Annex 4.16
Training Material for O&M of Electrical Equipment
in Fall 2017

O & M of Electrical Equipment
WSD 5231

Electrical Panel and Instrumentation Equipment

O & M of Mechanical and Electrical Equipment (Team)

Faculty Names	Contact Information
JICA Expert Takeo Maruyama (Electrical)	
Course Leader Mubasher Ahmad Cheema	
Instructor Jawad Shahid	
Instructor Ihsan-ul-haque Javed	
Young Professional Tanveer Shahzad	

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Course Dates

Modules	Dates	Themes
Module 1	December 11th to December 12th 2017	Electrical Control Panels
Module 2	December 13th to December 14th 2017	Generators & 5S
	December 15th 2017	Action Plan

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Class Introduction

- ✓ What do we cover in this module?
- ✓ What to expect in this module?
- ✓ What is the role of electrical control panels in WASA operations?

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Class Introduction

Your turn…

- ✓ How many of participants are from Electrical Engineering background?
- ✓ How many of you have experience in operating and maintaining electrical panels?
- ✓ Why interested in this module?
- ✓ What best skills do you bring to the team?

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Agenda

- ✓ Introduction of Main Electrical Units
- ✓ Components of Electrical Control Panel
- ✓ General Design (Wiring Diagram)
- ✓ Motor Starters

6/22

Agenda

- ✓ Introduction to Motor
- ✓ Power factor correction
- ✓ Record Keeping
- ✓ Standard Operation Procedure (SOP)
- ✓ Device Testing
- ✓ Preventive Maintenance

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Class Evaluation Structure

Attendance	**30 %**
Exercise 1	**10%**
Exercise 2	**10%**
Exercise 3	**10%**
Exercise 4	**15%**
Action Plan	**25%**

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Lecture Goals

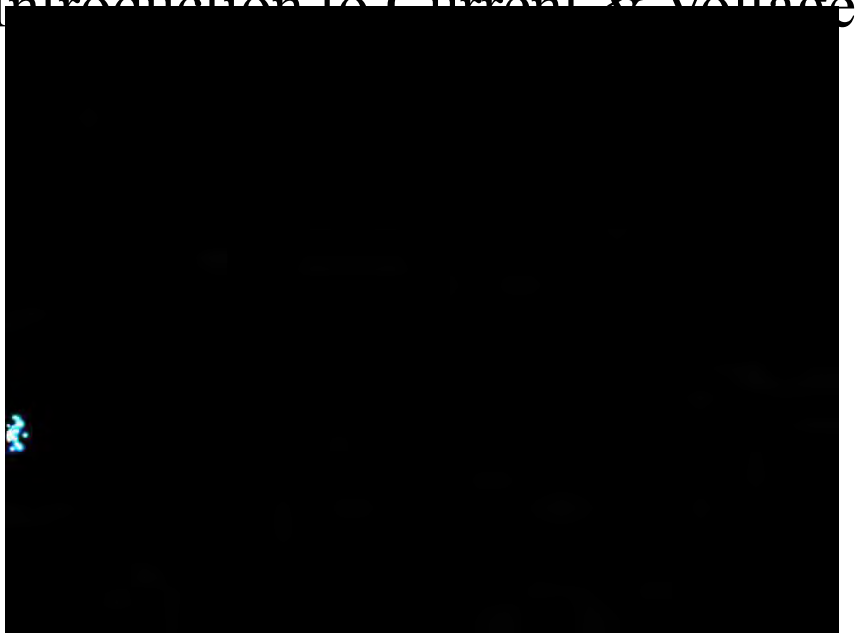
- **Distinguish types of panels in electrical systems of WASAs**
- **Understanding of basic sequence of the panel**
- **Testing and configuration of equipment**

9/22

Electrical Control Panel

10/22

Introduction to Current & Voltage



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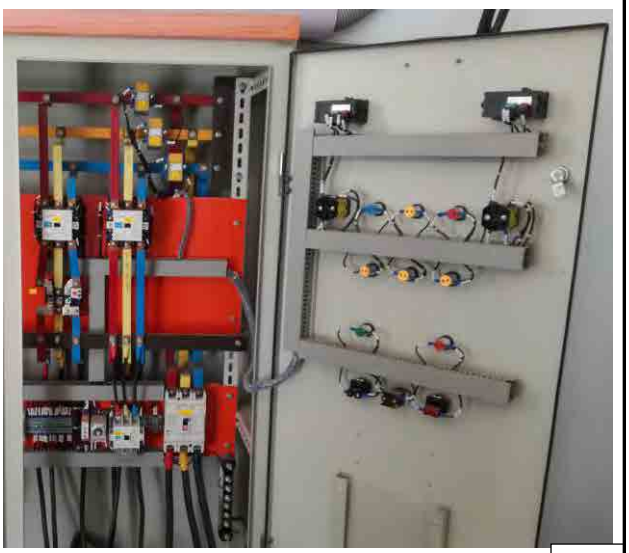
Electric Control Panel

- ✓ Provides electrical energy with all necessary protections equipped within it.
- ✓ Used to ensure the controlled, protected and smooth transfer of electrical energy from one system to another.



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Major types of electrical control panel used in WASAs

1. Motor control unit (MCU)
2. Changeover switch
3. Power factor improvement (PFI) panel
4. Electrical distribution panel

13/22

Which one?

14/18

1.Motor control unit (MCU)

Motor Control Unit or simply MCU, are used to control and protect the electric motor. It is equipped with multiple relays, contactors, connections and indication lamps

Changeover Switch

Distribution Panel

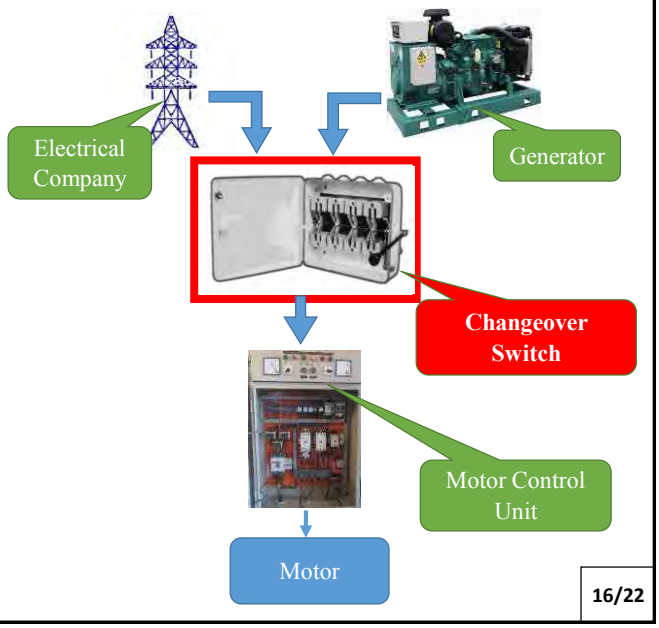
Motor control unit

Motor

15/22

2.Changeover switch

- ✓ Change over Panels are used to switch between primary and auxiliary power source. It is used in case of multiple connections from the electric supply company or generators



16/22

3.Power factor improvement panel

✓Power factor improvement panel is used to maintain the power factor to optimum value. It consists of a bank of capacitors connected together.

17/22

4.Electrical distribution panel

✓ It is basically a panel box, which receives electric supply from one or more sources and distributes it over the system through protections

18/22

Introduction to Panel Components

1/20

Goal

- **Understanding function of each component/ device in MCU**
- **Orientation to basic wiring connection along with wiring diagram**

2/20

What are these?

3/20

Components of Electrical Control Panel

~ Motor Control Unit (Outer View) ~

Digital Voltmeter

Locks

Name Plate

Digital Ammeter

Selector Switch

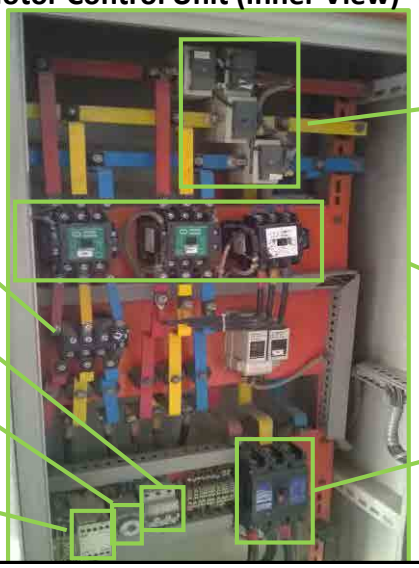
Alarm/ Indication Lamps

On-Off and Emergence Push Buttons

4/20

Components of Electrical Control Panel

~ Motor Control Unit (Inner View) ~



5/20

Selector Switches

- ✓ Used to select among each of the three phases to monitor currents and voltages on ampere and voltmeter.

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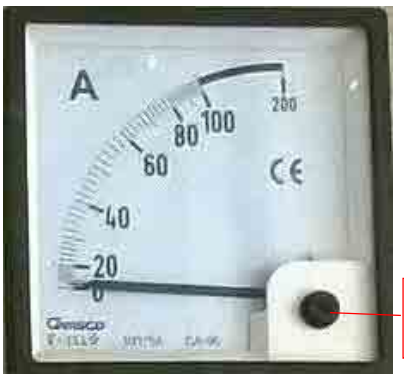
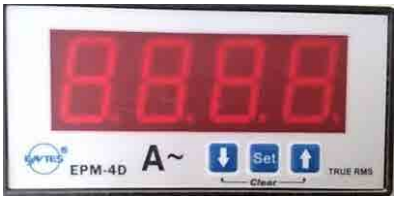
Ampere & Voltmeter meter

- ✓ Monitoring gauges for currents and voltages
- ✓ Digital and analog type Ampere and Volt meters are used by WASAs



Zero Adjustment



7/20

1. Circuit Breakers

Circuit breakers are switches that open/close electric circuits in normal and abnormal conditions specially in case of a short circuit.

8/20

2. Contactor

- ✓ A power contactor is typically used for “on / off” control of motors. A relay can be installed on the circuit for overload protection. Electromagnetic force works to “open /close” the contacts.

9/20

Protective Relays

- ✓ Protective relays detect electrical faults, isolate the faults from system and activate alarms is a faulty condition sensed

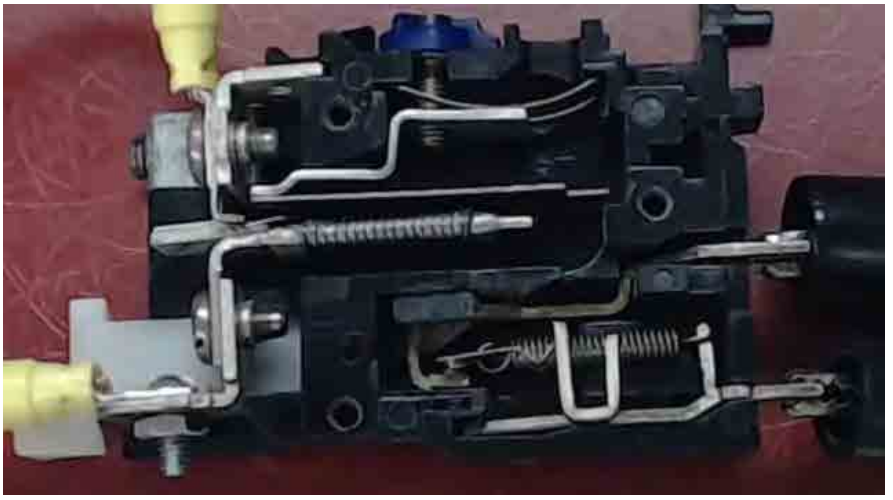
Thermal Relay

Under/Over Voltage Relay

Phase Failure Relay

10/20

Operation of thermal relay



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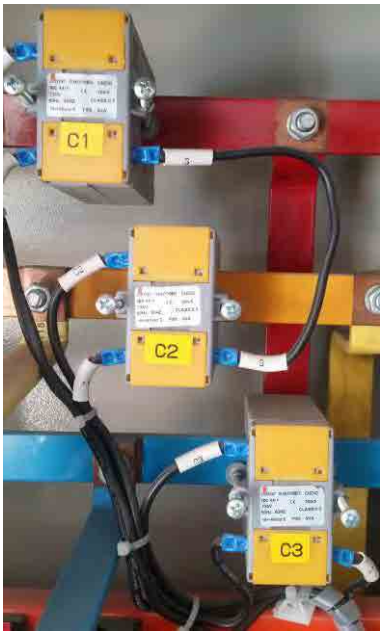
5. Current transformers (CT)

- ✓ CT's are used for stepping down current to be measured safely. It is also applied to protective relays



12/20

6. Timer

- ✓ Use to convert the motor connections from Star to Delta after specific time

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WIRING DIAGRAMS

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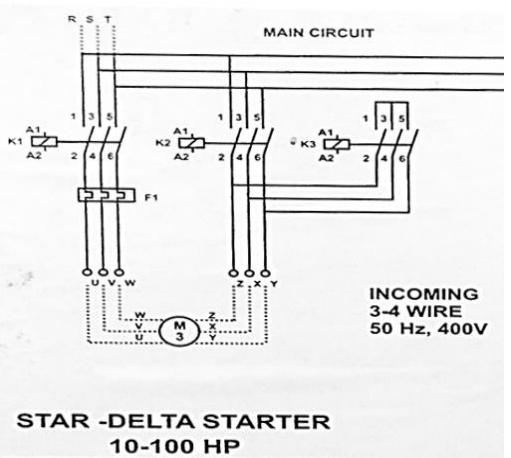
Wiring Diagram

✓ Shows how the components are connected

✓ It should be always available at the site



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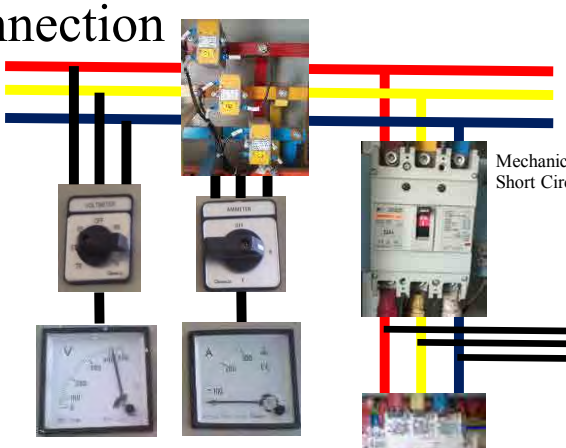
Basic Concept of Connection

WAPDA

3 phase, 400V



Basic Power Circuit for Motor in WASA

- Circuit Breaker
- Magnetic Contactor
- Over Load/Thermal Relay
- Over/Under Voltage Relay

