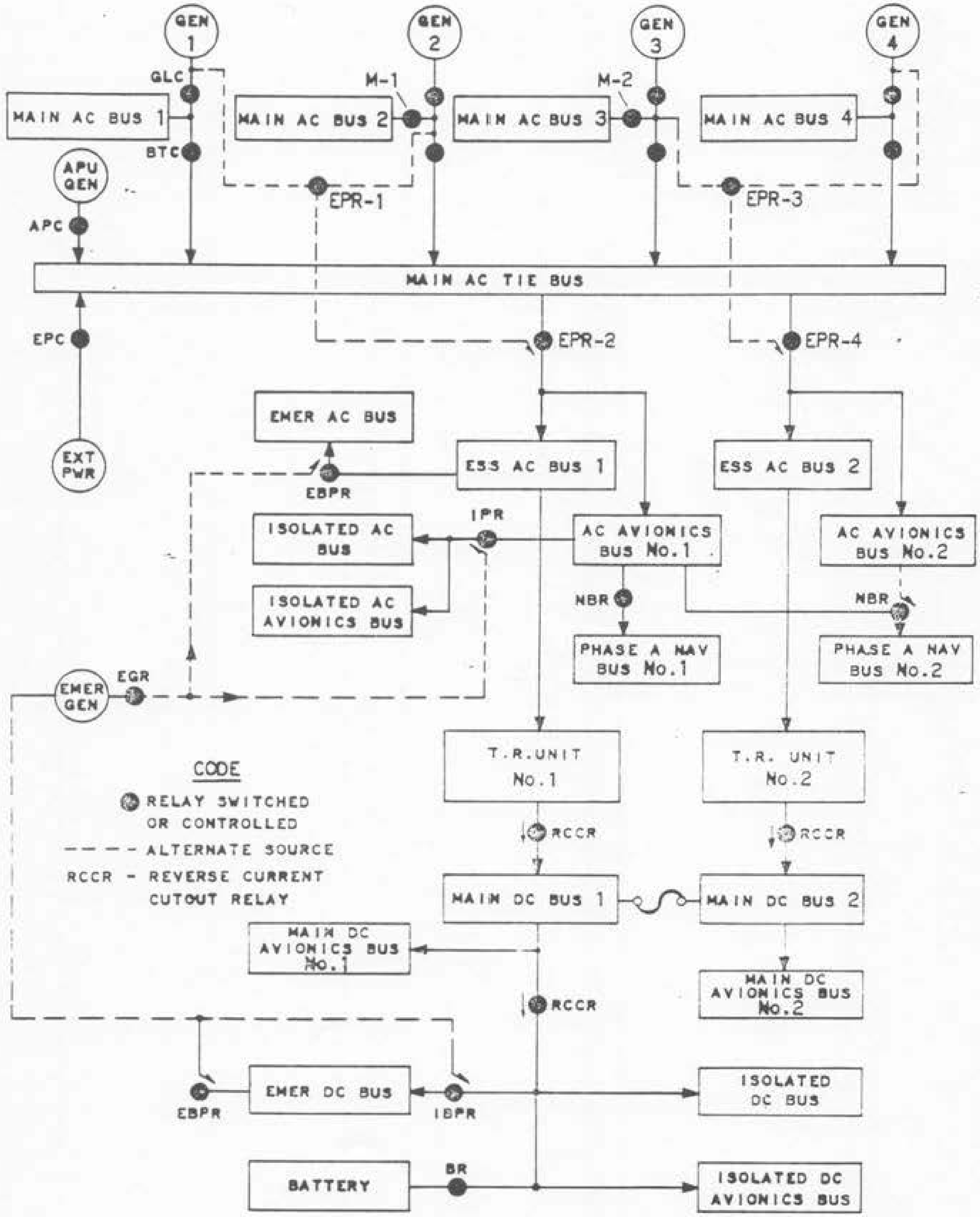
External A-C power can be used with the electrical systems for ground checkout. An external power receptacle is located on the forward right side of the fuselage. The Ground Power Unit (GPU) should supply a minimum of 50 KVA, at 115/200-volt AC at 400 Hertz. Phase sequence of the three-phase AC from the GPU must match the phase sequence of the aircraft systems or the unit cannot be used.

The DC power for the systems is supplied by two 28-volt DC Transformer Rectifier (TR) units. These units change AC to DC and provide 28- volt DC with a load capacity of 200 amperes per unit. A battery provides DC for APU ignition during starting when external A-C power is not available. The battery is rated at 24 volts and 11 Amperes Hours (AH). TR units are located in the electrical equipment rack below the flight station, and the battery is in a compartment between the racks.



RIGHT HAND UNDERDECK EQUIPMENT RACKS

An electrical control panel is provided at the flight engineer's station. Control switches, meters, and warning lights for the power sources are on this panel. Main generators normally operate in parallel to supply the electrical loads. Emer-



ELECTRICAL BUS DISTRIBUTION

gency generator operation is usually automatic but can be controlled by an instrument power switch on the pilot's instrument panel. The D-C system is automatic, controlled by the A-C system. The battery is switch-controlled so that it can be used or charged as necessary.

Each generator is rated to produce 120/200-volts AC. Voltage regulator units, protection panels, load controllers, and a bus protection panel are located in the electrical equipment racks. These units provide control, protection, regulation, and automatic sequencing of the power sources and the bus distribution system.

BUS DISTRIBUTION

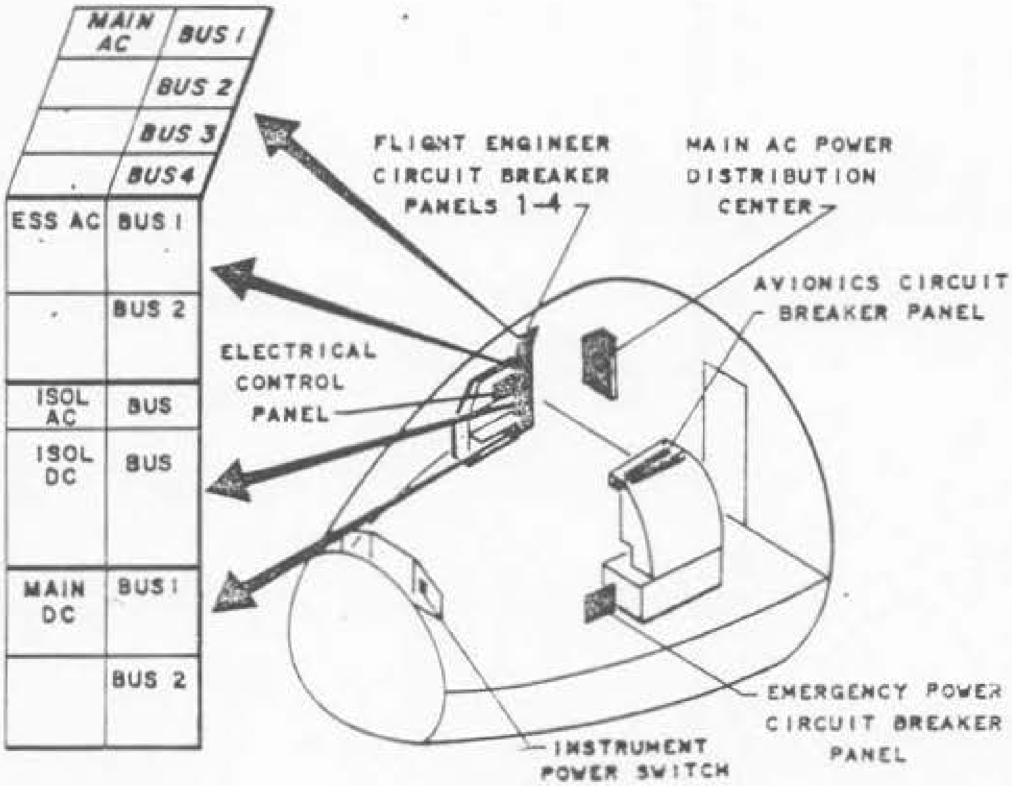
The main generator is normally connected to a main A-C bus through contacts of a Generator Line Contactor (GLC). Four main A-C buses are used, one for each main generator. Main generators also connect to a main A-C tie bus through Bus Tie Contactors (BTC). The GLC and BTC for each generator are in the same contactor housing. The BTC's and Main A-C tie bus are used for parallel operation (load sharing) of the main generators. Isolated operation is possible if the BTC's are opened by switches on the electrical control panel.

Main A-C buses No. 2 and No. 3 are controlled by monitor relays which prevent the buses from being energized until two or more main generators are operating. The relays automatically protect the generators by decreasing the electrical load when only one main generator is operating. The monitor relays may be energized through an "override" switch to energize the buses.

Two essential A-C buses are part of the electrical system. These buses are normally energized from the main A-C tie bus through four power relays. Alternate essential bus power sources are provided through the relays, allowing the main generators to supply the buses when the tie bus is not energized.

External A-C power or auxiliary generator power can be supplied to the main A-C tie bus. External and auxiliary power cannot be used simultaneously, and they will not parallel with any other power source. A combination External Power Contactor-APU Contactor (EPC/APC) connects the selected power source to the tie bus. The BTC's close to allow the main A-C tie bus to energize all main AC buses when the main generators are not operating. The BTC's open to prevent paralleling when the generators are operating and external power or Auxiliary power is in use.

The low-power emergency generator automatically supplies power to the isolated and emergency A-C and D-C buses when the normal power source fails. The normal power source is essential A-C bus No. 1.



CIRCUIT BREAKER PANELS

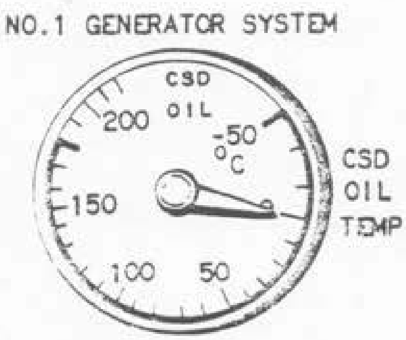
The heavy duty contactors and relays associated with the power sources and bus distribution are located in the main A-C distribution center. The distribution center is on the right side of the bulkhead between the cargo area and flight station. Power feeder circuit breakers, on the front of the panel in the flight station, distribute power to flight station circuit breaker panels. Relays, contactors, and the main A-C tie bus are accessible from the cargo area.

Other A-C buses, in addition to the main and essential, are the Avionics AC buses No. 1 and No. 2, phase A navigation buses No. 1 and No. 2, isolated, and emergency A-C buses. These buses are normally energized from the essential A-C buses.

The D-C buses are automatically energized from the essential A-C buses through the TR units. These buses are main D-C No. 1 and No. 2; main D-C avionics buses No. 1 and No. 2; and emergency D-C buses. Emergency power can be supplied to the isolated and emergency D-C buses when the emergency generator is operating. The battery can be used to supply the isolated D-C bus when other power sources are not available. Relays associated with the D-C system are located behind the circuit breaker panels.

A-C SYSTEM OPERATION

The Constant Speed Drive (CSD) unit oil temperature indicator, located on the electrical system control panel represents the beginning of the generating system and provides an indication of oil outlet temperature from the CSD. If oil temperature is above normal, the CSD load can be decreased by turning the main generator off, allowing the oil to cool. Above 179°C oil temperature, a switch closes causing illumination of the CSD OVERHT (overheat) light. The CSD can be disconnected from the engine drive by the CSD disconnect switch to prevent damage. Once disconnected, the CSD and generator cannot be used since reset must be accomplished mechanically at the CSD unit on the engine.

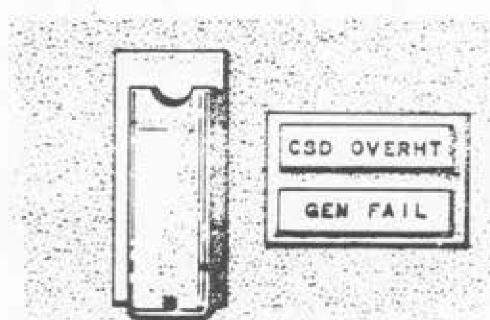


The generator fail light provides an indication of generator mechanical failure. To prevent damage to the generator or CSD, the CSD should be disconnected, and the generator replaced. The CSD is reset by pulling the reset plunger on the CSD unit (engine stopped).

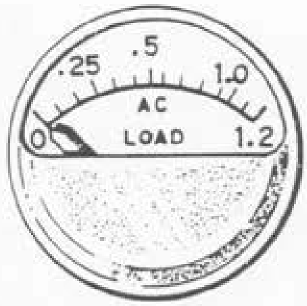
MAIN GENERATOR

The A-C loadmeter provides an indication of the percent load on phase A of the main generator output. Since balanced three-phase loading is used in the aircraft systems, the indication is representative of each phase load. One hundred percent load represents a total three-phase load of 50 KVA. When the generators are in parallel, the meter readings should be equal since the generators are sharing the load.

The GEN OUT light illuminates when the generator switch is "ON" and the generator is not functioning to supply the required load. The light is extinguished when the trouble is cleared. The generator circuit can be reset by positioning the generator switch to "OFF" then "ON". If a differential fault has occured, the circuit will not be reset from the switch. To reset after a differential fault has been cleared, the engine must be stopped and a reset push-button on the generator protection panel

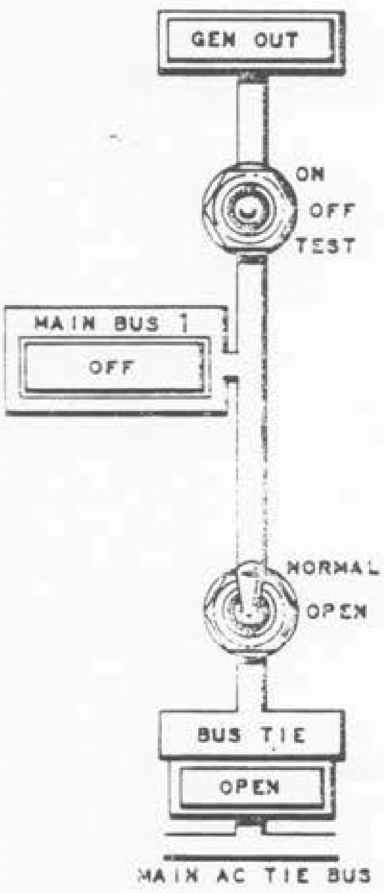


must be depressed. A differential fault is indicated when the GEN OUT light remains illuminated in the "OFF" position of the generator switch.



The "ON" position of the generator switch is used to energized the GLC which connects the generator to the main AC bus load. The "OFF" position deenergizes the GLC and the generator output. The momentary "TEST" position is used to check the generator output voltage and frequency without a load. The switch is spring-loaded from "TEST" to "OFF."

The main bus OFF light illuminates when the bus is not energized or has a low voltage power source. The light is normally extinguished.



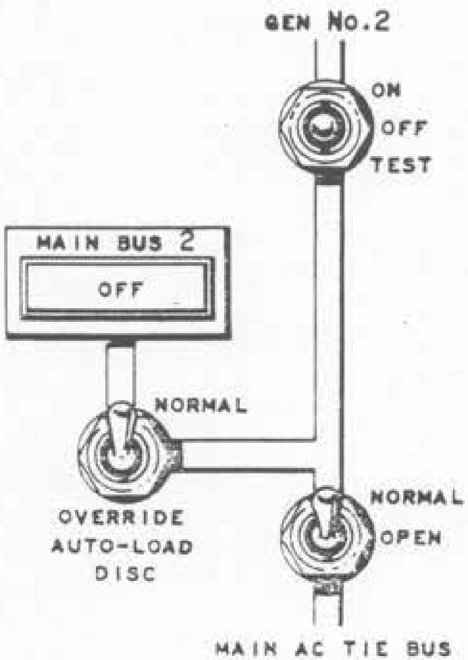
BUS TIE

The "NORMAL" position of the bus tie switch controls the BTC, allowing the generator to automatically supply the main A-C tie bus during generator parallel operation. It also allows the main A-C tie bus source to supply the main A-C bus when the associated generator is not operating. The "OFF" position of the switch opens the BTC, isolating the generator and main A-C bus from the tie bus.

The bus tie OPEN light illuminates when the BTC is not energized. In the "OFF" position of the bus tie switch, the light remains illuminated. In "NORMAL", the light extinguishes when the generator switch is turned "ON" or when the main A-C tie bus is energized. The BTC circuit may be reset if the light fails to extinguish by positioning the bus tie switch to "OFF" then "NORMAL."

All main generators normally operate in parallel, sharing the load equally. The GLC's BTC's and buses are normally energized with the associated light extinguished. Generator isolated operation can be accomplished by positioning the bus tie switches to "OFF". The electrical buses are energized in parallel or isolated operation.

Main A-C buses No. 2 and 3 are controlled by monitor relays. The relays decrease the electrical load when only one engine generator or the auxiliary generator is operating. Monitor relay No. 1 controls the main A-C bus No. 2, and monitor relay No. 2 controls main A-C bus No. 3. Main A-C buses No. 1 and 4 do not have monitor relays.



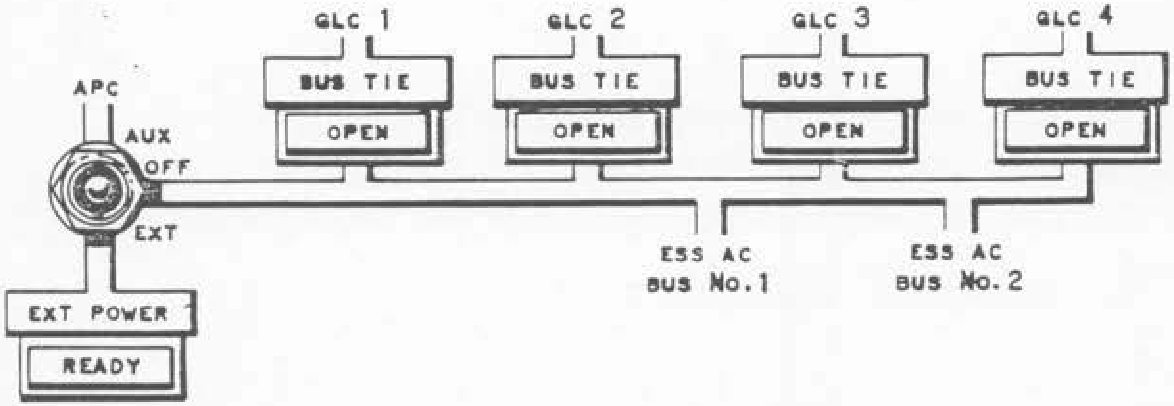
When the auto-load disc switch is in "NORMAL" and two or more main generators are operating, the monitor relays automatically energize. The relays also energize when external A-C power is used. The OVERRIDE switch is used to energize the monitor relay, bypassing the automatic relay control circuit. Override must be used in order to energize main A-C bus No. 2 and 3 when the auxiliary generator or one main generator is the only power source.

The main A-C tie bus is normally energized through the BTC's by the four main generators in parallel. If a generator fails, or is turned off, the other generators pick up the load through the BTC circuit. The main generators share the load equally as indicated on the loadmeters.

EXTERNAL A-C POWER

When the external A-C power plug is inserted into the external power receptacle, the green READY light on the electrical panel illuminates. If the AUX/OFF/EXT power switch is positioned to "EXT", external power will connect to the main A-C tie bus. Since the same switch is used for the auxiliary and external power sources ("AUX" and "EXT" positions) only one power source can be selected at a time. With external power as the only power source, the BTC's close to energize all A-C buses. If a main generator is turned on, the associated BTC opens to isolate the power sources.

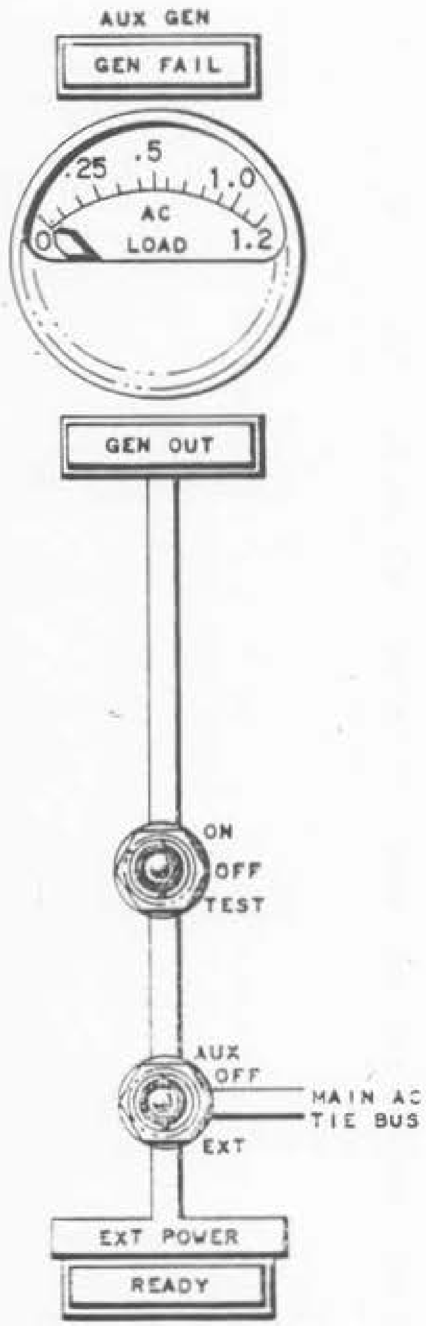
External A-C power or the auxiliary generator cannot be paralleled with the engine generators. If external power or APU power is selected while the engine generators are operating, the four BTC's open. The generators then supply the main buses and the external or APU power is supplied to the tie bus. When a main generator is turned off, the BTC automatically closes, allowing the tie bus to supply the associated main A-C bus.



AUXILIARY (AUX) GENERATOR

The auxiliary generator is driven directly by the APU when the aircraft is on the ground. The generator is used for ground checkout of the aircraft systems. Since a CSD is not used with the APU, an oil temperature indicator, overheat light, and CSD disconnect switch are not provided.

Two switch selections are required to connect the auxiliary generator to the main A-C tie bus. The generator switch allows the generator to supply the tie bus when the switch is "ON", and the AUX/OFF/EXT power switch is in the "AUX" position. When the tie bus is energized, the BTC's close, allowing main A-C buses No. 1 and 4 to be energized. Main A-C buses No. 2 and 3 can also be energized by positioning the AUTO LOAD DISC switch to "OVERRIDE", energizing the monitor relays. If a main generator is turned on, the BTC opens to isolate the power sources. If a fault occurs causing loss of the generator, the circuit can be reset by positioning the control switch to "OFF" then "ON."



MAIN A-C TIE BUS

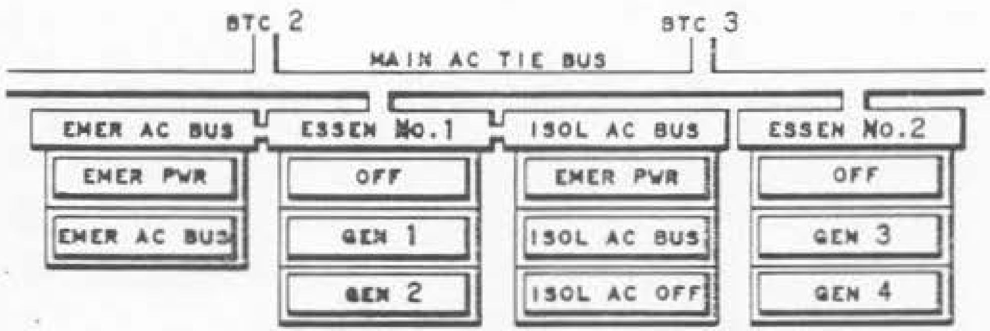
The main A-C tie bus is the source supply point for all aircraft systems except those connected to the four main A-C buses. The tie bus can be energized from the four main generators individually or combined, during flight or on the ground. External power or auxiliary generator power can energize the tie bus when the aircraft is on the ground.

The main A-C tie bus normally supplies power to the essential A-C buses. The essential bus No. 1 supplies the emergency and isolated A-C buses. Warning lights illuminate to indicate the bus condition or alternate power source. Normally all bus lights are extinguished.

The normal power source for essential bus No. 1 is the main A-C tie bus. The first alternate power source for essential No. 1 is Generator No. 1 and the second alternate is Generator No. 2. The "GEN 1" or "GEN 2" lights illuminate to indicate the power source when the tie bus is not energized. If all three sources are not energized, the essential OFF light illuminates indicating bus power failure.

When the essential bus No. 1 is deenergized, the emergency generator automatically turns on the supply the emergency and isolated A-C buses. In this condition the EMER PWR - EMER AC BUS and the EMER PWR - ISOL AC BUS lights illuminate. The lights identify the bus and power source. If the isolated AC bus is not energized, the ISOL AC OFF light illuminates and the other two lights remain extinguished.

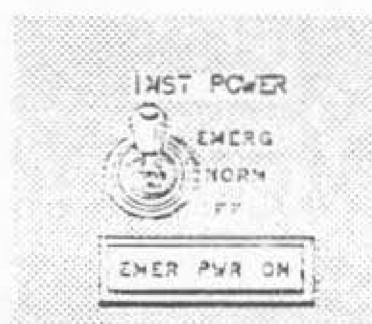
Essential bus No. 2 is similar to bus No. 1 except generator No. 4 is the first alternate power source and generator No. 3 is the second. Essential bus No. 2 does not control the emergency generator and cannot be used to supply the isolated and emergency A-C buses.



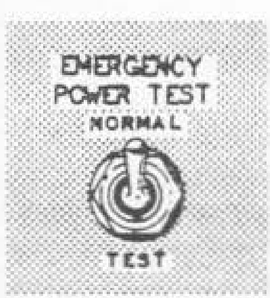
EMERGENCY GENERATOR

The emergency generator has priority over the normal power source to supply the isolated and emergency buses. The generator is controlled by the instrument power switch on the pilot's instrument panel. In the "OFF" position of the switch the generator will not operate. In the "NORMAL" position generator operation is automatic, and loss of power to the essential A-C bus No. 1 causes the generator to turn on. While on, the emergency generator supplies power to the emergency and isolated A-C and D-C buses and the EMER PWR ON light illuminates.

In the "EMERG" switch position, the automatic function is bypassed and the generator continuously supplies the emergency and isolated buses. The generator is driven by a hydraulic motor and requires hydraulic pressure from the No. 2 hydraulic system. The generator and associated components are located in the No. 2 hydraulic service center.



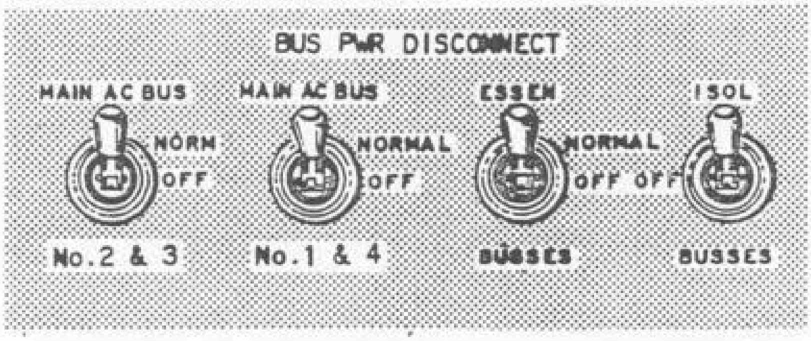
An emergency power test switch at the flight engineer's station allows the voltage and frequency of the generator to be checked under a "No-load" condition. The switch is springloaded from "TEST" to "NORMAL."



BUS POWER DISCONNECT

Bus power disconnect switches provide bus isolation to remove power from the various buses in case of internal fire or emergency. The "NORMAL" switch positions allow automatic control of the system. The "OFF" positions isolate the buses by controlling relays and contactors.

With the main generators operating in parallel and the main A-C buses' No. 2 and 3 switch in the "OFF" position, the two monitor relays deenergize causing loss of main A-C buses No. 2 and 3. The main A-C buses No. 1 and 4 switch opens GLC 1 and 4 and BTC 1 and 4, causing loss of main A-C buses No. 1 and 4. The essential buses switch causes the loss of both essential A-C buses, and the emergency generator turns on to supply isolated and emergency AC and DC. Loss of the essential A-C buses results in failure of the TR units, resulting in loss of main A-C and D-C buses. The only buses remaining energized are the emergency A-C and D-C buses, which are energized by the emergency generator. When the switches are positioned to "NORMAL" the system is again energized from the parallel generators.

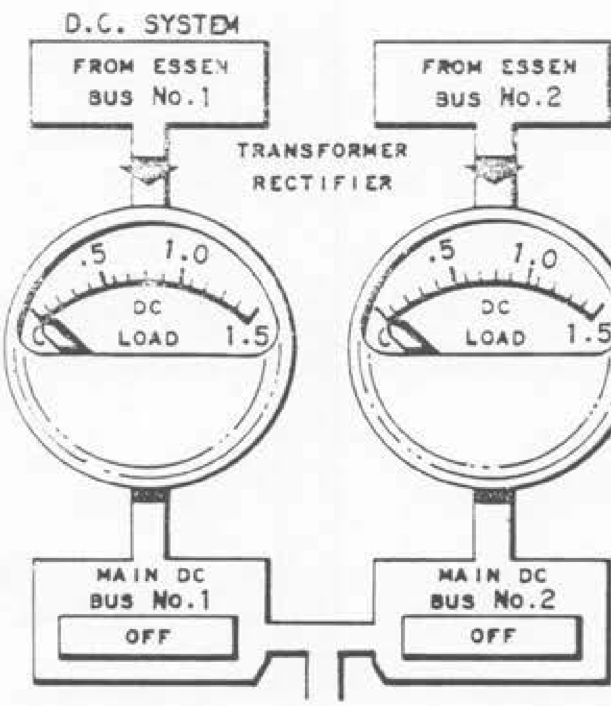


D-C SYSTEM OPERATION

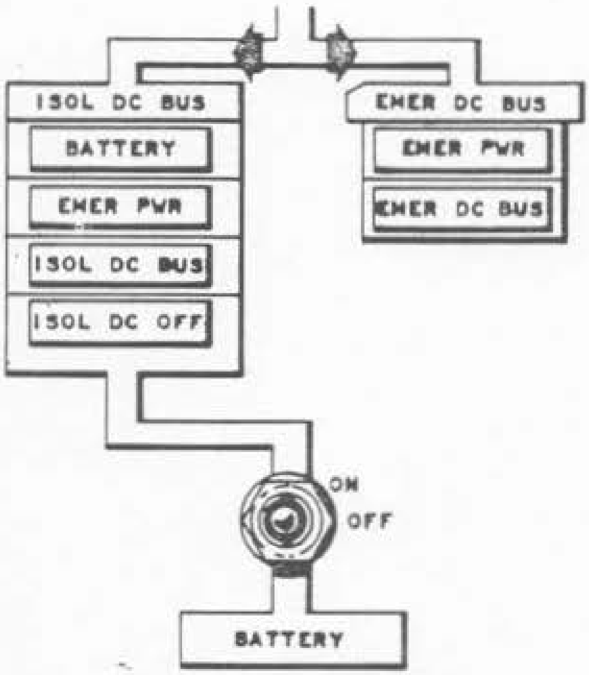
The D-C system of the aircraft receives 28-volt DC from two Transformer-Rectifier (TR) units. These units change three-phase from the essential A-C buses to 28 volt DC to the main D-C buses.

TR UNITS

Loadmeters indicate the percent of the load carried by each TR unit. One hundred percent load is 200 amperes. The output of TR unit No. 1 is supplied to main D-C bus No. 1, and TR unit No. 2 supplied main D-C bus No. 2. The main D-C buses are paralleled to share the aircraft loads. If the main D-C buses are not energized, the main bus OFF lights illuminate.



The main D-C buses supply 28-volt DC to the isolated

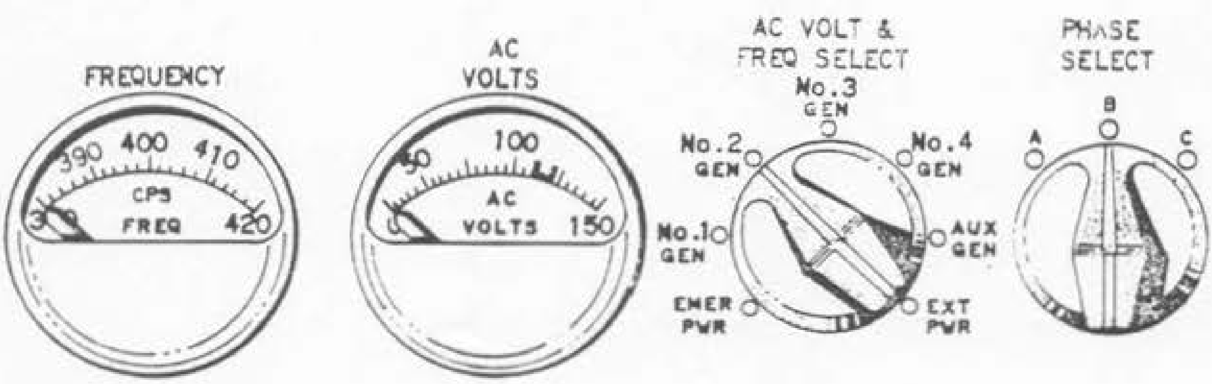


and emergency D-C buses. If the isolated D-C bus is not energized, the ISOL DC OFF light is illuminated. When the emergency generator is supplying DC to the isolated and emergency buses, the EMER PWR - ISOL DC BUS and EMER PWR - EMER DC BUS lights are illuminated.

BATTERY

An additional power source for the isolated D-C bus is the aircraft battery. When the battery switch is "ON", the battery connects to the isolated D-C bus and the BATTERY light illuminates. When main D-C bus voltage is supplied to the isolated D-C bus, the battery is charging and the light extinguished. The battery switch "OFF" position disconnects the battery from the bus. When emergency generator power is in use, relays disconnect the battery from the isolated bus.

Battery voltage is required when external power is not available for APU ignition and control. The APU is started hydraulically from an accumulator which is part of hydraulic system No. 3. The engines are started pneumatically with compressed air from the APU.



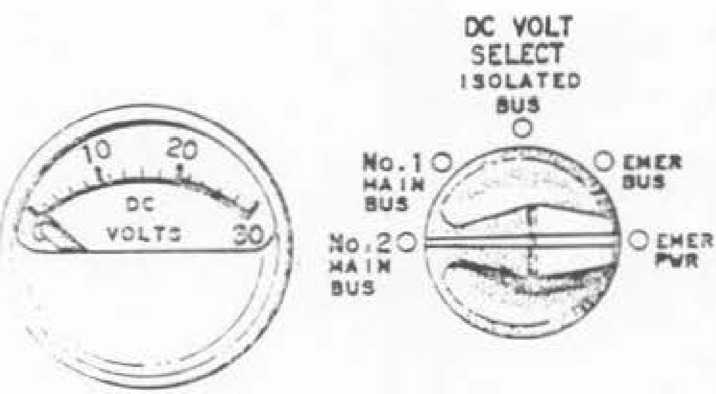
ELECTRICAL METERS

The frequency meter and A-C voltmeter are connected in parallel to provide a voltage and frequency indication for the generators and external power. The A-C VOLT & FREQUENCY SELECT switch, and PHASE SELECT switch determine the meter selections.

The frequency of the six generators and external A-C power can be displayed on the 380-420 Hertz scale of the frequency meter. The voltmeter provides an indication of the phase voltage (A-B-C) for each of the generators, or external A-C power, on a 0 to 150-volts scale. The frequency should be 400 Hertz and the voltage 115-volt AC. The frequency is controlled by engine speed through the CSD, and the voltage is controlled by the voltage regulator unit.

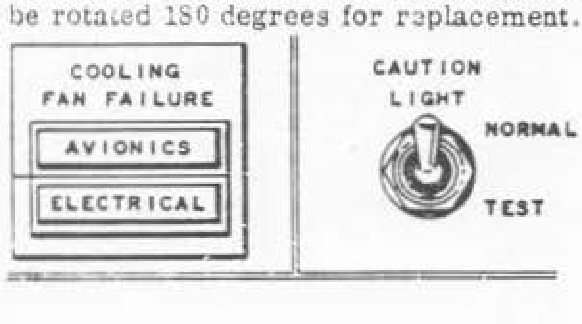
A D-C voltmeter and selector switch provides an indication of the D-C bus voltages as selected. The meter scale is 0 to 30-volt DC and should indicate 28 volts, DC. When the battery is the only power source, the isolated bus reading should be 24-volt DC.

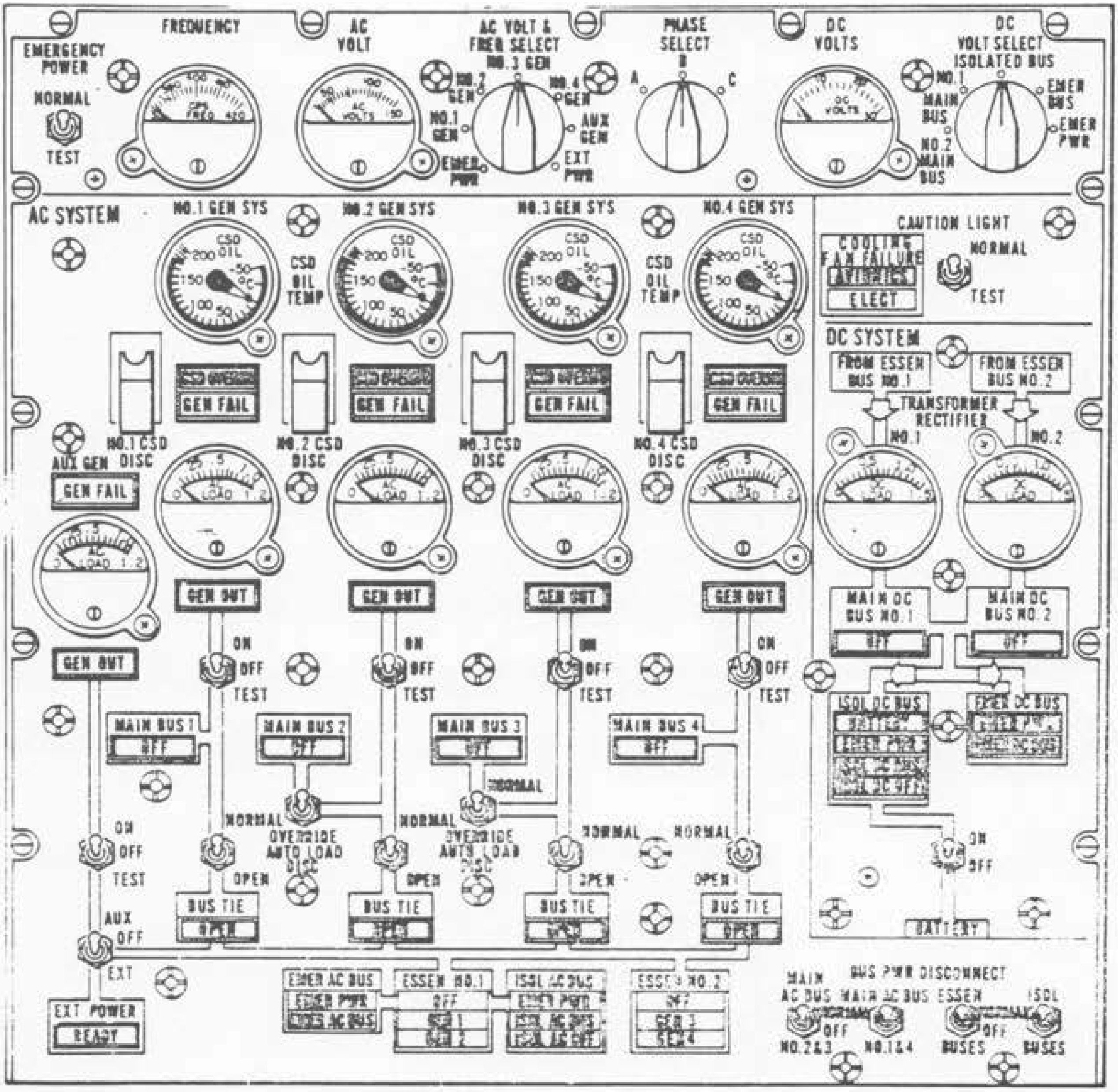
COOLING FANS



Dual cooling fans are installed in cooling ducts of the electrical and avionics cooling system. If the fans fail, the warning lights illuminate. The AVIONICS fan circulates air through the avionics equipment in the left and center avionics equipment racks. The ELECTRICAL fan circulates air around the electrical equipment racks.

A caution lights TEST - NORMAL switch, springloaded to "NORMAL", allows simultaneous test of all warning lights at the flight engineer's station. If a light fails, the lens may be rotated 180 degrees for replacement.





FLIGHT ENGINEERS ELECTRICAL CONTROL PANEL

A-C POWER SYSTEM

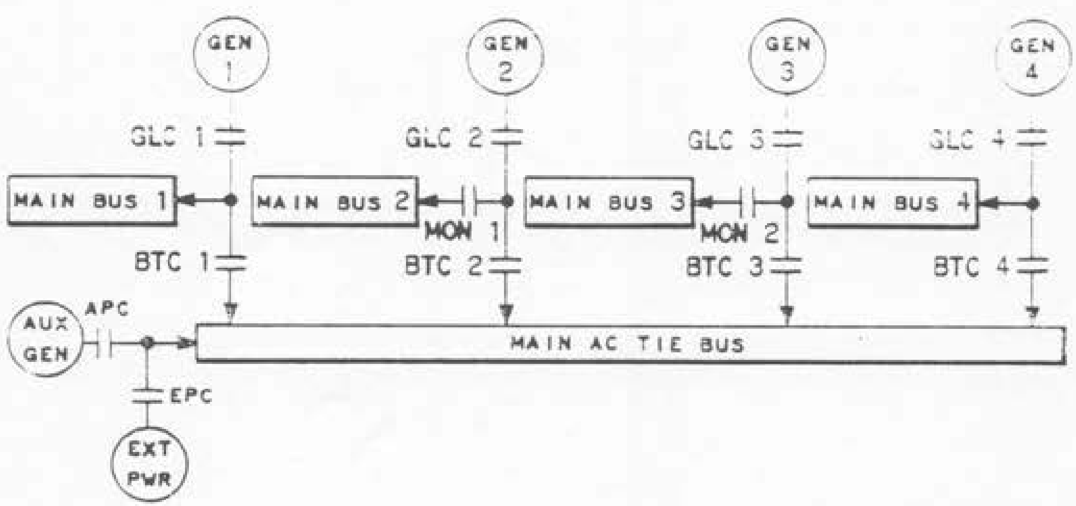
GENERAL

Electrical system power is normally supplied by four engine-driven A-C generators operating in parallel. Power can also be supplied from an external source, or an APU-driven generator, for ground checkout. Each source is capable of supplying sufficient power to checkout the electrical systems. Care should be exercised during ground checkout to ensure that overloading does not occur, since generator cooling air temperature is higher on the ground.

An emergency A-C/D-C generator can be used if hydraulic pressure is available to check part of the systems. The generator is quite small and can be used with the isolated and emergency A-C and D-C buses only.

BUS DISTRIBUTION

The primary A-C buses include four main A-C buses, two essential A-C buses, main A-C tie bus, isolated A-C bus, and emergency A-C bus. Other minor buses, such as the avionics and navigation buses, are energized by the primary buses.

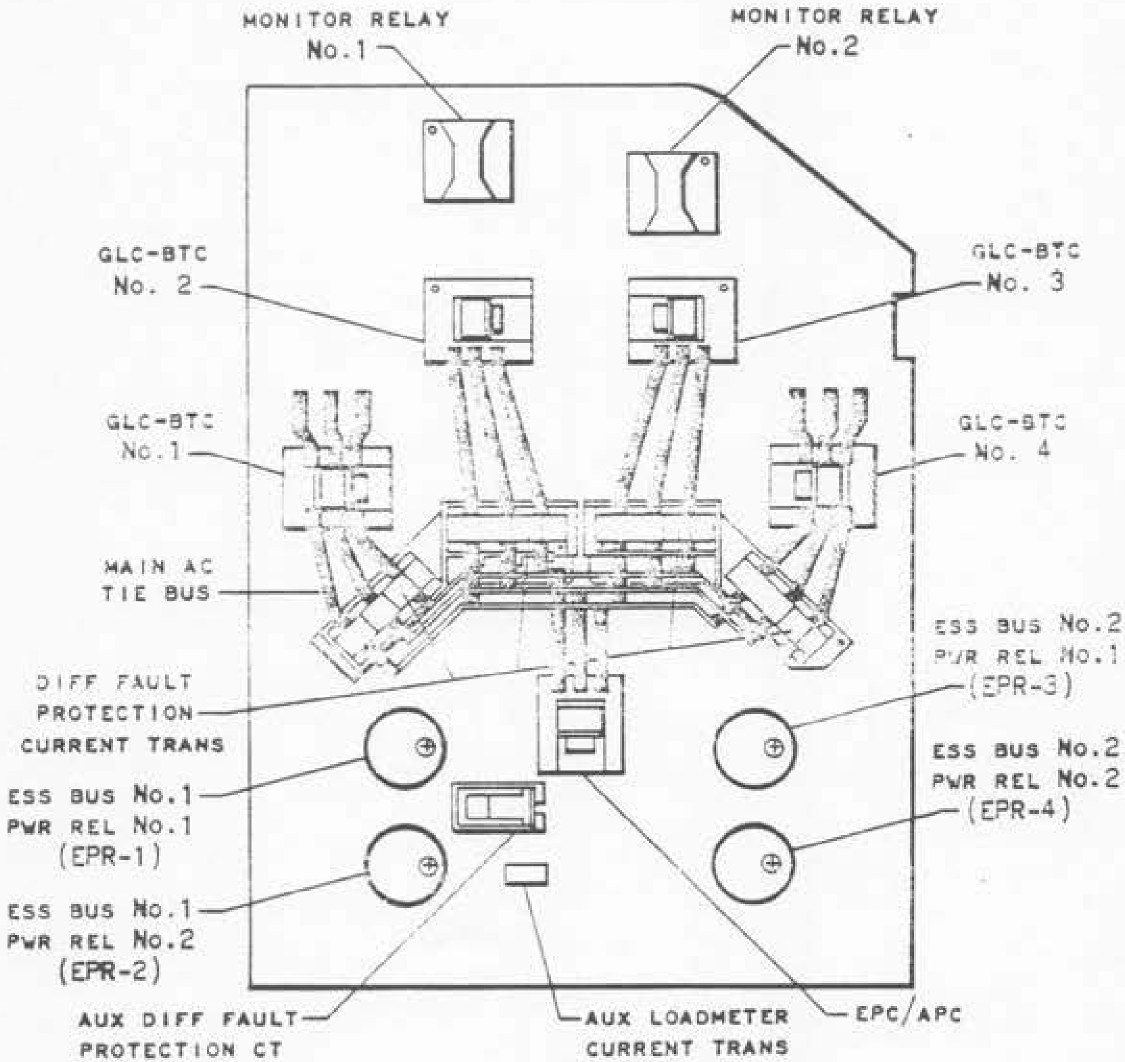


AC DISTRIBUTION

EXTERNAL POWER

External A-C power connects to the main A-C tie bus through an External Power Contactor (EPC). The Bus Tie Contactors (BTC) automatically close when the tie bus is energized. Main A-C buses 1 and 4 energize from the tie bus through the BTC's.. Main buses 2 and 3 are energized through BTC's and Monitor Relays. The monitor relays automatically energize when external power is used.

If an operational main generator is turned on while external power is in use, the BTC of the associated generator opens to isolate the generator and respective main A-C bus from the tie bus. The Generator Line Contactor (GLC) closes, energizing the associated main bus from the generator. External power continues to supply the tie bus and other main and essential buses, but the sources do not parallel. The relays and contactors associated with the generators and bus distribution systems are located in the main A-C distribution center.



MAIN AC DISTRIBUTION CENTER

AUX GENERATOR

When the AUX (APU) generator is used, the Auxiliary Power Contactor (APC) is energized to connect the generator to the main A-C tie bus. The EPC and monitor relays are open when auxiliary power is used. Main A-C buses 1 and 4 are energized from the tie bus through the BTC's. If "OVERRIDE" is selected on the AUTO LOAD DISC (ALD) switches, the monitor relays energize, allowing the auxiliary generator to supply main A-C buses 2 and 3. If the auxiliary generator is in use and a main generator is turned "ON," the respective BTC will open to isolate the power sources. The main generator supplies the associated main A-C bus through the GLC, and the auxiliary generator supplies the tie bus and other main buses. Main buses 2 and 3 cannot be energized from the auxiliary generator unless "OVERRIDE" is selected.

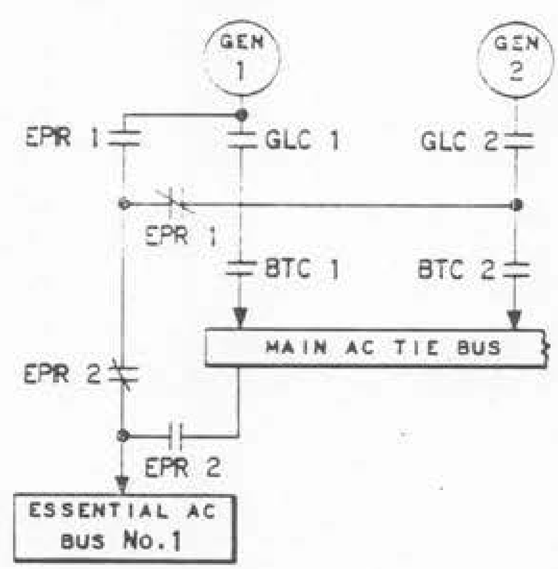
MAIN GENERATORS

The main generators normally supply the individual main buses through GLC's, and parallel at the main A-C tie bus through the BTC's. Monitor relays 1 and 2 automatically energize when two or more main generators are operating. "OVERRIDE" must be selected to energize the monitor relays when only one main generator is operating.

