NMC-27

Electrical Training

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About NYK

Nippon Yusen Kabushiki Kaisha is one of the world's leading transportation companies. At the end of March 2013, the NYK Group was operating 846 major ocean vessels, as well as fleets of planes, trains, and trucks.

The company's shipping fleet includes 389 bulk carriers, 144 containerships (including semi-containerships), 120 car carriers, 82 tankers, 51 wood-chip carriers, 28 LNG carriers, 18 heavy-load carriers / conventional ships, three cruise ships, and 29 other ships.

NYK's revenue in fiscal 2012 was about $20 billion, and as a group NYK employs about 56,000 people world wide. NYK is based in Tokyo and has regional headquarters in London, New York, Singapore, Hong Kong, Shanghai, Sydney, and Sao Paulo.

Applicable Trainees: Engine Officers

Objectives of the Training:

After completion of the training, the trainees should have understanding of the following:

1) The Safety Guidelines and Hazardous zone precautions

2) Electrical drawings

3) Arrangement of the Main switchboard and group starter panel

4) Function of the equipments for switchboard and starter panel

5) Measurement tools

6) Sequence Diagram

7) Programmable logic controller, sequence controller

Duration of Training: 4 Days

Course Schedule:

	Contents of the Course	**Contents of the Course**
	AM	PM
1st Day	Safety Guidelines Electrical Finished Drawings	Electrical Finished Drawings
2nd Day	Main Switchboard Electrical Equipment	Electrical Equipment AC Generator Measuring Tools
3rd Day	Wiring Training Troubleshooting	Wiring Training Troubleshooting
4th Day	Wiring Training Troubleshooting	Wiring Training Troubleshooting Assessment

Contents and Syllabus

6.1.3 Procedure for measuring Current

6.2 Current Clamp meter

6.3 Insulation testing

7. Programmable logic controller (Sequence controller)

7.1 Outline of Sequencer

7.2 Advantages of Sequencer

8. Practical training

8.1 Understanding of Wiring diagrams, Maker's finished plans, using actual vessel drawings

8.2 Understanding of sequence diagram for Motor starting circuit

8.3 Wiring training for Motor starting circuit, using training board.

8.4 Troubleshooting exercises regarding Motor starting problem

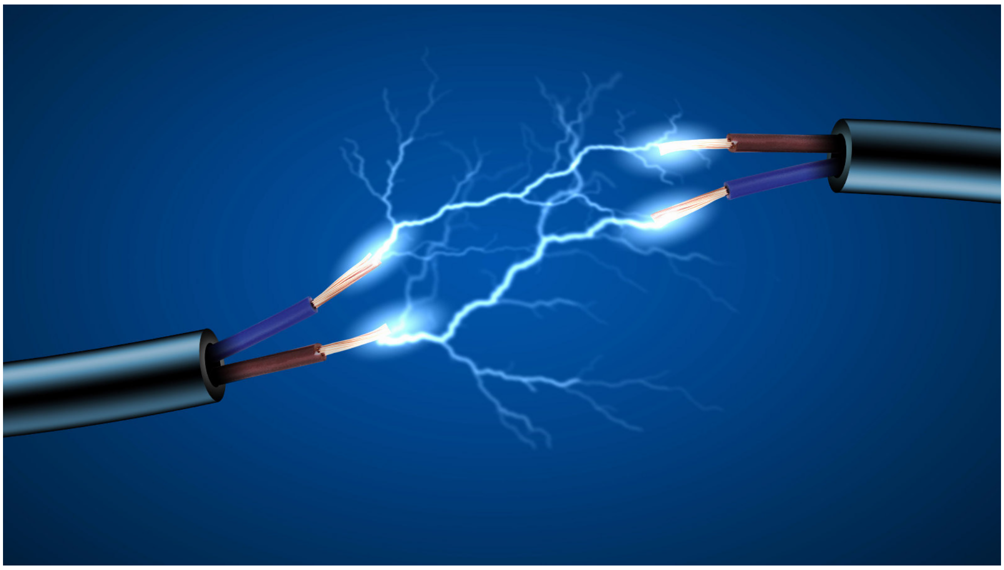
8.5 Demonstrate the installation and setting of program for Programmable controller

8.6 Wiring training for connecting Programmable controller

9. Equipment, Materials, Teaching Aids

Wiring training board, Programmable controller training kit, Multi meters, Actual vessel drawings, Various actual electrical parts.

Foreword



Electricity is present everywhere in our lives. Electricity lights up our homes, cooks our food, powers our computers, television sets, and other electronic devices. Electricity from batteries keeps our cars running and makes our flashlights shine in the dark.

Here's something you can do to see the importance of electricity. Take a walk through your school, house or apartment and write down all the different appliances, devices and machines that use electricity. You'll be amazed at how many things we use each and every day that depend on electricity.

But what is electricity? Where does it come from? How does it work? Before we understand all that, we need to know a little bit about atoms and their structure. All matter is made up of atoms, and atoms are made up of smaller particles. The three main particles making up an atom are the proton, the neutron and the electron.

Electrons spin around the center, or nucleus, of atoms, in the same way the moon spins around the earth. The nucleus is made up of neutrons and protons. Electrons contain a negative charge, protons a positive charge. Neutrons are neutral – they have neither a positive nor a negative charge.

There are many different kinds of atoms, one for each type of element. An atom is a single part that makes up an element. There are 118 different known elements that make up every thing!

Some elements like oxygen we breathe are essential to life.

Each atom has a specific number of electrons, protons and neutrons. But no matter how many particles an atom has, the number of electrons usually needs to be the same as the number of protons. If the numbers are the same, the atom is called balanced, and it is very stable.
So, if an atom had six protons, it should also have six electrons. The element with six protons and six electrons is called carbon. Carbon is found in abundance in the sun, stars, comets, atmospheres of most planets, and the food we eat. Coal is made of carbon; so are diamonds.
Some kinds of atoms have loosely attached electrons. An atom that loses electrons has more protons than electrons and is positively charged. An atom that gains electrons has more negative particles and is negatively charge. A "charged" atom is called an "ion."

Electrons can be made to move from one atom to another. When those electrons move between the atoms, a current of electricity is created. The electrons move from one atom to another in a "flow." One electron is attached and another electron is lost.
This chain is similar to the fire fighter's bucket brigades in olden times. But instead of passing one bucket from the start of the line of people to the other end, each person would have a bucket of water to pour from one bucket to another. The result was a lot of spilled water and not enough water to douse the fire. It is a situation that's very similar to electricity passing along a wire and a circuit. The charge is passed from atom to atom when electricity is "passed."
Scientists and engineers have learned many ways to move electrons off of atoms. That means that when you add up the electrons and protons, you would wind up with one more proton instead of being balanced.
Since all atoms want to be balanced, the atom that has been "unbalanced" will look for a free electron to fill the place of the missing one. We say that this unbalanced atom has a "positive charge" (+) because it has too many protons.
Since it got kicked off, the free electron moves around waiting for an unbalanced atom to give it a home. The free electron charge is negative, and has no proton to balance it out, so we say that it has a "negative charge" (-).

So what do positive and negative charges have to do with electricity?
Scientists and engineers have found several ways to create large numbers of positive atoms and free negative electrons. Since positive atoms want negative electrons so they can be balanced, they have a strong attraction for the electrons. The electrons also want to be part of a balanced atom, so they have a strong

attraction to the positive atoms. So, the positive attracts the negative to balance out.
The more positive atoms or negative electrons you have, the stronger the attraction for the other. Since we have both positive and negative charged groups attracted to each other, we call the total attraction "charge."
Energy also can be measured in joules. Joules sounds exactly like the word jewels, as in diamonds and emeralds. A thousand joules is equal to a British thermal unit.

When electrons move among the atoms of matter, a current of electricity is created. This is what happens in a piece of wire. The electrons are passed from atom to atom, creating an electrical current from one end to other, just like in the picture.

Electricity is conducted through some things better than others do. Its resistance measures how well something conducts electricity. Some things hold their electrons very tightly. Electrons do not move through them very well. These things are called insulators. Rubber, plastic, cloth, glass and dry air are good insulators and have very high resistance.
Other materials have some loosely held electrons, which move through them very easily. These are called conductors. Most metals – like copper, aluminum or steel – are good conductors.

Chapter 1

Safety

1.1 General Information on Electric Shock

With every contraction, the heart pumps blood carrying oxygen throughout the body. The rhythm of the heartbeat is controlled by electrical impulses, which can be seen on an electrocardiogram. Current passing through the heart can cause an irregular heartbeat called arrhythmia, or even total disorganization of the rhythm, called ventricular fibrillation.

When ventricular fibrillation occurs, the heart stops pumping. The victim rapidly loses consciousness and dies if a healthy heartbeat is not restored by applying a second electric shock with a device called a defibrillator.
Heart rhythm disturbances can occur at the time of the shock or in the 24 hours following the accident.

Muscles are stimulated by electricity. The effect of an electric shock depends on which muscles the current goes through. A current of more than 10 mA causes sustained contraction (tetanus) of the flexors, that is, the muscles that close the fingers and draw the limbs towards the body. The victim thus cannot let go of the source of current.

If the extensors (the muscles that open the figures and extend the limbs away from the body) are tetanized, the victim is propelled away from the current source, sometimes as much as ten metres!

Muscles, ligaments and tendons may tear as a result of the sudden contraction caused by an electric shock. Tissue can also be burned if the shock is lasting and the current is high.

Nerves are the tissue that offers the least resistance to the passage of an electric current. Some nerve damage caused by shock clears up with time, but some is permanent. The victim may feel pain, tingling, numbness, weakness or difficulty moving a limb.

When a shock occurs, the victim may be simply dazed or may experience amnesia, seizure or respiratory arrest.

Ultimate damage to the nerves and the brain will depend on the extent of the injuries caused by the heat along the path of the electric current and may develop up to three years after the shock. Nerve damage can also cause psychiatric disorders.

Electrical burns are not like burns caused by fire or by touching something hot. Electrical burns result from the heat generated by an electric current passing through the body, which literally cooks the tissue from within.

We've all felt that buzzing or tingling sensation without experiencing injury. A current as low as 0.25 milliamperes (mA) can cause this feeling.

Starting at 10 mA, most people cannot let go of the shock source because their muscles contract.

Above 50 mA, an electric current can trigger cardiac arrest if it passes through the heart.

Above 100 mA, electrical marks appear on the body at the points of contact.

Above 10,000 mA (10 amperes), burns are severe and amputation is required.

The damage may be much more serious than the external injuries suggest. This is known as the Iceberg Effect.

Electrical marks appear at the body's point of contact with the current. They are typically tiny charred or hard craters that do not hurt because the nerves have been destroyed.
If a lot of tissue is destroyed, the waste generated can cause serious kidney or blood circulation disorders.

Electrical burns often have serious consequences: scarring, amputation, loss of function, loss of sensation and even death.

Electric shock can also affect the eyes, causing cataracts to develop over time.

Other disorders can appear in the weeks or months following the accident, depending on which organs the current passed through.

The table below shows relationship between Electrical Shock Currents and Physiological Effects on Human body.

Influence of Electric Shock	Direct Current (mA)		Alternating Current (mA)			
			60 Hz		1000Hz	
	Male	Female	Male	Female	Male	Female
Minimum sensed current	5.2	3.5	1.1	0.7	12	8
A little shock without pain *Possible control the muscle	9.0	6.0	1.8	1.2	17	11
A few shock with pain *Possible control the muscle	62	41	9	6	55	37
A shock with pain *Limit to escape out of source	74	50	16	10.5	75	50
Severe shock with pain *Rigor of muscle & difficulty breathe	90	60	23	15	94	63
Possible occurrence the ventricle spasm *Electric shock = 0.03second	1300	1300	1300	1300	1300	1300
Possible occurrence the ventricle spasm *Electric shock = 0.03second	500	500	500	500	500	500
Absolutely occurrence the ventricle spasm *Absolutely death	2.75 times above current					

1.1.1 Danger of Electricity

What are the physical differences between shocks by AC and DC current? Both are dangerous and can be lethal in high amounts. Learn more here.

An AC current is alternating in nature and follows a sine curve. It changes direction continuously and passes through zero to a maximum positive value and then to a maximum negative value. The voltage of an AC current is a RMS or root mean square value, and the peak or maximum value is 1.4 times the RMS value. It means that a 220 V AC supply is going to 308 Volts before coming down to zero and changing direction.

DC current is direct current and does not change in magnitude, though it can be negative or positive depending on the direction of the circuit. DC current is ideal for electronic circuits whereas AC is ideal for electrical installation and motors, etc.

The three basic factors that determine what kind of shock you experience are the amplitude of the current, the duration of the current passing through the body, and the frequency.

Direct currents actually have zero frequency, as the current is constant. However, there are physiological effects during electrocution no matter what type of current.

The factor deciding the effects of the AC and DC current is the path the current takes through the body. If it is from the hand to the foot, it does not pass through the heart, and then the effects are not so lethal.

However DC current will make a single continuous contraction of the muscles compared to AC current, which will make a series of contractions depending on the frequency it is supplied at. In terms of fatalities, both kill but more milliamps are required of DC current than AC current at the same voltage.

If the current takes the path from hand to hand thus passing through the heart it can result in fibrillation of the heart. Fibrillation is a condition when all the heart muscles start moving independently in a disorganized manner rather than in a state of coordination. It affects the ability of the heart to pump blood, resulting in brain damage and eventual cardiac arrest.

Either AC or DC currents can cause fibrillation of the heart at high enough levels. This typically takes place at 30 mA of AC (rms, 60 Hz) or 300 – 500 mA of DC.

Though both AC and DC currents and shock are lethal, more DC current is required to have the same effect as AC current. For example, if you are being electrocuted or shocked 0.5 to 1.5 milliamps of AC 60 Hz current is required and up to 4 mA of DC current is required. For the let-go threshold in AC a current of 3 to 22 mA is required against 15 to 88 of DC current.

Some interesting facts about electric shock,

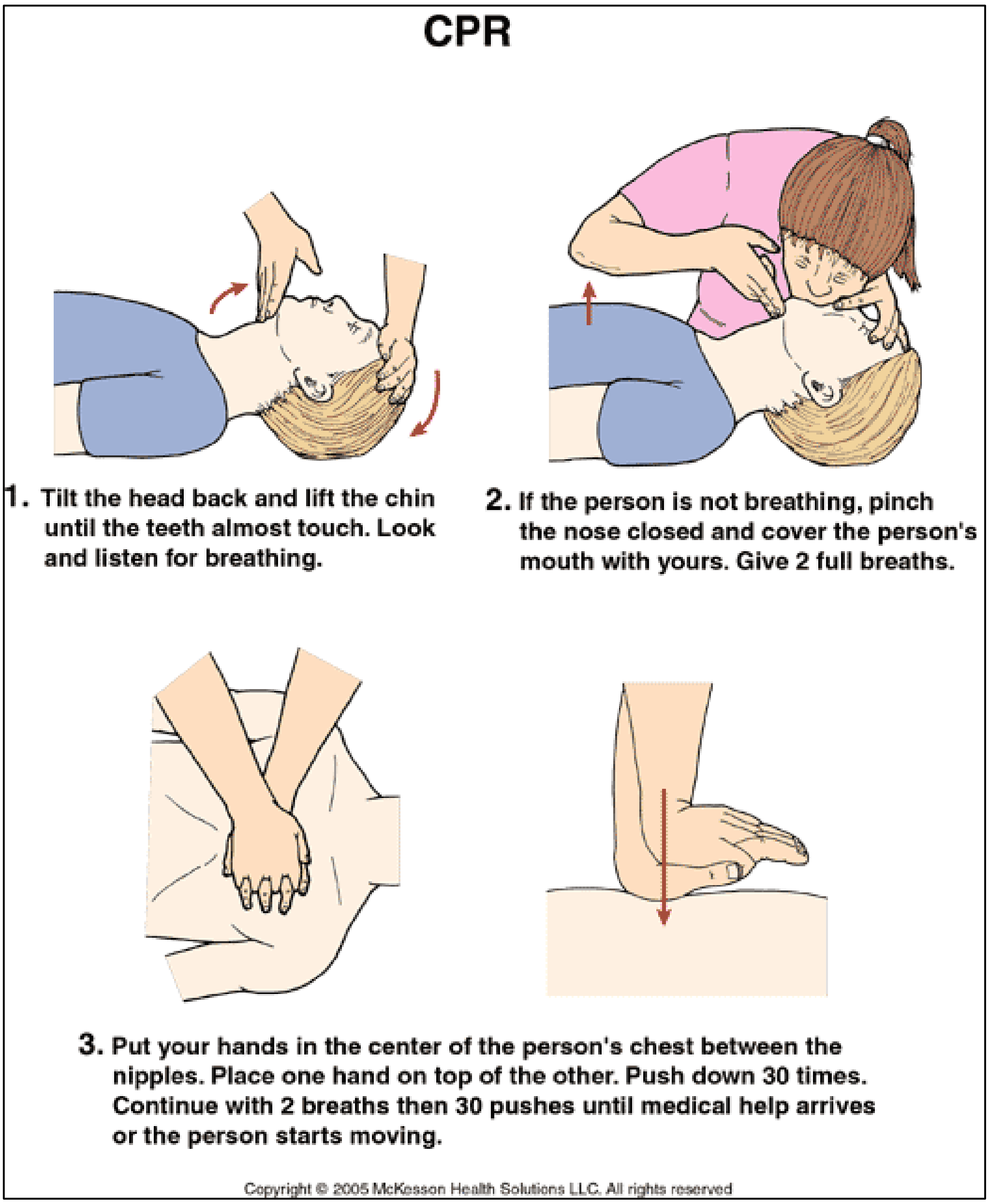
- It is the magnitude of current and the time duration that produces effect. That means a low value current for a long duration can also be fatal. The safe current/time limit for a victim to survive at 500mA is 0.2 seconds and at 50 mA is 2 seconds.
- The voltage of the electric supply is only important as it ascertains the magnitude of the current. As Voltage = Current x Resistance, the bodily resistance is an important factor. Sweaty or wet persons have a lower body resistance and so they can be fatally electrocuted at lower voltages.
- Let-go current is the highest current at which subject can release a conductor. Above this limit, involuntary clasping of the conductor is present. It is 22 mA in AC and 88 mA in DC.

- Apart from electric shock the other equally dangerous hazards of playing (or working) with electricity are electrical arc flash and electrical arc blast.
- Placing your hand in your pocket may protect you by preventing a current from traveling through the heart making a shock non-lethal.
- The severity of the electric shock depends on the following factors: body resistance, circuit voltage, amplitude of current, path of the current, area of contact, and duration of contact.
- Death may also occur from falling in case of electric shock.
- Burn injury may occur at both the entrance and exit of the current.
- Low frequency AC is more dangerous than high frequency AC.
- AC and DC both kill so treat them with respect.

1.1.2 Symptoms of Electric Shock

The symptoms described below must be treated immediately with artificial respiration or Cardiopulmonary Resuscitation (CPR) until the victim recovers. These are symptoms of electric shock and should not be considered fatal. It is not unusual for a person suffering from these symptoms to recover even after several hours of artificial respiration or cardiopulmonary resuscitation (CPR).

See the illustration for cardiopulmonary resuscitation (CPR) techniques.



The symptoms are listed in order from mild to most serious case.

(1) Breathing stops

Normal breathing can usually be restored after continuing artificial respiration for a short while.

(2) Breathing stop, face is pallid and pulse is very weak or undetectable.
(3) Totally unconscious

In the worst of cases, the body of the victim may become rigid within two or three minutes after the shock.

1.2 Prevention of Electric Shock

The person, who performs operation, maintenance, repair, etc. or the person in the position of supervising these persons must observe the following safety guidelines to prevent an electric shock.

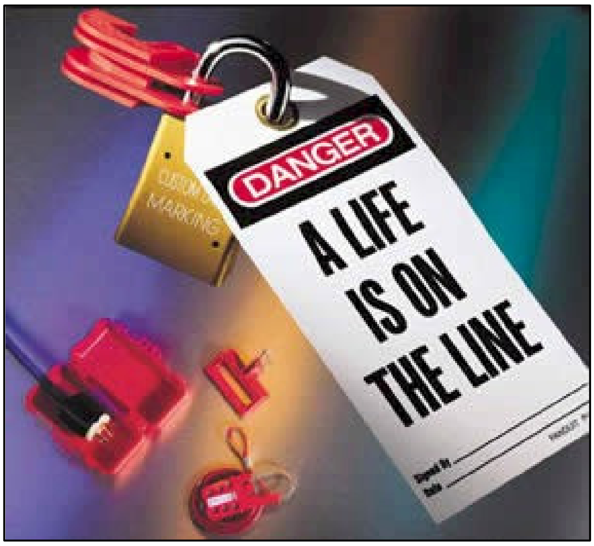
1.2.1 Safety Guidelines

These guidelines are to protect you from potentially deadly electrical shock hazards as well as the equipment from accidental damage.
Note that the danger to you is not only in your body providing a conducting path but particularly your heart.
Any involuntary muscle contractions caused by an electric shock, while perhaps harmless in them, may cause collateral damage. There are many sharp edges inside this type of equipment as well as other electrically live parts you may contact accidentally. The purpose of this set of guidelines is not to frighten you but rather to make you aware of the appropriate precautions.

a) Switch off the electric power supply. Discharge the remaining electric power by earthing the wire and then confirm that there is no voltage.
b) Don't work alone - in the event of an emergency, another person's presence may be essential.
c) Always keep one hand in your pocket whenever you are around a powered line-connected or high voltage system.
d) Wear rubber bottom shoes or sneakers.
e) Wear eye protection - large plastic lens eyeglasses or safety goggles.
f) Don't wear any jewelry or other articles that could accidentally contact circuitry and conduct current, or get caught in moving parts.
g) Set up your work area away from possible grounds that you may accidentally contact.
h) Know the equipment you are going to work on, instrument and tools, that are to be used.
i) When handling static sensitive components, an anti-static wrist strap is recommended.

It is recommended that **static dissipative materials** are used as the medium for discharging static charge to ground.
Materials which are conductive (e.g. stainless steel surfaces) are not recommended for use as a static-safe work surface; the low electrical resistance could result in a transient-like (surge) discharge of static electricity.
A rapid discharge is far more damaging to the electronic device than a gradually paced discharge through a static dissipative
j) Don't attempt repair work when you are tired. Not only will you be more careless, but also your primary diagnostic tool - deductive reasoning – will not be operating at full capacity.
k) Finally, never assume anything without checking it out for yourself. Don't take shortcuts!
l) Tag the power supply switch when doing electrical work.

(Ex. “Do Not Turn on Power: Maintenance Work”)

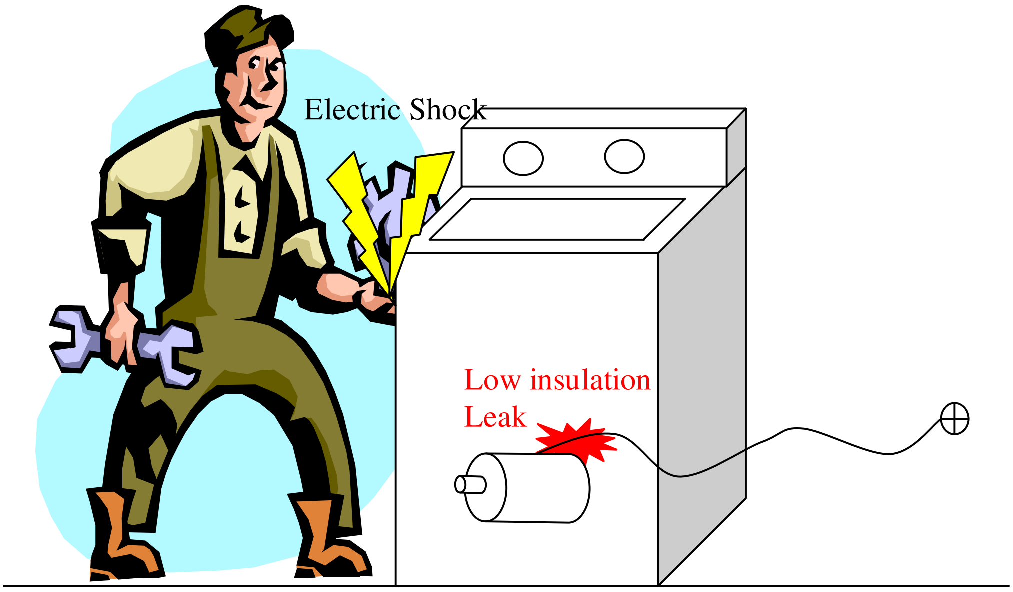


If someone turns on the power while maintenance work is being done, an accident could occur.

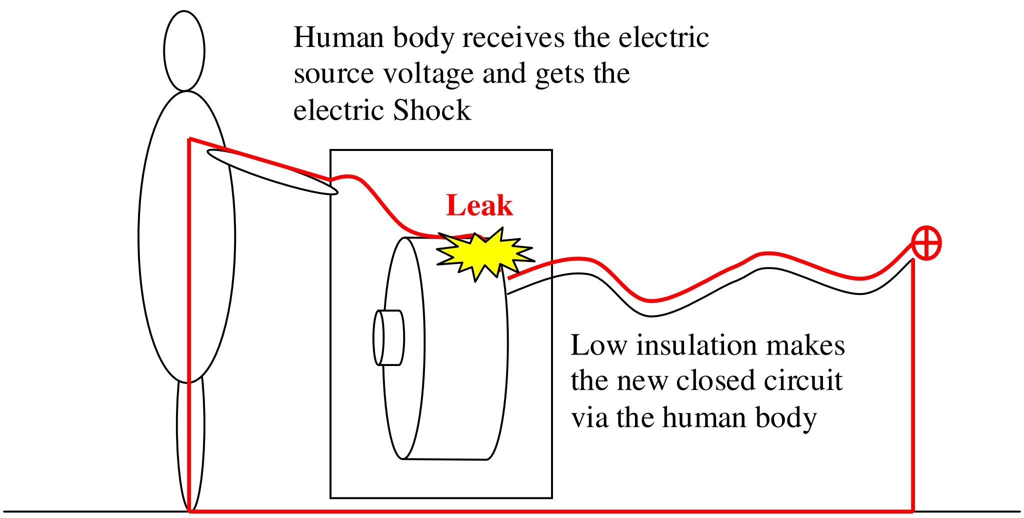
1.2.2 Importance of Earth line

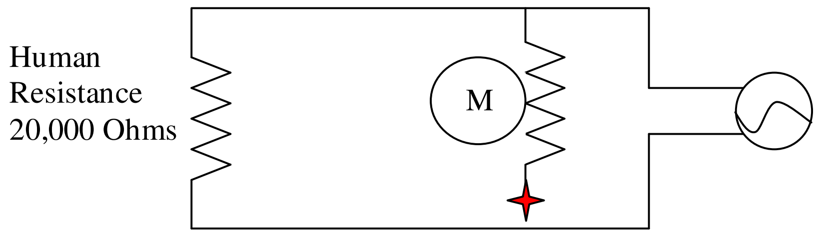
The earth line protects the human injuries for example the electric shock. Especially risk machines located in the lavatory, kitchen, laundry, etc. outfits the earth line.

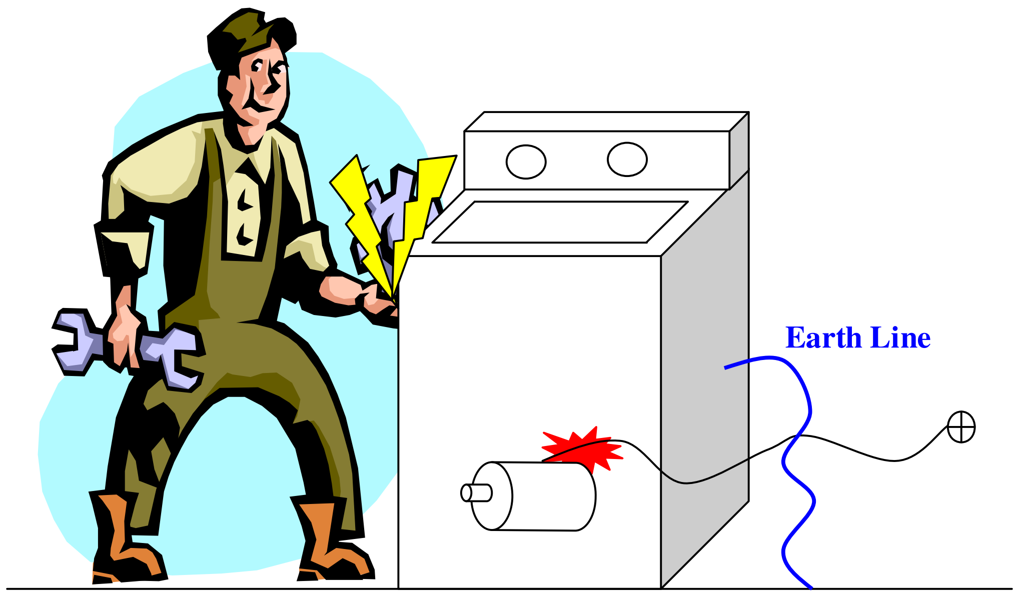
Why does the earth line make it possible to protect the human injury?

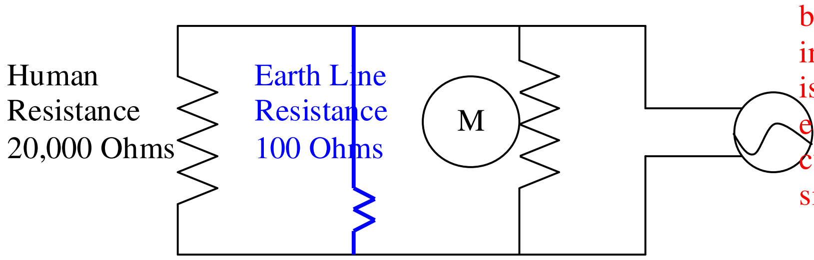


The human body, consisting of about 60% water, is effectively a liquid conductor.









Human body and earth line can be considered to be connected in parallel. Since, Human side is having higher resistance than earth line, therefore human side current is smaller than the earth side

1.3 Electrical Equipment in Gas Dangerous Space

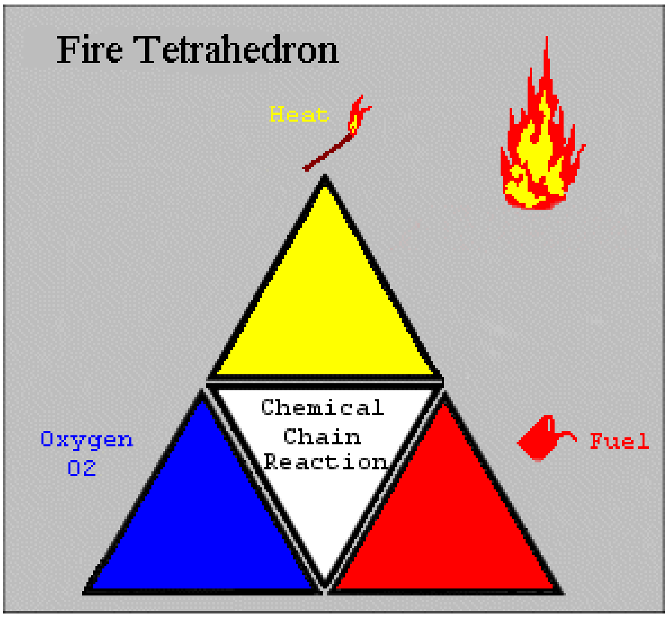
The various areas for use of electrical equipments in shore and ship installations can be classified as given below:
Zone 0: An area with a flammable mixture **continuously** present
Zone 1: An area where flammable mixtures are **likely** during normal operation
Zone 2: An area where flammable mixtures are **unlikely** during normal operations

Elements of Combustion

Combustion requires a combination of flammable materials, oxygen, and heat (a source of ignition).

Therefore, fire is prevented by ensuring that at least one of the three elements is excluded, if possible, it is safer to exclude two.

And combustion of flammable gas requires one more elements. It is "chain reaction".



Electrical installations on gas carriers are subject to the requirements of the classification society and the Gas Codes. Zones and spaces on ships are classified as either gas-safe or gas-dangerous, depending on the risk of cargo vapor being present. For example, accommodation and machinery spaces are gas-safe, while cargo tank deck, cargo tank domes, cargo machinery spaces, gas burning equipment spaces and hold spaces are gas-dangerous. In gas-dangerous spaces, only electrical equipment of an approved standard may be used; this applies to both fixed and portable electrical equipment. There are several types of electrical equipment certified as being safe for use on gas carriers and these are described in the following sections.

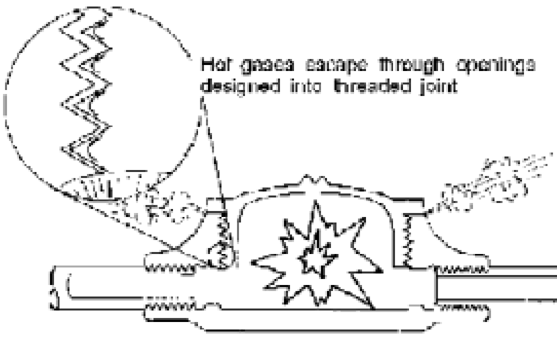
1) Intrinsically safe equipment

Intrinsically safe equipment can be defined as an electrical circuit in which a spark or thermal effect is of such low level (under normal operation or specified fault conditions) that it is incapable of causing the ignition of a given explosive mixture.
*Defective circuits may be bypassed temporarily in case of an emergency but this action should only be taken with the full agreement of the responsible officer, and the decision should be recorded. The defect should be rectified and the circuit repaired as soon as possible, and the bypass removed.
Because of very low energy levels to which they are restricted, intrinsically safe systems cannot be used in high power circuits.
Certified safe equipment should be carefully maintained, preferably by qualified personnel; advice from the manufacturer should be sough in case of doubt.

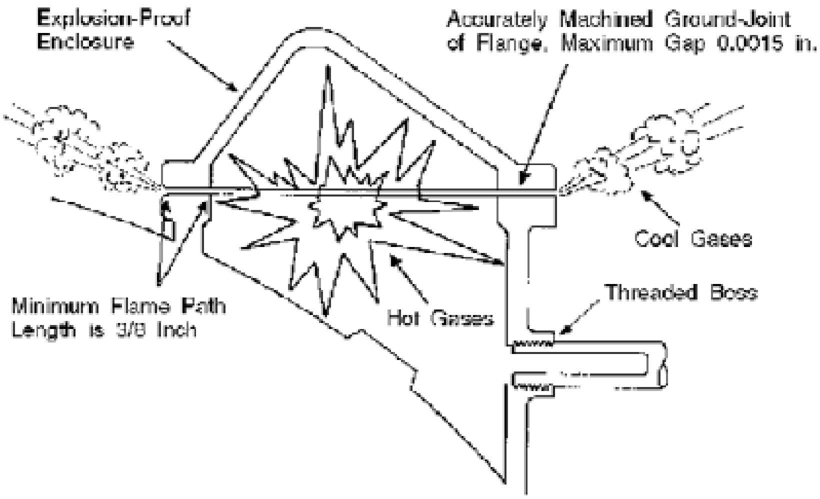
2) Flameproof equipment

A flameproof enclosure is one which can withstand the pressure developed during an internal ignition of a flammable mixture. Furthermore, the design is such that any flames, occurring within the enclosure, are cooled to below ignition temperatures before reaching the surrounding atmosphere.
Therefore, the gas through which hot gases are allowed to escape is critical and great care must be taken in assembly and maintenance of flameproof equipment to ensure that these gaps are well maintained. No bolts must be omitted or tightened incorrectly, while the gap must not be reduced by painting, corrosion or other obstructions.