Monitoring Device

- Voltage Meter
- Ampere Meter

Mechanical Protection from Short Circuit & Main Switch

Protection from abnormal voltage

Auto/Manual Switch ON/OFF

Mechanical Protection from Over Current

Motor

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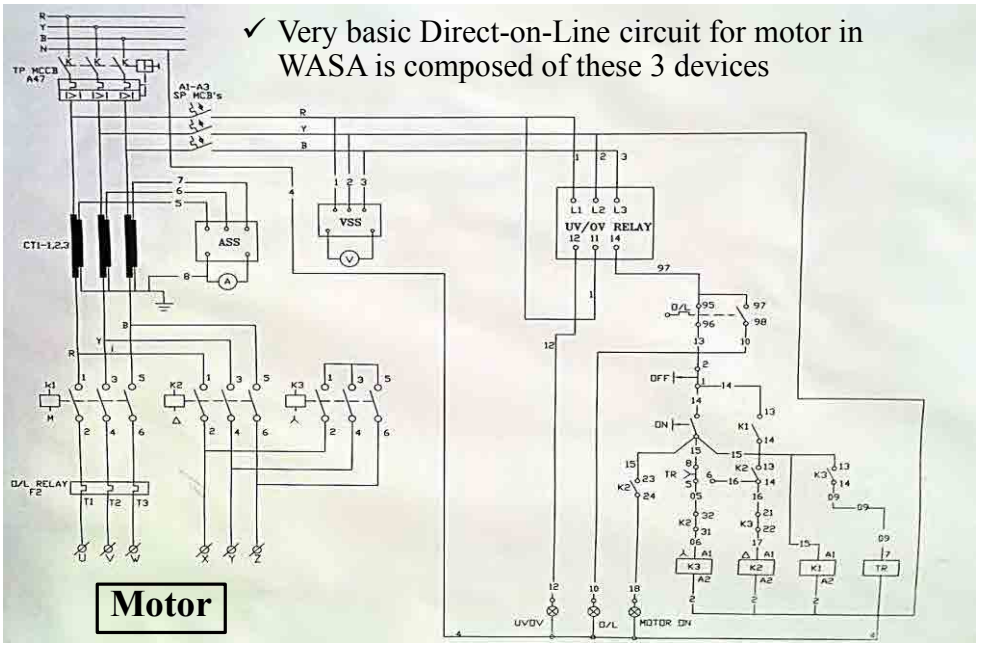
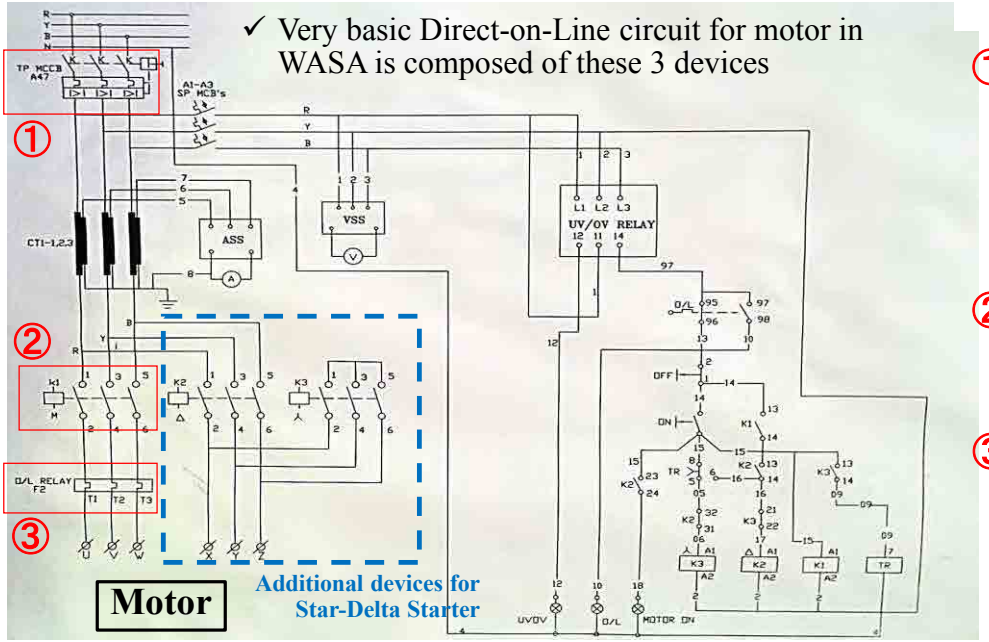
Main Power Circuit



- ✓ Very basic Direct-on-Line circuit for motor in WASA is composed of these 3 devices

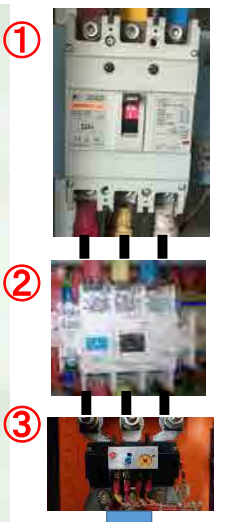
17/20

Main Power Circuit



- ✓ Very basic Direct-on-Line circuit for motor in WASA is composed of these 3 devices

Basic Power Circuit for Motor



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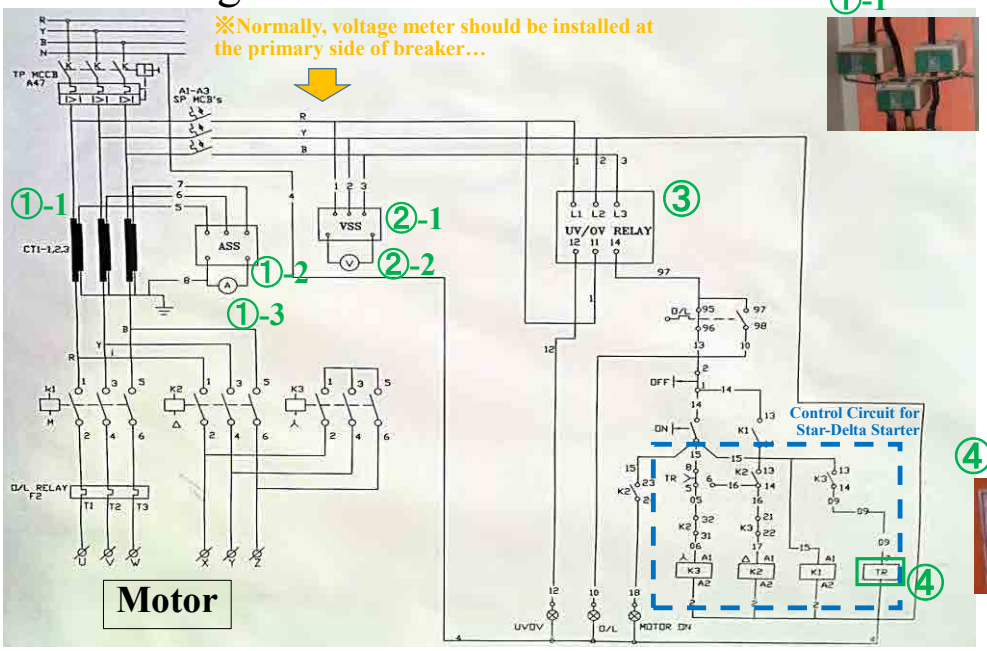
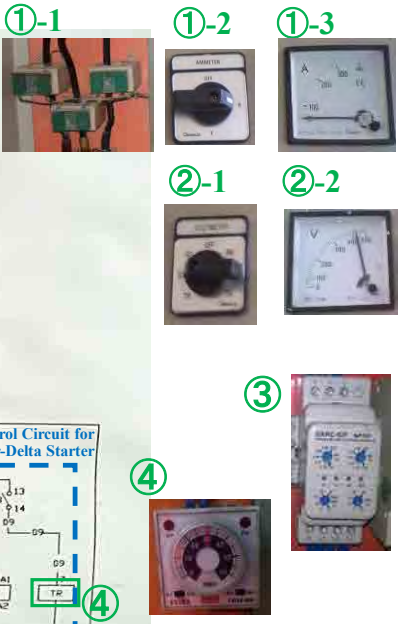
Monitoring and Control Circuit





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ACTIVITY – 1

Complete the wiring diagram with the suitable components

20/20

Motor, Motor Starters & Power Factor Improvement

1/18

Goal of this Lecture

- **Gain common concept of motor, motor starter and its variety**
- **Understand the effect of Power Factor Improvement**

2/18

Motor Starters

- ✓ An extremely large current of about (5) five to (8) eight times the rated current flows at startup
- ✓ The power factor is extremely low at 0.2 at the start.
- ✓ Motor winding coil is subjected to thermal stress load. Voltage fluctuation occurs in the power system and its effect becomes more pronounced.
- ✓ The starting method of three-phase induction motor includes a method of restricting current at start as mentioned above, and other methods described below.

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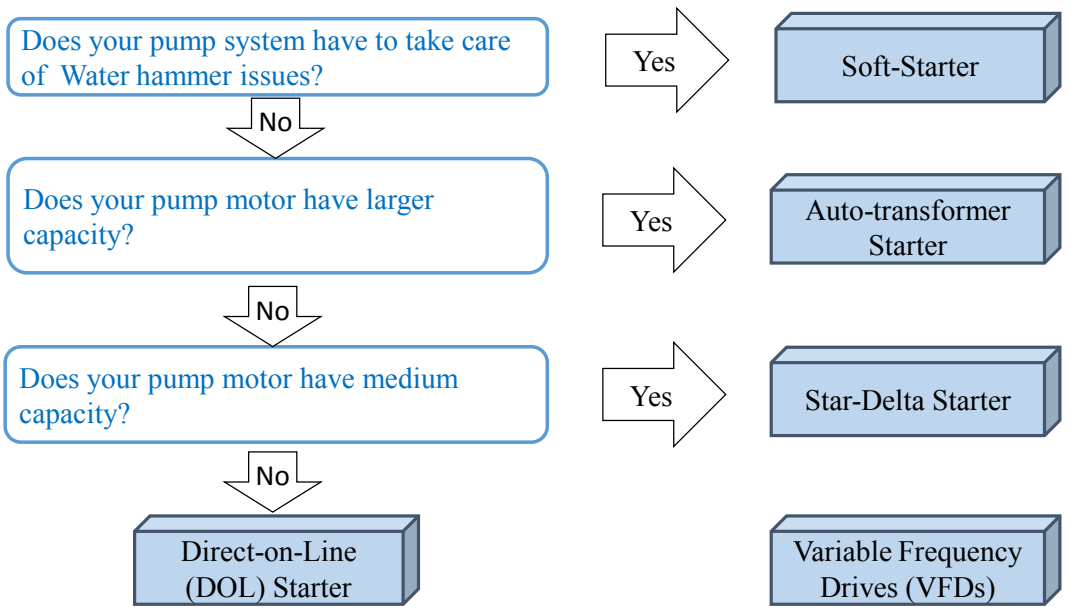
Selection of Motor Starter



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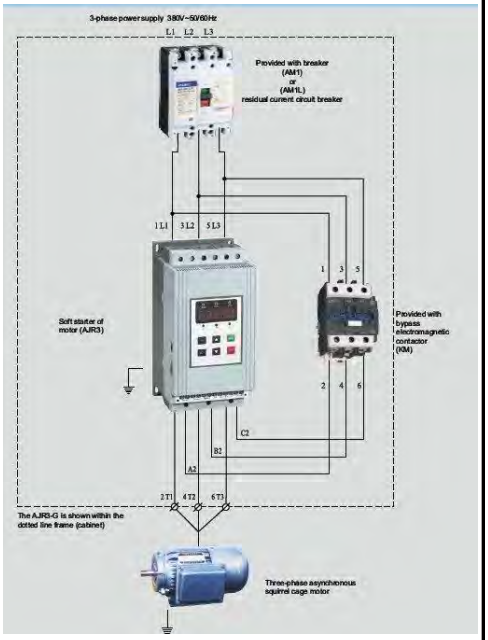
Soft Starter

Function:
Automatically starts/ stops the pump gradually slowly to avoid water hammer

Advantage:
Possible to make the stop slow as well as start operation

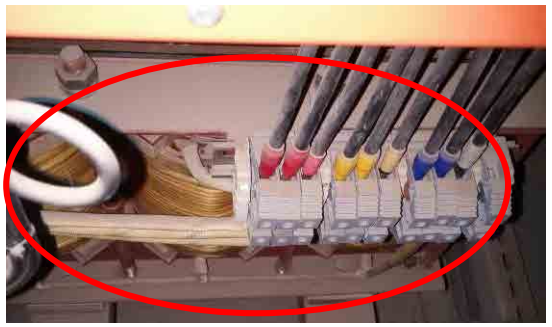
Disadvantage:
Electronic device shall be installed in a good environment so extra care is required



Single Line Diagram of Soft Starter

Auto-transformer Starter

Function:
Automatically controls voltages by changing transformer taps to reduce the starting current

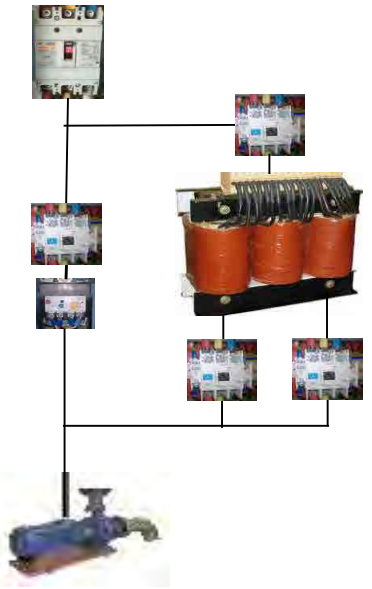


Transformer

Auto-transformer Starter

Advantage:
Less stress to the circuit due to flexible adjustment of voltage in the starting process

Disadvantage:
Expensive and wider space for installation is required



Single Line Diagram of Auto-transformer starter

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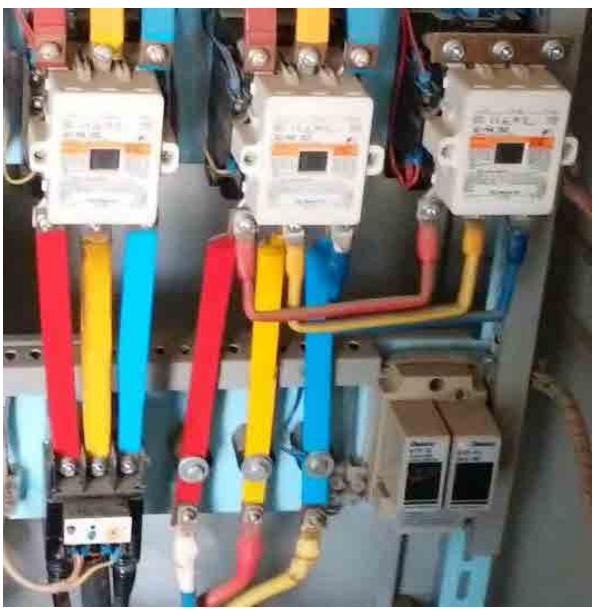
Star-Delta Starter

Function:

Arrangements of relays are so done that motor starts using star type connection and transferred to the delta type connection after few seconds



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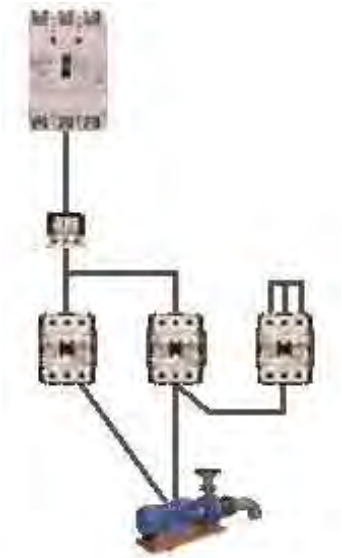
Star-Delta Starter

Advantage:
Easy, economical and common system to reduce starting current

Disadvantage:
Inrush current occurs in a moment of changing Star to delta
Six leads of the motor are required



Single Line Diagram of Star-Delta Starter

9/18

Starting method	Type of equipment	Current input (mains load)	Run-up time	Heat build-up in motor during start-up	Mechanical loading	Hydraulic loading	Cost relation	Recommended motor designs	Comments
D. o. l.	Contactor (mechanical)	4–8 · I_N	Approx. 0.5–5 s	High	Very high	Very high	1	All	Mostly limited to ≤ 4 kW by energy supply companies
Star-delta	Contactor combination (mechanical)	$^1/_3$ of d. o. l. values	Approx. 3–10 s	High	Very high	Very high	1.5–3	All; canned motors and submersible motors subject to a major drop in speed during switchover	Usually stipulated for motors > 4 kW by energy supply companies
Reduced voltage	Autotransformer, mostly 70% tapping	0.49 times the d. o. l. values	Approx. 3–10 s	High	High	High	5–15	All	No currentless phase during switchover (gradually replaced by soft starters)
Soft start	Soft starter (power electronics)	Continuously variable; typically 3 · I_N	Approx. 10–20 s	High	Low	Low	5–15	All	Run-up and run-down continuously variable via ramps for each individual load application; no hydraulic surges
Frequency inverter	Frequency inverter (power electronics)	1 · I_N	0–60 s	Low	Low	Low	Approx. 30	All	Too expensive to use solely for run-up and run-down purposes; better suited for open- or closed-loop control

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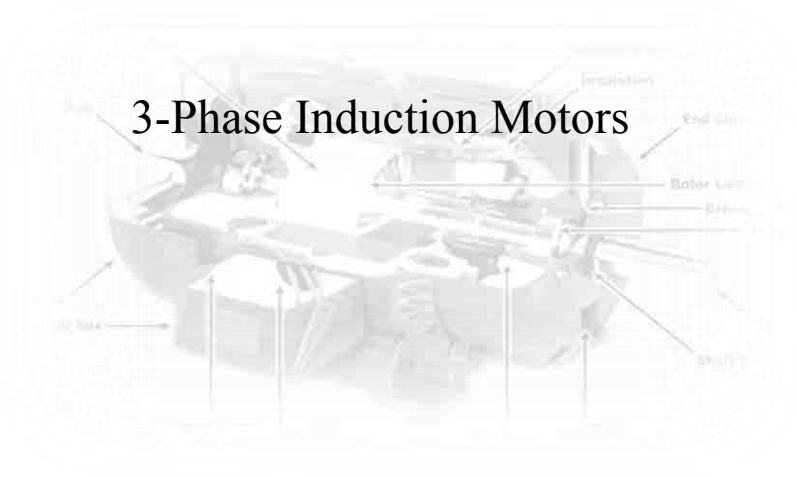
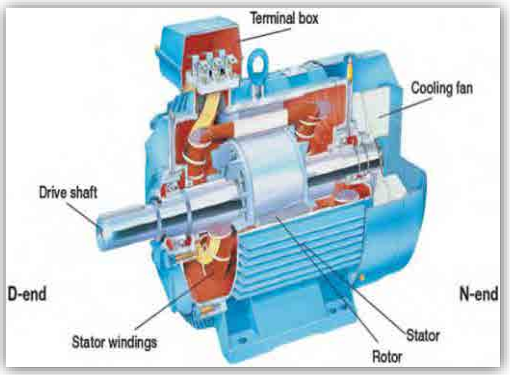
3-Phase Induction Motors



Introduction

- Electrical motor is an electromechanical device, which converts electrical energy to mechanical energy.
- Three-phase induction motors are the most common electrical motors used in the industry.