When a main generator is turned to the "ON" position, the respective GLC and BTC close thus energizing the main A-C bus and the main A-C tie bus. The tie bus causes the other BTC's to close. As the remaining generators are turned to the "ON" position, the GLC's and BTC's energize through the automatic paralleling circuits. With all four generators operating, the BTC's, GLC's, and monitor relays are energized and the generators share the load.

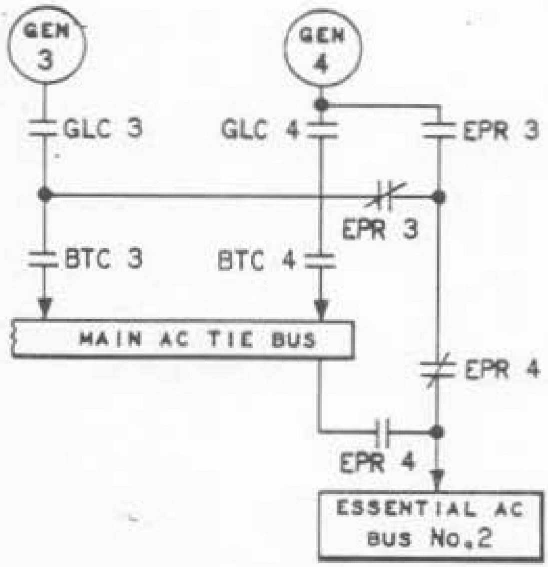
ESSENTIAL A-C BUSES

The essential buses are controlled by two power relays for each bus. The normal power source is the main A-C tie bus. When the tie bus is energized, the No. 2 Essential (Bus) Power Relays (EPR-2 and EPR-4) energize, and both essential buses receive power from the tie bus. If the tie bus fails, or is not energized, EPR-2 and EPR-4 deenergize. Essential power is then obtained from alternate power sources through EPR-1 and EPR-3.



ESSENTIAL AC BUS NO. 1 POWER SOURCES

Main generator 1 is the first alternate and generator 2 the second alternate source for essential A-C bus 1. Main generator 4 and 3 are the first and second alternates for essential A-C bus 2. EPR-1 and EPR-2 determine which alternate source is used. If the first alternate power source is operating, EPR-1 and EPR-3 are energized and generator 1 supplies essential bus 1. Generator 4 supplies essential bus 2. When the first alternate source is not operating, the relays are deenergized and the second alternate supplies the bus.



ESSENTIAL AC BUS NO.2 POWER SOURCES

The alternate power source in use causes illumination of GEN 1 or GEN 2 light for essential bus 1, and a GEN 4 or GEN 3 light for essential bus 2. When the main A-C tie bus or alternate sources are not energized, bus power fails, and the main and essential bus OFF lights illuminate. The tie bus causes all lights to extinguish when energized.

SUMMARY CHART

The following summary chart provides a listing of primary power sources, relays, contactors, and buses. As each power source or combination of power sources are energized, relays and contactors energize to provide power to the correct buses. The buses are listed and power sources identified under various operational conditions. Switches necessary for operation are considered to be in the "ON" or "NORMAL" positions as required.

POWER SOURCES						RELAYS - CONTACTORS																AC BUSES						
						EPC	APC	G L C				MONITOR		BTC-NORMAL				E P R				MAIN				TIE BUS	ESS	
EXT	AUX	G1	G2	G3	G4			1	2	3	4	1	2	1	2	3	4	1	2	3	4	1	2	3	4		1	2
*						*						*	*	*	*	*	*		*		*	E	E	E	E	E	E	E
	*						*							*	*	*	*		*		*	A			A	A	A	A
		*						*						*	*	*	*	*	*		*	1			1	1	1	1
		*	*					*	*			*	*	*	*	*	*	*	*		*	P	P	P	P	P	P	P
		*	*	*				*	*	*		*	*	*	*	*	*	*	*		*	P	P	P	P	P	P	P
		*	*	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	P	P	P	P	P	P	P
*		*	*	*	*	*		*	*	*	*	*	*	— OPEN —				*	*	*	*	1	2	3	4	E	E	E
	*	*	*	*	*		*	*	*	*	*	*	*	— OPEN —				*	*	*	*	1	2	3	4	A	A	A
*		*				*		*				*	*		*	*	*	*	*		*	1	E	E	E	E	E	E
	*	*					*	*							*	*	*	*	*		*	1			A	A	A	A
	*	*	*				*	*	*			*	*			*	*	*	*		*	1	2	A	A	A	A	A
*		*	*			*		*	*			*	*			*	*	*	*		*	1	2	E	E	E	E	E
*						*						*	*	BTC'S OPEN					*		*					E	E	E
	*						*								〃		〃		*		*					A	A	A
		*	*	*	*			*	*	*	*	*	*		〃		〃	*		*		1	2	3	4		1	4
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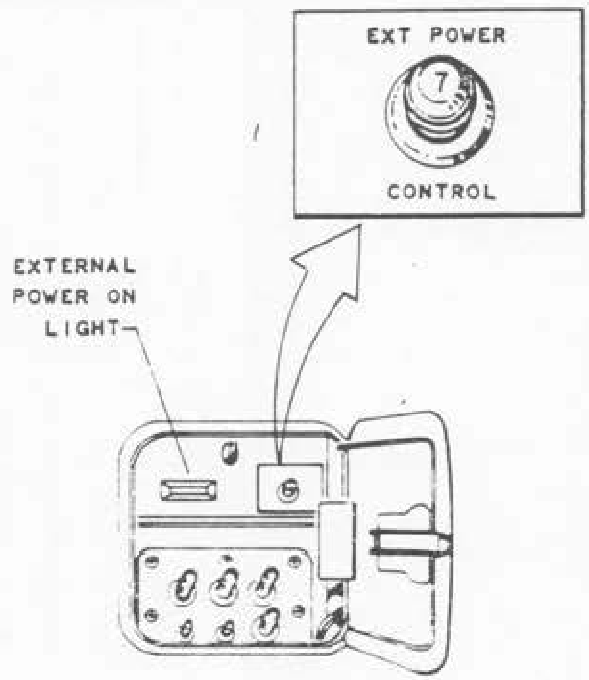
		*	*					*	*			*	*		〃		〃	*				1	2				1	
		*			*			*			*	*	*		〃		〃	*		*		1			4		1	4
					*						*				〃		〃			*					4			4
				*						*					〃		〃											3

* - ENERGIZED
E - EXTERNAL POWER
A - AUX GEN POWER
1-4 - MAIN GEN POWER
P - PARALLEL SOURCES
BLANK - DEENERGIZED OR NO POWER
EPR - ESSENTIAL POWER RELAYS

A-C DISTRIBUTION RELAY CHART

EXTERNAL A-C POWER

Power from an external A-C source can be supplied to all A-C buses. The external power unit should be capable of 50/60 KVA, three-phase 115/200-volt AC at a frequency of 400 Hertz. Phase sequence should match the phase sequence (A, B, C) of the aircraft's generating systems. Incorrect phase sequence, or loss of individual phase voltage, prevents use of the unit with the aircraft.



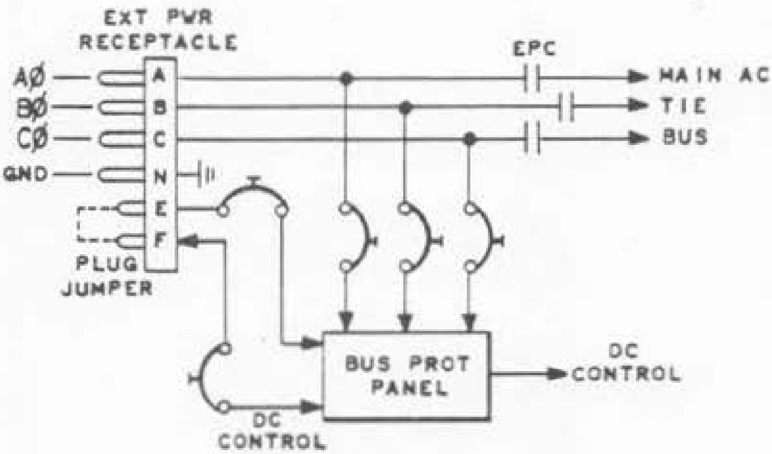
EXTERNAL POWER RECEPTACLE

The external power system consists of a receptacle, external power contactor, and bus protection panel. The receptacle is on the forward right side of the fuselage. The contactor is in the main A-C distribution center, and the protection panel is in the electrical equipment rack.

The receptacle is in a recessed compartment which also contains an external power control circuit breaker and an external power "on" light. The circuit breaker is in the control circuit for external power and prevents the use of external when pulled. The light illuminates when the external power unit is supplying power to the aircraft systems.

The receptacle has four large pins and two small pins. Three of the large pins carry three-phase (A, B, C), 115-volt, AC from the power unit. The fourth pin is grounded to the aircraft structure. The small (short) pins are used in the control circuit to prevent arcing at the receptacle. No load can be applied until the plug is firmly engaged and the short control pins are mated.

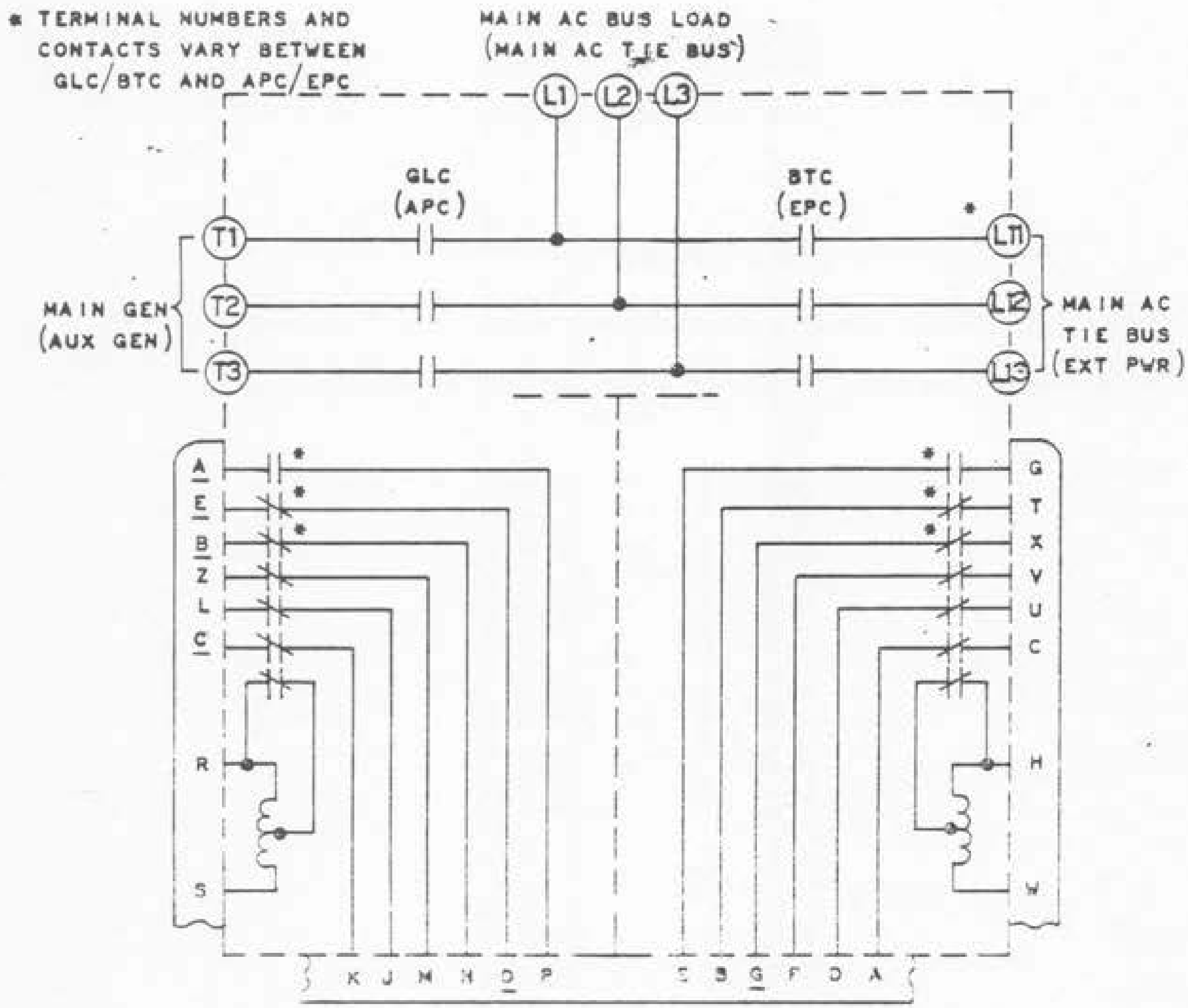
Control voltage is provided from the bus protection panel which changes the three-phase AC from the power unit to a D-C output. A jumper is provided in the plug, or GPU, between the small pins. When the plug is inserted into the receptacle, control voltage is supplied through the jumper to the aircraft's external power circuit for use with the EPC. If the power source is operating properly, the green EXT POWER READY light on the control panel illuminates.



EXTERNAL POWER CONTROL

EXTERNAL POWER CONTACTOR/AUXILIARY POWER CONTACTOR (EPC/APC)

This contactor is a relay containing interlock switches and heavy-duty relay contacts. Two functional contactors are enclosed in one housing. The EPC is energized when external A-C power is selected as a power source. The APC is energized when the auxiliary generator is selected. The actuators are mechanically interlocked to prevent simultaneous use of the contactors. The system is also electrically interlocked by the AUX/EXT power selector switch and the contacts of the GLC's and BTC's of the main generators.



GLC/BTC - EPC/APC , CONTACTOR SCHEMATIC

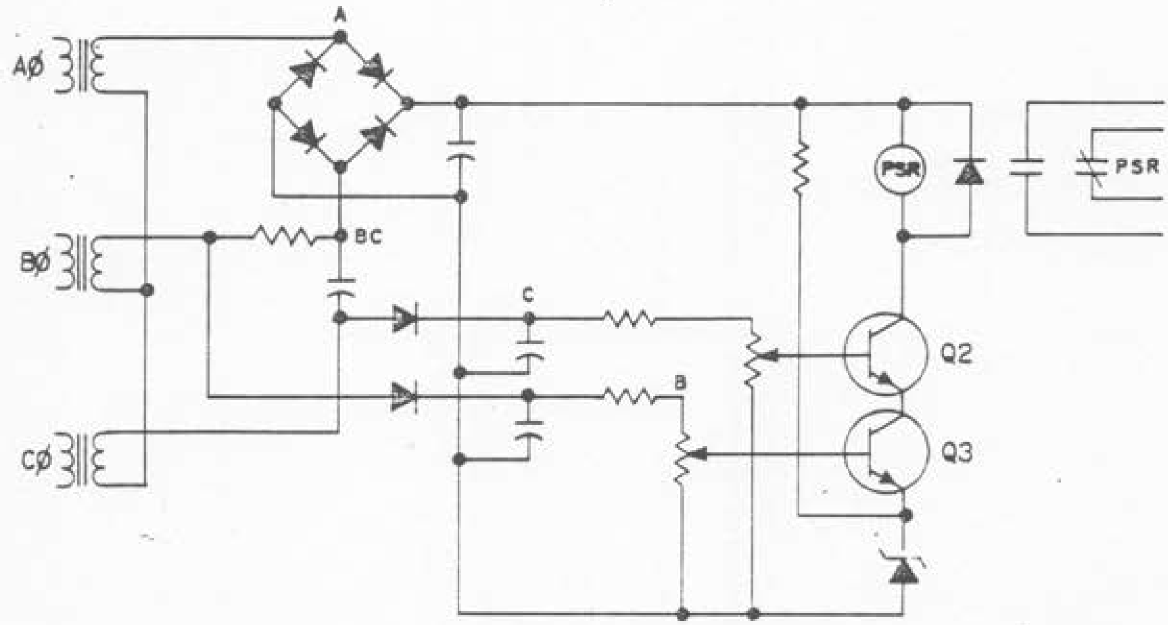
BUS PROTECTION PANEL

A combination of static components and relays is provided in the protection panel. The relays provide undervoltage and phase sequence protection when external power is being used. Panel relays are the Phase Sequence Relay (PSR), LOR, Auxiliary External Power Relays (AER-1 and AER-2), and the Synchronizing Bus Relay (SBR). The panel controls the BTC's to allow the main A-C buses to be energized from external, auxiliary generator, or main generator power.

PHASE SEQUENCE CIRCUIT

Three-phase A-C voltage is supplied to stepdown transformers and full-wave rectifiers in the bus protection panel. The D-C output is used to control the

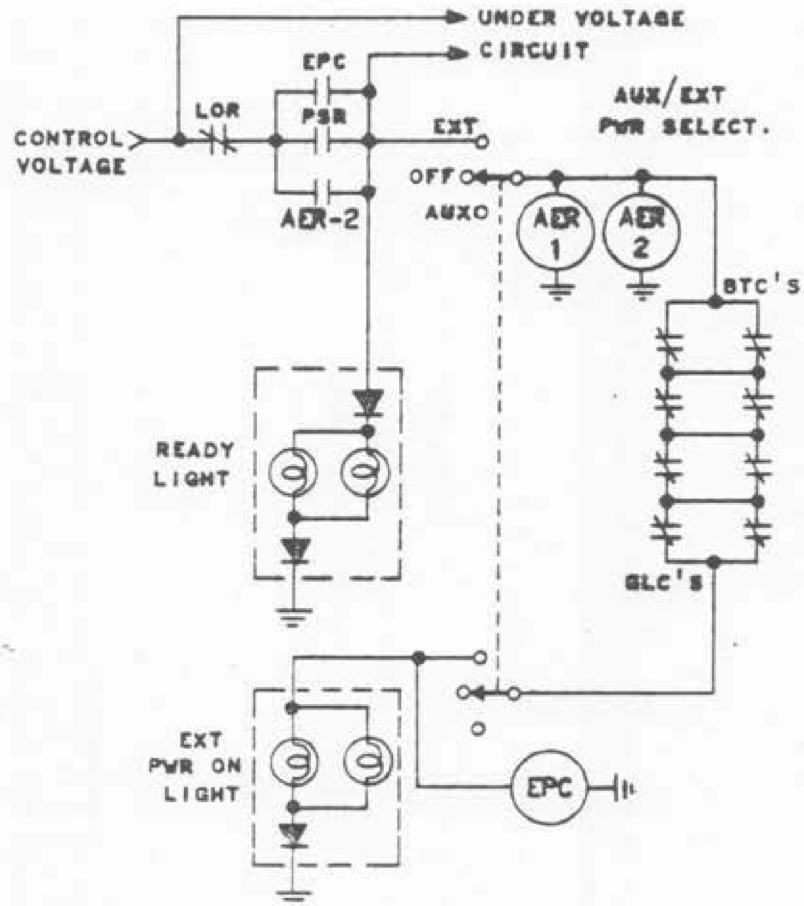
EPC and undervoltage circuit; AG is supplied to the phase sequence circuit. Phase sequence must be A, B, C or the PSR cannot energize.



PHASE SEQUENCE CIRCUIT

The phase sequence circuit consists of the PSR in series with two transistor switches and a Zener diode. The Zener diode establishes a D-C reference voltage for the transistor switches. Collector voltage for the transistors is obtained from a full-wave bridge rectifier which produces a pulsating D-C output. Output voltage is proportional to the phase A to phase BC voltage inputs. Phase BC is obtained by phase-shifting phase C and adding the result to phase B at one side of the bridge rectifier. Phase A is applied to the other side of the bridge. The positive pulsating D-C output is filtered by a capacitor and applied to the PSR in the transistor collector circuit. The PSR is energized when both transistor switches conduct. Phase B and phase C voltage is applied to half-wave rectifiers and filters then to the base of the transistor switches. When Q3 base voltage (1/2 of phase B) is more positive than the Zener voltage reference, the transistor can conduct. At the same time Q2 base voltage (1/2 of phase C) must be more positive than the collector of Q3. When its condition exists, both switches conduct to energize the PSR. Any other phase sequence, or loss of phase voltage, will not allow the PSR to energize. The PSR is energized when the three-phase average A-C input is above 93 volts, AC.

The energized PSR completes the control circuit to the external power READY light and opens the undervoltage sensing circuit. If the power selector switch is in "EXT," the EPC is energized, thus connecting external power to the main

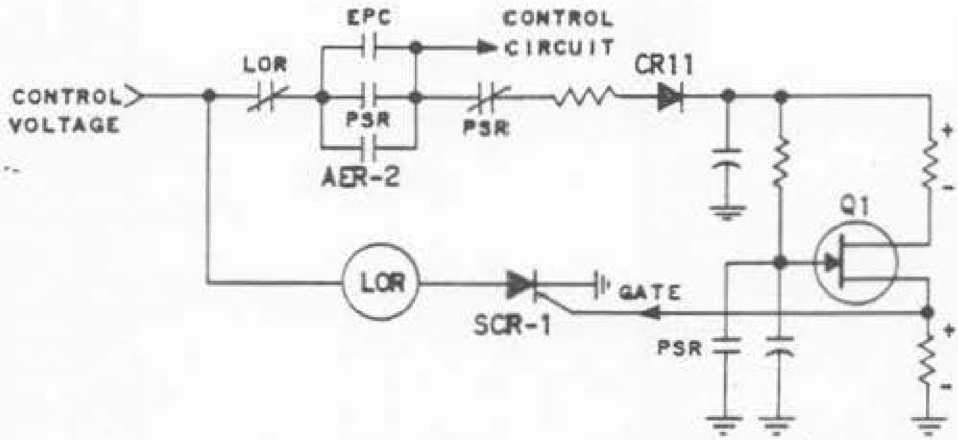


EPC CONTROL

A-C tie bus. A combination of GLC-BTC contacts controls the EPC to ensure that paralleling of internal and external power sources does not occur. A set of EPC contacts bypass the PSR contacts when energized, allowing the PSR to deenergize during low-voltage conditions. A low-voltage condition exists when the three-phase average is 93 volts, AC, or less.

UNDERVOLTAGE CIRCUIT

The undervoltage circuit is normally open due to PSR contacts. A second set of PSR contacts bypasses a time delay capacitor (C1). During a low-voltage condition, the PSR is deenergized, and the delay capacitor starts charging. Emitter voltage of a unijunction transistor (Q1) is controlled by the charging capacitor. If the low-voltage condition exists for 3 to 7 seconds, the capacitor is charged to a sufficient voltage to cause the transistor switch to conduct. Current between the two bases of the unijunction transistor develops a positive D-C output



UNDERVOLTAGE CIRCUIT

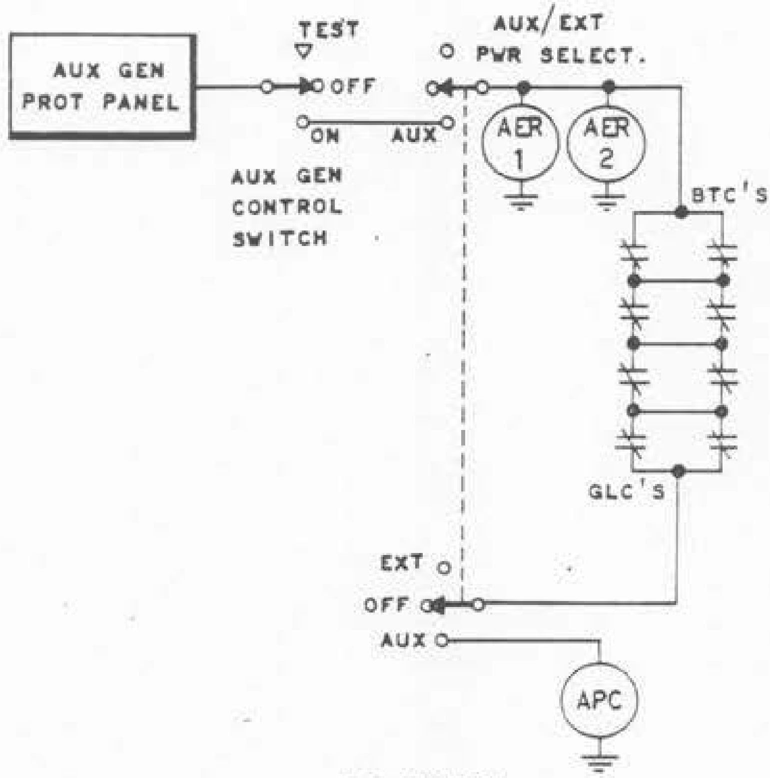
voltage. The output is supplied to a Silicon Control Rectifier (SCR). The D-C voltage gates the SCR into conduction, energizing the LOR.

The energized LOR opens the D-C control circuit to the EPC and extinguishes the READY light. External power control voltage keeps the LOR energized through the SCR which is conducting. The SCR conduction can be stopped (reset) only by removing the control voltage. To reset the circuit, the EXT POWER CONTROL circuit breaker can be momentarily pulled to deenergize the LOR. Other methods of reset would be to remove the external power plug from the receptacle or to shut down the ground power unit. Normal power can be restored after reset of the LOR is accomplished. External A-C power cannot be used until the circuit is reset.

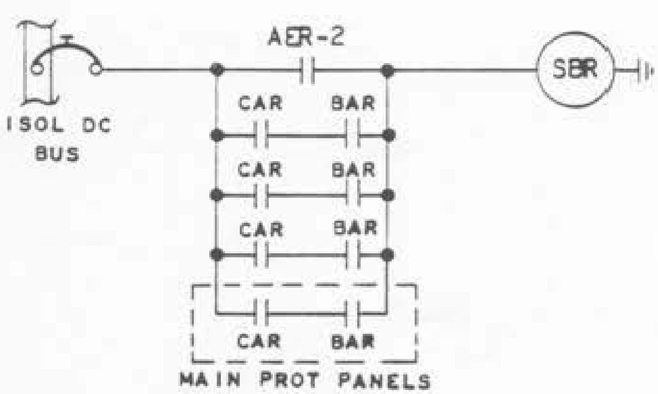
The "AUX" position of the power selector switch is used to energize the APC, thus connecting auxiliary generator power to the main A-C tie bus. The GLC-BTC combination of contacts again prevent paralleling of power sources. Additional relay contacts for the EPC or APC are provided by the AER-1 and AER-2 in the protection panel. The relays energize when the power selector switch is in "EXT" or "AUX" position. When the auxiliary generator is used, a set of AER-2 contacts bypasses the PSR contacts for the undervoltage circuit. External undervoltage protection is provided even though external power is not in use.

SYNCHRONIZING BUS RELAY CIRCUIT

The SBR circuit is energized through contacts of AER-2 when external or auxiliary generator power is used. The SBR is also energized through the main generator protection panels when the main generators are connected to the main A-C tie bus. Contacts of the SBR allow the BTC's to energize when external or auxiliary power is used or will allow the BTC to energize when the generator switch is in the "OFF" position. The Contactor Auxiliary Relay (CAR) is energized when the GLC is energized, and the BTC Auxiliary Relay (BAR) is energized when the BTC is energized. The SBR is energized through series BAR-CAR contacts when a generator is supplying the main A-C tie bus, automatically energizing the BTC of an inoperative generator.



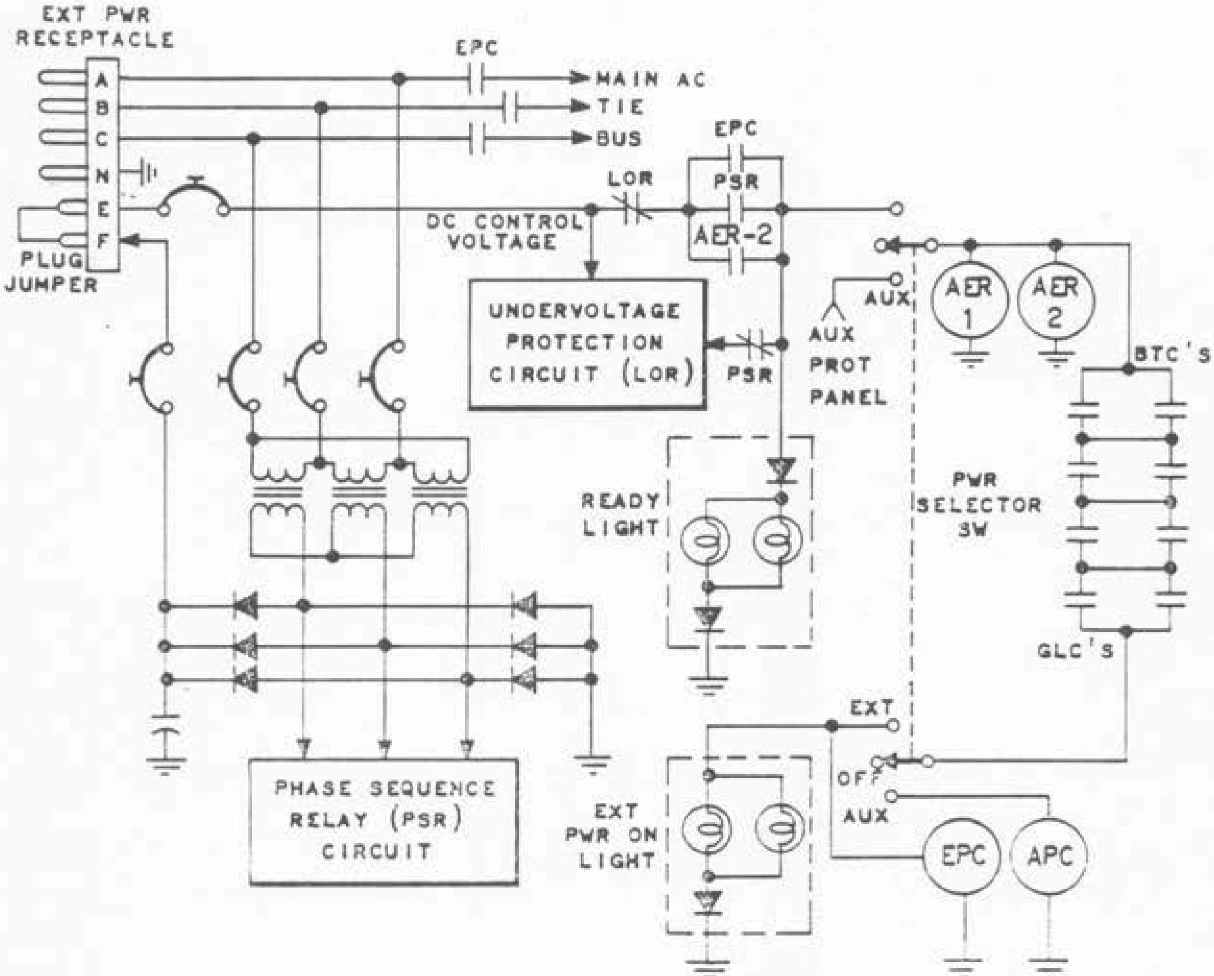
APC CONTROL



SBR CONTROL

MAIN GENERATOR SYSTEM

The main generating system consists of four generators, CSD's, Voltage Regulators (VR's), protection panels, and load controllers. Each generator is bolted to a CSD unit which mounts on the engine accessory drive case. A Quick Attach-Detach (QAD) bolt and ring secures the CSD to the engine. The QAD is used to remove the generator and



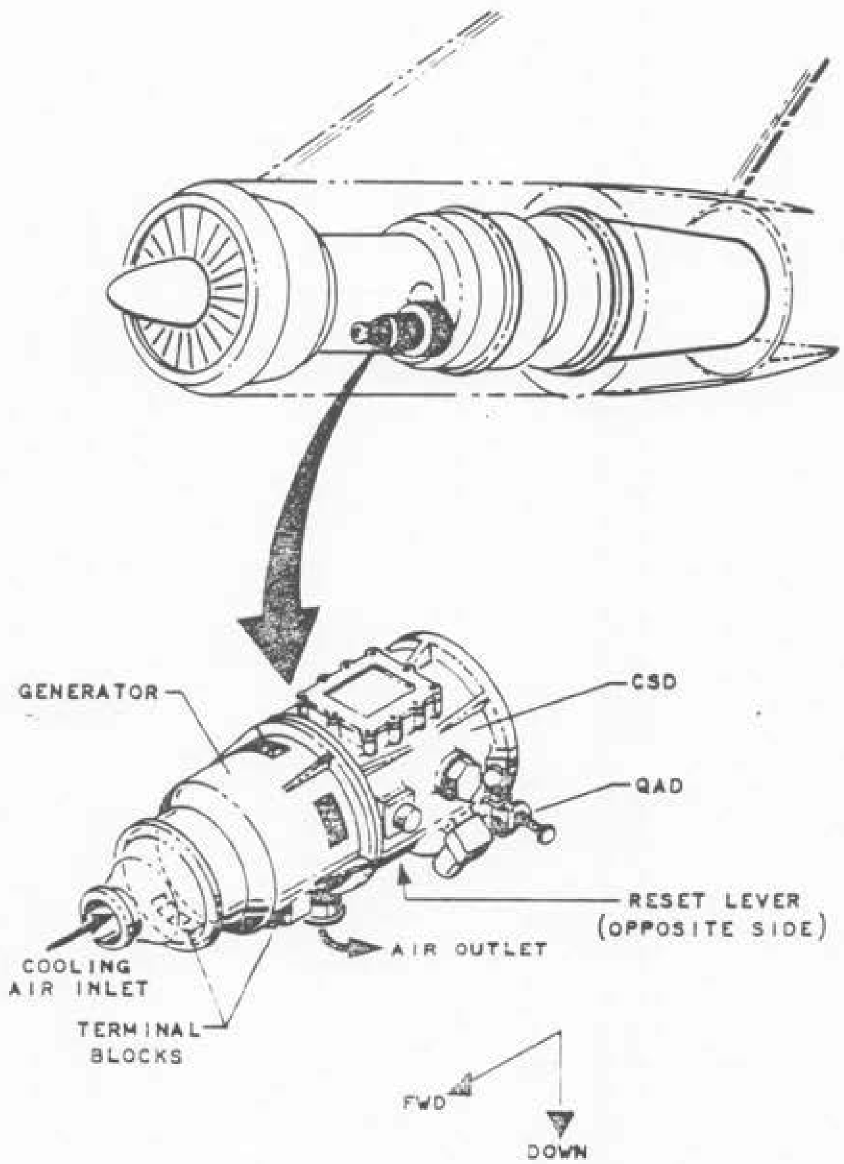
EXTERNAL AC POWER SCHEMATIC

CSD as a unit for replacement. Protection panels, VR units, and the load controllers are installed in the electrical equipment rack.

The generating systems are practically identical. The protection panels contain circuits and relays for control and protection of the generators. The voltage regulator maintains the generator voltage output at 115 volts, AC. The load controller is used in generator parallel operation to control the CSD for load equalization between generators.

GENERATOR

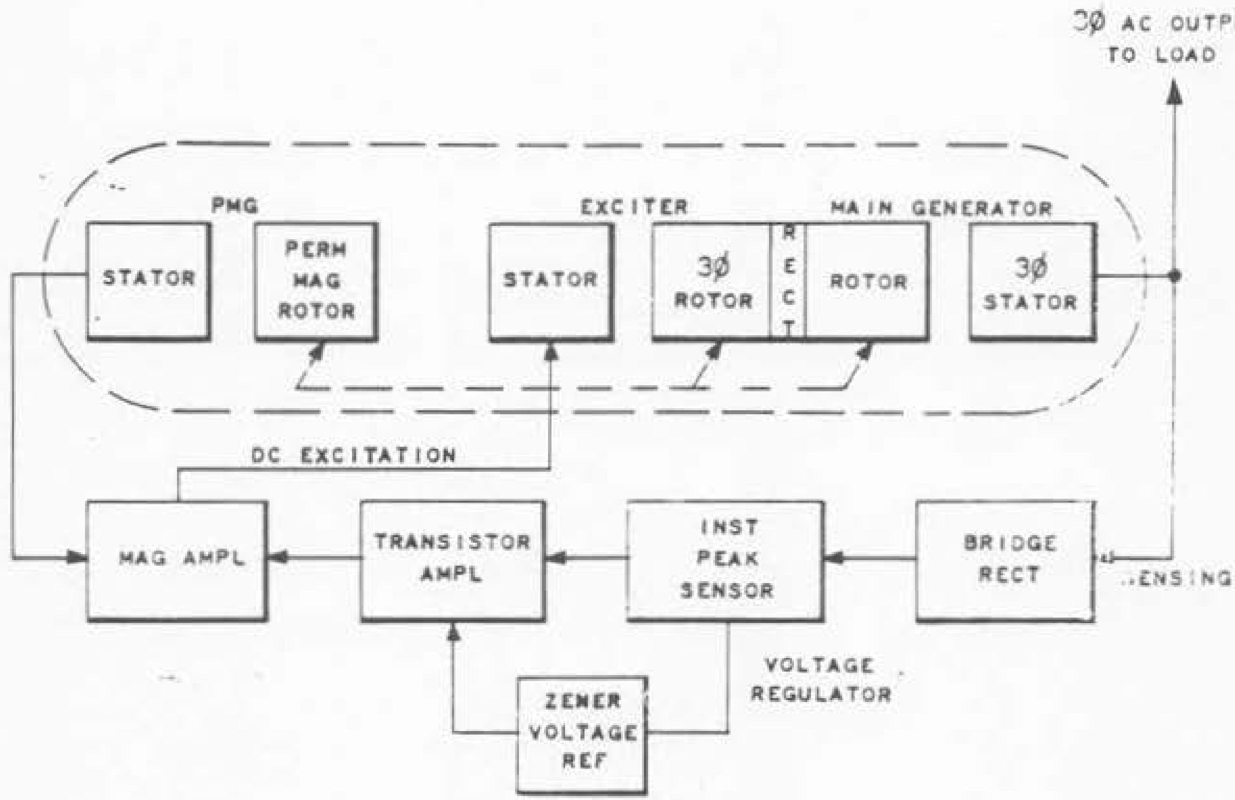
The generator is an electro-mechanical device which converts mechanical energy into electrical energy. The generator electrical output rating is 40 KVA but each generator has a thermal output rating of 50 KVA as a continuous power source.



ENGINE DRIVEN GENERATOR LOCATION

Cooling is provided by the engine fan discharge air. Output three-phase voltage rating is 120/208 volts, AC, but is maintained at 115/200 volts, AC, by the VR unit for use with the load. The CSD is a hydraulic mechanical constant speed drive which provides a generator shaft speed of 6000 RPM. At 6000 RPM the generator produces a frequency of 400 Hertz.

A brushless generator is actually three generators in one housing. It has no sliprings, brushes, or commutator. The housing contains a Permanent Magnet Generator (PMG), exciter generator, and main generator.



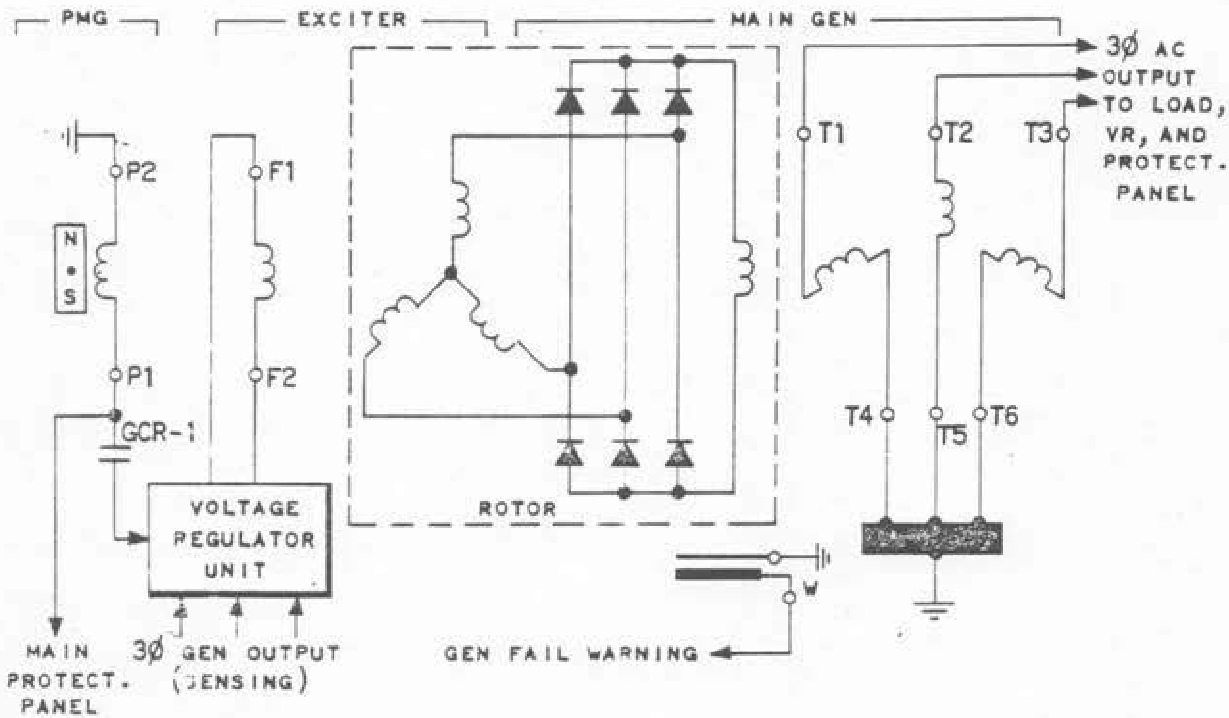
BRUSHLESS GENERATOR AND REGULATOR

The PMG rotor, which is part of the same shaft as the main rotor, contains [illegible] permanent magnets and produces a single-phase output of 105 volts, AC, at a frequency of 1600 Hertz. The output from the stator (terminal P1) is supplied to the protection panel and then to the VR unit. The PMG voltage is used for protection and control of the generator system.

Contacts of a Generator Control Relay (GCR-1) in the protection panel complete the PMG circuit to the VR unit. The contacts disable the generator exciter and high-voltage output until the generator is turned to the "ON" position. The PMG output to the protection panel is continuous when the engine is running.

The VR unit's D-C output is supplied to the generator exciter field (stator) in the exciter section. The exciter rotor contains three windings 120 degrees apart and generates a three-phase, A-C voltage. The AC is changed to DC by a three-phase, full wave rectifier which provides excitation to the main generator's rotor field windings.

The main field windings consist of four rotating electromagnets (8 poles). The main stator has three fixed windings at 120-degree intervals. Each stator has



BRUSHLESS GENERATOR

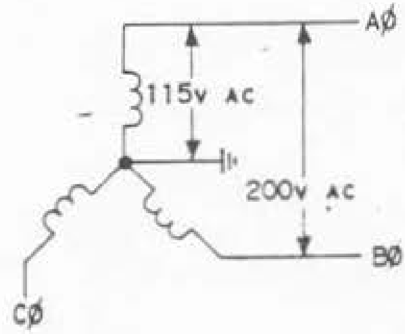
develops 115 volts, AC, at 400 Hertz when the shaft is 6000 RPM. The VR unit determines the generator voltage by sensing the output voltage and varying exciter field current accordingly to maintain the 115-volt output.

The main generator's stator windings provide three A-C voltages at 120-degree phase relationships. Terminals T4, T5, and T6 are connected to ground (aircraft structure) to provide a three-phase, four-wire (WYE) generating system. Three-phase AC is obtained from terminals T_1 (phase A), T_2 (phase B), and T_3 (phase C). It is supplied to contactors in the main A-C distribution center. The fourth wire is grounded to the aircraft structure. Voltage from phase-to-ground is 115 volts, AC. The voltage from phase-to-phase is 200 volts, AC (1.73 times phase voltage) since the voltages are 120-degree out of phase.

A Warning (W) terminal provides an indication of generator bearing failure. An insulated copper bar runs lengthwise along the surface of the stator, close to the rotor. The stator frame is the ground. If the bearings fail, the rotor shears the bar causing it to ground against the stator frame. When this occurs, a GEN FAIL light on the electrical panel illuminates. The generator can be disabled by disconnecting the CSD. The CSD disconnect switch energizes a solenoid in the CSD which causes the CSD to disconnect from the engine drive. Disconnect must not be attempted with a stopped engine. Reset of the CSD can be accomplished only when the engine is fully stopped by pulling the RESET lever on the CSD unit.

MAIN PROTECTION PANEL

The protection panels provide relay control and protection of each generating system. The panels provide the following:

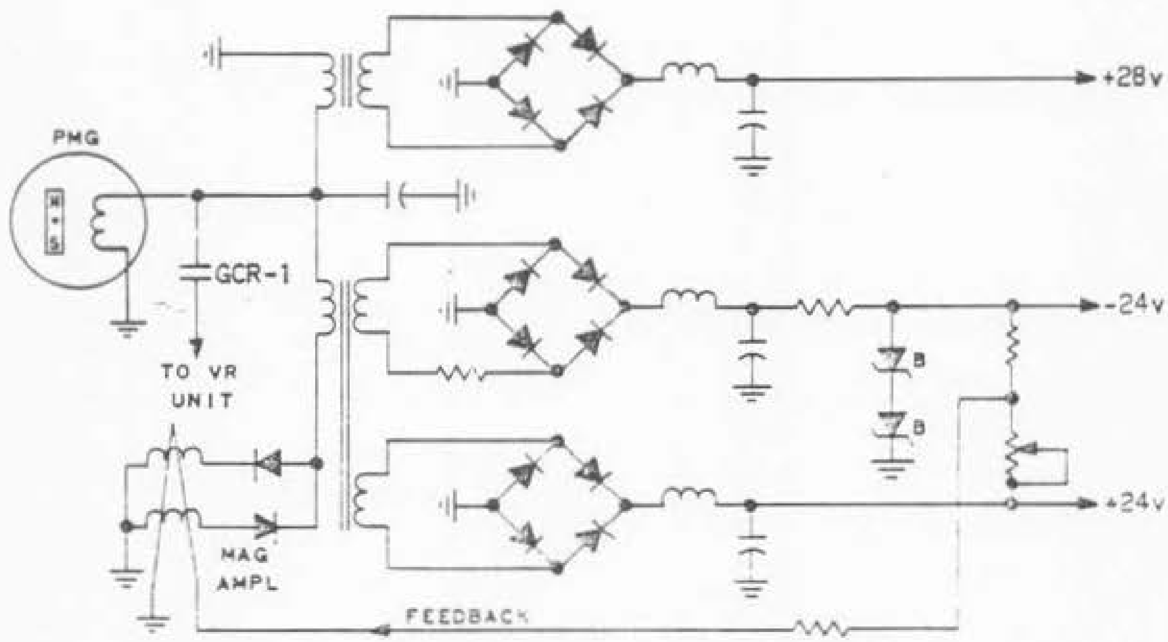


115/200 V AC GENERATOR OUTPUT

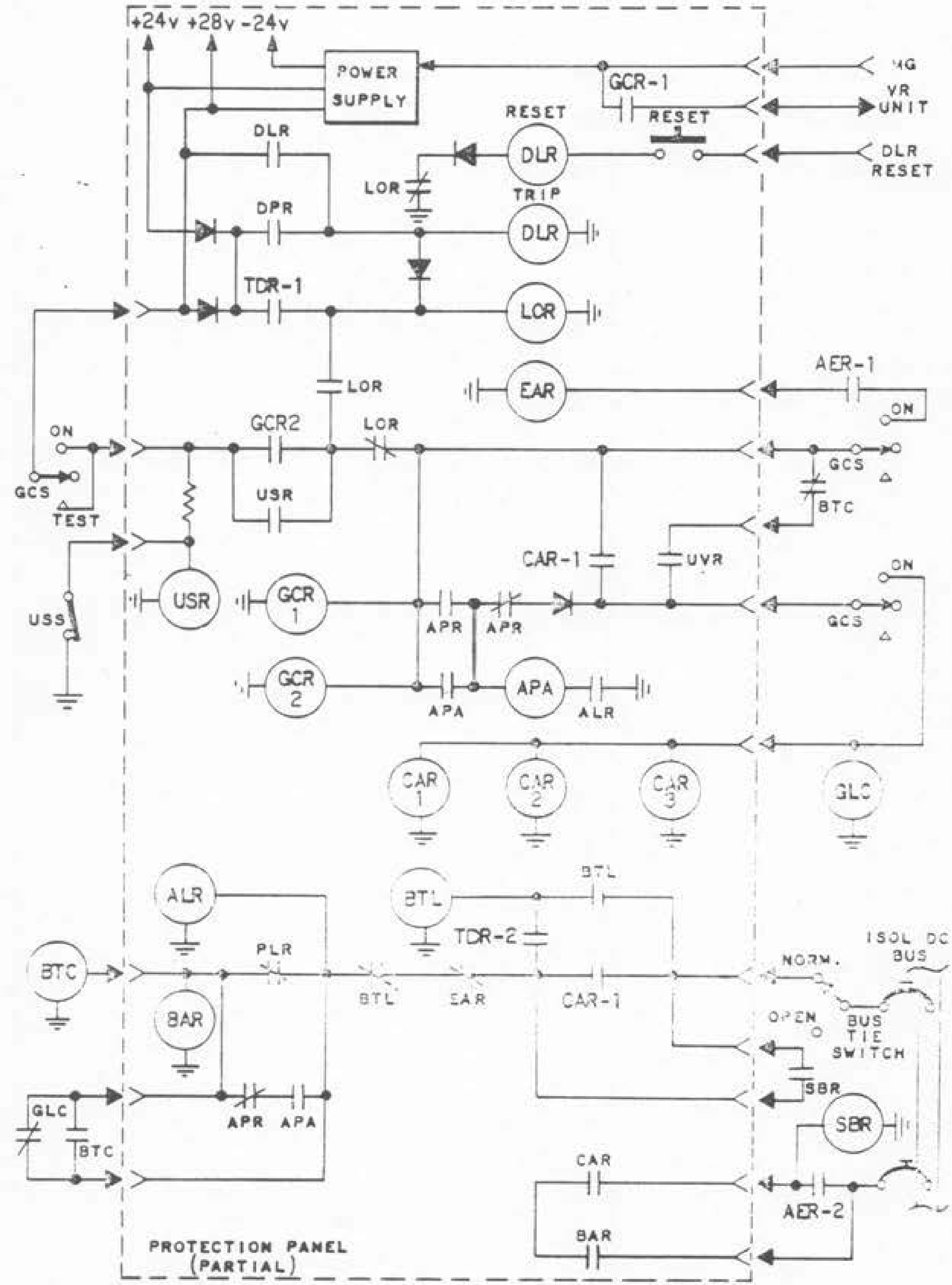
- o A D-C source for control of each system
- o Individual phase voltage sensing
- o Undervoltage protection with fixed time delay
- o Overvoltage protection with variable time delay, time inverse to amplitude
- o Differential fault (ground fault) protection with fixed time delay
- o Neutral current protection with fixed time delay
- o Unbalanced current protection with fixed time delay
- o Reactive bias circuit for load equalization
- o Underexcitation protection
- o Power lockout circuit
- o Automatic paralleling circuit
- o Auxiliary relays

POWER SUPPLY CIRCUIT

The protection panel D-C supply provides positive and negative D-C voltage for the various protection, control, and relay circuits. The power supply input is PMG voltage from the main generator which is supplied to stepdown transformers. A variable impedance magnetic amplifier in series with one transformer primary controls primary current. The transformer secondary windings supply AC to a bridge rectifier which produces positive and negative 24-volt, D-C outputs. Zender diodes regulate the negative 24-volt D-C output.