Flame Paths



OPENINGS DESIGNED INTO THREADED JOINT



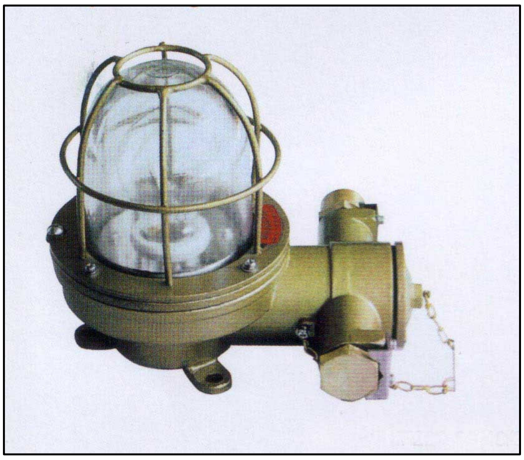
OPENINGS DESIGNED INTO GROUND JOINT

The equipment is designed with air gaps (flame paths), between covers or removable parts and the enclosure, closely controlled and so narrow that, if ignition occurred in the equipment, the resulting hot gases or flame would emerge at such velocities that surrounding flammable gas would not be ignited by the explosion. The concept is applicable to motors, junction boxes, circuit breakers and a wide range of other equipment. A certificate for the integrity of the equipment is issued after laboratory testing.

Care is essential in the maintenance and re-assembly of equipment to ensure that the design features are not destroyed. In particular, the flame path should be kept and should never be filled with joining compound.

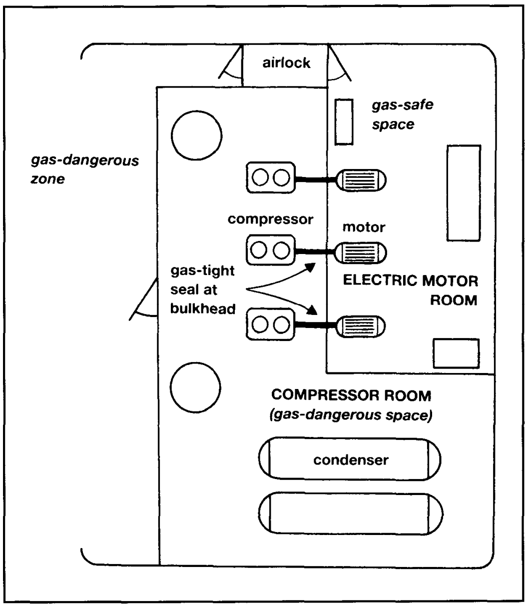
In addition, suitable glands should be provided, for example, motor shaft pass through the gastight bulkhead or deck.

Some flameproof equipment has interlock system.
An interlock is a device used to help prevent a machine from harming its operator or damaging itself by stopping the machine when tripped.



3) Pressurized or purged equipment

The pressurization or purging of equipment is a technique used to ensure that an enclosure remains gas-free. In the case of pressurization, an over-pressure of about 50kpa, relative to the surrounding atmosphere, must be maintained. In the case of a purged enclosure, a continuous supply of purging gas must be provided to the enclosure. Air or inert gas can be used.



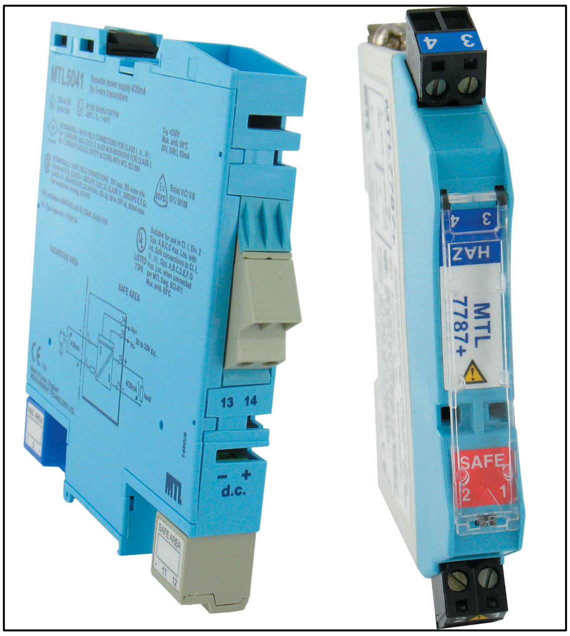
4) Increased safety equipment

The use of increased Safety Equipment is Appropriate for electrically powered light fittings and motors. This equipment has a greater than normal separation between electrical conductors and between electric terminals. Starters are designed to minimize both arcing at contactors and to limit the temperature of components. Increased safety motors, with flameproof enclosures, are frequently used on deck on gas carriers. Here they may be found driving deep well pumps or booster pumps. In such cases they must be protected by a suitable weatherproof covering.

*The batteries for all equipment must be changed in a gas-safe area.

5) Zener Barrier

Intrinsically safe equipment can be achieved by placing a barrier, in the electrical supply. These Intrinsic safety barriers or ZENER safety barrier are intrinsic safety device which has been developed through many years of research and experience. This barrier must be positioned in a safe area. The rise in voltage is limited by the use of Zener diode so that the current flow to the hazardous area is restricted by the resistors. In combination other intrinsic safety devices such as pilot lights, contacts, Resistance Temperature Detector, and thermocouples, Zener Barrier constitutes a simple explosion proof system: one for installation at non-hazardous locations and another for hazardous locations.



Testing zener barrier at regular intervals in accordance with maker instructions. If the zener barrier is found in abnormal condition, it should be changed to new one. Do not open Zener barrier in gas dangerous area.

Restrictions of Use of Electric Appliances

Non-explosion proof electric appliances must not be used in a dangerous area where there is a likelihood of flammable gas being present. The electric appliances means the electric equipment including electric appliances with power cables, flash lights, televisions, radios, tape recorders, cameras with flashlights, portable telephones, transceivers and others.

Restrictions in Use of Radio Equipment and Radar

(1) During Cargo Work

The operation of radio equipment and radar during cargo work must be in accordance with the following.

a) The transmission of radio waves from radio equipment (excluding VHF of 1 W or less output which are properly grounded) and the starting up of radar must be prohibited.
b) The main transmission antenna must be either taken down or appropriately grounded.
c) When it is necessary to transmit radio waves from radio equipment or start operating radar for repair purposes, confirm the matter with the pier representative and carry out the repair work after the completion of cargo handling operations.

(2) During Gas-free Operations

When the radio equipment and/or radar is to be operated during gas-free, the safety check must duly be made taking into consideration of the following items. In addition, the transmission of radio waves from radio equipment must be prohibited without any permission of the Master.

a) The existence or not of an outflow of explosive gas, and, if so, the quantity.
b) The relationship between wind direction and force and the ship's course and speed (a wind from abeam is desirable).

c) The extent of gas lying on deck.
d) The relationship between the time and duration of transmission of radio waves and the gas-free operations plan.

(3) Communications via INMARSAT

Communications equipment using communications satellite may be used but as some terminals restrict their use, obtain the permission of responsible person of the terminal

(4) Restrictions of Use of Transceivers
The transceivers other than the explosion-proof type UHF/VHF with battery must not be used.

Inspection & Maintenance of Explosive Rated Electrical & Intrinsically Safe Equipment On Board Tankers / Gas Carriers

Electrical installations on gas carriers are subject to the requirements of classification society and gas codes. Zones and spaces on ships are classified as either gas–safe or gas –dangerous, depending on the risk of cargo vapor being present. For example, accommodation and engine room machinery spaces are gas safe, while gas tanker compressor room, cargo tank areas and holds are gas-dangerous.

In gas dangerous spaces only electrical equipment of an approved standard may be used; this applies to both fixed and portable electrical equipment. There are several types of electrical equipments, certified as being safe for use on a gas carrier
Example: Intrinsically safe type; Explosion proof type.

Company's Safety Management Manuals state the procedures to be followed for the purpose of inspection & maintenance of explosive rated electrical and intrinsically safe equipment. The responsible officers on board must exercise due diligence to avoid the possibility of receiving potentially high risk observations during OCIMF SIRE Inspection. The following are considered as potential high risk observations:

- Use of non-intrinsically safe electrical equipment in gas hazardous areas (e.g. radios, digital cameras, torches, mobile phones, pagers, etc.).

- The general appearance & condition of flameproof electrical equipment electrical equipment in gas hazardous areas including the cargo compressor room & electric motor room are in poor condition or not of approved type.

Inspection & Checks

(a) All apparatus, systems and installations, including cables, conduits and similar equipment, should be maintained in good condition.
(b) To this end, they should be inspected regularly by qualified personnel (Electrical Officer or responsible Engineer) to ensure that no damage, change, or deterioration has occurred that may degrade intrinsic safety.
(c) Correct functional operation does not necessarily imply compliance with the required standards of safety.
(d) Some of the equipments and apparatus that fall into the category of Explosive Rated are mentioned below for reference. The below list is not exhaustive and should there be any doubt, further advise shall be sought from the company and/or manufacturer;

- i) Explosion proof lights located into pump room, deck stores, compressor room etc.
- ii) High-high and independent overfill alarm system.
- iii) Fixed gauging system for cargo and/or ballast tanks.
- iv) Bilge level alarm in cargo compressor room, motor room or forepeak store.
- v) Fixed gas detection system;
- vi) Intrinsically safe light for life buoys.
- vii) Explosion-proof flash lights.
- viii) Hand held UHF radios.

Following any repair, adjustment or modification, those parts of the installation that have been disturbed should be checked to be maintaining same standard as original.

Periodic Mechanical Inspections & Insulation Testing

During inspections of electrical equipment or installations, particular attention should be paid to the following:

(a) Cracks in metal, cracked or broken glasses, or failure of cement around cemented glasses in flame-proof or explosion-proof enclosures;
(b) Covers of flame-proof enclosures, to ensure that they are tight, that no bolts are missing, and that no gaskets are present between mating metal surfaces;
(c) Each connection to ensure that it is properly connected;

(d) Possible slackness of joints in conduit runs and fittings;
(e) Clamping of cable armoring;
(f) Stresses on cables that might cause fracture;
(g) Each cable and wire outer insulation or insulating jacket is intact with no exposed conductors, burns, cracks, or splits.
(h) Insulation testing should only be carried out when no flammable gas mixture is present.

Following guidance is advised:

- The integrity of the protection afforded by the design of explosion-proof or intrinsically safe electrical equipment may be compromised by incorrect maintenance procedures.
- Even the simplest of repair, modification and maintenance operations shall be carried out in strict compliance with the manufacturer's instructions in order to ensure that such equipment remains in a safe condition. This is particularly relevant in the case of explosion-proof lights where incorrect closing after changing a light bulb could compromise the integrity of the light.
- As recommended in Maker's manual, it shall be sent to an authorized manufacturer's representative for carrying out maintenance and repairs.
- All maintenance work on such equipment should be undertaken under the control of a permit, with procedures that ensure that electrical and mechanical isolations are effectively managed. The use of lock-out and tag out devices shall be implemented (reference SMS chapter 9).
- Maintenance of any portable equipment shall only be done in a gas safe area.

Alterations to Equipment, Systems and Installations of Explosive Rated Electrical & Intrinsically Safe Equipment

(a) No modification, addition or removal should be made to any approved equipment, system or installation at a terminal without the permission of the appropriate authority, unless it can be verified that such a change does not invalidate the approval.
(b) No modification should be made to the safety features of equipment that relies on the techniques of segregation, pressurizing, purging or other methods of ensuring safety.
(c) When equipment in a gas dangerous area is permanently withdrawn from service, the associated wiring should be removed from the hazardous zone or should be correctly terminated in an enclosure appropriate to the area classification.

(d) When equipment in a gas dangerous area is temporarily removed from service, the exposed conductors should be correctly terminated as above, or adequately insulated, or solidly bonded together and earthed.
(e) The cable cores of intrinsically safe circuits should either be insulated from each other or bonded together and insulated from earth.

Cold Work

When carrying out any job in a hazardous area which does not involve generation of high temperature conditions which in turn may cause ignition of combustible gases, vapors, or liquids within the area or an adjacent area for e.g. Connecting Disconnecting pipes etc, the activity is known as Cold Work.

By definition, Cold Work is applicable to Tankers and Gas Carriers for work on deck or other hazardous areas only.

(a) Cold Work should not be carried out on any apparatus or wiring, nor should any flame-proof or explosion-proof enclosure be opened, nor the special safety characteristics provided in connection with standard apparatus be impaired, until all electrical power has been cut off from the apparatus or wiring concerned.
(a) The electrical power should not be restored until work has been completed and the above safety measures have been fully reinstated. Any such work, including changing of lamps, should only be done after approval of Chief Engineer by Electrical Officer/Engineer.

Intrinsically Safe Equipment is usually light, compact and robust, everything we need for a portable device. So, why would anyone want to use Explosion Proof (XP) as a protection concept?

The answer is simple: power. With an I.S. system the entire power of the system - which includes but is not limited to the batteries – is controlled. This means that inductive and capacitive loads are also assessed to the extent that they cannot cause a spark. These limitations can cause problems when a device needs to operate in a power range higher than allowed. High Voltage Switchgear for example could never be considered I.S. as the power in the conductors is far higher than that accepted by the I.S. standard. Similarly, high energy components such as a camera flash cannot be part of an I.S. device as the flash itself is powered by a capacitor which has a discharge greater than accepted. By using XP as a protection concept, “high” power devices can be used safely in an explosive area. The XP device itself is designed and tested to contain any explosion which may occur within, protecting the operator and the facility from harm.

In short, intrinsically safe and explosion proof equipment are different types of electrical equipment and should not be confused with each other.

The terms “Intrinsically Safe” and “Explosion Proof” should not be used interchangeably and commonly for all equipment as both are as different as chalk and cheese!

Chapter 2

Electric Finished Drawing

The Electric Finished Drawing is composed of the Wiring diagrams, the Arrangements, the Test results, the Maker Drawings and the Spare parts.
The engineer can understand the flow of electric power supply to the equipments such as lighting equipments, switches, motors, junction boxes, etc., the location and type of equipments and the type of cables, being used, by reading the wiring diagrams and arrangements drawings.

2.1 Wiring Diagrams

The wiring diagrams provide information regarding the voltage, location and so on for systems such as Power system, Lighting system, Interior communication system, Electric Navigation equipment, Control system, etc.
We can get the outline information regarding the current and outline of equipments by using the wiring diagrams.
The important wiring diagrams are explained in the following sections:

2.1.1 Electric Power System Wiring Diagram

Wiring Diagram of Power System shows the electric power flow form the Generator to the electric power machinery with the help of One-Line diagrams.

Generator — Main Switchboard — Group Starter Panel — Equipment

The first part of this diagram shows the Symbol list. Most of the symbols consist of many letters; therefore it is very difficult to read them on the diagram. Normally simplified symbol is used.

An Engineer can understand the following items from the wiring diagram.

1) Kind or type of cable
2) Circuit Mark Number or Cable Number

3) Type of Circuit breaker
4) Type of Transformer
5) Junction Box Number

But wiring diagram is written by the One-Line cable, therefore an Engineer finds it difficult to understand the details of actual wire connection. In order to understand the details, it is necessary to use the maker instruction manual and so on.

The Figure 2.1(A) shows a one line diagram of the electric power flow from No.1 Diesel Generator to Main Switch Board bus bar via ACB.

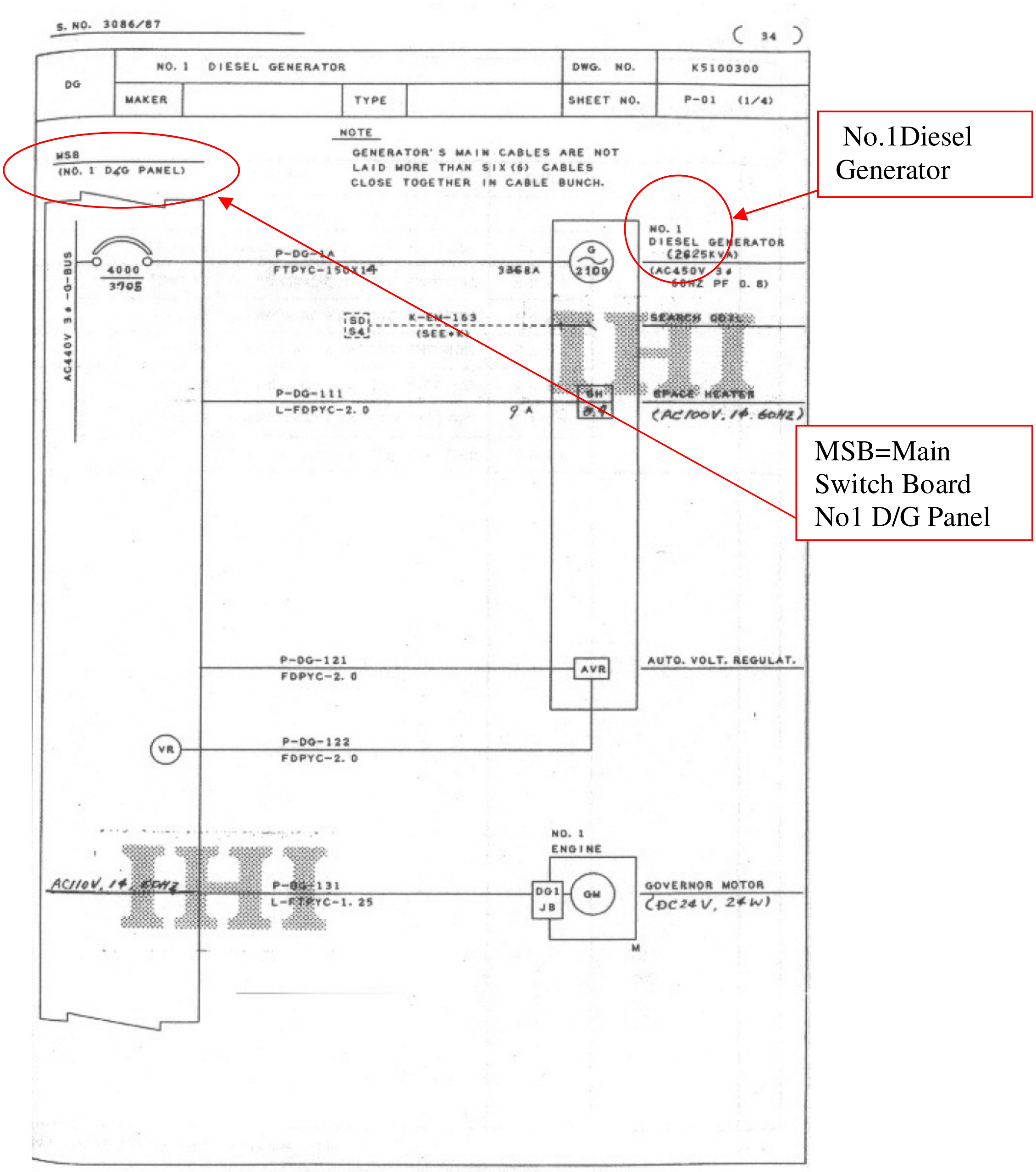


Fig. 2.1 (A) Typical Electric Power System Wiring Diagram

The Figure 2.1 (B) shows one line diagram for power flow from 440 volt Main Switch board to 440 volt GSP (Group Starter Panel).

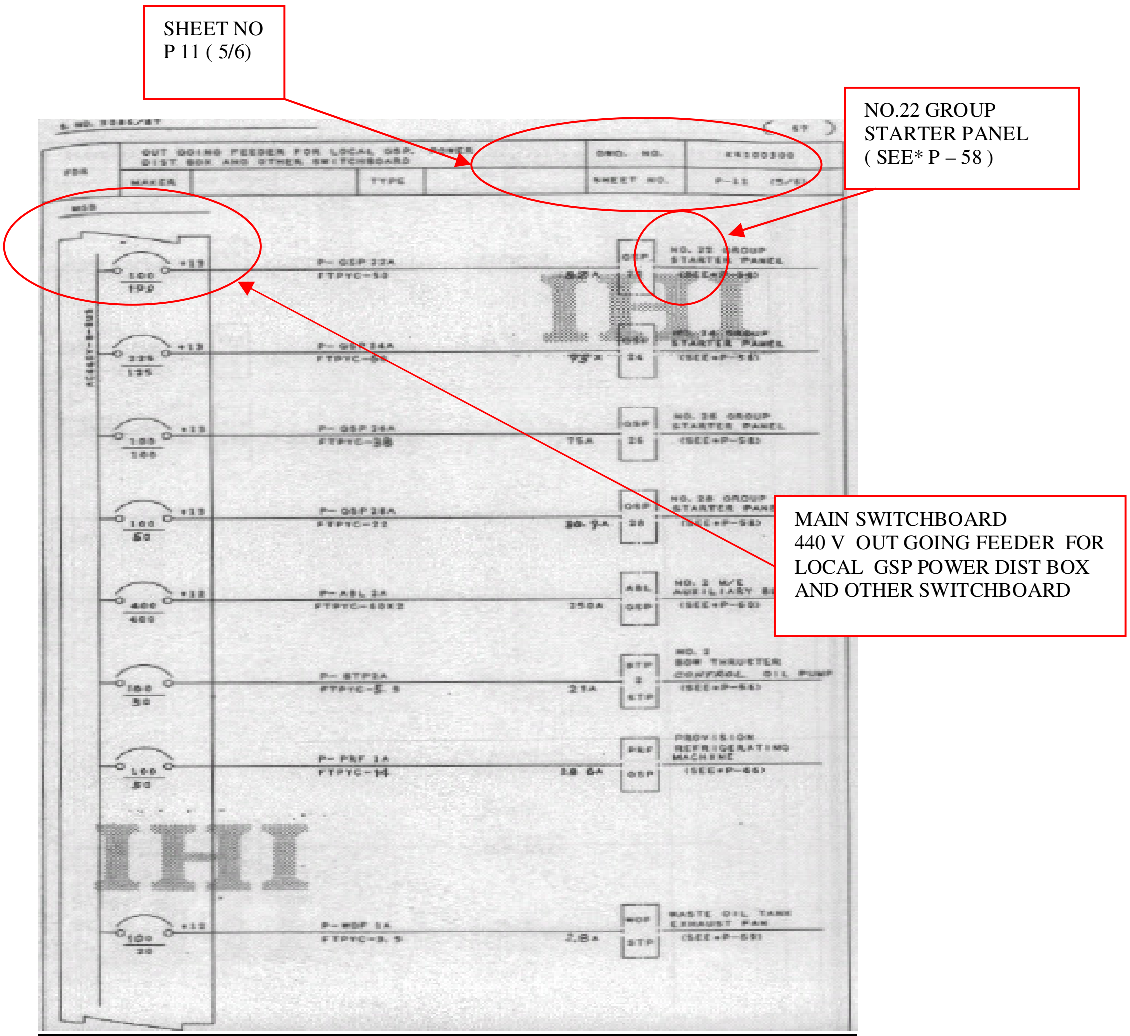


Fig. 2.1 (B) Typical Electric Power System Wiring Diagram

The Figure 2.1 (C) shows one line diagram for power flow from GSP to 440 volts Junction Box and Feeder Panel and from Junction Box electric power reaches the final equipment i.e. NO3 CARGO HOLD EXHAUST FAN(1) in this case.

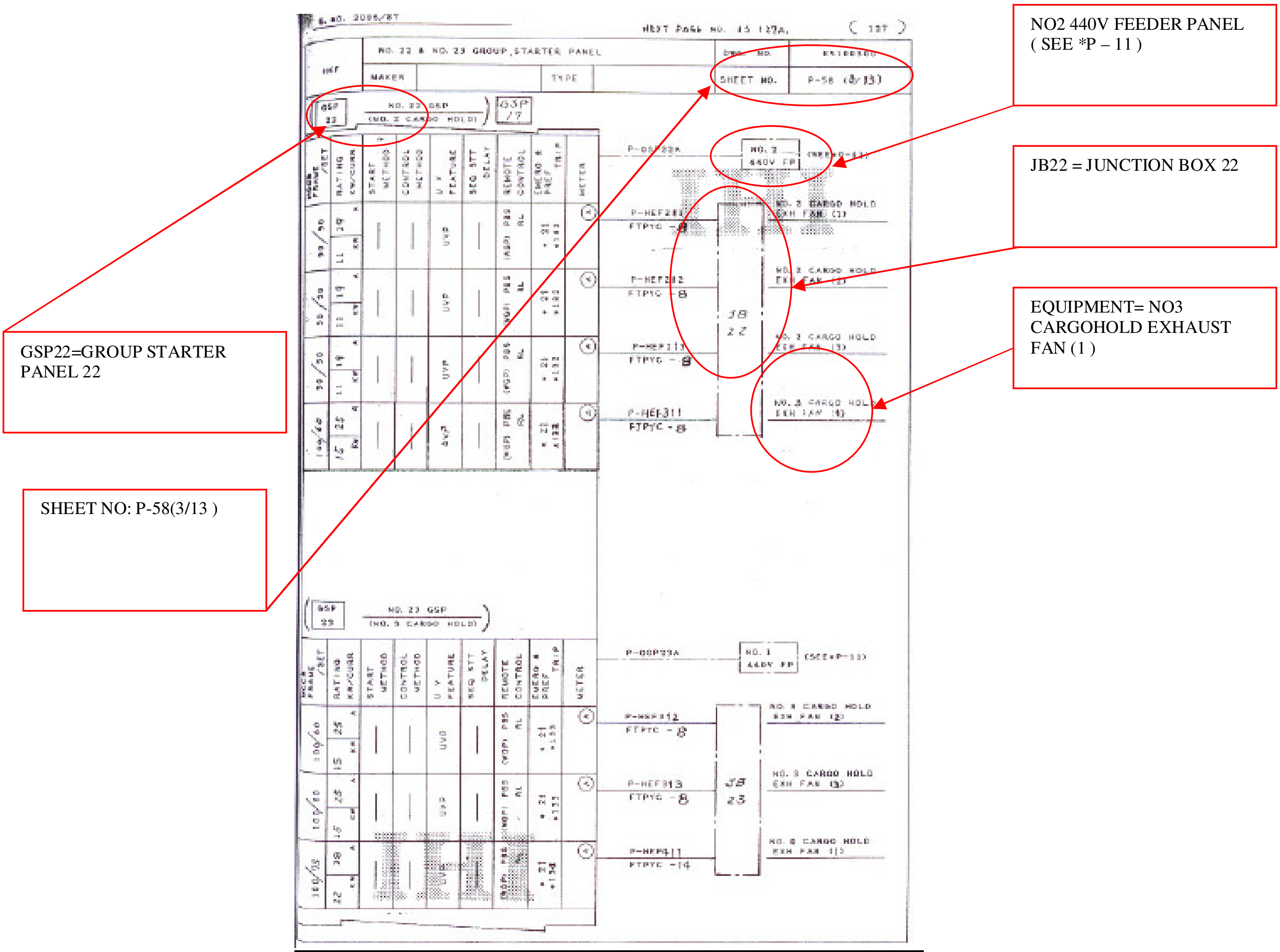


Fig. 2.1 (C) Typical Electric Power System Wiring Diagram

To enable us to locate the equipments in the electrical drawings, we need to follow the reference drawings – the mark, the drawing title and the drawing number.

As illustrated below in Figure1.2, letter “P” is designated to electric power system wiring diagram, where as letter “L” refers to lighting system wiring diagram.

S. NO 3086/87 (1 2)

1. GENERAL DESCRIPTION

1.1. REFERENCE DRAWINGS

Mark		Title	Dwg. No.
* P	:	Electric Power System / Wiring Diagram	K5100300
* L	:	Electric Lighting System / Wiring Diagram	K5300300
* C	:	Interior Communication & Navigation System / Wiring Diagram	K5410300
* F	:	Fire Detector System / Wiring Diagram	K5410350
* K	:	Engine Measuring & Control System / Wiring Diagram	K5451300
* D	:	Deck Measuring & Control System / Wiring Diagram	K5452300
* R	:	Electronic System / Wiring Diagram	K5800300

1.2. ABBREVIATION OF ELECTRICAL EQUIPMENT

MSB	:	Main Switchboard
GSP	:	Group Starter Panel
CHB	:	Battery Charging & Discharging Board
ASB	:	Auxiliary Switchboard
ESB	:	Emergency Switchboard
SSB	:	Sub-Switchboard
CCC	:	Engine Control Console
VCC	:	Valve Control Console
EM	:	Engine Monitor OR Data Logger Cabinet
BGD	:	Boiler Gauge Board
WCS	:	Wheelhouse Console
WIS	:	Wheelhouse Indicator Stand
WGP	:	Wheelhouse Group Panel
WMP	:	Wheelhouse Meter Panel
COC	:	Cargo Oil Control Console
RSB	:	Radio Switchboard

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Fig. 2.2 General Description/Abbreviation of electrical Equipment

The Figure 2.3 shows a typical cable designation, which helps to identify the electrical cable type, insulation grade, number of cores etc.

(13)

1.3. CABLE DESIGNATION
(ALL AREA EXCEPT CABIN UNIT
In cabin unit, cables without "F" & "C" shall be used.)

	DESIGNATION	VOLTAGE GRADE	CONSTRUCTION				
			Core No. of Conductor	Insulation	sheath	Mechanical Protection	Conductor Size
Japanese Industrial Standard (J.I.S.) Cable of flame retardant type complied with 1981 Amendments to SOLAS 1974. (Flammability test by 18.13.5 in IEEE std.45 by 6.7 in JIS C3410)	F [n] PYC - [a]	660v	[n]	"P"	"Y"	"C" Steel wire Braided	[a] Nominal sectional area
	L-F [n] PYC - [a]	250v	S:Single	Ethylene	P.V.C.		
	F [n] PYCY- [a]	660v	D:Double	propylene	(Poly-	"CY" Ditto with P.V.C.protective covered	
	L-F [n] PYCY- [a]	250v	T:Three	rubber	vinyl-		in mm2 ,
	FMPYC - [n]	660v	[n]		chrolli	"C" Steel wire Braided	1.25 mm2/
	L-FMPYC - [n]	250v	Multi core		de)		
	FMPYCY - [n]	660v	5,7,9,12,16			"CY" Ditto with P.V.C.protective covered	
	L-FMPYCY - [n]	250v	,23,27,or33				
	FMPYCS - [n]		Same as above but with common shield.				
	L-FMPYCS - [n]						
	FMPYCYS - [n]						
	L-FMPYCYS - [n]						
	FMPYC - [n] S		Same as above but with individual shield.				
	L-FMPYC - [n] S						
	FMPYCY- [n] S						
	L-FMPYCY- [n] S						
	F [n] SRLC- [a]	660v	[n] S:Single D:Double T:Three	"SR" Silicon Rubber	"L" Lead	"C" Steel wire Braided	[a] Nominal sectional area in mm2
	FTTYC - [m] S	250v	Polyvinyl chloride(P.V.C.) insulated, P.V.C. sheathed, and steel wire braided telephone cable with individual pair shield. [m]:Number of pair(s) of conductors				
	FTTYCY- [m] S		Same as above but with outer P.V.C. protective covered.				
	FTTYCS - [m]	250v	Polyvinyl chloride(P.V.C.) insulated, P.V.C. sheathed, and steel wire braided telephone cable with common shield. [m]:Number of pair(s) of conductors				
	FTTYCYS- [m]		Same as above but with outer P.V.C. protective covered.				

Fig. 2.3 Table showing Cable Designation (Symbol Mark Table of Power Wiring Diagram)

1) Kind or type of cable

Cables are of many types, depending upon the insulation grades, number of cores, insulation materials, sheathes, sectional areas, etc.
Followings are some examples of cable symbols.

Cable type 1: FDPYC-2

F= High voltage insulation grade 660V
D= Double cores
P= EP rubber insulation material
YC (Type of sheath) = Polyvinyl chloride Sheathed & Steel Wire Braided

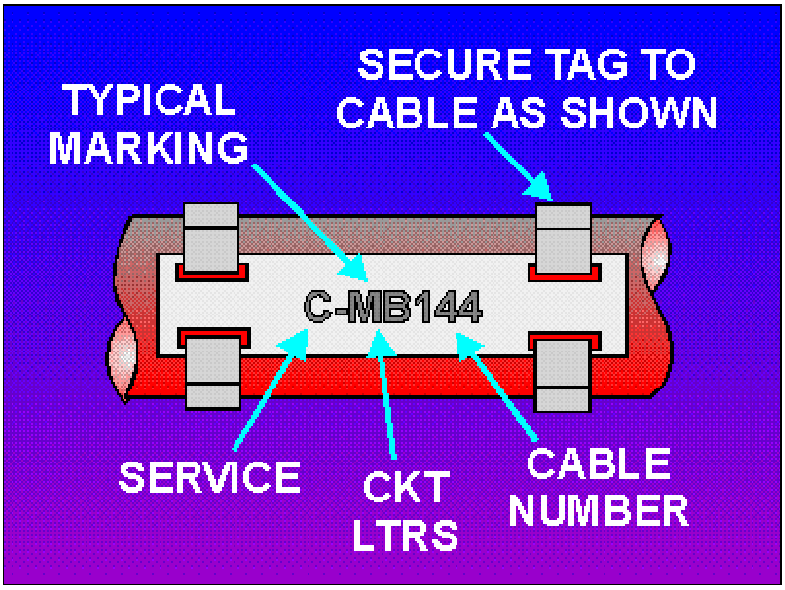
Cable type 2: FMPYC-12

F= High voltage insulation grade 660V
M= Multi cores: 12 Cores
P= EP rubber insulation material
YC (Type of sheath) = Polyvinyl chloride Sheathed & Steel Wire Braided
12= 12 Cores
*Note: Core sectional areas: 1.25mm2
The letters and order of wire symbols also have some meaning.
The 1st letter is voltage grade.
The 2nd letter is number of core.
The 3rd letter is insulation material
The 4th or 4th /5th letters are type of sheath
And last letter is core sectional area or number of cores, if multi core wire.
The following table can be used for understanding the Cable symbols.