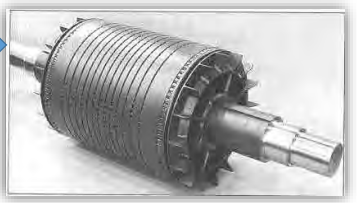


Basic Design and Construction

An induction motor has two main components:

1. (Stationary part) Stator

2. (Revolving part) Rotor



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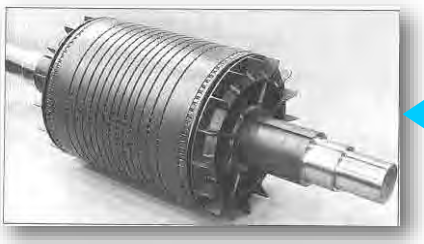
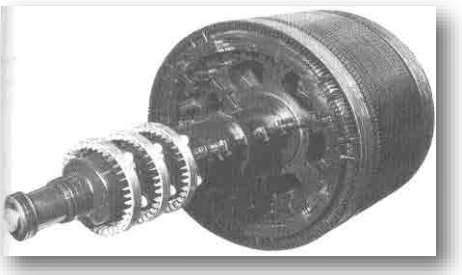
Basic Design and Construction

Rotor Types



Squirrel cage rotor

Slip ring rotor



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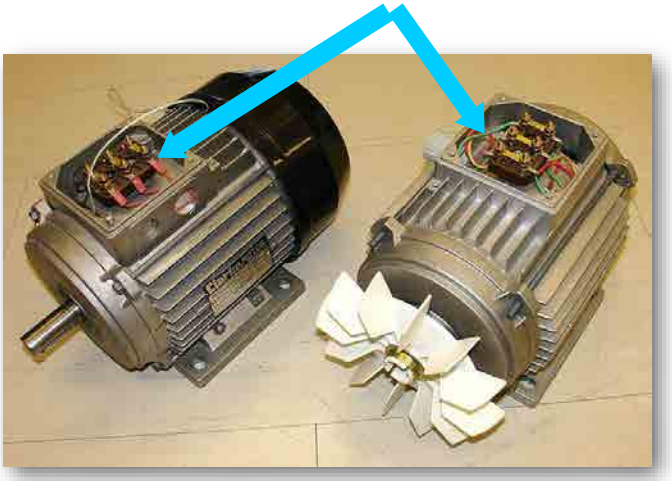
Basic Design and Construction

Terminals



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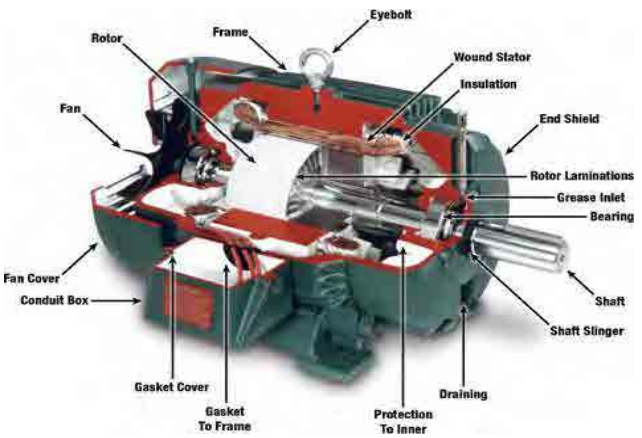
Basic Design and Construction

Section View



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Basic Design and Construction

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Motor Burnout and Rewinding

Causes…

1. Fluctuation in phase voltages
2. Malfunctioning of protective relays
3. Manufacturing defects
4. Damage before or during installation
5. Improper installation
6. Misapplication (overload)

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Motor Burnout and Rewinding

- Copper or aluminum wire should be used for rewinding the motor
- Preferably inside of the winding wire should be enameled copper wire (magnet wire)

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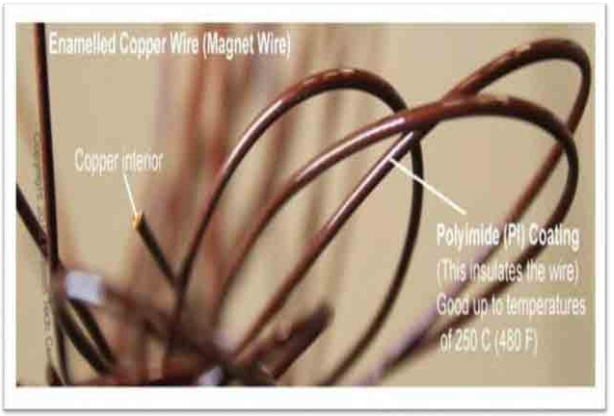
Motor Burnout and Rewinding

- After re-winding the assembly should be coated with risen and baked.
- Special care should be taken when inserting the rotor into the stator assembly.



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Troubleshooting

Sr. No.	Fault Indication	Causes
1.	Motor fails to start	Blown fuse or open circuit breaker
		Motor overload relay on starter tripped
		Low voltage or no voltage applied to the motor
		Defective motor windings
		Motor burnout
		Mechanical overload
2.	Excessive motor noise and vibration	Insufficient cooling/lubrication
		Overload
		Low phase voltage

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Troubleshooting

Sr. No.	Fault Indication	Causes
3.	Motor overload protector continually trips	Excessive load
4.	Heated up bearings	Bent or sprung shaft Electrical Damage (Fluting)
5.	Worn bearings	Life span completed
		Foreign Matter (Dust and dirt)
		Electrical Damage (Fluting)
		Improper Bearing Lubrication
		Bearing Fatigue
		High Temperatures

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Troubleshooting

Sr. No.	Fault Indication	Causes
6.	Mechanical locking in	Decreased air gap, jammed bearings or any foreign matter stuck
7.	Wrong rotation	Wrong sequence of phases
8.	Motor overheat	Overload
9.	Starter or circuit breaker not operating	Non availability of power or faulty relay
10.	Overheating of cable	Cable size inadequate

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Wrap-up

Things to take home…

1. Motors drive your operations
2. Always do a root cause analysis
3. Repair is not preventive maintenance
4. Keep records, always !!!

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POWER FACTOR IMPROVEMENT

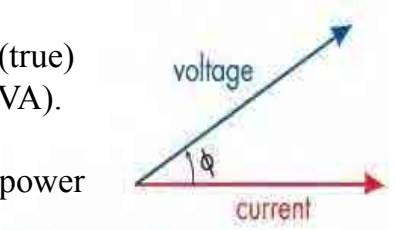
25/18

Power Factor Improvement

What is Power Factor?

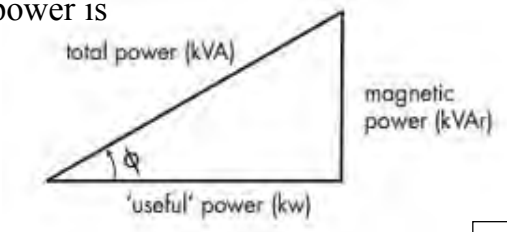
- ✓ Power factor is the ratio between the useful (true) power (kW) to the total (apparent) power (kVA).

Power factor (pf) = (Useful Power kW)/(Total power kVA) kW= kVI cosø



Phaser diagram of voltage and current

- ✓ It is a measure of how efficiently electrical power is converted into useful work output.
- ✓ The ideal power factor is unity.



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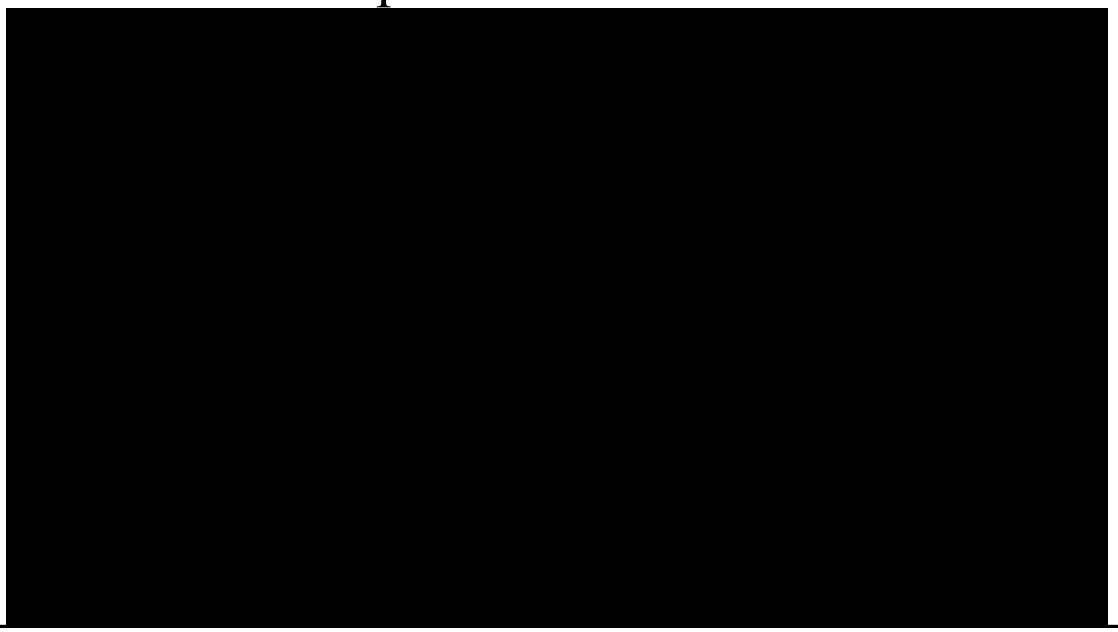
Power Factor Explained



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Power Factor Improvement

- ✓In case of Low Power factor, Improvement/ correction is required.
- ✓Correction is achieved by the addition of capacitors in parallel with the connected motor at the origin of the installation.

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Power Factor Improvement Panel

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Auto Power Factor Controller

- ✓ Capacitors are selectively used to make the power factor of the system close to 1.00
- ✓ Actual power factor needs to be monitored by operators regularly
- ✓ Check the power factor mentioned on the electricity bill and do necessary action if required

30/18

Fuse

- ✓ Fuses avoid the flow of over currents by melting down itself
- ✓ They have to be replaced every time after use since they are not reusable like circuit breakers
- ✓ Regular inspection of its availability and maintaining enough quantity of spare parts in store is very important

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Power Factor Penalty

LAHORE ELECTRIC SUPPLY COMPANY - ELECTRICITY CONSUMER BILL(MDI)

http://www.lesco.gov.pk

CUSTOMER I.D.	ED@	BILL MONTH	READING DATE	ISSUE DATE	DUE DATE
1001380	1.0%	Jun 16	30 JUN 16	11 JUL 16	22 07 2016

REFERENCE No.	TARIFF	LOAD	OLD A/C No.
24 11351 9000901U	B3 (14)T	696.6	24135190009017

WEB GENERATED BILL
24 11351 9000901U

GST # 0352271600251

NAME & ADDRESS
XEN WASA
SEWRAGE PUMPING STATION KHOKHAR ROAD SHAD BAGH LA

SDO : 04237288866/03470011351
XEN : 04299250067/03470011350

Low power factor less than 0.9

SUB-DIVISION	KOT KHAWAJA SAEED
DIVISION	BAGHBANPURA
FEEDER	WASA

			P.F
0	0	85	.64

KWH	KWH METER READING			KVARH METER READING			MDI METER READING		METER STATUS
METER NO.	PREVIOUS	PRESENT	MF	PREVIOUS	PRESENT	MF	PRESENT	MF	
100329	8976.18	9135.87	2000	10742.39	10935.35	2000	48	2000	
100329	2074.9	2106.09	2000	2467.34	2505.55	2000	48	2000	

UNITS CONSUMED	(O)319380 (P)62380	(O)385920 (P)76420	CHARGED LOAD.=	960

ENERGY/ FIXED CHARGES	METER / SERVICE RENT	LPF PENALTY SEASON CHARGES	DEFERRED AMOUNT/	BILL ADJUSTMENT	EXTRA TAX	SALES TAX	FUEL PRICE ADJ PTV FEE	E-DUTY TR-SUR
3842058.00		189696	Low power factor penalty				-2470411.24	26967.78
364800				104156.80				1177218.00

N.J.S.	G.S.T	INCOME TAX	I.TAX SURCHARGE	FURTHER TAX
38176	785335 *			92392

MONTH	MDI	KWH UNITS	BILL AMOUNT	PAYMENT
JUN15	960	463280	10105463	8228707
JUL15	1080	576340	11658711	10535124
AUG15	1160	448160	9172438	8503979
SEP15	1000	418820	7418497	7418497
OCT15	1200	420600	5671270	5671270
NOV15	920	418880	5829203	7263435
DEC15	1000	406600	5686585	5686585

CURRENT BILL	6911781
ARREARS/AGE	2724756 / 1
XXXXXX P.M RELIEF TO INDUSTRY	-1145280
XXXXXX NET FPA	-1325131.24
PAYABLE WITHIN DUE DATE	9636537
L.P. SURCHARGE	463082
PAYABLE AFTER DUE DATE	10099619

32/18

Benefits of power factor correction

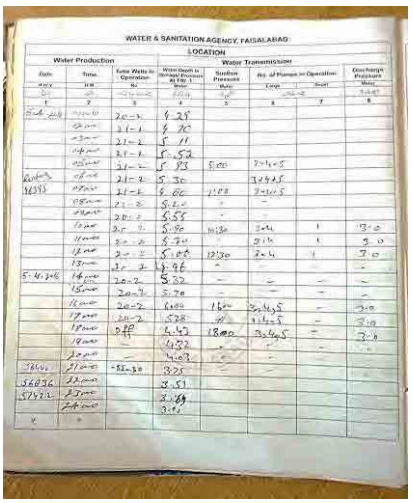
- ✓ Reduction of power consumption due to improved energy efficiency.
- ✓ Reduction of electricity bills.
- ✓ Extra kVA available from the existing supply.
- ✓ Reduction of I^2R losses in transformers and distribution equipment.
- ✓ Reduction of voltage drop in long cables.
- ✓ Extended equipment life.
- ✓ Reduced electrical burden on cables and electrical components.