PROTECTION PANEL POWER SUPPLY



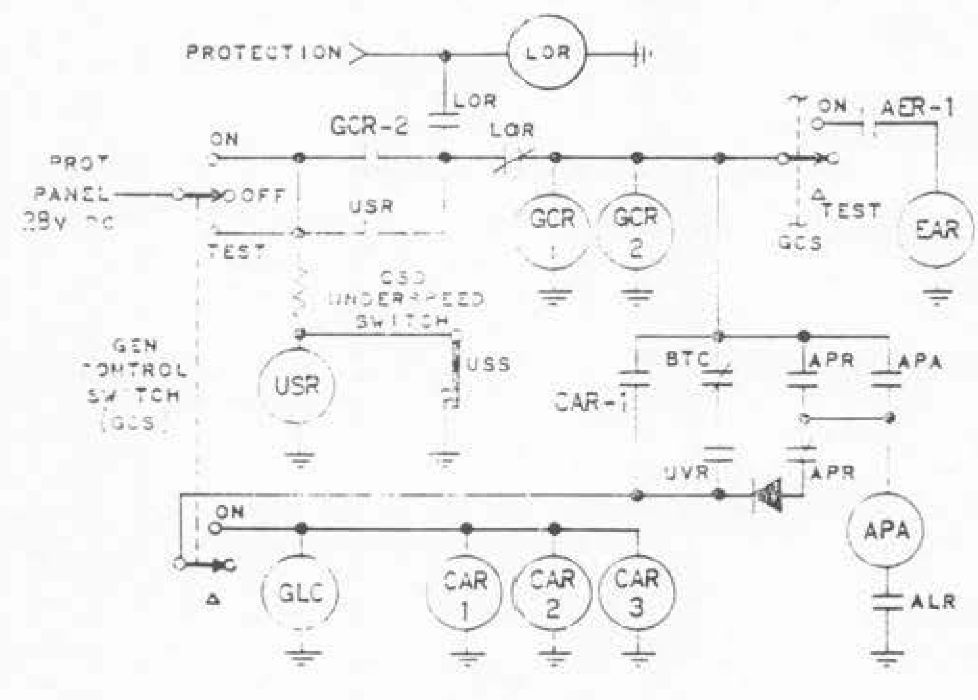
GENERATOR PROTECTION PANEL

Feedback is supplied to the magnetic amplifier from the center point between the negative and positive supply. If the D-C voltage changes, feedback to the magnetic amplifier varies the transformer primary current to maintain a constant 24-volt output. The PMG voltage is supplied to a second transformer and bridge rectifier which provides a positive 28-volt D-C output.

UNDERSPEED RELAY CIRCUIT

The 28-volt, D-C output of the power supply is routed through the "ON" position of the generator control switch to the Underspeed Relay (USR). The USR is energized when the underspeed switch (USS) in the CSD opens. The switch opens when the CSD operating speed is above 5700 RPM and closes when the speed is below 5400 RPM.

The energized USR contacts allow GCR-1 and GCR-2 to energize. Relay GCR-1 connects the PMG output of the generator to the VR unit which then provides excitation to the generator. Contacts of GCR-2 provide a holding circuit to the GCR's, bypassing the USR contacts. The bypass prevents loss of power during momentary underspeed conditions.



GLC CIRCUIT

GLC CONTROL

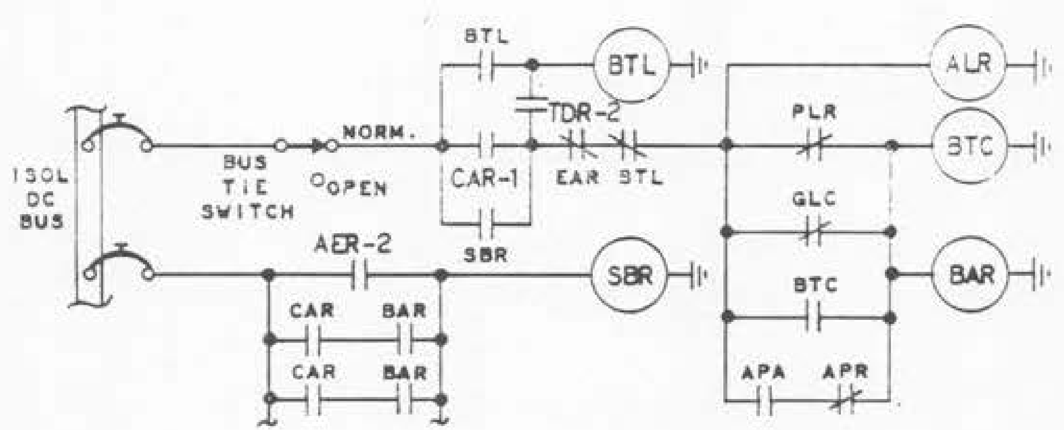
When the generator output voltage is above 103 volts, AC, per-phase, the under-voltage relay (UVR) is energized thus completing a circuit through BTC contacts to the GLC and CAR-1, CAR-2, and CAR-3. Relay CAR-1 is used with the GLC-BTC circuit; CAR-2 is used with the SBR circuit; and CAR-3 is used with the unbalanced current circuit.

The GLC can be energized through normally closed BTC contacts or through the automatic paralleling circuits. When the GLC and CAR's energize, the BTC is controlled by the automatic paralleling circuits. If the BTC is energized, the GLC is controlled by the automatic paralleling circuits.

Contacts of CAR-1 bypass the BTC-UVR contacts and GLC paralleling circuit to hold the GLC energized, thus preventing power loss during momentary undervoltage conditions. The GLC connects the generator output to the main A-C bus. If the generator control switch is in the "TEST" position, the generator produces an output, but the GLC cannot energize. The generator operates but does not supply a load.

The normally deenergized LOR is energized from the protection circuits during a fault or trouble to disable the generator (GEN OUT). It remains energized after a trouble through LOR holding contacts.

The system is reset by positioning the generator control switch to "OFF" then "ON," breaking the LOR holding circuit.

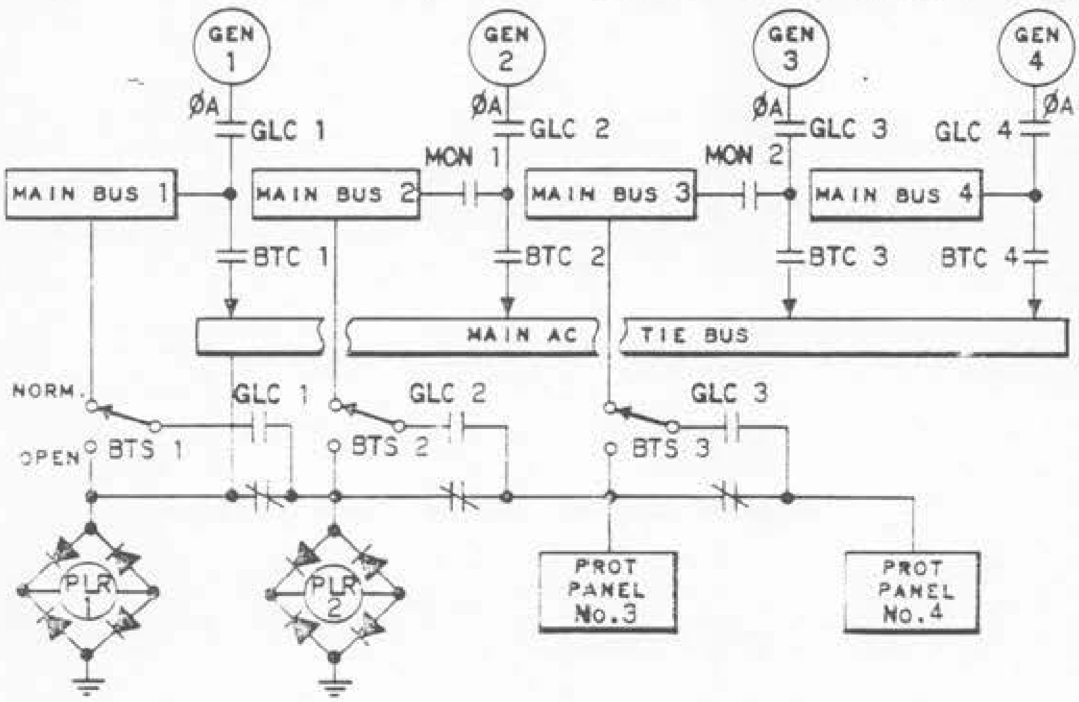


BTC CIRCUIT

BTC CONTROL

The BTC can be energized when the BUS TIE switch is in "NORMAL" and D-C voltage is supplied through CAR-1, External Power Auxiliary Relay (EAR), and Bus Tie Lockout Relay (BTL) contacts. The CAR-1 contacts are used when the generator is operating and the SBR contacts are used if the generator switch is in the "OFF" position. The BTC and BTC Auxiliary Relay (BAR) energize through the Power Lockout Relay (PLR) contacts, or through the GLC contacts if the generator switch is in the "OFF" position. Contacts of the BTC connect the power source to the load and provide a holding circuit to the BTC. The main A-C bus source can supply the main A-C bus through the BTC.

The EAR controls the BTC to prevent auxiliary or external power from paralleling with the generators. If external or auxiliary power is supplying the main A-C tie bus, the EAR is energized due to relay AER-1 which causes the BTC's to deenergize. The AER-1 is energized when external or auxiliary power is in use.

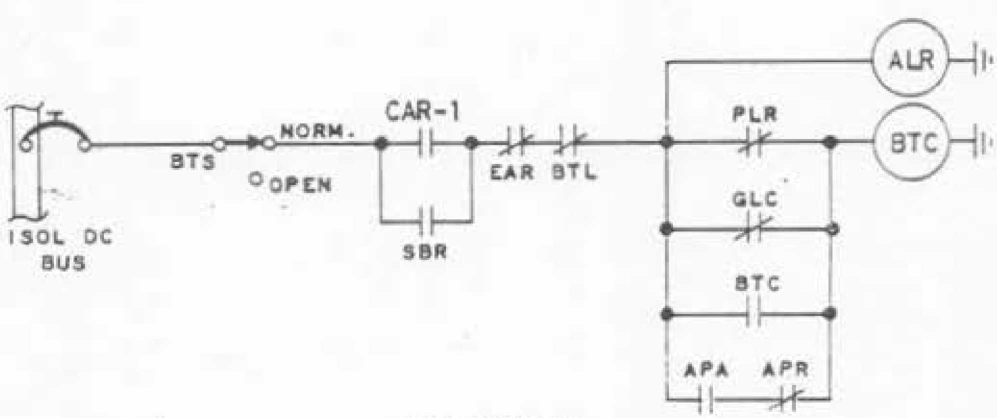


PARALLELING SEQUENCE CIRCUIT

AUTOMATIC PARALLELING

The PLR, the Automatic Paralleling Auxiliary Relay (APA), and the Automatic Paralleling Relay (APR) are part of the automatic paralleling control circuits. The paralleling sequence and synchronizing circuits allow the main generators to operate in parallel. The first generator in operation is connected to the main A-C tie bus through the BTC. The remaining generators synchronize with the tie bus source and then parallel through the respective BTC's or GLC's.

Normal paralleling priority of the generators when all four are operating is the Main Generators 1, 2, 3, or 4 to the main A-C tie bus. The priority is established by the PLR's. PLR-1 is energized by the first power source connected to the tie bus. If generator 1 is in the "ON" position, GLC-1 and the CAR's energize. The BTC-1 is energized through the PLR-1 contacts since the tie bus and PLR-1 are not yet energized. Generator 1 supplies power to the tie bus through BTC-1, and PLR-1 is energized. BTC-1 remains energized through holding contacts of BTC-1. The remaining generators automatically synchronize with Generator 1 and then connect to the tie bus.

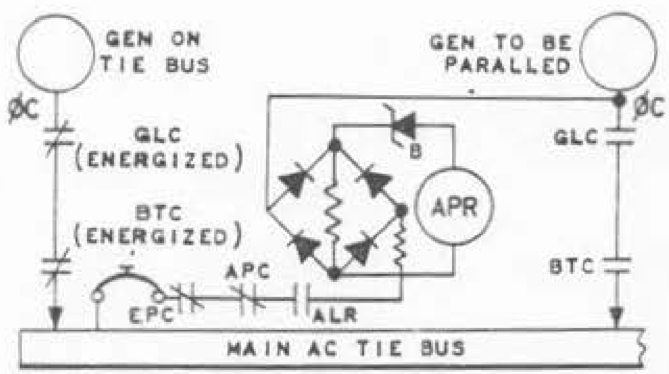


BTC CONTROL

PLR-2 is energized from main A-C bus 1 (Generator 1) through the Bus Tie Switch (BTS) and GLC-1 contacts (energized). BTC-2 can be energized only through the series contacts of APA and APR since PLR-2 contacts are open. The APR is energized by D-C voltage from Bridge A rectifier. The rectifier changes the tie bus Phase C voltage and generator Phase C voltage to DC for the APR. The APR is normally energized until the voltages are approximately equal in amplitude and phase. A Zener diode in series with the APR determines the minimum voltage difference below which the APR is deenergized. The deenergized APR allows the APA to energize. The APA-APR contacts are then closed and BTC-2 is energized thus paralleling the sources to the tie bus. The remaining generators automatically parallel in a similar manner through the respective BTC's or GLC's due to the PLR, APR, and APA.

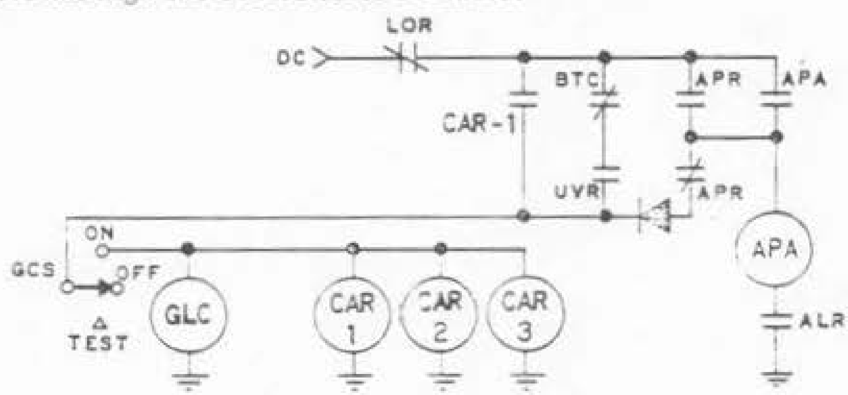
Holding contacts of the APA bypass the APR contacts to keep the APA energized, during voltage fluctuations to the APR. The sequence circuits are bypassed through the BTC holding contacts after paralleling is completed. Paralleling is indicated by equal readings on the generator loadmeters.

If Generator 1 switch is in the "OFF" position, Generator 2 would be the first generator connected to the tie bus. If the bus tie switch of an operating generator is placed in the "OPEN" position, the BTC cannot energize. The associated PLR is energized from the tie bus to allow paralleling of the bus loads. The BTC is energized througn GLC contacts, allowing the main A-C to be energized from the tie bus power source.



AUTOMATIC PARALLELING

The automatic paralleling circuits control the GLC when the generator switch is "OFF" and the BTC is energized. When the generator control switch is placed in the "ON" position, the APR is energized. The APR allows the APA to energize and to hold through APA contacts. The APR is already energized through the BTC control circuit. When the generator phase C voltage is approximately in-phase with the main A-C tie bus voltage, the APR is deenergized. The GLC is then energized through the series APA contacts.

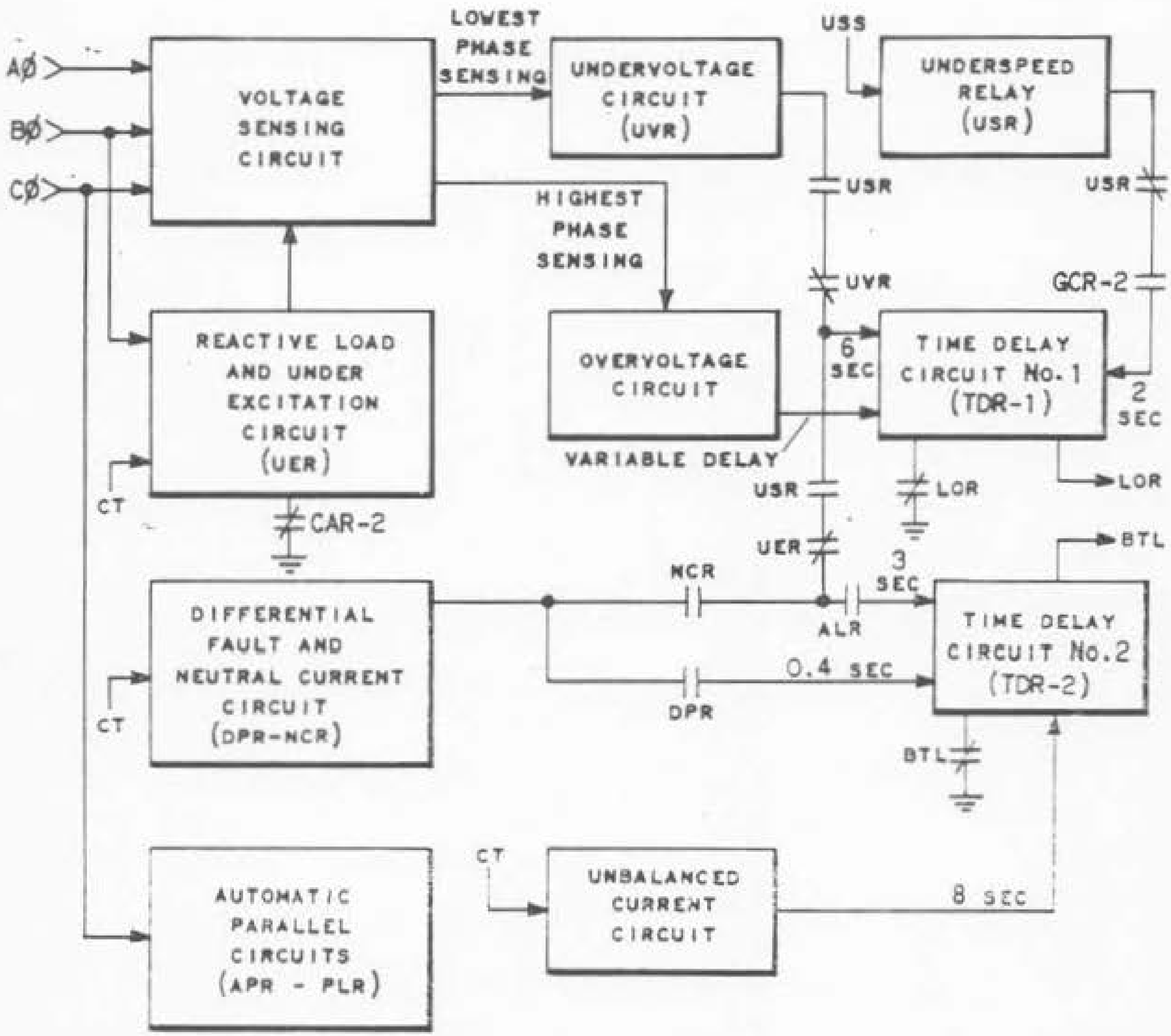


GLC CONTROL

If external A-C power or auxiliary generator power is in use, the BTC's are energized through the SBR contacts. The BTC's are also energized through SBR contacts if the associated generator switch is in the "OFF" position thus allowing the tie bus source to supply power to the main A-C bus.

PROTECTION CIRCUITS

The generator protection panel contains circuits which protect the generating and bus distribution system. The panel provides undervoltage, overvoltage, differential fault, neutral current, unbalanced current, and underspeed protection. Delay circuits are used to prevent transient conditions from energizing the protective relays.



PROTECTION CIRCUITS

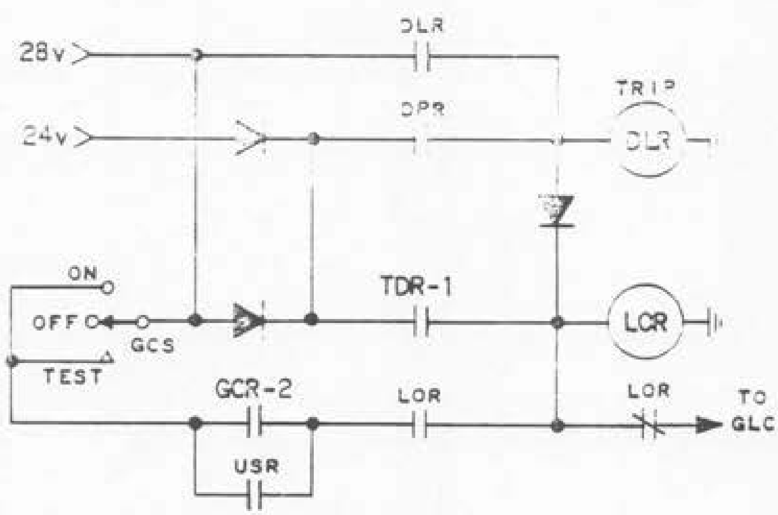
An undervoltage condition trips the BTC in 3 seconds and the GLC in 6 seconds. If the undervoltage condition is due to underexcitation of the generator, the BTC does not trip. An overvoltage condition trips the GLC in a time period inverse to voltage, maximum time not to exceed 10 seconds. A differential fault trips the GLC immediately. If the GLC does not clear the fault, the BTC is tripped 0.4 second after the GLC.

CONDITION	TRIP	TIME	REMARKS	AUX GEN
UNDERVOLTAGE	BTC	3 SEC	DOES NOT TRIP IF DUE TO UNDEREXCITATION	
UNDERVOLTAGE	GLC	6 SEC		*
OVERVOLTAGE	GLC	VARIABLE	TIME IS INVERSE TO VOLTAGE, MAX. TIME 10 SEC	*
DIFFERENTIAL FAULT	GLC	INSTANT		*
DIFFERENTIAL FAULT	BTC	0.4 SEC	BTC TRIPS IF FAULT IS BETWEEN GLC-BTC	
NEUTRAL CURRENT	BTC	3 SEC		
UNBALLANCED CURRENT	BTC	8 SEC		
UNDERSPEED	GLC	2 SEC	CONTROLLED BY UNDERSPEED SWITCH	*

NOTE: * AUX GENERATOR PROTECTION

GENERATOR PROTECTION CHART

The GLC is controlled by the LOR which is normally deenergized. The LOR is energized through TDR-1 or through the DPR. The TDR-1 is energized during an overvoltage, undervoltage, or underspeed condition, causing the LOR to energize. The DPR is energized during a differential fault (ground fault) condition, causing the LOR and trip coil of the Differential Lockout Relay (DLR) to energize. The DLR is a two coil relay which remains in either condition (tripped or reset).

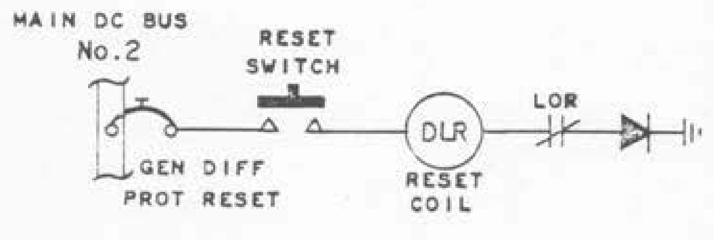


LOR CONTROL

The energized LOR disables the generator by deenergizing the GLC, CAR's and

GCR's. The LOR is held energized through LOR contacts, or through DLR contacts after a differential fault.

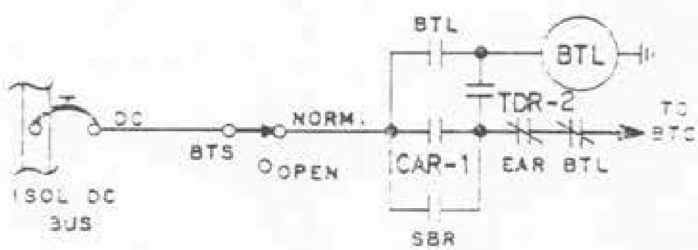
The LOR can be reset by stopping the engine in order to remove the PMG input voltage to the power supply. Loss of the power supply causes the LOR to deenergize. The DLR can be reset by energizing the DLR reset coil after the LOR is reset. A reset pushbutton on the protection panel must be pushed to energize the DLR reset coil.



DLR RESET

A differential fault is indicated by illumination of the GEN OUT light when the generator control switch is in the "ON" and "OFF" positions. The other faults require the generator control switch to be "ON" before the GEN OUT light illuminates.

The BTC is controlled by the BTL relay which is normally deenergized. The BTL is energized through TDR-2 and is held through BTL contacts. The TDR-2 is energized due to an undervoltage, differential fault, neutral current, or unbalanced current condition. The energized BTL opens the circuit to the BTC and BAR.

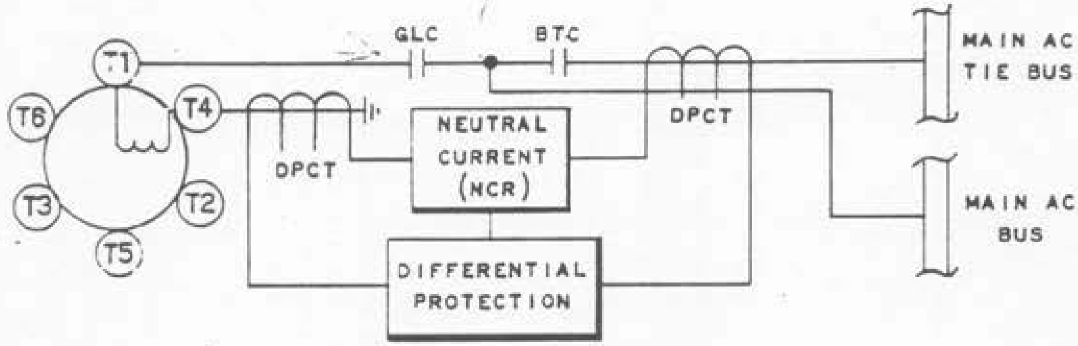


BTL CONTROL

The BTL is reset by positioning the Bus Tie Switch (BTS) to "OPEN" then "NORMAL." The bus tie OPEN light illuminates when the BTC is open and is extinguished after reset is accomplished.

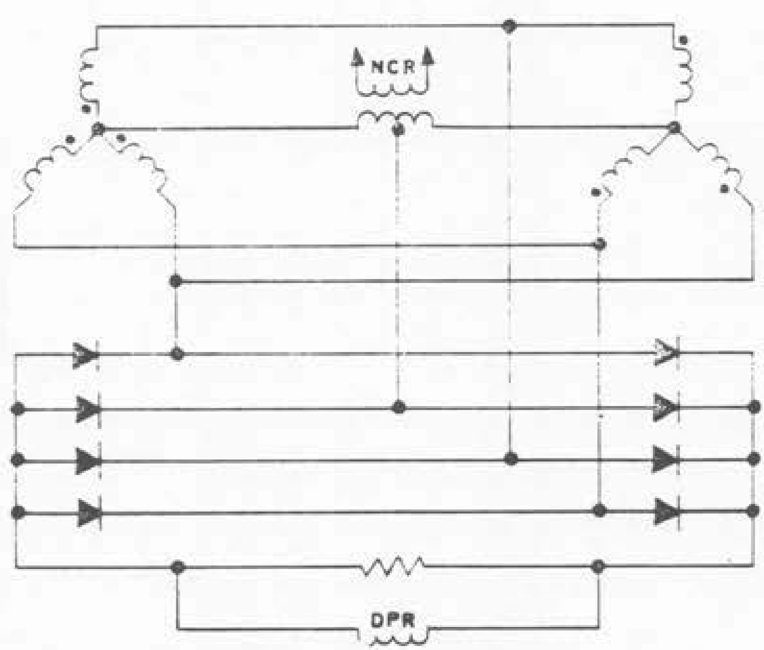
DIFFERENTIAL FAULT PROTECTION

The differential fault circuit disables the generator immediately if a fault occurs on a feeder wire between the generator and GLC. If the fault is between the BLC and BTC, the BTC is opened 0.4 second after the GLC thus isolating the fault from the main AC Tie Bus. The generator is disabled through the BLC circuit due to the LOR. The main bus is isolated by opening the BTC due to the BTL. The BTL is controlled by TDR-2 which provides the 0.4 second delay.



DIFFERENTIAL PROTECTION CURRENT TRANSFORMERS

A differential fault is sensed by current transformers around the phase feeders and ground wires of the generator. Two transformers are connected in opposition to each other on each phase of the generator. An output, which is proportional to the current difference between the feeder and ground wire, is provided by the transformers. If a sufficient difference exists due to a fault, the resultant output is rectified and energizes the Differential Protection Relay (DPR).



DIFFERENTIAL FAULT PROTECTION CIRCUIT

The DPR contacts cause the LOR to energize. The LOR opens the circuit to the GLC and GCR's disabling the generator. The DPR contacts also start the timing circuit of TDR-2. If the fault is not cleared by opening the GLC, TDR-2 is energized 0.4 second later. Contacts of TDR-2 allow the BTL to energize, deenergizing the BTC and BAR.

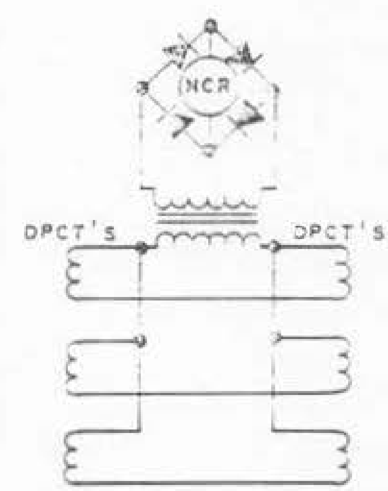
An indication of a differential fault is provided by illumination of the GEN OUT light with the generator control switch in the "OFF" or "ON" position. After the fault is corrected, the system can be reset by stopping the generator and pressing the reset pushbutton on the protection panel. The generator is stopped in order to remove the PMG input to the protection panel power supply. Loss of power supply voltage will deenergize the LOR in the GLC circuit. The BTC circuit can be reset by positioning the BUS TIE switch to "OPEN" then "NORMAL" position, which deenergizes the BTL.

NEUTRAL CURRENT PROTECTION

The neutral current sensing detects an open generator phase, or fault, not detected by the differential protection or undervoltage protection circuits. Current in the common wire between the current transformers is sensed by a transformer. Rectifiers change the transformer voltage to DC, which controls a Neutral Current Relay (NCR).

If the sensing current between the current transformers is unequal, the NCR is energized. Contacts of the NCR start the TDR-2 timing cycle. If the condition still exists after 3 seconds, TDR-2 is energized. TDR-2 opens the BTC by energizing the BTL. The generator continues to supply the main bus load but is isolated from the main A-C tie bus.

If the unbalance condition continues, protection is provided by the undervoltage circuit which disables the generator. The NCR contacts also bypass the reactive biasing circuit to prevent tripping of a good generator system. The BTC tripped condition is indicated by illumination of the BUS TIE OPEN light. The BTC can be reset, and the light extinguished, by positioning the BUS TIE switch to "OPEN" then "NORMAL."



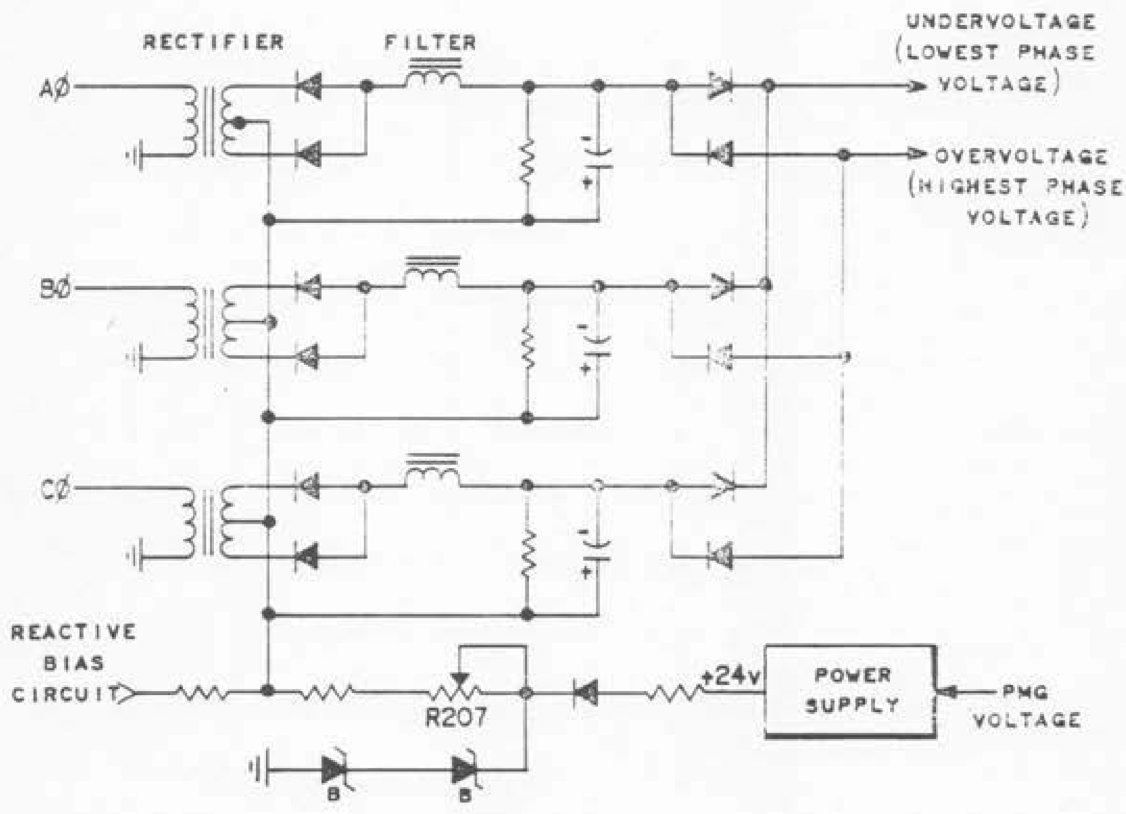
NEUTRAL CURRENT CIRCUIT

VOLTAGE SENSING

The three-phase A-C output of the generator is stepped down by transformers, rectified, and filtered to provide a D-C output. The output is referenced to the 24-volt output of the protection panel power supply. Zener diodes regulate the D-C reference voltage.

Isolating diodes between the individual-phase DC outputs control which phase voltage is used with the overvoltage circuits. Only one of each group of three diodes conducts, providing reverse bias to the other diodes. The overvoltage circuit senses the highest phase voltage which is rectified and coupled as a negative input to the overvoltage circuit. The overvoltage isolating diodes are normally cutoff until the overvoltage condition exceeds 129 volts, AC.

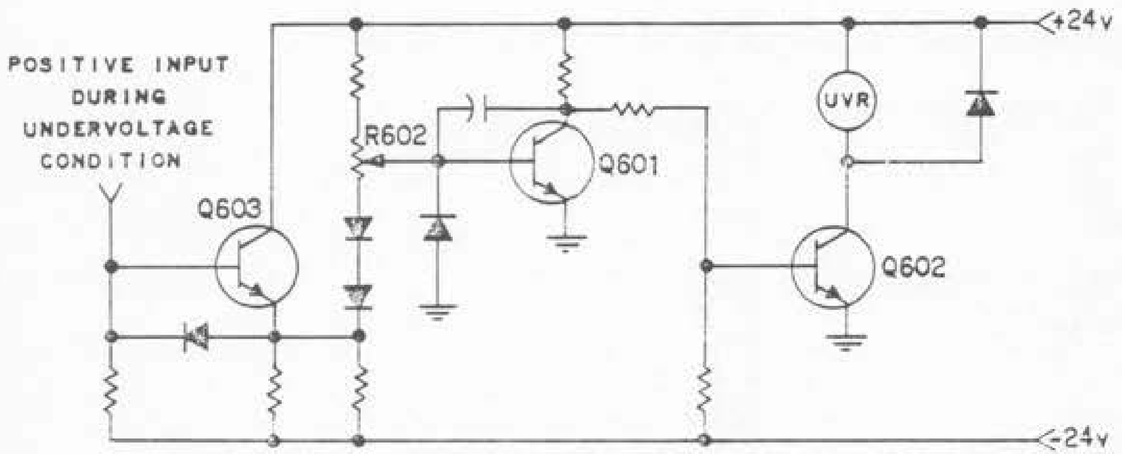
The undervoltage isolating diodes are normally cutoff while phase voltage is above 103 volts, AC. If phase voltage decreases, a diode conducts due to the positive reference voltage. The diode with the lowest phase voltage provides a positive output to the undervoltage circuit. The overvoltage and undervoltage sensing reference is also varied by the reactive load circuit.



VOLTAGE SENSING

UNDERVOLTAGE PROTECTION CIRCUIT

In the undervoltage circuit the UVR is normally energized due to conduction of transistor Q602. Transistor Q603 and Q601 are normally cutoff. During an undervoltage condition the positive input from the voltage sensing circuits cause transistor Q603 to conduct. The positive output from the emitter of Q603 causes Q601 to conduct. The negative collector voltage of Q601 turns off Q602, and the UVR is deenergized.



UNDERVOLTAGE

Contacts of the UVR start the timing cycle of TDR-1 and TDR-2. If the undervoltage condition continues, TDR-2 will time out in 3 seconds and TDR-1 in 6 seconds. The TDR-2 opens the BTC, and TDR-1 opens the GLC which disables the generator. If the condition is momentary the TDR's will not time out. If the undervoltage condition is eliminated by TDR-2 and the BTC, TDR-1 will not time out since the UVR is again energized. If the undervoltage condition is caused by underexcitation of the generator, the UER is energized to prevent loss of the BTC.

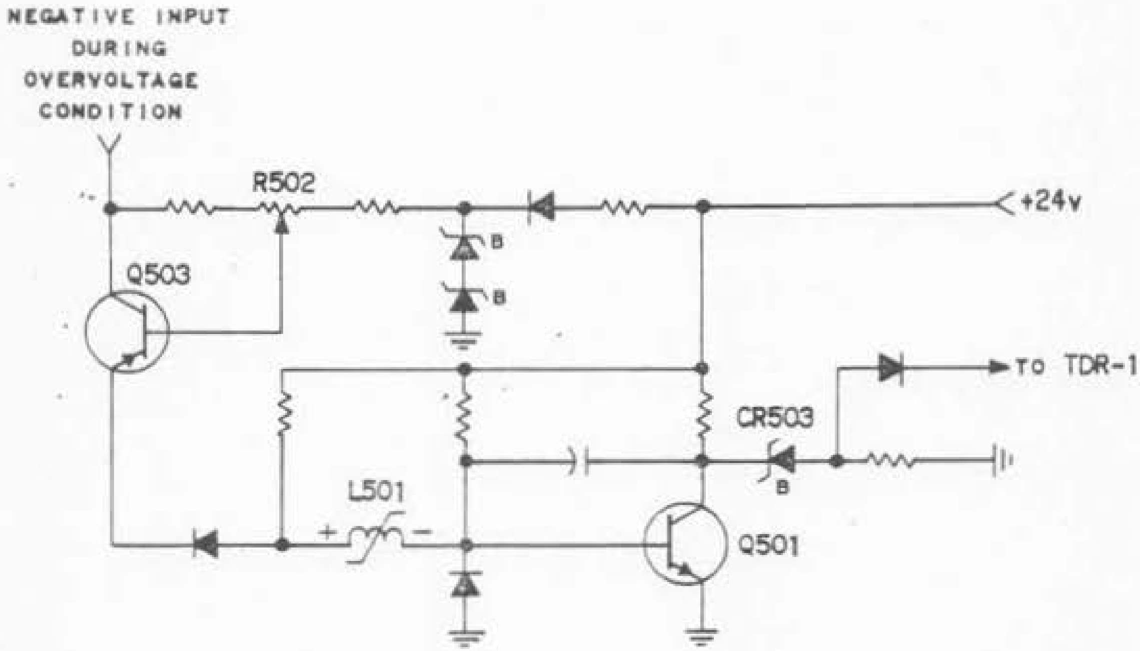
OVERVOLTAGE PROTECTION CIRCUIT

The overvoltage circuit produces an output with a delay time which varies inversely to the amplitude of the overvoltage condition. A maximum of 10 seconds delay is produced at 129 volts, AC. Delay time is equal to 5 divided by the number of volts above 129, or

$$\text{Delay} = \frac{5}{\text{number of volts} - 129.}$$

Example: At a phase voltage of 134 volts,

$$\text{Delay} = \frac{5}{134 - 129} = \frac{5}{5} = 1 \text{ second.}$$



OVERVOLTAGE

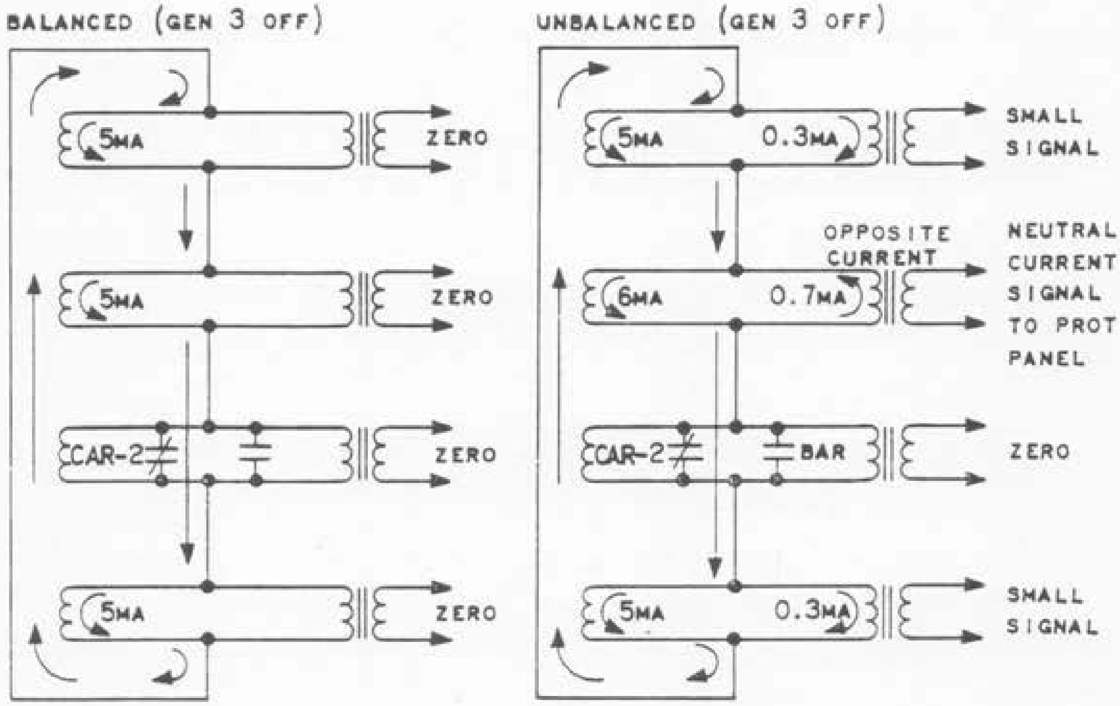
In the overvoltage circuit, delay time is determined by saturation of reactor L501. Transistor Q503 is normally cutoff and Q501 is conducting. The reactor is saturated due to base current of transistor Q501.

During an overvoltage condition, the negative output from the voltage sensing circuit causes Q503 to conduct. The negative emitter signal is coupled to the reactor, reversing the reactor current. The delay time is the time required for the reactor field to collapse and saturate in the opposite direction, causing Q501 to cutoff. A larger signal saturated the core earlier thus decreasing the delay time.

As Q501 stops conducting, collector voltage increases towards the 24-volt source voltage. When the voltage is above the breakdown voltage of the Zener diode, the diode conducts, producing a positive output. The positive output gates an SCR to energize TDR-1 immediately. The TDR controls the LOR, which deenergized the GLC and GCR's. To reset after an overvoltage condition, position the generator control switch to "OFF" then "ON."

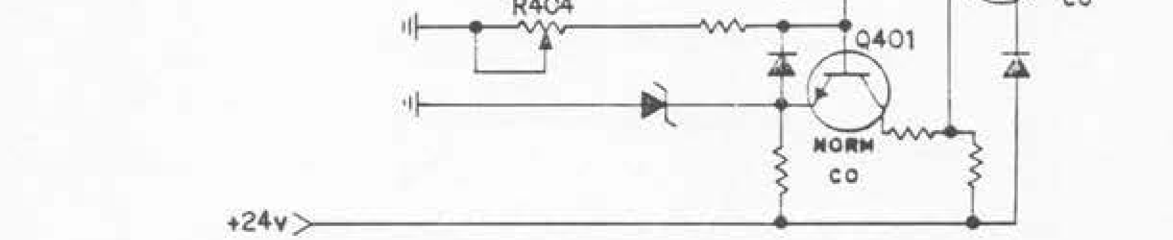
UNBALANCED CURRENT PROTECTION

During generator parallel operation, the unbalanced current circuit senses the load current of each generator. If the load currents are not equal, an output is provided to the protection panel of the faulty generator system. The faulty generator is disconnected from the main A-C tie bus in 5.5 seconds. Current is



CURRENT TRANSFORMER LOOP

sensed by current transformers around the phase B feeder of each generator. When the generators are paralleled, the CAR-2 and BAR contacts open. In a balanced current transformer (CT) circuit, current is through the low impedance of the CT's bypassing the transformer input of the protection panels. When an unbalance exists between the generator loads, the current change of the CT results in current through the parallel transformer since the series circuit current is average current. The transformer provides an input to the unbalanced current circuit. The input is



UNBALANCED CURRENT CIRCUIT

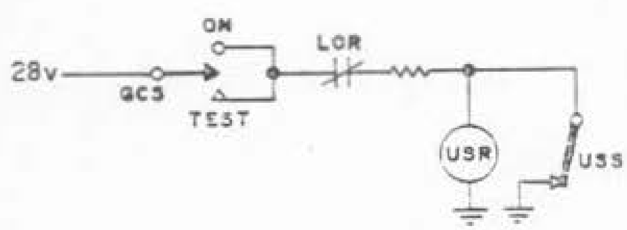
rectified, filtered, and supplied to transistor Q401. Transistor Q401 and Q402 are normally cutoff. A Zener diode in the emitter circuit of Q401 determines the signal amplitude necessary before Q401 conducts. The rectifier's positive output causes Q401 to conduct and breakdown the Zener diode.

The negative output from the collector of Q401 causes Q402 to conduct, producing a positive output to time delay circuit No. 2. The delay circuit controls TDR-2 which is energized after 8.5 seconds. The TDR-2 controls the BTL and BTC to disconnect the generator from the main A-C tie bus. The BTC can be reset by positioning the BUS TIE switch to "OPEN" then "NORMAL."

Contacts of the energized BTL open the unbalanced current circuit when the generator is not paralleled. Contacts of the CAR-2 bypass the current transformer when the generator is "OFF," completing the CT circuit for the remaining generators. The BAR contacts bypass the CT when the generator is operating but not paralleled (BTC open).

UNDERSPEED PROTECTION

Underspeed protection is provided by the underspeed switch (USS) in the CSD unit. At a normal CSD operating speed above 5700, the switch is opened, allowing the underspeed relay (USR) to energize. Contacts of the USR control the GLC and CAR's

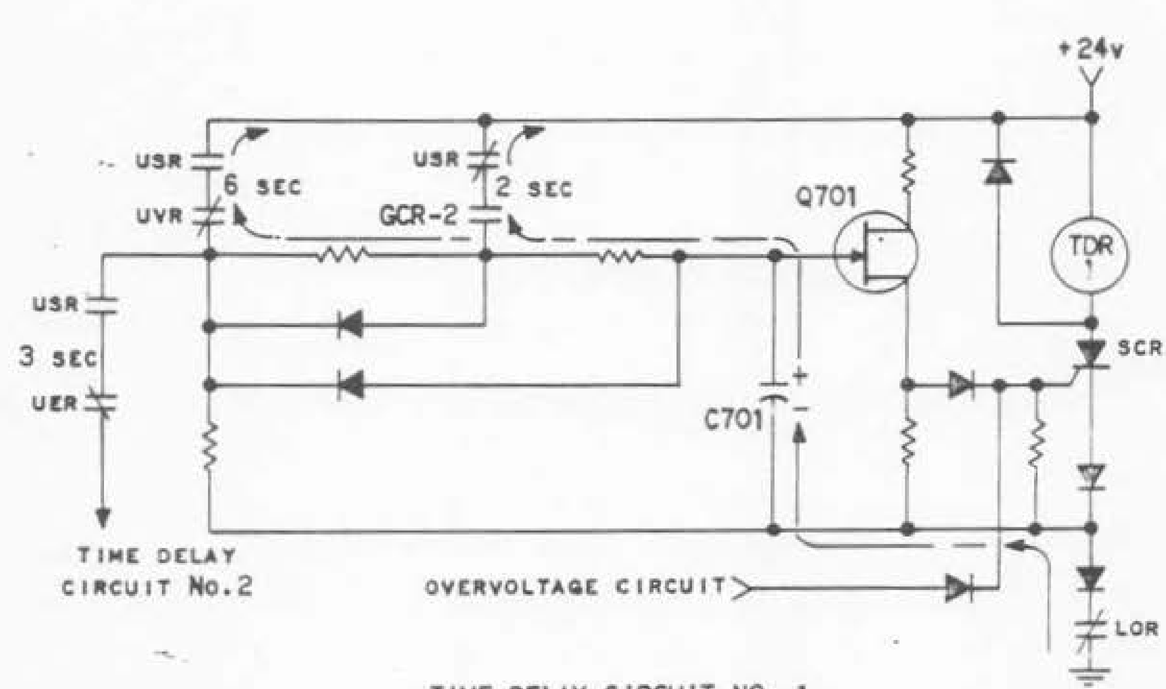


UNDERSPEED CIRCUIT

During an underspeed condition with the generator in operation, the USR contacts start the 2-second timing cycle of TDR-1. If the CSD remains in the underspeed condition for more than 2 seconds, the TDR-1 times out to energize the LOR and disable the generator. The USR contacts also disable the undervoltage protection circuit during an underspeed condition. Overspeed protection of the generating system is not required since the CSD and APU are already protected against the overspeed.