Voltage grade	F : 660V Grade L : 250V Grade
Number of core	S: Single core D: Double Core T: Three Core M: Multi core
Insulation material	P: EP Rubber SR: Silicon Rubber
Type of sheath	YC: Polyvinyl chloride Sheathed & Steel Wire Braided LC: Lead Sheathed & Steel Wire YCY: YC with P.V.C. Covering
Other	S: Tinned Annealed Copper Wire Braided for Shielding
Core sectional area	1.25、2、3.5、5.5、8、14、22、30、38、50、60、80、100、125、200mm^2 or number of cores, if multi core wire.

2) Cable Tags

Embossed metal tags are used to identify cables throughout the vessel. The tags are located at the distribution panel and the component. Tags are also attached to the cables where penetration of the bulkhead is necessary.



The Figures 2.4.1 to 2.4.6 list the symbols used to denote the various items of the Electrical Power System Wiring Diagram.

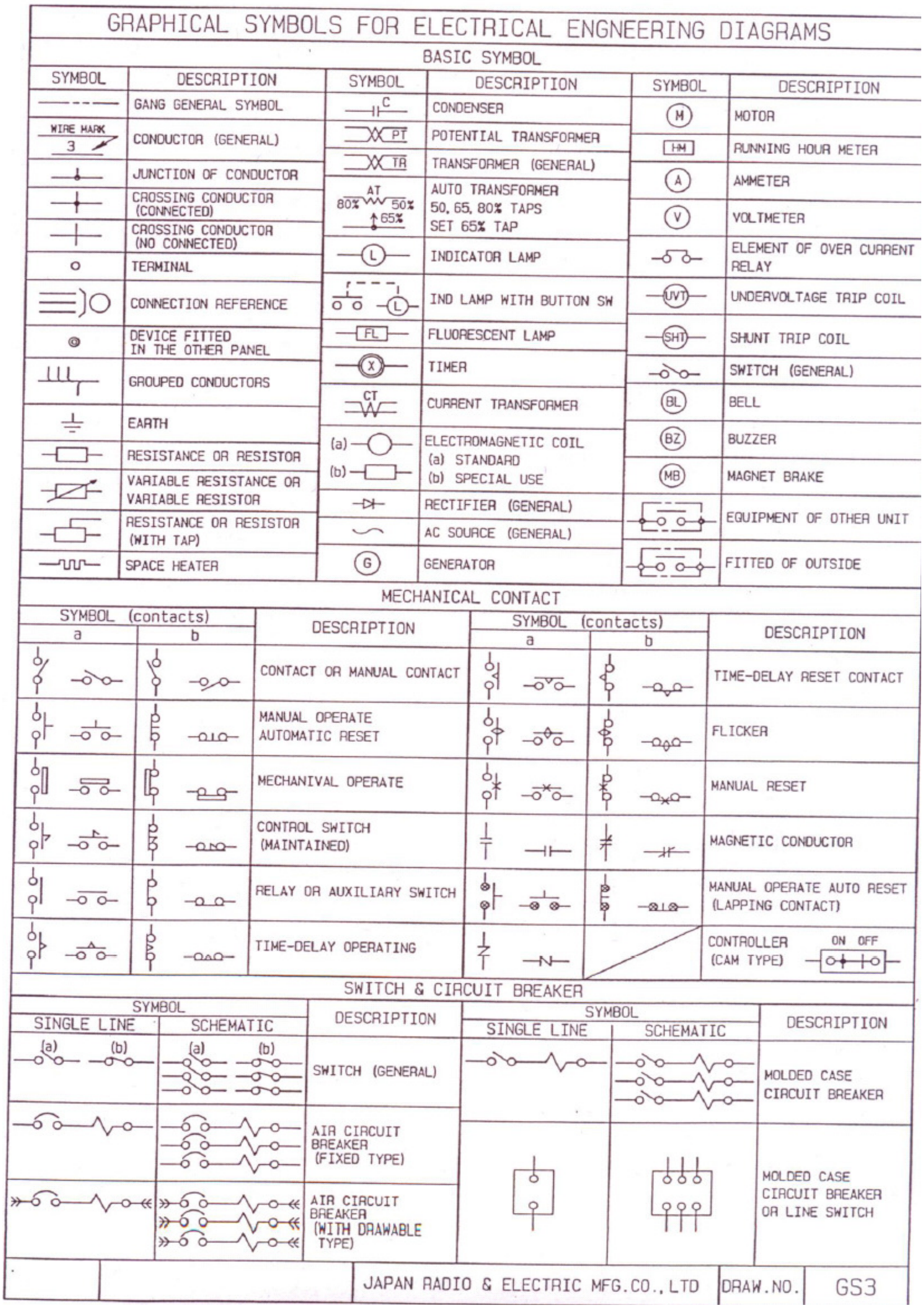


Fig. 2.4.1 General Symbols for Electrical Engineering Diagrams

S. NO. (29)

5. SYMBOL LIST (1/5)

NOTE: THE MARK • MEANS SYSTEM MARK.

SYMBOL	NAME	SYMBOL	NAME
	A.C. GENERATOR		MOTOR
EX	ROTARY EXCITER	CSP	GROUP STARTER PANEL
GM	GOVERNOR MOTOR	STP	STARTER PANEL
DC/AC / AC/DC	STATIC INVERTER/CONVERTER	STCP	STARTING PANEL WITH STARTING COMPENSATOR
	ROTARY INVERTER/CONVERTER	• ASP	AUTO-START PANEL
AVR	AUTO VOLTAGE REGULATOR	• CTR	CONTROLLER
EXP	STATIC EXCITER	• SW	SWITCH BOX
TRD	TRANSFORMER	• COS	CHANGE OVER SWITCH
BAT	BATTERY	• GCS	GOVERNOR CONTROL SWITCH
AC/AC	FREQUECY CONVERTER	• ALP	ALARM PANEL
MSB	MAIN SWITCHBOARD	ES-	EM'CY STOP SWITCH BOX
ASB	AUX. SWITCHBOARD	• STS	SUPPLY TRANSFER SWITCH
ESB	EM'CY SWITCHBOARD	A B	AIR CIRCUIT BREAKER 3P A:FRAME RATING CURR(A) B:SETTING VALUE (A)
SSB	SUB SWITCHBOARD	A B	MOULDED CAST CIRCUIT BREAKER 3P A:FRAME RATING CURR(A) B:SETTING VALUE (A)
CHB	CHARGING & DISCHARGING BOARD	A B	DO 2P DO
TSP	TESTING PANEL	M	EXPLOSION TYPE MOTOR
SC	SHORE LINE CONNECTION BOX		
RSB	RADIO SWITCHBOARD	SHT	SHUNT TRIP COIL
		UVT	UNDER VOLT. TRIP COIL
R	RESISTOR		DISCONNECTING SWITCH 3P
• JB	JUNCTION BOX		DO 2P
JB-•	JUNCTION BOX		FUSE
CRL	CABLE REEL		BUS LINK

Fig. 2.4.2 Table of Electrical Symbol for Power Wiring Diagram

S.NO. (30)

5. SYMBOL LIST (2/5)
-CONTINUED-

SYMBOL	NAME	SYMBOL	NAME
RNG	ELECTRIC RANGE	SH	SPACE HEATER
ERG	ELECTRONIC RANGE		PROPELLER FAN
OVN	ELECTRIC BAKING OVEN		EXPLOSION TYPE PROPELLER FAN
REF	REF CABINET		
CWF	COLD WATER FOUNTAIN		
TST	TOASTER		
COF	COFFEE URN		
WBR	WATER BOILER		
RBR	ELECTRIC RICE BOILER	P	PRESSURE SWITCH
H	HEATER	T	THERMAL SWITCH
HP	HOT PLATE	F	FLOAT SWITCH
DIS	DISPOSER	FL	FLOW SWITCH
PPL	POTATO PEELER	SP	SPEED SWITCH
MSL	MEAT SLICER	LS	LIMIT SWITCH
D SH	DISH WASHER	PX	PROXIMILTY SWITCH
DMX	DOUGH MIXER	E	ELECTRODE
CML	COFFEE MILL		THERMO RESISTANCE BULB
STL	STERILIZER		THERMO COUPLE
ICE	ICE FREEZER	TI	TEMPERATURE INDICATOR
WM	WASHING MACHINE	MV	MAGNETIC VALVE
EXT	EXTRACTOR	SOL	SOLENOID
HSL	HAM SLICER	TG	TACHOMETER-GENERATOR
IRN	IRON		
UC	UNIT COOLER	RY	AUXILIARY RELAY

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Fig. 2.4.3 Table of Electrical Symbol for Power Wiring Diagram

S.NO. (31)

5. SYMBOL LIST (3/5)
-CONTINUED-

SYMBOL	NAME	SYMBOL	NAME
	PUSH BUTTON SWITCH	INSTRUMENTS ON CONSOLE, ETC.	
	DO (WITH STOP LOCK)	RL RL/SL	RUNNING LAMP (GREEN) RUNNING LAMP WITH ALARM (GREEN)
	DO (WITH PILOT LAMP)	SBL	AUTO STAND-BY LAMP (WHITE)
		OL CL	VALVE OPEN LAMP (GREEN) VALVE CLOSE LAMP (ORANGE)
		OV L ABN L	OVER LOAD ALARM LAMP (RED) ABNORMAL TRIP ALARM LAMP (RED)
		ESL PH F	EMERG STOP ALARM LAMP (〃) PHASE FAILURE ALARM LAMP (〃)
		PW F	POWER FAILURE ALARM LAMP (〃)
	JOINT BOX (N.W.T.)	PH PL	PRESS.(HIGH) ALARM LAMP (〃) 〃 (LOW) 〃 〃 (〃)
	JOINT BOX (W.T.)	TH TL	TEMP. (HIGH) ALARM LAMP (〃) 〃 (LOW) 〃 〃 (〃)
	PLUG (N.W.T.)	LH LL	LEVEL (HIGH) ALARM LAMP (〃) 〃 (LOW) 〃 〃 (〃)
	PLUG (W.T.)		
	RECEPTACLE (N.W.T.)	COS CS	AUTO-MANU CHANGE-OVER SWITCH CONTROL SWITCH
	RECEPTACLE (N.W.T.FLUSH)	PBS	PUSH BUTTON SWITCH
	RECEPTACLE (W.T.)		
	SINGLE OUTLET RECEPTACLE WITH SWITCH (W.T.)		
	DOUBLE OUTLET 〃 〃 (〃)	DESCRIPTION FOR REMARKS COLUMN	
		A, A RH	AMMETER RUNNING HOUR METER
		(SEC) (P)	SEQUENTIAL START TIMER SET NO. OF MOTOR POLES
		DISPLAY METHOD OF CABLE AND EQUIPMENT ON THE THIS DRAWING.	
		——·——·——:	DETAIL IS SHOWN ON OTHER PAGE OF THIS DRAWING
		— — — — —:	DETAIL IS SHOWN ON OTHER DRAWING

K5P00-37

Fig. 2.4.4 Table of Electrical Symbol for Power Wiring Diagram

S.NO 3086/87 (32)

4. SYMBOL LIST (4/5)
-CONTINUED-

	ITEM	SYMBOL	DESCRIPTION
1	START METHODE	—	DIRECT ON LINE
		⅄ − Δ	STAR − DELT
		ATR	AUTO TRANSFORMER 50 , 65 % TAPS ****** 80 % TAP ************
2	CONTROL SYSTEM	—	NON AUTO
		ASS	AUTO START AND STOP
		AST	AUTO START
		ASP	AUTO STOP
		ACO-NV	AUTO CHANGEOVER BY NO VOLT
		ACO-NV/PS	AUTO CHANGEOVER BY NO VOLT OR PRESSURE
		ACO-NV/FL	AUTO CHANGEOVER BY NO VOLT OR FLOW
3	UNDER VOLTAGE FEATURE	UVP	UNDER VOLTAGE PROTECTION
		UVR-E	UNDER VOLTAGE RELEASE
		UVR-ET	UNDER VOLTAGE RELEASE WITH TIMER START
		UVP-AP	"UVP" even when the changeover switch of automatic start and stop is set at "Automatic" position
		UVP-AR	"UVR" when the changeover switch of automatic start and stop is set at "Automatic" position
		UVP-ART	"UVR" when the changeover switch of automatic start and stop is set at "Automatic" position WITH TIMER START
4	EMERGENCY STOP	* 1 1	EMERGENCY STOP "ACCOM FIRE"
		* 1 2	EMERGENCY STOP "ENG ROOM FIRE"
		* 1 3	EMERGENCY STOP "DECK PART FIRE"
		* 1 4	EMERGENCY STOP "PURIFIER ROOM CO2 RELEASE"
5	PREFERENTIAL TRIP	* 2 1	PREFERENTIAL TRIP (1ST STAGE)
		* 2 2	PREFERENTIAL TRIP (2ND STAGE) ONLY BOW THRUSTER

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Fig. 2.4.5 Table of Electrical Symbol for Power Wiring Diagram

S.NO 3086/87 (3 3)

4. SYMBOL LIST (5/5)
-CONTINUED-

	• ITEM	SYMBOL	DESCRIPTION
4	EMERGENCY STOP	*131	EMERGENCY STOP "NO.1 CARGO HOLD CO^2 RELEASE"
		*132	EMERGENCY STOP "NO.2 CARGO HOLD CO^2 RELEASE"
		*133	EMERGENCY STOP "NO.3 CARGO HOLD CO^2 RELEASE"
		*134	EMERGENCY STOP "NO.4 CARGO HOLD CO^2 RELEASE"
		*135	EMERGENCY STOP "NO.5 CARGO HOLD CO^2 RELEASE"
		*136	EMERGENCY STOP "NO.6 CARGO HOLD CO^2 RELEASE"
		*137	EMERGENCY STOP "NO.7 CARGO HOLD CO^2 RELEASE"
		*138	EMERGENCY STOP "NO.8 CARGO HOLD CO^2 RELEASE"

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Fig. 2.4.6 Table of Electrical Symbol for Power Wiring Diagram

2.1.2 Electrical Cables

Ships' electrical cable has to withstand a wide variety of environmental conditions such as extreme of ambient temperature, humidity and salinity, dusty atmosphere, etc.
The normal distribution voltage on ships is 440 volts and cables for use at this voltage are designated for 600/1000 volts i.e. 600V to earth or 1000 V between conductors.
Conductors are annealed stranded copper, which may be circular or shaped.
Cable insulation has thickness appropriate to the system voltage rating. Insulation materials are organic plastic materials. Butyl rubber, which is tough and resilient, has good heat, ozone and moisture resistance. Ethylene Propylene Rubber (EPR) has similar electrical and physical properties.
Cross-linked polyethylene (XLPE) is also used as cable insulation, but has inferior mechanical and electrical properties in comparison to EPR.
PVC cables are generally not used for ships' cable as they tend to soften at high temperature and crack at low temperature.

Purpose of cable sheath

The sheath of a cable protects the insulation from damage and injury- it is not considered as insulation.
The sheath offers good resistance to cuts, abrasions and resists weather, ozone, acid fumes and alkalis and yet maintains flexibility for ships use.

Armoring of cable

Extra mechanical protection is provided by armoring with basket woven wire braid of either galvanized steel or tinned phosphor bronze. The non-magnetic property of phosphor bronze is preferred for single core cables.

Reason for wire braiding

The wire braiding acts as screen to reduce interference caused by magnetic field in adjacent communication and instrumentation circuits.

Cable gland: A cable is insulated, mechanically protected and watertight. The cable gland maintains this property where the cable terminates at the appliance. Cable gland is screwed into the appliance terminal box. Nuts on the gland compress the sealing ring to maintain watertight sealing and to clamp the armored braiding.

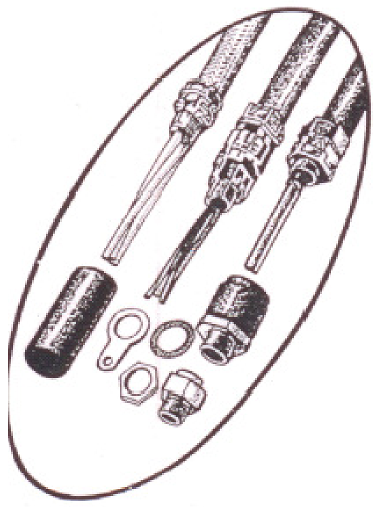


Fig. 2.5 Electrical Cable Gland Arrangement

1) Cable Markings (Europe)

Different countries adopt various cable codes. Such documents can be found on ships.
Example of cable marking: 0.6/1KV M Pr Th A G is interpreted as:

France

0.6 / 1 KV	Rated Voltage
M	Marine Cable
Insulation	
Pr 85°C	Cross linked polythene
Pr 95°C	Cross linked polythene
Th	Thermoplastic compound, common quality t75
	Thermoplastic compound, Heat resistant Quality T85
	Thermoplastic compound, Extra Heat Resistant Quality T90
Armour	
A	Metal Braid Armour
	Metal Tape Armour
	Metal Wire Armour
Sheath	
N	Synthetic Rubber (polychloroprene)
G or Th	Thermoplastic Compound
H	Chlorosulphonated polyethylene (Hypalon)

Japan

Symbols for the number of cores and main uses

S	Single core for lighting and power	M	Multi core for control and signals
D	Double core for lighting and power	TT	Telephone and instrumentation
T	Three core for lighting and power	P	Portable or flexible
F	Four core for lighting and power	STW	Switchboard

Insulation		Outer Covering	
P	EP rubber	L	Lead sheath
SR	Silicon rubber	Y	PVC sheath
Y	Poly vinyl chloride	N	PCP sheath
		D	Braid
Armoring			Protective Covering
C	Steel wire braid	Y	PVC protective covering
B	Copper alloy braid		

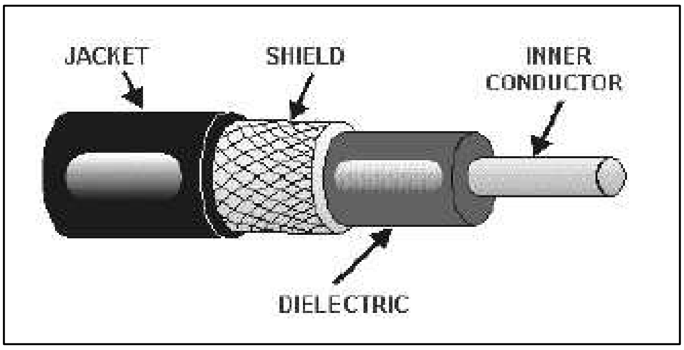
Fig.2.6 Table Showing Cable Markings- EU- Standard

2) Cable Rating

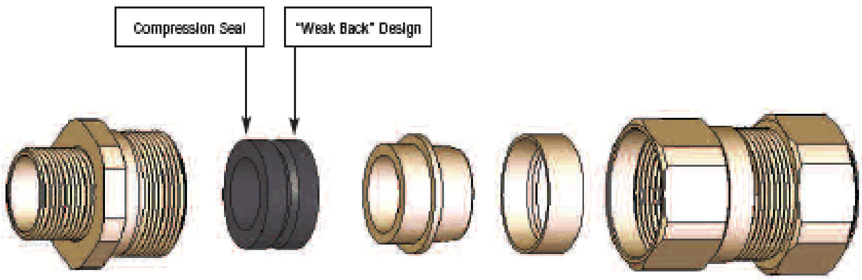
The current rating of a cable is the current that the cable can carry continuously without the conductor exceeding 80℃ with ambient temperature of 45℃ (i.e. a 35℃ rise). This rating must be reduced (de-rated), if the ambient temperature exceeds 45℃ or when cables are bunched together or enclosed in a pipe or trunking, which reduces the effective cooling.
The voltage drop in cables from main switchboard to the appliance must not exceed 6% (in practice it is usually 2%).
The longer the cable run and the smaller the size (conductor cross sectional area), the greater will be the voltage drop.

3) Cable Inspection and Testing

Megger test on main cable run should be carried out (e.g. along the flying bridge of a tanker).
The survey of cables and their installation is largely based on close visual inspection, which must include:
Check for external damage of cable's outer sheath and wire or basket weave



Check for adequate cable supports by suitable cable ties or clips.
Check for abrasion and wear, since Cable runs along open deck have expansion loop.
Check that they are correctly fitted with gland, where cables pass through fire bulkheads.



Cables should be periodically tested and checked. Cable insulation resistance should be measured and value logged.

4) Coloring of phase and pole: 3 phases of RST, UVW and poles of positive and negative for wires and bus bar are color marked depend on the shipyard.

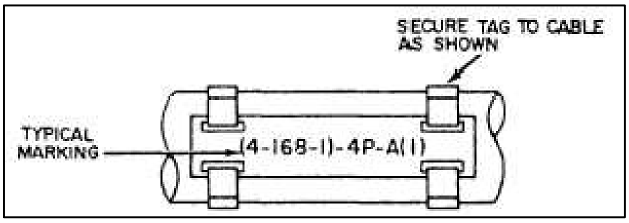
Power source side	Load side	Coloring
R	U	Green
S	V	Yellow
T	W	Brown

Coloring of direct current

Pole	Coloring
Positive (+)	Red
Negative (-)	Blue

5) Wire number or Circuit Number

Wire number or Circuit Number is entered near the cable symbol on the wiring diagrams. This same wire number or Circuit number is used on all drawings. For example, number of the maker instruction manual is same as the shipyard-wiring diagram. Therefore, engineer is able to investigate the connection of different drawings by using the number and to investigate the connection terminal of junction box by using the number.



Below is a one line electrical power system wiring diagram.

As example: Fig.2.7 Reefer Container Feeder Panel drawing has the following information

- Drawing Number-K5100300 /Sheet No.P-11A (2/2)
- The 440 volt Port Side Reefer Container Distribution Panel receives power through Transformer –TR PO5. The specifications of transformer: AC450/450V 3-ph 60 HZ rated capacity 380KVA on load side.

- The Transformer receives supply from the Reefer Container Feeder Panel, which is part of the Main Switch Board.
- Also we get information regarding the type of cable (FTPYC-80x3) and the cable No. (D-RCP5A), the type of circuit breaker, if it is an ACB or an MMCCB, the rated current, breaking current and the tripping method (drawing shows UVT –Under Voltage Trip).

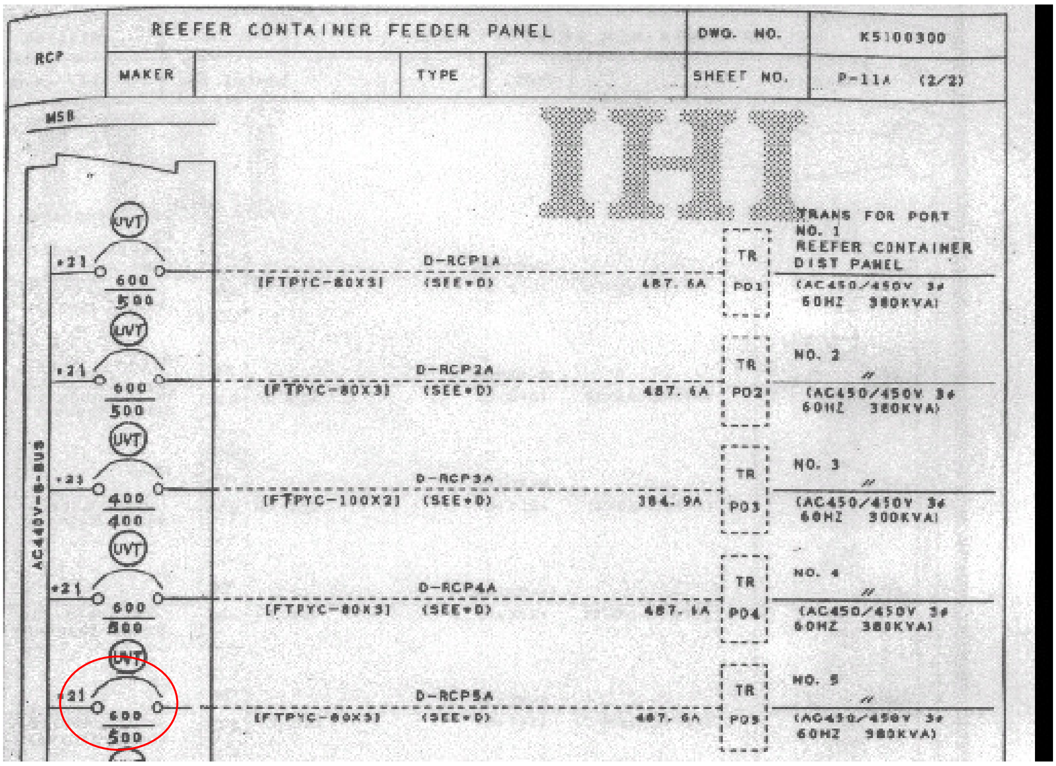


Fig. 2.7 Reefer Container Feeder Panel

S.NO. (29)

5. SYMBOL LIST (1/5)

NOTE: THE MARK • MEANS SYSTEM MARK.

SYMBOL	NAME	SYMBOL	NAME
ASB	AUX. SWITCHBOARD	STS	SUPPLY TRANSFER SWITCH
ESB	EM'CY SWITCHBOARD	A B	AIR CIRCUIT BREAKER 3P A:FRAME RATING CURR(A) B:SETTING VALUE (A)
SSB	SUB SWITCHBOARD	A B	MOULDED CAST CIRCUIT BREAKER 3P A:FRAME RATING CURR(A) B:SETTING VALUE (A)
CHB	CHARGING & DISCHARGING BOARD	A B	DO 2P DO
TSP	TESTING PANEL		EXPLOSION TYPE MOTOR

Fig. 2.7 (A) Reefer Container Feeder Panel, Symbol List

S.NO. (29)

5. SYMBOL LIST (1/5)

NOTE: THE MARK • MEANS SYSTEM MARK.

SYMBOL	NAME	SYMBOL	NAME
ASB	AUX. SWITCHBOARD	STS	SUPPLY TRANSFER SWITCH
ESB	EM'CY SWITCHBOARD	A B	AIR CIRCUIT BREAKER 3P A:FRAME RATING CURR(A) B:SETTING VALUE (A)
SSB	SUB SWITCHBOARD	A B	MOULDED CAST CIRCUIT BREAKER 3P A:FRAME RATING CURR(A) B:SETTING VALUE (A)
CHB	CHARGING & DISCHARGING BOARD	A B	DO 2P DO
TSP	TESTING PANEL		EXPLOSION TYPE MOTOR

Fig. 2.7 (B) Reefer Container Feeder Panel, Symbol list (1/5)

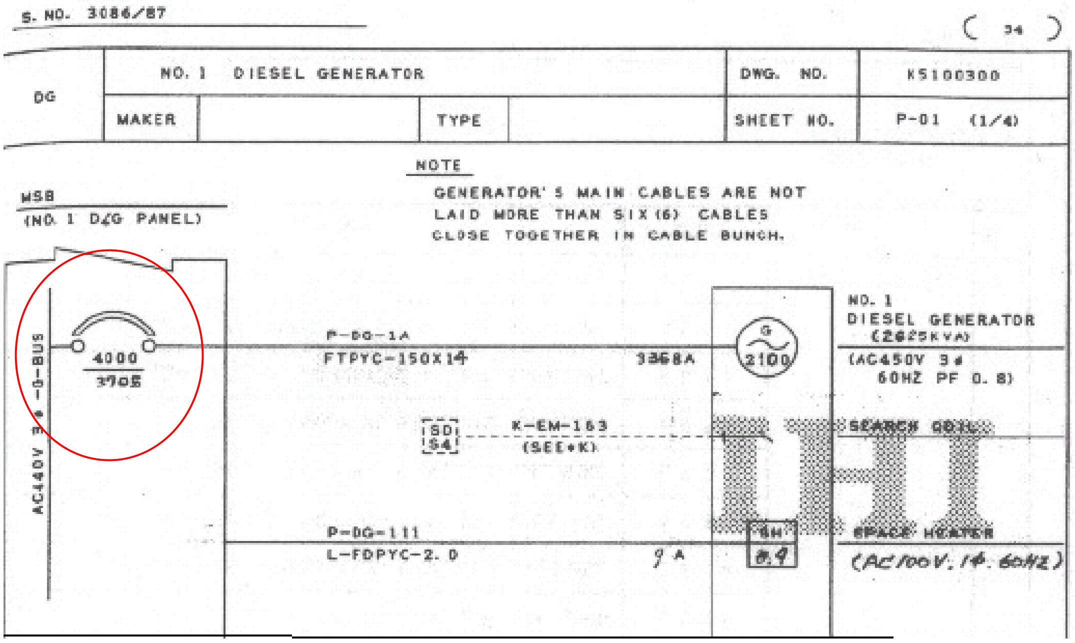


Fig.2.7 (C)   No.1 Diesel Generator panel on MSB

(Dwg no. K5100300/Sheet No. P-01(1/4)

S.NO. (29)

5. SYMBOL LIST (1/5)

NOTE: THE MARK • MEANS SYSTEM MARK.

SYMBOL	NAME	SYMBOL	NAME
	A.C. GENERATOR		MOTOR
EX	ROTARY EXCITER	GSP	GROUP STARTER PANEL
GM	GOVERNOR MOTOR	STP	STARTER PANEL
DC/AC / AC/DC	STATIC INVERTER/CONVERTER	STCP	STARTING PANEL WITH STARTING COMPENSATOR
	ROTARY INVERTER/CONVERTER	ASP	AUTO-START PANEL
AVR	AUTO VOLTAGE REGULATOR	CTR	CONTROLLER
EXP	STATIC EXCITER	SW	SWITCH BOX
TRD	TRANSFORMER	COS	CHANGE OVER SWITCH
BAT	BATTERY	GCS	GOVERNOR CONTROL SWITCH
AC/AC	FREQUECY CONVERTER	ALP	ALARM PANEL
MSB	MAIN SWITCHBOARD	ES-	EM'CY STOP SWITCH BOX
ASB	AUX. SWITCHBOARD	STS	SUPPLY TRANSFER SWITCH
ESB	EM'CY SWITCHBOARD	A B	AIR CIRCUIT BREAKER 3P A:FRAME RATING CURR(A) B:SETTING VALUE (A)
SSB	SUB SWITCHBOARD	A B	MOULDED CAST CIRCUIT BREAKER 3P A:FRAME RATING CURR(A) B:SETTING VALUE (A)
CHB	CHARGING & DISCHARGING BOARD	A B	DO 2P DO
TSP	TESTING PANEL		EXPLOSION TYPE MOTOR
SC	SHORE LINE CONNECTION BOX		
RSB	RADIO SWITCHBOARD	SHT	SHUNT TRIP COIL
		UVT	UNDER VOLT. TRIP COIL
R	RESISTOR		DISCONNECTING SWITCH 3P
JB	JUNCTION BOX		DO 2P
JB--	JUNCTION BOX		FUSE
CRL	CABLE REEL		BUS LINK

Fig.2.7 (D) Reefer Container Feeder Panel, Symbol List (1/5)

From above example it is clear that to investigate electrical faults in main power system, we need to check several electrical drawings.

2.1.3 Wiring Diagram of Lighting System

The One-Line cable diagrams show the power-supply outline from the distribution box to the lighting devices and receptacles.

The Engineer should have clear understanding of the kind or type of cable, circuit mark number or cable number, type of circuit breaker items from the wiring diagram, similar to the Power supply wiring diagrams.

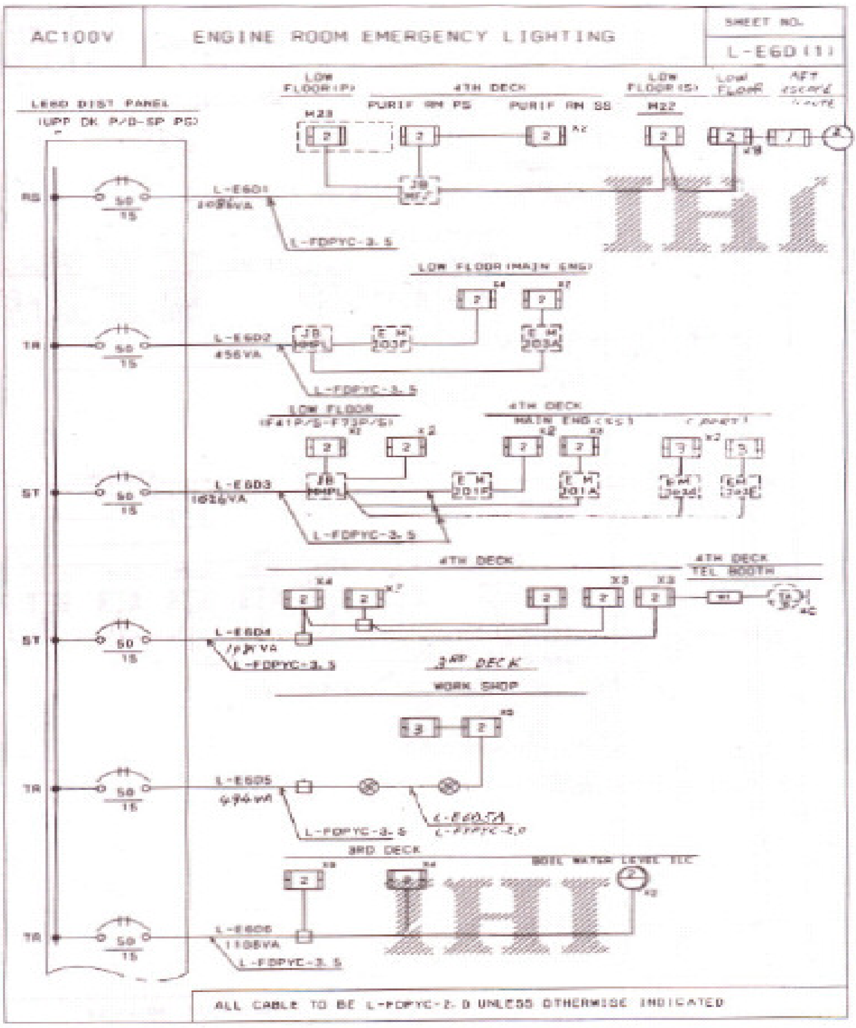


Fig. 2.8 Typical Figure of Lighting Wiring Diagram

The followings are the additional items:

1) Destination from distribution box

Understanding the part from the distribution box

2) Source of phase from 3 phases to single

Normally AC 100V 3 phase electric source supplies to distribution box for lighting system, which is then made single phase. This wiring diagram shows the use of phases for example R-S, S-T and R-T.

3) Number and type of lighting equipments

Example of using Wiring diagram:

* When switch will be put off for repairing the equipment, engineer should understand the equipment, those are not receiving electric power supply.
* Concrete example
Low insulation Alarm is very common occurrence, engineers investigates the part of low insulation.
A procedure of investigation is to switch off the supply one after the other and then check that the insulation resistance of switching off part is good or bad. In this procedure, switching off of the breaker for safety devices is prohibited. Therefore engineer escapes the dangerous situation by using the wiring diagram before switch off the breaker for safety devices.

Other than that above mentioned items, there are many cases that require investigation of the electric follow at beginning of the work by using the wiring diagram.