33/18

RECORD KEEPING

Record keeping

- Make balance of operation time of each load
- Predict & Prepare for future maintenance/procurement plan e.g. lubrication oil ,bearing, fuel, filters for generator
- Detect unsatisfied design, installation or repairing work by contractor



How to make daily operation record

Factors to note down during record keeping (Pumps):

- ✓ Pump operating time (Hrs.)
- ✓ Flow
- ✓ Pressure
- ✓ Power factor
- ✓ Voltage
- ✓ Ampere

3/21

STANDARD OPERATING PROCEDURE (SOP)

4/21

Standard Operating Procedure (SOP)

- ✓Before turning on the motor, values of all protective relays must be checked once a day
- ✓Following format and slides are showing some of the general ideas for O&M and errors in operation in WASA's Motor Control Unit:

Check List of Standard Operation Procedure for Electrical Facility

Approved by :

Inspected by :

Motor Specification: Rated Capacity (kW/HP) _____

Rated Voltage (V) _____Rated Current(A) _____

Efficiency____Power Factor_____RPM_____

Evaluation Criteria

✓: Good ×: No care at all or need to be newly installed

Δ: Need to be improved —: Not available to be checked

Sr. No.	Site/Pump Name	Inspection Date	Inspection Items for Electrical Panel Condition															
			Document			Visual (Outside)						Visual (Inside)				Operation		
			Operation Record	Drawings	Vender Manual	Identification of Lamp/Switch	Status/ Fault Indication Lamps	Ampere Meter	Voltage Meter	Status Selector Switch		Cleanliness	Intrusion Path	Bypass-Circuit	Neatness of cabling	How to operate changeover switch	Frequency of Start/Stop	
			Compare with the sample	Pump installation , electrical line diagram	Pump/ Panel devices	all lamps /switches have name tag	all lamps are visibly bright enough	Proper functioning and zero adjustment	Proper functioning and zero adjustment	Ampere	Voltage	No dust, sand, spider's nest, insect, small animals	No hole/ crack to let foreign matters come in	No bypass / burnt mark		Turn off by breaker or switch first.	Maximum 2-3 times/ hour	
1																		

Check List for Standard Operation Procedure

Check List of Standard Operation Procedure for Electrical Facility

Approved by : SDO

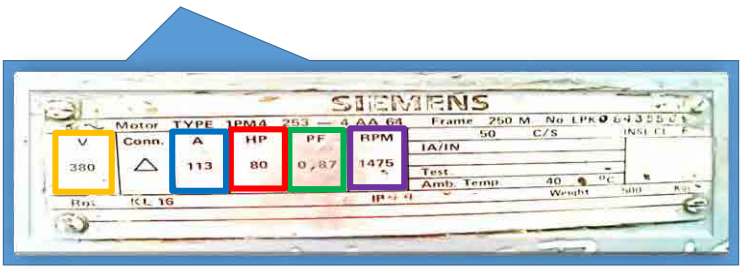
Inspected by : Sub Engineer (Electrical)

Motor Specification: Rated Capacity (kW/HP) 80 HP x 0.746 = 60KW

Rated Voltage (V) 380 Rated Current(A) 113

Efficiency — Power Factor 0.87 RPM 1475

Sr. No.	Site/Pump Name	Inspection Date
1	Tube well 103	12-DEC-16



Check List for Standard Operation Procedure

Check List of Standard Operation Procedure for Electrical Facility

Approved by :

Inspected by :

Motor Specification: Rated Capacity (kW/HP) _____

Rated Voltage (V) _____Rated Current(A) _____

Efficiency_____Power Factor_____RPM_____

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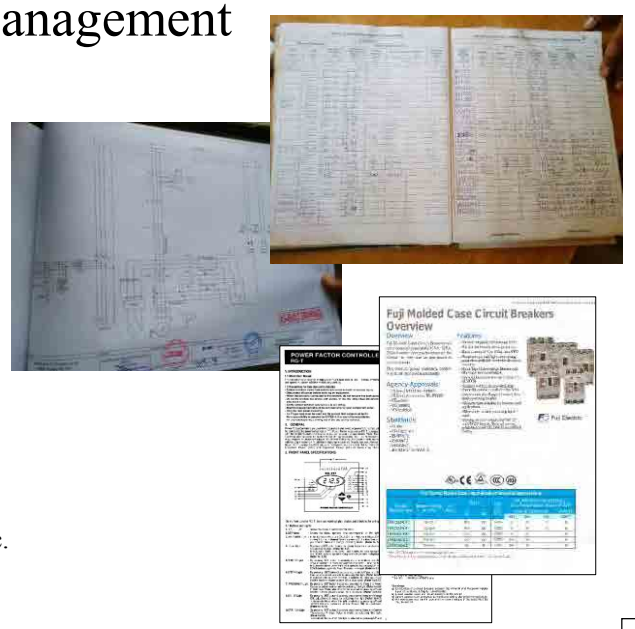
1																	
2																	
3																	

Basic Documentation Management

- ✓ Operation Record
  - Time of Start/Stop, Total Operation
  - Maintenance/Replacement Record
  - Trouble Record, Any Remarks etc.
- ✓ Drawings
  - Shop-Drawings, As-Built Drawings (Equipment and Installation Drawings)
  - Electrical Wiring Diagram etc.
- ✓ Vender Manuals
  - Installation Manuals
  - Operation & Maintenance Manuals
  - Device Catalogs & Manuals etc.



Check List for Standard Operation Procedure

Check List of Standard Operation Procedure for Electrical Facility

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1																	
2																	
3																	

Comparison of the Panel Conditions

NEED TO BE IMPROVED

No name plate or information about panel

Malfunction or non-zero adjustment meters

No/bypassing Protective relays

Energized parts are revealed without any caution and protection

No Proper connections

Large uncovered hole letting small unwelcome friends come in

Dusty

Comparison of the Panel Conditions

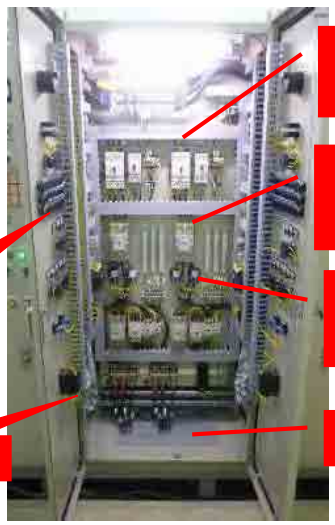
IDEAL CONDITION OF A PANEL

Meters are showing proper values

working properly and

No extra wires or insulation tape

Clean



Devices are fixedly mounted

Proper connections with connectors

Proper settings of protective relays

Covered from the bottom

Check List for Standard Operation Procedure

Check List of Standard Operation Procedure for Electrical Facility

Approved by :

Inspected by :

Motor Specification: Rated Capacity (kW/HP) _____

Rated Voltage (V) _____Rated Current(A) _____

Efficiency_____Power Factor_____RPM_____

Evaluation Criteria

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1																		
2																		
3																		

Difference between…

Disconnection Switch

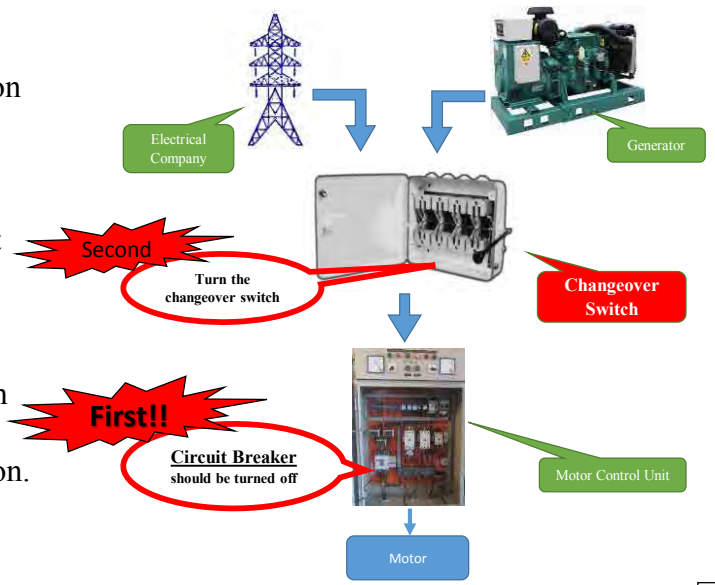
- ✓ **Offline** operation
- ✓ Isolate system
- ✓ Disconnecting system for safety purpose

Circuit breakers

- ✓ **Online** operation
- ✓ Capable of making, carrying and breaking currents under normal conditions
- ✓ Short-circuit switching

- How to operate changeover switch -

- ✓ Don't directly open/turn the changeover switch during operation of load
- ✓ Changeover switch does not have function to break the active circuit so you have to turn off the circuit breaker/magnetic contactor first!
- ✓ The terminal of changeover switch would spark and get burnt if you operate it in the energized condition.



- Frequency of Motors' Start/Stop -

- ✓ Each motor has a condition of number of start to prevent burnout and damage to insulation material
- ✓ There are two types of conditions to be confirmed with manufacturer, "Hot-start" and "Cold-start". Number of Hot-start should be more limited.
- ✓ Frequent and immediate ON/OFF operation (equivalent to Hot-start) could cause stress to the motor and shorten its life time.

PREVENTIVE MAINTENANCE

Goal of this Lecture

- Understand importance of Preventive Maintenance
- Get familiar with the required equipment and tools for Preventive Maintenance on MCU

Circuit Breaker Failure

- **WHY> Due to Carbon deposits on it terminals**
- **WHY> Due to fatigue (life cycle completed)**
- **WHY> Was periodic inspection conducted?**
- **WHY> YES! Wear and tear was observed and replacement was recommended**
- **WHY> The specific model was out of inventory**

3/20

Preventative maintenance

- What is definition of electrical preventative maintenance?

✓The scheduled inspection, testing and maintenance of critical electrical components to prevent failure and enhance equipment life cycle.

4/20

Preventative maintenance

Scheduled!!!

1) Start with a plan
2) Depending on the time of maintenance and the environment, the frequency can vary
3) Be proactive rather than reactive

5/20

Preventative maintenance

The cost of ignoring maintenance

A well administrated preventative maintenance program :

- Reduces accidents
- Saves lives
- Minimizes costly breakdowns and unplanned outages

Impending troubles can be identified and solutions applied, before they become major problems requiring more expensive, time consuming solutions.

6/20

Inspection Tools

1. Voltage Tester

2. Screw Drivers Set

3.Pliers

4. Adjustable Wench

5.Ratchet Screwdriver

6. Ratchet Socket Wrench Set

Analysis and Testing Equipment

9/20

Sample Format for Preventive Maintenance

Preventive Maintenance Sheet for Electrical Facility

Sub Division :		**Motor Specification**			**Rated Capacity (kW/HP)**	
Site Name:		**Rated Voltage**	**Rated Ampere**	**Efficiency**	**Power Factor**	**RPM**
Equipment Name:		(V)	(A)	-	-	
Date						
Inspected By						
Weather						
Bolt Tightening						
Insulation Resistance (MΩ)	U1-E	U2-E				
	V1-E	V2-E				
	W1-E	W2-E				
	U1-V1	U2-V2				
	V1-W1	V2-W2				
	W1-U1	W2-U2				

① Test in OFF Condition

② Test in Running Condition

Voltage by Clamp Meter (V)	RY					
	YB					
	BR					
Ampere by Clamp Meter (A)	R					
	Y					
	B					
Power Factor						
Vibration	Upper Bearing	Lower Bearing				
Revolution Per Minute (RPM)						
Temperature	Upper Bearing	Lower Bearing				
	Shaft					
Reference for Insulation Resistance Value:				Good → more than 1.0MΩ		
Need to Adjust, Clean,Care → 1.0MΩ ~ 0.4M Need to repair immediately →less than 0.4MΩ						
- Remarks -						

10/20

What is “Insulation Resistance” ?

- Insulation resistance is the value showing if there is electrical leakage or not with the measured equipment.
- Insulation resistance tester is a tool to check how properly the system/equipment is insulated.
- If the value show less than 1 MΩ, need to be cared. If less than 0.4 MΩ (i.e. for 400V), detect the faulty parts and replace them immediately.
- It is necessary to check not only one time value but also the trend and comparison with the previous value.

Insulation Resistance Tester

11/20

Appendix

12/20

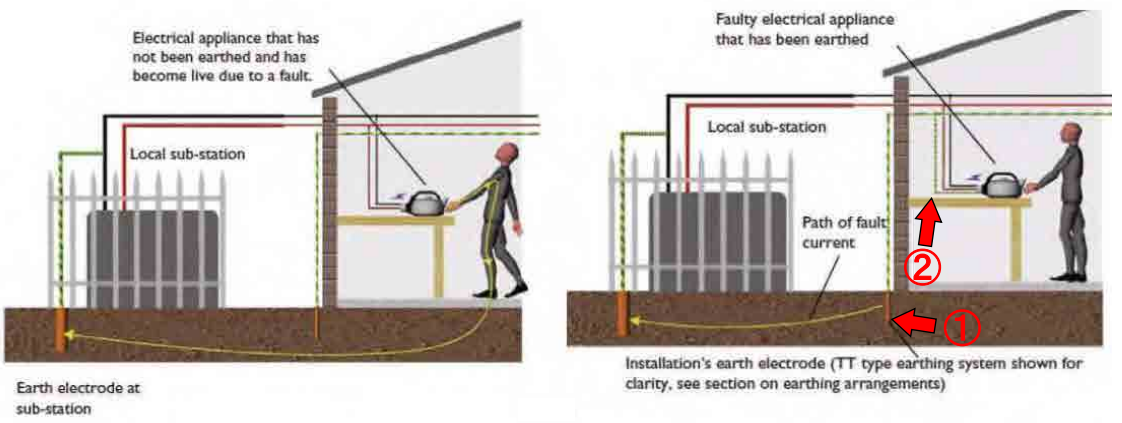
Electrical Leakage

- Electrical leakage is dangerous for not only machinery but also humans
- Any electrical leakage has to be found in the early stage and remedied properly for the system safety and efficiency

Current	Effect to Human
1mA	Feeling
5mA	Feeling keenly
10mA	Unbearable feeling of pain
20mA	The contraction of muscles and The victim cannot let go of the circuit.
50mA	Danger, Extreme pain
100mA	Fatal injury

13/20

Electrical Leakage - Importance of Grounding -



In order to avoid any trouble caused by electrical leakage, it is very important to
① Install an earth electrode giving sufficiently low resistance and
② Properly connect it with casing of electrical facility

Reference: https://www.linkedin.com/pulse/20141104174845-23740981-earthing-system-how-save-are-you-from-electric-shocks

14/20

ELECTRICITY DIRECTROTE

DIRECTOR ELECTRICITY

Muhammad Rafiq Ch.

HOW TO MINIMIZE THE ELECTRICITY EXPENDITURES.

WASA electricity expenditure can be controlled if each and every officer/official knows the essential information and its implementation to electricity billing, consumption, load compatibility, losses & payment.

ELECTRIC LOADS

There are three kinds of electric load and has major role in billing.

i- Sanctioned Load:-

The load applied by Consumer/WASA and approved / sanctioned by WAPDA (LESCO) is known as sanctioned load and its unit is KW.

ii- Installed Load.

The load installed at site is known as the installed load e.g 150 BHP

1HP=0.746 KW

150 BHP=150x0.746=111.9KW=112KW

At disposal/lift station installed load is mostly more than the sanctioned load due to the reason that extra load is installed as a backup.

At tube well installed load should not more than the sanctioned load.

iii- Running Load.

The load actually runs the system is called the running load/ Shaft Load.

Maximum Demand Indicator (MDI):

MDI stands for maximum demand indicator and it should not be more than the sanction load. MDI Meter noted that load which runs half an hour continuously of that month.

Multiplying Factor (MF):

In electricity bills, there is a column of MF (Multiplying Factor) MF is depend upon the current transformer ratio these Current transformers are installed in the meter security box.

Power Factor (P.F):

There is a limit of power factor and that limit is 0.90 to 1.00. Power factor should not deviate this limit. In case of deviation power company imposes the low power factor penalty.