TIME DELAY CIRCUIT NO. 1

The delay timing is controlled by a resistor-capacitor network in the emitter of a unijunction transistor (Q701). The transistor is normally cutoff until capacitor Q701 charges to a sufficient voltage to overcome the transistor base supply voltage. The rate of capacitor charge determines delay time and is varied by adding resistors in series with the capacitor. The resistors are selected through contacts of the protection relays.



TIME DELAY CIRCUIT NO. 1

In normal operation, the USR's, UVR, and GCR-2 energize opening the capacitor circuit. An underspeed condition causes the USR to deenergize, and the capacitor starts charging. Two seconds later, capacitor voltage is sufficient to cause the transistor to conduct. Base-to-base current through the transistor produces a positive output, which is supplied as a gating voltage to an SCR. The SCR conducts, energizing TDR-1.

The TDR-1 contacts control the LOR to disconnect the generator and to open the TDR-1 circuit. During an underspeed condition, the USR contacts in the LOR holding circuit are open. The LOR is energized momentarily to disconnect the generator. If engine speed increases to normal, the USR is energized and the generator automatically connects to the load through the GLC. The circuit does not require reset of the Generator Control Switch (GCS) for an underspeed condition.

An undervoltage condition causes the circuit to time out in 6 seconds, energizing TDR-1. An additional resistor is in the capacitor charging circuit to increase time by decreasing the charging rate. In normal operation, the USR and UVR are deenergized. During an undervoltage condition, the UVR is deenergized to start the timing cycle. After 6 seconds, TDR-1 is energized and the generator is disabled.

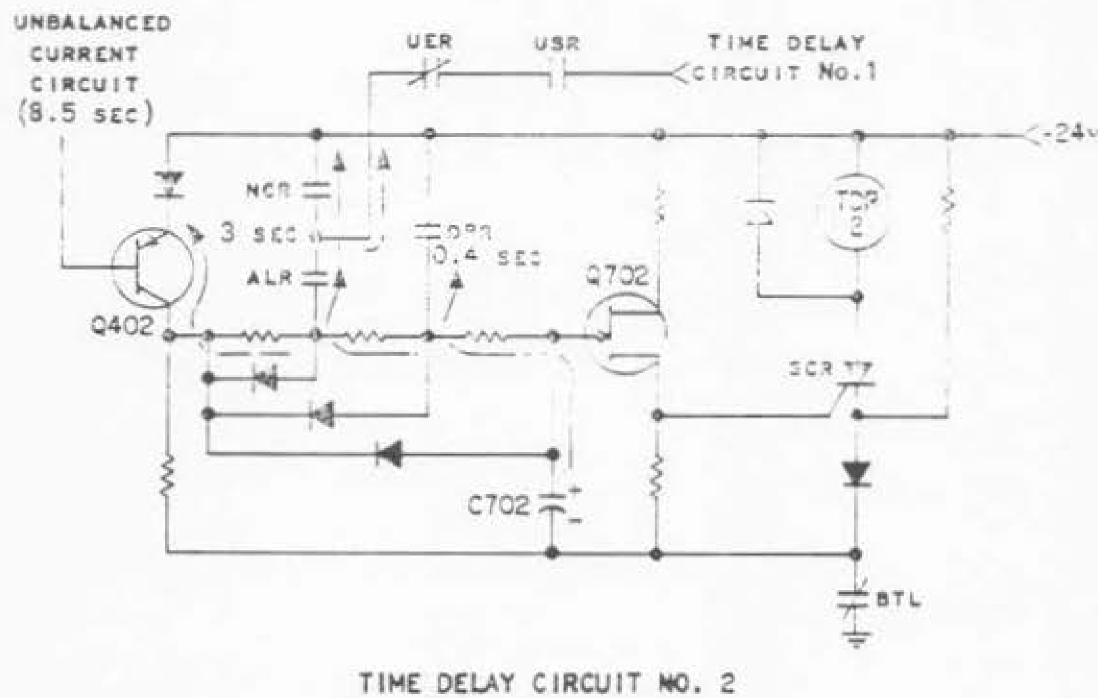
The undervoltage condition also supplied 24 volts through the USR-UER contacts to timing circuit No. 2. The circuit times out in 3 seconds to energize TDR-2 and open the BTC. If TSR-2 clears the undervoltage condition, the UVR is again energized to stop the timing of TDR-1. If TDR-2 does not clear the undervoltage condition, TDR-1 times out after 6 seconds to disable the generator. The TDR-2 timing cycle does not start if the UER is energized, preventing loss of the BTC during a generator underexcitation condition.

The circuit can be reset by positioning the generator control switch to "OFF" then "ON," and the BUS TIE switch to "OPEN" then "NORMAL." Reset is required to break the holding circuit of the LOR which controls the GLC and the holding circuit of the BTL which controls the BTC.

The overvoltage circuit provides an input to the SCR of TDR-1 through an isolating diode. Delay time is determined in the overvoltage circuit. The SCR is gated into conduction energizing TDR-1. To reset the generator circuit, the control switch must be positioned to "OFF" then "ON."

TIME DELAY CIRCUIT NO. 2

The circuit of TDR-2 is similar to the circuit of TDR-1 except for timing. When the generator is operating normally, the USR and UVR energize. In parallel operation, the ALR is energized due to the BTC circuit. The UER, NCR, DPR and BTL are normally deenergized.



TIME DELAY CIRCUIT NO. 2

During an undervoltage condition, the UVR is deenergized and the circuit times out in 3 seconds. The TDR-2 is energized, causing the BTL to energize. The BTC and TDR-2 circuit is opened and locked out by the BTL. If the undervoltage condition results from underexcitation, the UER is energized. The UER contacts open the undervoltage circuit to TDR-2, preventing the timing cycle. The TDR-1 circuit does not time out if the undervoltage condition is cleared by TDR-2 since the UVR will energize.

If a differential fault (ground fault) occurs, the Differential Protection Relay (DPR) is energized. The DLR and LOR in the GLC control circuit immediately disable the generator due to DPR contacts. The DPR contacts of timing circuit No. 2 start the timing cycle. If the fault is cleared by disabling the generator, the DPR is deenergized and TDR-2 does not time out. A fault between the GLC and BTC would not be cleared by disabling the generator since the main A-C tie bus continues to supply the load through the BTC. The TDR-2 circuit times out in 0.4 second after the DPR is energized, opening the BTC.

A neutral current abnormal condition will energize the NCR, starting the timing cycle. If the condition continues for 3 seconds, TDR-2 is energized, opening the BTC.

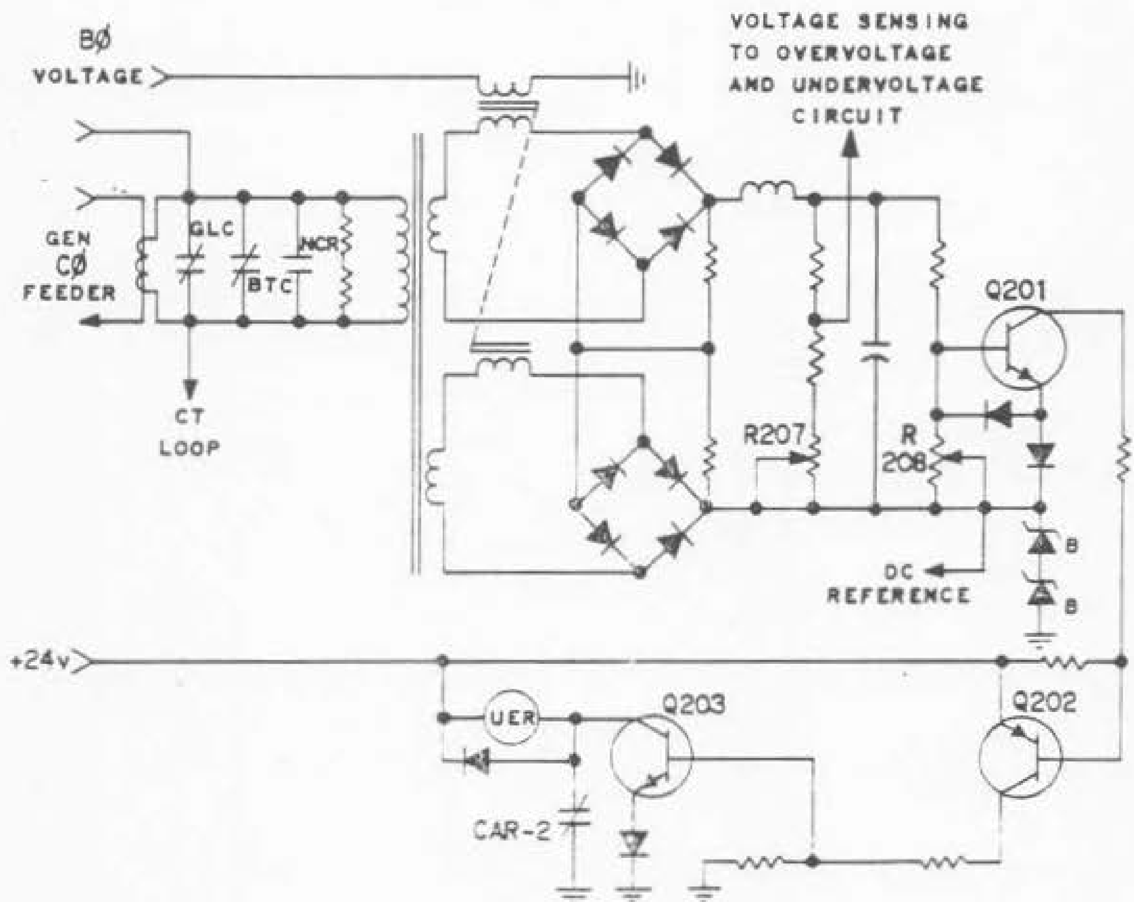
An unbalanced current condition between the generators operating in parallel causes TDR-2 to energize. The parallel generators normally share the load equally. If an unbalance exists, transistor Q402 conducts. The charging circuit of the timing capacitor is through the series resistors and the transistor. TDR-2 is energized after a delay of [illegible].5 seconds, and the BTC is opened. The circuit is reset by positioning the BUS TIE switch to "OPEN" then "NORMAL."

REACTIVE BIAS CIRCUIT

The Reactive Bias Circuit (RBC) of the protection panel is paralleled by the RBC circuit of the VR unit, using the same current transformers. The VR unit bias ensures equal reactive load sharing between generators in parallel. The protection panel bias changes the reference voltage to the overvoltage and undervoltage sensing circuits. The bias also controls the UER to open the undervoltage protection circuit of TDR-2 during an underexcitation condition.

Generators in parallel share the resistive and reactive loads equally. If one generator has more or less reactive load, an input is supplied to the protection panel. If the load is larger than the load on the other generators, the reactive bias decreases the reference voltage, increasing voltage amplitude to the overvoltage circuit. The overvoltage protection is biased closer to the trip point for the defective system.

Since the generators are paralleled, the actual bus voltage does not change. The defective systems generator is disabled due to the changing reference voltage when



REACTIVE LOAD AND UNDEREXCITATION CIRCUIT

the reactive load is sufficiently large. The remaining generators pick up and share the additional load. Reactive bias to the normal generator systems increases the reference voltage to prevent disabling.

The reactive bias input signal is obtained from current transformers and phase B generator voltage. The CT input is bypassed by contacts of the GLC or BTC if the generator is not paralleled, or by NCR contacts if the neutral current is excessive. The inputs are applied to transformers, bridge rectifiers, and filters. The rectifier outputs are positive and result in zero difference in potential when voltages are equal. The phase B input produces a zero output until the CT input unbalances the bridge rectifiers. The resultant output is a negative or positive difference voltage which is compared with the fixed reference voltage of Zener diodes. The difference voltage increases or decreases the reference voltage of the overvoltage circuit and is the input to the underexcitation circuit.

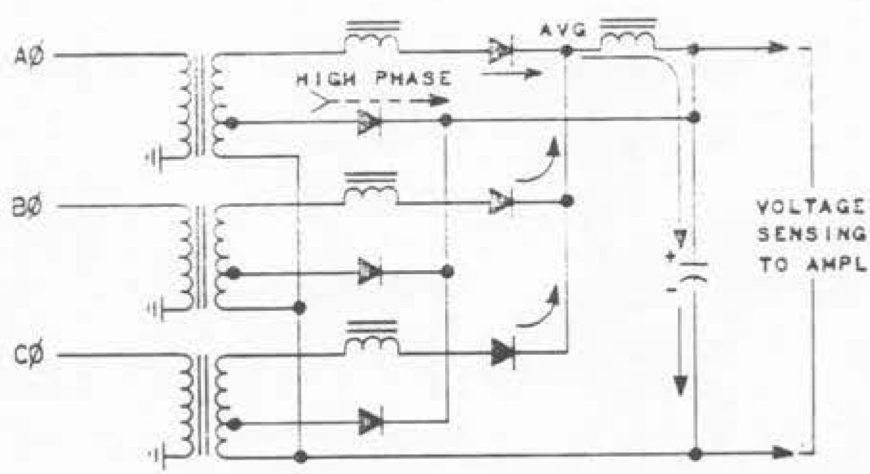
The UER is controlled by transistors Q201 and Q203, which are normally cutoff. If the generator has low excitation, the reactive bias output is a positive signal to the base or A201. A signal of sufficient amplitude will cause Q201 to conduct, turning on Q202. Conduction of Q202 causes Q203 to conduct, energizing the UER. The UER contacts open the undervoltage circuit to TDR-2 preventing loss of the BTC during an underexcitation condition. Contacts of CAR-2 bypass Q203 to keep the UER energized when the generator is off.

VOLTAGE REGULATOR

Each voltage regulator provides automatic regulation of generator output voltage. The regulators are located in the electrical equipment rack. The regulator maintains a constant 115-volt, AC, at the generator terminals under the various load conditions by sensing output voltage and comparing the voltage with a preset reference. Excitation to the generator field is varied to maintain voltage to the desired level.

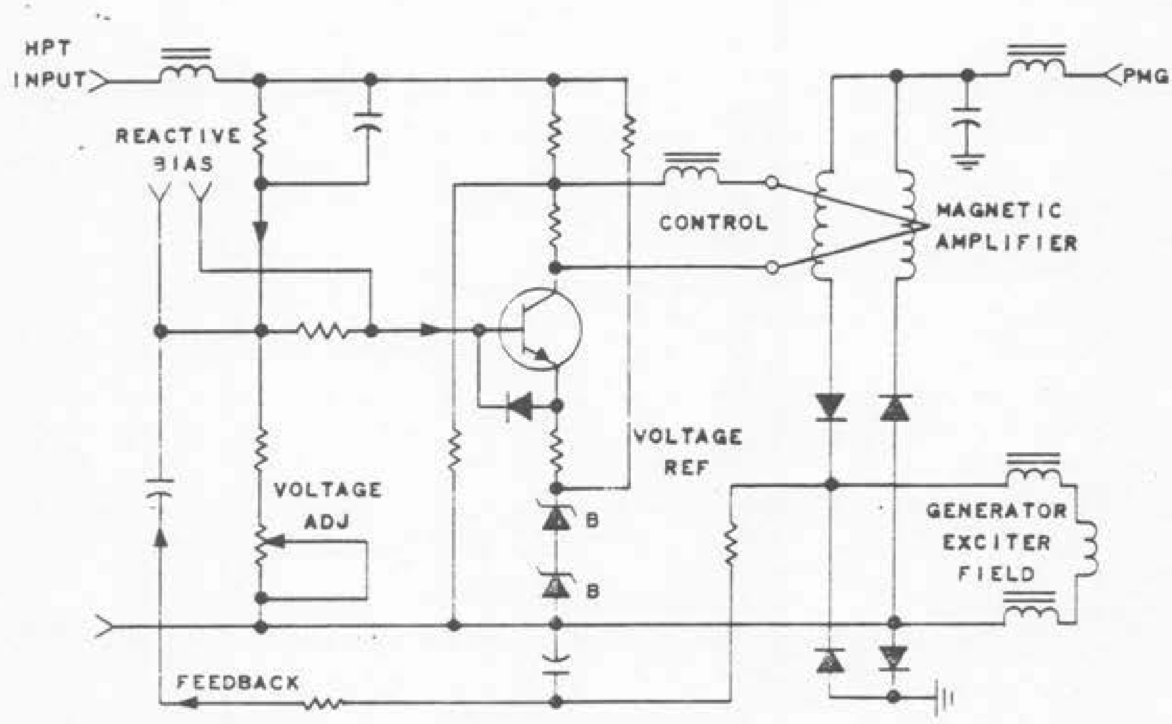
The VR is a static device consisting of a High Phase Takeover (HPT) circuit, Zener diode voltage reference, transistor preamplifier, reactive bias, and magnetic amplifier. The regulator input is PMG voltage, three phase A-C generator voltage, and a reactive bias current transformer signal. The current transformers are also used with the reactive bias circuit in the protection panel.

When the generator is operating. PMG voltage is supplied through GCR contacts to the VR unit. The PMG voltage is approximately 108 volts, AC, at 1600 Hertz. The voltage is rectified and supplied through a magnetic amplifier to the exciter field of the generator. When excitation is applied, an A-C output is obtained from the generator.



HIGH PHASE TAKEOVER (HPT)

Output of the generator is applied as a sensing voltage into the VR unit transformer. The transformer supplied the three-phase AC to the high-phase takeover circuit, consisting of diodes and filters. The positive half-cycle of each phase input voltage will forward-bias sensing diodes to charge a filter capacitor. The capacitor is charged to the average voltage of the three inputs. The high-phase takeover diodes are reverse-biased by capacitor voltage. The highest phase voltage input overcomes the average capacitor voltage and a diode conducts, charging the capacitor to the high-phase voltage.

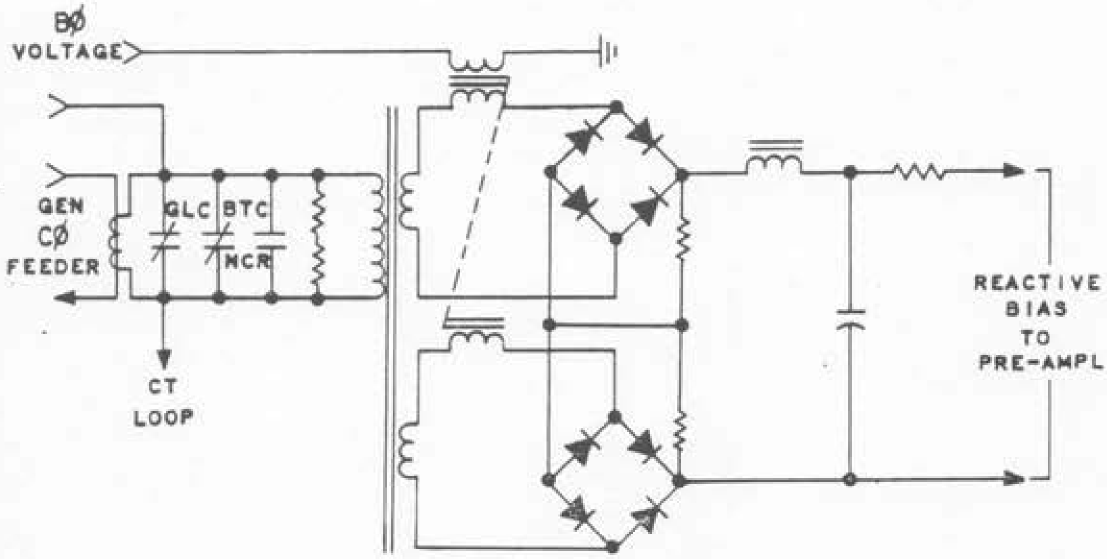


PRE-AMPLIFIER - MAGNETIC AMPLIFIER

The sensing output is filtered and applied through a voltage divider to the transistor amplifier. Zener diodes provide a constant D-C reference signal for the amplifier and establish the operating point. The transistor is normally conducting, providing current through the control winding of the magnetic amplifier. Collector current controls the output of the magnetic amplifier by controlling its saturation.

With minimum control current, the magnetic amplifier provides maximum average current output. The output is rectified and supplied to the generator exciter field As transistor current increases, the magnetic amplifier current decreases to maintain the generator voltage at 115 volts, AC.

In generator parallel operation, load sharing is accomplished by an RBC. The biasing circuit produces a signal proportional to the unbalance of reactive current between generators, as detected by the reactive load current transformers. The bias signal adds to, or subtracts from, the reference voltage to change the input to the amplifier.



REACTIVE BIAS CIRCUIT

The RBC inputs are obtained from phase B of the generator and a reactive bias current transformer. When the generator is not paralleled, contacts of the BTC or GLC bypass the CT and the bias circuit is inoperative. The CT is also by-passed when the neutral current relay is energized.

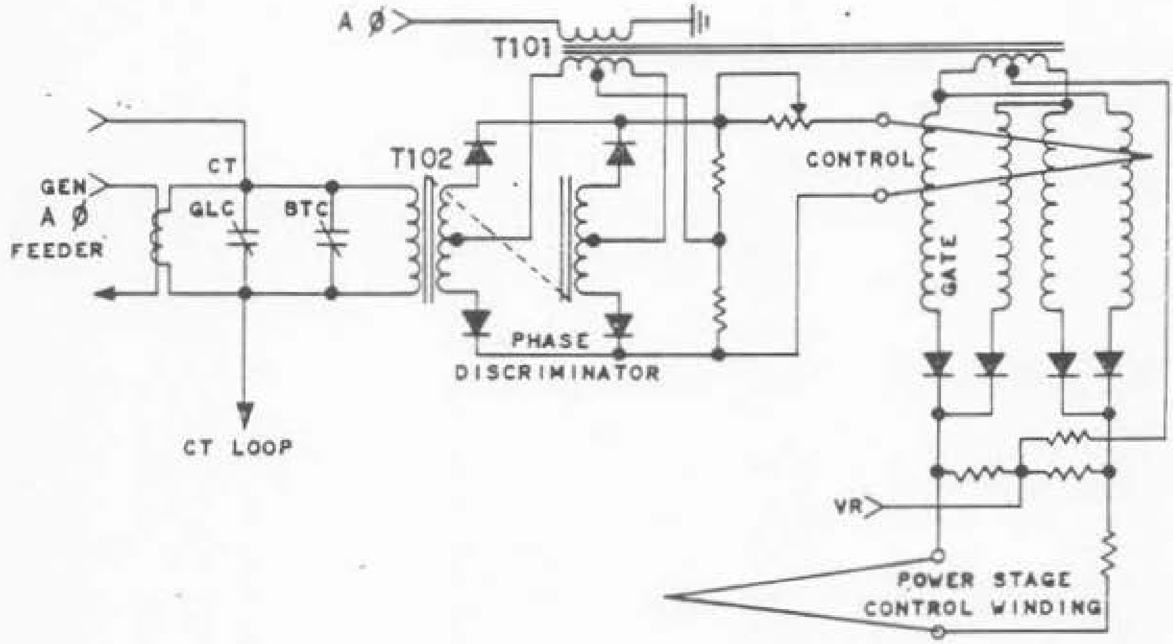
The error signal from the CT's, due to generator reactive load, is applied to transformers and rectifiers. The rectifier outputs are of the same polarity and result in a zero signal until the CT input unbalances the bridge rectifiers. If the generator is supplying a larger reactive load, the bridge is unbalanced and the resultant D-C voltage of the reactive bias circuit is applied to the transistor. An increase in transistor collector current causes a decrease in exciter field current, decreasing generator output. If the generator output is decreased, the load decreases. The parallel generators then pick up more of the reactive load, equalizing the load between generators.

LOAD CONTROLLER

The load controller provides an electrical trimming signal to the load-biasing solenoid of the CSD. The solenoid controls fine trimming of CSD torque which drives the generator. The load controller varies CSD torque to ensure load sharing between parallel generators. The load controllers are located in the electrical equipment rack.

During generator parallel operation, the load controller receives inputs from phase A of the generators and from load-biasing current transformers. The CR signal consists of the real (watts) and reactive (vars) load components and varies with the unbalance of load between generators. The phase of the CT signal indicates the generator is supplying more, or less, load than the other generators.

Each CT is paralleled by contacts of the BTC and GLC, bypassing the CT when the generator is not paralleled. The load controller is used only in parallel operation.



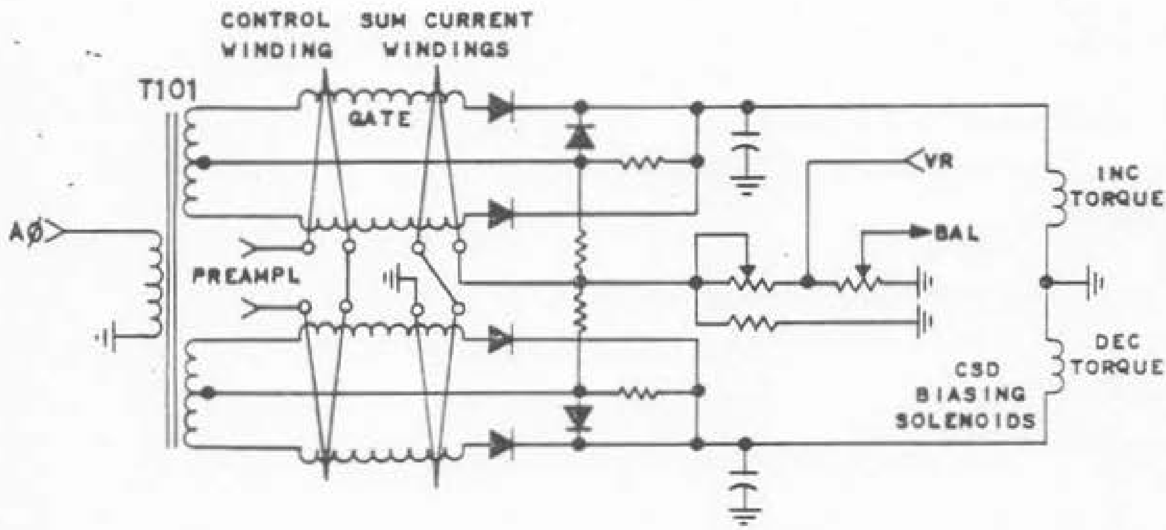
LOAD CONTROLLER INPUT

The load controller is a static device containing magnetic amplifiers, phase discriminator, and voltage regulator. Magnetic amplifiers are used as a preamplifier, transient response amplifier, and power amplifier. The voltage regulator provides D-C reference voltages to the amplifier windings.

The phase discriminator inputs are phase A voltage of the generator and the load biasing current transformer signal. Both inputs are required to produce an output. The D-C output is proportional to the real component of the CT input, with a polarity determined by the phase of the CT input. The output polarity determines if CSD torque is to increase or decrease.

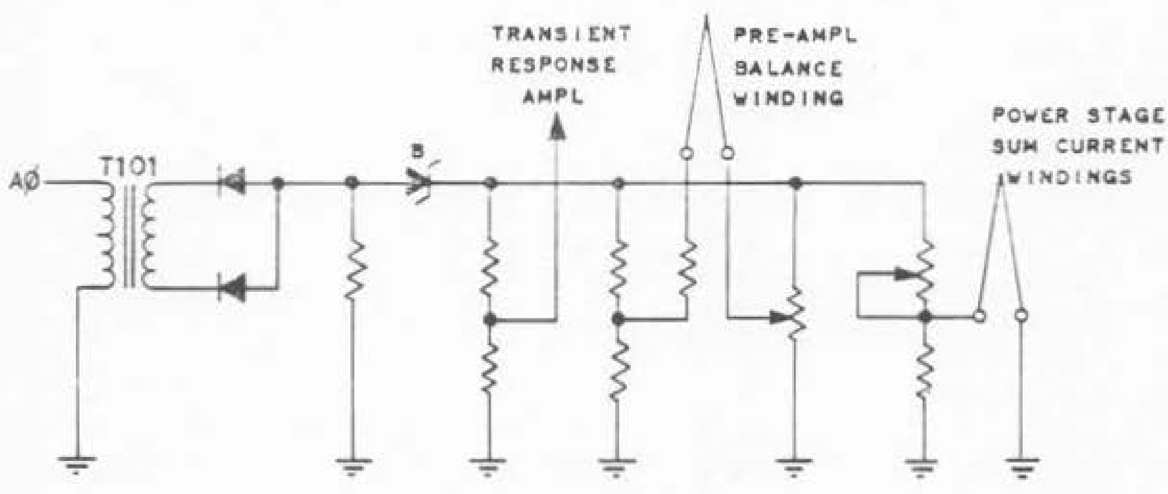
Discriminator D-C output is supplied to the control winding of the preamplifier, and controls saturation of the magnetic amplifier. Each magnetic amplifier output winding receives an A-C input from the power transformer and uses rectifiers to provide D-C outputs. The preamp operates as a push-pull amplifier and provides control current to the power stage magnetic amplifier.

The power stage output drives the load-biasing solenoid in the CSD unit to increase or decrease CSD torque. An increase in torque allows the generator to carry a larger real load, equalizing the generator loads. A decrease in torque decreases the generator load.



POWER STAGE

The transient response magnetic amplifier controls the response of the magnetic amplifiers to signals from the current transformers. The amplifier prevents the load controller from responding to signals of short duration. The voltage regulator is a full-wave rectifier and voltage divider, using a Zener diode for regulation. The D-C voltages bias the magnetic amplifier windings for proper operation.

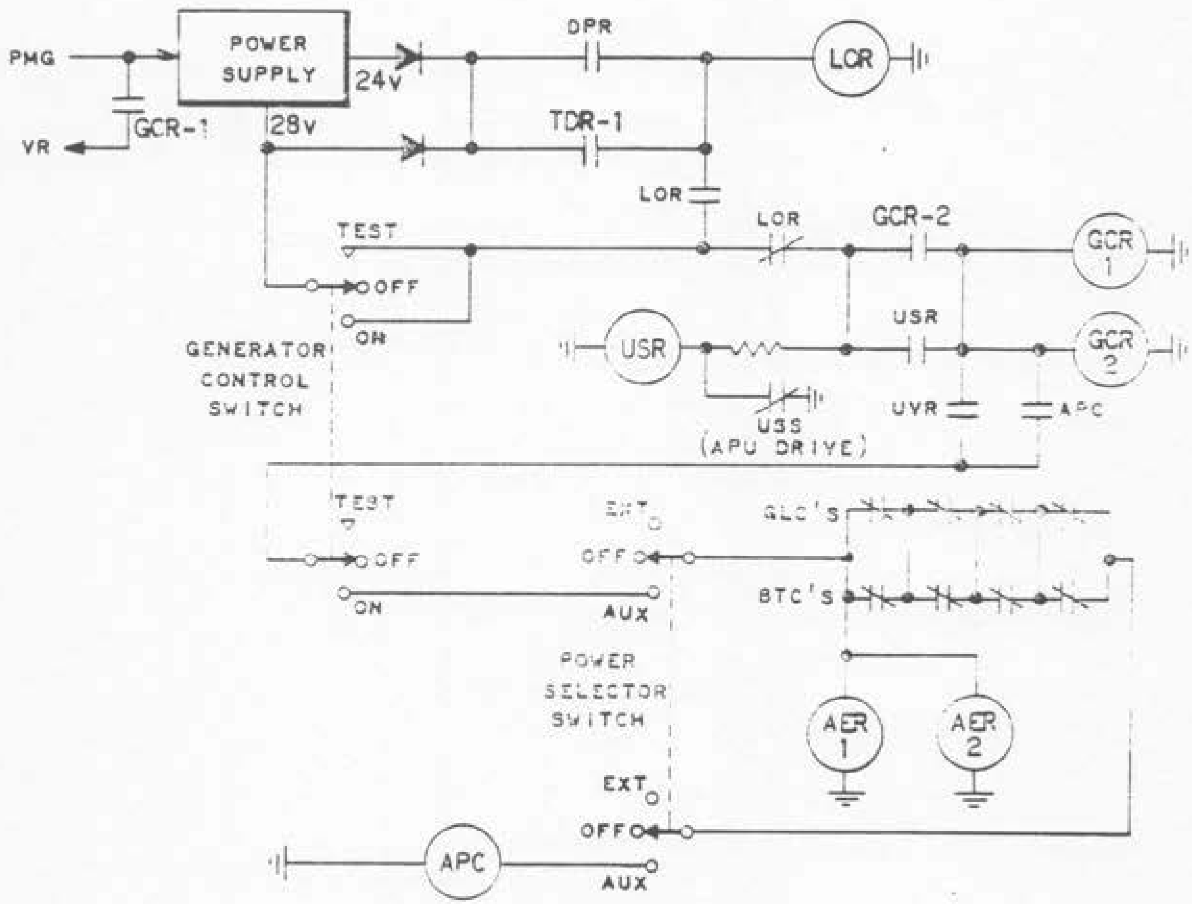


VOLTAGE REGULATOR

The magnetic amplifiers contain many windings to control the saturable reactor core. A control winding is the magnetic amplifier's D-C input winding. A bias winding establishes the operating point of the amplifier by biasing the core. Gate windings have A-C power inputs, and rectifiers to change the A-C to D-C. The gate windings are the output windings of each stage. Feedback and frequency response windings are used for linearity and stability. A sum current winding and balance winding are used to establish the correct output of the amplifiers when the CT input signal is zero.

AUXILIARY GENERATOR SYSTEM (APR GENERATOR)

The fifth A-C power source is driven by the APU to provide three-phase A-C power during ground checkout of the systems. The auxiliary generator cannot be used in flight and does not parallel with any other A-C power source. The



AUX GENERATOR CONTROL CIRCUITS

auxiliary generator system consists of a generator, protection panel, and VR unit. The APU and generator are located in the forward left main wheel well. The generator is identical to the main generators, capable of selectively supplying power to all aircraft buses. An APU-driven fan provides cooling air for the generator. The protection panel and VR unit are located in the electrical equipment rack.

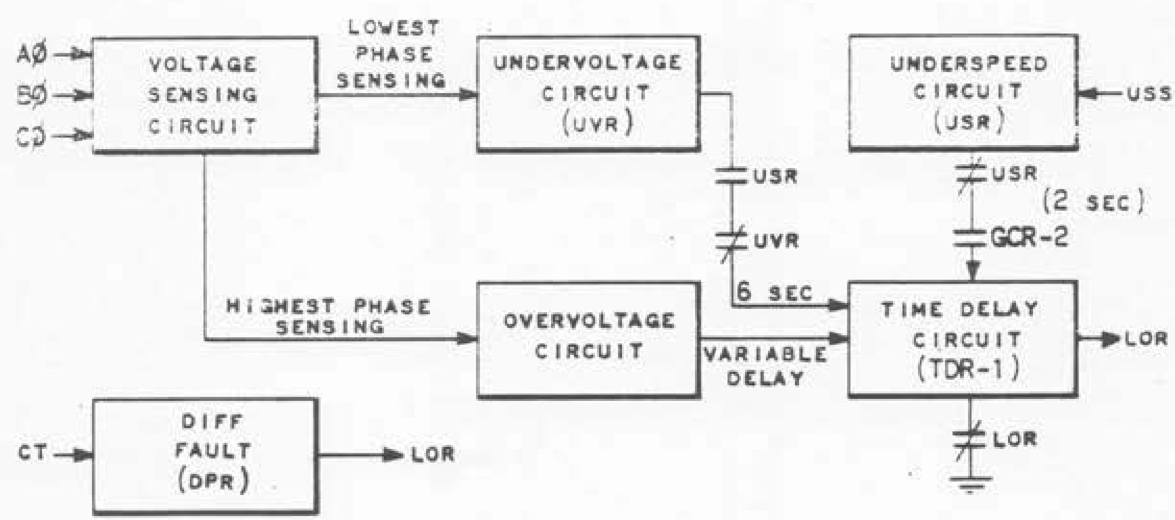
The auxiliary generator is controlled by both the Generator Control and Power Selector switches. If the control switch is "ON" and the power selector is in "AUX," the generator output connects to the main A-C tie bus. The APC is energized to connect the generator output to the bus. With auxiliary power in use, main A-C buses No. 2 and 3 can be energized by positioning the Auto Load Disconnect switches to "OVERRIDE." The "OVERRIDE" position energized the monitor relays. The auxiliary generator loadmeter should be monitored as a precaution against overloading the generator when "OVERRIDE" is used.

VOLTAGE REGULATOR

The voltage regulator automatically maintains the generator three-phase voltage output, 115-volt, AC per phase. The regulator is similar to the main generator regulator but does not contain reactive biasing since the generator does not parallel with the other power sources.

GENERATOR PROTECTION PANEL

The protection panel contains the protection and control circuits of the system. The panel is similar to the main protection panels but contains few circuits and relays since paralleling protection and control are not required. The panel contains a PMG, D-C power supply plus individual phase sensing, undervoltage



AUX GENERATOR PROTECTION CIRCUITS

with fixed time delay, overvoltage with time delay inverse to amplitude, underspeed with fixed time delay, and differential fault protection circuits.

The power supply, individual phase sensing, overvoltage, undervoltage, and underspeed circuits are basically the same as the main generator protection circuits. One TDR is used to control the APC. The TDR times out to energize the LOR, disabling the generator.

The TDR timing is initiated by an undervoltage or underspeed condition. The overvoltage circuit determines the variable delay which is inverse to voltage amplitude and then energizes the TDR. The underspeed switch is controlled by the APU to energize or deenergize the USR. To reset the generator after a fault, position the Generator Control switch to "OFF" then "ON." The switch breaks the holding circuit of the LOR in the "OFF" position.

A differential fault between the generator and APC immediately disables the generator by energizing the LOR. The fault indication is the same as the other faults on the auxiliary generator system, and reset is accomplished by positioning the Generator Control switch to "OFF" then "ON." If the fault still exists, the generator is immediately disabled.

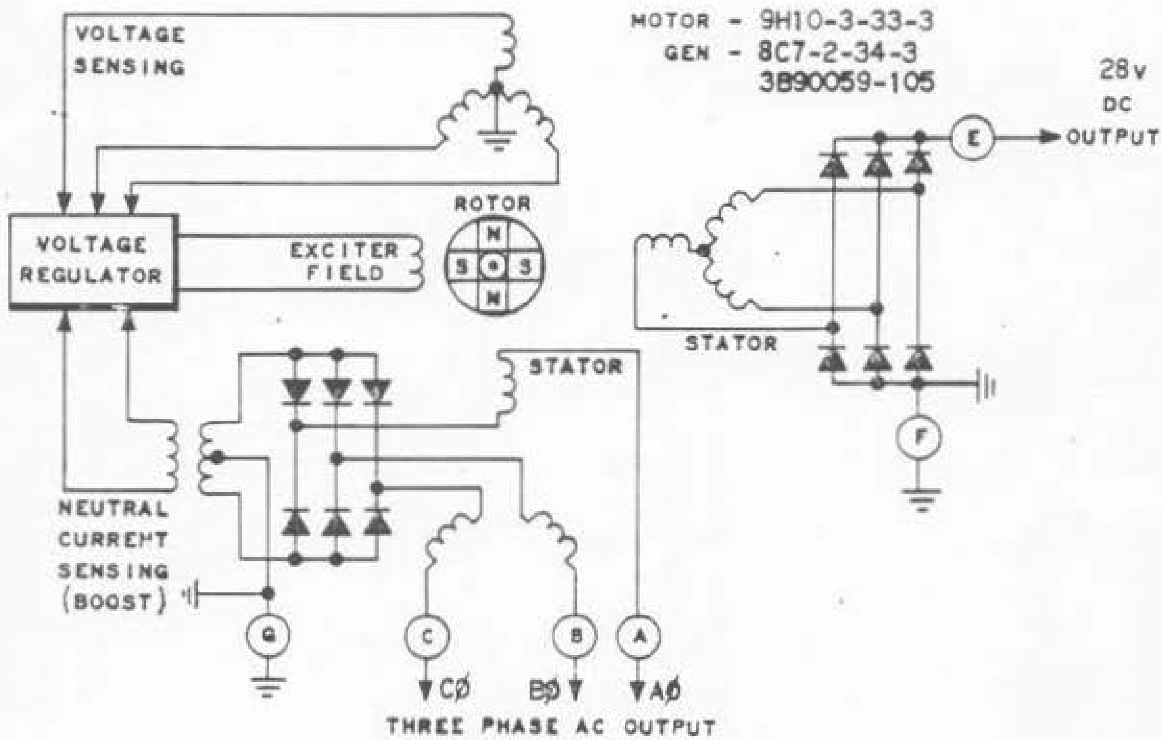
EMERGENCY POWER SYSTEM

The emergency system automatically provides A-C and D-C power if the normal power sources fail. If power to the essential A-C bus No. 1 is lost, the emergency generator automatically operates. Generator output is three-phase, 115/200-volt, AC, at 2 KVA and 28-volt, 20-ampere DC. The generator supplies the emergency and isolated A-C and D-C buses. Emergency power cannot be used to supply the other buses or to charge the battery.

EMERGENCY GENERATOR

The emergency generator is located in hydraulic service center No. 2. A four-pole, Lundell-type generator is used. The continuous A-C power output is 2 KVA. However, the generator is capable of supplying 2.5 KVA for 5 out of 30 minutes. A rotor speed of 12,000 RPM is maintained by a constant-displacement hydraulic motor. Generator output voltage is regulated to 116 volts, AC, by an integral voltage regulator. A fan attached to the rotor provides generator cooling air.

The generator contains a permanent magnet rotor and three sets of stator windings. The rotor magnetic field strength is varied by field excitation current from the voltage regulator. Three sets of stator windings provide the generator outputs. The stators provide a three-phase A-C output, 28-volt D-C output, and three-phase sensing voltage into the voltage regulator.



EMERGENCY GENERATOR

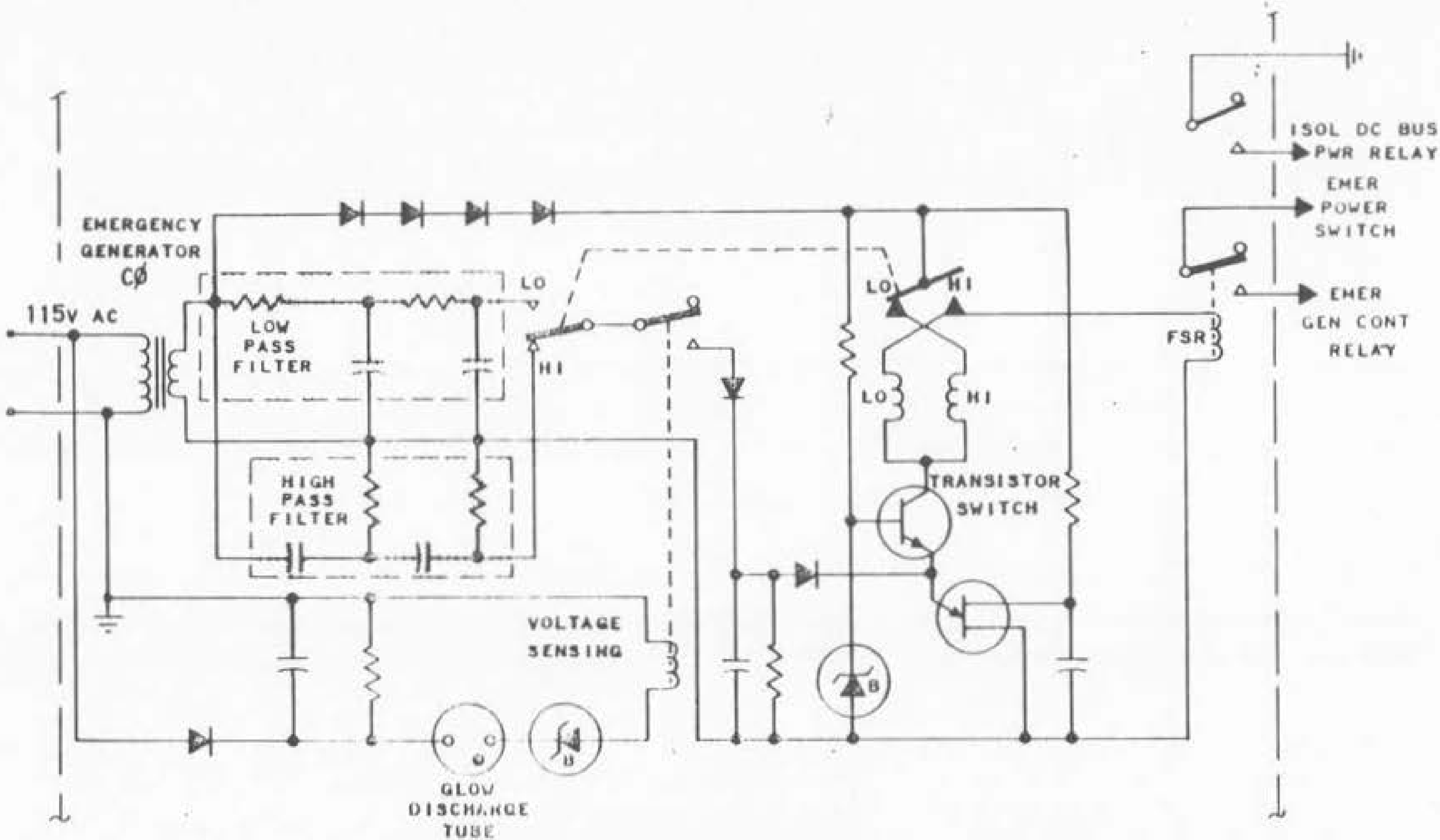
The three-phase A-C output is supplied to the emergency and isolated AC buses when the generator is operating. The neutral wire current of each phase is rectified and supplied into the VR as boost current during an overload.

The three-phase voltage sensing windings provide AC into the voltage regulator. The regulator rectifies the AC to provide CR operating voltage and compares the sensed voltage against a zener diode voltage reference. The resulting signal from the comparison circuit is amplified and supplied to the exciter to regulate generator output voltage.

The third stator voltage is rectified and supplied to the emergency and isolated D-C buses. A full-wave rectifier changes the AC to 28-volt, D-C output. The rotor is the equivalent of a four-pole magnetic rotor driven at 12,000 RPM to provide 400 Hertz A-C output. Without excitation, the residual magnetism would provide approximately 30-volt A-C output. The VR controls the exciter to maintain the output at 116 volts, AC.

FREQUENCY SENSITIVE RELAY

The Frequency Sensitive Relay (FSR) contains a voltage sensing circuit, high-pass low-pass filter, transistor switch, and relay coils. The FSR senses generator



FREQUENCY SENSITIVE RELAY (FSR)

phase C voltage and frequency and is energized when voltage is above 100 volts, AC and the frequency is above 380 Hz. A 3 to 6-second delay is provided in the FSR to prevent relay dropout during a transient voltage or frequency condition.

As generator voltage builds up, the voltage sensing coil is energized. The voltage required to energize the coil is determined by a glow discharge tube and Zener diode in series with the coil. Relay contacts connect the high-pass or low-pass filter signal to the transistor switch. Above 380 Hertz, the high-pass filter signal is rectified, filtered, and supplied to the switch. The positive rectified voltage causes the unijunction transistor and transistor switch to conduct, energizing the HI coil of a polarized relay. The HI relay contacts close to energize the FSR coil which controls the generator system. The low-pass/high-pass filters are switched by the polarized relay and the transistor switch stops conducting. The polarized relay remains in the "HI" position due to the permanent magnet relay armature.