2.2 Arrangement of Electrical Equipments

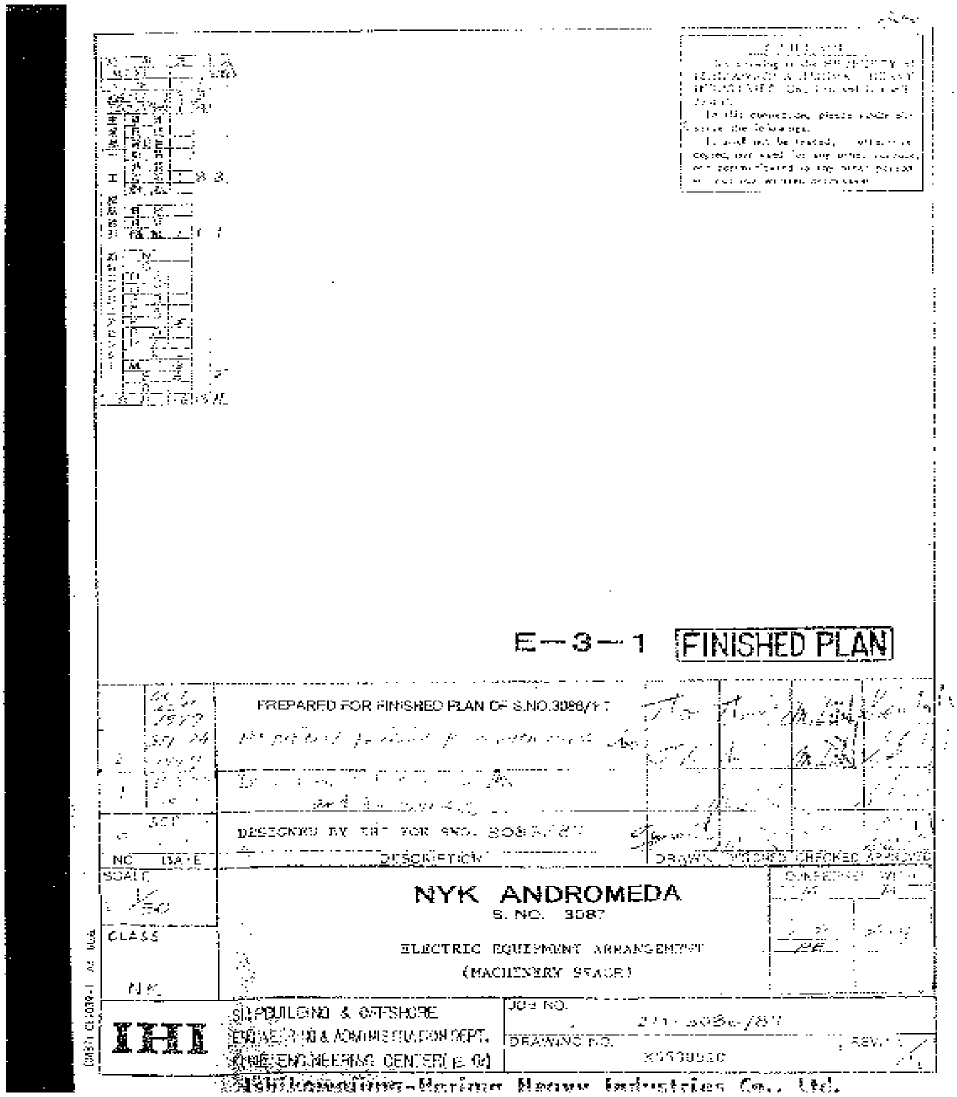


Fig. 2.9 Electrical Arrangement (Machinery Space)

Arrangement is the location of the electric equipments. Arrangements are composition with every deck and show the frame number and location of electric equipments. Normally, arrangements use the same symbol mark of the wiring diagrams. Engineers can investigate the location of electric equipments by using the arrangement when they cannot find out the machine side.

Some shipyards show the cable duct or path with the electric equipment on the arrangements. It is useful to understand the connection of equipments.

(4)

NOTES:

1) THIS DRAWING SHOWS THE ARRANGEMENT OF ALL ELECTRIC EQUIPMENT EXCEPT SOME PART OF ENGINE MEASURING/CONTROL SYSTEM SENSORS. AS FOR THE ARRANGEMENT OF ALL ENGINE MEASURING/CONTROL SYSTEM SENSORS, REFER TO DWG. NO. K4600300 "PIPING DIAGRAM (MACH. PART)".

2) DENOMINATIONS BESIDE EACH ELECTRIC LIGHTING SYMBOL IDENTITY THE CIRCUIT NO. AS FOLLOWS:

EXAMPLE

2

"E" MEANS CIRCUITS WHICH ARE FED FROM THE EMERGENCY GENERATOR

L-E2D-5
L-11D01 — CIRCUIT NO.

SOMETIMES THE CIRCUIT NO. FOR LIGHTS & SWITCHES IN CONTROL ROOM & STORE IS INDICATED REPRESENTATIVELY BELOW THE NAME OF THIS ROOM. IN THIS CASE ONLY THE LIGHTS OR SWITCHES IN THIS ROOM SUPPLIED FROM OTHER CIRCUITS ARE IDENTIFIED AS ABOVE.

3) SYMBOL FOR ELECTRIC EQUIPMENT TO REFER TO EACH WIRING DIAGRAM.

4) REFERENCE DRAWINGS:

ELECTRIC POWER SYSTEM WIRING DIAGRAM	K5100300
ELECTRIC LIGHTING SYSTEM WIRING DIAGRAM	K5300300
INTERIOR COMMU./NAV. SYSTEM WIRING DIAGRAM	K5410300
FIRE DETECTOR SYSTEM WIRING DIAGRAM	K5410350
ENG. MEASURING/CONTROL SYSTEM WIRING DIAGRAM	K5451300
DECK MEASURING/CONTROL SYSTEM WIRING DIAGRAM	K5452300
ELECTRONIC SYSTEM WIRING DIAGRAM	K5800300
PRACTICE FOR ELECTRICAL INSTALLATION	K5700200

※ MARK SHOWS THE EQUIPMENT FITTED ON THE M/E.

⚹ MARK SHOWS DETECTOR FOR MAIN WIRE WAY OF D/G.

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Fig. 2.9(A) Electrical Arrangement (Machinery Space)

2.3 Maker's Finished Plans

Maker finished plans are made up as the instruction book of equipments, intimate drawing and wiring. Shipyard purchased the electric equipments from the maker, fixed on the place and connected the cables. Therefore, internal connection and wiring inside of the equipment is not entered on wiring diagrams of shipyard, but it is entered on maker's instruction or drawing. It is important thing that wiring number or circuit number is same for both the shipyard's wiring diagram and maker's instructions.
For example, location, type, etc. for wiring, connection, terminal block, relay, etc. entered on maker's instruction.
When engineer investigates the wiring or connection, there is a procedure involving the use of one drawing or many drawings including the Machinery drawings. Investigation of wiring and connection is difficult because it is necessary to investigate not only one drawing but also many drawings of other category for example the Machinery part and Electric part.

2.4 Procedure for using Electrical drawings

<Case study No.1>

Bilge separator oil content high alarm failure

1) Use drawings

E-5-31: Monitoring System
E-2-5: Eng. Measuring / Control System wiring diagram
M-3-5: Bilge Separator & After Treat unit
E-3-1: Elec. Equip. Arrangement (Machinery Space)

2) Supposition

* Bilge separator oil content high alarm is abnormal situation
* Unknown cause and trouble position

3) Investigation steps

<STEP 1>

To investigate the “E-5-31: Monitoring System” and find the page M37.
Engineer understands the DBU number, CH number, TAG number, etc.

<STEP 2>

See the page U37 (10=sender box number 16 channel number) and understanding

* TAG number
* Terminal bock number: 63 & 64
* Cable number: K-DBW111 same as the circuit number
* Cable type: L-FDPYC-1

<For reference>

E-5-31 Sheet No.E02: Datachief Alarm & Monitoring System External Cable Diagram shows the type of DBU10 (SAX2) and Sheet No.E51: DWG.NO. HA334061 SAX 8810 is the input channel in EMC cabinet shows the layout of the cabinet inside.

<STEP 3>

To investigate the “E-2-5: Eng. Measuring / Control System wiring diagram” and find the page 31 (Sheet No. K-25).
Engineer understands the wiring from the Oil content meter to the Sender box (SDP4), in this case very useful the cable number. E-5-31 and E-2-5 are using same cable number K-DBW111.
And page 52 (Sheet No.K-30) shows the outline of wiring.

<STEP 4>

Engineer wants more details, for example the oil content meter connection.
To see the M-3-5: Bilge Separator & After Treat unit.
Engineer understands the location of external terminals and using the terminal number from the M-3-5.

<STEP 5>

If actual location cannot find in engine room, engineer uses the arrangement.
E-3-1: Elec. Equip. Arrangement (Machinery Space) shows the location.

Above case No.1 is using not only the electric part drawings but also the machinery part drawings and requires total 4nos. of drawings.

<Case study No.2>

Starboard Boat Deck Light power supply not available

1) Using drawings
E-2-2: Electrical Lighting System Wiring Diagram (Drawing No K5300300)

2) To investigate the cause of supply failure

<Case Study 3>

Main Air Compressor failure (Abnormal condition) to investigate cause
By use of relevant electrical diagrams

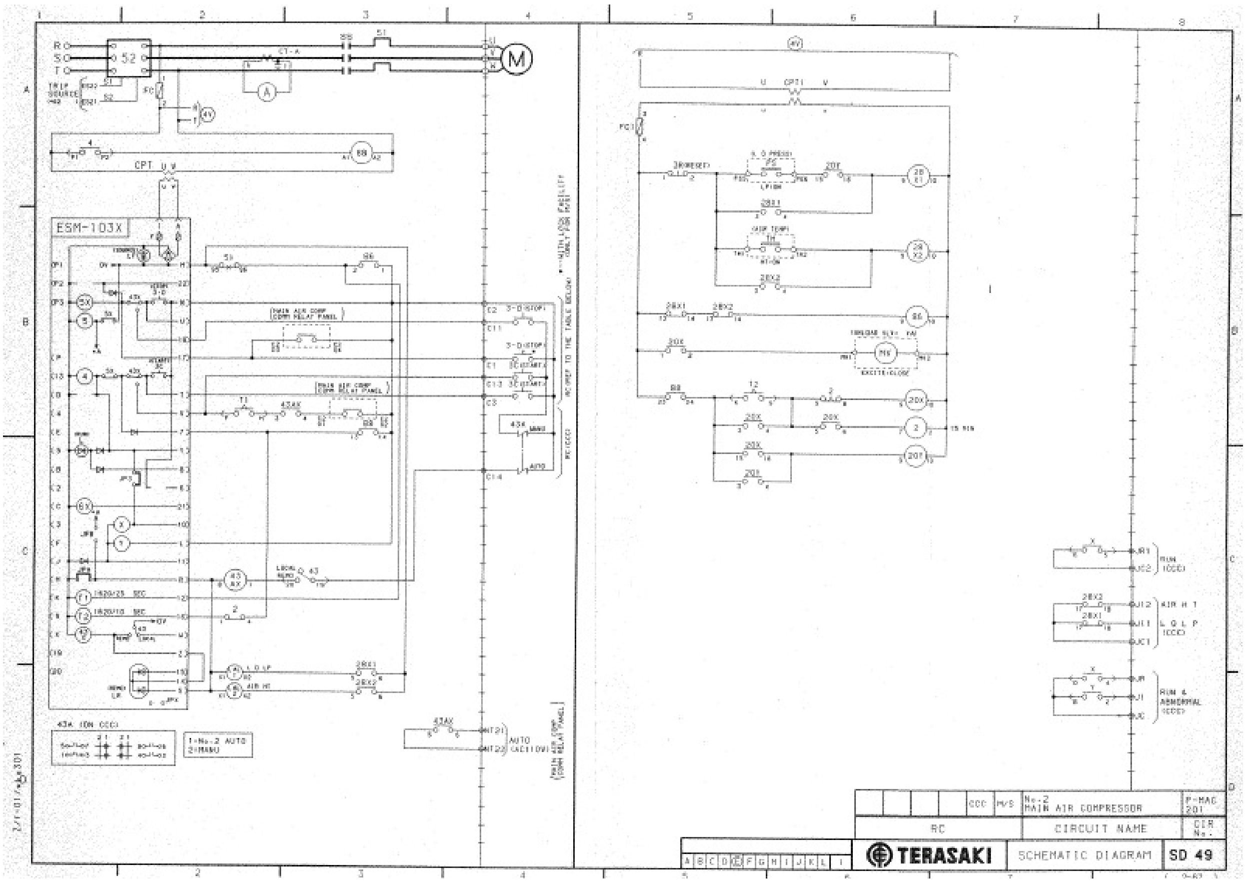


Fig. 2.9(C) Main Air compressor control circuit

The circuit shows a typical main air compressor electrical diagram having manual and automatic mode of operation.

To investigate or to use the electrical drawings, it is essential to know the electrical symbols.

Listed below are the symbols /abbreviations relevant to the diagram for the electrical diagram for the main air compressor.

Abbreviations /symbols	Function/Explanation
R,S,T	Main 3 phase power source(supply to the breaker)
CB	Circuit Breaker
U,V,W	3 –phase power supply to the motor
M	Compressor motor
Tr.	Control circuit step down transformer
FT	Transformer fuse
FC	Control circuit's fuse
FL	Signal Lamp circuit's fuse
WL	White Lamp – Power Supply Available indicating lamp
GL	Green Lamp- Compressor running indicator lamp
RL1	Red Lamp – Low Lub Oil Pressure –failure indicating
RL2	Red Lamp –High Cooling water Temperature- failure indication
3T(2)	Manual Stop Push – Remote (useful in both manual and auto modes)
3R	Alarm reset push button de-energises 63Y and 23X when pressed
3D	Manual unloader /drain solenoid – breaks the automatic control circuit when pressed
Abbreviations /symbols	Function/Explanation

<Case Study-No4>

Learn to locate relays and associated contactors on a electrical drawing
Using Finished Drawing : E-5-15 Group Starter Panel & Individual Starter
Locate :

Circuit name: No.1 Lubricating Oil Pump
Circuit No.: P-LOP 101

With the help of the table below

1) Name the relays to be found in the diagram.
2) For each of the relays/contactors state how many of the contacts are being used.
3) Status of the contacts whether the contacts are NO (normally open) or NC (normally closed) in de-energized condition of the circuit.
4) State the location of the contacts to be found on the drawing.

SL No	Relay/Contactor/Timer	No. of Contacts	Status	Location in the diagram (X-Y axis)

Why do we use 3-phase power versus 1-phase / 2-phase power supply?

The generator plant produces three different phases of AC power simultaneously, and the three phases are **offset 120 degrees** from each other. There are three wires coming out of every generating unit: the **three phases**. There is nothing magical about three-phase power. It is simply three single phases synchronized and offset by 120 degrees!

In 1-phase and 2-phase power, there are 120 moments per second when a sine wave is crossing zero volts. In 3-phase power, at any given moment one of the three phases is nearing a peak. High-power 3-phase motors (used in industrial applications) and things like 3-phase welding equipment therefore have even power output. Four phases would not significantly improve things but would add a fourth wire, so 3-phase is the natural settling point.

The first electrical systems generated direct current by means of dynamos. It was soon realized that there were serious limits to the area and the number of customers that could be served, and alternating current took over – which as we all know can be transformed from one voltage to another with minimal loss. Very quickly (in 1885) Italian Galileo Ferraris realized that two windings set at an angle to each other could produce a rotating magnetic field, something of great help when motion is required, and just two years later the 3-phase alternator appears. Three phase is where you have 3 related voltage sources supplying the same load. It is a significant improvement over single phase or two-phase because the three voltage or current waves follow each other _ cycle apart, and if you sum the currents together at any instant, you find that they perfectly balance.

More importantly, the power is continuous and constant, so three phase motors run more smoothly. Also, the main advantage comes with motors. The three phase currents set up a rotating magnetic field inside the motor and so the motor will naturally start to rotate on its own, no special mechanism (like a phase shift capacitor and an extra winding that you usually need with a single-phase motor) is required.

Chapter 3
Main Switch Board

Switch Board is assembled to provide the functions such as monitoring, controlling, measuring, indicating, safety devices and so on for the electrical circuits or equipments. Therefore, the Switch Board rationally manages and controls all the electrical circuits and equipments as a central station. Main Switch Board distributes the electric power to the ship's loads and protects the electrical equipments by the safety devices, depending on the troubles. Switch Board is equipped with the Air Circuit Breaker, Circuit Breaker, Auto Synchronizer, Synchronism Lamp, Synchronism Scope, Earth Lamp, Auto Power Control System, Voltage Monitoring System, Frequency Monitoring System, Voltage Establish Relay, Reverse Power Trip Device and Insulation Resistance Meter.

3.1 Layout of Main Switchboard (Outline View –Front)

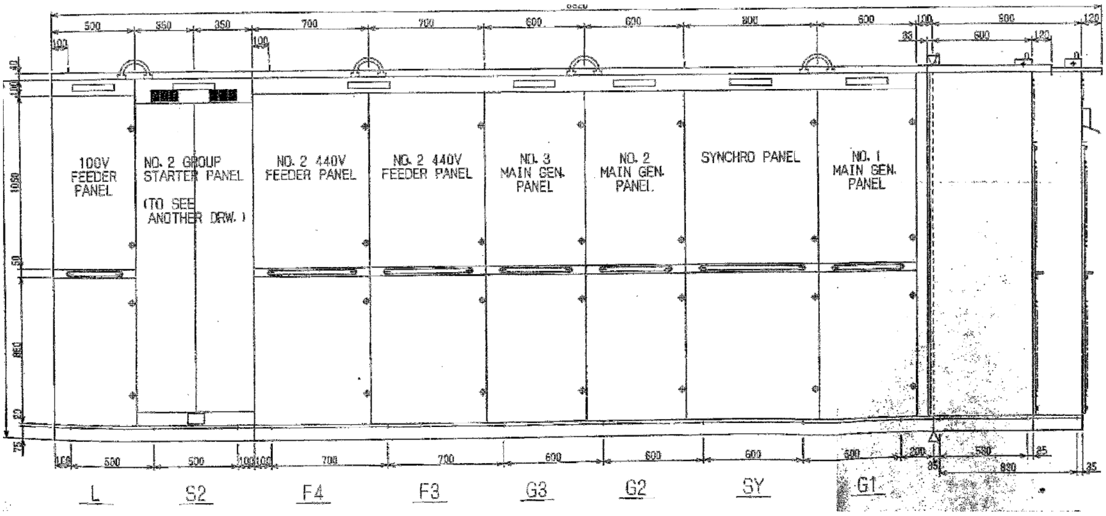


Fig. 3.1 Layout of Main Switch Board

A typical layout of a ship's main switchboard is shown above. This is invariably made up of panels, which are arranged to accommodate all the electrical components necessary for receiving and distributing the electrical supply. Power produced by the generators is delivered to the various motors, lightings, galley services, navigation aids, steering gear, deck machinery, etc., which comprise the ships electrical load.

The electrical energy is routed through the main switchboard, then distributed via switchboards or panels to section and distribution boards and then ultimately to the final load consumers. The switchboard is capable of withstanding mechanical, electrical and thermal stresses, which may arise from shock or vibration of the vessel or short circuit fault. The central section of the main switchboard is used for the control of the main generators. The breakers of the generator panels are used for essential services and flanking these are group motor starter panels. The majority of ships have a 3-phase A.C. 440 - volt insulated supply. Lighting and low power single-phase supplies usually operate at the lower voltage of 110 volt A.C. The Main switchboard will also supply to the Emergency switchboard.

The other essential services to the engine room, bridge supplies and feeder panels, provisions will be made for alarms and earth insulation resistance monitors on each volts and parts sections. The switchboards or panels are usually linked (or interlocked) to an isolating system.
The breakers are isolating the supply side and delivery side, when switching on / off or when tripped at the occurrence of troubles.

The main breakers are ACB (Air Circuit Breaker). They can be completely withdrawn and removed to ensure complete safety, when carrying out maintenance on equipment. Maintenance is explained in later sections of this handout.
For reference, kindly go through NYKSM SMS manual “Generator, Switchboard, Cable and Wiring Maintenance Document No.: ZZ-S-P-10.60.02 E
Revision date 2001.11/01
and detailed information as given in NYK Line Marine Engineering Information, Date 2/08/99
Ref No.: 99-003
SEQ No.: 483
Re: Guidelines for Inspection/Maintenance Procedure of Main Switchboard, Distribution Panel and Starter Panel

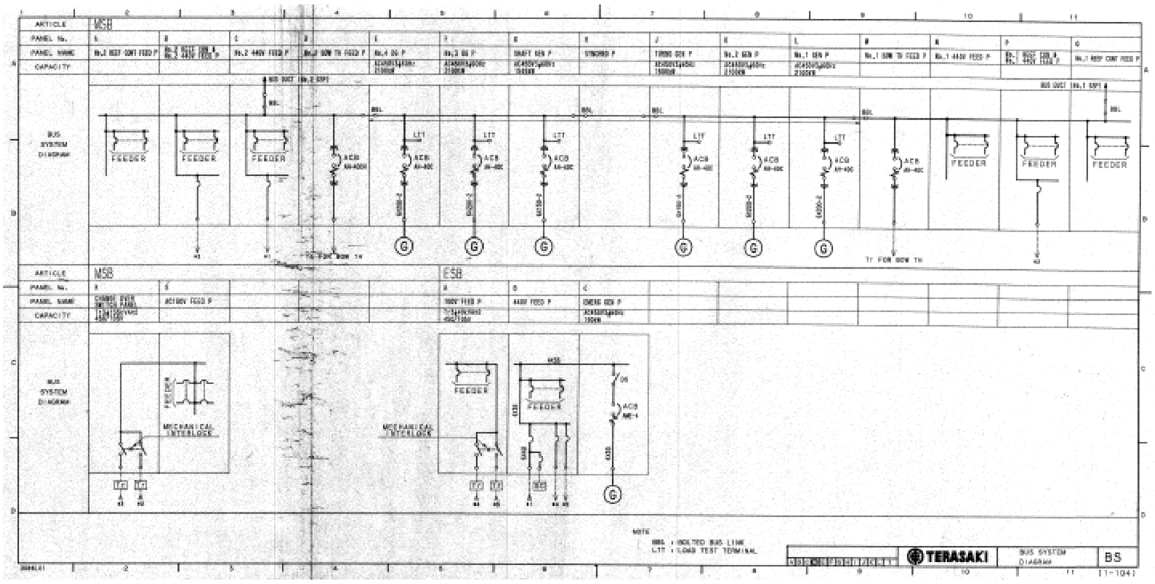


Fig. 3.1(A) Example of Main Switch Board Bus System Diagram

To parallel the incoming generator on to the bus bar smoothly, it needs to be synchronized with the running generator which is already connected to bus bars.

The following conditions are essential:

- Same frequency

  The frequency differential between the Bus (Running generator) and the Incoming generator is sufficiently small.
  The incoming generator voltage is set by its AVR to be equal to the bus bar voltage

- Same voltage

  The voltage differential between the Bus (Running generator) and the Incoming generator is sufficiently small.

- Same phase sequence

  The voltage phase between the Bus (Running generator) and the Incoming generator is extremely same.

The speed of the incoming machine is controlled and fine tuning is observed on the Synchronism Scope or synchronizing lamps.

3.2.1 Manual synchronization operation

When we operate the generator in parallel by manual, we carry out the following operation to satisfy the above requirements.
1. Start the incoming generator
2. Adjust the frequency to sufficiently small differential between the Bus (Running generator) and the Incoming generator by governor motor for the incoming generator
3. Confirm that the frequency differential between the Bus (Running generator) and the Incoming generator is sufficiently small.
4. Confirm that the voltage differential between the Bus (Running generator) and the Incoming generator is sufficiently small.

If the voltage differential is not sufficiently small, adjust the voltage by adjusting the set point (Voltage Trimmer) of the Automatic Voltage Regulator.

5. Close the ACB of the incoming generator at the time of same phase by confirming the Synchroscope.

∆ CAUTION Manual Synchronous Closing Operation
Do not close generator ACB unless it synchronizes with the generator: **a) Close the generator ACB within a range of approximately 15º on the FAST side, considering the synchronization point as the 12 O'clock position** **b) ACB synchronous closing operation outside the range described in item a) above may pull the generator out of synchronism and cause abnormal tripping of the ACB** **ACB abnormal tripping may result in no voltage on the main bus**

Synchroscope

The incomer is adjusted so that Synchroscope indicator rotates slowly clockwise in the "FAST" direction and the circuit breaker of incoming generator should be closed as the indicator approaches 12 o'clock. If synchronized, when running slow, the incoming machine would draw a motoring current, which may operate its reverse power relay and 'trip" the circuit breaker of the machine already on the "bus bar' due to overloading. The likely consequence of attempting to close the incoming breaker when the generators are not in synchronism are that at the instant of closing the breaker the voltage phase difference causes a large circulating current between the machines, which results in a large magnetic force to pull the generators into synchronism. This means rapid acceleration of one rotor and deceleration of the other. The large forces may physically damage the generators and their prime movers, which may include deformation of the stator windings, restrict movement of stator core and frame. It may also cause failure of the rotor diodes in brushless type generators, twisted rotor shafts, damage of shaft keys and broken couplings. The large circulating current may also trip each generator breaker. The ultimate result is blackout.

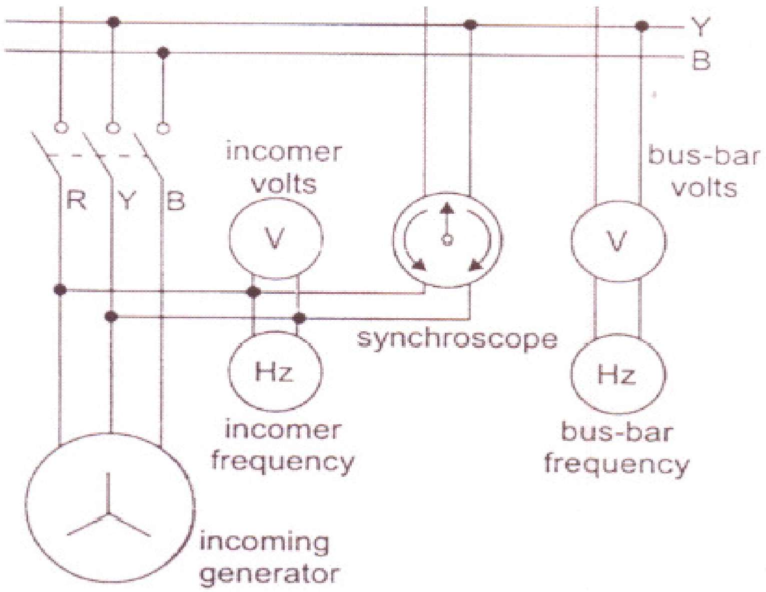


Fig. 3.2 Arrangement of Synchronizing Instrument

3.2.2 Automatic Synchronization operation

The auto synchronizing function detects whether the generator frequency is higher or lower than the bus bar frequency and controls automatically the governor motor which minimizes the frequency difference. When the difference in frequency and voltage become smaller than the set values, the function gives a closing signal to the circuit breaker so that the circuit breaker will be closed at the point where the phase of the generator coincides with that of the bus bar.

Synchronizing unit monitors the voltage, phase angle and frequency of the incoming generator with respect to the bus bars.

3.3 Automatic Power Control System

The Auto Power Control System is an automation system for parallel operation of generators. There are the Proportional load control and the Optimum load control. The Proportional load control is generator load equal control.

The Optimum load control is the method that one generator load is adjusting the balance load, others generator or generators is / are setting load. That setting load is optimum load for generator. Both methods control the number of the generator, when total load is reached setting load, stand-by generator is started automatically, closes ACB of incoming generator automatically and then load is shifted to incoming generator automatically.

3.4 Safety Devices

The ability of Protection system to discontinue only faulty circuits and to maintain the electrical supplies to proper circuits is known as protection discrimination. In other words discrimination occurs when the breaker nearest to the fault operates, leaving all the other breakers or protective devices intact.

3.4.1 Voltage Monitoring System

The Voltage Monitoring System monitors voltage of bus-bar side and generator side.
When voltage is over the low and high setting point, this system outputs the alarm and trip signal to the breakers.

3.4.2 Frequency Monitoring System

The Frequency Monitoring System monitors frequency of bus bar. When frequency is over the low and high setting point depend on the abnormal of the generator trouble or abnormal fluctuation load, this system outputs the alarm signal, preference signal and stand-by generator auto start signal.

3.4.3 Voltage Establishing Relay

The Voltage Establish Relay monitors voltage of generator. When generator output voltage is reached setting point, this relay outputs the signal to the other device. This signal uses to confirm the voltage before closing the ACB and so on.

3.4.4 Reverse Power Protection Device

When the running generator receives electric power from the other generator via a bus bar, it means generator changing to motor. The Reverse Power Protection Device detects the reverse power by the induction coil and outputs the tripping signal to the generator ACB to protect the generator from overheat or burn-out.

3.4.5 Insulation Resistance Meter

Regulations require that Main switchboard should be fitted with earth fault indicators to indicate the presence of an earth fault in each isolated section of a distribution system e.g. on 440 V and 220 V sections. Earth fault indicators can either be a set of lamps or an instrument calibrated in Kilo ohms.

Earth indicator lamps are arranged as shown in below in Figure 3.2. If system is healthy the lamps will glow with equal brightness as there is a potential difference across each of them. If earth fault occurs on one line, the lamp connected in that line is dim or extinguished and other lamps glow comparatively brighter. The reason is that there would be no potential difference across the faulty lamp, due to potential falling to zero or near zero.

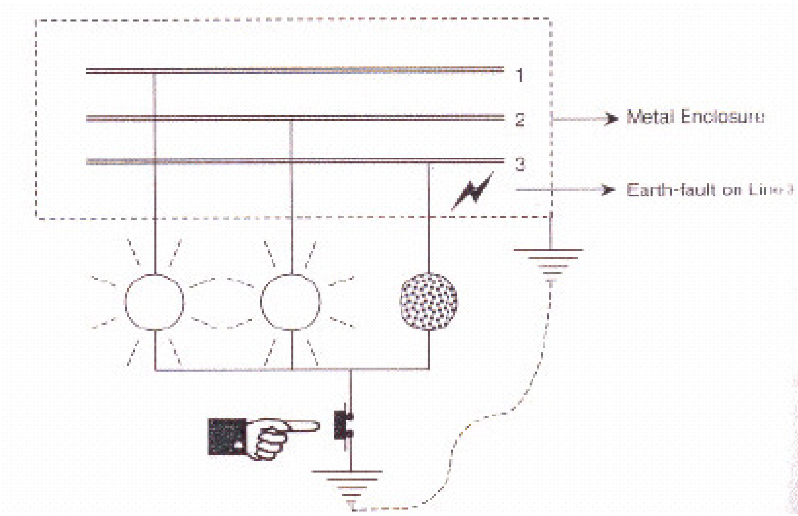


Fig. 3.2 Earth lamp Connection

What is the concept of earthing of electrical conductors on ship versus practice followed ashore?

We all know about 3-phase 4-wire system which is commonly used in shore. But how is this different on a ship? The earthing / grounding system used on ships provides double safety.

Before delving into ship grounding, let us study about shore grounding to have a basic understanding of the concept. In shore we use 3-phase 4-wire systems, in which 3 wires are representing each phase and 4th wire is neutral which carries the return current. The neutral is earthed at many places for the safety of human beings against shocks. If any conductor carrying current has its insulation failure, then if the conductor comes in contact with the metal enclosure part of the machinery, then it may cause voltage accumulation, leading to shock to human being which is highly fatal. Thus to maintain the safety of human beings against the accidents due to circuit failures, the neutral is earthed at various places like transformers, distribution sub-stations etc. This makes the equipment to automatically get out of supply by tripping the protection devices.

The requirement ashore is the safety of human beings. So, in order to prevent human-electrical accidents, the neutral is earthed. The priority is neither the safety of the machinery nor the continuous necessary operation of the machinery. But the scenario onboard ship is totally different. The priority is the continuous operation of the machineries which are classed "essential". The distribution system followed onboard is "insulated neutral" system. The main priority onboard is the safety of ship which includes navigation & fire safety, etc. If due to earth fault, the machinery classed as "essential" gets isolated; say for e.g. steering gear, the safety of ship is at question, which may lead to collision, grounding, fire & pollution etc. So the priority onboard ship is to maintain the continuity of the supply to the machinery in the event of "single earth fault occurring".

A basic circuit consists essentially of two parts:

1. The Conductor--which carried the current around the circuit.

2. The Insulation---which keeps the current inside the conductor.

Only 2 types of circuit faults can occur. Either break in the insulation or break in the conductor.

The break in the conductor leads to non-flow of current in the circuit. A break in the insulation leads to an earth fault, allowing the conductor to touch the hull or earthed metal enclosure.

A short-circuit fault is due to the double break in the insulation, allowing both conductors to get connected, thus a very high current passes through, by-passing the load.

A majority of earth faults occurs within the equipment. Generally insulation failure occurs which leads to the conductor getting in contact with the body of the metal enclosure. When such earth faults happen, the metal enclosure of the equipment if not earthed, it would cause a heavy shock, and may result in fire accidents too..

If an earth fault occurs in an "earthed distribution system", it would be equivalent to a "short-circuit" fault across the load via ship's hull. The resulting large earth fault current will immediately "blow-up" the fuses in the line. Thus the equipment is isolated from the supply and thus rendered safe. This may result in hazardous situation, if the equipment is classed as "essential" for eg: steering gear. Thus the "earthed distribution system" requires only one earth fault on the line conductor to cause an earth fault current to flow.

If the earth fault occurs in "insulated neutral distribution system", will not cause any equipment to go out of operation and thus maintains the continuity of operation of the equipment. This point is to be noted," the machinery still continues to operate". Thus a single earth fault will not provide a complete circuit for the fault current to flow. If a second earth fault occurs, then the two earth faults together would be equivalent to a short circuit fault (via ships hull) thus resulting large current would operate the protection devices, cause disconnection of, perhaps, essential services creating a risk to the safety of the ship.

An insulated neutral distribution system requires two earth faults on two different lines to cause an earth fault current to flow. Thus an insulated neutral system, is, therefore, more effective than an earthed system in maintaining continuity of supply to equipments. Hence it is adopted for most marine electrical systems.

Chapter 4
Equipments/Devices

National and international standards define the way electrical circuit installations must be realized and the capacities of and limitations of Air Circuit Breaker (ACB), Molded Case Circuit Breakers (MCCB), which are collectively referred to as switchgear.

The main functions of Switch gear are:

>Electrical Protection
>Electrical Isolation of sections of an installation
>Local or remote switching

Electrical Protection	**Isolation**	**Control**
Against: Over currents Short circuit currents Insulation failure	Isolation clearly indicated by an authorized fail proof mechanical indicator A gap or inter posed insulating barrier between the open contacts, clearly visible	Functional switching Emergency switching Emergency stopping Switching off for mechanical maintenance

The aim of electrical protection is to avoid or to limit the destructive or dangerous consequences of excessive (short circuit) currents or those due to overloading and insulation failure and to separate the defective circuit from the rest of the installation.