In order to get rid of low power factor penalty custodian office must install low power factor improvement plant at its installations

Power Factor (P.F):

Power factor is the ratio of real power and apparent power

OR

the percentage of the kilowatt hours to the kilovolt amprs hours consumed during the month.

$$P.F = \frac{\text{Real Power}}{\text{Apparent power}}$$

$$= \frac{KWh}{KVAh}$$

Real Power (P):

Real power is the working power measured in kilowatt.

$$\text{Power} = \sqrt{3}\ VI\cos\phi$$

where v is volt, I is current and Cos ϕ is power factor

Apparent Power:

In the AC circuit, the product of the voltage and the current is called apparent power. Measured in kilovolt amps (KVA)

Reactive Power:

Reactive power is the non working power caused by the magnetizing current measured in kilovars (KVAR)

Calculation Of Power Factor (P.F):

Reactive power (KVARh) = KVARh units mentioned in the utility bill (charged/month)

Apparent power (KVA) = ? (Not mentioned in the utility bill) it may be calculated by the Pythagoras theorem

$$(KVA)^2 = (KVARh)^2 + (KWh)^2$$

$$KVA = \sqrt{(KVARh)^2 + (KWh)^2}$$

Calculation Of Power Factor (P.F):

Power factor is calculated by the power triangle illustrated below

Real power =100 kw

Apparent power = 142 KVA

Reactive power =100 KVAR

$$KVA = \sqrt{(KVAR)^2 + (KWH)^2}$$

$$= \sqrt{(100)^2 + (100)^2} = 141.42 \text{ say } 142$$

Calculation Of Power Factor (P.F):

$$\text{Power factor} = \frac{\text{Real Power (KWh)}}{\text{Apparent Power (KVA)}}$$

Power factor = 100/142 = 0.70 or 70%

This indicate that only 70% of the current provided by the electrical utility is being used to produce useful work

L.P.F Penalty:

Average power factor of a consumer in a month shall not be less than 90%, in case of below 90%, consumer shall pay a penalty and that penalty will be 2% increased in the fixed charges of that month corresponding to 1% decreased in the power factor below 90%

L.P.F penalty is as:

=2xMDI Charged in that month x Rate of MDIx(0.9 - Charged P.F)

L.P.F Penalty:

For Example: In the billing month Jun-17 against Reference No. 24-11245-9001400 LESCO power factor was 0.78 and MDI 109.68

L.P.F Penalty= 2x109.68x200x(0.90-0.78)

L.P.F Penalty (Rs.) = 5280

* Keep in mind for 0.9 power factor Kvarh should be less than half of kwh value. In case of increasing Kvarh half of the Kwh power factor penalty will be increased.

Advantages and disadvantages of leading and lagging power factor:

there are two types of power factor leading and lagging power factor. The symbol of power factor = cos ϕ

Leading power factor:

In case, leading power factor the kVAh and Kvarh is going to be more and kWh less. In this way current will be increased which will damage the electrical equipment/motor.

Lagging power factor:

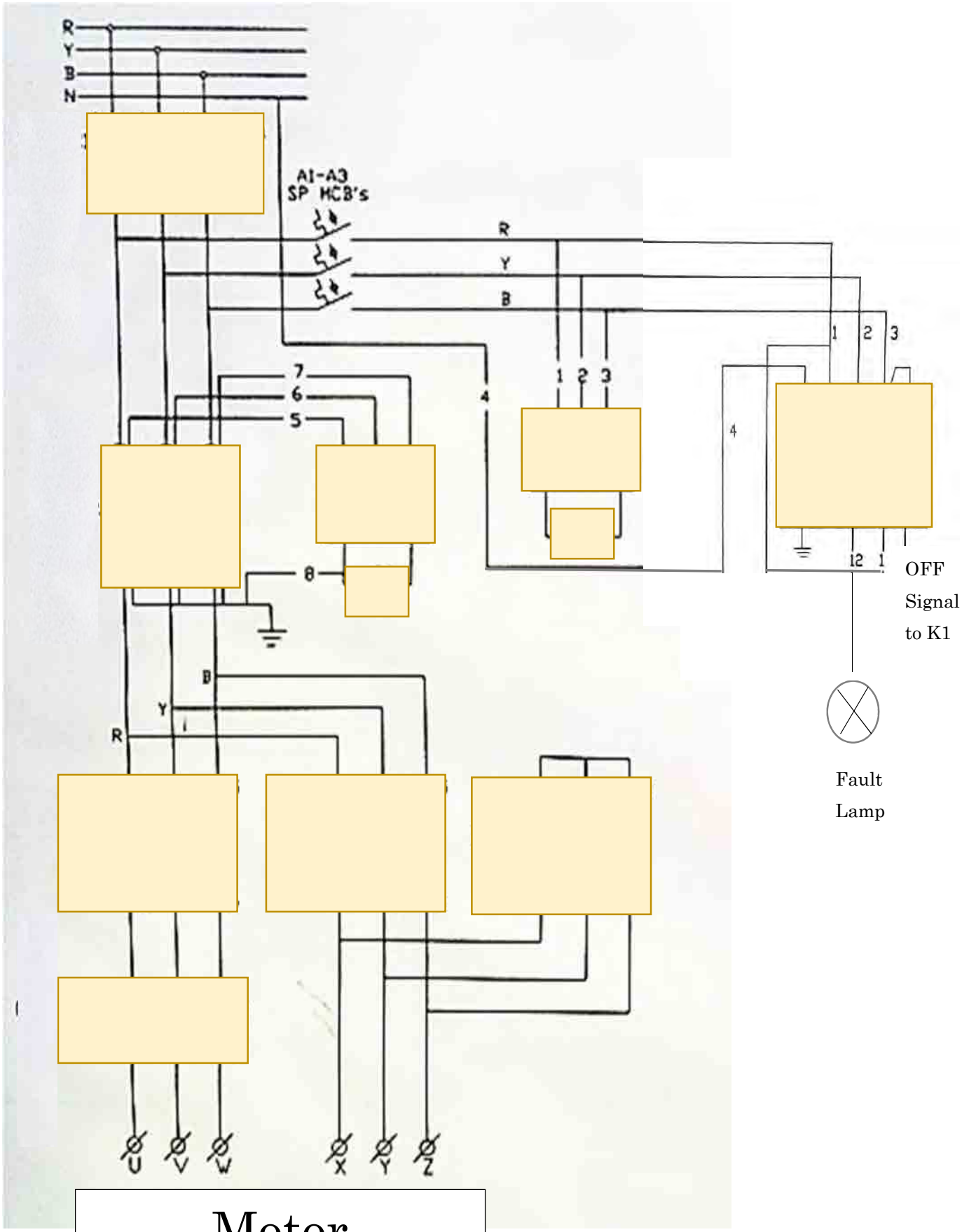
Lagging power factor is beneficial up to a limit and i.e 0.9 to 1.00 (lagging). In case of lagging less than 0.9, LPF Penalty will be imposed, Kvarh and current will also increased. This increased will damage the system.

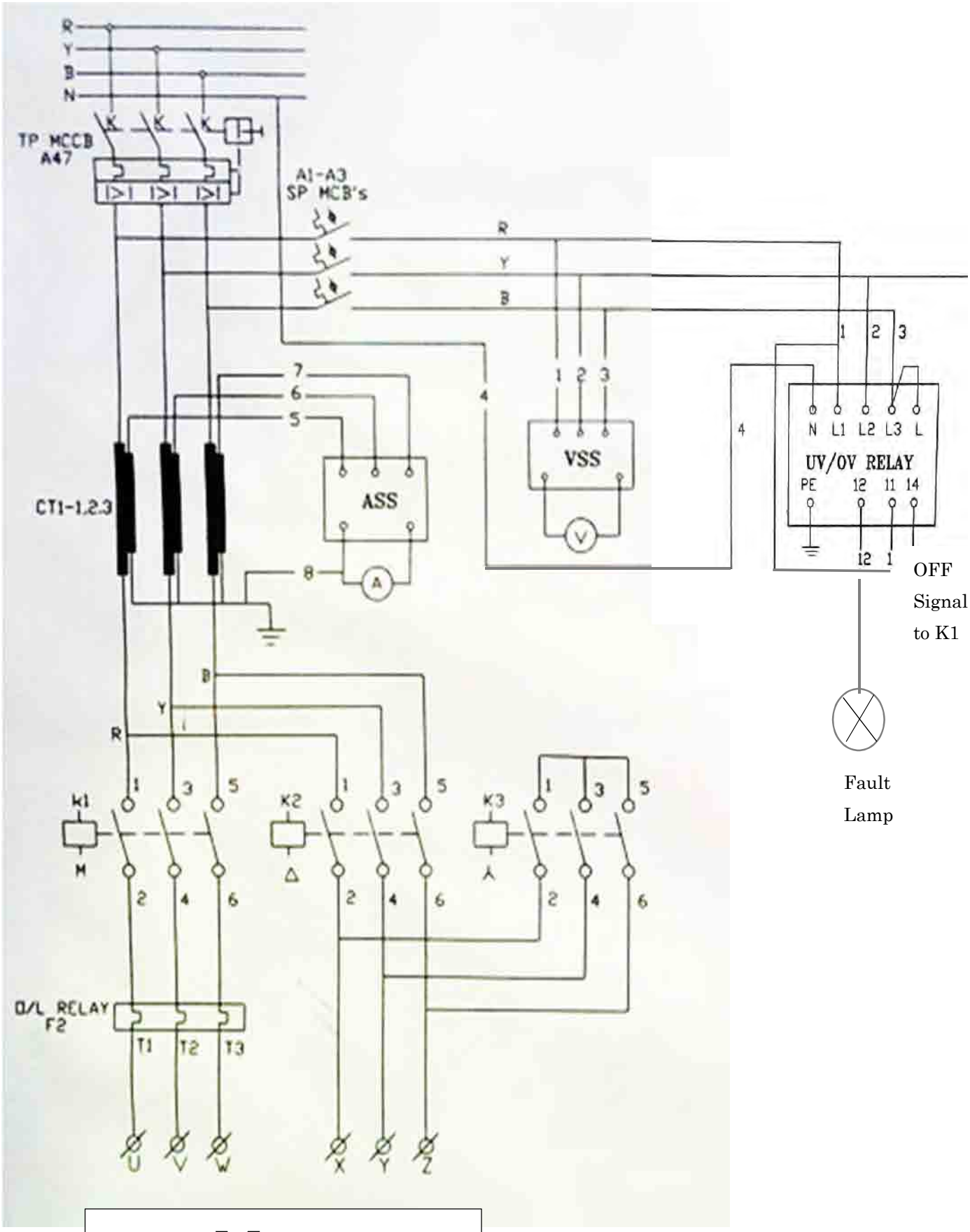
*Leading power factor is more harmful than lagging power factor and its amount of penalty is also high as compared to lagging power factor.

How to improve power factor:

For avoiding the deviation of power factor from its define limit, automatic PFI plants may be installed. PFI plants contains static capacitors bank, they are economical and easy to maintain.

Thanks


R
Y
B
N
A1-A3
SP MCB's
R
Y
B
1 2 3
7
6
5
4
1 2 3
4
8
12 1
OFF
Signal
to K1
B
Y
R
Fault
Lamp
U
V
W
X
Y
Z
Motor


R
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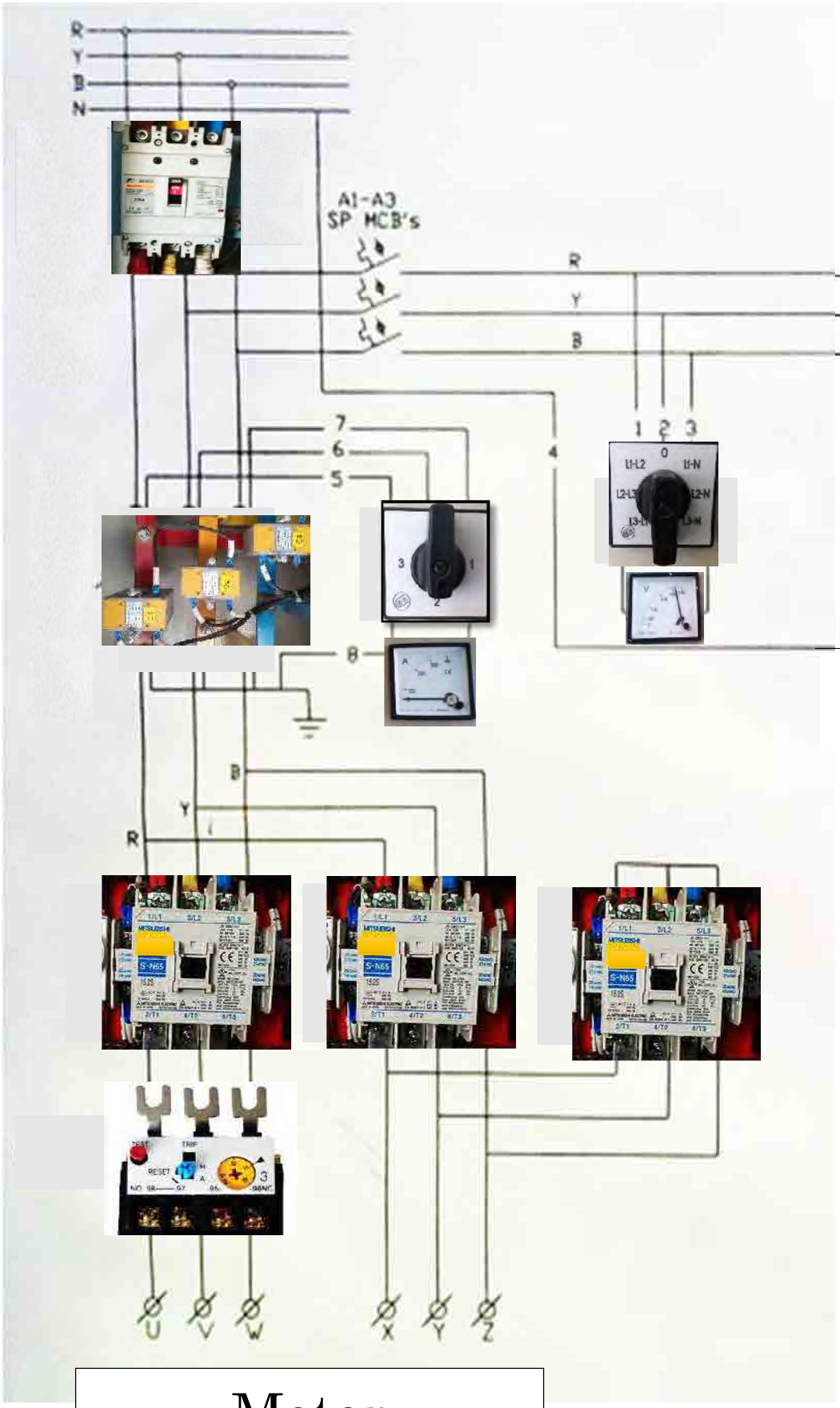
N
TP MCCB
A47
A1-A3
SP MCB's
CT1-1,2,3
ASS
VSS
UV/OV RELAY
PE
N L1 L2 L3 L
12 11 14
12 1
OFF
Signal
to K1
Fault
Lamp
K1
K2
K3
M
Δ
Y
O/L RELAY
F2
T1 T2 T3
U V W X Y Z

Motor


R
Y
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N
A1-A3
SP MCB's
R
Y
B
7
6
5
4
B
Y
R
ZAHRA RST 25
Low-Medium-High
voltage control relay
OFF
Signal
to K1
Fault
Lamp
U
V
W
X
Y
Z