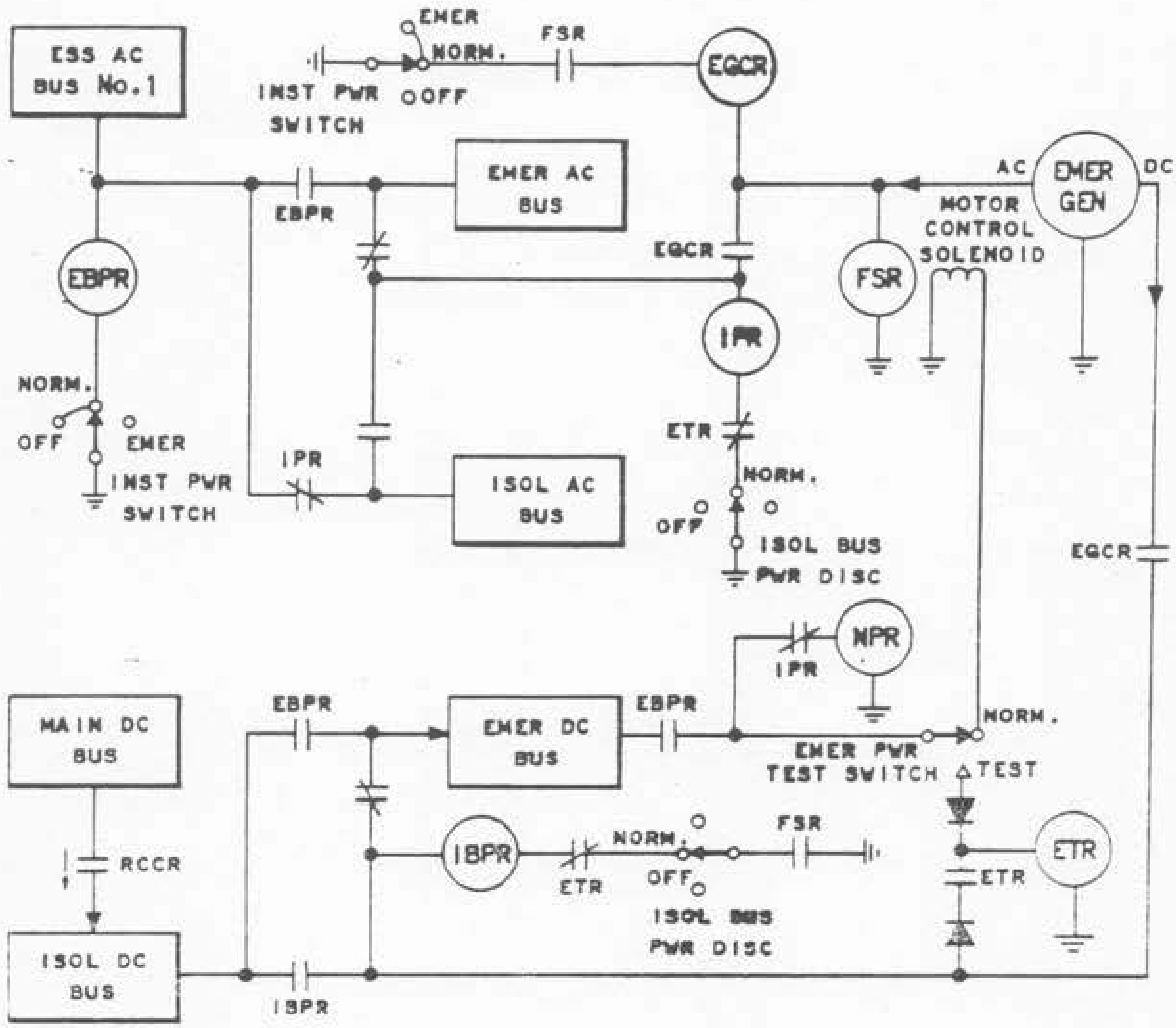
When frequency decreases below 360 Hertz, the low-pass filter output is rectified, filtered, and supplied to the transistor switch. Filter voltage builds up until the transistors conduct, energizing the LO coil of the polarized relay. The relay contacts switch to the LO side, deenergizing the FSR. The FSR contacts remove the generator from the load through the EGCR. The lower frequency of the low pass filter and the filter capacitors provide the 3 to 6-second delay on relay dropout.

EMERGENCY GENERATOR CONTROL

An energized motor-control solenoid prevents hydraulic fluid from driving the hydraulic motor, preventing generator operation. The solenoid is deenergized due to loss of power to essential A-C bus No. 1, or loss of the emergency D-C bus. The deenergized solenoid opens a hydraulic shutoff valve allowing the motor to operate. The solenoid is located below the motor generator.

When power to the essential A-C bus No. 1 fails, the Emergency Bus Power Relay (EBPR) is deenergized. Relay contacts open the circuit to the solenoid and the motor starts. An FSR senses generator output frequency through a low-pass high-pass filter. The FSR is energized when frequency is above 380 Hertz and deenergized below 360 Hertz. The FSR contacts provide a ground to energize the Emergency Generator Control Relay (EGCR), and Isolated DC Bus Power Relay (IBPR)

The energized EGCR connects the A-C and D-C generator outputs to the buses. The emergency buses are supplied through the deenergized EBPR, and the isolated buses are supplied through the energized Isolated A-C Bus Power Relay (IPR) and the Isolated D-C Bus Power Relay (IBPR). The FSR and EGCR



EMERGENCY GENERATOR CONTROL CIRCUITS

are located in the generator control box within hydraulic service center No. 2. The bus power relays are behind the emergency circuit breaker panel in the flight station.

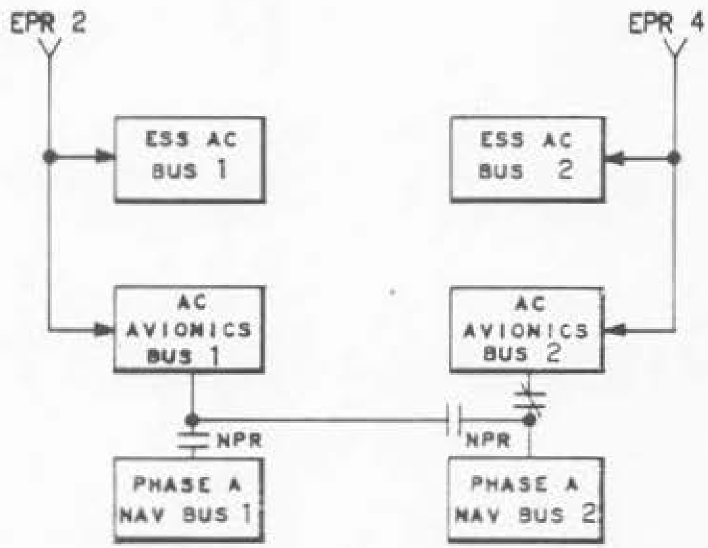
The "EMER" position of the switch deenergizes the EBPR to start the generator. The "OFF" position prevents use of the emergency generator with a load by opening the EGCR circuit but does not prevent generator operation.

An EMERGENCY POWER test switch, located on the electrical control panel, is used to check the generator without a load. The voltmeter and frequency meter can be used to monitor generator output. The "TEST" position removes emergency D-C bus power from the solenoid to start the generator. The output of the generator will not connect to the buses in "TEST" since the TEST RELAY opens the IPR and IBPR to the isolated bus. Power from the emergency generator cannot reach the emergency bus due to open contacts of EBPR.

An isolated bus power disconnect switch can be used to disconnect the isolated buses from the emergency generator. The "OFF" position deenergizes the IBR, and IBPR. The relays prevent generator power from reaching the isolated buses, and the emergency buses remain energized from the emergency generator.

NAVIGATION BUSES

The avionic buses are energized from the primary bus power sources. The Phase A navigation buses are normally energized through the Navigation Bus Power Relay (NBR). The NBR is energized from the emergency D-C bus when the normal power sources are operating. The navigation buses are normally supplied power from the A-C avionics bus No. 1.



NAVIGATION BUS POWER SOURCES

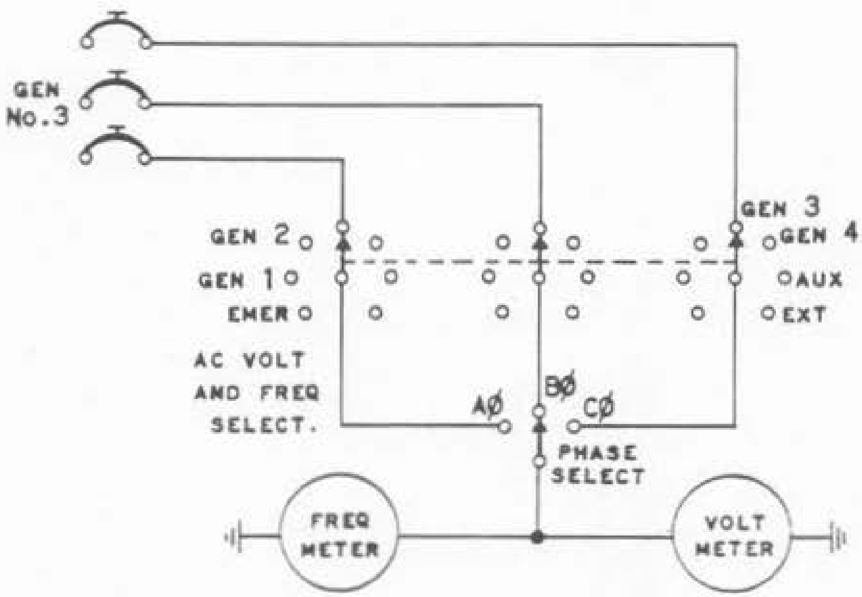
If the emergency generator is operating, the NBR is deenergized. The NBR opens the circuit to the Phase A navigation bus No. 1, and connects Phase A navigation bus No. 2 avionics bus No. 2. The avionics bus No. 2 is supplied from essential A-C bus No. 2 which may still be energized, even though the emergency generator is operating. The emergency generator is controlled by loss of power to essential A-C bus No. 1.

FLIGHT ENGINEER"S ELECTRICAL CONTROL PANEL

The control switches, selectors, and indicators necessary to monitor and maintain control of the electrical power system are on the flight engineer's electrical control panel.

AC METERS

The output frequency and phase voltage of all generators or external A-C power can be monitored on the frequency and volt meter through switch selections.

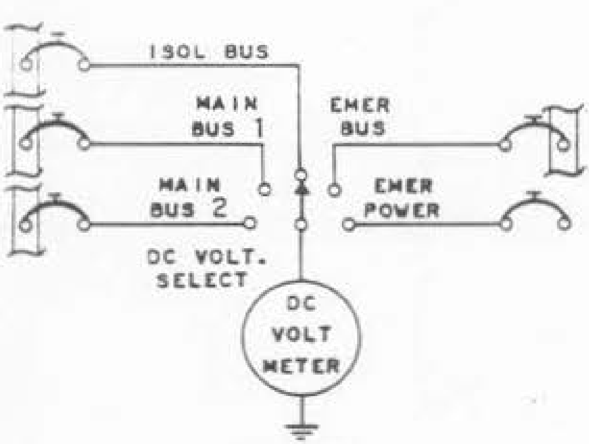


AC METERS

The system to be monitored is selected on the AC VOLT & FREQ SELECT switch and phase on the PHASE SELECT switch. During parallel operation, the voltmeter reading is the voltage of the parallel generators, not the selected generator. Isolated operation, or "TEST" of the generator is used to obtain a single generator indication.

D-C METERS

Voltage of all D-C sources may be checked on the D-C volt meter through the DC VOLT SELECT switch. Battery voltage may be read on the isolated D-C bus when the TR units and emergency generator are not operating. The battery switch must be positioned to "ON," energizing the isolated D-C bus from battery voltage.

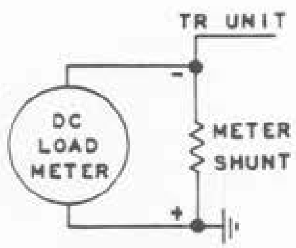


DC METER

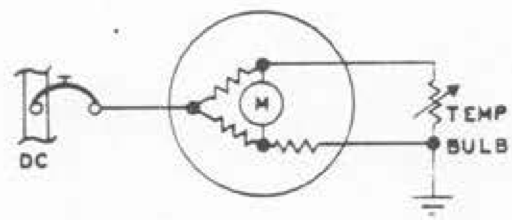
Two D-C load meters indicate the percent load on each TR unit. A 100 percent reading is equal to 200 amperes. The reading is provided by a meter shunt in series with the TR unit ground wire.

CSD MONITORING

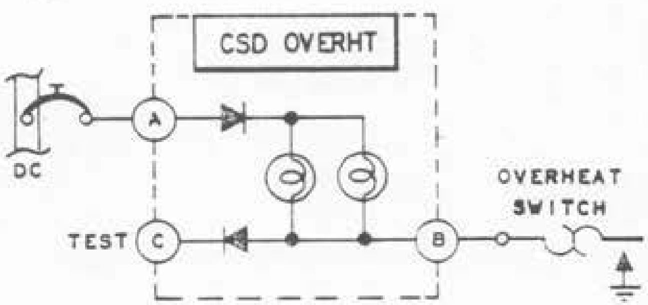
Each CSD unit has a temperature indicator, warning light, and disconnect switch. The indicator and warning light are controlled by CSD oil temperature. The CSD overheat switch closes above 179° C to illuminate the warning light. The CSD DISC switch controls a solenoid in the CSD unit. If the switch is actuated while D-C power is available, the CSD will be disconnected. The CSD remains disconnected until the manual lever on the CSD is reset.



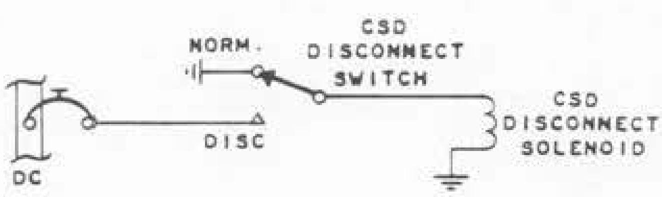
LOADMETER



CSD OIL TEMP



CSD OVERHEAT LIGHT

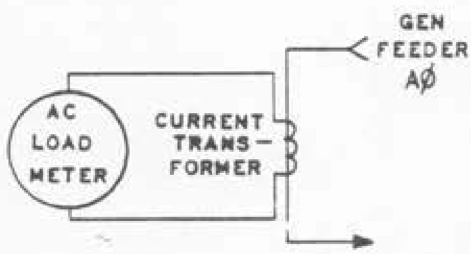


CSD DISCONNECT

GENERATOR MONITORING

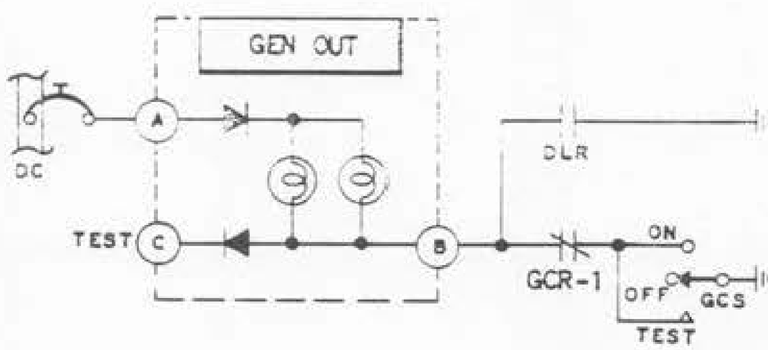
Each main generator and auxiliary generator has a GEN FAIL light, loadmeter, generator OFF light, and control switch. The fail light illuminates due to a mechanical circuit in the generator when the generator bearings fail. The load may be removed from the generator by moving the control switch to "OFF," or the generator can be stopped by disconnecting the CSD. The auxiliary generator can be stopped by turning the APU to "OFF."

The generator loadmeter indicates percent load, with 100 percent equal to 50KVA. During normal parallel operation, the main generator load meters should read the same. The loadmeter reading is provided by a current transformer around the Phase A feeder of the generator.

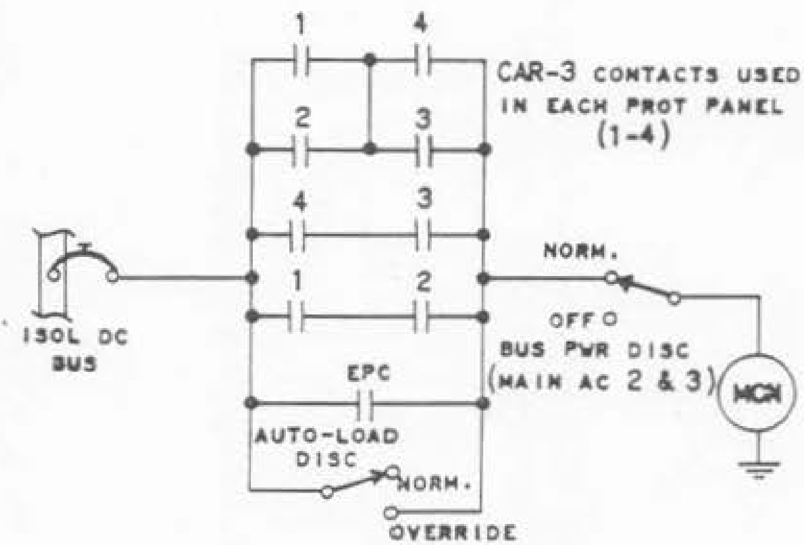


LOADMETER

The generator OUT light illuminates through GCR-1 or DLR contacts when the protection circuits trip the generator. The light is extinguished by placing the control switch in "OFF." If a ground fault exists, the light remains illuminated in "OFF" due to the DLR until reset is accomplished. The auxiliary generator OUT light is extinguished in the "OFF" position of the control switch since the auxiliary generator does not have a DLR. The bus tie OPEN light is identical to the generator OUT light but is controlled by normally closed BTC contacts.



GENERATOR OUT LIGHT



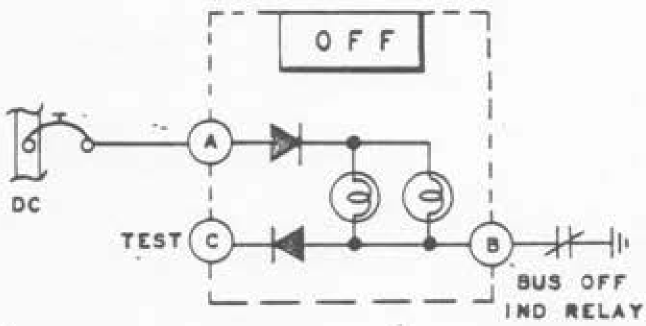
MONITOR RELAY CONTROL

AUTO LOAD DISCONNECT SWITCHES

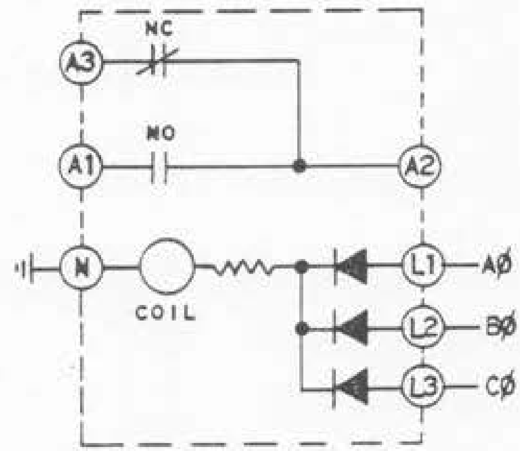
The No. 2 and No. 3 main generator systems have auto load-disconnect switches to permit override of the monitor relays. The relays are normally energized through two series CAR-3 contacts of the protection panels. Two or more main generators in operation close the CAR-3 contacts to energize the relays. External power also energizes the relays through EPC contacts. The auto load disconnect switch is used to bypass the CAR-3 contacts (override) to energize the monitor relays.

BUS WARNING LIGHTS

The A-C bus OFF warning lights are provided for main A-C buses No. 1 and 4, essential A-C buses No. 1 and 2, and isolated A-C bus. The OFF lights are controlled by bus OFF indicator relays which sense the three-phase bus voltage. The relays are energized when bus voltage is normal. Rectifiers change the three-phase bus voltage to DC for the relay coil. When the bus fails or has low voltage (three-phase average below 90 volts AC), the relay is deenergized and the light illuminates. The relays are located in the flight station relay panel below the flight engineer's table.

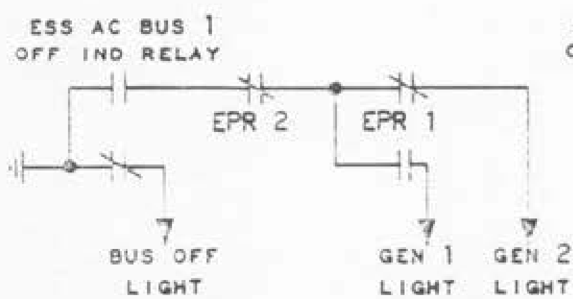


BUS "OFF" INDICATOR

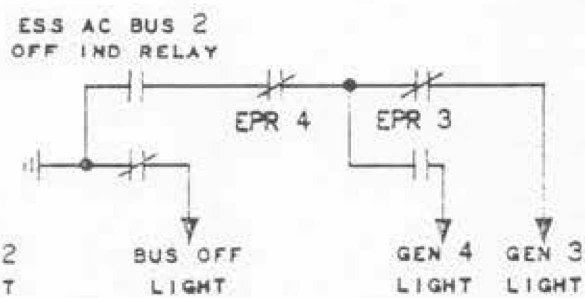


BUS "OFF" INDICATOR RELAY

The essential bus indicator lights are OFF - GEN 1 and GEN 2 for essential bus 1. The essential bus No. 2 lights are OFF - GEN 3 and GEN 4. The OFF light is illuminated through the deenergized bus off indicator relay when the bus source fails. The GEN 1 light is illuminated through the energized bus off indicator relay, deenergized EPR-2 and energized EPR-1. The bus is supplied power from generator No. 1.



ESS BUS 1 LIGHTS



ESS BUS 2 LIGHTS

The GEN 2 light is illuminated through the deenergized EPR-1. The bus is supplied power from Generator 2. All three lights extinguish when the main A-C tie bus has a power source due to the energized bus off indicator relay and EPR-2. The essential bus No. 2 lights function the same as bus 1 using EPR-3 and EPR-4.

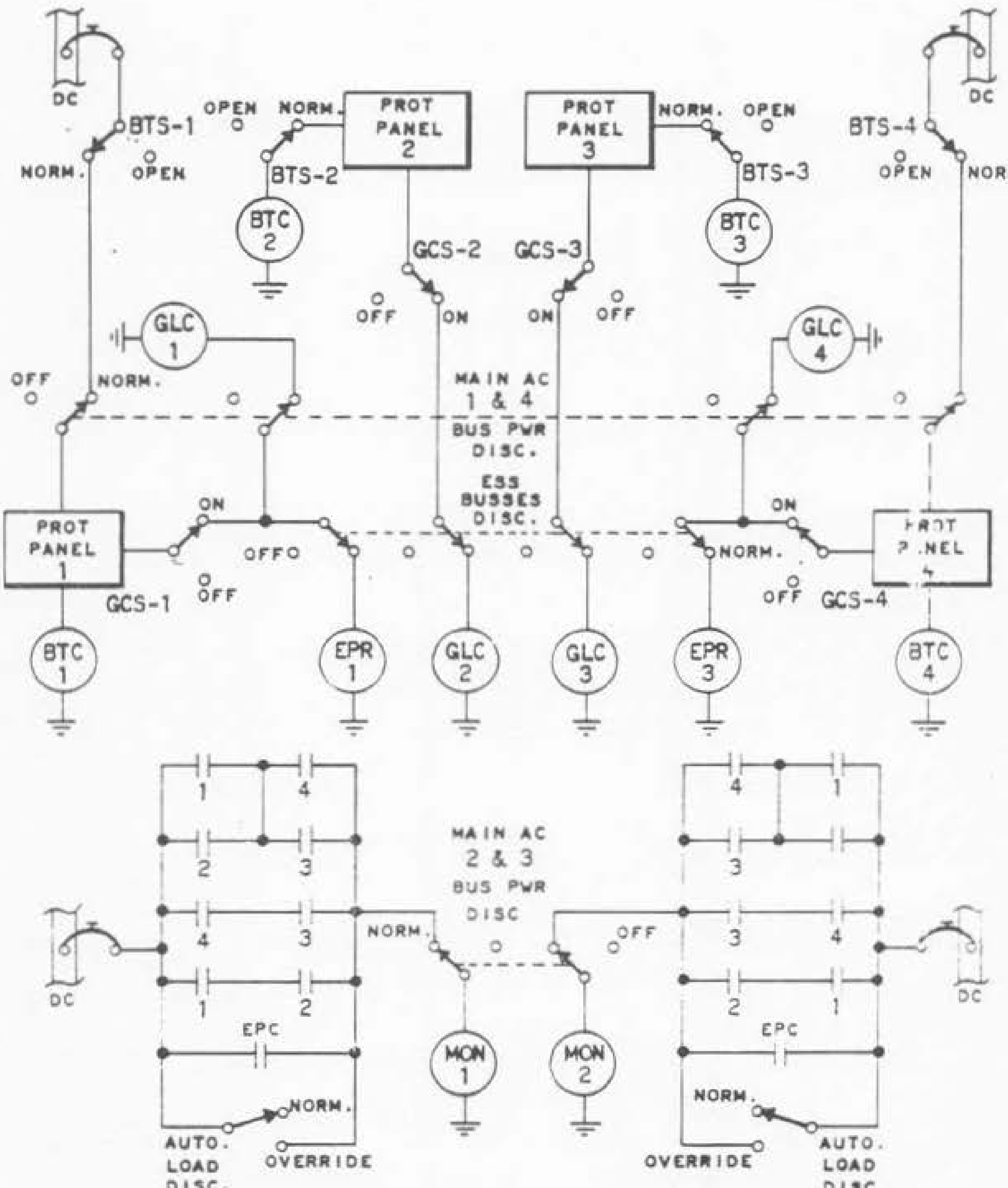
The isolated A-C bus off indicator relay is energized by three-phase A-C voltage from the isolated A-C bus. The relay controls the isolated A-C OFF light. The EMER PWR and ISOL AC BUS light illuminate when the emergency generator is supplying power to the bus. The lights are controlled through the energized IPR. The EMER PWR EMER AC BUS lights illuminate when emergency bus is supplied power from the emergency generator. The lights are controlled through the energized EGCR and deenergized EBPR. An EMER PWR ON light, located on the pilot's instrument panel, also illuminates to indicate emergency power is supplying the emergency A-C bus. The light is in parallel with emergency bus lights.

BUS POWER DISCONNECT SWITCHES

The disconnect switches are provided to remove the bus load quickly in case of a fire or emergency condition. The main A-C buses No. 2 and 3 switch in the "OFF" position opens the monitor relays, disconnecting main A-C buses No. 2 and 3. The main A-C buses No. 1 and 4 switch opens GLC's 1 and 4 and BTC's 1 and 4, disconnecting main A-C buses No. 1 and 4. The essential buses switch opens GLC-2 and GLC-3, deenergizing the essential A-C buses and main A-C tie bus by deenergizing EPR-1 and EPR-3.

The main A-C bus disconnect switches should be "OFF" before the essential buses' disconnect switch is effective in generator parallel operation. The isolated bus switch deenergizes the isolated A-C and D-C power relays (IPR and IBPR).

The switch connects the isolated buses to the normal system by deenergizing the relays. If the normal power source is operating, the switch has no effect and the isolated buses remain energized. The emergency generator must be the only power source before the isolated bus disconnect is effective.



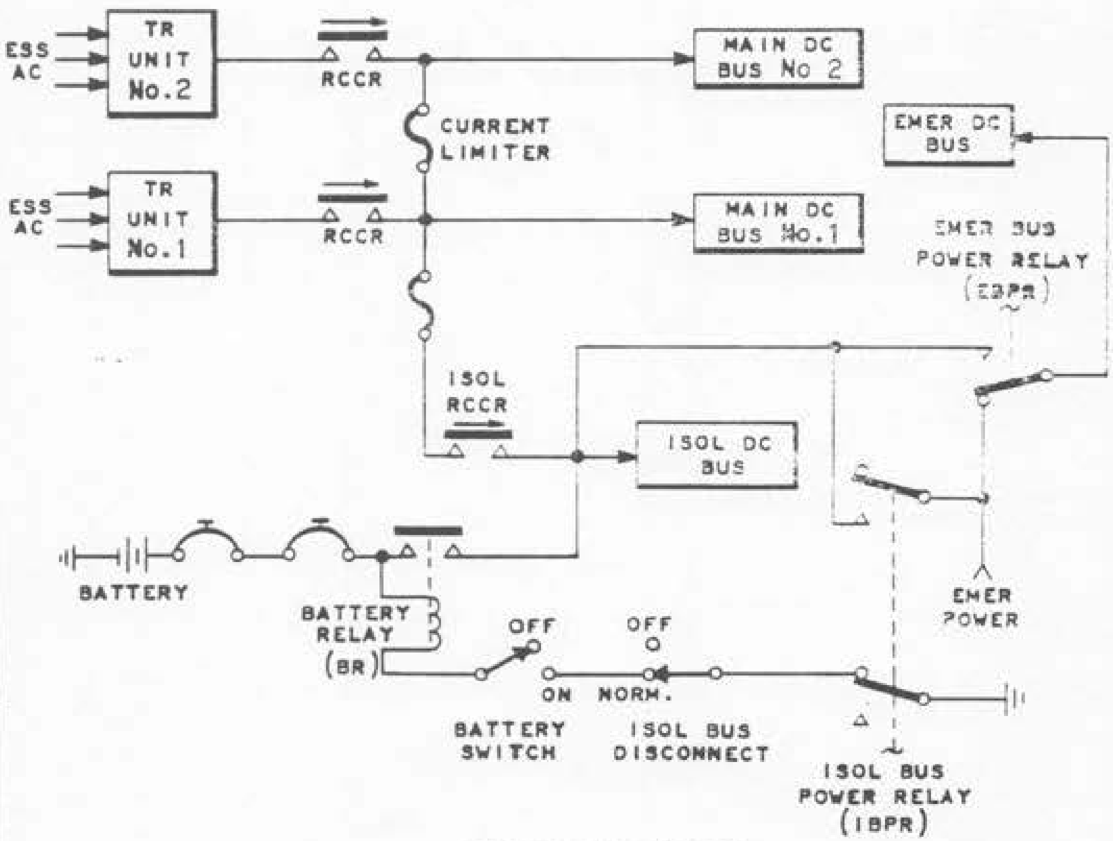
NOTE: 1-4 IS CAR-3 CONTACTS OF PROTECTION PANELS

BUS POWER DISCONNECT

D-C POWER SYSTEM

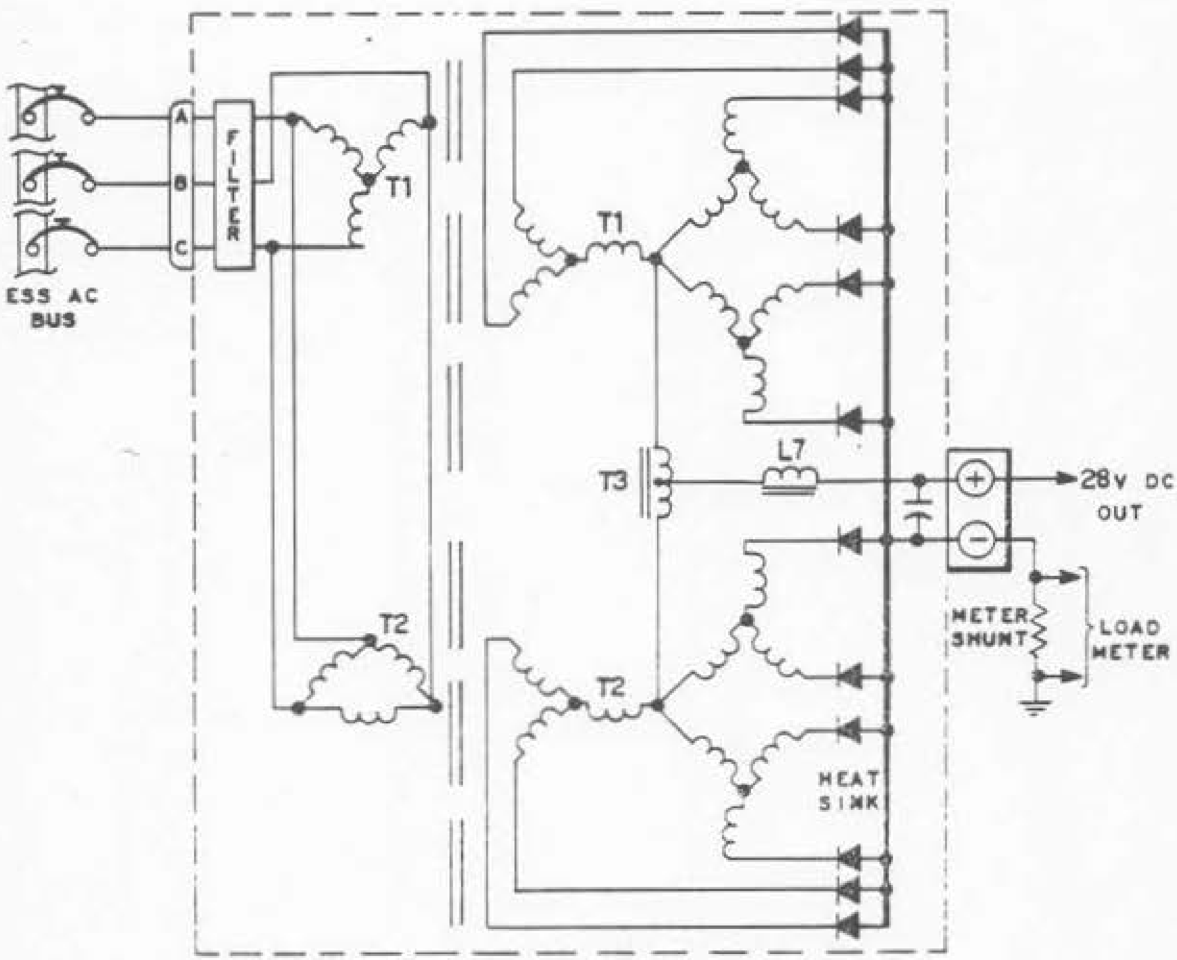
GENERAL

The normal source of D-C power for the StarLifter is two transformer-rectifier (TR) units. These units change three-phase AC to 28-volt, DC. Each unit is rated at 28 volts and 200 amperes. The units are located on the right hand forward underdeck rack. Cooling of these units is provided by normal air circulation.



DC BUS DISTRIBUTION

A 24-volt lead-acid battery is provided as an emergency source of power. The battery is used primarily to start the auxiliary power unit but may also be used in flight if the emergency generator is inoperative. Inflight emergency power is supplied by a hydraulically-driven A-C/D-C generator as long as hydraulic pressure is available.

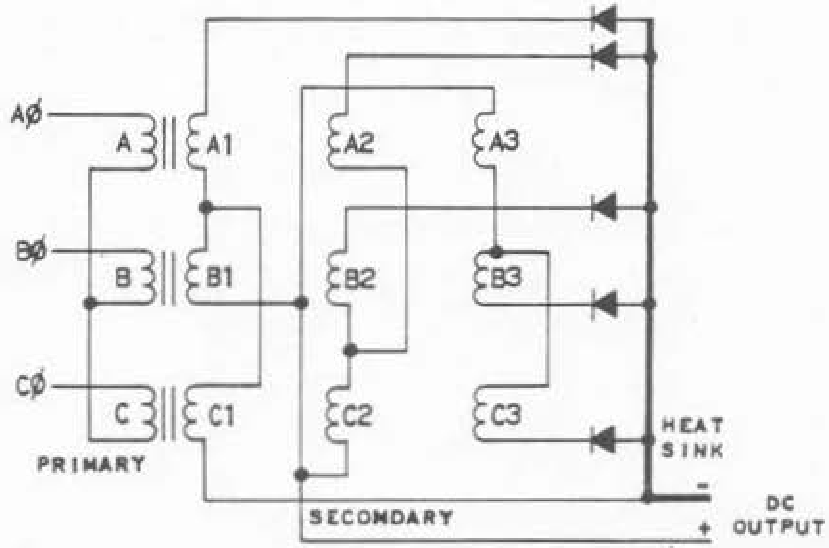


T R UNIT (CHATHAM)

TR UNITS

The input to each TR unit is 200-volt, phase-to-phase, 400 Hertz AC from the No. 1 or No. 2 essential A-C bus. One unit is connected to each bus. The output is supplied through reverse current cutout relays to the D-C buses. No. 1 and No. 2 DC buses are interconnected and both can furnish power to the isolated D-C bus. The TR units contain step-down transformers to reduce the input voltage to a lower value and silicon rectifiers to change the AC to DC. The silicon rectifiers are mounted on a heat sink to dissipate heat.

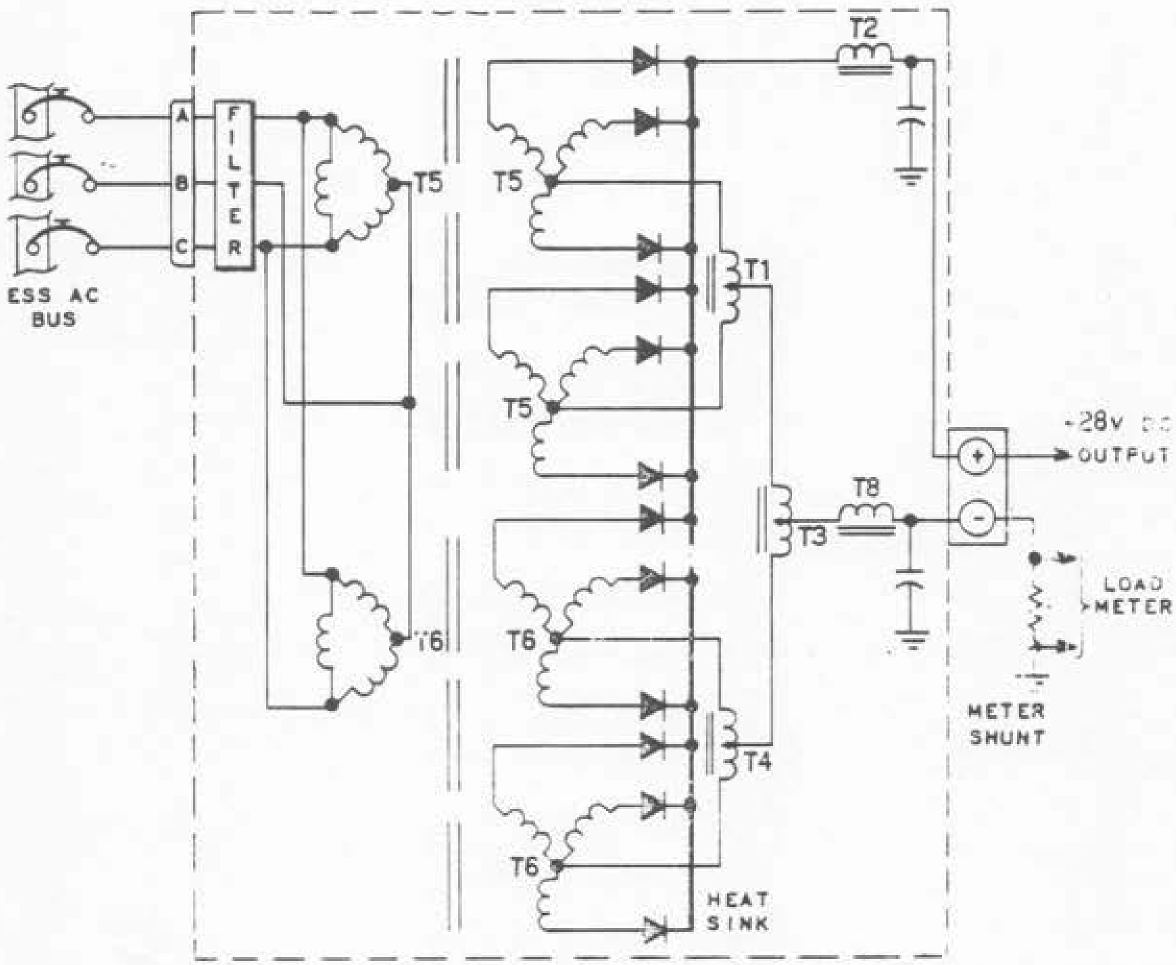
TR units from three different manufacturers are used interchangeably on the airplane. The three manufacturers are Chatham, Westinghouse, and Electrosolids. The three different TR units are described in the following:



SIX-PHASE HALF WAVE RECTIFICATION

The Chatham TR unit essentially is two, three-phase, half-wave power supplies which are connected in parallel. One of the power supplies has a wye-to-wye, step-down transformer followed by six diodes to give half-wave rectification and a ripple frequency of 1200 pulses per second. The other power supply has a delta-to-wye step-down transformer which also has six diodes for half-wave rectification. It also develops a ripple frequency of 1200 pulses per second. Due to the 60-degree phase shift between a delta-to-wye transformer, the ripple developed by the two power supplies is also out of phase by 60 degrees. The two power supplies are connected in parallel to double the ripple frequency to 2400 pulses per second.

The Westinghouse TR unit also consists of two power supplies which are connected in parallel. The difference between the Westinghouse unit and the Chatham unit is in transformer connections. The Westinghouse unit has two wye-to-wye, step-down transformers. One of the wye-to-wye transformers is 180 degrees out of phase with the other. Even through each of the power supplies has half-wave rectification, the fact that one power supply is out of phase with the other gives effective full-wave rectification. The ripple frequency of the Westinghouse unit is 2400 pulses per second.

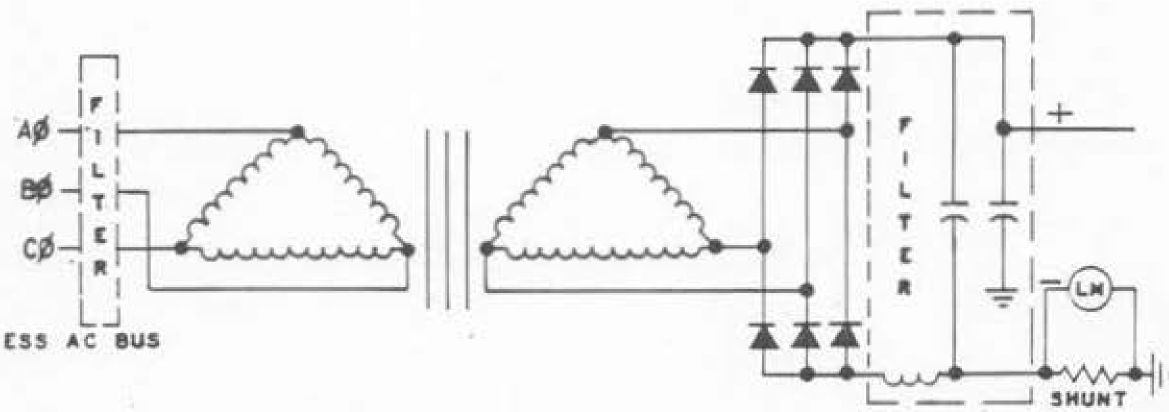


T R UNIT (WESTINGHOUSE)

The Electrosolid TR unit has a delta to delta step-down transformer. Rectification is accomplished by a full-wave, three-phase bridge. Again, ripple frequency is 2400 pulses per second.

Voltage output of the transformer rectifier unit is dependent on the load. With no load on the TR unit, the voltage would rise to an over-voltage condition. To improve voltage regulation, the D-C electrical system is designed to provide a nominal load for the TR units at all times.

The TR units are the normal source of D-C power for the StarLifter. They are capable of supplying all the D-C power requirements of the D-C electrical systems. To protect the D-C buses in the event of a failed TR unit, Reverse Current Cutout Relays (RCCR) are installed in series between the TR unit and the bus that it supplies.

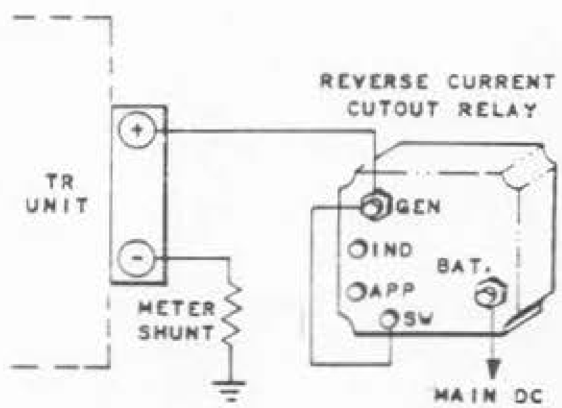


TR UNIT 26.1 V DC 200 AMPERES
(ELECTROSOLIDS CORP)

REVERSE CURRENT CUTOUT RELAY

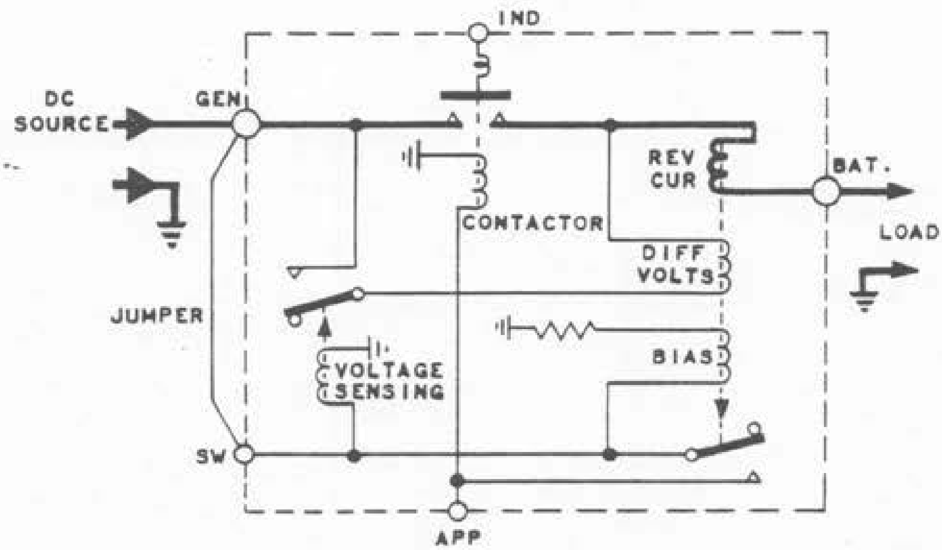
The reverse current cutout relay is composed of three individual relays which are the voltage, control, and current relays. The current relay has three separate coils which are wound on one common core. The three coils are the differential voltage coil, bias coil, and the reverse current coil.

OPERATION



R C C R

When 28-volt DC is applied to the switch terminal, the voltage sensing coil will close its contacts. The bias coil sets up a magnetic field which tends to close the bias contacts. This field is not strong enough due to a series resistor. The voltage sensing contacts complete the circuit between the generator terminal and the battery terminal through the differential voltage coil. When the generator terminal is at a higher potential than the battery terminal, this field and the bias field will aid in closing the bias contacts. The bias coil will hold the contacts closed. The bias contacts apply 28-volt DC to the main contactor coil from the switch terminal; the contactor energizes, closing the heavy duty contacts which completes the circuit between the generator and battery terminals.

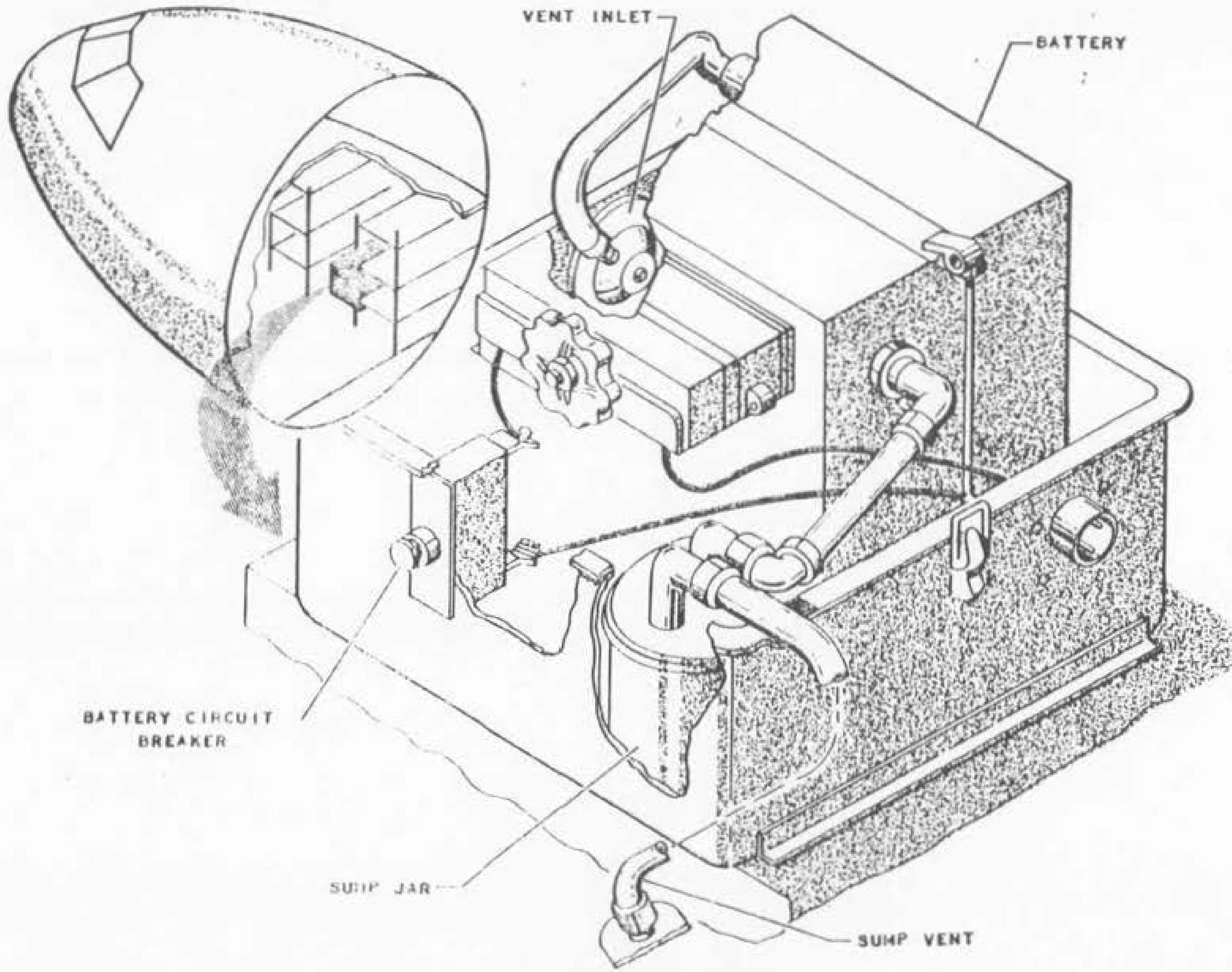


REVERSE CURRENT CUTOUT RELAY

The reverse current coil is one or two turns of heavy wire wrapped around the bias and differential voltage coils. Its field has little effect under normal operating conditions. If the current reverses, its field opposes the bias coil. Flux developed by the reverse current will cancel enough of the flux in the current relay to cause it to open. Reverse current occurs when the battery terminal is at a higher potential than the generator terminal. Reverse current could be causes by a faulty TR unit. When the current relay contacts open, the circuit for the coil of the main contactor is opened. This action opens the circuit between the load and the source. The reverse current cutout relay will reconnect the load source when the generator terminal becomes more positive than the battery terminal. The RCCR's between the TR units and the bus are rated at 200 amperes. Another RCCR, rated at 100 amperes, is used to connect the isolated D-C bus to main D-C bus No. 1. All of the reverse current relays are mounted behind the flight engineer's No. 3 circuit breaker panel.