The aim of isolation is to separate a circuit or apparatus or an item or plant (such a motor) from the remainder of the system which is energized, so that personnel may carry out work on the isolated part in perfect safety.

In broader terms “control” signifies any facility for safely modifying a load carrying power system at all levels of an installation. The operation of switchgear is an important part of the power system control

4.1 Air Circuit Breaker (ACB)

ACB is equipment that connects or disconnects the generator and bus-bar by the manual operation or the electric remote operation.

The connection method of ACB is mounted to the bus-bar and it is not the bolt connection type. Therefore the ACB is disconnected from the source side bar and load side bar by drawing out operation.

4.1.1 Out-view and Structure of ACB

List of parts

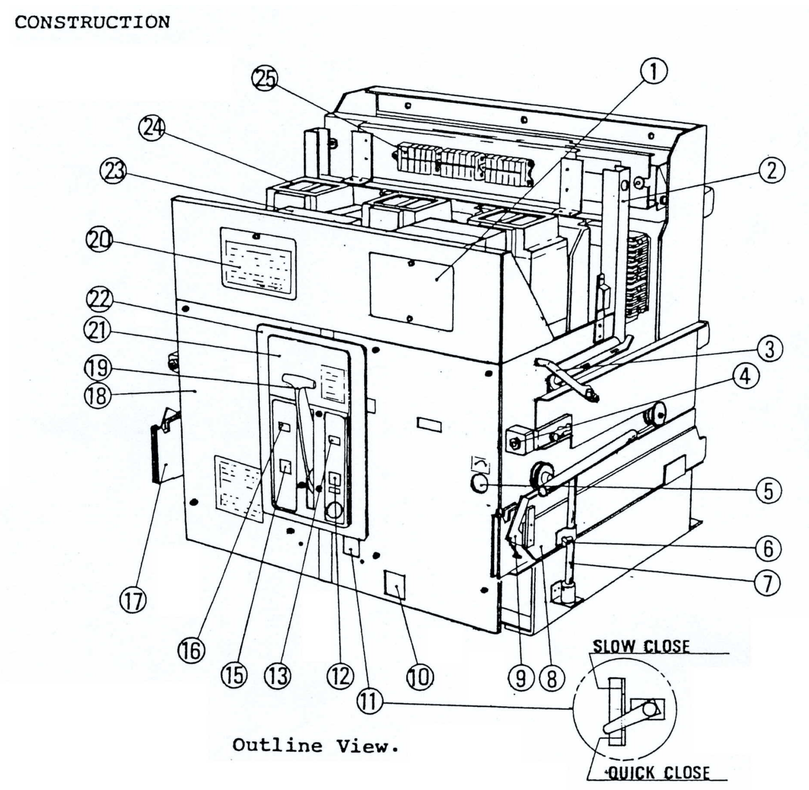
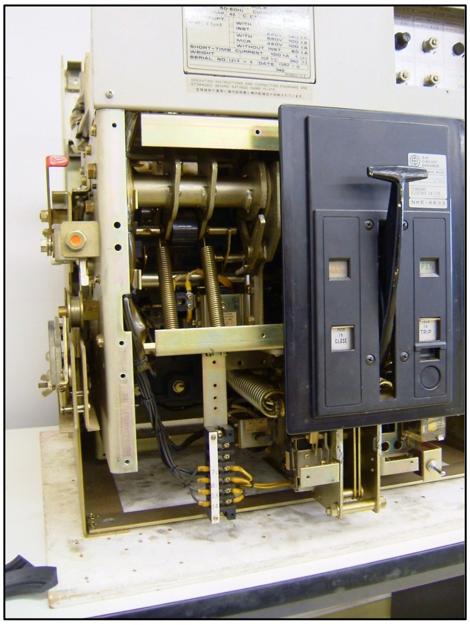


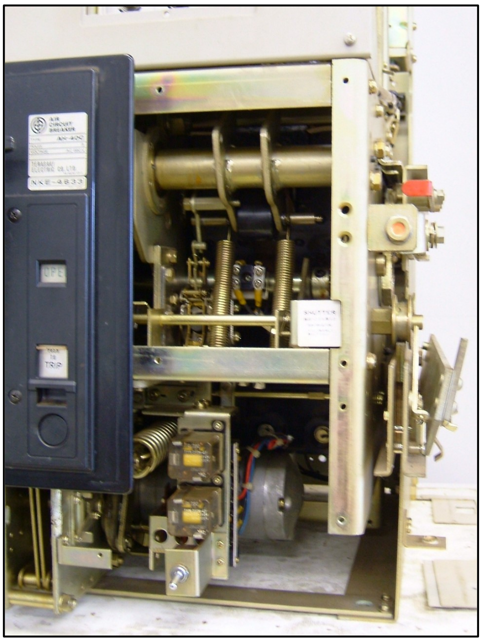
Fig. 4.1 Structure of ACB

1. Over-current Trip Device
2. Lifting plate
3. Release Lever
4. Fixing Screw
5. Draw-out Handle Insertion Hole
This hole is normally covered by a shutter linked to the "TRIP" button
6. Wing Screw, draw-out handle and extension rails
7. Draw-out handle
8. Extension Rail
9. Breaker Stopper
10. Charging Motor Switch (Motor Charging type only)
11. Quick-Close/Slow-Close Selector Lever
12. Trip Button
13. Open-Close Indicator
15. Close Button
16. Spring Charge Indicator
17. Draw-out Rail
18. Front Covers
19. Charging Handle
20. Ratings Plate
21. Front Panel
22. Dust Plate
23. Auxiliary Switch unit
24. Arc chutes

AIR CIRCUIT BREAKER
AH-40C

OPEN
CLOSE
TRIP





List of parts

1. Toggle Links
2. Copper ribbon lead
3. Trip lever
4. Trigger
5. Trip piece
6. Close button link
7. Closing spring
8. Charging latch
9. Charging hook
10. Drive lever (Motor operation)
11. Drive pawl (Motor operation)
12. Ratchet wheel
13. Drive pawl (Manual operation)
14. Drive lever (Manual operation)
15. Charging lever links (B)
16. Springs for charging lever links
17. Charging lever link (A)
18. Trip springs
19. Charging handle
20. Reset springs
21. Closing latch
22. Connector levers
23. Operating rod/pole
24. Moving contact arm/pole
25. Stationary contact assembly

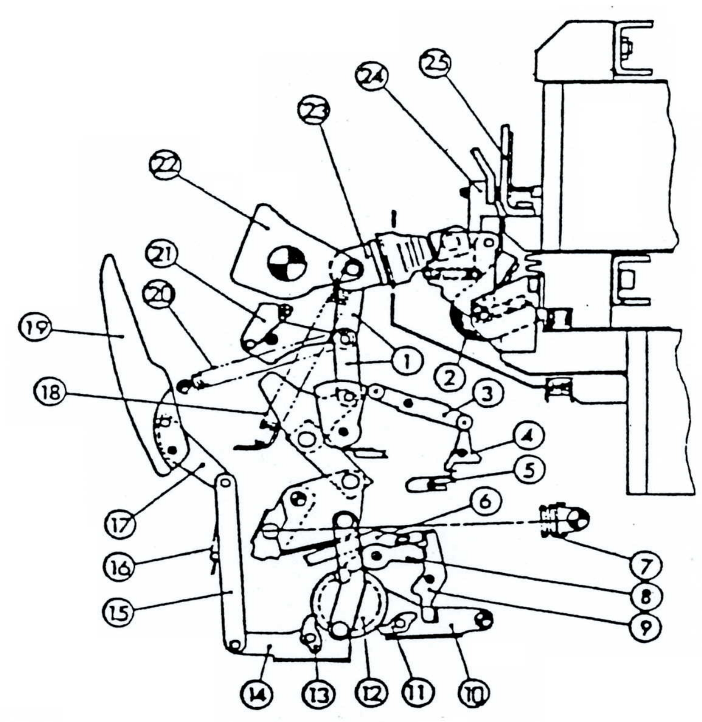
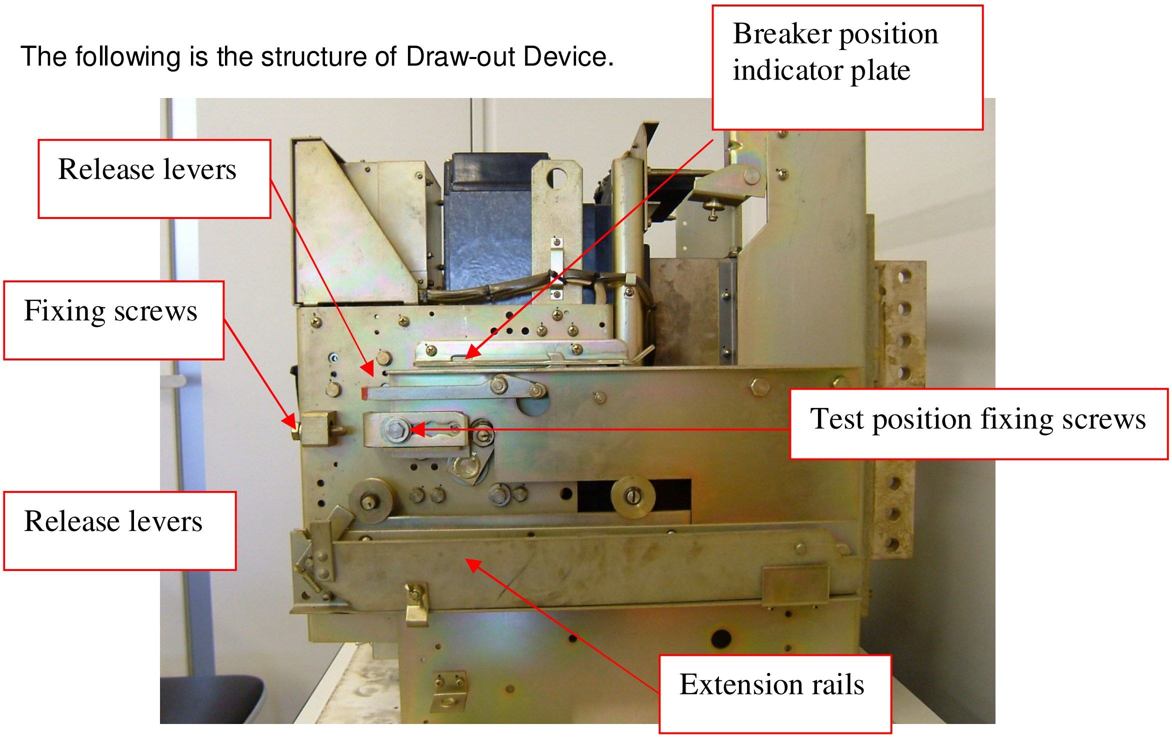


Fig.4.1A ACB operating Mechanism

4.1.2 Draw-out Device

The draw-out mechanism is so designed that drawing out, taking out and remounting of the breaker body can be easily made. This permits easy inspection, maintenance and replacement of the parts. The procedure for drawing out and remounting follows the maker's Instruction Manual. This section explains using the AH type of Terasaki Electric Co Ltd.

The following is the structure of Draw-out Device.



Pic.4.2 ACB (AH Type Terasaki Electric Co. Ltd) Draw Out Device

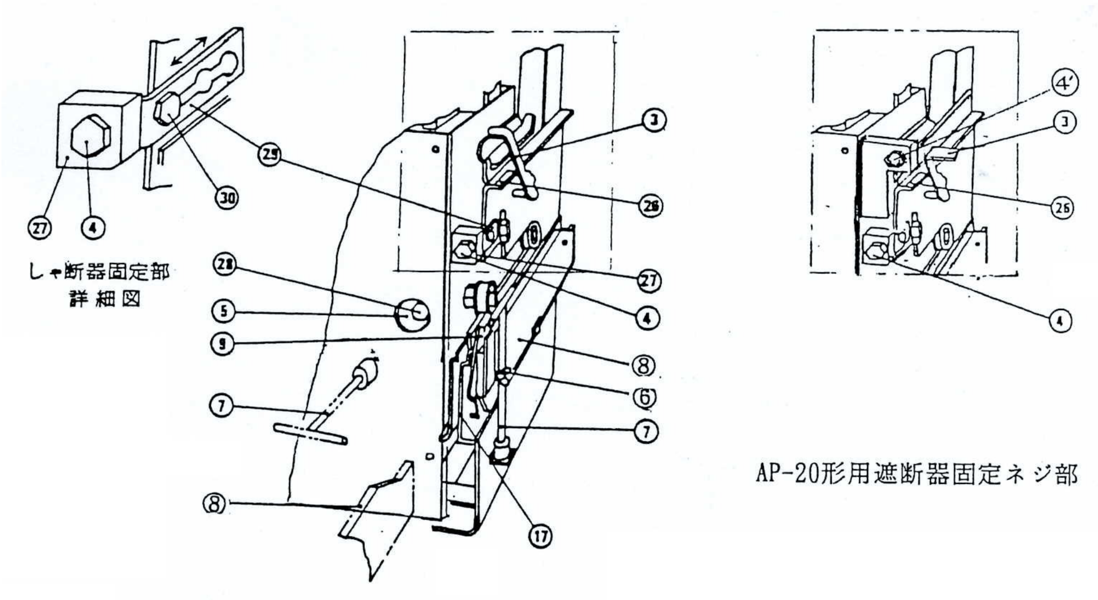


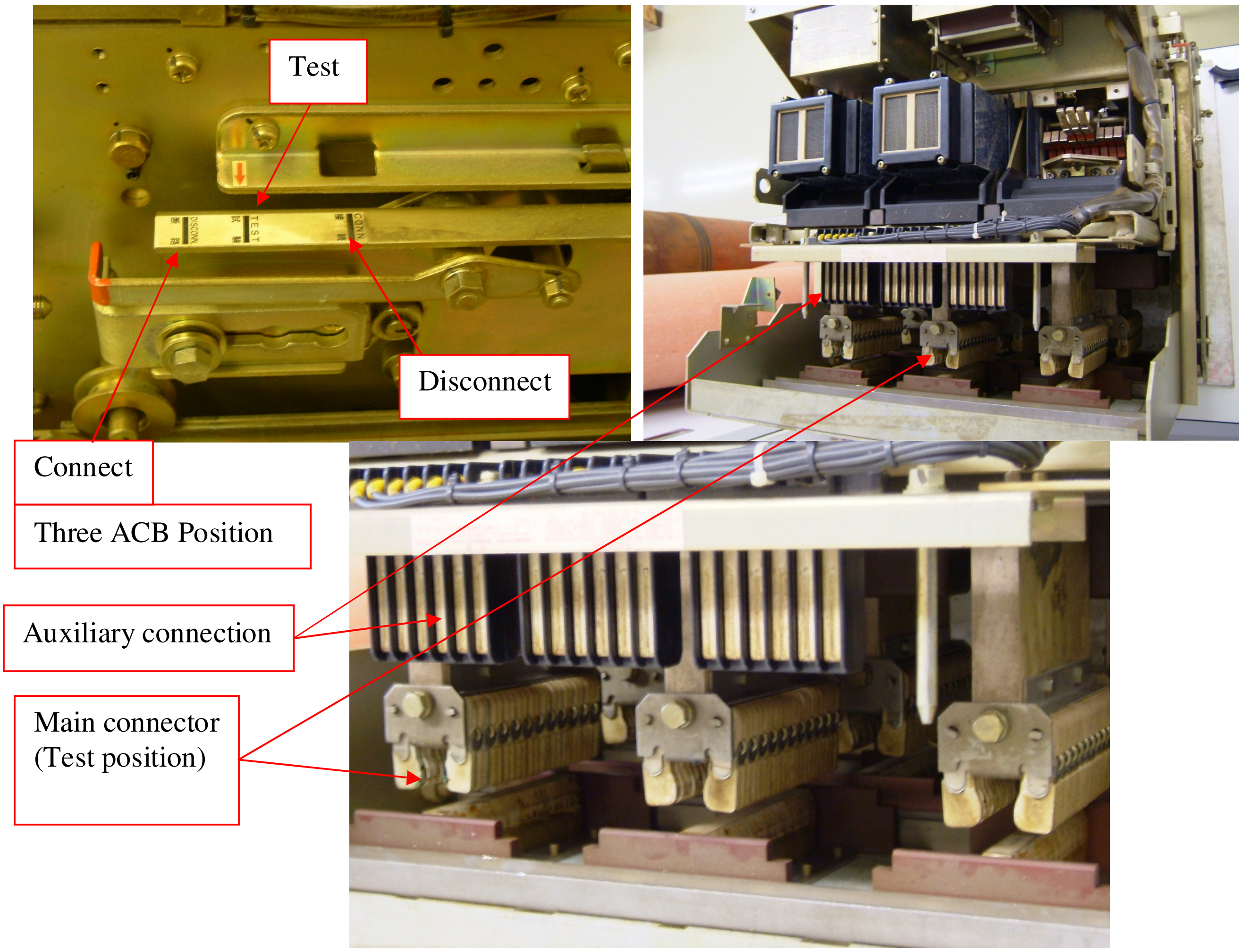
Fig. 4.3 ACB Draw-out Mechanism, note location of release lever, draw out handle and insertion hole

List of parts

3. Release levers
4. Fixing screws
4’. Fixing screws for type AP-20 only
5. Draw-out handle insertion hole
6. Wing screws, draw-out handle and extension rails
7. Draw-out handle
8. Extension rails
9. Breaker stopper
17. Draw-out rails
26. Breaker position indicator plate
27. Breaker body fixing pieces
28. Draw-out operation shaft
29. Breaker fixing plates
30. Test position fixing screws

The draw-out mechanism has the following three breaker body positions, one stationary and two draw-out positions and the breaker body can be locked in any of these positions.

Breaker Body Positions	Main Circuit	Control Circuit	Description
Connected	Connected	Connected	Normal service position
Test	Disconnected	Connected	Position for close-open operation check and control circuit operation test
Disconnected	Disconnected	Disconnected	Breaker completely de-energized



Pic.4.3 ACB body position - Connected, Test and Disconnected

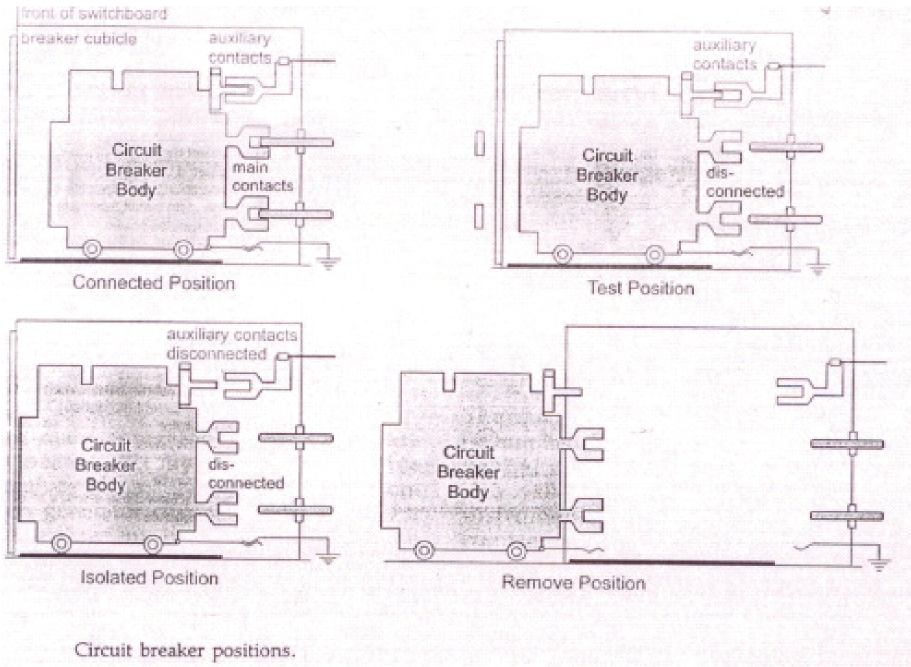


Fig.4.4 Circuit Breaker Position

Draw-out operation must be carried out in ACB "OPEN" condition. If the ACB condition is "CLOSE" position, the draw-out handle is inserted to the hole, automatically handle pushes the trip button therefore ACB is opened as mechanical interlock system.

Connected Position

Both main and control circuit isolating contacts on the breaker body are connected with their counter parts on the draw out frame – this is the normal service position.

Test Position

The main circuit isolating contacts are separated, but the control circuit isolating contacts are connected. In this position, the breaker can be tested for operation with the switchboard front panel shut.

Disconnected Position

Both main and control circuit isolating contacts are separated. In this position the switchboard front panel cannot be shut.

Removed Position

The breaker body is just out of the draw-out frame. More than 2000amp –frame ACB are further drawn out using extension rails (attached)
The action of withdrawing the breaker causes a safety shutter to cover the live bus-bar contacts.

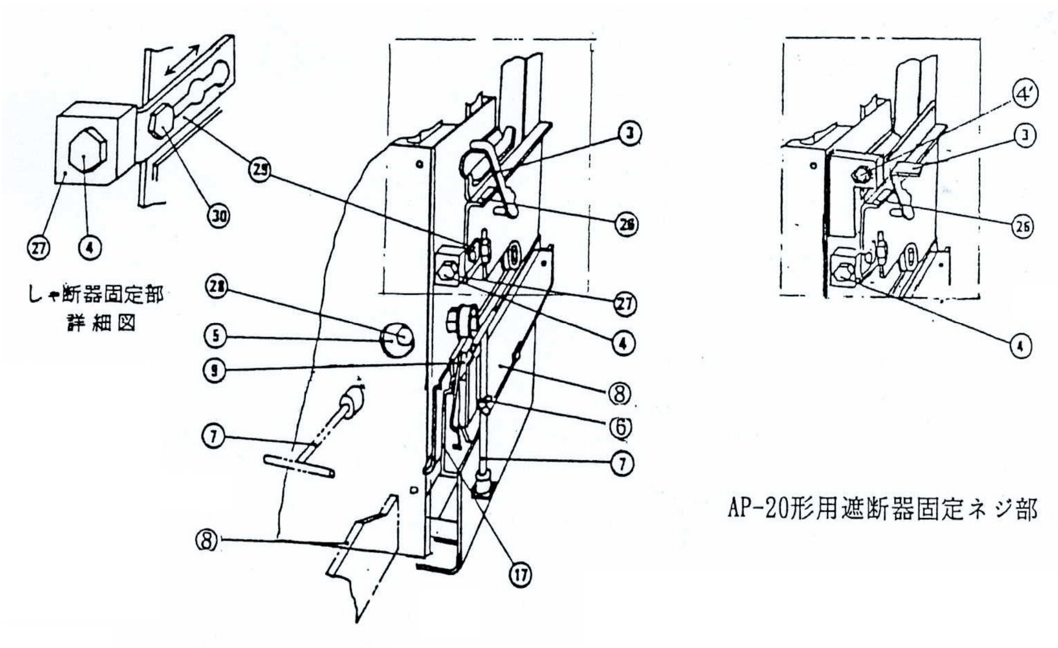


Fig. 4.5

List of parts

3. Release levers
4. Fixing screws for type AP-20 only
5. Draw-out handle insertion hole
6. Wing screws, draw-out handle and extension rails
7. Draw-out handle
8. Extension rails
9. Breaker stopper
17. Draw-out rails
26. Breaker position indicator plate
27. Breaker body fixing pieces
28. Draw-out operation shaft
29. Breaker fixing plates
30. Test position fixing screws

1. Drawing out the breaker from "CONNECTED" to TEST" position

- Loosen and free the right and left fixing screws 4.
- Push the right and left release levers 3 down.
- Pressing the "Trip" button 12, open the shutter, which is covering the draw-out handle insertion hole 5 and engage the draw-out handle 7 with the draw-out operation shaft 28 by inserting the handle 7 through the insertion hole 28.
- Turn the draw-out handle 7 anticlockwise; the breaker slides out.
- When the breaker body slides out to the "TEST" position, the draw-out position stoppers operate and lock the breaker body in position. If locked, do not turn the draw-out handle any further.
- When opening and closing test, etc. are made at this position, be sure to remove the draw-out handle

2. Drawing out to "DISCONNECTED" Position

- After draw-out the breaker body to the "TEST" position, push up the release levers 3.
- Turn the draw-out handle 7 further anticlockwise; the breaker body slides out to the "DISCONNECTED" position and the draw-out position stoppers operate again to lock the breaker body in position.
- If locked, do not turn the draw-out handle any further.

3. Drawing out from "DISCONNECTED" Position to OUT of Draw-out Framework

The breaker body can be further drawn out by using the extension rails 8 for making inspection, maintenance, or parts replacement or for removing the breaker body from the framework.

- Draw out the breaker body to the "DISCONNECTED" position with the draw-out handle 7 and then remove the draw-out handle.
- Insert the extension rails 8 into the end sockets of the right and left hand draw-out rails 17 respectively.
- Push down the release levers 3, and then pull the breaker body forward by holding the breaker body fixing pieces 27 by hands until the extension-rail end stoppers stop the breaker body.
- The draw-out position stoppers will operate at half-way between the "DISCONNECTED" position and fully draw out position and lock the

breaker body in position; unlock by pushing up the release levers 3, if this occurs.

- ❖ After drawing out the breaker body to the fully drawn out position, lift the breaker body off the rails with a chain block or the like, using the lifting plates 2 of the breaker body.

4. Remounting the Breaker Body

- ❖ Insert the extension rails 8 into the end sockets of the draw-out rails 17 and place the breaker body on them.
- ❖ Push up the release levers 3 and push breaker body into the draw- out framework by hands; the draw-out position stoppers will operate and lock the breaker body in the "DISCONNECTED" position.
- ❖ Push the release levers 3 down, then pressing the "TRIP" button 12, open the shutter, which is covering the draw-out handle insertion hole 5 and engage the draw-out handle 7 with the draw-out operation shaft 28.
- ❖ Turn the draw-out handle 7 clockwise.
- ❖ The draw-out position stoppers will operate again when the breaker body reaches the "TEST" position; If locked, do not turn the draw-out handle any further.
- ❖ Push up the release levers 3 and turn the draw-out handle 7 further clockwise. The draw-out position stoppers will operate once again and this is the "CONNECTED" position.
- ❖ Remove the draw-out handle 7 and tighten the right and left fixing screws firmly.
- ❖ Put the extension rails 8 and draw-out handle 7 back to original place and fix in place by tightening the wing screws 6.

4.1.3 Methods for operation of ACB (Stored energy type)

There are three methods for ACB operation depending on the power.

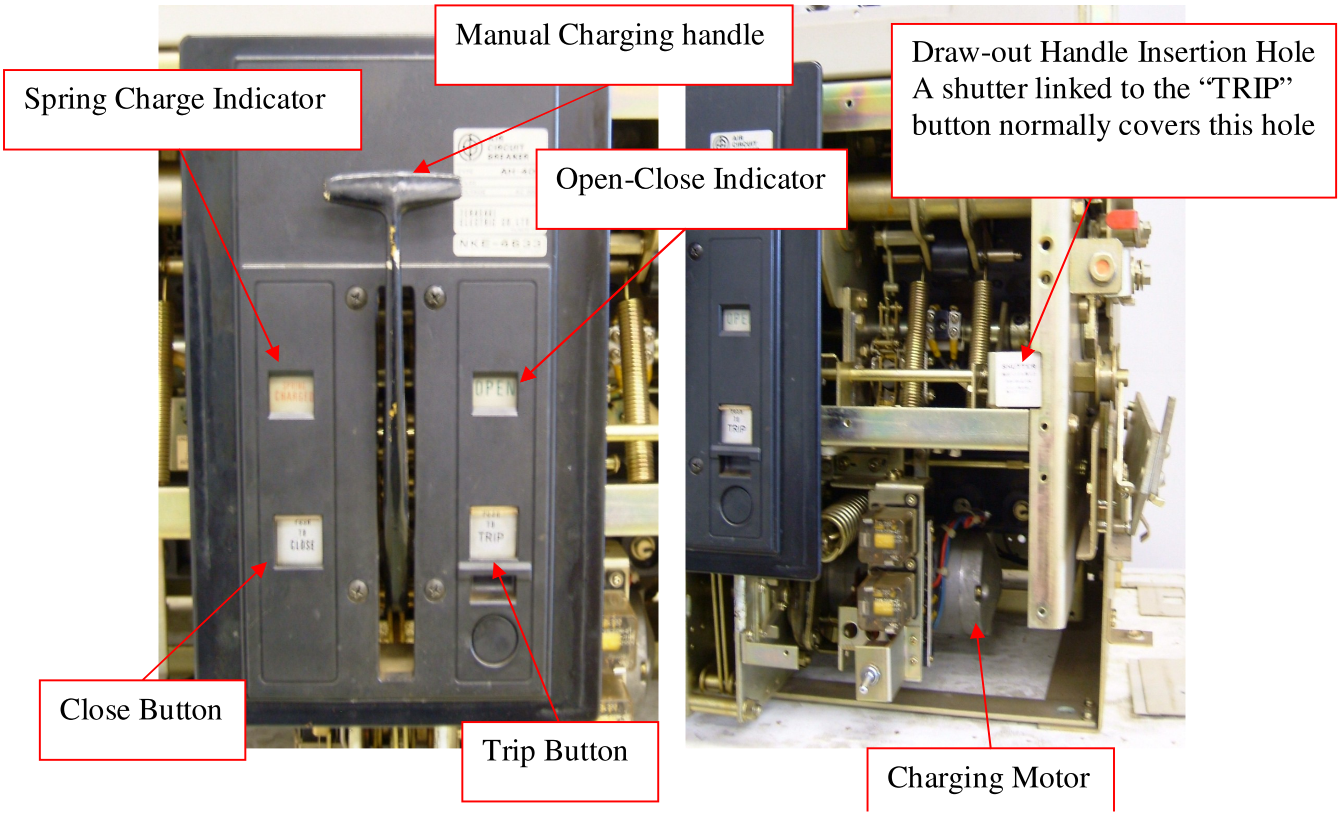
1: Manual hand operation   Example: Non Fuse Breaker
2: Electric magnetic power Example: Mitsubishi Electric DB-50 type
3: Using the spring power Example: Terasaki Electric AH type

This section explains outline of the Terasaki Electric AH; Stored energy type.
Stored energy, charged spring power is charged by hand or electric motor.

1. Manual Charging refer AH type figure

On manually operated breakers, all operations including charging of the closing springs, and closing and opening of the breaker are done by hand, except that tripping is automatic.
The closing springs must be charged before the breaker can be closed. To charge the closing springs, follow the procedure below:

- Check that the quick close / slow-close selector lever 11 is in the "quick close" position; Lower position.
- Pump the charging handle 19; each down stroke charges the springs and the full stroke is about 105 deg by angle.
- Continue the pumping operation until a metallic "click" sound is heard; no further pumping will be possible. When the charging handle 19 is operated in full stroke, four down strokes will be necessary to complete the charging. Check that the spring charge indicator 16 now shows "SPRING CHARGED".



Pic. 4.4 ACB, Terasaki Electric Co Ltd type –AH stored energy type

- The Drive lever is derived by electric motor, and moving the drive pawl and then the ratchet wheel turns.

Control circuit operates the charging motor.

The closing spring power uses not only the closing power, but also charging the trip springs

3. Maintenance Inspection

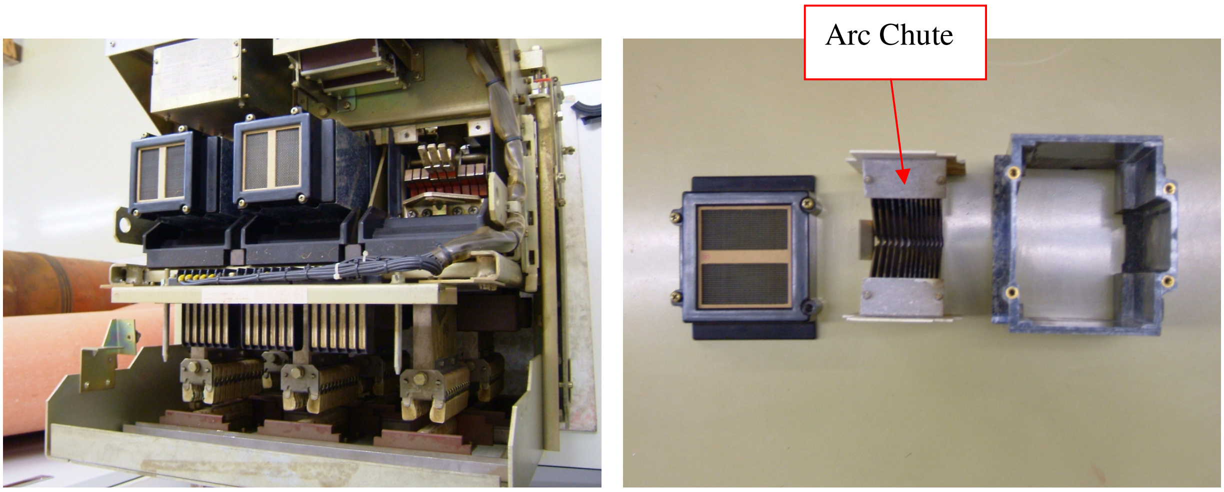
Inspection and maintenance of the mechanism for closing and opening operations such as linkages are carried out periodically, minimum every 6 months depending upon the maker's instruction manual or the management company's instruction.

4.1.4 Arc Chutes (De--ion type)

In the conventional type of ACB, the arc is extinguished at zero current. Hence, in the event of short circuit, it takes a larger time to clear the fault. The operating time is about 15-20 msec. During this cycle, the entire circuit would under go tremendous stress and at times, results in damage to the downstream equipment. The great problem is the influence of arc when it occurs at the time of connecting or disconnecting operation of the contactor. The following items are countermeasures to diminish the arc influence.

1. Magnetic Blow Out
2. Arc Horn, Horn Gap
3. Arc Chute

Current limiting breakers have break time short enough to prevent the short circuit current reaching its prospective peak value. To meet these requirements, the current limiting ACB must respond quickly in case of fault. The operating time is less than 10 msec. This is accomplished by forcing the arc into the arc chute and is cooled and broken into segments in the arc chute until it is de-ionized and ceases to conduct current, thus being extinguished.



Pic.4.5 Structure of Arc chute

4. Other type

The De ion type that uses the magnetic blow out and arc chute for turning off the arc quickly. The structure in above picture 4.5 shows, the number of magnetism plates are arranged with appropriate clearance inside the frame which is heatproof and insulated.
Moving contacts pass through hollow space of the number of magnetism plates.
At the time of connecting or disconnecting the contacts, the arc is broken out, the arc is drawn into the magnetism plates by the electromagnetism force, the arc is interrupted by the number of magnetism plates and makes the new element points, therefore the arc losses the energy. The Arc Chute breaks out the arc shortly by diffusion/re-combination action and cooling action.
Inspect each arc chute during the regular inspection or after short-circuit current was interrupted. Inspection is carried out periodically; minimum every 6 months depending upon the maker's instruction manual or the management company's instruction.