Motor

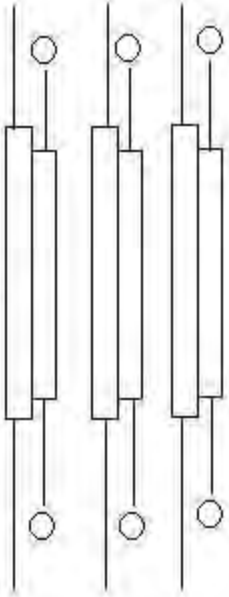
Name:_____

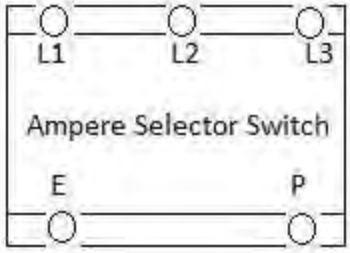
Designation:_____

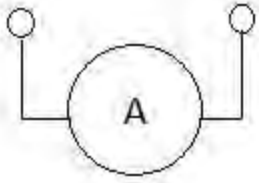
WASA:_____

EC-M1-04

Current
Transformer







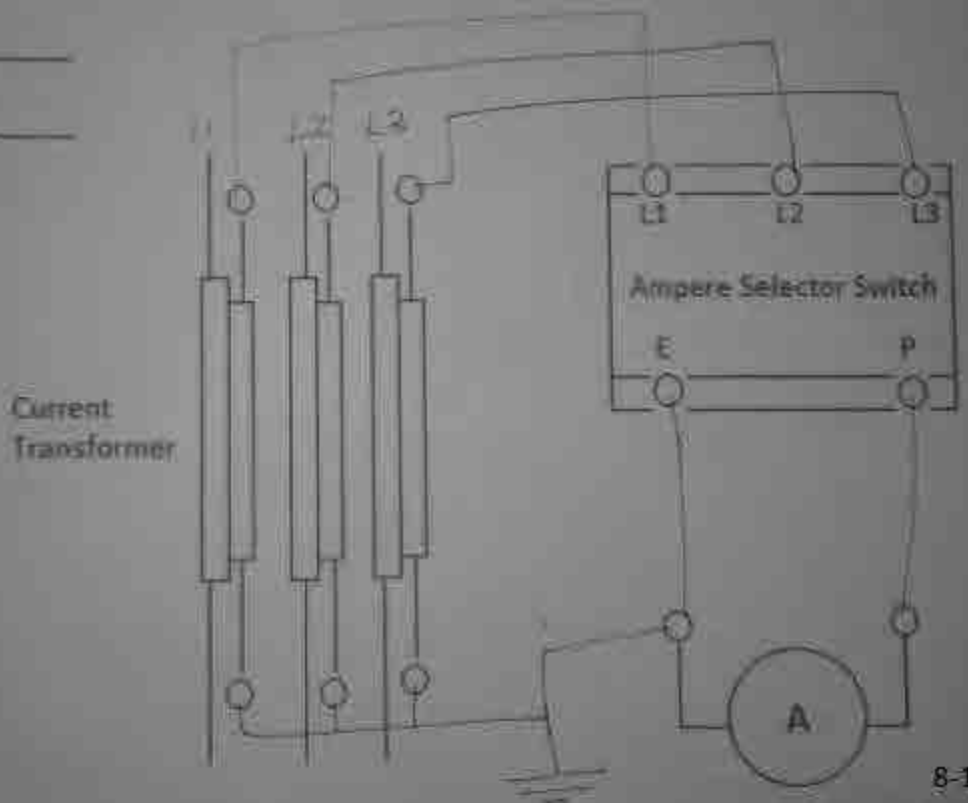
8-12-17

Name: _____

Designation: _____

WASA: _____

EC-M1-05



Current Transformer

8-12-17

EC-M1-06

Name: _____

Designation: _____

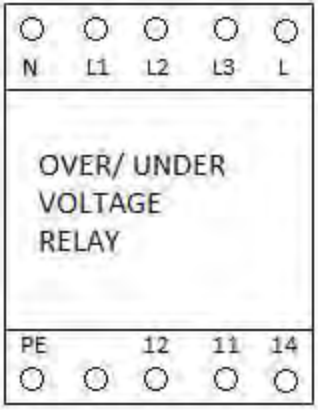
WASA: _____

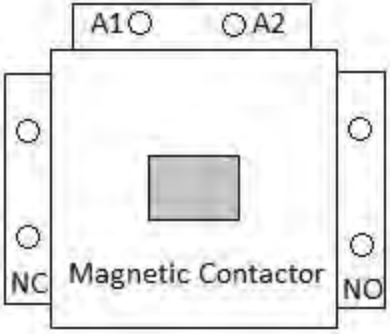
L1 _____

L2 _____

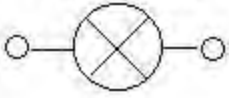
L3 _____

N _____





FAULT LAMP



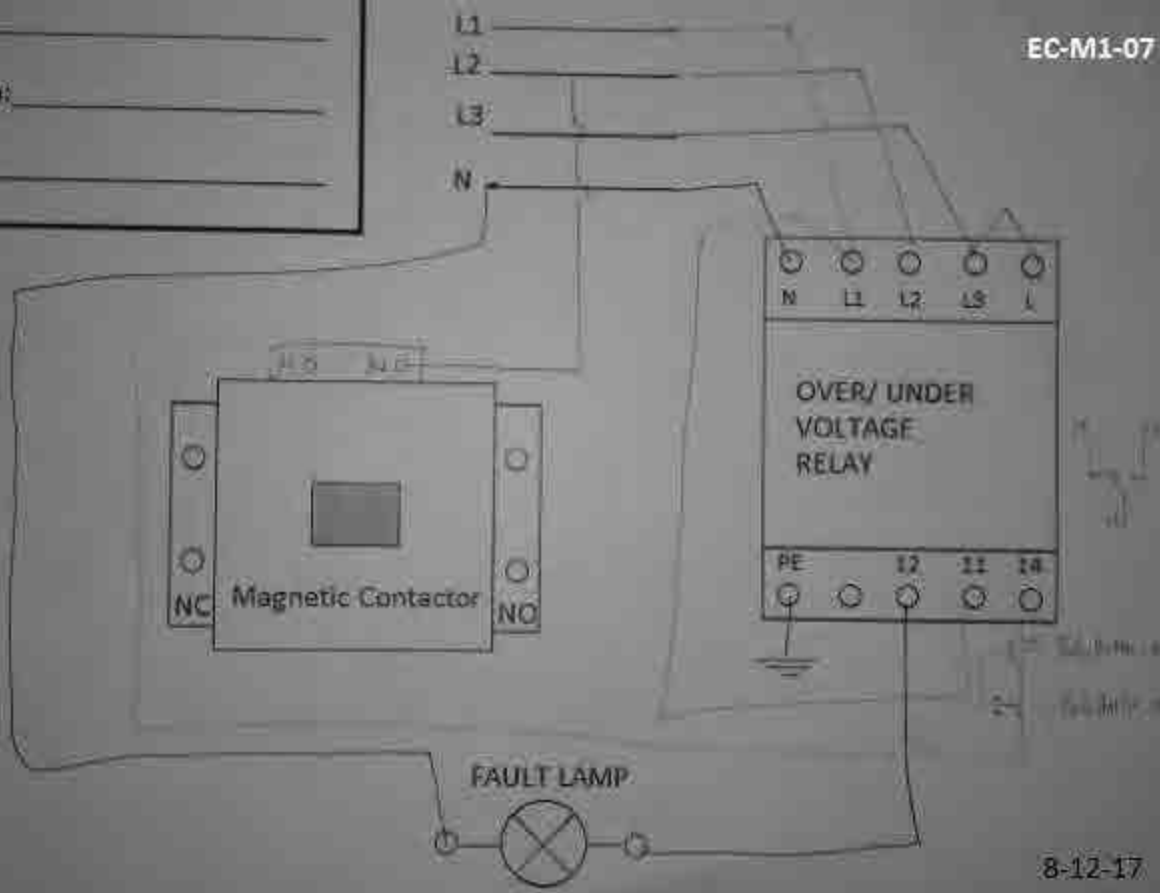
8-12-17

Name: _____

Designation: _____

WASA: _____

EC-M1-07



8-12-17

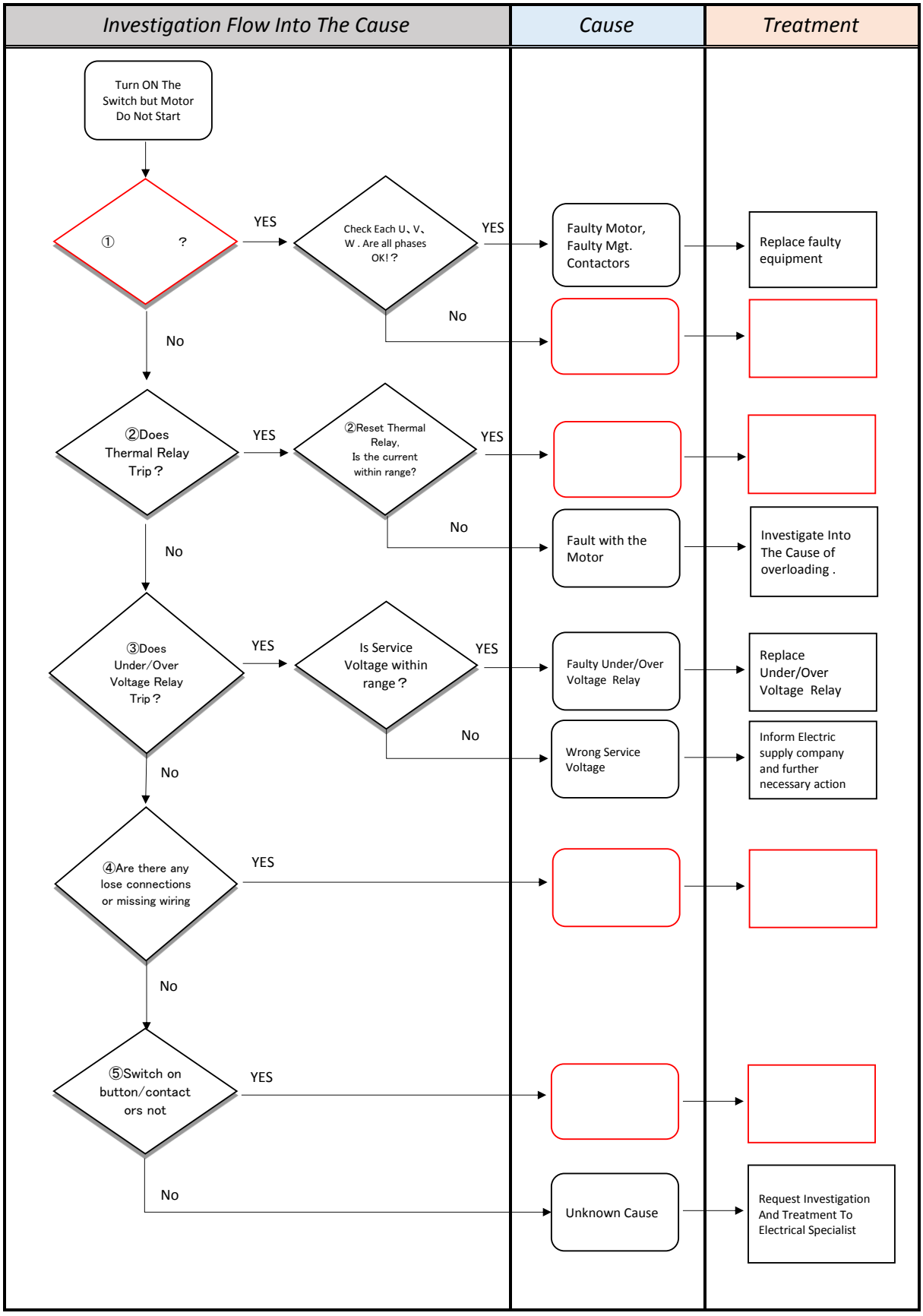
Participants Name: _____

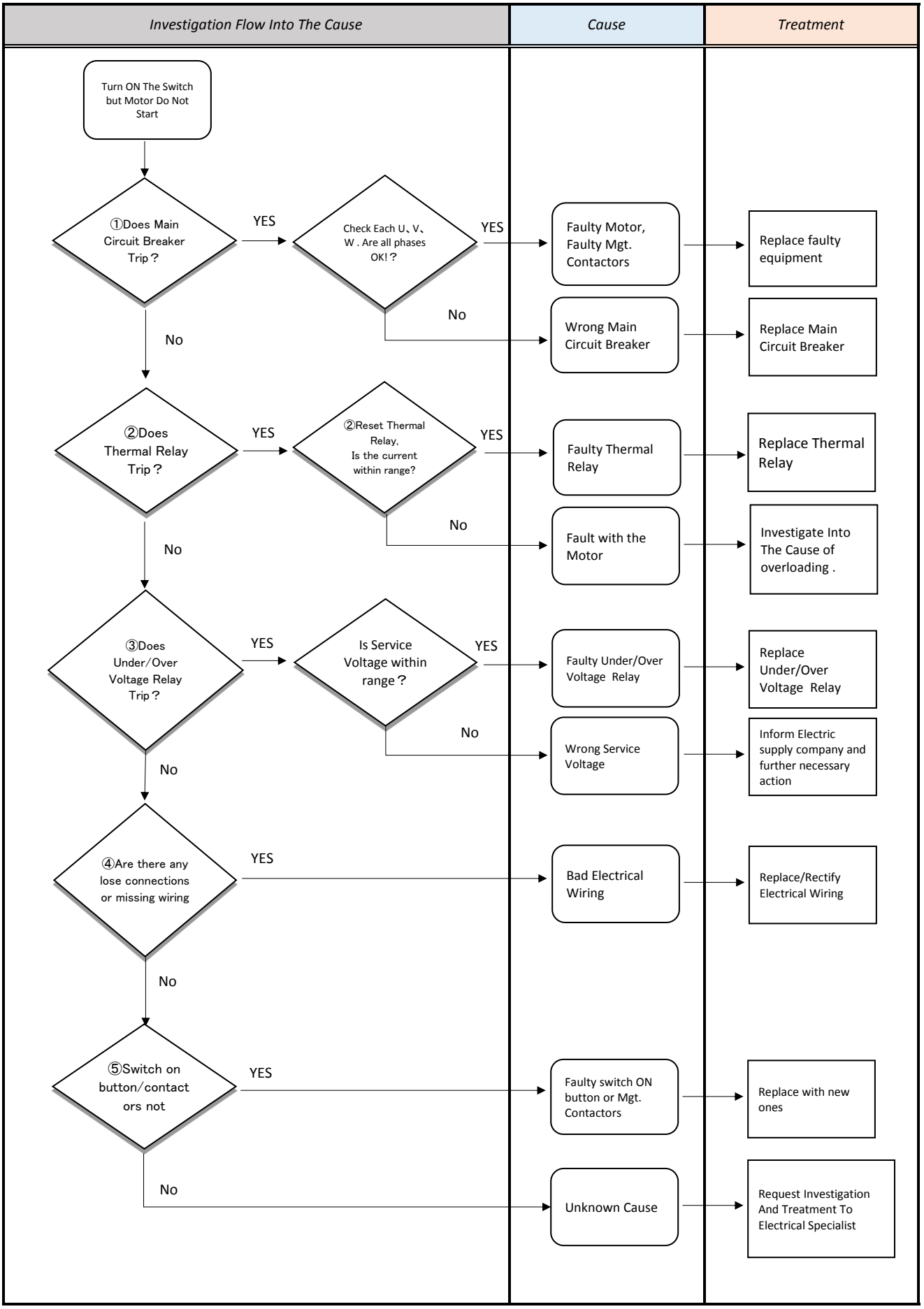
Motor Name Plate					
Voltage	**Connection**	**Ampere**	**HP**	**PF**	**RPM**
380	Delta	115	80	0.85	1480

An 80HP induction motor with Phase-to-Phase service voltages, V_1=460V, V_2=440V and V_3=470V is having issue of overheating windings. Kindly refer to the owners O&M manual and identify the fault and suggest remedy.