BATTERY SYSTEM

The battery system consists of a battery, battery relay, battery switch, power circuit breaker, and an indicator light. The battery switch is used for ignition in starting the APU. It also provides a standby source of power for emergency operations. The 24-volt, 11 ampere-hour, lead-acid battery is installed in a removable battery box located in the right hand underdeck area. A venting system is provided to conduct the explosive gases overboard through an opening in the bottom of the fuselage. The venting system consists of a sump jar tubing and works on a difference in pressure between the cargo compartment and outside air pressure. When outside pressure is less than the cargo compartment pressure, air flows through the battery box, through the sump jar, and then to outside air.

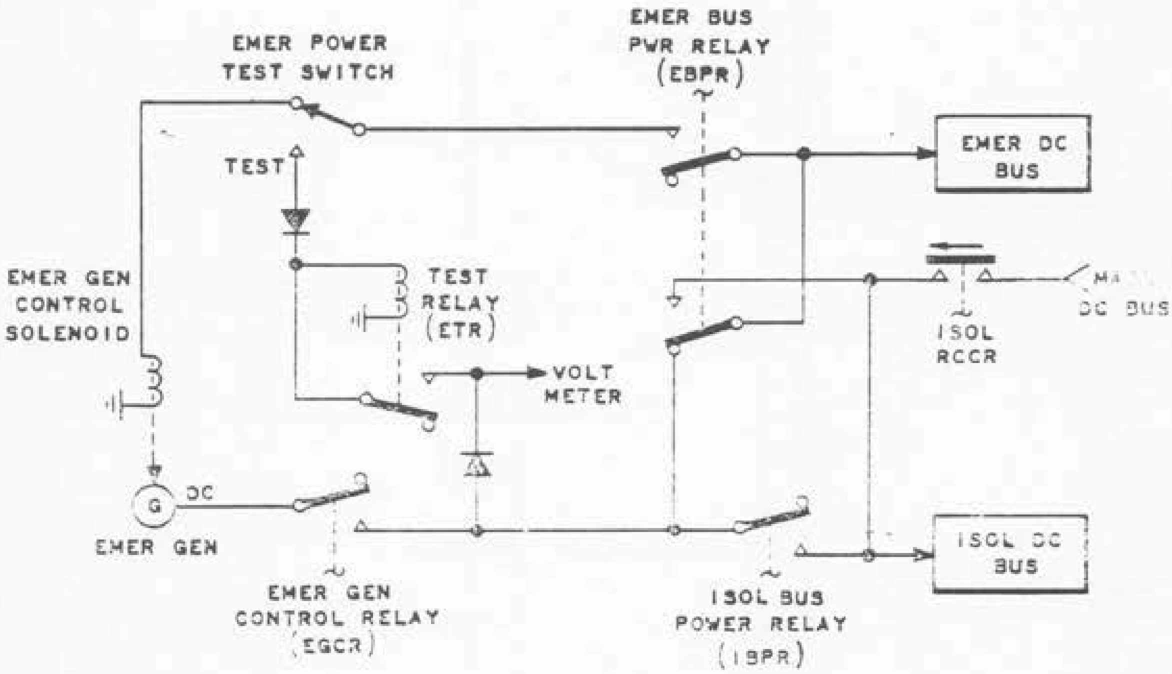


BATTERY COMPARTMENT

A check valve on the battery box allows air to flow from the cargo compartment to the outside but blocks airflow in the reverse direction.

OPERATION

The battery switch is located on the flight engineer's electrical control panel. When the switch is in the "ON" position, the battery relay is closed to connect the battery to the isolated D-C bus. The battery cannot be connected if the emergency generator is operating or if the isolated bus disconnect switch is in the disconnect position. The battery relay is located behind the flight engineer's number 3 circuit breaker panel. With power on the isolated D-C bus and the battery switch "ON," the battery is on charge. There is no charge-regulating system for the battery. Battery charging current is determined by bus voltage and the state of charge of the battery.

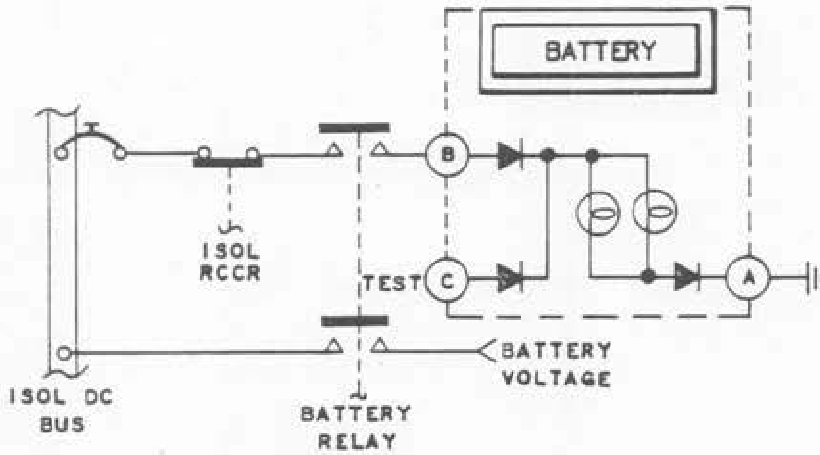


EMER GEN DC OUTPUT

BATTERY INDICATOR LIGHT

The battery indicator light is located on the flight engineer's electrical control panel. When illuminated, the light indicates that the battery is the only source of power on the isolated buses. If the isolated D-C bus reverse current relay is energized, the open auxiliary contacts will interrupt the battery on the indicator light circuit. If the emergency generator is connected, the isolated D-C bus

bus power relay will be energized, and a set of auxiliary contacts will prevent the light from illuminating.



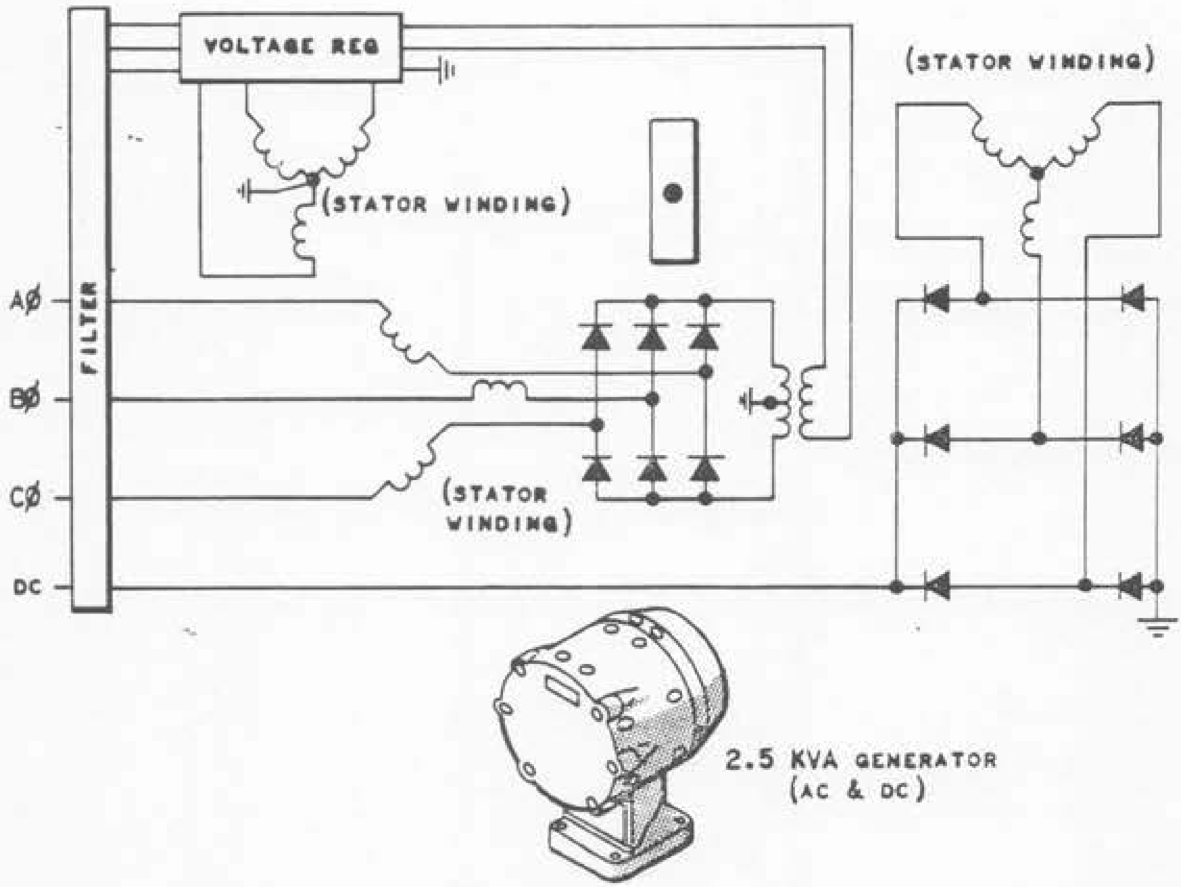
BATTERY LIGHT

EMERGENCY GENERATOR SYSTEM

A hydraulically driven A-C/D-C emergency generator is provided to furnish emergency D-C power in the event of loss of the normal D-C power system. In the event that power on the essential A-C bus No. 1 is lost, the hydraulically driven A-C/D-C emergency generator will be actuated. When the emergency bus power relay deenergizes, the hydraulic motor control solenoid deenergizes to allow hydraulic pressure to drive the hydraulic motor which drives the emergency generator. When the generator comes up to speed, the frequency sensitive relay energizes and provides a ground for the emergency generator control relay. When energized, the control relay connects the generator output to the emergency bus. Emergency generator output is also supplied to the isolated D-C bus and the isolated D-C avionics bus through the closed contacts of the isolated D-C bus power relay.

> NOTE: A loss of D-C power will not automatically activate the emergency generator.

The emergency generator can be manually activated by placing the INSTRUMENT POWER switch on the left side of the pilot's instrument panel in the "EMERGENCY" position. Positioning the instrument power switch to "EMERGENCY" removes the ground from the emergency bus power relay and causes the relay to deenergize.



EMERGENCY GENERATOR SCHEMATIC

An emergency power test switch is located on the flight engineer's electrical control panel. In the "TEST" position, the emergency generator is operating but is not connected to the buses. The voltmeter can be used to check the output voltage of the generator.

The emergency D-C generator consists of a wye-wound stator and six silicon diodes. The generator develops a 28-volt, D-C output and a load capacity of 20 amperes continuously, or 30 amperes for 5 minutes out of each 30-minute period of operation. The rotating field strength is controlled to maintain desired voltage output to the rectifiers which furnish full-wave rectified voltage to the emergency D-C bus distribution system.

D-C BUS DISTRIBUTION SYSTEM

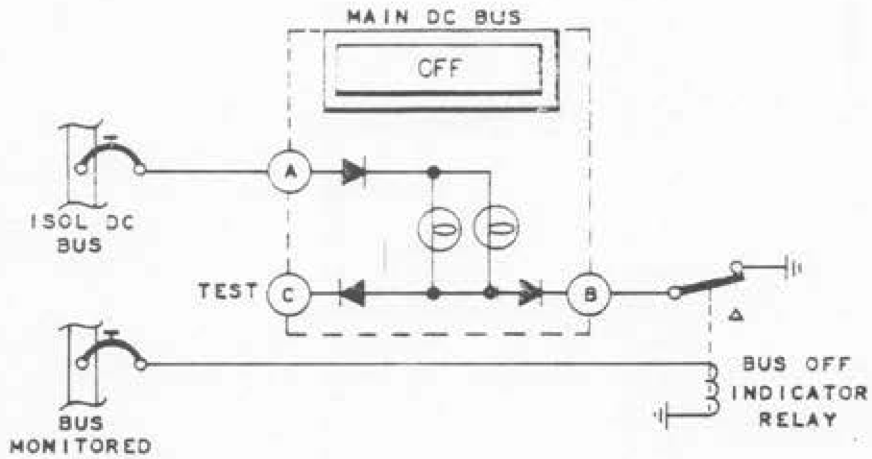
There are seven D-C buses on the Starlifter: No. 1 main, No. 2 main, No. 1 main avionics, No. 2 main avionics, isolated DC, isolated D-C avionics, and

B - BATTERY POWER
M - MAIN DC - ESS AC
E - EMERGENCY GEN
* - ENERGIZED

	EMER GEN TEST	EMER GEN	ESS AC AND MAIN DC BUS	BATTERY	RELAYS									ISOL DC BUS	EMER DC BUS	ISOL AC BUS	EMER AC BUS	MAIN DC BUS
					RCCR	BR	IBPR	EBPR	EGCR	FSR	NBR	ETR	IPR					
					ISOL RCCR	BATTERY RELAY	ISOL DC BUS PWR RELAY	EMER BUS PWR RELAY	EMER GEN CONT RELAY	FREQ SENS RELAY	NAV BUS PWR RELAY	EMER PWR TEST RELAY	ISOL AC BUS PWR RELAY					
				*		*								B				
			*		*			*			*			M	M	M	M	M
			*	*	*	*		*			*			M	M	M	M	M
		*					*		*	*			*	E	E	E	E	
		*		*			*		*	*			*	E	E	E	E	
		*	*				*		*	*			*	E	E	E	E	
	*		*		*			*	*	*	*	*		M	M	M	M	M

DC POWER SOURCE - RELAY - BUS DISTRIBUTION CHART emergency D-C bus. During normal operation, the buses are interconnected, allowing power from both TR units to be supplied to the buses as shown in the D-C bus diagram. The No. 1 and 2 main D-C bus will supply the isolated D-C bus; however, the isolated D-C bus cannot supply No. 1 or 2 main due to the isolated D-C bus RCCR. The RCCR opens if the isolated D-C bus attempts to supply the main buses.

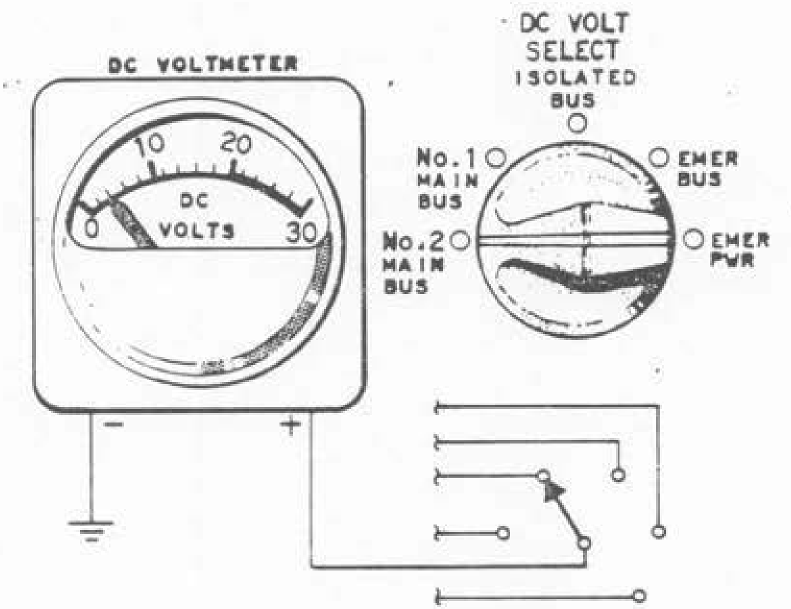
The No. 1 main D-C bus power feeder circuit breakers are on the main A-C power distribution panel. Distribution circuit breakers are located on the flight engineer's No. 4 circuit breaker panel. The No. 2 main D-C bus power feeder circuit breakers are located on the main D-C power panel. Distribution circuit breakers are also on the flight engineer's No. 4 circuit breaker panel. The main D-C avionics bus receives power from the main D-C power distribution panel. The isolated D-C bus is normally powered from main D-C bus No. 1 through the closed contacts of the isolated bus RCCR. Distribution circuit breakers are located on the flight engineer's No. 3 circuit breaker panel. The isolated A-C avionics bus is normally supplied with power from the No. 1 main D-C bus through the energized contacts of the isolated D-C bus RCCR. During emergency operation, it will be supplied power from the isolated D-C bus which can be powered by the battery or the emergency generator. The emergency D-C bus is normally supplied from the No. 1 main DC bus through the closed contacts of the energized isolated D-C bus RCCR and through the closed contacts of the energized emergency bus power relay. Feeder circuit breakers are located on the main D-C power panel. The emergency D-C generator can supply power to the emergency D-C bus through the power circuit breaker located on the emergency generator control box.



MAIN DC BUS OFF LIGHT

BUS INDICATOR LIGHTS

The indicator light control circuit for the No. 1 main D-C bus is energized by power from the No. 1 main DC bus. In the event that No. 1 main D-C bus loses power, the indicator light relay will deenergize and furnish a ground for the "OFF" light causing it to illuminate. The light is located on the flight engineer's electrical control panel. Operation of the No. 2 bus indicator light is the same as No. 1. These lights also represent their respective avionics buses.



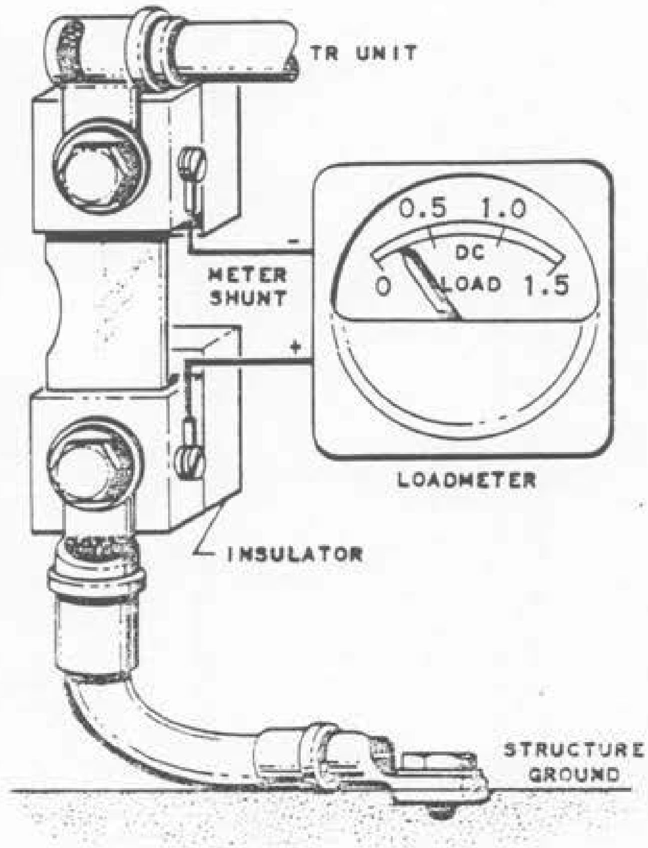
DC VOLTMETER CIRCUIT

VOLTMETER AND SELECTOR SWITCH

The voltmeter and selector switch are located on the flight engineer's electrical control panel and are used to monitor D-C bus distribution system voltages. The meter has a 0 to 30-volt scale, and the selector switch has five positions as shown in the illustration. The "EMER PWR" position monitors the output of the emergency generator.

D-C LOADMETERS

Two D-C loadmeters are installed on the flight engineer's electrical control panel below the D-C voltmeter. The loadmeter monitors current of the TR unit with one loadmeter for each TR unit. Calibration of the loadmeter is in terms of percent of rated load of the TR unit. Full scale on the loadmeter is 150 percent but the scale is marked 1.5. 1.0 or 100 percent on the loadmeter is 200 amperes. The loadmeter is made up of the meter and a loadmeter shunt. The shunt is connected in the negative lead of the TR unit. The loadmeter shunt is a 50-millivolt, 200 ampere shunt.



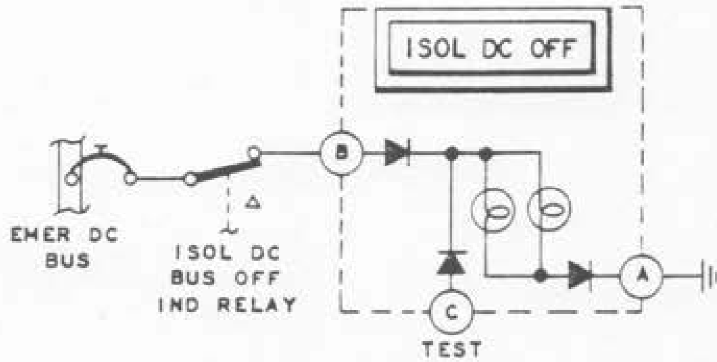
D-C LOADMETER

ISOLATED BUS DISCONNECT SWITCH

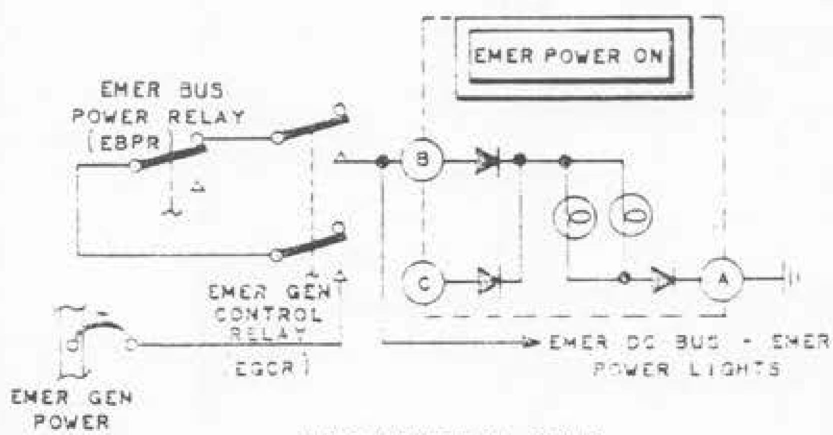
A two-position switch on the flight engineer's electrical control panel, decaled ISOL BUSES - "ON-OFF" can be used to disconnect the isolated D-C bus from the emergency generator by deenergizing the isolated D-C bus power relay.

EMERGENCY POWER TEST SWITCH

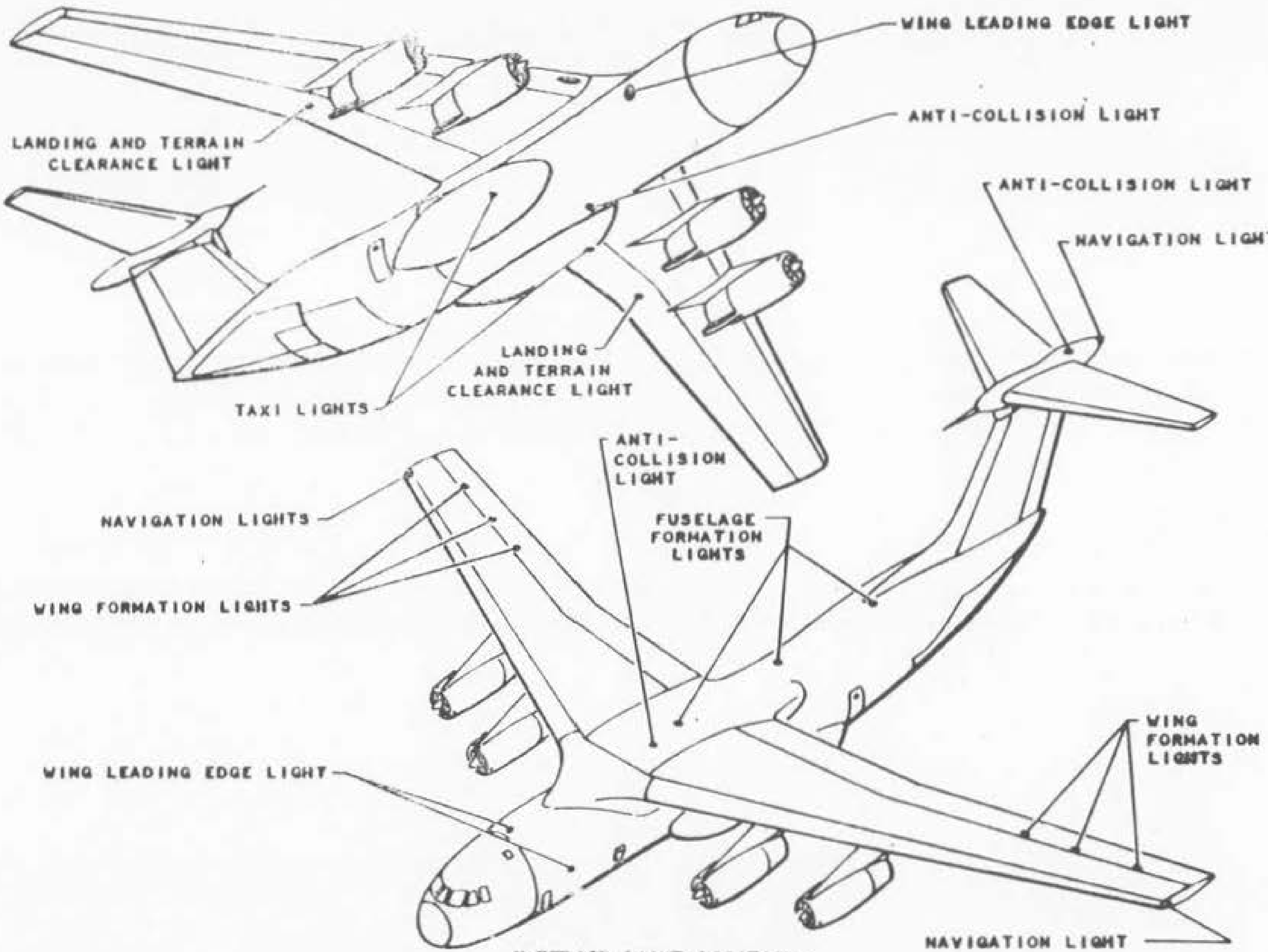
This switch is used with the D-C voltmeter and D-C volt selector switch to check the D-C generator output without putting it on the line. Positioning the test switch to "TEST" removes the ground from the hydraulic motor control solenoid and the isolated bus power relay coils.



ISOL DC BUS OFF LIGHT



EMER POWER ON LIGHT



EXTERIOR LIGHT LOCATIONS

MISCELLANEOUS ELECTRICAL

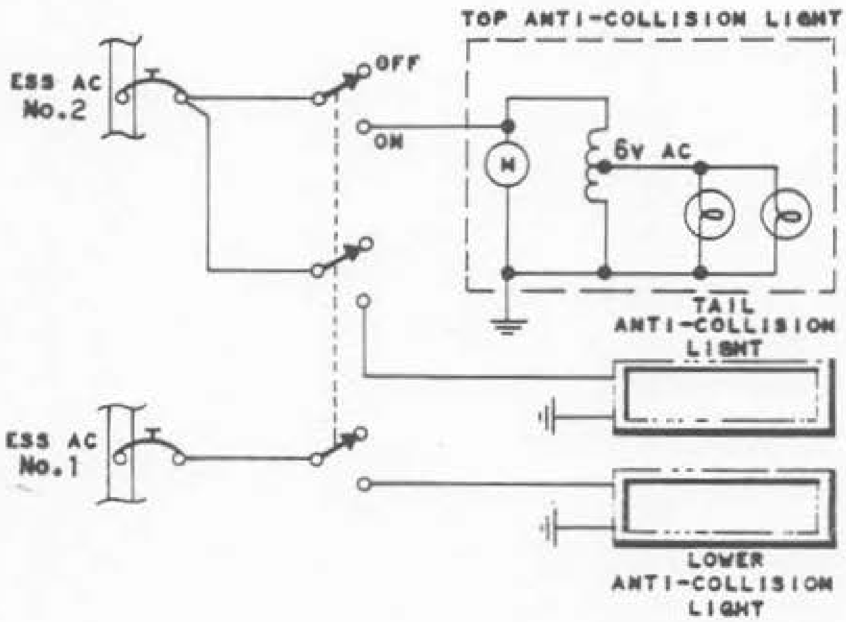
LIGHTING SYSTEM

The light system consists of the exterior, interior, and emergency lighting. Exterior lighting consists of anti-collision, taxi, wing leading edge, formation, navigation, and landing lights. The exterior lighting is controlled from the overhead panel in the flight station.

The interior lighting provides illumination of the flight station and cargo areas and consists of dome lights, instrument panel lights, utility lights and reading lights in the flight station. The cargo area lighting consists of dome lights, cargo loading lights, jump platform lights, lavatory lighting, and maintenance lighting. Maintenance lights are provided in the underdeck equipment rack area, aft crawlway, vertical stabilizer tunnel, and wheel well areas. The interior lighting is controlled from the overhead panel and switch panels at the various light locations. Emergency lights are provided next to each exit. Relays and autotransformers of the lighting systems are located in the flight station relay panel and the center fuselage junction box.

ANTI-COLLISION LIGHTS

Three anti-collision light assemblies are installed on the aircraft. The lights are on the bottom fuselage, top fuselage, and top of the horizontal stabilizer. The top lights are energized from the essential A-C bus No. 2 and bottom light from essential A-C bus No. 1.



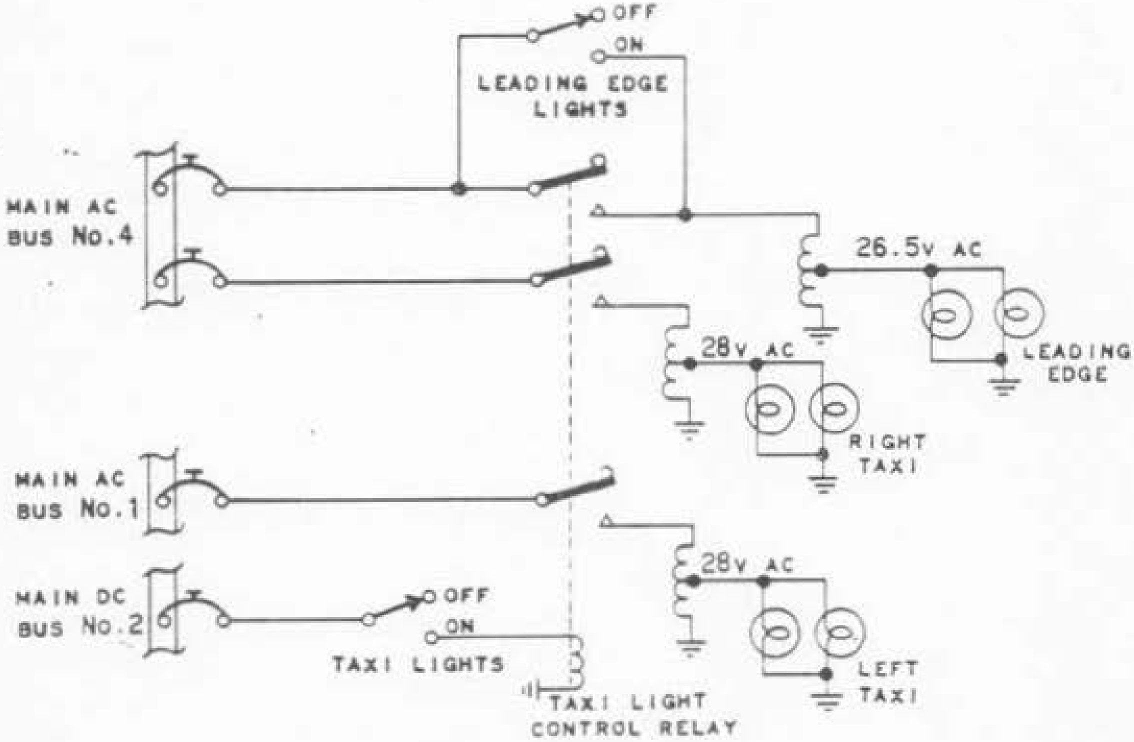
ANTI-COLLISION LIGHTS

Each light assembly consists of a motor, autotransformer, and two clear sealed-beam lamps. The sealed-beam lamps produce a high intensity direction beam of light that is only visible when the beam is directed toward the observer.

The lamps are placed back-to-back and swept through an arc of 180 degrees by the drive motor. This produces the illusion of a single beam rotating through an arc of 360 degrees. The drive speed is adjusted to produce 50 flashes per minute.

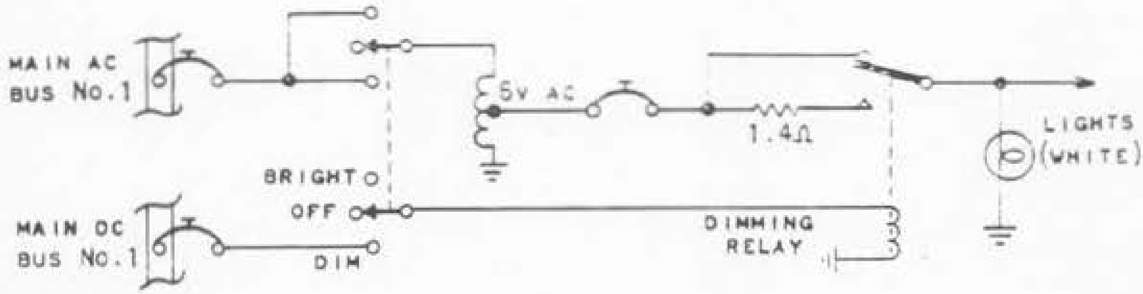
TAXI LIGHTS AND LEADING EDGE LIGHTS

Two taxi lights are installed on each main landing gear door. The lower light faces forward and the upper light faces outboard. Autotransformers reduce the A-C voltage to 28-volt, AC, for the lights. When the control switch is "ON," a taxi light control relay is energized to connect AC to the transformers.



TAXI AND LEADING EDGE LIGHTS

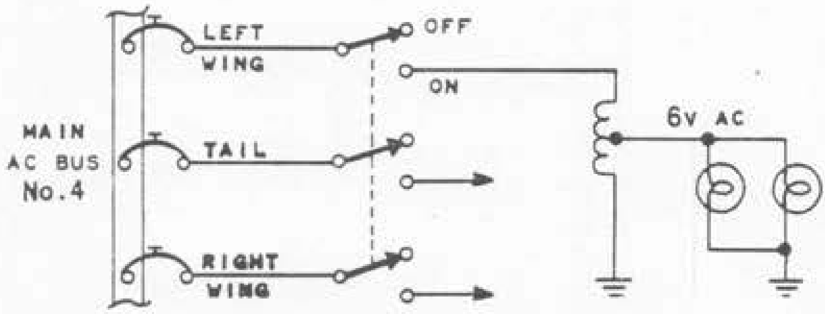
One leading edge light is located on each side of the fuselage. A prismatic lens bends the light beam 30 degrees aft to illuminate the wing leading edge and nacelle inlet, as well as the area forward of the wing. The lights are controlled by a switch and autotransformer. The switch is bypassed by contacts of the taxi lights control relay when the taxi lights are "ON."



FORMATION LIGHTS

FORMATION LIGHTS

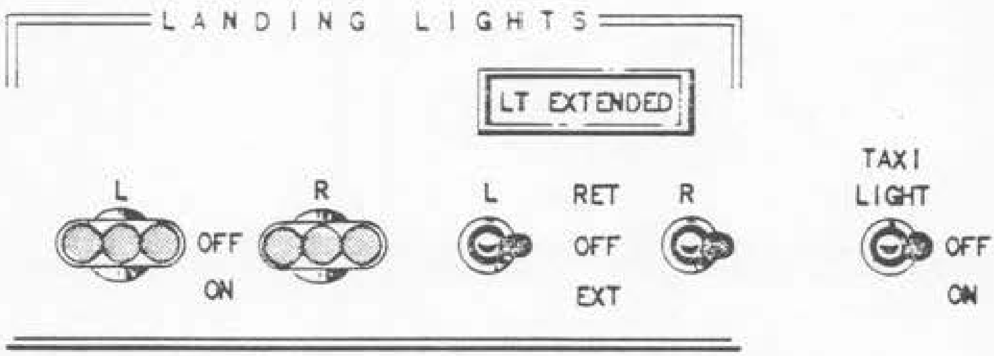
Nine formation lights are installed on the aircraft. Three lights are in a row on top of the fuselage, and three lights are on each of the outer wing panels. An autotransformer reduces the A-C voltage to 6-volt, AC, for the lights. The "BRIGHT" position of the formation lights switch connects 6-volt, AC, to the lights. The "DIM" position energizes the dimming relay which adds a resistor in series with the lights.

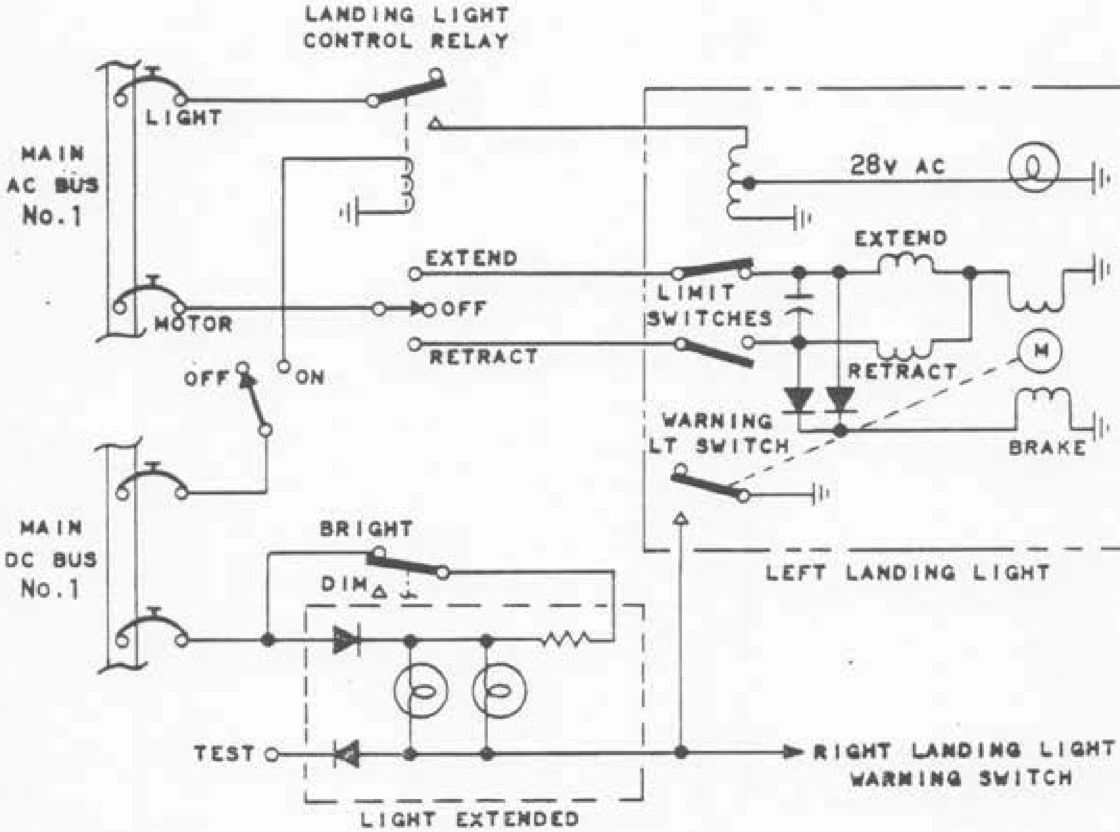


NAVIGATION LIGHTS

NAVIGATION LIGHTS

The navigation lights consist of three light assemblies. A red light assembly is on the left wing tip, and green is on the right wing tip. White lights are on the tail. Each assembly contains an autotransformer and two lights. The autotransformer reduces the 115-volt, AC, to 6-volt, AC, for the lights. When the navigation lights switch is "ON," the lights illuminate. The wing tip lights may be observed through the flight station windows.





LANDING LIGHTS

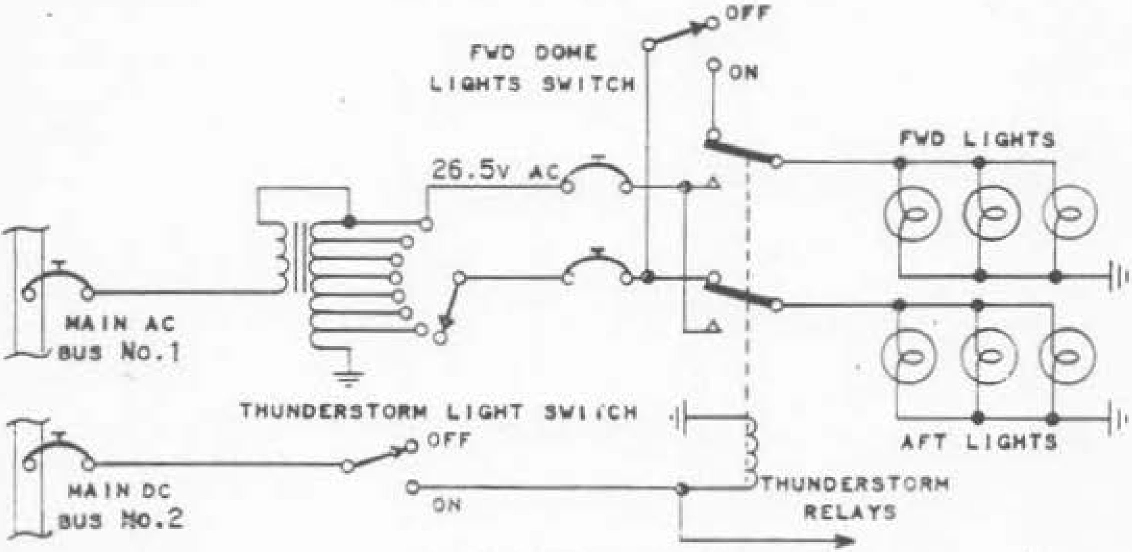
LANDING AND TERRAIN CLEARANCE LIGHTS

One landing light assembly is mounted on the bottom of each wing between the inboard and outboard flaps. Each assembly contains a motor, a light, limit switches, and a warning light switch. The extend limit switch is open when the light is fully extended. The retract limit switch is open when the light is retracted. Between the extended and retracted positions, both switches are closed allowing motor operation in either direction. The warning light switch is closed when the light is not fully retracted, causing illumination of the LT EXTENDED warning light.

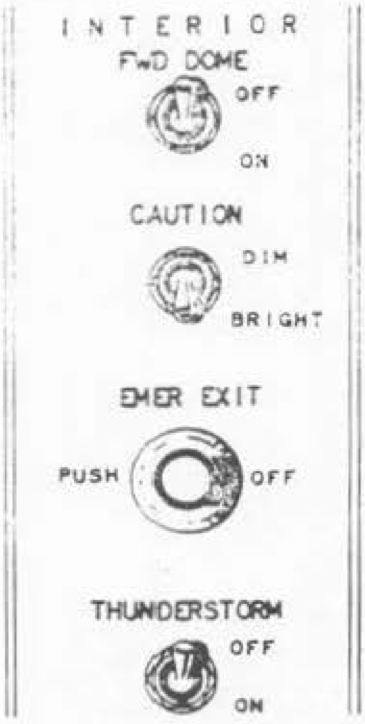
When the landing lights switch is "ON," the landing light control relay is energized. The autotransformer reduces the 115-volt, AC, to 28-volt, AC, for the light. The motor control switch in the "EXTEND" position energizes the opposite motor field and the motor reverse direction. The A-C voltage is rectified and applied to a brake coil to allow motor rotation.

FLIGHT STATION DOME (FLOOD) AND THUNDERSTORM LIGHTS

Six flight station dome lights are controlled by a variable tapped autotransformer. The autotransformer output is variable from a maximum of 26.5 volts, AC, to a minimum of 3 volts, AC, or "OFF." The aft dome lights are controlled from the autotransformer. The forward dome lights are controlled from the autotransformer and a forward dome lights ON-OFF switch. The thunderstorm lights switch energizes a relay causing illumination of the six dome lights at maximum brightness, thus bypassing the normal circuit.

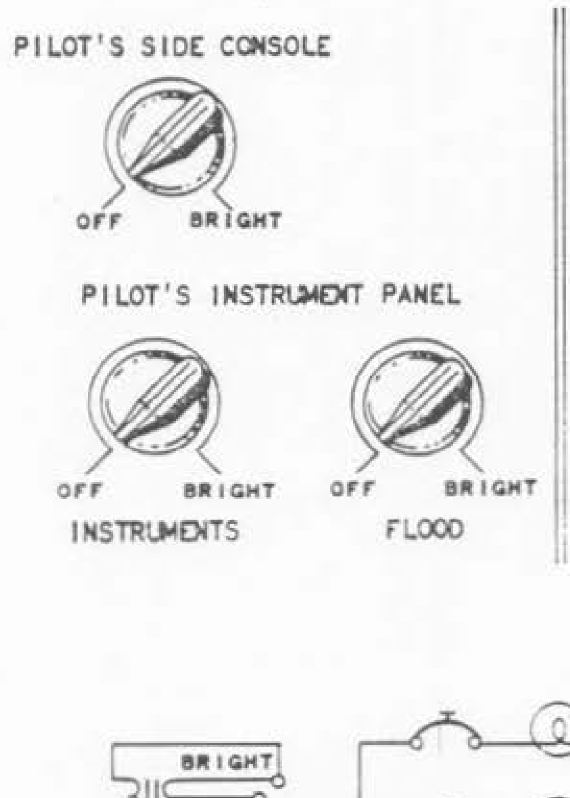


THUNDERSTORM LIGHTS



PILOT"S LIGHTING

The pilot's lighting consists of instrument lights, side console lights, overhead panel lights, instrument panel floodlights, and overhead panel floodlights. The instrument panel floodlights are controlled by a rheostat from the 28-volt, D-C, source. The rheostat is bypassed by the thunderstorm lights switch for maximum brightness. The other lights are controlled through variable autotransformers. The voltage varies from zero to a maximum of 5.4 volts, AC. The overhead panel floodlights autotransformer varies from zero to 26.5 volts, AC. The pilot's instrument light switch also controls the warning lights dimming circuit. When the pilot's instrument panel lights are "OFF," a switch is open. The switch ensures bright warning light illumination during daytime operation when the instrument lights are "OFF." The thunderstorm switch also bypasses the overhead floodlights autotransformer for maximum illumination.



PILOT'S INSTRUMENT PANEL LIGHTS

COPILOT'S LIGHTING

The copilot's lighting consists of instrument lights, side console lights, and instrument panel floodlights. The circuits use variable autotransformers which provide a maximum of 26.5 volts, AC to the floodlights and 5.4 volts, AC, to the other lights. The lights and controls function similar to the pilot's circuits.

Center instrument panel and center console lighting variable autotransformers control the voltage to the center instrument panel and center console lights. The maximum voltage is 5.4 volts, AC.

UTILITY LIGHTS

Three utility lights are installed in the flight station. Each light has an ON-OFF switch and rheostat brightness control. The lights are type C-4 and are provided at the pilot, copilot, and flight engineer stations. The lights operate from 28-volt, AC, which is provided from the flight station lighting bus.

FLIGHT ENGINEER'S LIGHTING

The flight engineer's lighting consists of instrument panel lights, instrument lights, circuit breaker panel lights, floodlights, and worktable light. The circuit breakers and controls for the lights are on the flight engineer's lighting control panel. The floodlights and worktable lights are controlled by a FLOOD-BOTH-TABLE switch in addition to the autotransformer. The individual lights can be selected in "FLOOD" or "TABLE." All flood and table lights can operate in "BOTH." The thunderstorm lights switch also controls the floodlights. The remaining lights function similar to the pilot's lights.

NAVIGATOR'S LIGHTING

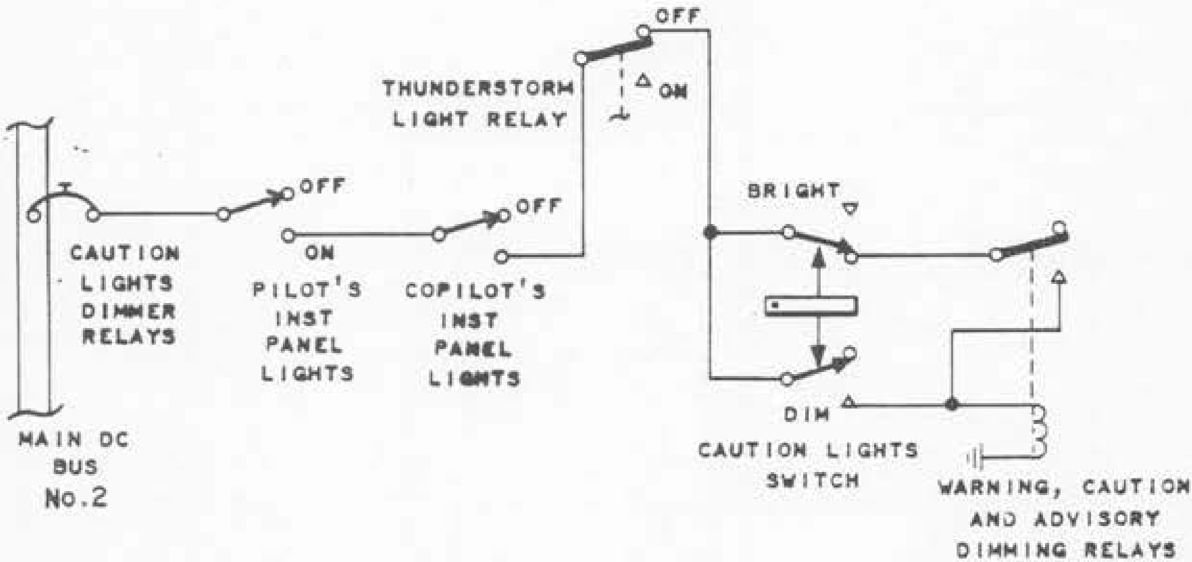
The navigator's lighting consists of instrument panel lights, instrument lights, floodlights and worktable light, similar to the flight engineer's lighting. The controls and switches are on the navigator's lighting control panel.