Inspection Item	Method, Criterion and Maintenance
Dirt, dust or foreign material	Check visually. Must be clean and free of dirt, dust and foreign materials. Blow out with air if not clean.
Flaw or crack	Check visually. Must be free of flaw, crack or other damage. Replace arc chute if damaged.

4.1.5 Arcing and Main Contacts

The arcing contact that equips the arc gap or arc horn except the arc chute is used to prevent contact damage at the time of connecting or disconnecting the contact.
Generally the arc damages the contact surface hard when the arc occurs at the contact surface at the time of disconnecting the contact. The carbon, tungsten, makes the arcing contact and so on; these are strong resistance of arc. The main contacts electrify, the arc occurs at the arcing contact. The arc does not occur at the main contact; therefore the main contact does not have the arc damage.

List of parts

1. Stationary arcing contact
2. Stationary main contact
3. Moulded base
4. Hinge
5. Copper ribbon lead
6. Contact holder
7. Contact spring
8. Contact tips
9. Operating rod
10. Contact arm pin
11. Moving main contact
12. Moving arcing contact

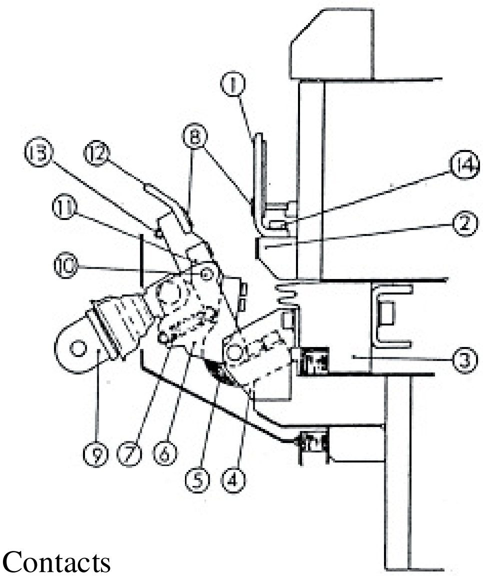
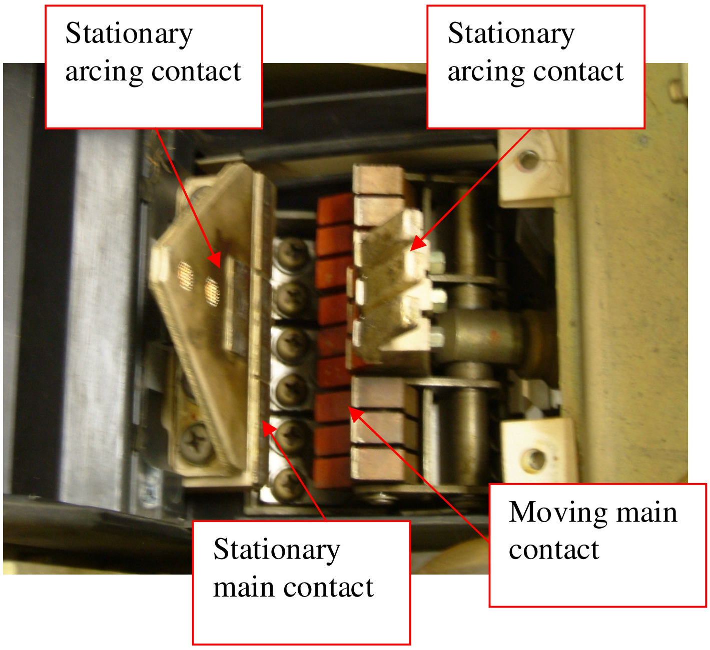


Fig. 4.6 Arcing Contacts and Main Contacts



Pic.4.6 ACB Stationary Contact/moving contact

The gap between stationary and moving contacts of the main contacts is smaller than the arcing contacts at the disconnect condition. Also the form of the arcing contacts is expanded as an arc horn, so the arcing contacts have an angle.

At the disconnected condition, the arc does not occur at the place of main contacts 2, 11. The arc occurs at the arcing contact tips 8, the arc moves from the tip 8 to the end of arc horn. Therefore, the arc does not damage the main contacts.
The arcing contacts surface damage is reduced because of the arc moves from the arcing contacts surface to the end of contacts. This arc horn is used for other breakers for example NFB.
At the connected condition, the main contacts are in connected condition but the arcing contacts are not touching and there is a gap.

The main contacts do not get consumed, but their surface will get roughened, therefore maintenance is to clean the contacts' surface during inspection. But the arcing contacts are damaged due to the arc, so it is necessary to inspect and maintain them.

Maintenance and Inspection of the Arcing Contacts

Inspection Item	Method, Criterion, Maintenance
Contact tip surface	a. Check visually b. Blackening of surface is due to oxidation and sulfide. This will give no problem as it is wiped off when breaker is closed. c. Remove deposition of dirt, oil, etc. if any. d. If surface is rough, polish it with fine sandpaper (#200). If contact tip thickness is reduced to 1/3 or less of original thickness as a result of polishing, replace both moving and stationary contacts with new ones.
Mounting Conditions	a. Check each moving contact for loosening or missing of mounting nut. Tighten or restore as necessary. b. Check each stationary contact for loosening or missing of mounting screws. Tighten or restore as necessary. c. Close breaker and check each pair of contact tips for alignment.
Others	a. Check each contact shaft for missing snap ring. b. Check each contact spring for breaking and disengagement.

Maintenance and Inspection of the Main Contacts

Inspection Item	Method, Criterion, Maintenance
Operation	Charge the closing springs and close the breaker by pressing the “CLOSE” button, then open the breaker by pressing the “TRIP” button; the mechanism should move smoothly without binding. Next, make slow-closing operation with the “TRIP” button kept pressed and check that the moving arcing contacts do not move than 10mm (check of trip free feature).
Lubrication	Feed a slight amount of spindle oil to each of the shafts, pins and bearings. Also apply grease, if necessary, over the engaging tooth surfaces of the ratchet wheel and pawls. Avoid excessive oiling and greasing, or they will result in accumulation of dirt, dust, etc.
Dirt and Dust	The latches must be free of dirt or dust. Wipe off dirt and dust, if any, with clean cloth wet with spindle oil.
Screws, Bolts and Springs	Check the fixing screws and bolts for loosening or missing. Tighten or restore as necessary. Check the springs for disengagement or breakage and repair as necessary.

4.1.6 Under Voltage Trip Device

The under voltage release is used for protecting the installation against undesired low voltage situation. The under voltage release is designed to operate when the voltage drops below the tripping threshold. This can also be used for remote tripping & electrical interlocking purpose. The tripping voltage is 35% to 70% of the rated voltage. Pick-up voltage is 85% of the rated coil voltage
When the generator voltage is below the setting point, the UVT trips the ACB as a safety device. Under Voltage Relay checks the generator voltage. If the generator voltage is above the setting point, the magnetic coil of the UVT is energized by the UVR output signal and then the tripping lever is kept in the reset position.
On the contrary, if the generator voltage is below the setting point, UVT is not energized. When the ACB is in closed condition, the ACB is tripped by UVT device. When the ACB is in open condition, the ACB keeps the tripping condition by the UVT device.

UVT function lock

The breaker closing operation is not possible when rated voltage is not supplied to the UVT. To allow for breaker closing operation without applying the rated voltage to the UVT for inspection and maintenance purposed, lock the UVT function by keeping the reset pin lever 17 pulled toward the front such as by securing with a piece of wire. When returning the breaker into service, be sure to remove this securing wire.

List of parts

1. E-ring retainer
2. Terminal mounting plate
3. Mounting screw for above, pan head M5
4. Stationary core mounting plate screw,
   pan head M4
5. Stationary core mounting plate
6. Terminal block
7. UVT mounting plate
8. UVT mounting screw, hex head M6
9. Breaker crossbar bearing
10. UVT Fixing screw, hex head M5
11. Reset pin
12. Trip plate
13. Coil
14. Moving core guide plate
15. Terminal nameplate
16. Trip piece
17. Reset pin lever

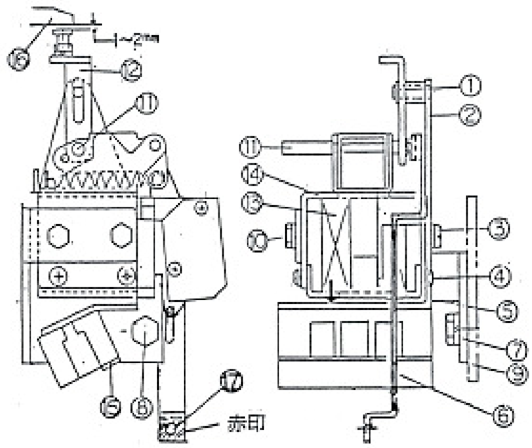
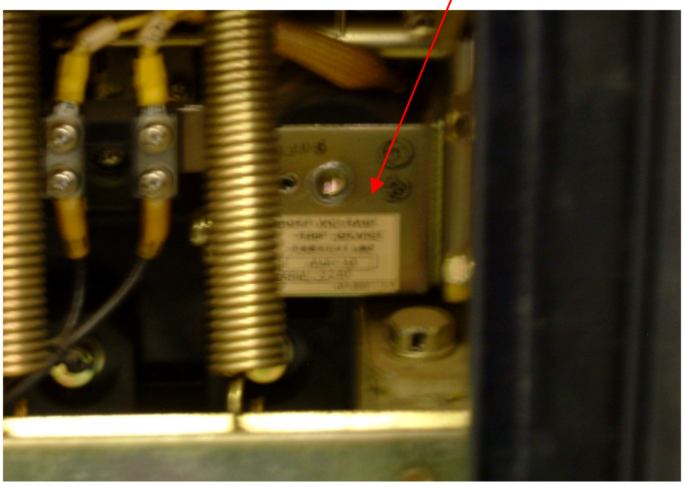


Fig. 4.7 Under Voltage Trip Device

Under Voltage trip Device

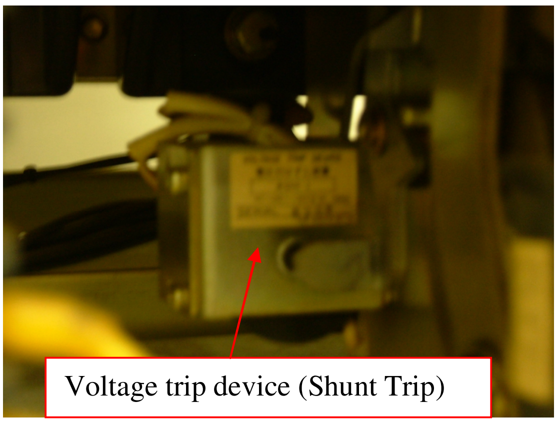


Pic. 4.7 Under Voltage Trip Device

Inspection Item	Method, Criterion and Maintenance
Operation	a. With the UVT de-energized, make a slow closing operation and check that the breaker does not close (check of trip free feature). b. With the UVT energized at normal voltage, check that the breaker can be normally closed (this check may be made with the breaker at the "TEDT" position).
Coil	Measure the coil resistance with an ohmmeter or VOM; it should be about 160 ohms. If the measured resistance is considerably lower than this value or if a discontinuity is found, replace the coil with a new one.
Terminals and Mounting Screws	Check the terminals and mounting screws for loosening or missing. Tighten or restore as necessary.

4.1.7 Shunt Trip Device: Voltage Signal Trip Device

Shunt release is used for remote tripping of the circuit breaker under emergency conditions. The operating voltage is 70% to 110% of the rated voltage. The shunt release is short time rated.
The SHT is one of the tripping devices for the ACB by the outside safety device. The ACB is tripped by energizing coil of the SHT; the voltage signal trips the ACB. The shunt mechanism for NFB is same as that of mechanism for this SHT of the ACB.



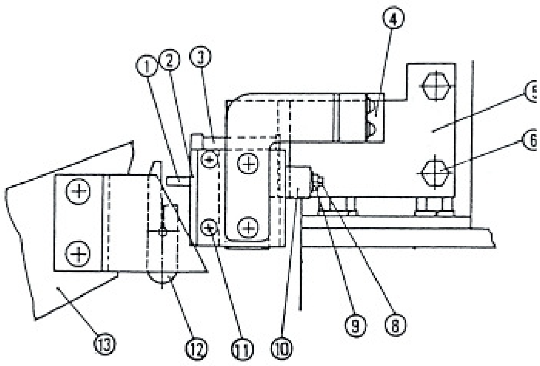
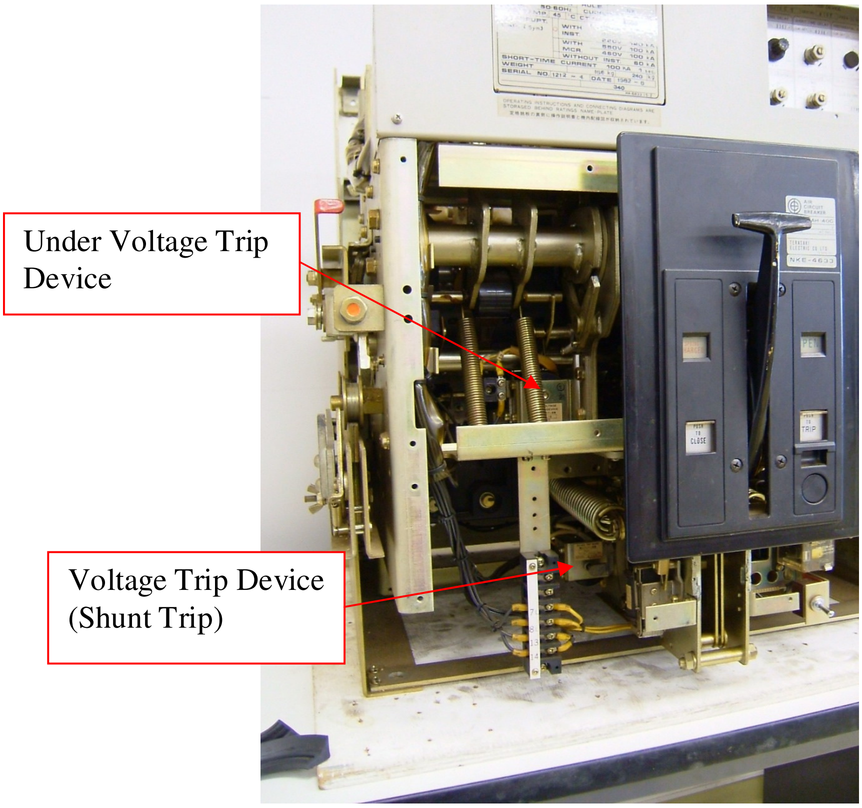


Fig. 4.8 Shunt Trip Device

List of parts

1. Plunger
2. Stationary core mounting plate
3. Coil
4. Terminal block
5. Support
6. Support mounting screws (hexagon head, M6)
7. Support base
8. Adjusting screw
9. Lock nut
10. Moving core
11. Mounting screws, stationary core mounting plate (pan head, M4)
12. Trip piece
13. Breaker frame

When the Shunt Trip Device receives the tripping voltage signal, Plunger 1 pushes the trip piece 12 and then the breaker is tripped.

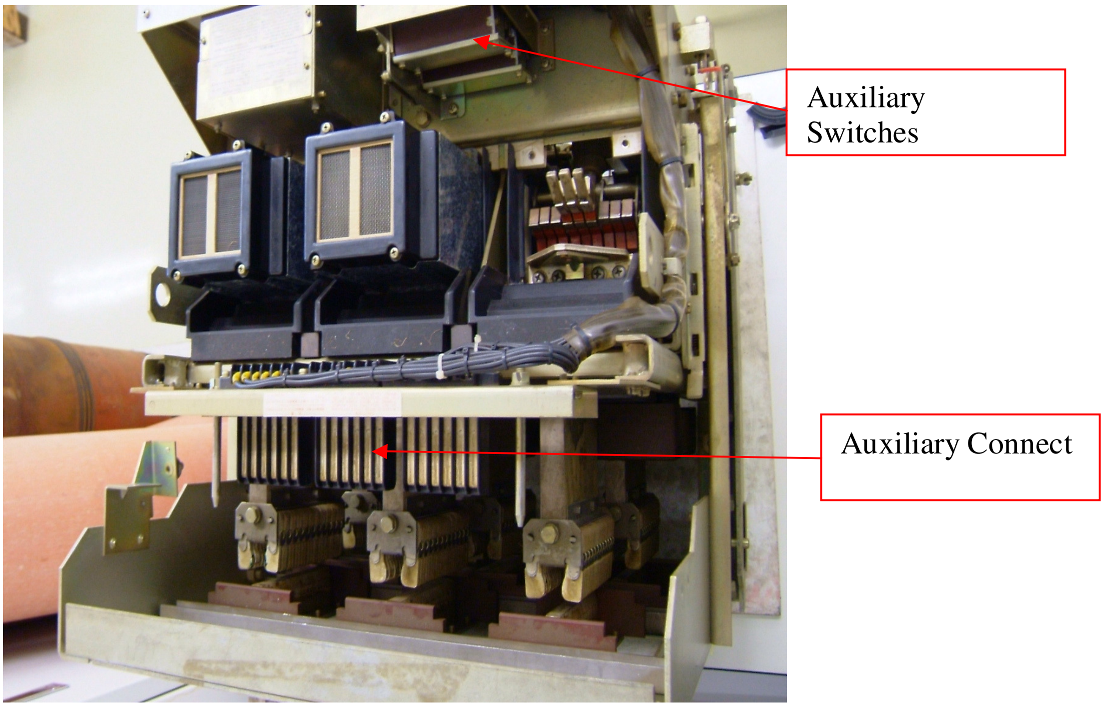


Pic. 4.8 Under Voltage Trip Device

Inspection Item	Method, Criterion and Maintenance
Operation	a. Remove the left-hand Front Cover (18) push the moving core (10) of shunt trip device with a trip of a screw-driver or the like, release slowly, and check that the moving core returns lightly as released. b. With the moving core kept pushed, make a slow-closing operation and check that the breaker does not close (Check of trip free feature).
Coil	Measure the coil resistance with an ohmmeter or VOM. If the resistance is considerably lower than the specified value or if a discontinuity is found, replace the coil with a new one.
Terminals and Mounting Screws	Check the terminals and mounting screws for loosening or missing. Tighten or restore as necessary.

4.1.8 Auxiliary Switches

The signal of open or close position of the ACB is necessary for controlling the other devices. Therefore the auxiliary switches, which are linked with the ACB open or close position, are equipped.



Pic. 4.9 Auxiliary Contact

4.1.9 Over Current Trip Device

The over current trip device detects the over current and trips the breaker. Trip types are long and short time delay, having different characteristics in relation between the current and period.

Pic. 4.10 Over Current Trip Device

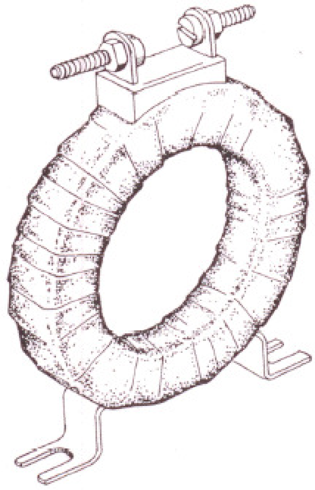
The over current trip device is of two types, one is the direct operation type, other is the indirect operation type. The direct operation type uses the electromagnetic force in which the power source is the main poles current transformers. The indirect operation type uses the electromagnetic force in which the power source is the ordinary electric but the trip signal comes from the inside device of ACB. Now, most ACBs are of indirect operation type.

<Indirect type Over Current Trip Device>

In Indirect type, the control and safety device receives the over current signal from the current transformer in the same unit and is operated by other coils electromagnetic forces.

1) Operational Base Current

The appropriate current transformer is selected depending upon the rated current of the circuit as same as the generator rated current. In addition, the operational base current is adjusted to equal the rated current of the circuit by the input matching on the internal over current relay equipment. The setting point of the over current trip device is selected as a percentage, based on the operational base current.



Bar primary CT.

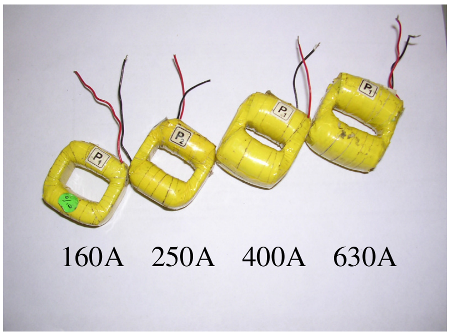


Fig. 4.9 Bar Primary Current Transformer

Current Transformers

All current transformers are accurate within1% of full rating. They are used to supply instruments and protection relays with proportionally small currents derived from the main bus bar.

One side of the secondary of all current transformers is grounded.

All current transformers (CT) are molded epoxy resin insulation.

The standardized operating current output is 1 Amp or 5 Amps.

The secondary circuit of a CT must never be opened while mains primary load current is flowing. Excessive heating will be developed in open-circuit with an extremely high voltage arising at the open secondary terminals. If an ammeter is to be removed from the circuit, the CT secondary output terminal must be first short circuited with the primary circuit switched off. The secondary short circuit will not damage the CT, when primary current is switched on

1) Long Time-delay Trip

- ❖ Range of Trip Current: 100%, 105%, 110%, 115%, and 125% of the rating current
- ❖ Range of Time-delay: 15 to 60 second variable time-delay at the 120% trip current setting.

2) Short Time-delay Trip

- ❖ Range of Trip Current: 200-250-300-350-400% of the rating current variable %
- ❖ Range of Time-delay: 120 to 420 millisecond variable time-delay over the setting current.

3) Instantaneous Trip

- ❖ Range of Trip Current: 200 to 1600% of the rating current variable %.

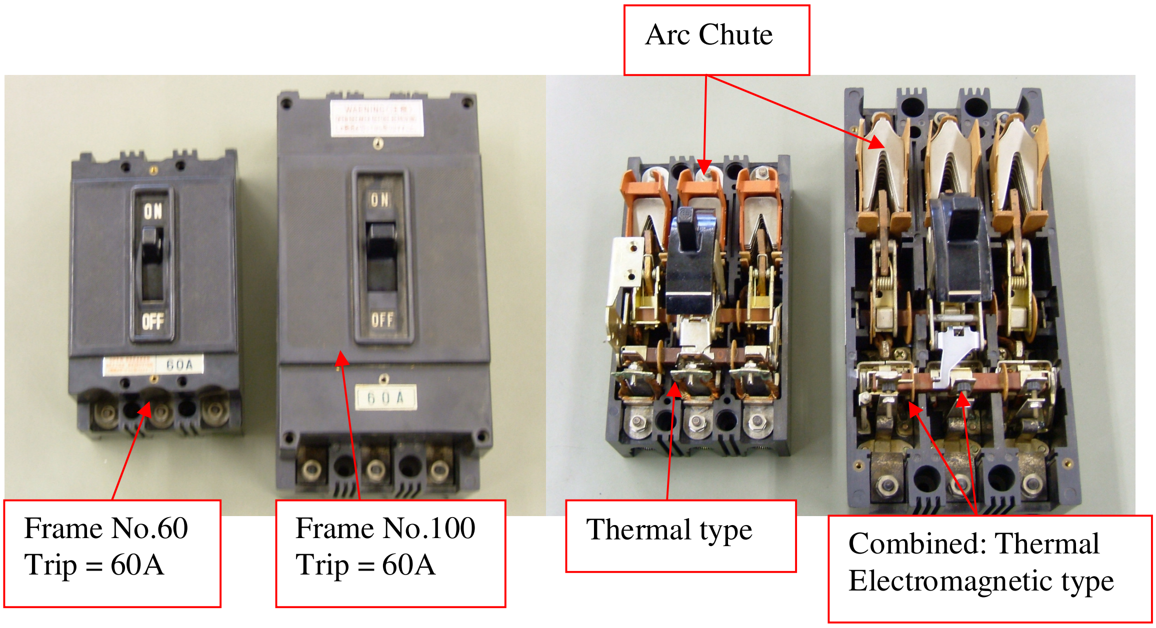
4) Preferential Signal

- ❖ Setting current range of the output signal: 82-84-86-88-90-92-94-96% of the long time-delay trip setting current.
- ❖ Range of Time-delay: 5 to 10 second time-delay at the 120% the long time-delay trip setting current.

4.2 No Fuse Breaker (NFB) or Molded Case Circuit Breaker (MCCB)

The Circuit Breaker is used to prevent the troubles of over current for the lighting equipments or the motor for pumps and fans. NFB is generally used for the circuit breaker. It is not only used for the electric source “ON” “OFF” operation, but also trip action for protection of the over current trouble.
After tripping, a fuse element requires replacement where as in case of NFB it can be reset and used, but replacement is not necessary.
Features of MCCB:
All parts of the circuit breaker are enclosed in a moulded housing, which is made of heat resisting insulating material. Only terminals are accessible for external connections.
Operating knob gives a clear trip indication. It assumes a position midway between ON and OFF on tripping.
The breaker is usually provided with magneto-thermal release, which has three bimetal strips to give thermal release for overload protection and electromagnets, which offer short circuit protection.

Rating Current(A)	Rating Current×1.25 multiples	Rating Current×2 multiples
Less than 30A	Less than 60 min	Less than 2 min
30A- 50A	Less than 60 min	Less than 4 min
50A-100A	Less than 120 min	Less than 6 min
100A- 225A	Less than 120 min	Less than 8 min
225A- 400A	Less than 120 min	Less than 10 min
400A- 600A	Less than 120 min	Less than 12 min



Pic. 4.11 Moulded Case Circuit Breaker

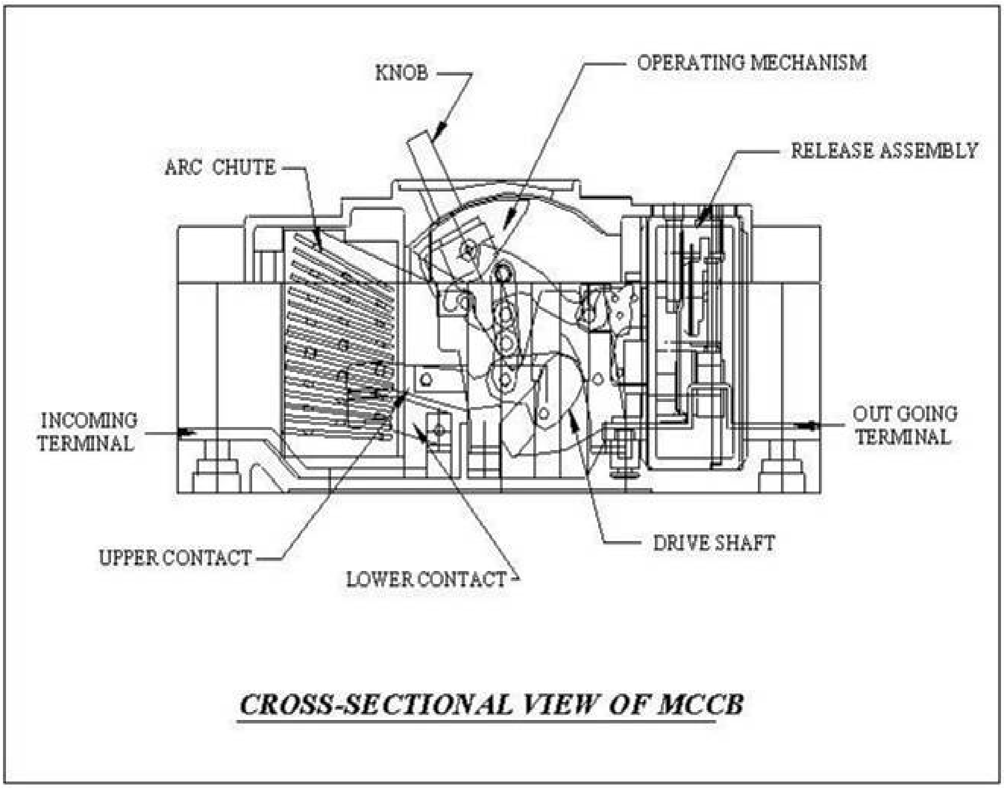


Fig. 4.10 MCCB Cross-Sectional view

The NFB is composed of the Mould parts, Open/Close mechanism, Arc Chute, Trip mechanism and Connect parts.
* Mould parts
The mould parts are base, cover, handle, etc. and are made of phenol resin. These are designed to have sufficient mechanical strength as well as able to withstand heat.

Open/Close mechanism

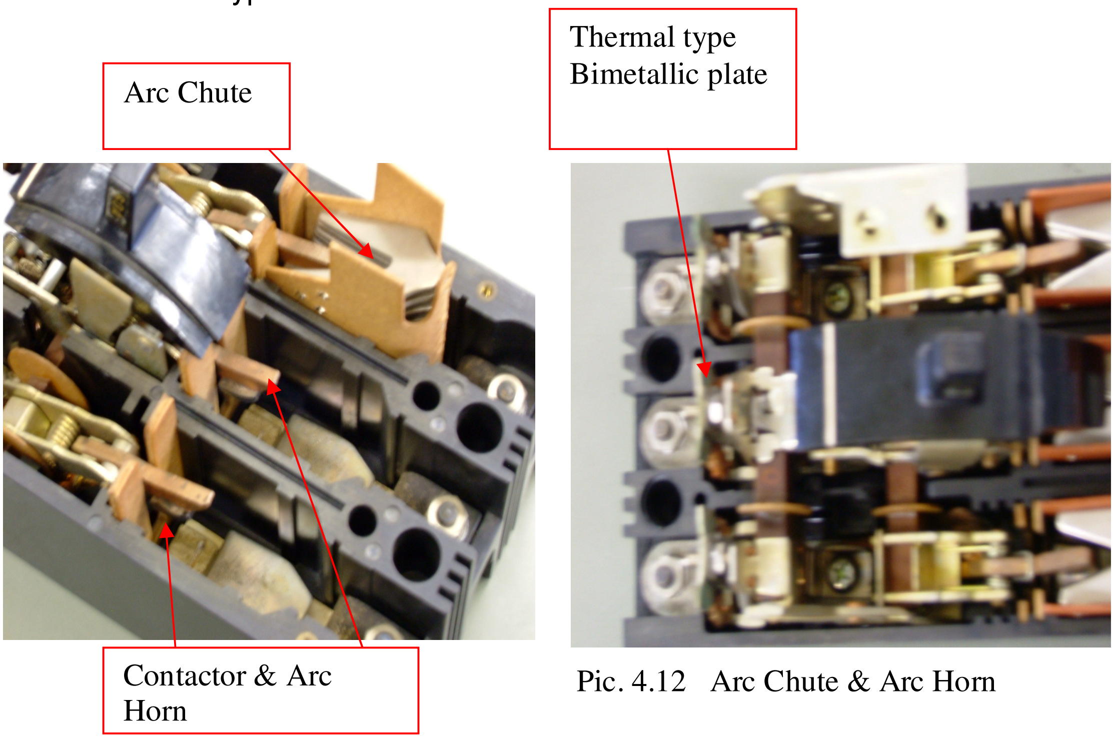
Open/Close mechanism is the Quick make - Quick break system by the spring and the Toggle links. The contact part is composed of the stationary contact and moving contact. The large capacity contactors are equipped with the arcing contacts and arc horn to prevent damage to the main contacts.
The release mechanism operates on a common trip bar, so that all the phases are disconnected even when fault occurs on only one of them, thus eliminating the possibility of single phasing. Contacts are of silver alloy, which have long electrical life

Arc Chute

Consists of profiled de-ion plates housed in special grade vulcanized fibre casing. Individual arc-chutes envelop each contact and draw the arc away from the arching tips and thus quench the arc
The arc chute is De ion type. Please refer the ACB arc chute.

Trip mechanism

The types of trip mechanism are the thermal type, the electromagnetic type and the combined type.



Pic. 4.12 Arc Chute & Arc Horn

1) Thermal type

The thermal type uses the bimetallic plate, when current is increasing the bimetal temperature increase, therefore bimetallic plate is bent and activates off the tripping trigger.

2) Electromagnetic type

The electromagnetic type uses the magnetic coils, when current is increasing. The coil pass current increases and then the magnetic force increases, therefore the magnetic power moves the plate for tripping trigger.

3) Combined: Thermal Electromagnetic type

The combined type uses the thermal system together with electromagnetic system.
Normally the thermal system covers a long time-delay and the electromagnetic system covers short circuit current.

❖ Connection parts

There are many connection types, the front connected type, the rear connected type, the rear plug-in type, etc.

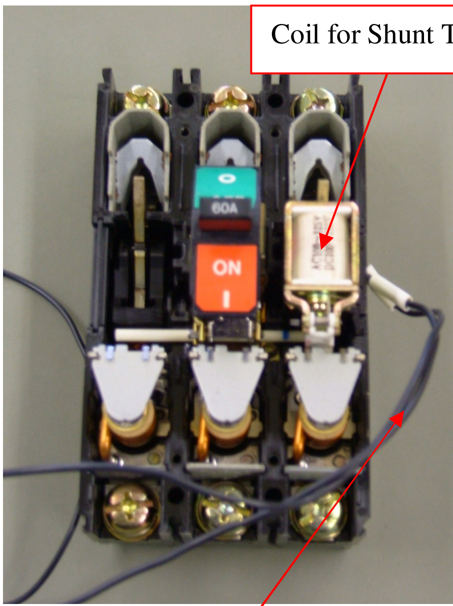
❖ Type

Classify the NFB into the ampere frame and breaker rated current. Classify the type into the connection type and accessories e.g. the alarm switch, voltage signal tripping, etc.
There are Frame Nos 60, 100, 125, 200 and so on ampere frame and 10A, 15A, 20A, 30A and so on breaker rated current. The interception current is 5,000A to more.

❖ Voltage trip device

The voltage trip device is one of the accessories, which remotely breaks off the NFB by using the voltage signal. The voltage signal energizes the tripping coil, the electromagnetic force takes off the tripping hook and then NFB is tripped.

NFB with the Shunt Trip



Coil for Shunt Trip

Wiring for the Voltage Trip
(Shunt Trip) Device

Pic. 4.13 NFB with Shunt Trip

4.3 Thermal relay

The thermal relay is one of the safety devices for the electric motor and set up before main contactor. The current passes through the bimetallic plate. When the current is increasing, temperature of the bimetallic plate increases, thus the bimetallic plate is bent and position of contact is changed.
The thermal relay is not a breaker. When the current is over the setting point, the thermal relay outs put the signal to other devices.