Over/Under voltage relay is set to V_{min}=390V and V_{max}=470V and timer is set at 7 seconds

Participant Name:_____




Investigation Flow Into The Cause
Cause
Treatment
Turn ON The Switch but Motor Do Not Start
①Does Main Circuit Breaker Trip？
YES
Check Each U、V、W . Are all phases OK!？
YES
Faulty Motor, Faulty Mgt. Contactors
Replace faulty equipment
No
Wrong Main Circuit Breaker
Replace Main Circuit Breaker
No
②Does Thermal Relay Trip？
YES
②Reset Thermal Relay, Is the current within range?
YES
Faulty Thermal Relay
Replace Thermal Relay
No
Fault with the Motor
Investigate Into The Cause of overloading .
No
③Does Under/Over Voltage Relay Trip？
YES
Is Service Voltage within range？
YES
Faulty Under/Over Voltage Relay
Replace Under/Over Voltage Relay
No
Wrong Service Voltage
Inform Electric supply company and further necessary action
No
④Are there any lose connections or missing wiring
YES
Bad Electrical Wiring
Replace/Rectify Electrical Wiring
No
⑤Switch on button/contactors not
YES
Faulty switch ON button or Mgt. Contactors
Replace with new ones
No
Unknown Cause
Request Investigation And Treatment To Electrical Specialist

Operation Time Record (Pump)

EC-M1-10

Month/Year : ／

Date : ～

Approved by (Engineer)	
Prepared by (Operator)	

Sr. No.	Date	Shift #	Operating Time		Operating Hours	Chlorine Dosing	Flow Reading (Start)	Flow Reading (Stop)	Flow Amount	Pressure	Power Factor	Voltage			Ampere		
			Turn On	Turn Off	hrs.	Y/N	m3	m3	m3	MPa	%	RY (V)	YB (V)	BR (V)	R (A)	Y (A)	B (A)
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
Total/ Sum																	

Remarks:

12/08/2017

Check List of Standard Operation Procedure for Electrical Facility

EC-M1-11

Approved by :

Inspected by :

Motor Specification: **Rated Capacity (kW/HP)** _____

Rated Voltage (V) _____**Rated Current(A)** _____

Efficiency_____**Power Factor**_____**RPM**_____

Evaluation Criteria

✓: Good ×: No care at all or need to be newly installed

△: Need to be improved —: Not available to be checked

Sr. No.	Site/Pump Name	Inspection Date	Inspection Items for Electrical Panel Condition															
			Document			Visual (Outside)						Visual (Inside)				Operation	
			Operation Record	Drawings	Vender Manual	Identification of Lamp/Switch	Status/ Fault Indication Lamps	Ampere Meter	Voltage Meter	Status Selector Switch		Cleanliness	Intrusion Path	Bypass-Circuit	Neatness of cabling	How to operate changeover switch	Frequency of Start/Stop
			Compare with the sample	Pump installation, electrical line diagram	Pump/ Panel devices	all lamps /switches have name tag	all lamps are visibly bright enough	Proper functioning and zero adjustment	Proper functioning and zero adjustment	Ampere	Voltage	No dust, sand, spider's nest, insect, small animals	No hole/ crack to let foreign matters come in	No bypass / burnt mark		Turn off by breaker or switch first.	Maximum 2-3 times/ hour
1																	
2																	
3																	

- Remarks -

12/08/2017

Device Inspection Sheet

EC-M1-12

Approved by :

Inspected by :

Motor Specification: **Rated Capacity (kW/HP) _____**

Rated Voltage (V) _____Rated Current(A) _____Efficiency_____

Power Factor_____RPM_____

Evaluation Criteria

✓: Good ×: No care at all or need to be newly installed

△: Need to be improved —: Not available to be checked

Sr. No.	Site /Pump Name	Inspection Date	Continuity Test of components (Using Clamp Meter)									Current Transformer			Relays Adjustments					
			Circuit Breakers					Magnetic Contactor			Fuse				Over/Under Voltage Relay			Over Current (Thermal) Relay		Y-Δ Timer
			MCCB	MCB 1	MCB 2	MCB 3	MCB 4	K1	K2	K3		CT1	CT2	CT3	Under Voltage Tripping Function	Over Voltage Tripping Function	±10% of rated voltage of motor	Tripping Function	Value Set	Not less than 5 seconds
1																				
2																				
3																				
4																				
5																				

- Remarks -

Preventive Maintenance Sheet for Electrical Facility

EC-M1-13

Sub Division:	**Motor Specification**			**Power (kW/HP)**	
Site Name:	**Rated Voltage (V)**	**Rated Ampere (A)**	**Efficiency (%)**	**Power Factor**	**RPM**
Equipment Name:					
	Date				
	Inspected By				
	Weather				

Activity			**Reference Value**	**Data of Site**		**Data of Site**	
Bolt Tightening			No loose point				
Insulation Resistance (MΩ)	U1-E	U2-E	≥ 1 M Ω = Good				
	V1-E	V2-E					
	W1-E	W2-E					
	U1-V1	U2-V2					
	V1-W1	V2-W2					
	W1-U1	W2-U2					
Earth Resistance Test	Earthing Pit/ Bar		< 5Ω				
	Electric Motor	Electric Panel					
Voltage by Clamp Meter (V)	RY		Rated ± 10%				
	YB						
	BR						
Ampere by Clamp Meter (A)	R		Rated ± 5%				
	Y						
	B						
Power Factor			≥ 0.9				
Vibration	Upper Bearing	Lower Bearing	< 5.1 mm/s				
Revolution Per Minute (RPM)			1450 (4 Pole)				
Temperature	Upper Bearing	Lower Bearing	< 90˚C				
	Shaft						

- Remarks -

Reference for Insulation Resistance Value:

Good → more than 1.0MΩ

Need to Adjust, Clean,Care → 1.0MΩ ~ 0.4MΩ

Need to repair immediately →less than 0.4MΩ

O & M of Electrical Equipment
WSD 5231

Generators

Module 2

Agenda

- ✓ Introduction to generators
- ✓ Basic assembly design of generators
- ✓ Components of generator
- ✓ SOP's and Best Industry Practices
- ✓ Periodic Maintenance and record keeping
- ✓ Reliability based preventative maintenance.
- ✓ Troubleshooting for various failures

Class Introduction

- ✓ Importance of Generators in WASA operations
- ✓ What do we cover in this module?
- ✓ What to expect in this module?
- ✓ Goal and objectives of this module?

Introduction to Generators

A generator is machinery that converts mechanical energy to electrical energy by electromagnetic action to generate electrical power

✓Principle of Generator

✓Frequency of the synchronous generator is determined according to the rate of rotation

✓Basic components of Generator:

1. **Diesel Engine**
2. **Alternator**
3. **Control Panel**

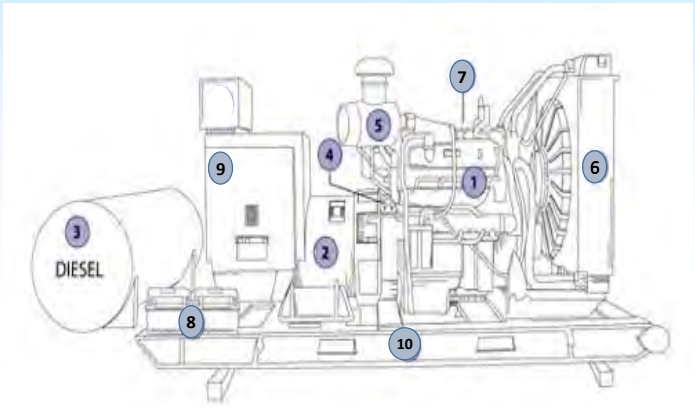
Flow of Systems

1. Starter motor starts operation using power supplied by batteries
2. Crank Shaft of engine starts rotating
3. Combustion cycle starts
4. Rotor of alternator starts to rotate
5. Stator of alternator generates power

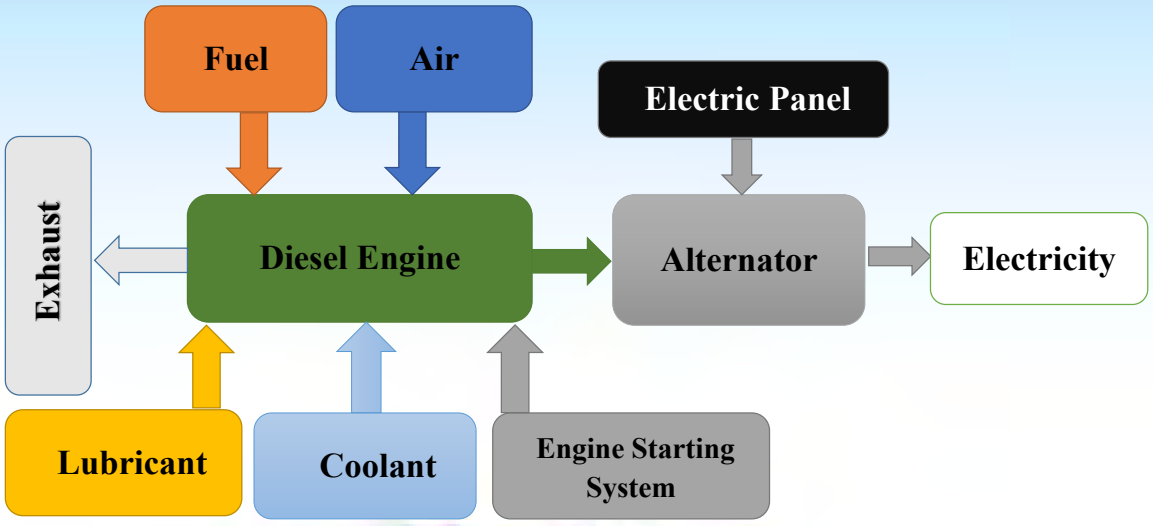
Basic design of generator

✓ Major components of a diesel generator

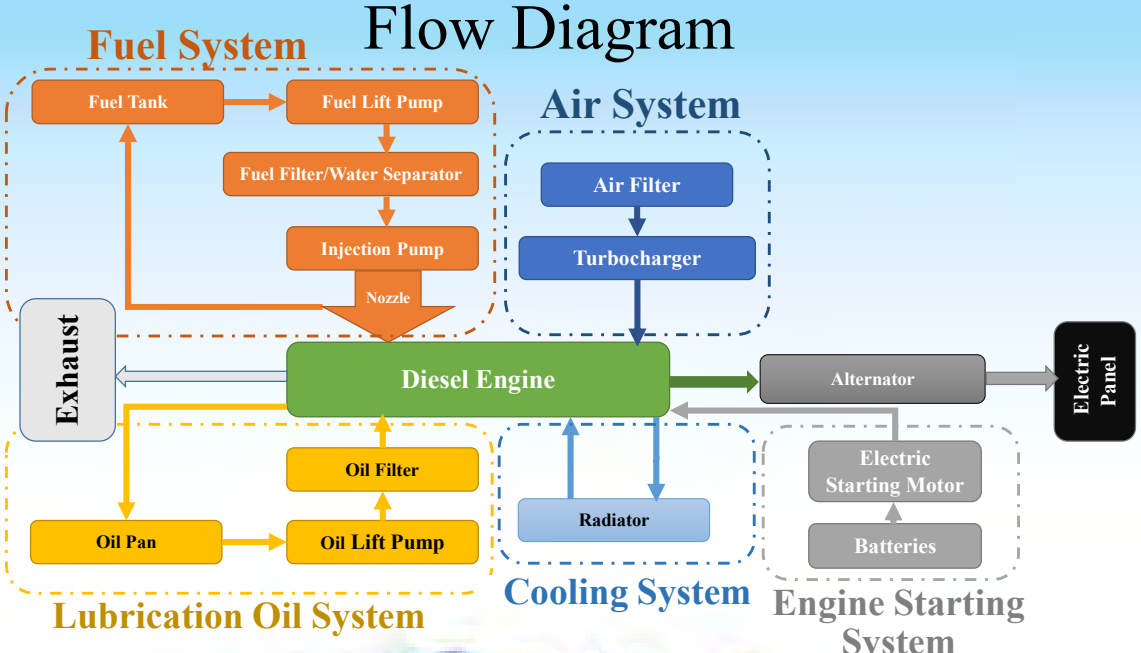
1. Engine
2. Alternator
3. Fuel Tank and related system
4. Voltage Regulator
5. Air Intake and Exhaust Systems
6. Cooling Systems
7. Lubrication System
8. Battery (Engine Starting System)
9. Control Panel
10. Main Assembly / Frame



Block Diagram of generator



Flow Diagram



1.Engine

- ✓ The engine is the source of the input mechanical energy to the generator.
- ✓ The size of the engine is directly proportional to the maximum power output the generator can supply.
- ✓ Source of energy for the operation of Generator

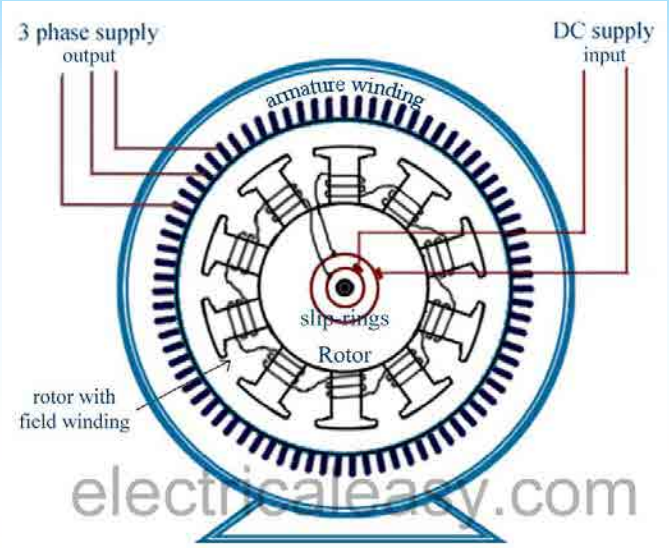
Engine

2. Alternator

- ✓ The alternator is the mechanical equipment that produces electrical output from the mechanical input supplied by the engine.
- ✓ It is coupled to the diesel engine through a drive shaft.

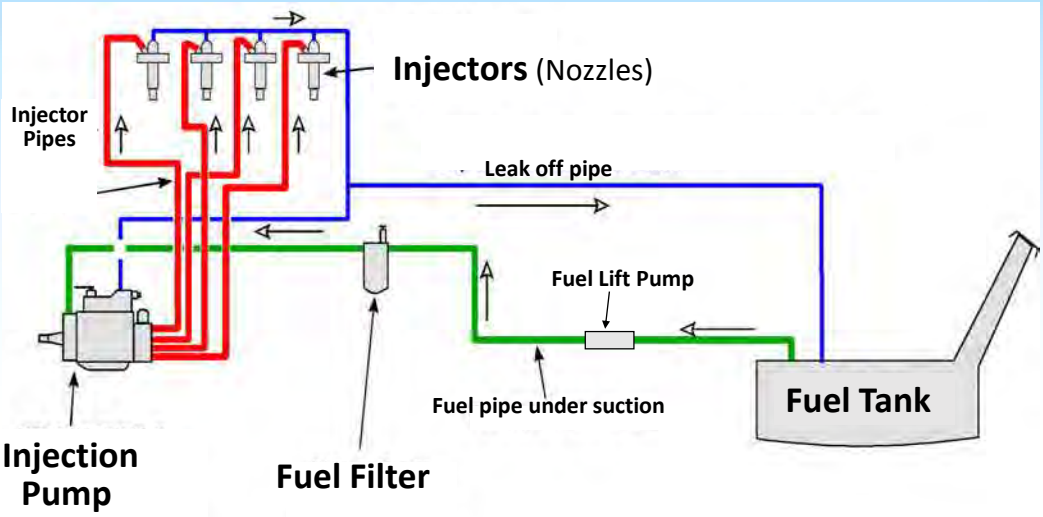
Alternator

2. Alternator



2. Alternator

3.Fuel System



Components of Fuel System

Fuel Tank	Fuel Lift Pump	Fuel Filter
		
Store enough fuel for combustion.	Lift the fuel from the fuel tank	Remove any solid particle in fuel

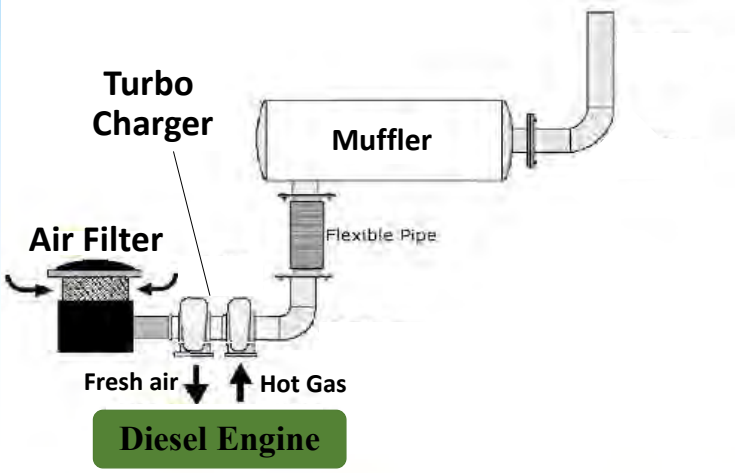
Components of Fuel System

Fuel Water Separator	Injection Pump	Nozzle
		
Separate and remove water from the fuel	**Inject fuel through nozzles at certain pressure**	**Throw fuel into the cylinders in small particle form**

4. Automatic Voltage Regulator (AVR)

AVR function is to control the magnetic field of the generator such that the output voltage will be constant.