READING LIGHTS

Five floodlights are provided in the crew rest area. Each light has an on-off switch and operates from 28-volt, AC.

WARNING LIGHTS DIMMING

The warning lights are controlled by relays for bright or dim indications. The relays energize and remain energized when the BRIGHT-DIM switch on the overhead panel is positioned to "DIM" (momentary switch). Dimming resistors in each light assembly are inserted in series with the light to decrease intensity. The



WARNING LIGHTS DIMMING

pilot's and copilot's instrument panel lights switch must be "ON," and the thunderstorm lights switch must be "OFF," before the warning lights dimming circuit is operational. The instrument lights are normally used at night and allow the warning lights to be dim or bright as required.

CARGO COMPARTMENT DOME LIGHTS.

Cargo compartment dome lights consist of white and red lights. Control is provided by the CARGO COMPARTMENT LIGHTS switch, and BRIGHT-DIM switch. The switches are mounted on the forward crew door interphone panel. Secondary control of the system is provided by a CARGO COMPT DOME LITS switch located on the flight station. This guarded switch overrides the other switches to provide maximum illumination of the white lights. A CARGO COMPT LIGHTS RED-WHITE switch is mounted on the ramp control panel. The switch permits selection of white or red cargo compartment lighting. Red is used during night operations to enable personnel in the cargo area to adapt their vision to darkness. The autotransformer provides a fixed 28-volt A-C output and a variable A-C output up to 28-volts. The variable output adjusts the intensity of the white lights and can only be used when "DIM" is selected on the CARGO COMPARTMENT LIGHTS switch.

CARGO RAMP LOADING LIGHTS.

Two loading lights are located overhead at the paratroop doors. Each light is mounted on a swivel base for adjustment. The lights are controlled by the RAMP LOADING LIGHTS switch on the ramp control panel.

PARATROOP JUMP PLATFORM LIGHTS.

Jump platform lights are mounted on each side of the fuselage at the jump doors. Red lights illuminate the platform area. The PLATFORM LIGHTS switch on the left jumpmaster panel controls the left light. The right light is controlled by the PLATFORM LIGHTS switch mounted on the right jumpmaster panel.

AFT CRAWLWAY AND VERTICAL STABILIZER LIGHTS

Clear-vision lights are installed in the aft crawlway and vertical stabilizer area for maintenance. Control is provided by the VERT STAB LIGHTS switch on the ramp control panel.

WHEEL WELL LIGHTS

One clear-vision light is installed in each wheel well area. The lights provide illumination for inspection of the gear down-lock assembly. Control is provided by WHEEL WELL LIGHT switches. One switch is mounted beside each observation window.

LAVATORY LIGHT

Two clear-vision lights are installed in the overhead area of the lavatory. Control is provided by the LIGHT switch located on the left side of the canted ceiling.

UNDERDECK EQUIPMENT RACK LIGHTS

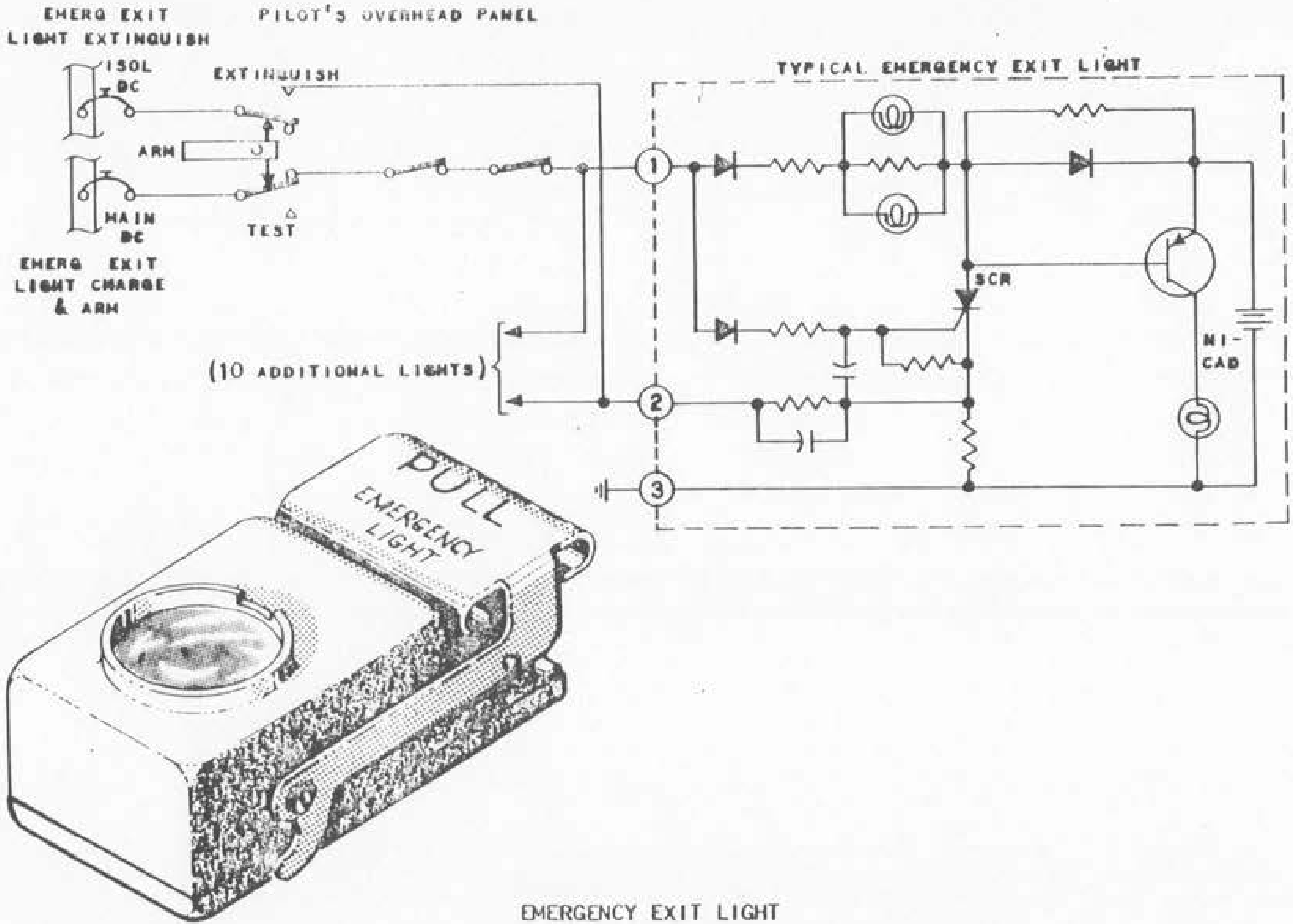
Two clear-vision lights are installed in the underdeck rack area. The lights provide illumination of the avionics and electrical equipment racks. Control is provided by switches adjacent the lights.

FLIGHT STATION ACCESS LIGHTS

A clear-vision light is installed to the right of the flight station door. The light provides illumination of the flight station access door and ladder area. Control is provided by the LADDER LIGHTS switch on the left side of the flight station area.

EMERGENCY EXIT LIGHTS

Portable, battery operated, emergency exit lights are installed next to each door and emergency exit. Eleven light assemblies are installed. Each light assembly



EMERGENCY EXIT LIGHT

contains two nickel-cadmium batteries, one transistor, one silicone controlled rectifier, three bulbs, and associated circuitry. The emergency exit lights control switch is on the pilot's overhead panel. During normal operation, the aircraft bus maintains the nickel-cadmium batteries fully charged.

The lights will be illuminated automatically in the event of loss of main D-C bus power or a deceleration force of 2 g's. Also, when the lamp is removed from the mounting bracket, the handle will close an internal switch to illuminate the lamp.

CAUTION LIGHTS

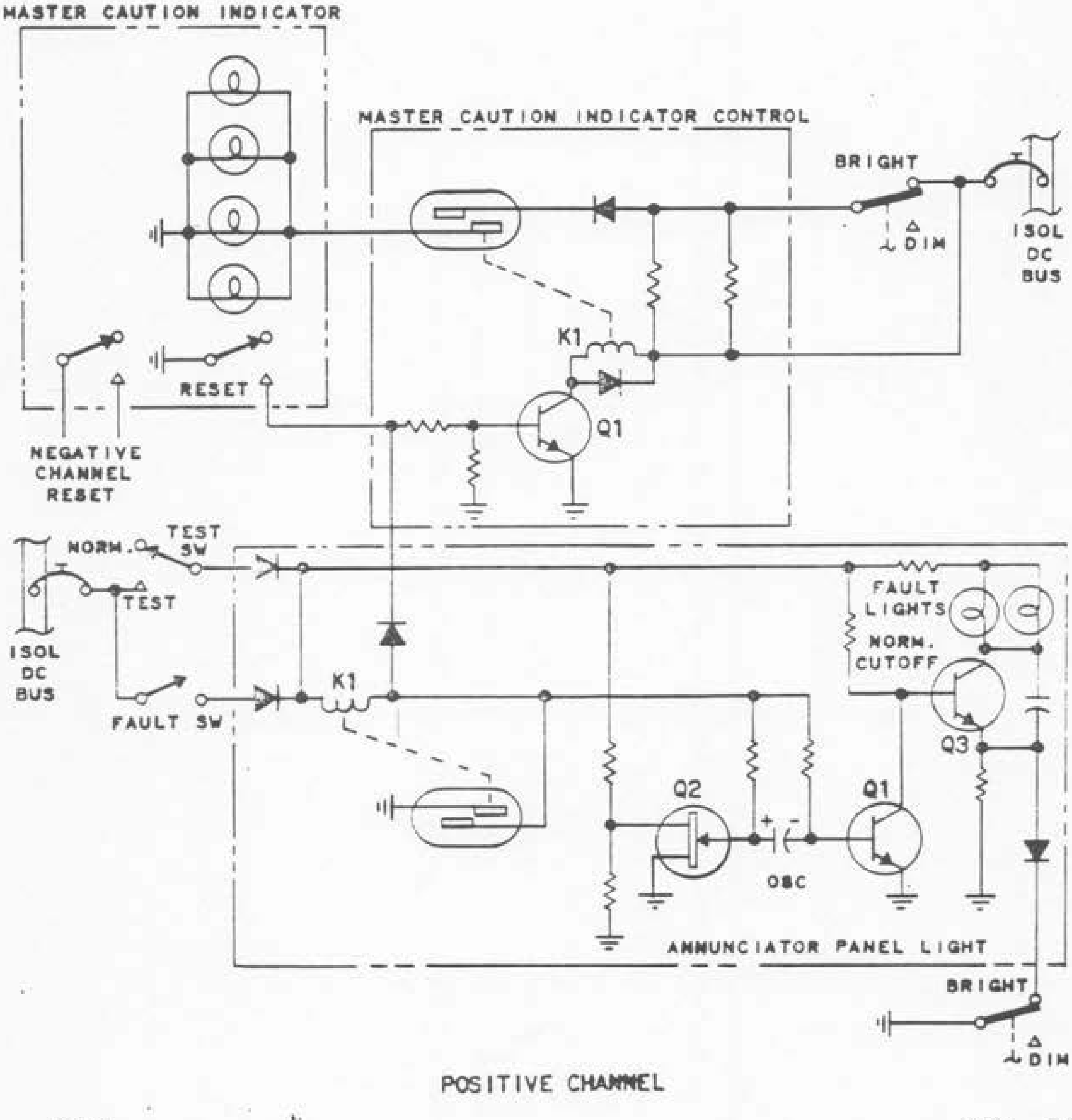
The caution lights consist of 10 annunciator assemblies, two master caution light assemblies, and one master caution indicator control unit. Each annunciator assembly contains five caution lights allowing a maximum of 50 systems to be monitored. The annunciator panel is the forward part of the center console. The master CAUTION lights are on the pilot's and copilot's instrument panel. The control unit is below the center main instrument panel.
When a monitored system fails, an annunciator light flashes and the master caution lights illuminate. The annunciator light faceplate indicates which system has failed. The master caution lights contain lamps and reset switches. The master caution light should be pushed to reset after a trouble. When reset, the master light is extinguished until another trouble occurs and the annunciator illuminates continuously. The annunciator light is extinguished when the monitored system trouble is corrected or when the power source is removed. The annunciator may contain positive or negative channels. A positive channel receives a positive D-C signal when the monitored system fails, and a negative channel receives a ground. The positive and negative channels supply signals to the control unit causing illumination of the master caution lights.

If a fault is detected for a positive channel, a D-C voltage is supplied into the annunciator. Transistor Q3 is controlled by an oscillator and is normally cutoff. The fault voltage causes Q1 in the oscillator to conduct, charging the base capacitor. When th^ capacitor voltage is sufficient, the unijunction transistor is forward biased into conduction. The capacitor then discharges, cutting off Q1. When Q1 is cutoff, Q3 conducts and the annunciator lights illuminate. The capacitor discharges to a low voltage until Q2 turns off. Transistor Q1 again conducts and Q3 turns off causing the annunciator lights to extinguish. The RC time constant of the capacitor charge and discharge path determines the flashing rate. The rate is 100 to 175 flashes per minute. The warning lights dimming circuit controls light intensity by adding resistors in series with the lights.

AILERON SYS 1 PWR	AILERON SYS 2 PWR	PLT PUSHER OFF	ENG 1 FUEL PRESS	ENG 2 FUEL PRESS	ENG 3 FUEL PRESS	ENG 4 FUEL PRESS	DOOR OPEN	PITOT HEAT	CO-PLT PUSHER OFF
ELEV FEEL MALFUNC	ELEV EMER PWR	YAW DAMPER FAULT	FIRE BOTTLE 1	FIRE BOTTLE 2	FIRE BOTTLE 3	FIRE BOTTLE 4	MACH TRIM INOP	WG ANTI-ICE OVHT	RAIN REMOVAL OVHT
ELEV SYS 1 PWR	ELEV SYS 2 PWR	UNDR SPLR SPEED	SPARE	CADC 1 INOP	CADC 2 INOP	SPARE	FLT REC INOP	OXY QUANTITY LOW	ICING
RUDDER SYS 1 PWR	RUDDER SYS 2 PWR	RUDDER OVERPRESS	SPARE	L AIL. TAB OPER	R AIL. TAB OPER	STALL PREV 1	CABIN PRESS LOW	SPARE	CARGO SMOKE
FLAP ASYM DET	FLAP ASYM	L BLEED DUCT OVHT	2 SPOILER INOP	3 SPOILER INOP	SPARE	STALL PREV 2	R BLEED DUCT OVHT	APU FIRE	SPARE

ANNUNCIATOR PANEL

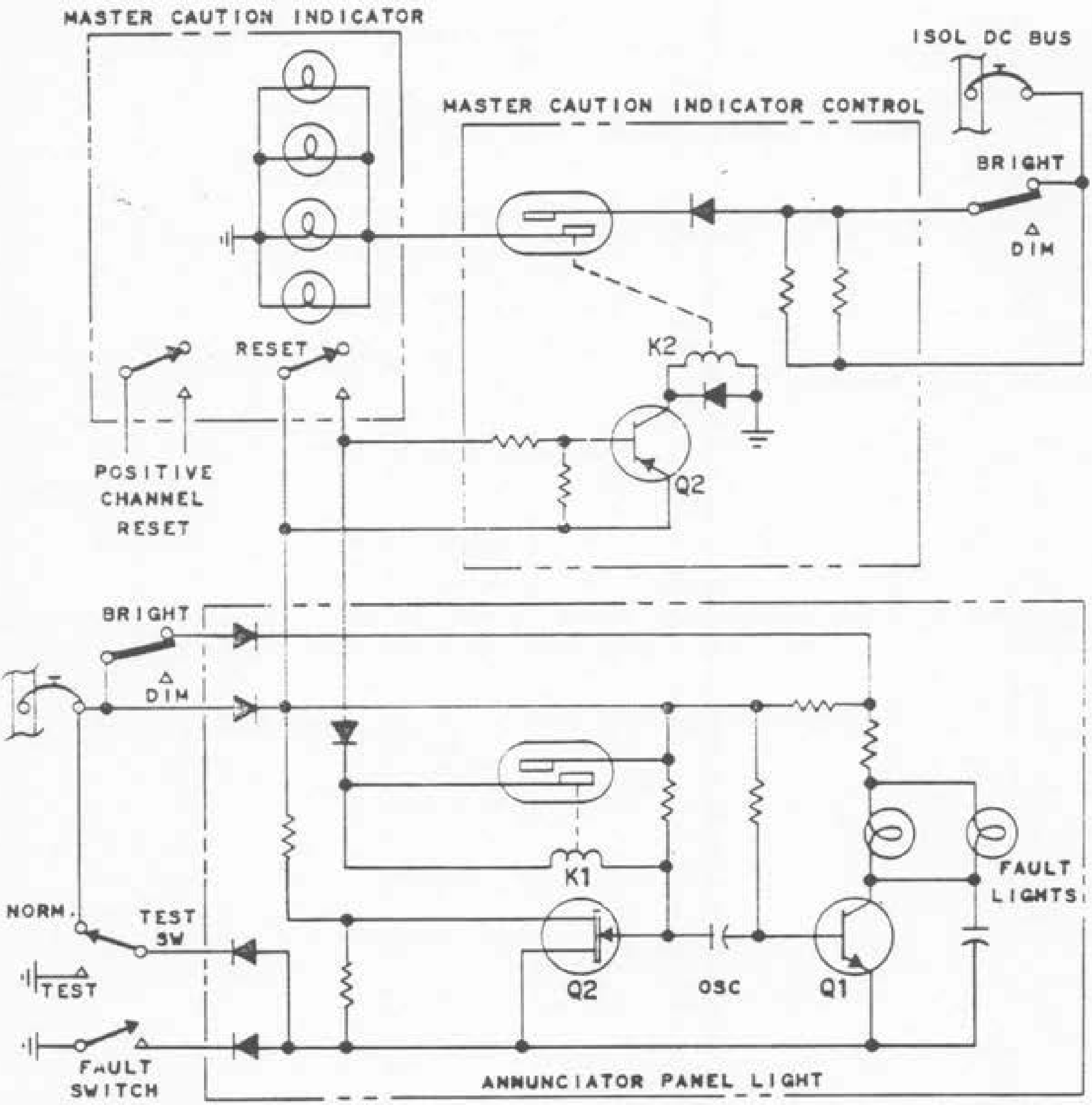
The fault voltage is also supplied to a transistor amplifier in the control unit. The transistor conducts, energizing a magnetic reed relay. The relay completes the circuit to the master CAUTION light which illuminates continuously. If the master CAUTION light is pushed to "RESET," a ground is supplied to a relay in the annunciator. The relay did not energize during the fault due to the low oscillator current. Reset causes the relay to energize and provide a holding circuit through relay contacts. The relay remains energized as long as the fault exists. The fault signal is grounded when reset to extinguish the master CAUTION light. Reset also stops the oscillator with Q1 cutoff and Q3 from conducting. The annunciator illuminates continuously until the fault is cleared. The TEST switch bypasses the fault circuit in "test" for fault simulation. When the switch is released, the simulated fault is cleared.



POSITIVE CHANNEL

The negative channel functions similar to the positive channel but uses a different section of the control unit and a second reset switch in the master CAUTION light. The fault provides a ground to the oscillator allowing the capacitor to alternately charge and discharge. Two transistors are used in the oscillators, and Q1 conduction controls annunciator lights.

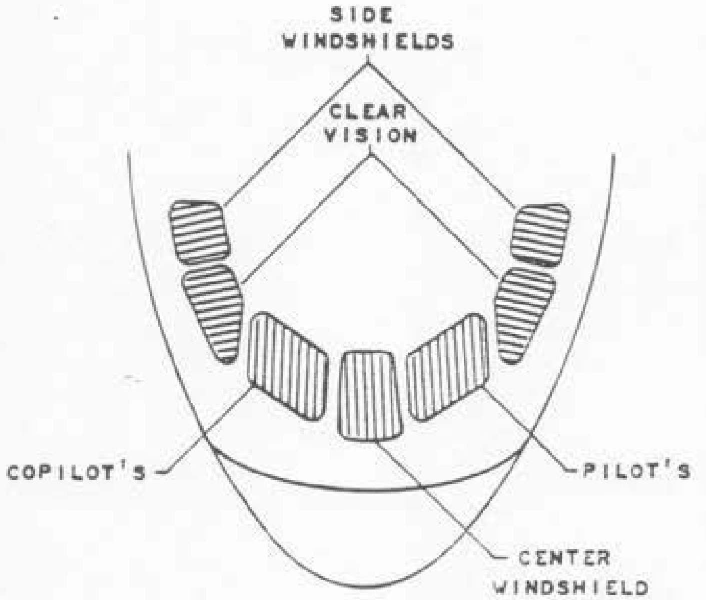
The master CAUTION light is controlled by a transistor and the magnetic reed type relay in the control unit. The transistor conducts when the oscillator is operating due to the reduced positive base voltage. The reset switch causes the control unit amplifier to cutoff and stops the oscillator with both transistors conducting. The oscillator relay is energized when reset due to emitter current through the unijunction transistor. It is held energized through relay contacts. After reset, the annunciator light illuminates continuously and the master CAUTION light is extinguished.



NEGATIVE CHANNEL

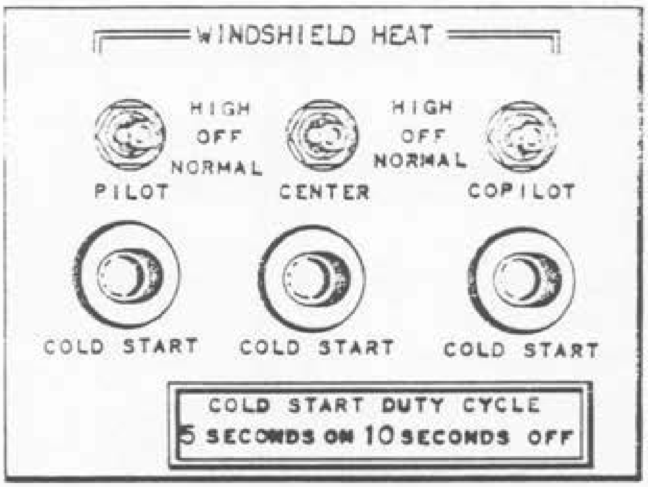
WINDSHIELD ANTI-ICING AND DEFOGGING SYSTEMS.

Seven windshields are electrically heated to prevent icing or fogging from distorting the pilot's and copilot's vision. The three main windshields are anti-iced, and the four side windshields are defogged. Windshield temperature is automatically maintained at approximately 94°F. The pilot's and copilot's windshield heating is interconnected with the rain removal system to prevent use of electrical anti-icing when the rain removal system is operating.



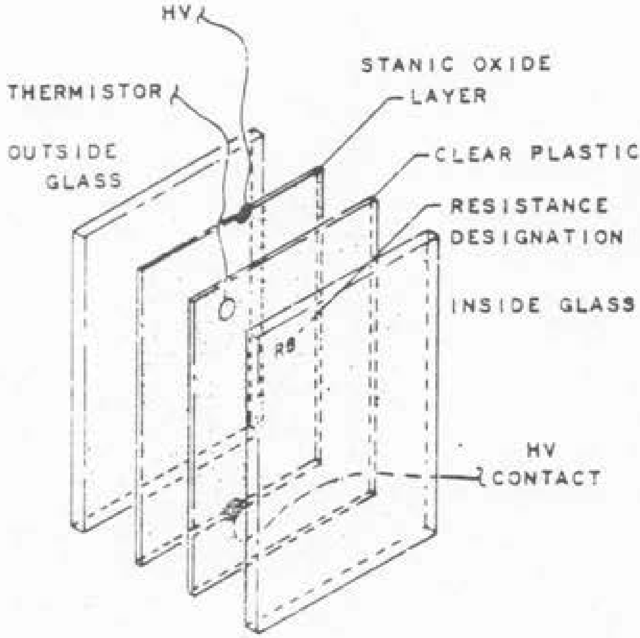
The pilot's, copilot's and center windshield heat control switches are located on the over head panel in the flight station. Each of the three anti-icing systems consist of a windshield, autotransformer, control box, two power relays and control switch.

Each defogging system consists of two windshields, autotransformer, control box, window cutoff switch, and control relay. The pilot's defogging system is controlled from the pilot's WINDSHIELD HEAT switch and the copilot's is controlled from the copilot's WINDSHIELD HEAT switch. the autotransformers and control boxes are located in the electrical equipment rack. The relays are located in the underdeck relay panel.



Each windshield is constructed of a layer of vinyl plastic and coating of stannic oxide sandwiched between two plates of glass. The plastic is for safety in case the glass shatters. The stannic oxide layer is on the inner surface of the outer glass plate and is the heating element of the window. Stannic oxide is a compound which dissipates power in the form of heat due to current through the high resistance oxide.

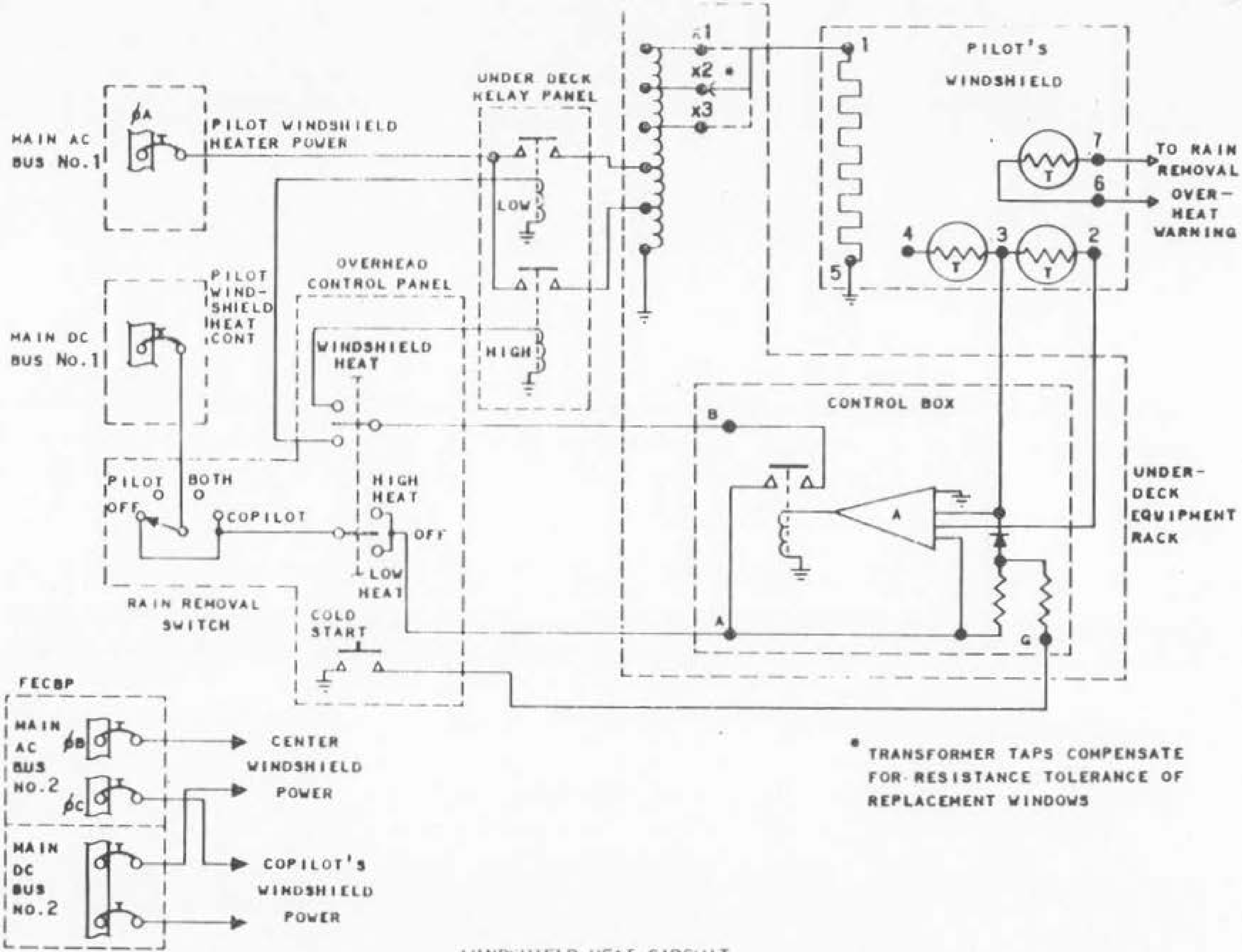
Thermistors are imbedded in the plastic of all but the clear-vision windows. One thermistor connects into the control unit temperature control circuit for automatic windshield temperature control. The second thermistor is a spare. The pilot's and copilot's windshields contain a third thermistor which is used with the rain removal system.



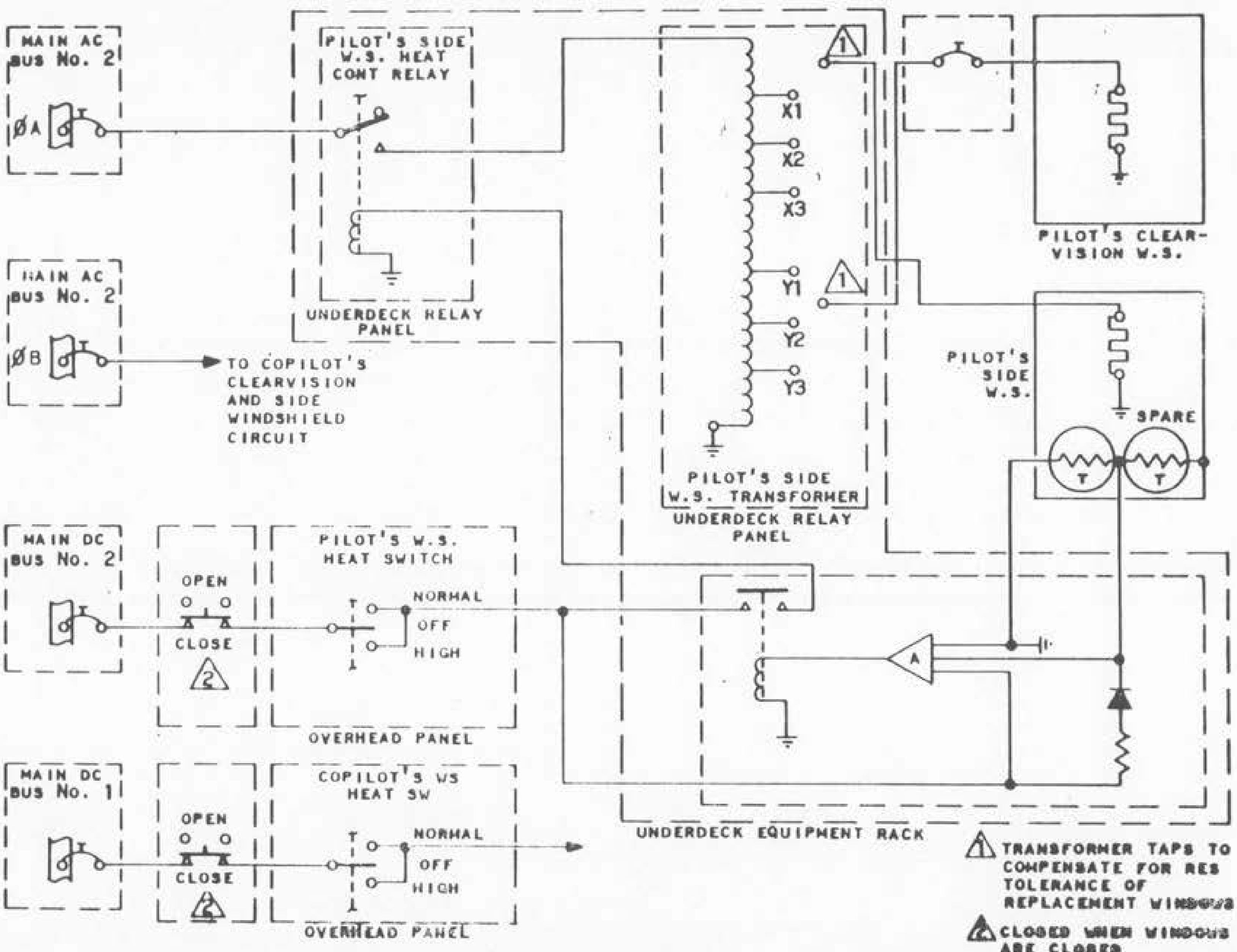
NESA WINDOW BREAK-DOWN

A thermistor is the temperature sensing element of the system and has a negative temperature coefficient. Thermistor resistance decreases as windshield temperature increases. The resistance determines when the heating voltage is to be applied or removed from the windshields.

When the WINDSHIELD HEAT control switch is positioned to "NORMAL" or "HIGH," the control box is energized. The transistor amplifiers in the control box sense thermistor resistance and energize a control box relay if heat is required. The relay contacts cause a power relay to energize, applying 115-volt, AC, to the autotransformer. A low-heat relay is energized in "NORMAL," resulting in a high voltage output to the windshield. If the high-heat relay is energized, the autotransformer high voltage output is increased due to the transformer turns ratio. The high heat relay is energized when "HIGH" is selected on the control switch.



WINDSHIELD HEAT CIRCUIT



RAIN REMOVAL CIRCUIT

As the windshield temperature increases, the thermistor resistance decreases. When resistance is equivalent to a 94°F windshield temperature, the control box relay is deenergized, turning off the high voltage. As the windshield cools, thermistor resistance again causes the control box relay to energize, and the heating cycle is repeated.

If the automatic control circuits fail to operate due to extreme cold or thermistor failure a COLD START pushbutton allows manual control of the automatic circuits. When the pushbutton is pressed, the thermistor is bypassed, causing the control box relay to energize. The duty cycle of cold start is 5 seconds on and 10 seconds off. High heat should be used only in flight when normal heat is insufficient. In "NORMAL" or "HIGH" the thermistor controls windshield maximum temperature, but the higher voltage increases the rate of temperature change.

DEFOGGING CIRCUITS

The defogging circuits are similar to the windshield anti-icing circuits. The cold start circuit is not used, and only one heating voltage is provided. A window switch on each clear vision window opens the defogging control circuits when the window is open. A single tapped autotransformer provides outputs to the two side windshields. The pilots defogging circuit is controlled by the pilot's WINDSHIELD HEAT switch and the copilot's by the copilot's switch.

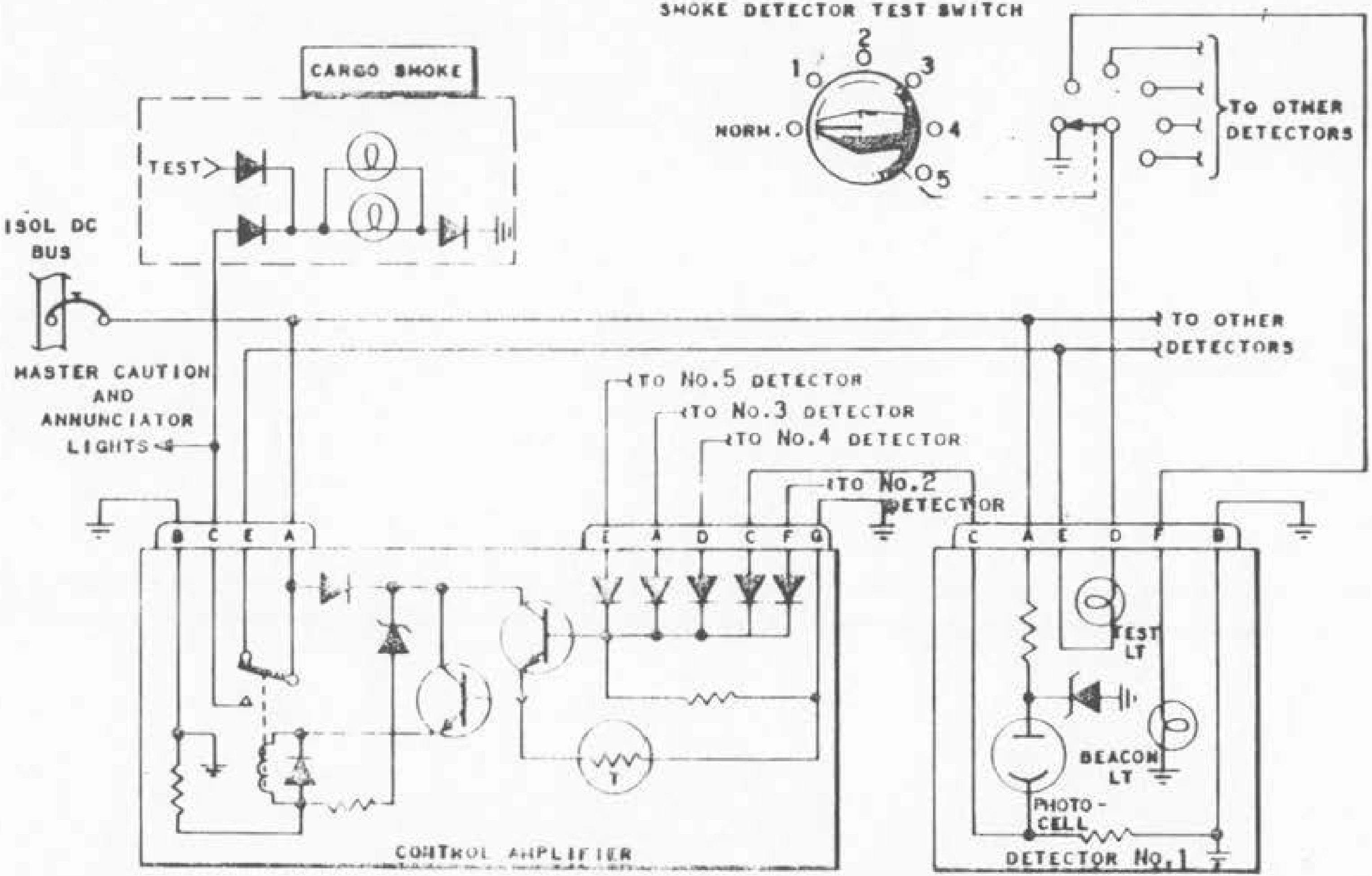
Resistance of the oxide varies between replacement windows. Each panel is marked with letters "RA," "RB" OR "RC" according to resistance. A replacement window containing different letters than the existing window requires a different voltage for proper heating. Each autotransformer contains voltage taps which are selected according to the window resistance letters. The autotransformer taps and wire number are listed for each type window in a chart on the aircraft wiring diagram of the windshield anti-icing systems.

SMOKE DETECTION SYSTEM

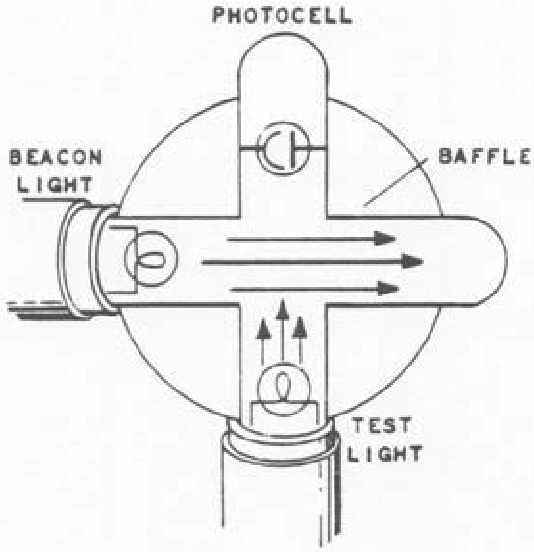
The smoke detection system consists of a control amplifier, warning lights, and five smoke detectors. One detector is mounted under the flight deck and four detectors within the cargo compartment. The control amplifier is located in the electrical equipment rack.

DETECTOR

Each detector consists of a photocell, two lights, and a baffle. The beacon light operates continuously but is shuttered from the photocell by the baffle. The beam from the beacon light is parallel to the photocell face. If air within the vented baffle is clear, the beam bypasses the photocell. If smoke is present, the light is diffused into the photocell causing conduction. Photocell conduction produces an output voltage which is supplied to the amplifier.



SMOKE DETECTION SYSTEM SCHEMATIC



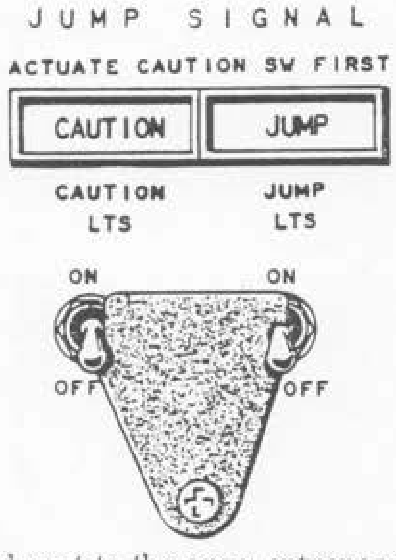
SMOKE DETECTOR

CONTROL AMPLIFIER

The control amplifier contains isolating diodes, power supply, transistor amplifiers, and control relay. The diodes isolate the detector signal lines into the amplifier. A positive detector signal through a diode causes the two transistors to conduct, energizing the relay. The relay provides a D-C output to the CARGO SMOKE light at the flight engineer's position and to the annunciator and master CAUTION lights. The annunciator light flashes and the other lights illuminate continuously. A Zener diode provides regulated DC to the transistor circuits. A transient protector diode protects against D-C bus transient negative pulses.

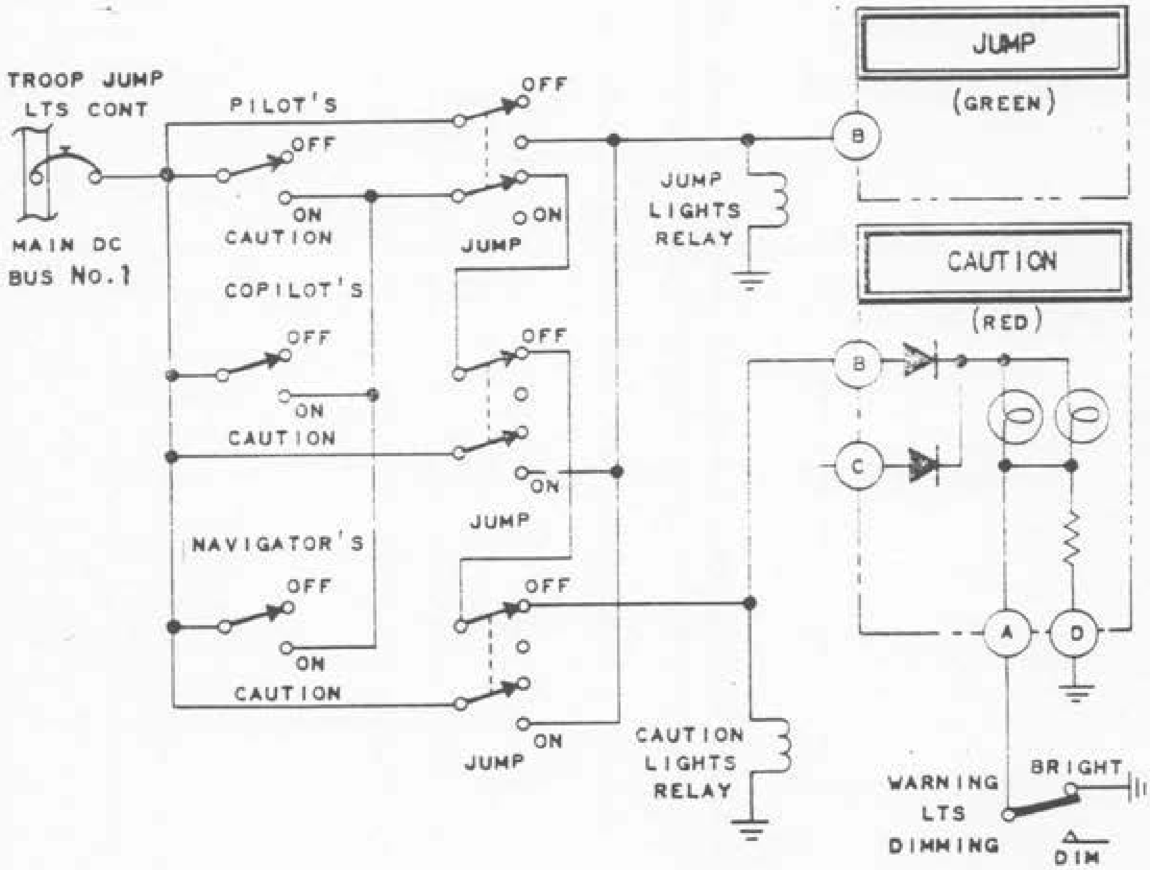
A SMOKE DETECTOR TEST switch is on the flight engineer's smoke detector panel. The "NORMAL" position should be used in flight. Positions "1" through "5" allow checkout of the five individual detectors and amplifier. In each position a switch connects a detector test light in series with the beacon light. The test light beam is directed into the photocell face, causing the photocell to conduct simulating smoke. The test light is in series with the beacon light to ensure that both lights are good. Time should be allowed between each test switch position to ensure that the previous detector has returned to normal.

TROOP JUMP LIGHTS



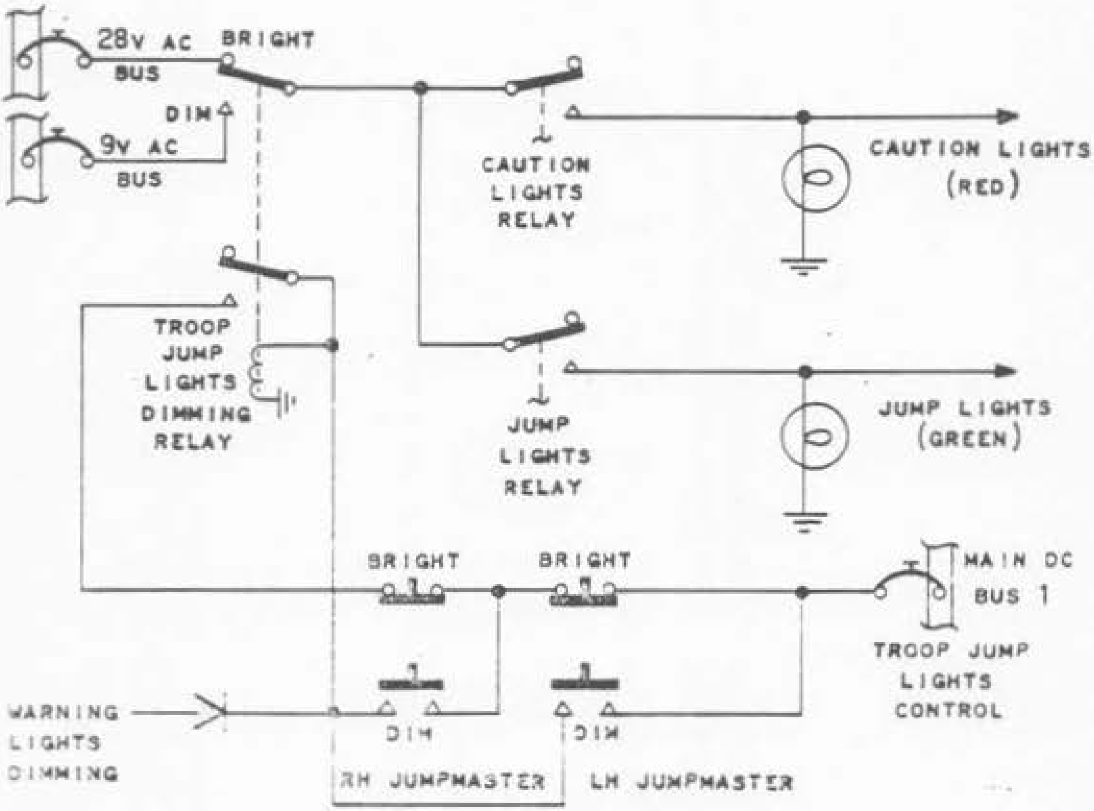
The troop jump lighting consists of three control panels and seven sets of lights. The control panels are located on the pilot's side console, copilot's side console and navigator's panel. Each control panel contains a CAUTION light, JUMP light, and two switches. The switches are mechanically interconnected to prevent actuation of the JUMP switch prior to actuation of the caution switch.

Each set of lights consist of a red caution and green jump light. The lights are located next to the crew entrance door, each side of the ramp, and both sides of each paratroop door. The ramp lights are not visible until the pressure door is opened.



CAUTION - JUMP SWITCHES

When a caution switch is "ON" and the jump switches are "OFF," the caution lights on the control panels illuminate and the caution lights relay is energized. The relay causes illumination of all caution lights in the cargo area. If the jump switch is positioned to "ON," the caution lights extinguish and the JUMP lights illuminate. The jump lights relay is energized to control the cargo area lights. The pilot's, copilot's, or navigator's switches may be used for the lights.