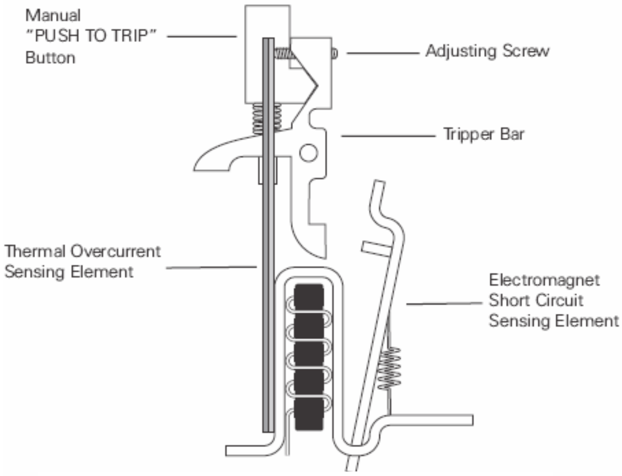
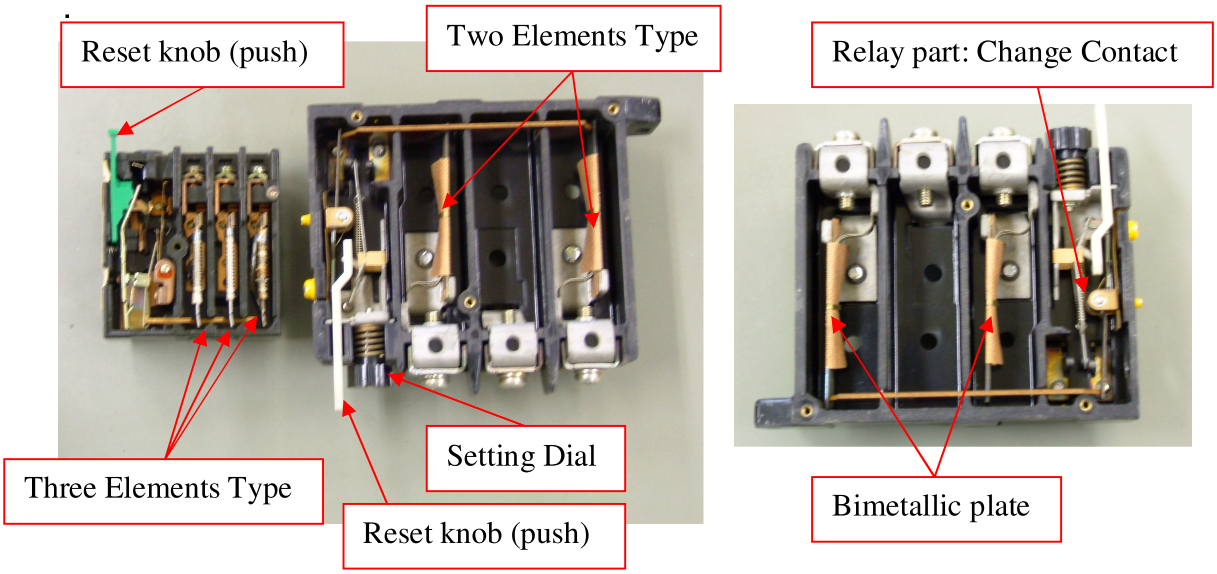


Fig. 4.11 Thermal Magnetic Release



Pic. 4.14 Thermal Trip

The characteristic of the delay time and current curve is as same as the characteristic curve of the electric motor coil. Therefore the thermal relay is the most useful to prevent the motor protection.

Necessary operational characteristics are

1. operates in less than 45 seconds at the 500% of rated load current of the motor
2. operates in less than 4 minutes at the 200% of rated load current after the saturation of the rated load.
3. no operation at the rated current, but operation the 125% of rated load current.

The heater elements, the bimetallic plate of the thermal relay is set at two phases normally, but in few cases set at three phases. Most of the thermal relays are with temperature compensation, therefore the diversification characteristics of temperature, depending upon the surrounding temperature, is less than 10%.

4.4 Magnetic Contactor

Structure

The magnetic contactor connects the main wiring by using the electromagnetic power.

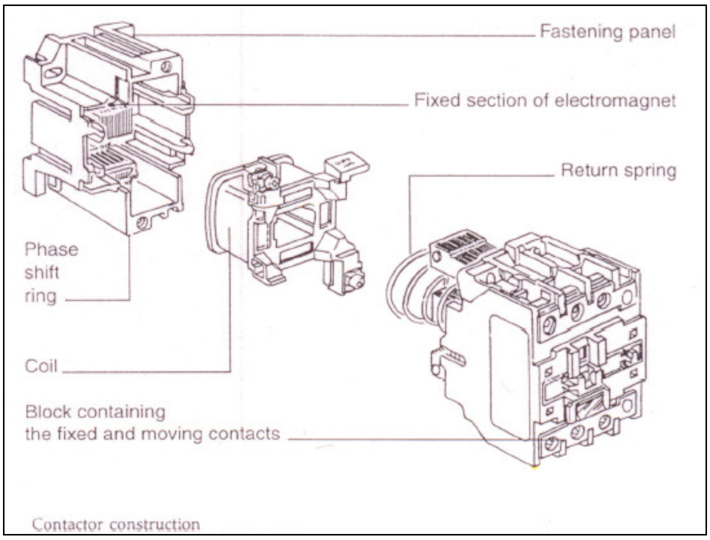
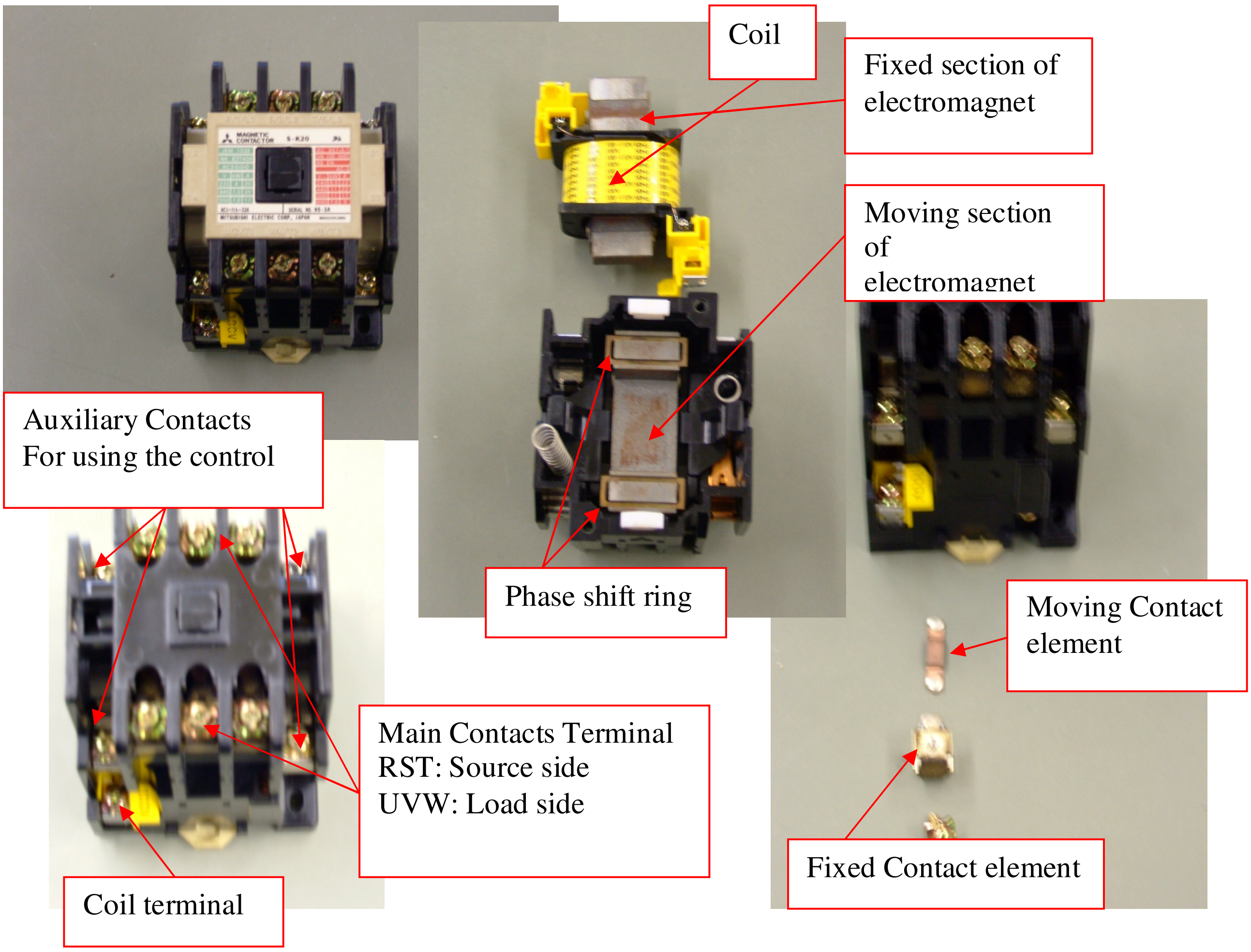


Fig. 4.12 Magnetic Contactor



Pic. 4.15 Magnetic Contactor

Maintenance

Contactor

The contact face color is sometime changed to black by the sulfide film. The arc makes the sulfide film, but this film does not influence the performance.
When the contact face has a rough skin due to abnormal current, it is repaired by removing the asperity of contact face, but no polishing should be carried out.
The contactors get consumed due to prolong usage, so the wipe is reduced. It means reduction in compression of the spring, therefore contact pressure is reduced. If the wipe value reaches limitation, it is necessary to renew the contactor tips. It is necessary to renew the three phases moving and stationary contactors' tips at the same time.

Electromagnet

When the dust adheres to or rusts the contact face of iron core for the electromagnet, the electromagnet is capable of producing a buzzing sound. It creates a risk of burning out the coils. If contact face is rusty or dusty, remove the rust or dust by rubbing with dry and clean cloth. Supplying the oil to the contact face is prohibited. If the emery cloth polishes the contact face, it causes buzzing.

<Replacing the contact tips>

- Stationary contacts tip

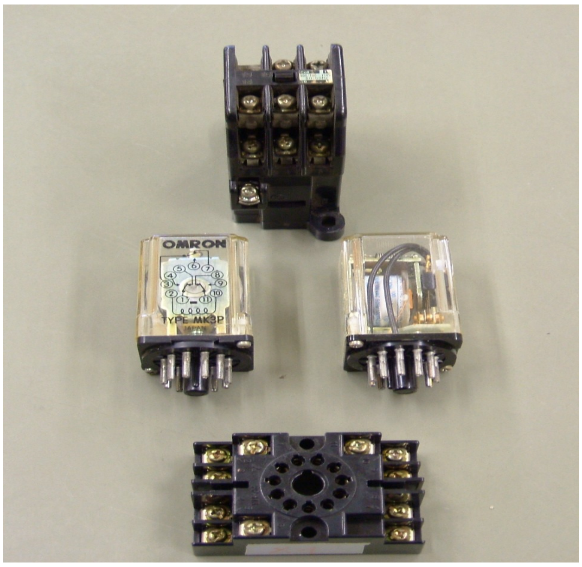
A small screw fixes the stationary contact tip, therefore it is possible to replace the tips by removing the setting screw.

- Moving contact tips

Lift up the clip part by using the minus screwdriver, grip the moving contact tip, slant it and pull it out.

4.5 Auxiliary Relay

There are cable shoes connecting type with “a” and “b” contacts and plug - in type with “c” contacts of auxiliary relay. The structure of cable shoes connecting type is same as the magnetic Contactor. In case of the socket type, out view and pin numbers are same but these are also of different types such as magnetic coil type, voltage relay and current relay.
Confirmation of the type of coil is important.



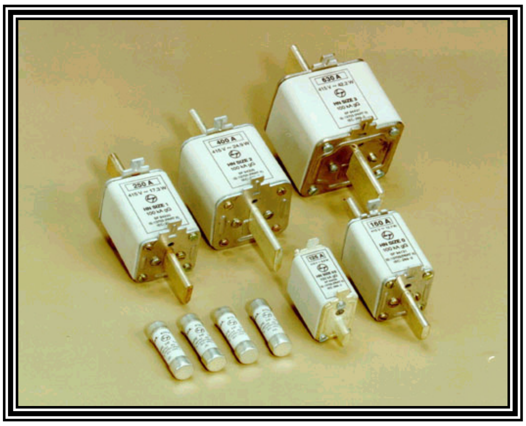
Pic. 4.16 Auxiliary Relay

4.6 Fuses

The fuses are used for the control circuit, which does not use the NFB, and are of many types.

The types of fuses are given below:

1) Glass tube fuse
2) Cello - Lite cartridge fuse
3) Wire fuse
4) Claw fuse
5) Plug fuse
6) Fuse with alarm
7) Rapid fuse
8) Time lag fuse
9) Cartridge fuse



Pic. 4.17 Fuses

4.7 Miscellaneous

4.7.1 Classification of Insulation material:

The electric equipment temperature rises by the heat of electric loss. The insulation resistance decreases, when the temperature rises.

The insulation is classified according to the capacity to withstanding the limit temperature continuously without problem and denoted as class “A”, “B”, etc.

Insulation Class	Limit Temperature	Applicable Insulation Material
Y	90ºC	Cotton tape, Cotton sleeve, Japanese paper, Fiber, Kraft paper, etc.
A	105 ºC	Varnish cloth, Varnish tube, Bakelite, Polyvinyl, etc.
E	120 ºC	Polyethylene, mica-film, Polyurethane resin, etc.
B	130 ºC	Micanight, Micanight paper, etc.
F	155 ºC	Varnish glass cloth, Varnish asbestos, etc.
H	180 ºC	Silicon resin, Silicon varnish, etc.
C	180 ºC Over	Mica, Ceramic, Glass, Quartzes, etc.

4.7.2 Standard range of Insulation Resistance

The normal insulation resistance should be taken as per NK rules.

The 500-voltage resistance meter is used to measure the insulation resistance.

The minimum required insulation resistance for each equipment is given below.

1) Generator, Transformer, Electric motor
Rating voltage (V) x 3 / (Rating output kW or kVA plus 1,000   Mega-ohm

2) Switch board and panel equipment
Between line and earth = 1 Mega-ohm

3) Electric way for lighting, power and electric heater equipment

Current	Insulation Resistance
less than 5A	0.025MΩ
5A - 10A	0.05MΩ
10A - 25A	0.1MΩ
25A - 50A	0.35MΩ
50A - 100A	0.4MΩ
100A - 200A	1MΩ
over 200A	2 MΩ

What is a Preferential Trip? How does it help prevent a Blackout?

Generator is the heart of the ship and it is of utmost importance that in case of overloading of the system the generator remains intact. You certainly are aware of a situation when the electric supply gets lost temporarily on land and how inconvenient it can be. Just imagine the similar situation on a ship sailing in the middle of the ocean with no external source of power. It is certainly an emergency situation and hence the best thing is to avoid such a situation in the first place. We have several mechanisms so ensure this and we will study one such system here.

Preferential trip is a part of the ship's generator protection system. The tripping system is designed in such a way that it removes all non essential loads from the generator in case of overload or partial failure of supply, thus preventing main power loss on the bus-bar. For the purpose of preferential tripping, machinery is classified as essential and non-essential.

Examples of non-essential loads are: fans, refrigerator compressor, crane, lathe, grinder, arc welder, air conditioning, deck powered equipment like cooking, baking oven, etc.

In between non-essential and essential, there may be some machinery like boiler feed water pump, boiler water circulating pump, fuel transfer pump, oil purifier, sludge, ballast pump, hot water circulating pump, distillation pump, freshwater and potable pumps that could be tripped off to reduce the load. These may be set to trip if tripping the non-essential loads could not reduce the overall overloaded condition.

Essential loads are mostly equipment that is related to the working of the main engine, steering gear and the safety of the ship. Examples of these are: Cooling seawater pump, jacket cooling water pump, piston cooling water pump, lubrication oil pump, fuel valve cooling water pump, turbocharger oil pump, stern tube lubrication oil pump, stern tube seal oil pump, steering gear pump, fire and general service pump, bilge pump, main air compressor, auxiliary seawater pump, auxiliary air compressor, condensate water pump, fuel oil booster pump.

Chapter 5

Brushless AC Generator

5.1 AC generator Construction

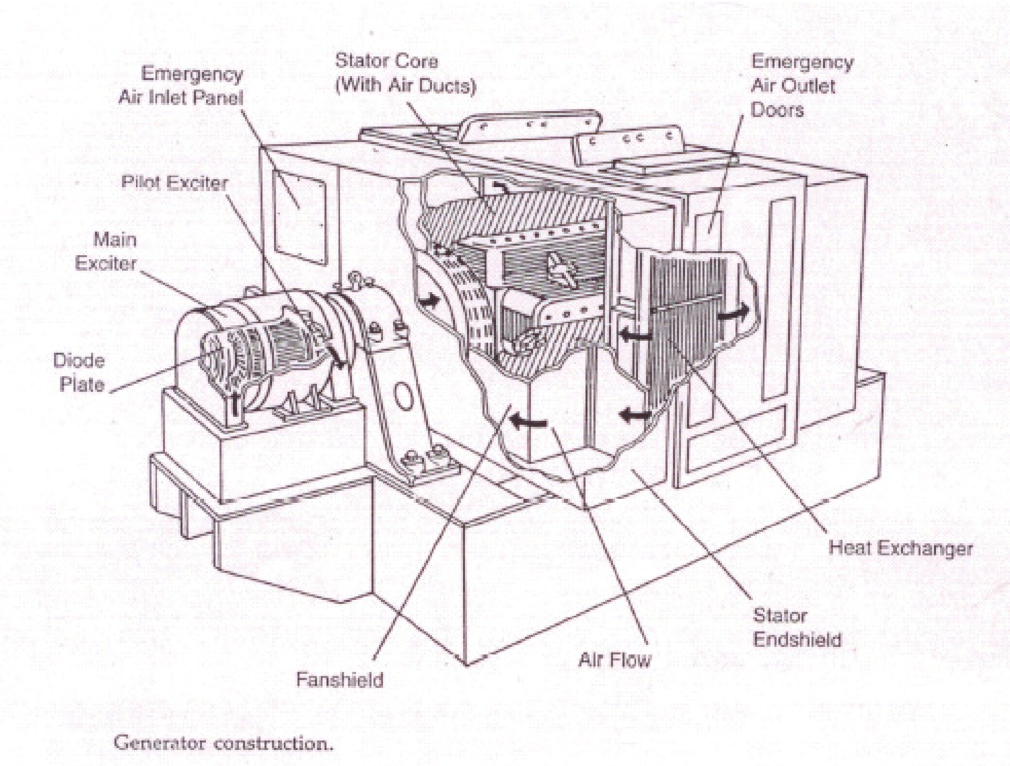
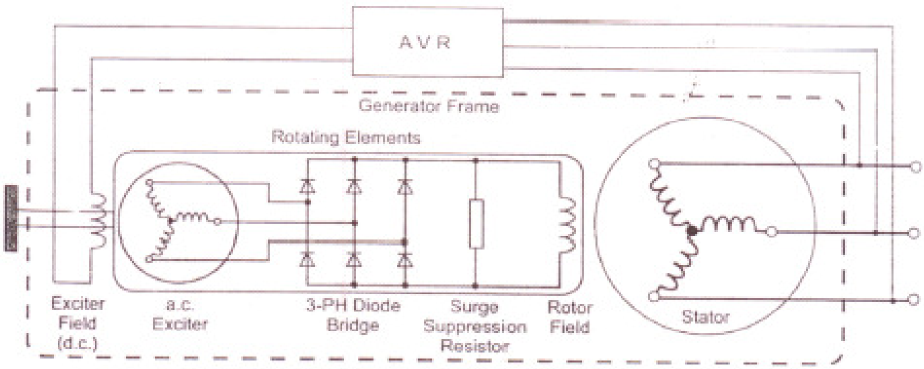


Fig. 5.1 Brushless AC Generator Construction

In this machine, slip rings and brushes are eliminated and excitation is provided not by a conventional direct current but by a small alternator within the set itself. There are no direct electrical connections between the rotating and stationary windings

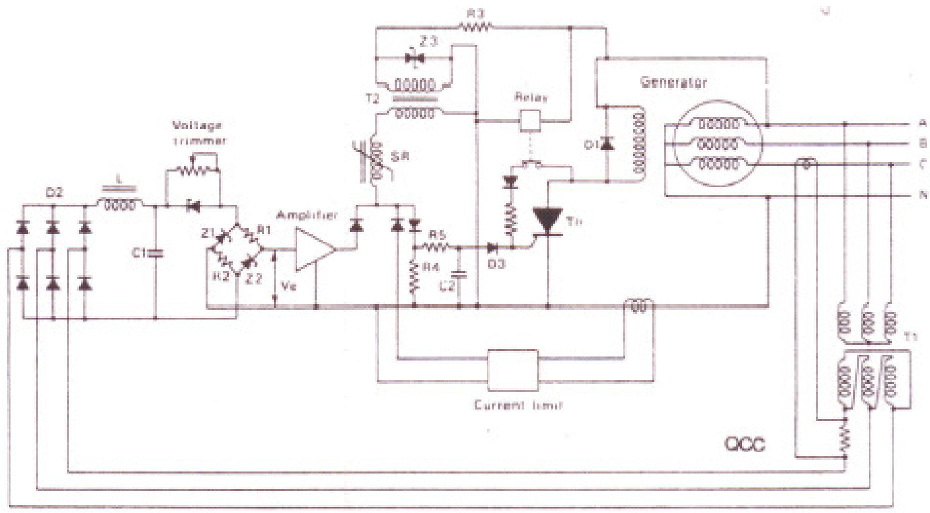
The exciter has the usual arrangement of three-phase output windings on the rotor and magnetic poles fixed in the casing. The casing pole coils of the exciter are supplied with direct current from a static automatic voltage regulator. Three-phase current generated in the windings on the exciter rotor passes through a rectifier assembly on the shaft and then to the main alternator poles. No slip rings are needed. The silicon rectifiers fitted at the end of the shaft are accessible for replacement and their rotation assist cooling. The six rectifiers facilitate full-wave rectification of the three-phase supply.



Brushless excitation scheme.

Fig. 5.2 Brush Less Excitation Arrangement

5.2 Exciter



Static excitation AVR circuit.

Fig. 5.3 AVR Circuit

The exciter portion of the AC Generator is a mini generator that develops the power necessary to develop the magnetic field in the main generator section.
The exciter field is a stationary DC energized winding. This is the winding where the DC. Magnetic field is initially developed. Even before any voltage regulation takes place, a residual magnetic field exists in the poles. During voltage

regulation, DC in the exciter's field induces an EMF resulting in flow of current in exciter armature.

5.3 Residual Magnetism/Voltage Built-up

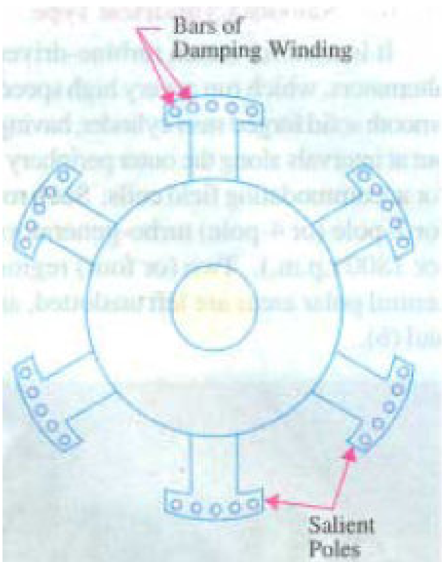
Residual magnetism exists in all ferrous metals which have had a current carried around it. The ships' generators have lot of metal and material mass maintaining adequate residual magnetism in the exciter's field which in turn helps to induce an EMF .The property of the metal will cater to a wide hysteresis loop or B/H curve. The residual magnetism in the generator's exciter field allows the generator to build up voltage when starting. The magnetism is sometimes lost due to shell time and improper use.
Restoring this residual magnetism is possible and is referred to as flashing the exciter field.

5.4 Main Rotating Field

The main rotating field of the generator can consist of four to eight individual coils or pole pieces keyed to the rotor shaft. The coils are connected in series. The direction of the wire, wound around the pole piece, determines the polarity of each field coil.
When the rotor is made to rotate at a constant speed, the stationary windings experience a periodically varying magnetic field. Thus, EMF (Electromotive Force

/or Voltage) is induced across these windings. This EMF is AC and periodic and each period corresponds to one revolution of the rotor. Because the windings are displaced equally in space from each other (by 120 degrees), the EMF waveform is displaced in time by 1/3 of a period. The machine is therefore capable of generating three-phase electricity. The machine has two poles, since its rotor field resembles that of a bar magnet with a north pole and a south pole.

5.5 Damper Windings



Embedded in the face of each main field pole piece is the damper winding. Damper windings on the rotor stabilize the speed of the AC generator to reduce hunting under changing loads. If the speed tends to increase, induction generator action occurs in the damper windings. This action places a load on the rotor, tending to slow the machine down. If the speed tends to decrease, induction motor action occurs in the damper winding, tending to speed the machine up. The windings are copper bars located in the faces of the rotor pole pieces. Mounted parallel to the rotor axis, the bars are connected at each end (short circuited to provide circulating current) by a copper rim.

5.6 Main Armature

The main armature consists of six individual windings. Two windings as a pair are connected to each other in series or parallel. Each armature winding pair is then connected to the other two armature winding pairs to form the common Y or Delta combination, each of which is spaced 120 mechanical and electrical degrees apart.

The actual winding is completed outside of the generator's frame in the attached terminal connector box. Since there are three pairs of windings, three separate single phase EMF values are induced. It is the development of each of the three single-phase values that together produce the three-phase output from the armature windings.

The main armature windings are connected directly to the electrical system through the switchboard. It is from here that AVR receives its input, which in turn controls the input to the exciter's stationary field.

When the stator windings are connected to an external (electrical) system to form a closed circuit, the steady-state currents in these windings are also periodic. These currents create own magnetic fields. Each of these fields is pulsating with time because the associated current is AC; however, the combination of the three fields is a revolving field. This revolving field arises from the space displacement of the windings and the phase difference of their currents. This combined magnetic field has two poles and rotates at the same speed or direction of the rotor. In summary, for a loaded synchronous AC generator operating in steady state, there are two fields rotating at the same speed: one is due to the rotor winding and the other due to stator windings.

It is important to observe that the armature circuits are in fact exposed to two rotating fields, one of which, the armature field, is caused by and in fact tends to counter the effect of the other, the rotor field. The result is that the induced EMF in the armature can be reduced when compared with an unloaded machine. This phenomenon is referred to as armature reaction. The EMF induced in a stator winding completes one period for every pair of north and south poles sweeping by; thus, each revolution of the rotor corresponds to two periods of the stator EMF. In general, a p-pole machine operating at 60Hz has a rotor speed of 3600/(p/2) rpm. That is, the lower the number of poles is, the higher the rotor speed has to be. In practice, the number of poles is dictated by the mechanical system (prime mover) that drives the rotor.

5.7 Outline of operation

- The prime mover starts. The prime mover crankshaft revolves and the generator shaft rotates. This turns the exciter armature, the main field and the rotating rectifier.
- The exciter initiates an EMF. The rotating exciter armature cuts the residual magnetic field (left-over in the exciter field pole pieces). A weak EMF is induced in the Y-wound (star-connected) rotating exciter armature windings. The exciter portion of the machine operates as a rotating armature alternator.
- Exciter A.C. is rectified to D.C. The exciter's three-phase A.C. is directed to the rotating poly-phase rectifier. Diodes convert A.C. into pulsating D.C. Five wires are connected to the rotating rectifier. Three wires are from the three-phase exciter armature to the rectifier and two wires direct the D.C. output to the main field winding.
- The main field induces an EMF into the main armature. Direct current enters the rotating main field; the alternating polarities induce an EMF of alternating potentials in the main armature windings.
- Three-phase A.C is produced from the main armature. The main armature has three windings producing three-phase A.C. The main portion of the generator is operating as a revolving field generator. Initially, only a low three-phase EMF is produced.
- Voltage control takes over. The voltage regulator senses an under-voltage and diverts the current flow back to the stationary exciter field. In this case, the exciter field winding is used for the initial voltage build-up. The current flow through the exciter field winding increases its magnetic field. The exciter armature conductors now cut through a greater magnetic field and the induced EMF in the exciter armature is increased.
- The process is repeated until satisfactory voltage is achieved. The increased exciter armature current is rectified by the rotating rectifier and directed again to the rotating main field. The increased magnetic field, of the rotating main field, sweeps past the conductors in the stationary main armature. This produces a greater three-phase EMF. The regulator controlling current to the exciter field maintains normal voltage control.

5.8 Automatic Voltage Regulator

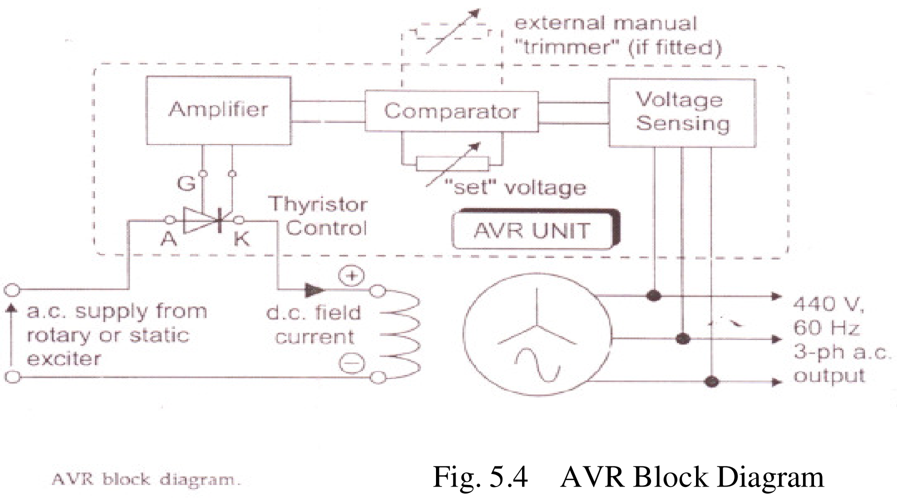


Fig. 5.4 AVR Block Diagram

Sudden load changes on a generator cause a corresponding change in out put voltage. This is due to internal voltage drop in the generator windings and the effect is called voltage dip. Similarly, load shedding will produce an over voltage at the bus bars. Automatic voltage regulator (AVR) equipment is necessary to rapidly correct such voltage change. The requirement is that voltage should not fall below 85% or raise 120% of the rated voltage, when such load with power factor zero to 0.4 is connected to or disconnected from the switchboard. Voltage must be restored within 3% of the rated voltage within 1.5 seconds.
The AVR senses the generator output voltage and acts to alter the field current to maintain the voltage at its set value

The main components of AVR are:

- A voltage comparison circuit
- An amplifier and conditioning circuit, which convert the signal output from the voltage comparison circuit into a control signal for actuating the control element.

The control circuit consists of transformers, rectifiers, zener diodes, transistors and thyristors. These circuits are mounted on circuit cards fitted either within the switchboard or local to the generator.
The voltage sensing unit transforms down, rectifies and smoothes the generator output voltage. This produces a low voltage D.C. signal that is proportional to the

A.C. generator voltage. This actual D.C. signal is compared with a set D.C. value produced by reference circuit of Zener diodes and resistors. An error signal output from the comparator is then amplified and made suitable for driving the field circuit regulating thyristor.

A thyristor is fast acting electronic switch controlled by voltage signal at its gate terminal. This device rectifies and regulates the generator field current.
Additional components/sub circuits in AVR unit ensure rapid response time, fair current sharing when generators are in parallel, quick voltage built up during generator run up and over voltage /under voltage alarm/trip protection.

What is Power Factor?

Power factor is characteristic of alternating current (AC) circuits.

Always a value between (0.0) and (1.0), the higher the number the greater/better the power factor.

Circuits containing only heating elements (filament lamps, strip heaters, cooking stoves, etc.) have a power factor of 1.0. Other circuits containing inductive or capacitive elements (ballasts, motors, personal computer, etc.) usually have a power factor below 1.0. Normal power factor ballasts (NPF) typically have a value of (0.4) - (0.6). Ballasts with a power factor greater than (0.9) are considered high power factor ballasts (HPF).

The significance of power factor lies in the fact that generator supplies consumer with **volt-amperes**, but power consumption is in **watts**. The relationship is (watts = volts x amperes x power factor). It is clear that power factors below 1.0 require a generating plant to generate more than the minimum volt-amperes necessary to supply the power (watts). This increases generation and transmission costs. Good power factor is considered to be greater than 0.85 or 85%.

Watts, or real power, is what real power consumption refers to and translates into bunker consumption. VARS is the extra “power” transmitted to compensate for a power factor less than 1.0. The combination of the two is called "apparent" power (VA or volt-amperes).

Chapter 6
Electrical Measurement Tools

6.1 Multi meters

Digital multimeter.

Fig.6.1 Digital and Analog Multimeter

Routine electrical test work involves measuring current, voltage and resistance i.e. Amps, Volts and Ohms. This is most conveniently done using a multi-meter with all the necessary functions and ranges. The instrument may be the traditional switched-range analogue type (pointer and scale) or the more common digital type with auto-ranging and numerical display.

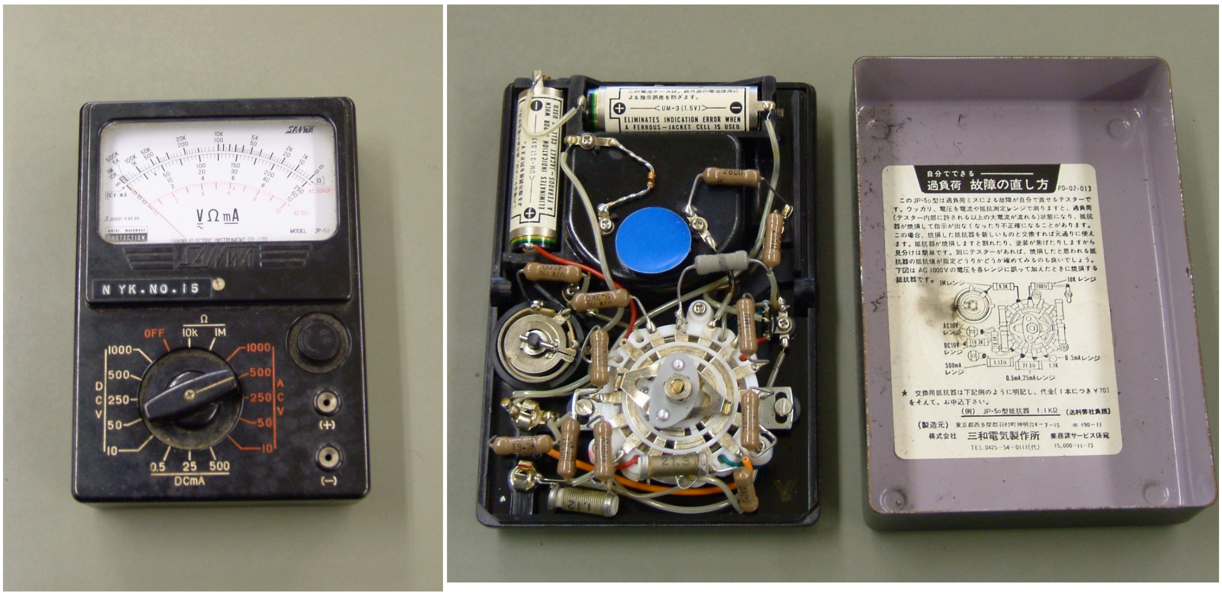
Digital meters are normally high impedance, therefore has high accuracy compared to analogue type, which has low impedance. Digital meters have a clear numeric readout, which may be supported by a bar graph display. Where distorted voltage waveforms are likely (e.g. with variable frequency motor drives), it is necessary to use a “true-rms” meter for accuracy. Digital meters are also available, which display the test voltage waveform shape with a storage oscilloscope facility on the LCD screen.
Digital meter is useful to measure the imperceptible voltage and resistance and it is possible to measure accurately, especially the semiconductor resistance and voltage of sharp movement.

In all instrument models, an internal battery is fitted for use when measuring resistance. Before measuring the resistance of a component, it is essential that

the circuit is switched off, locked off and any capacitor discharged. The instrument is likely to be damaged otherwise.
The multi-meter should be checked for correct operation before use. The manufacturer's instructions should be carefully followed for this, but a general procedure is as follows:
Use correct probe leads and insert into the correct sockets on the meter.

If the multi-meter is an analogue type:

Ensure the pointer indicates zero- adjust if necessary. Set the selector switch to "Ω" and connect probe tips together. Pointer should deflect to indicate 0 Ω. If not at the zero point, adjust trimming controls. Check each resistance range in this way.
Set selector switch to "A.C.V" (highest range). Connect probes to a suitable known live supply (with care) such as the electrical workshop test panel. Pointer should indicate correct voltage.



Pic. 6.1 Inside view Analog Multimeter

Very special care is necessary when using a multi-meter to check for live voltage. If the multi-meter has been accidentally set to current or resistance range, the instrument acts as a low resistance across live supply. The resulting short-circuit current may easily cause the meter to explode with local fire damage and very serious consequences for the operator.

Fused probe leads are therefore highly recommended for use with a multi-meter. Instrument battery failure is checked when the instrument is set to read "Ω" with the probe tips connected together. If the pointer fails to reach "0 Ω" after the adjustment of the resistance range trimmer, the battery must be replaced. The instrument should be switched-off when not in use to preserve battery life.

If the multi-meter is of digital type:

Switch on and connect the two probe tips together. Set selector switches to "D.C.V" (highest range). Display should indicate zero (000).
Repeat for all "D.C.V" selector switch positions and note the shift of the decimal point. Separate the probe tips. Set the selector switches to "Ω" (highest range). Display should indicate "0l" (over-range) or "100" (depends on the model). Connect probe tips together- display should indicate zero (000).
Repeat for all "Ω" selector switch positions and note movement of the decimal point.
Set selector switches to "AC V" (highest range). Connect probes to suitable known live supply. Display should indicate correct voltage.
Test the D.C. voltage range also and note the polarity indication on the meter.
Instrument battery failure is usually indicated by the numeric display. The display may show "BT" or the decimal point may blink.
The instrument should be switched off when not in use to preserve battery life
It is to be remembered that checking a circuit with a faulty instrument can be dangerous.

6.1.1 Procedure for measuring Resistance

PROVE the correct operation of the instrument.
ISOLATE and lock off the equipment.
PROVE the equipment to be dead.
SWITCH multi-meter to appropriate resistance range, connect the probes to the equipment and note the resistance value.

6.1.2 Procedure for measuring Voltage

PROVE the correct instrument operation.
SWITCH the instrument to the highest voltage range.
CONNECT the probes to the terminals being tested. Take care not to touch the probe tips, as equipment being tested is LIVE
NOTE the voltage reading.

No harm will be caused to the instrument by operating the selector range switches while connected to live supply. But great care must be taken not to switch into either the current or resistance mode. This may cause the instrument to trip on overload and possible damage to instrument and injury to person.
DISCONNECT the probes and switch off the instrument.

6.1.3 Procedure for measuring Current

The multi-meter current measuring facility is intended for only small current components and in particular for electronic circuits.
The multi-meter is not to be used for measuring current to motors and other power circuits
The procedure to measure small current in mili Amps:
* PROVE the correct instrument operation.
* SWITCH the instrument to the highest current range.
* TURN OFF the power to the circuit to be tested and discharge all capacitors.
* OPEN the circuit in which current is to be measured-removing a fuse link often gives a continent point for current measurement.
* SECURELY connect the probes in SERIES with the load in which current is to be measured.
* TURN ON the power to the circuit being tested; note the current size on the meter display
* TURN OFF the power to the circuit being tested and discharge all capacitors.
* Disconnect the test probes and switch the instrument to OFF and reconnect the circuit that was being tested.

6.2 Current Clamp-meter

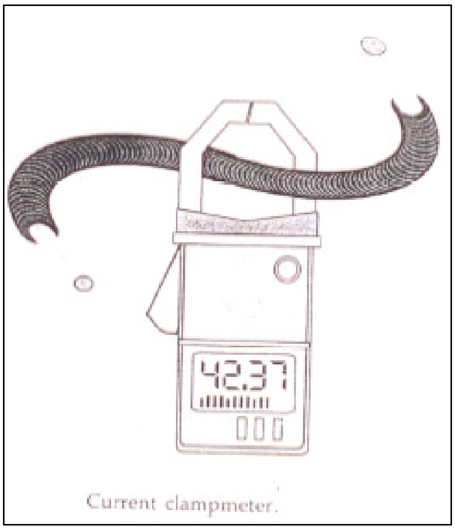


Fig. 6.2 Clamp Meter

The most convenient way to measure current is by the clamp- meter.
Power current (A.C.) can be measured by clamp-meter, which acts as a current transformer. The value of the current is obtained from the magnetic flux strength around the conductor. The instrument tongs are clipped around a single conductor and usually displayed on digital display.
Care to be taken when measuring current in uninsulated conductor.
If clamp-meter is clipped around a three core or two-core cable, the reading will indicate zero, as the net flux in balanced 3 or 2 cores is zero.

6.3 Insulation Testing (Megger Test)

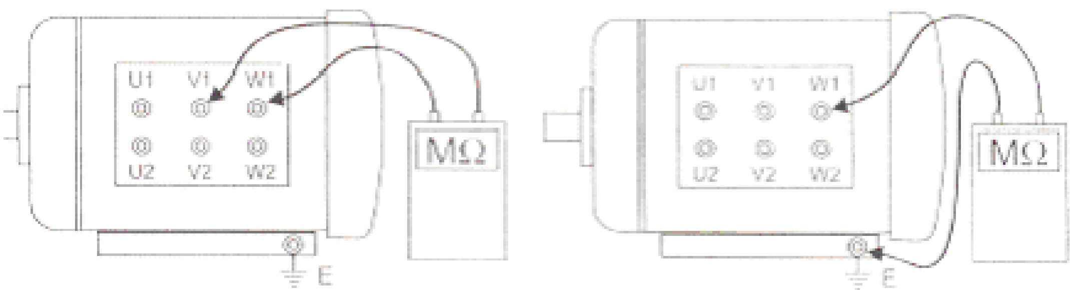


Fig. 6.3 Insulation Resistance connection for Motor

Pic. 6.2 Megger

The measurement of the insulation resistance (IR) gives one of the best guides to the state of health of electrical equipment.

The resistance is measured between insulated conductors and earth and between conductors.
The Megger is high reading resistance meter using a high-test voltage – usually D.C.

Test voltage of 500volts D.C. is suitable for ships equipments rated 440 V A.C.

Test voltage of 1000 volts D.C. is suitable for testing high voltage systems.

To test the meter, short the two probes together, switch ON to MΩ and press the test button- The pointer should indicate approximately 0MΩ
Before applying the test, the equipment must be disconnected from the live power supply and locked off.

For IR test on three-phase machine, measure and log the phase-to-phase insulation resistance value.

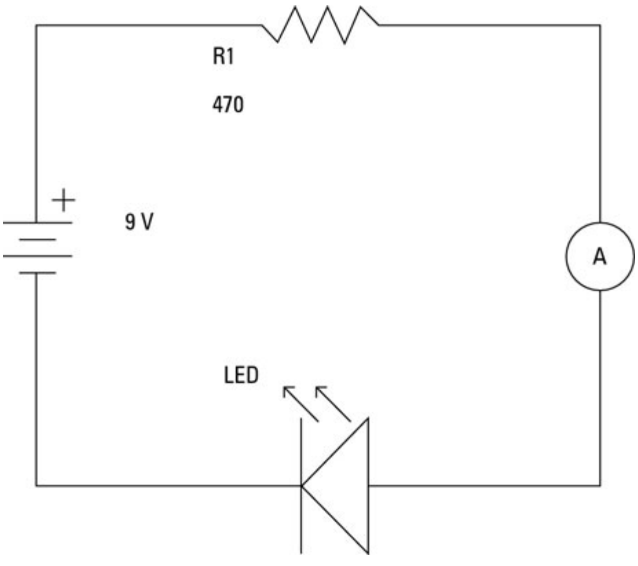
Three windings should be measured U-V, V-W and W-U.

Measure and record the phase-to-earth insulation resistance values. Three readings should be measured as U-E, V-E and W-E

How to measure current in an electronic circuit ?

Electric current is measured in amperes, but actually in most electronics work, you'll measure current in milliamps, or mA. To measure current, you must connect the two leads of the ammeter in the circuit so that the current flows through the ammeter. In other words, the ammeter must become a part of the circuit itself.

The only way to measure the current flowing through a simple circuit is to insert your ammeter into the circuit. Here, the ammeter is inserted into the circuit between the LED and the resistor.



Note that it doesn't matter where in this circuit you insert the ammeter. You'll get the same current reading whether you insert the ammeter between the LED and the resistor, between the resistor and the battery, or between the LED and the battery.

Chapter 7
Programmable Logic Controller
(Sequence controller)

7.1 Outline of sequencer

The name of SEQUENCER is not official name. The official name is Programmable Controller (PC). SEQUENCER is a maker product name as same as a WALKMAN (SONY).

The programmable controller is very wide scope. If a program is changed for the temperature control, it is electrical PID controller. If a program is for the motor control sequence, this is sequence controller or sequencer. Therefore there are many types of programmable controller.
All programmable controllers are composed of a memory, processing part, input interface and output interface. Sometimes, electric source part is included.
This section explains the sequence controller.
The program of sequence controller (Sequencer) is made for sequence diagram (sequence control process).

The sequencer requires input data and output devices.

The input data are push button switches for start/stop, change over switches for AUTO/MAN, Limit switches for level high/low, magnetic switches, thermal relay signal, etc.

The output devices are contactors, indicator lamps, solenoid valves, etc.
The electrical control sequence system for example motor starting and/or auxiliary boiler control sequence system compose of timers, counters, auxiliary relays plus above input and output equipments.

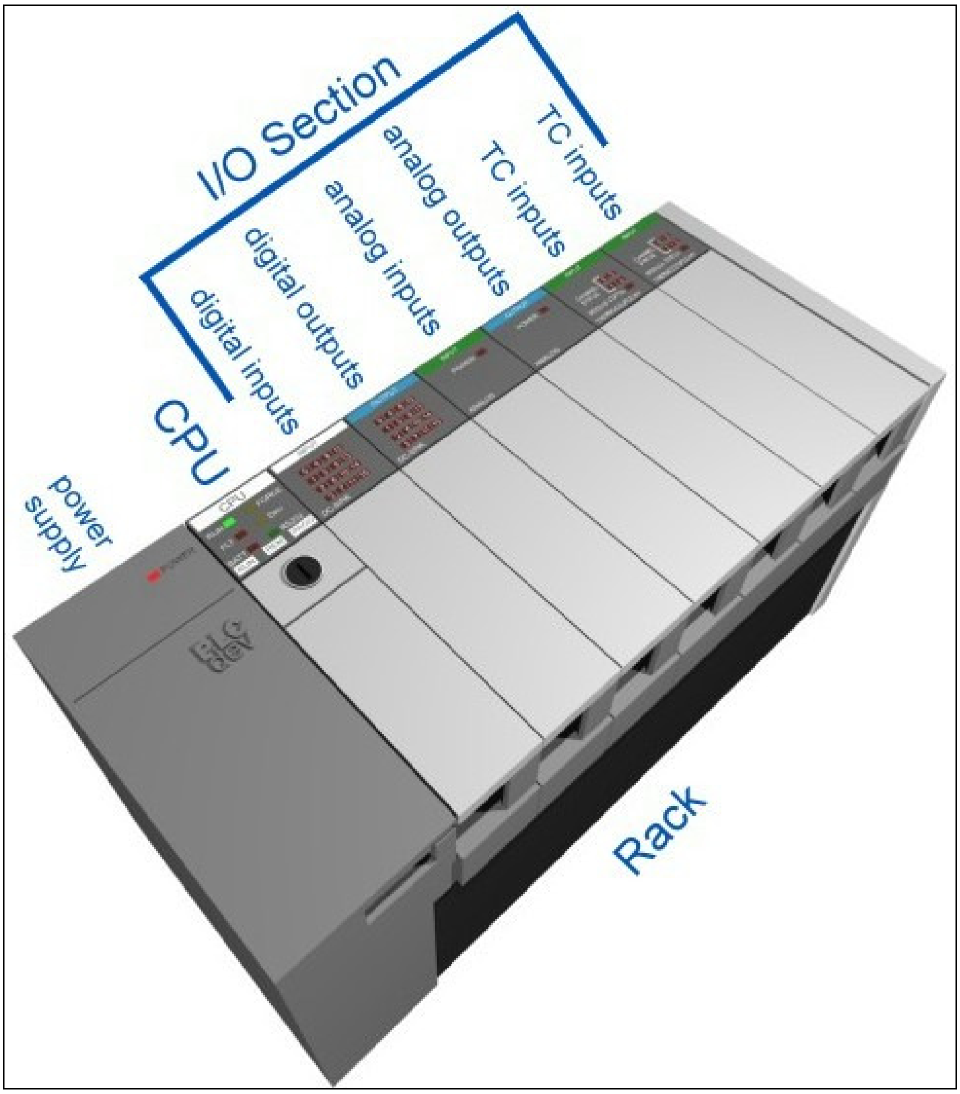
The sequencer is substitution to the auxiliary relays, timers and counters.

A programmable logic controller is a specialized computer used to control machines and processes. It therefore shares common terms with typical PCs like central processing unit, memory, software and communications. Unlike a personal computer though the PLC is designed to survive in a rugged industrial atmosphere and to be very flexible in how it interfaces with inputs and outputs to the real world.

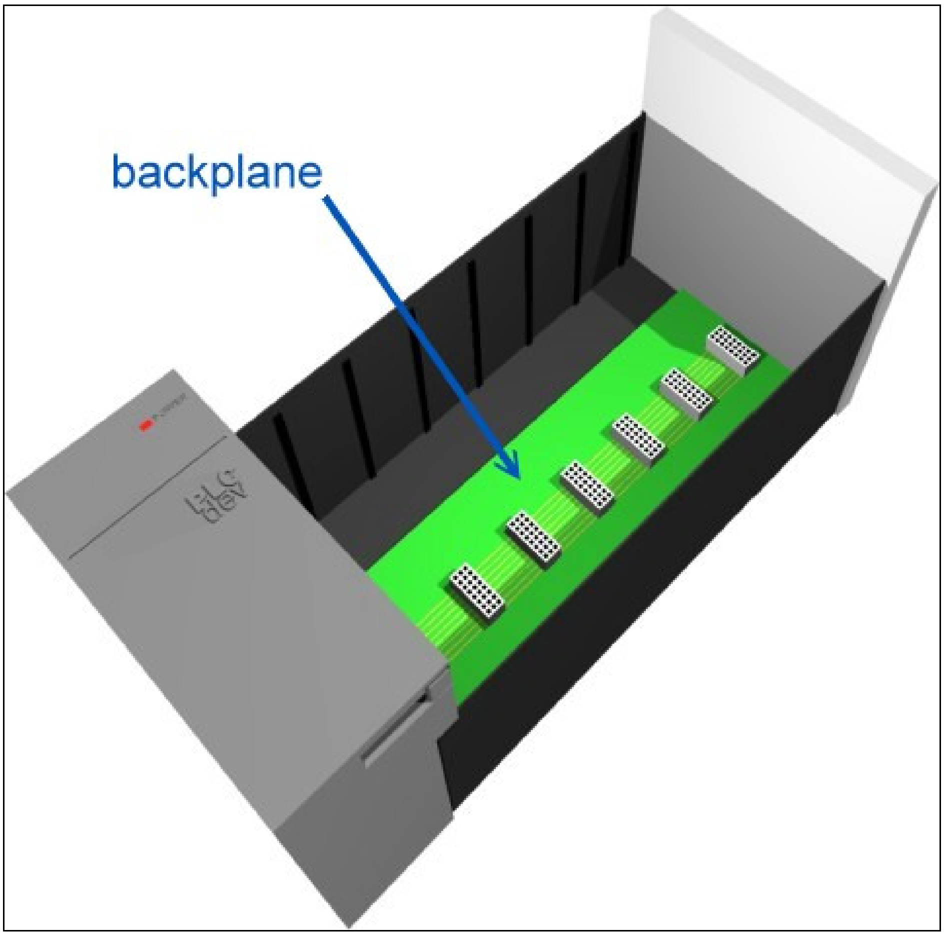
The components that make a PLC work can be divided into three core areas.

- The power supply and rack
- The central processing unit (CPU)
- The input/output (I/O) section

PLCs come in many shapes and sizes. They can be so small as to fit in your shirt pocket while more involved controls systems require large PLC racks. Smaller PLCs (a.k.a. “bricks”) are typically designed with fixed I/O points. For our consideration, we’ll look at the more modular rack based systems. It’s called “modular” because the rack can accept many different types of I/O modules that simply slide into the rack and plug in.



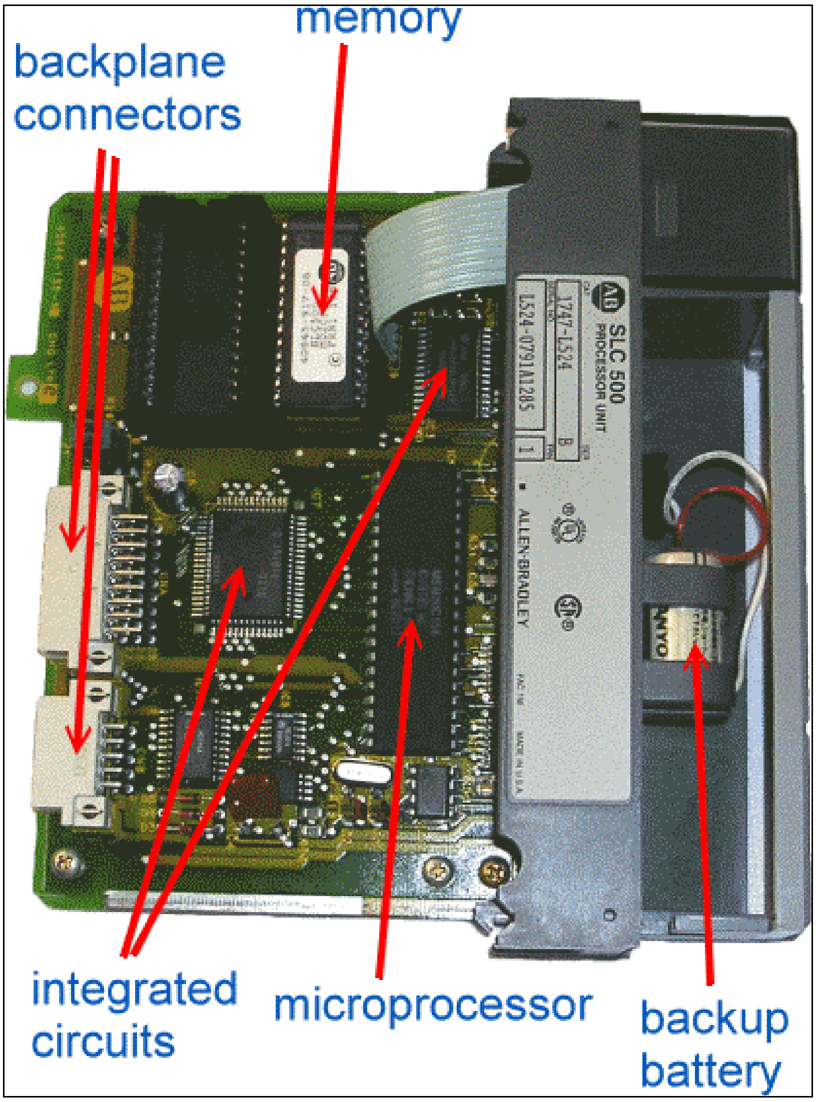
So let's start off by removing all our modules which leaves us with a naked PLC with only the power supply and the rack.



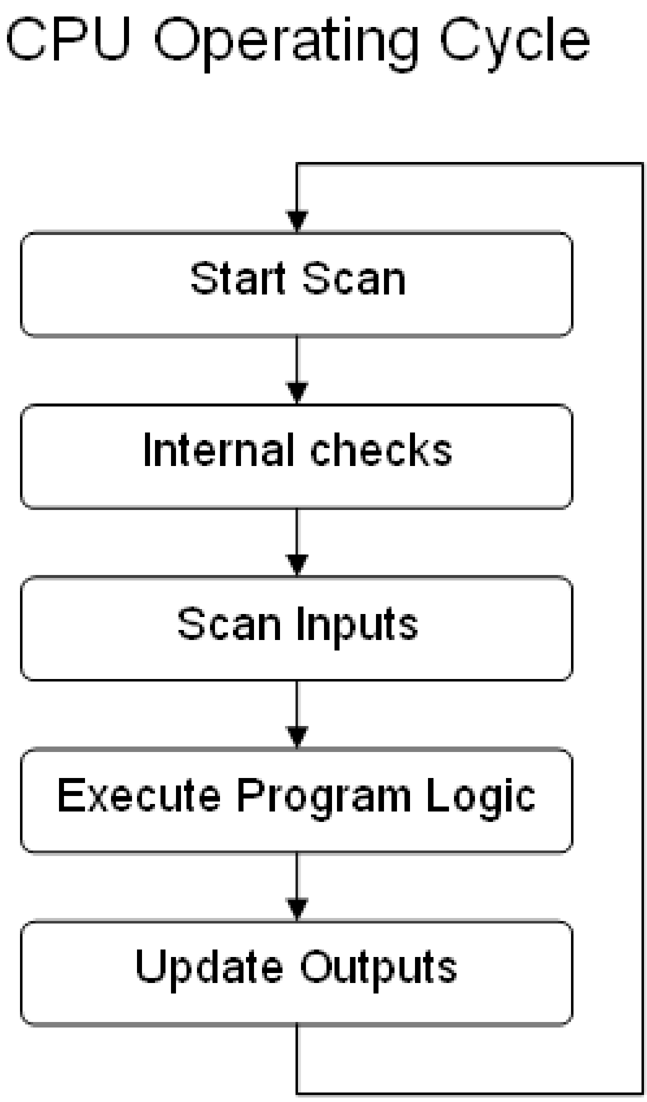
The rack is the component that holds everything together. Depending on the needs of the control system it can be ordered in different sizes to hold more modules. Like a human spine the rack has a backplane at the rear which allows the cards to communicate with the CPU. The power supply plugs into the rack as well and supplies a regulated DC power to other modules that plug into the rack. The most popular power supplies work with 120 VAC or 24 VDC sources.

The brain of the whole PLC is the CPU module. This module typically lives in the slot beside the power supply. Manufacturers offer different types of CPUs based on the complexity needed for the system.

The CPU consists of a microprocessor, memory chip and other integrated circuits to control logic, monitoring and communications. The CPU has different operating modes. In programming mode it accepts the downloaded logic from a PC. The CPU is then placed in run mode so that it can execute the program and operate the process.

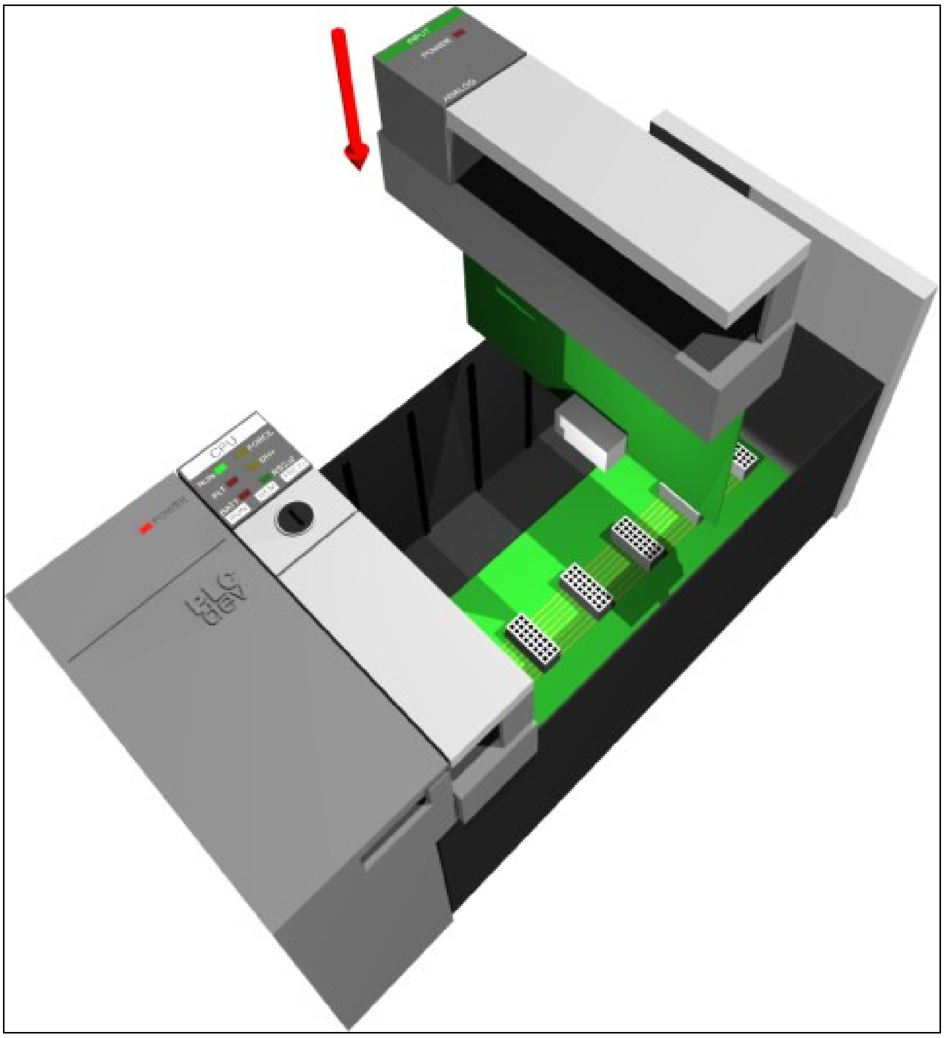


Since a PLC is a dedicated controller it will only process this one program over and over again. One cycle through the program is called a scan time and involves reading the inputs from the other modules, executing the logic based on these inputs and then updated the outputs accordingly. The scan time happens very quickly (in the range of 1/1000th of a second). The memory in the CPU stores the program while also holding the status of the I/O and providing a means to store values.



The I/O system provides the physical connection between the equipment and the PLC. Opening the doors on an I/O card reveals a terminal strip where the devices connect.

There are many different kinds of I/O cards which serve to condition the type of input or output so the CPU can use it for it’s logic. It's simply a matter of determining what inputs and outputs are needed, filling the rack with the appropriate cards and then addressing them correctly in the CPUs program.



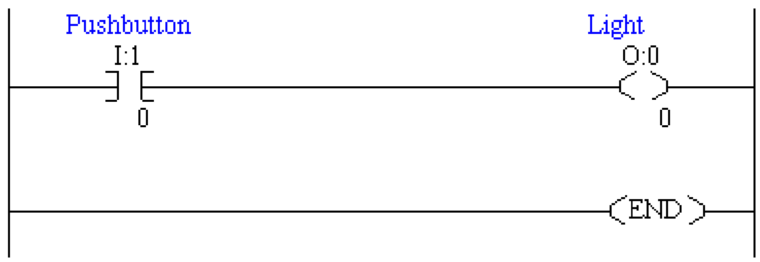
Input devices can consist of digital or analog devices. A digital input card handles discrete devices which give a signal that is either on or off such as a pushbutton, limit switch, sensors or selector switches. An analog input card converts a voltage or current (e.g. a signal that can be anywhere from 0 to 20mA) into a digitally equivalent number that can be understood by the CPU. Examples of analog devices are pressure transducers, flow meters and thermocouples for temperature readings

Output devices can also consist of digital or analog types. A digital output card either turns a device on or off such as lights, LEDs, small motors, and relays. An analog output card will convert a digital number sent by the CPU to it's real world voltage or current. Typical outputs signals can range from 0-10 VDC or 4-20mA and are used to drive mass flow controllers, pressure regulators and position controls.

In these modern times a PC with especially dedicated software from the PLC manufacturer is used to program a PLC. The most widely used form of programming is called ladder logic. Ladder logic uses symbols, instead of words, to emulate the real world relay logic control, which is a relic from the PLC's history. These symbols are interconnected by lines to indicate the flow of current through relay like contacts and coils. Over the years the number of symbols has increased to provide a high level of functionality.

The completed program looks like a ladder but in actuality it represents an electrical circuit. The left and right rails indicate the positive and ground of a power supply. The rungs represent the wiring between the different components which in the case of a PLC are all in the virtual world of the CPU. So if you can understand how basic electrical circuits work then you can understand ladder logic.

In this simplest of examples a digital input (like a button connected to the first position on the card) when it is pressed turns on an output which energizes an indicator light.



The completed program is downloaded from the PC to the PLC using a special cable that's connected to the front of the CPU. The CPU is then put into run mode so that it can start scanning the logic and controlling the outputs.

7.2 Advantages of sequencer

Following points are advantages of the sequencer

1) Economical

The lowest price of sequencer is cheaper than over ten relays.
If a sequence control system uses over ten relays and/or timers, the sequencer is at an advantage.
The sequencer is not high price.

2) Designing saving

It is possible to simplify the panel arrangements design, testing and adjusting.

3) Short term appointed data of delivery

The parts of sequence control system are reduced. Therefore, arrangement of parts is easy. The design changing is easy.

4) Compact & Standardization

The sequencer does not use the many relays, timers and counters. Therefore, sequence control panel does not require a wide space, it means compact size.
When one program of sequence control diagram is made, it is possible to use it for other control panels. The relay/timer type sequence control system requires necessary same wiring work, but sequencer is easy for reinstalling the program to suit the other control system.

5) High Reliability

The relay, timer and counter have moving parts and mechanisms. Malfunctioning of one relay is common.

6) Easy maintenance

Since, relay, timer and counter have moving parts and breakdown parts. Therefore, it is necessary to periodically maintain or replace the parts. But the sequencer does not have moving parts. It is not necessary to carry out short term periodical maintenance.

Comparison with the relay type system

	Relay		Sequencer	
Function	A	It is possible to make the advanced control by using the many relays, timers and counters.	G	It is possible to make the advanced control by programming.
Modify	B	Only re-wiring	G	Only modify the program
Reliability	A	Normally good, but a case of no action	G	Semiconductor is good reliability
Multipurpose	B	Not use the other control system: Fixed control	G	Change the control system by programming
Expansion	B	Difficult to expand due to no space	G	Not necessary additional relays, timers and counters
Maintenance	A	Necessary	G	Long time not necessary
Understanding	G	Easy and generalization	B	Can not understand inside the hardware
Size	A	Generally big size	G	Small
Design/delivery	B	Difficult and long term	G	Easy and short term
Economical	G	Less than 10 parts	G	Over the 10 parts

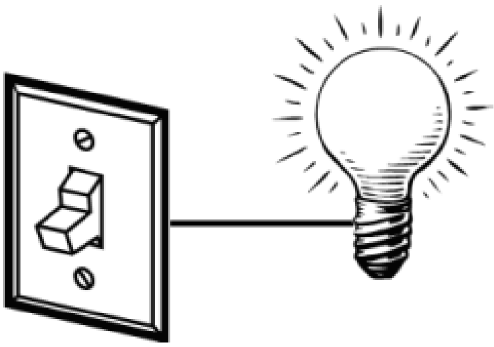
G= Good, A=Average, B=Bad

Why use the Programmable Logic Controller?

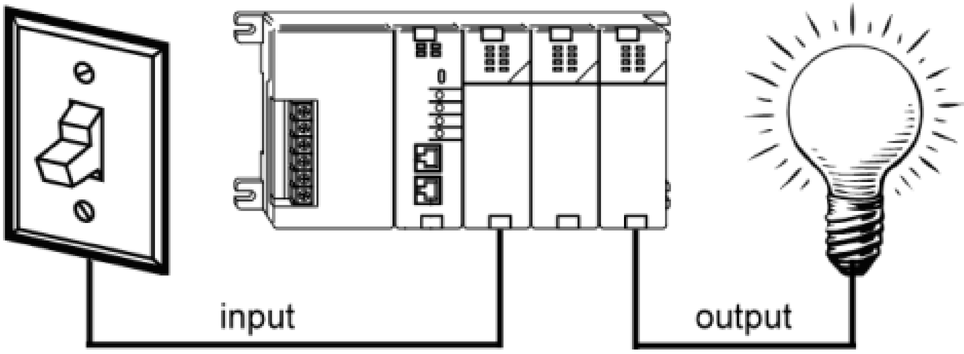
A Programmable Logic Controller, or PLC for short, is simply a special computer device used for industrial control systems. They are used in many industries such as oil refineries, manufacturing lines, conveyor systems and so on. Where ever there is a need to control devices the PLC provides a flexible way to "softwire" the components together.

The basic units have a CPU (a computer processor) that is dedicated to run one program that monitors a series of different inputs and logically manipulates the outputs for the desired control. They are meant to be very flexible in how they can be programmed while also providing the advantages of high reliability (no program crashes or mechanical failures), compact and economical over traditional control systems.

Consider something as simple as a switch that turns on a light. In this system with a flick of the switch the light would turn on or off. Beyond that though there is no more control. If your boss came along and said I want that light to turn on thirty seconds after the switch has been flipped, then you would need to buy a timer and do some rewiring. So it is time, labor and money for any little change.



Now consider the same device with a PLC in the middle. The switch is fed as an input into the PLC and the light is controlled by a PLC output. Implementing a delay in this system is easy since all that needs to be changed is the program in the PLC to use a delay timer.



This is a rather simple example but in a larger system with many switches and lights (and a host of other devices) all interacting with each other this kind of flexibility is not only nice but imperative. Hopefully a light bulb has now turned on over your head.