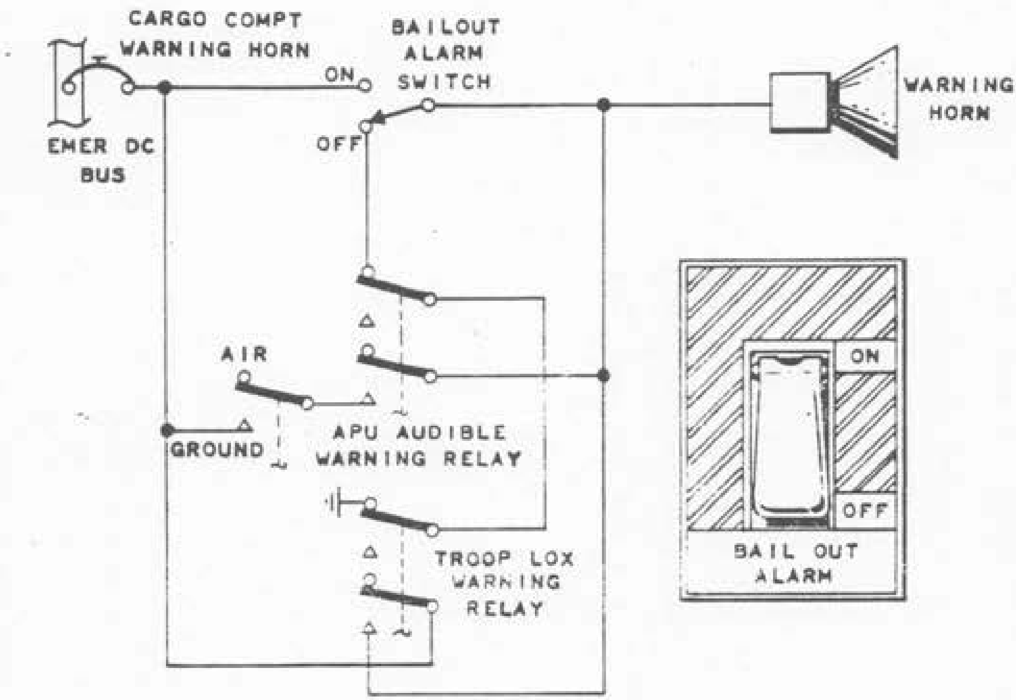


CARGO AREA CAUTION - JUMP LIGHTS

The control panel light intensity is controlled by the warning lights dimming circuit. The cargo area lights are controlled by BRIGHT-DIM pushbutton switches on the right and left jumpmaster panels and by the warning lights dimming circuit. The dimming switch causes the TROOP JUMP LIGHTS DIMMING relay to energize. Holding contacts keep the relay energized through the bright pushbuttons. The relay changes the power source to the lights from 28-volt, AC, in bright to 9 volts, AC in dim. If the BRIGHT switch is actuated, the dimming relay is deenergized. The A-C lighting voltage is supplied from the main A-C bus No. 1 through the miscellaneous lighting transformer.

BAILOUT ALARM SYSTEM

The bailout alarm system consists of a warning horn and control switch. The horn provides a manually controlled or automatic audible warning. The horn audible warning is automatically actuated if the troop liquid oxygen quantity decreases below 10 percent capacity (7.5 liters). A warning is also provided in case of an APU fire condition when the aircraft is on the ground.



BAILOUT ALARM

The warning horn is located overhead in the aft cargo area. The BAILOUT ALARM control switch is on the pilot's overhead panel, covered by a switch guard.

Emergency D-C bus power is supplied to the warning horn when the control switch is "ON." If the switch is "OFF," the horn can be automatically energized through the TROOP LOX WARNING RELAY or the APU AUDIBLE WARNING RELAY.

FIRE AND OVERHEAT DETECTION SYSTEM

An overheat or fire condition must be detected quickly for safety and to prevent damage to the aircraft. If detected early, corrective action can be taken minimizing damage. Overheat detection is provided in the four engines, and fire detection is provided in the engines and APU compartment. The fire and overheat detection system consists of sensing elements and five control units. The control units are identical, containing overheat and fire detection circuits and relays. The overheat output of the APU detector is not used. The sensing elements are installed in the engines, pylons, and APU compartment. The detectors are located in the forward electrical equipment rack. Audible warning relays and fire warning relays are controlled by the control units to provide an overheat or fire indication.

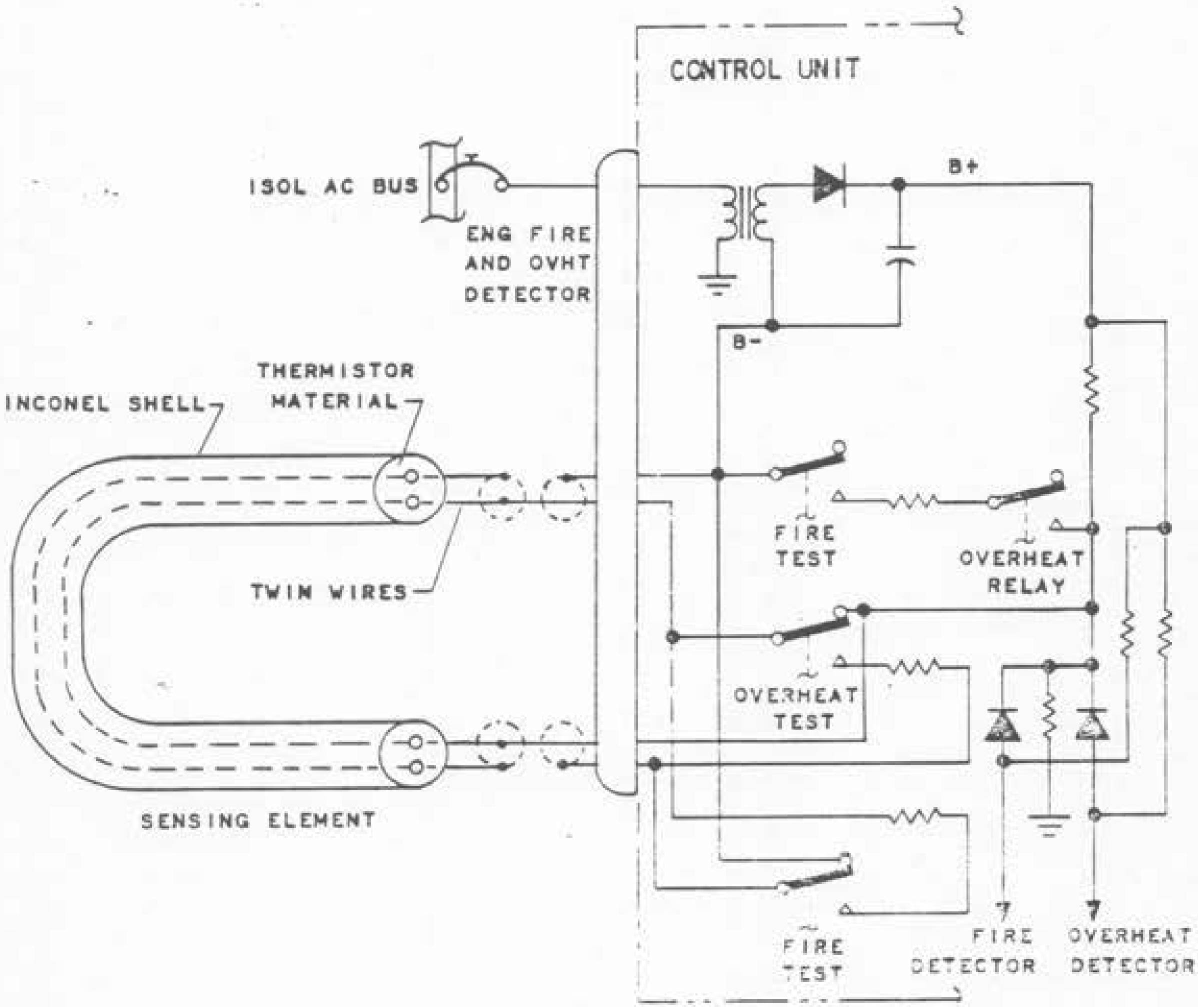
An engine fire or overheat condition is indicated by illumination of the pilot's and copilot's master FIRE warning lights and the fire emergency handle lights. An APU fire warning is indicated by illumination of the APU FIRE light on the annunciator panel; the pilot's and copilot's master CAUTION lights; the light in the emergency handle, located at the flight engineer's station; and another light in the cargo area. Audible fire warning is provided through the audible warning system. Test switches for checkout are located on the center console of the fire and overheat systems.

SENSING ELEMENT

The sensing element is a twin wire continuous loop inside several sections of metal tubing. The tube is inconel, a metal which does not harden with temperature variations. The wires are held in position within the shell by a thermistor material which has a negative temperature coefficient.

The twin wires are isolated from ground to prevent false alarm signals due to a single ground in the loop. Resistance of the thermistor material between the wires controls the detector. With wires isolated from ground, a single ground does not change the resistance between the wires.

The thermistor is a variable resistance controlled by temperature. As temperature increases, resistance decreases to a value related to an overheat condition. If temperature continues to increase, resistance decreases to a lower value related to a fire condition. Thermistor resistance is an overheat condition is approximately 1100 ohms, and a fire condition is 260 ohms.

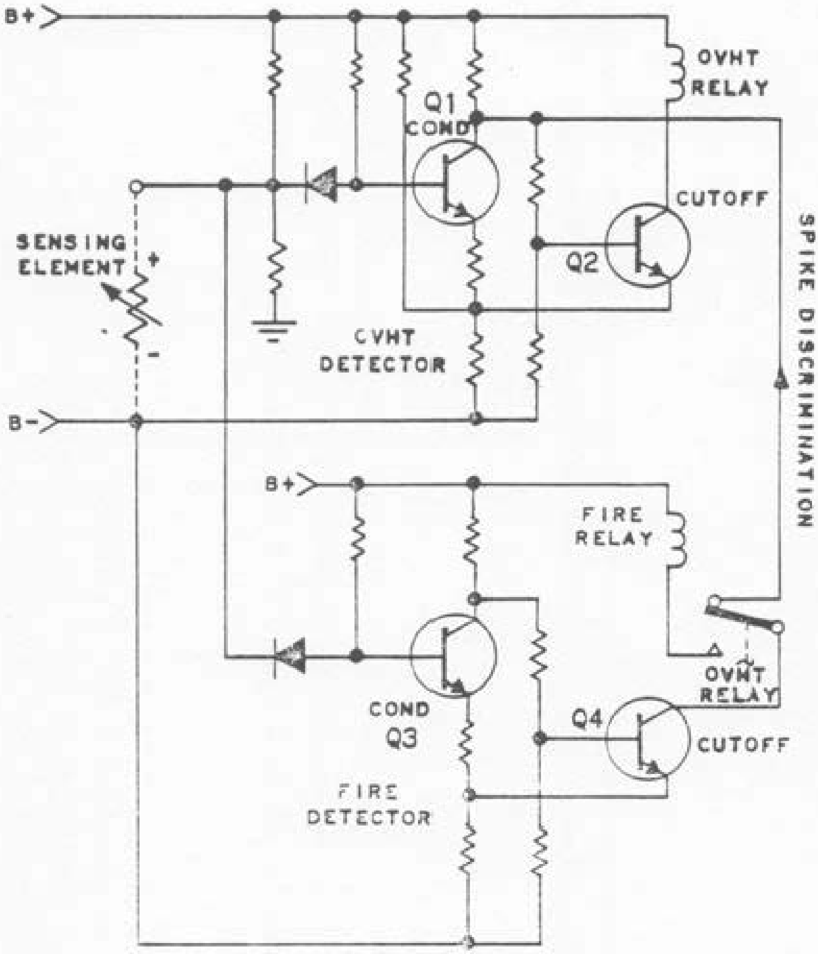


OVERHEAT AND FIRE SENSING

CONTROL UNIT

The control unit contains an overheat detector, fire detector, power supply, and test circuit. The power supply changes AC to DC for the transistorized detectors. The sensing element resistance controls D-C voltage into the detectors. The first transistor in each detector is normally conducting and the second is cutoff.

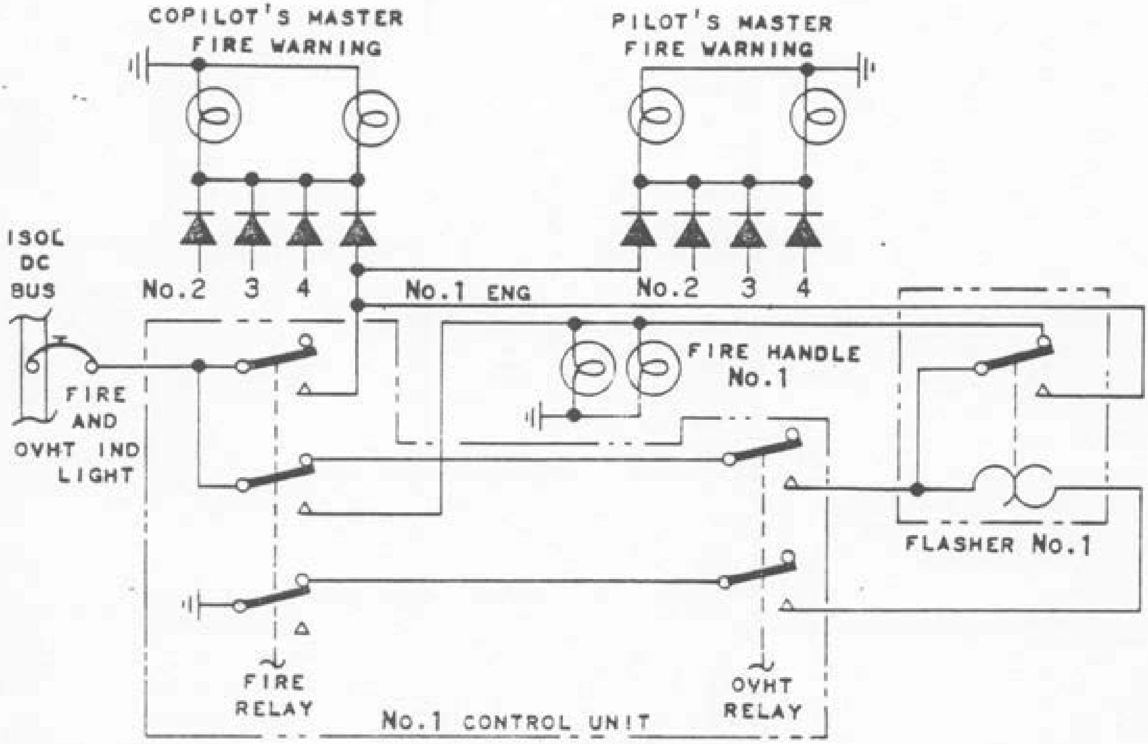
As the sensing resistance decreases, voltage to the base of the first transistor in the overheat detector decreases. The decreasing voltage decreases transistor current. When the first transistor is cutoff, the second transistor conducts to energize the overheat relay. A slight delay in circuit operation prevents relay actuation during a transient condition. Relay contacts complete a circuit to the warning lights flasher unit. This unit is thermally controlled



OVERHEAT AND FIRE DETECTION

to cycle between the master FIRE warning lights and fire handle lights, causing a flashing overheat indication.

If sensing resistance continues to decrease, the fire detector energizes the FIRE relay. The relay contacts bypass the overheat flasher causing a constant fire warning indication. An overheat indication occurs before a fire indication is possible due to overheat relay contacts in the fire detector. The sensing element returns to normal when the overheat or fire condition is corrected.

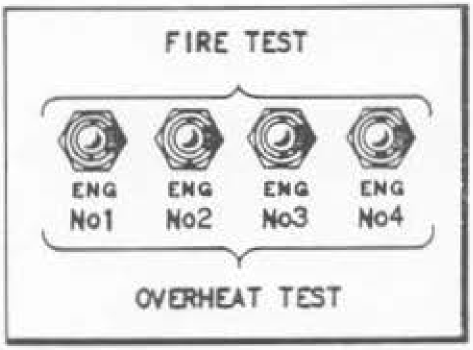


MASTER FIRE - OVERHEAT WARNING

The fire detector also discriminates against a short circuit, or transient, if the overheat relay is not energized. A rapid change in sensing resistance causes the fire detector transistors to change condition immediately before the overheat detector transistors. Collector voltage of the second transistor in the fire detector is supplied to the overheat detector through overheat relay contacts. Conduction in the second transistor of the fire detector keeps the overheat detector second transistor cutoff, preventing a fire or overheat indication.

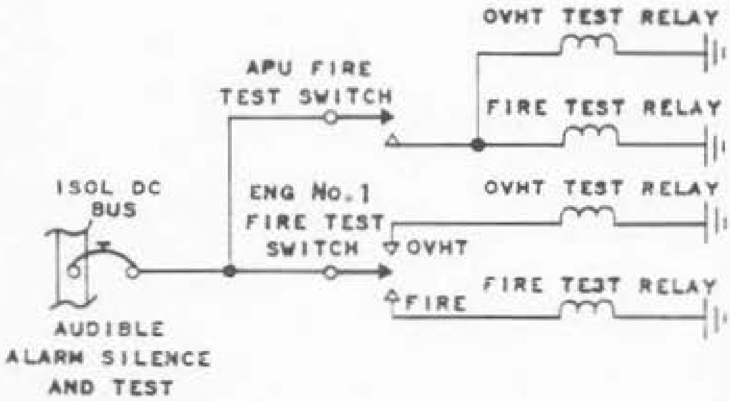
The APU control unit operates identically to the engine system. The APU overheat detector output is not used. An overheat condition causes the overheat relay and fire relay to energize. The fire relay contacts complete the APU FIRE and fire handle lights circuit.

Fire and overheat test switches on the center console allow checkout of the detectors, sensors, and lights. Test relays insert resistors across the sensing lines to simulate a fire or overheat. The OVERHEAT TEST relay connects a sensing wire into a series loop and inserts a resistance equivalent to an overheat condition. The fire test relay connects the second sensing wire into a series loop and inserts a resistance equivalent to an overheat condition, then contacts of energized overheat relay insert a second resistance equivalent to a fire condition. Each test checks continuity of one sensing wire. The APU fire test controls both test relays to simulate a fire condition and check continuity of both sensing wires.

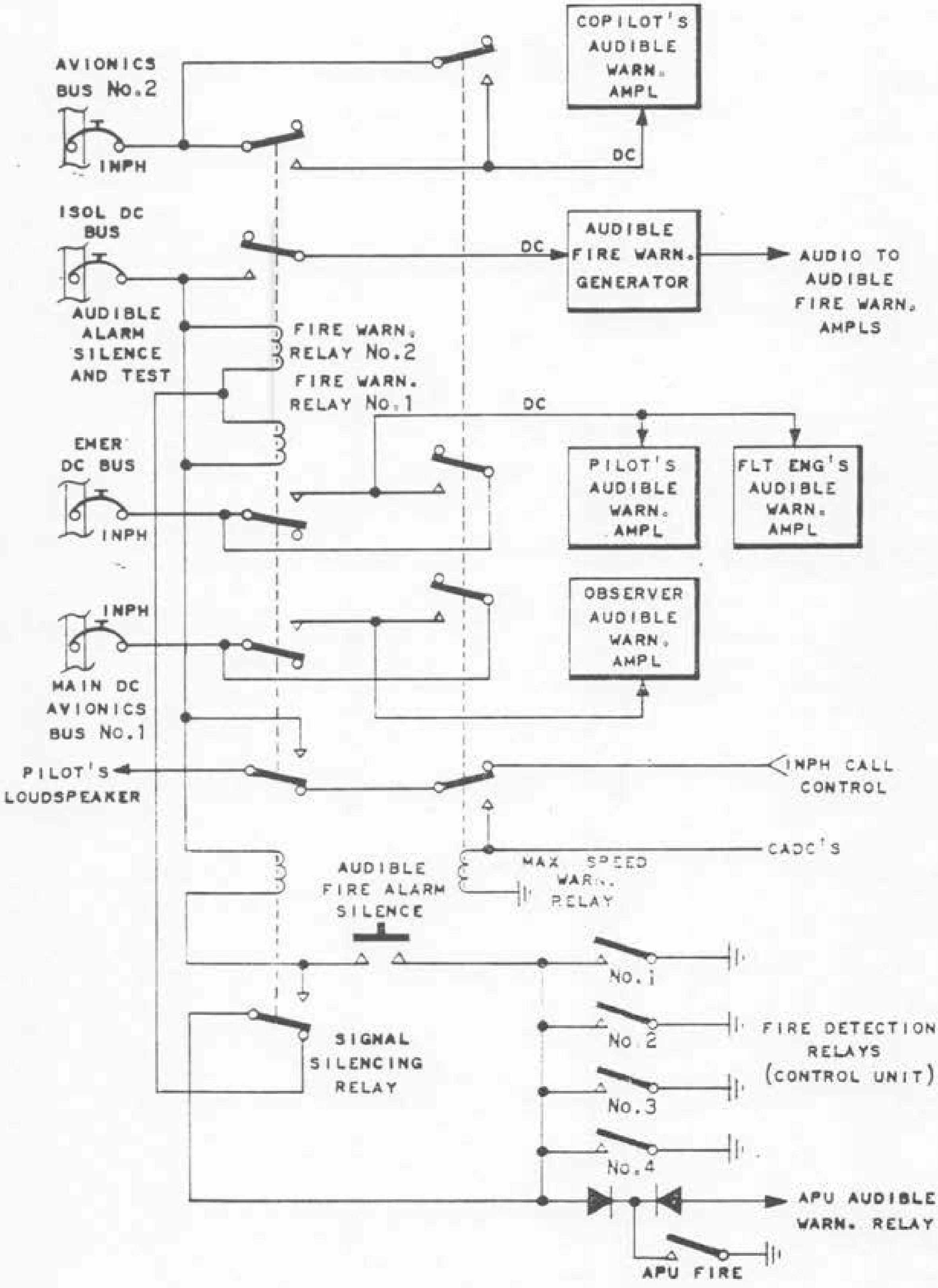


AUDIBLE WARNING SYSTEM

The warning system provides a varying tone audible warning if a fire condition is detected or if the aircraft exceeds a maximum speed limits. The warning signal is supplied to the pilot's copilot's, flight engineer's, and observer's headsets and to the pilot's loudspeaker. The fire warning is provided through the fire detection system, and the maximum speed warning is controlled by the Central Air Data Computers (CADC's). The audible fire warning is provided by a fire warning generator and four audible warning amplifiers. The amplifiers are also used with the maximum speed audible warning generator.

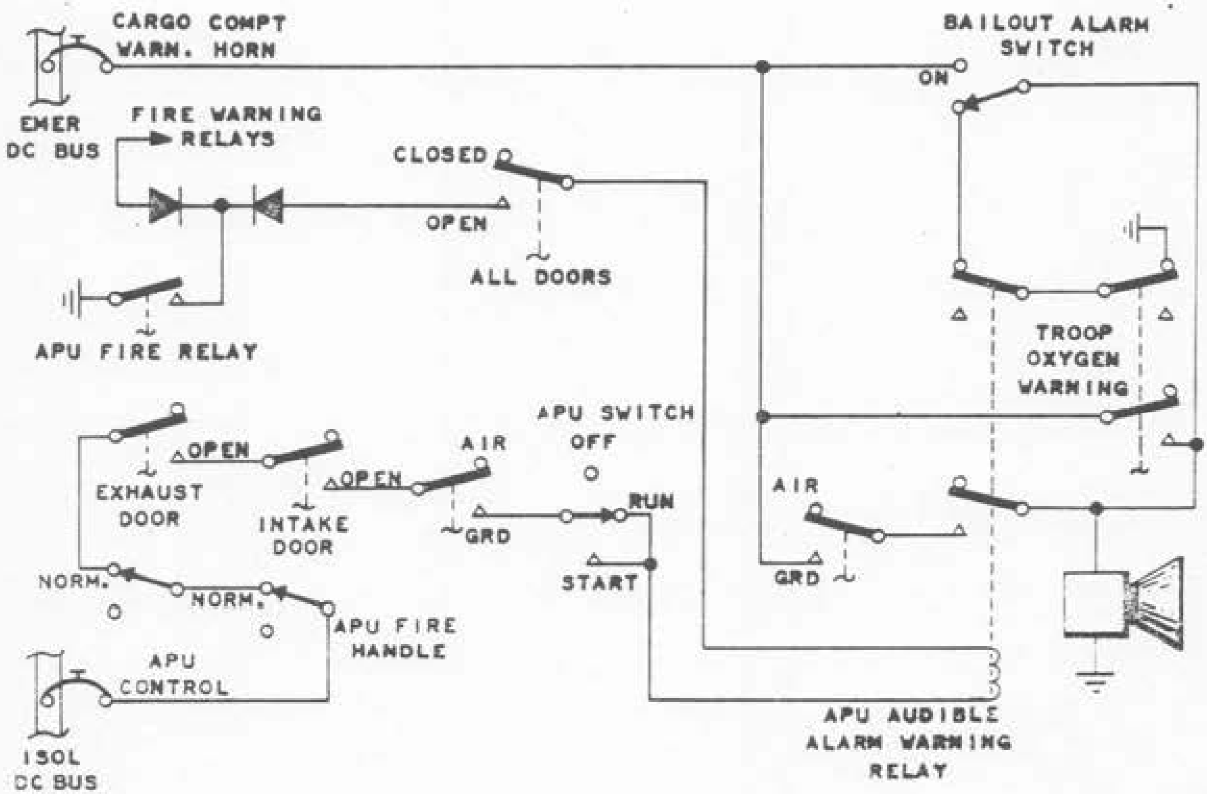


If a fire is detected in an engine, pylon, or the APU compartment, the respective fire relay in the fire detector control unit is energized. The control unit causes two fire warning relays to energize, turning on the audible warning generator and amplifiers. The generator supplies a varying tone into the amplifiers which control the headsets and loudspeaker. The generator, amplifiers, and relays are located in the audible warning relay panel in the center avionics equipment rack.



AUDIBLE WARNING RELAY CIRCUITS

The audible signal can be silenced by pressing the audible fire alarm silence switch located on the engine fire emergency panel. The pushbutton switch energizes the signal silencing relay. Relay contacts provide a holding circuit to the relay, keeping the relay energized until the fire is extinguished. Relay contacts also open the fire warning relay circuit to turn off the audible warning generator.

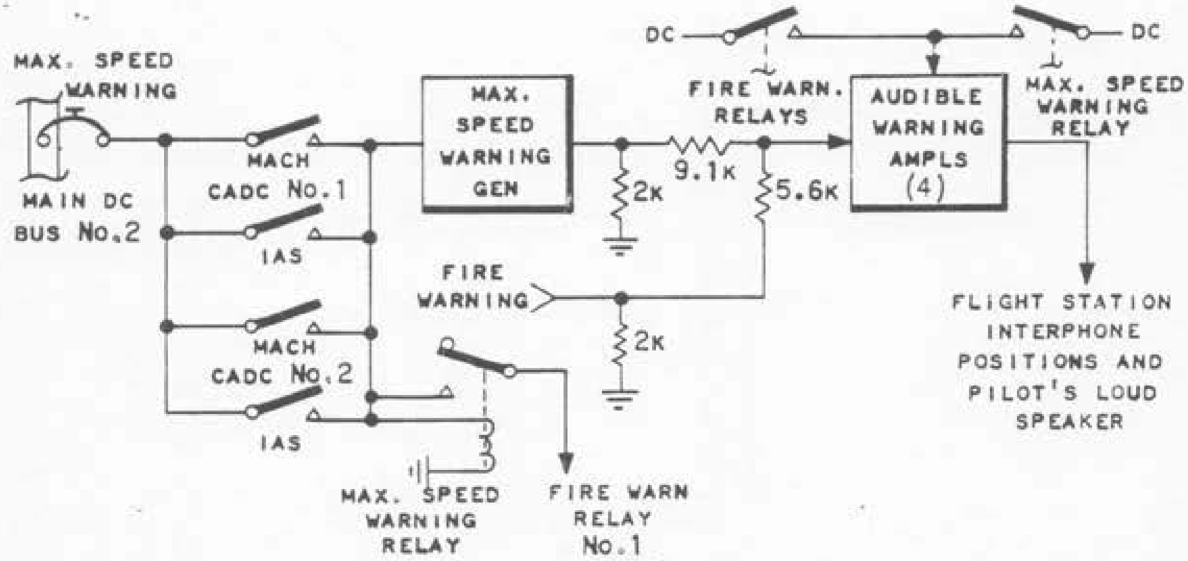


APU AUDIBLE WARNING

The APU fire detector controls the audible warning generator and also controls the cargo compartment warning horn. An APU fire energizes the fire warning relays to turn on the flight station audible warning generator and amplifiers. An APU fire also energizes the APU audible alarm warning relay which controls the warning horn. The relay can energize during an APU fire if the following conditions exist:

1. Door open (All doors circuit)
2. APU switch in "Run" or "Start" (APU Control)
3. Aircraft on the ground (Touchdown relay)
4. Exhaust and Intake Doors open (APU Control)
5. Both APU fire handles in normal

The warning horn can be silenced by pulling the warning horn circuit breaker or by pulling the APU fire emergency handle. The fire handle controls the APU system.



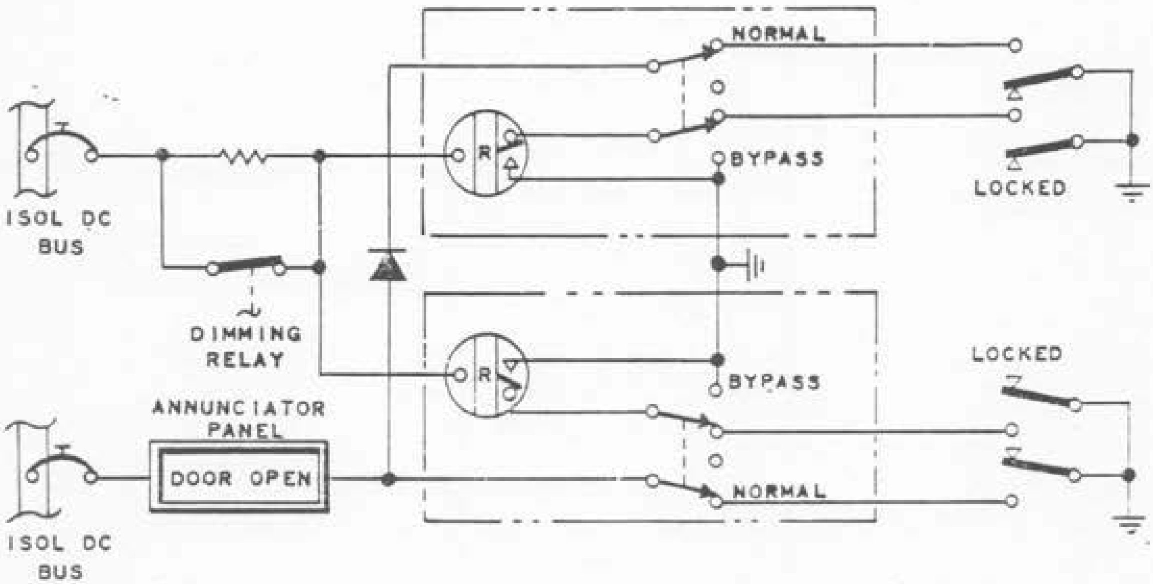
MAXIMUM SPEED WARNING

MAXIMUM SPEED WARNING SYSTEM

The maximum speed warning system provides an audible warning if the aircraft exceeds an Indicated Airspeed (IAS) of 350 knots or a Mach number of 0.825. The warning is provided through the pilot's loudspeaker and audible warning amplifiers.

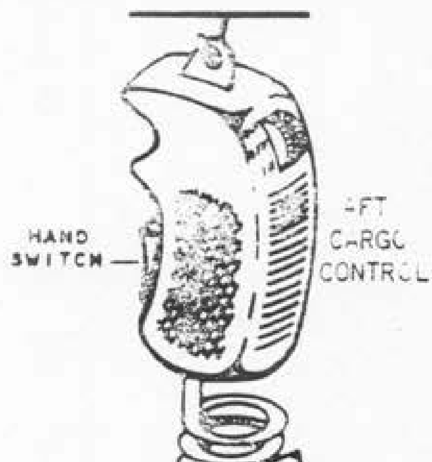
The system consists of a maximum speed warning generator, control relay, and the four audible warning amplifiers. The units are located on the audible warning terminal panel in the center avionics equipment rack.

Aircraft speed is sensed by the CADC's. Switches in the CADC's close when the maximum IAS or maximum Mach number is exceeded, applying 28-volt, AC, to the maximum speed warning generator. The generator output is supplied through the four amplifiers to the flight crew headsets. The generator output is a varying audio tone. The MAX SPEED WARNING relay is also energized to turn on the pilot's overhead loudspeaker. The same amplifiers are used with the audible fire warning generator.



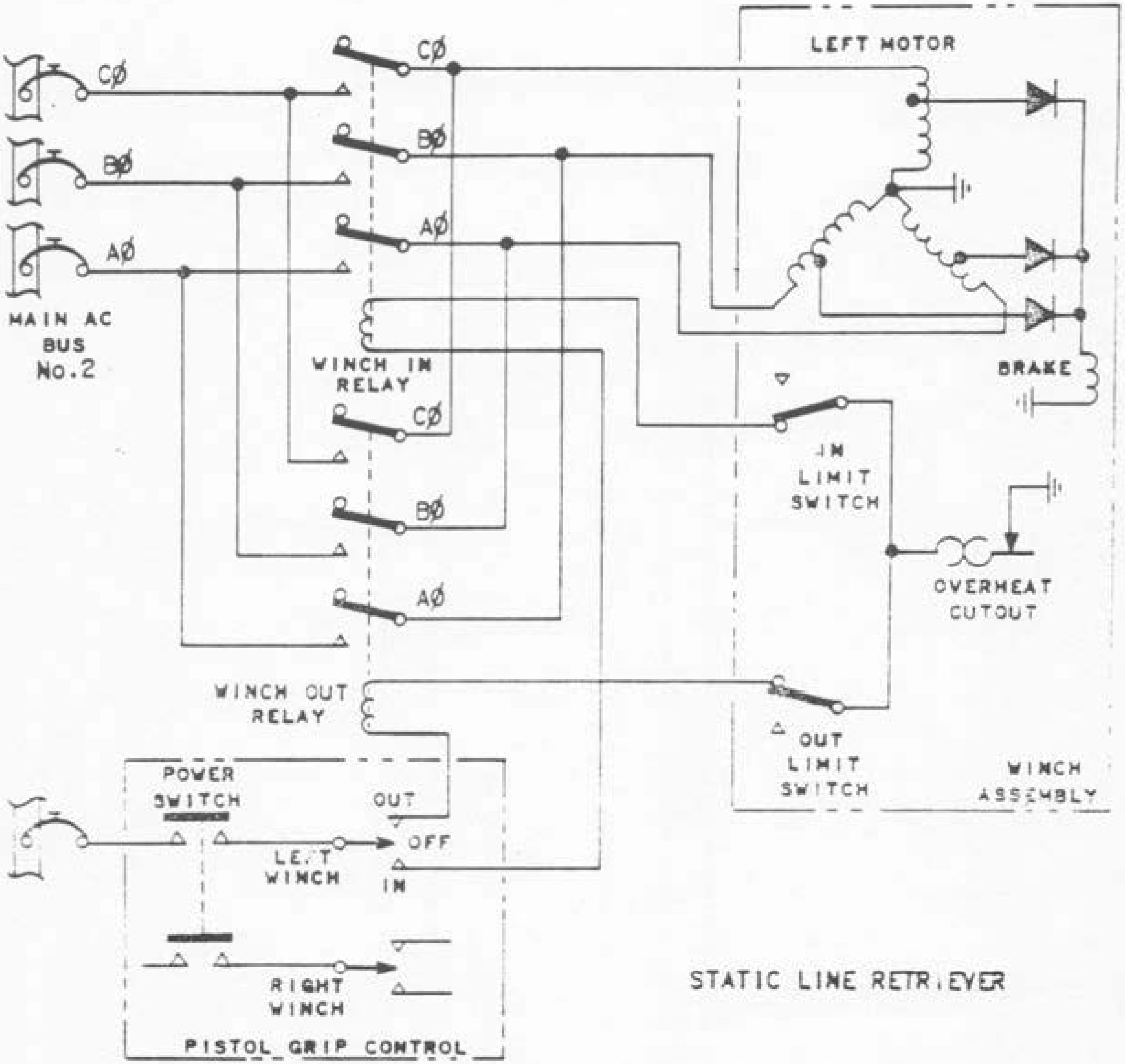
DOOR OPEN WARNING SYSTEM

The door warning system provides a visual indication when a door is not closed properly. The warning is provided by illumination of the DOOR OPEN light on the annunciator panel and the master CAUTION lights on the instrument panels. The annunciator lights flash and the CAUTION light is steady. When all doors and the ramp are closed and locked, micro-switches are opened and the lights are extinguished. An open door microswitch completes the warning light circuit. Each door contains a door open light and bypass switch. The light illuminates to indicate which door is open, and the bypass switch isolates the annunciator and master CAUTION lights. The bypass is used to extinguish the master CAUTION and annunciator lights when a specific door is to remain open. If any other door opens, the lights again illuminate to provide a warning.



PARATROOP STATIC LINE RETRIEVER SYSTEM

During an air drop mission, anchor cables are extended from one end of the cargo area to



STATIC LINE RETRIEVER

the other. The cables allow parachute static lines to be attached prior to the airdrop. Static lines open the parachutes on the packs when the packs are released. The static lines are retracted into the aircraft after the drop is completed by static line retrievers.

The retrieval system consists of two winch and cable assemblies, extension cables, control relays, and a pistol grip control. The two winch and cable assemblies and four control relays are located on the forward cargo area bulkhead. The retrieval cable attaches to an extension cable which fastens to spools on the anchor cables. The spools are pulled forward on the anchor cables to retrieve the static lines.

Anchor cables are secured between the forward and aft cargo area. The cables attach at the forward cargo support beam with anchor arms on each side of the ramp. A turnbuckle is used to adjust cable tension. Sliding spools on each cable attach to the retrieval winch cable. The winch rewinds the retrieval cable pulling the spool and static lines foward into the aircraft.

A pistol grip control is provided in the aft cargo area next to the ramp control panel. An extension cord permits freedom of movement while controlling the retriever system. The pistol grip contains an ON-OFF switch and two winch control switches. The ON-OFF switch is actuated by holding the pistol grip and the winches are controlled by thumb switches. Identical switches control the left or right winch to extend, stop, or rewind the cables. The "OUT" position energizes the WINCH OUT relay, which completes the power circuit of the motor. The left winch motor is supplied three-phase AC from main A-C bus No. 2; the right is supplied from main A-C bus No. 3. The winch drives the cable assembly to unwind the cable which must be extended manually. If the switch is released, or the maximum cable limit is reached, the winch stops. The control switch or limit switches deenergize the control relays to stop the winch.

The "IN" position energizes the WINCH IN relay, reversing the motor. Motor reversal is accomplished through the relay by reversing the Phase A and B power source to the motor. The motor rewinds the cable until the switch is released or until the rewind limit switch is actuated.

A thermal overheat cutout is provided in each winch assembly in case overheating occurs. The cutout opens the relay ground circuit to stop the winch. The cutout automatically resets after cooling. A brake holds the winch and cable assembly when power is removed. Rectifiers change AC to DC to release the brake when the motor is driving.

IRON LUNG OUTLETS

Two special 28-volt DC outlets are used to furnish power to iron lungs for medical evacuations. One is in the forward section of the cargo compartment and the other in the center section. Power to these outlets is furnished from the main D-C buses.

CARGO COMPARTMENT RECEPTACLES.

General service, three-phase A-C outlets are located at convenient positions in the cargo compartment. Power for the right side receptacles is furnished from the main A-C bus No. 2. Power for the left side receptacles is supplied from the main A-C bus No. 3.

CARGO WINCH POWER OUTLET

A special receptacle is on the left side of the forward cargo compartment bulkhead. It is used for a portable cargo winch to aid in loading the aircraft. The outlet is supplied three-phase, A-C power from main A-C bus No. 3.

AVIONICS TEST RECEPTACLES

Three avionics test receptacles are installed. The receptacles provide a source of A-C and D-C power for test equipment. Two receptacles are mounted in the underdeck avionics equipment area. A test receptacle is also installed in the nose wheel well area.

Power for the receptacles is supplied by main D-C bus No. 2 and phase A of main A-C bus No. 4.

GALLEY RECEPTACLES

Two galley receptacles are installed. One is provided for the crew galley, and the other is used when the comfort pallet is installed on the airplane.

The crew galley receptacle is supplied three-phase A-C power from main A-C bus No. 2. The receptacle used with the comfort pallet is installed on the right side in the forward cargo compartment. It is supplied from main A-C bus No. 3.

SIGNAL LIGHT RECEPTACLES

Two signal light receptacles are installed on the airplane. One is on the pilot's side console in the map cases and the other is on the copilot's side console in the map cases.

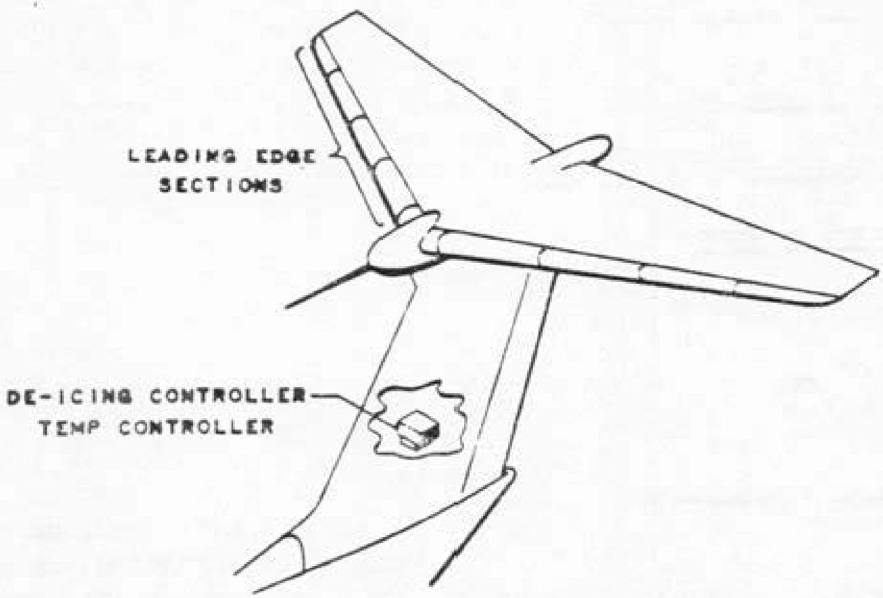
ELECTRIC LAVATORY SYSTEM

An electrically operated flush mechanism is used to remove waste products from the crew toilet. Power to the mechanism is supplied by main A-C bus No. 2.

An electric shaver outlet is provided in the crew lavatory. The circuit converts 115-volt, single-phase AC to 115-volt DC. Power to the outlet is supplied from phase B of main AC bus no. 2.

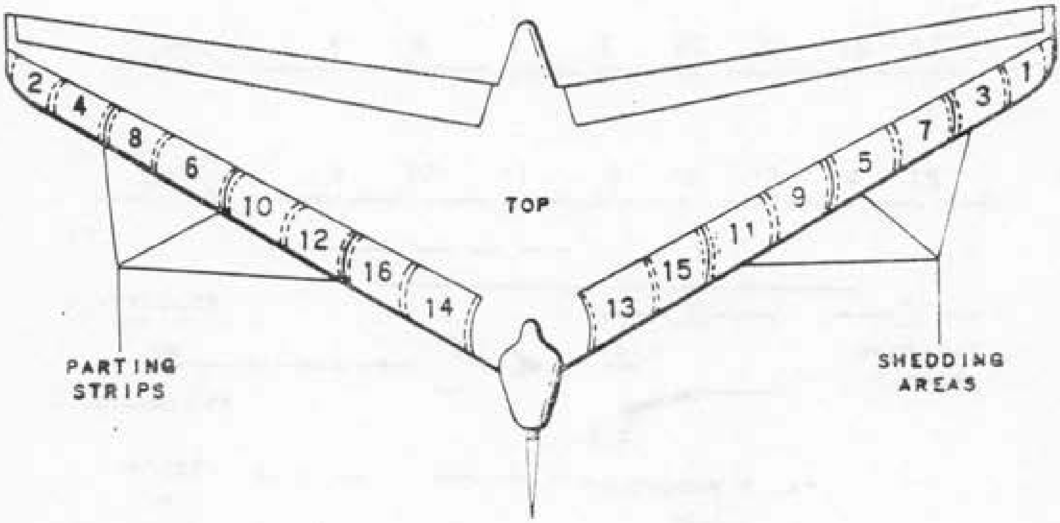
EMPENNAGE (HORIZONTAL STABILIZER) DE-ICING SYSTEM

The leading edge of the horizontal stabilizer portion of the empennage is electrically de-iced. Anti-icing and de-icing heaters are used to remove or prevent ice formation as required. Anti-icing is accomplished by use of shedding area heaters. The shedding area heaters are cycled on and off in a particular sequence by a de-icing controller. The same controller causes the parting strip heaters to operate continuously.

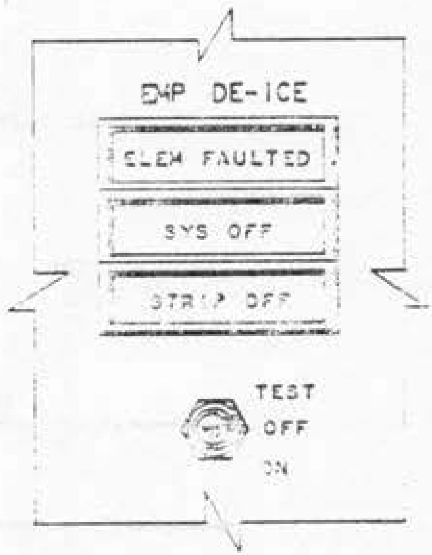


EMPENNAGE LEADING EDGE

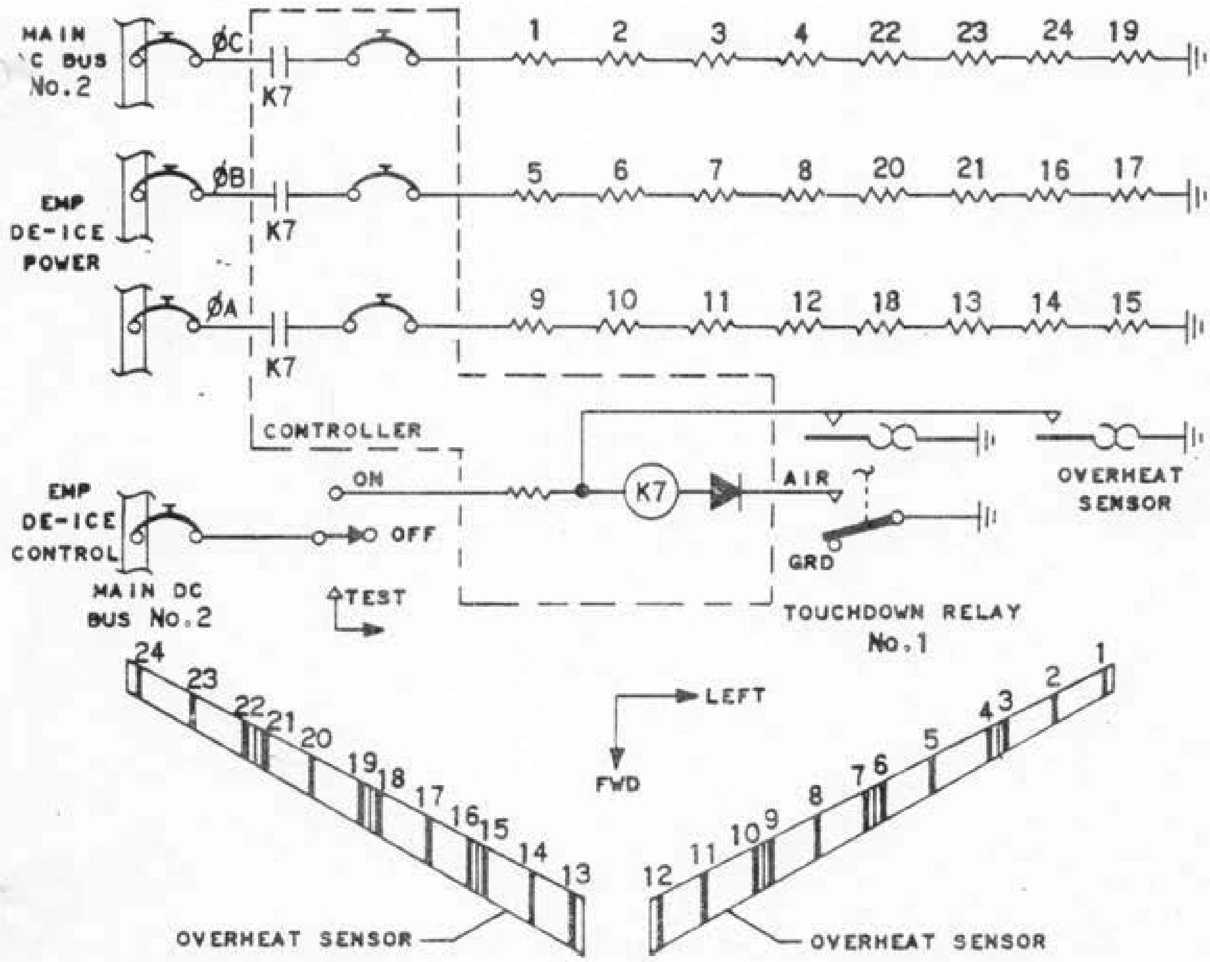
The empennage leading edge is constructed of fiberglas layers with a stainless steel outer layer. Resistive heating elements and temperature sensors (thermistors) are imbedded in the fiberglas. The leading edge is divided into eight approximately equal sections. Each section contains three parting strip and two shedding area heaters.



SHEDDING AREA NUMERICAL DESIGNATION



The de-icing cycle begins at the outboard shedding area and progresses inboard in numerical sequence; therefore the cycle alternates left and right shedding areas to maintain symmetrical ice removal. The controller allows shedding area an ON time of 15 seconds maximum during low-temperature icing conditions. However, the controller is capable of tailoring the ON time of the shedding areas, e.g. the controller will switch to the next shedding area when the temperature at the sensor reaches a predetermined value. Under relatively high icing temperatures, the entire de-icing cycle (all 8 sections) could possibly be completed in less than three minutes. Should this occur, the controller will delay the beginning of the next cycle until three minutes have elapsed since the beginning of the previous cycle. An open or shorted heater would cause the ELEM FAULTED lights on the overhead panel to illuminate. If the controller stops cycling, heater power is removed and the SYS OFF lights on the overhead panel will illuminate. Should the parting strip temperature exceed 90°F (anti-icing), the temperature controller removes power from the heater and illuminates the STRIP OFF light on the overhead panel. The controller may be tested when the aircraft is on the ground; however, power is not applied to the heaters at this time.



PARTING STRIP HEATERS