5. Air Intake & Exhaust Systems



Typical Air Intake and Exhaust System

Components of Air Intake & Exhaust System

Air Filter	Turbocharger
	
Clean air from dust particles	**Compress air before intake for better combustion**

6. Cooling System

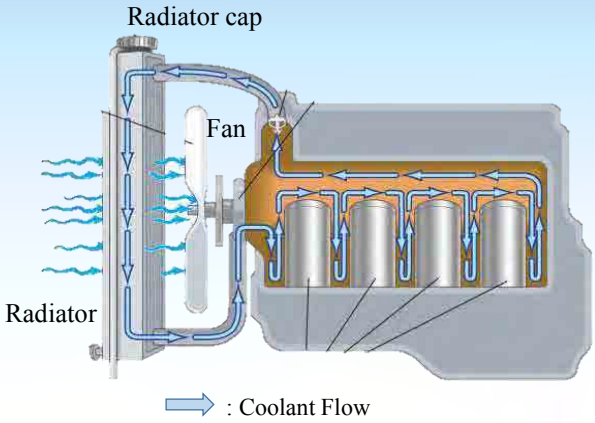
Function:

This system maintains the temperature of the engine assembly by introducing coolant into cooling channels. After completing the cycle coolant temperature increases which is then passed through radiator to radiate heat.

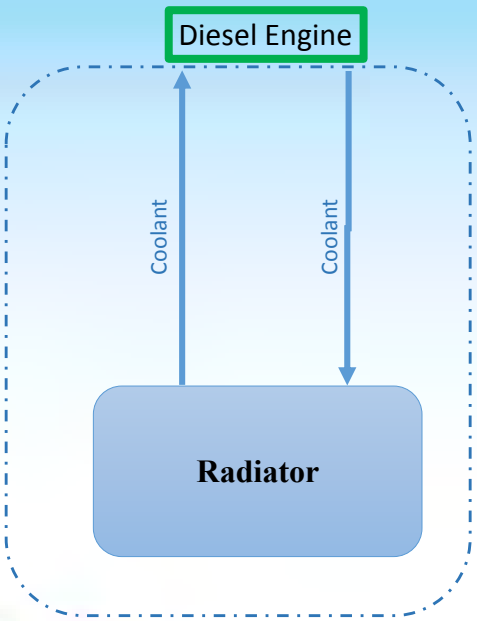
Components:

1. Radiator/ Charge air cooler
2. Thermostat

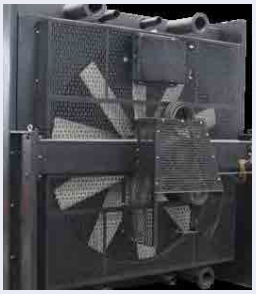
6. Cooling System



Cooling System

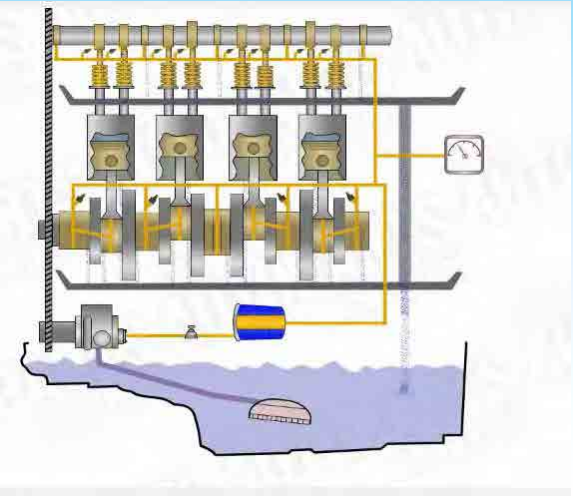


Components of Cooling System

Radiator	Fan
	
Reduce the temperature of the coolant	**Provide fresh air to radiator for cooling coolant**

7. Lubricating System

- ✓ Generator comprises moving parts in it's engine, So lubrication is required for long lasting operation.
- ✓ The generator's engine is lubricated by oil stored in an oil pan.



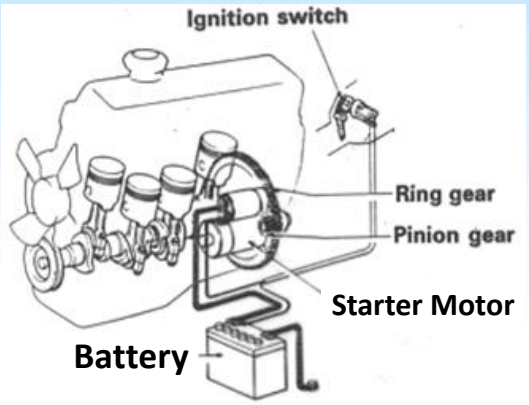
Lubrication system

Components of Lubricating System

Oil Pan	Oil Lift Pump	Oil Filter
		
Store enough engine oil for lubrication	**Lift and send oil from the oil pan to the oil filter and keep circulation**	**Remove any pollution or solid particle in engine oil**

8. Engine Starting System

- ✓ The start function of a generator is battery-operated.
- ✓ The engine needs initial rotating power to start combustion cycle so that starting motor provides the power by consuming battery DC power
- ✓ Battery is charged by DC alternator during generator operation



Components of Fuel System

Battery	Starter Motor	Alternator For Battery Charge
		
Provide starting current to the starter motor	**Start rotation of engine from the rest position**	**Generate power and charge the battery by utilizing engine rotation**

9. Control Panel

- ✓ This is the user interface of the generator and contains provisions for electrical outlets and controls.
- ✓ Electric start and shut-down
- ✓ Engine gauges
- ✓ Generator gauges
- ✓ Alarm monitoring
- ✓ Data logging
- ✓ Other controls

Electrical Control panel

Components of Electrical System

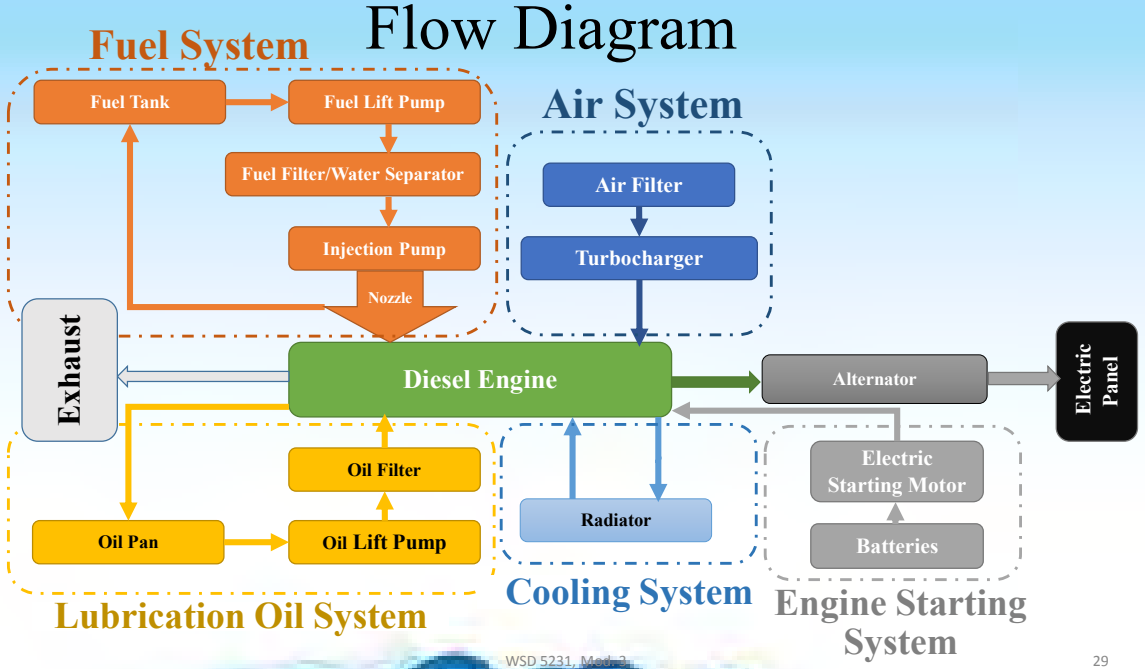
Alternator (Main)	Electrical Panel	Cables
		
Provide main alternative power supply	**Monitor and control the system through sensors and provide electrical energy with protection**	**Provide electrical connectivity between the alternator and other electrical component**

10.Main Assembly / Frame

- ✓ All generators, portable or stationary, have customized housings that provide a structural base support.
- ✓ The frame also allows for the generated to be earthed for safety.

Main frame of Diesel Generator

Flow Diagram



Capacity Calculations

- No specific or standard sizing solution is available.
- Highly depends upon the site conditions and running loads.
- Some manufacturers provide guide to estimate the required generator sizes.

Capacity Calculations

Following steps are required to calculate required size of the generator:

Step 1: Calculate the power of all non-motor loads

Step 2: Calculate starting power of the largest motor and running power of all other motors.

Step 3: Add all motor's running load and starting load of the largest motor

Step 4: Add non motor loads into the value of step 3

Step 5: Select Generator's rating of at least 125% of the final answer of step 4

Standard Operation Procedure for Generator

Electrical Connection's Overview

Standby Diesel Generators

Changeover Switch

Electrical Panel

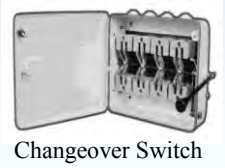
Motor of Pump

WAPDA Line
(11kV, 3phases)

Incoming Pole

Electrical Connection's Overview

Standby Diesel Generators



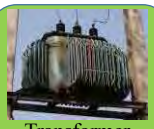
Changeover Switch

Electrical Panel

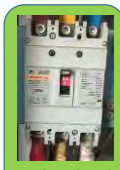
Motor of Pump

WAPDA Line
(11kV, 3phases)

Incoming
Pole



Transformer
11kV → 400V



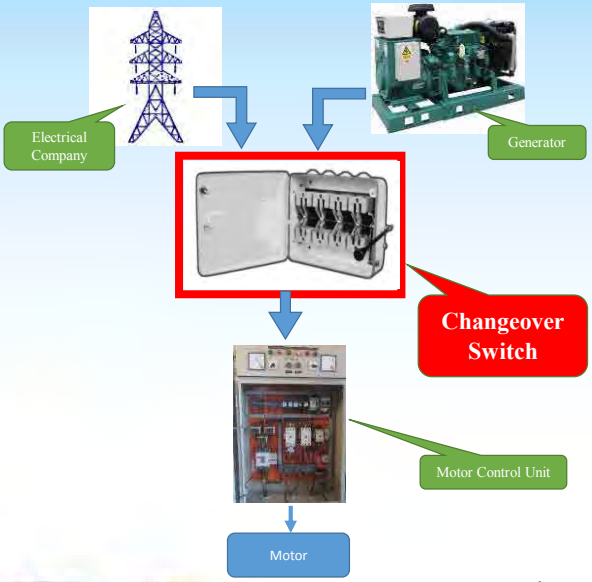
Main Circuit
Breaker

Terminal Box

3

Changeover Switch Operation

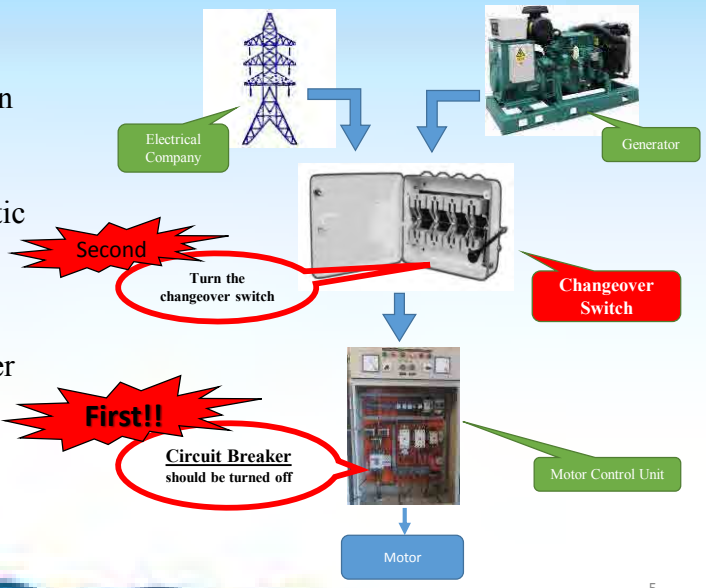
- ✓ Change over Panels are used to switch between primary and auxiliary power source. It is used in case of multiple connections from the electric supply company or generators



4

How to operate changeover switch ??

- ✓ Don't directly open/turn the changeover switch during operation of load
- ✓ Turn off the circuit breaker/magnetic contactor first !!
- ✓ Otherwise, The terminal of changeover switch would encounter sparking



5

Best practices in Generator Operations

Standard operating procedure **before operation**

Inspect the site

- **No Leakages**
- **No Unusual smell/ odour**

Inspect the generator

- **Circuit breaker of the generator**
- **Connections of batteries are fine**
- **No loose screw/ bolt**
- **Enough amount of fuel**
- **No indication or warning lamps are turned on**

Electrical isolation

- **Turn off the following devices first:**
- **Main circuit breaker of Electrical Company's line**
- **Circuit breaker of Motor control unit**
- **Circuit breaker of the generator**
- **Rotate changeover switch to generator**

Best practices in Generator Operations

Standard operating procedure **during operation**

Start and Observe

- **Turn on the Main Circuit Breaker of the Generator**
- **Start the generator**
- **The sound of generator should be normal**
- **Examine the frequency and voltages**

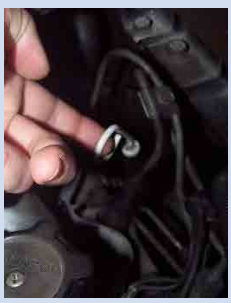
Connect the generator

- **Wait for 30-40 seconds till confirming voltage and frequency get stable enough**
- **Turn on the circuit breaker of the motor control unit**

Observe the operation

- **Sound should be normal**
- **No leakages of air, gas and oil from expected parts**

Parameters To Be Cared For Before Operation

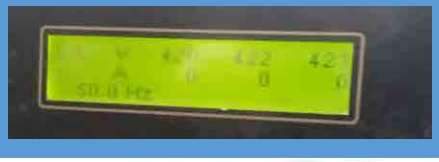
1. Circuit Breaker Off	2. Fuel Level	3. Battery water Level	4. Oil Level
			

Parameters To Be Cared For Before Operation

5. Coolant Level	6. Site Inspection		
	Leakage	Odor	General condition of Generator

Parameters To Be Cared For During Operation

1. Voltage	2. Frequency	3. Current	4. Over Heat



Parameters To Be Cared For During Operation

5. Earth Leakage	6. Gas, Air, Oil Leakage, Vibrations/ Abnormal noise
	

Preventative Maintenance & Record Keeping

Preventive Maintenance

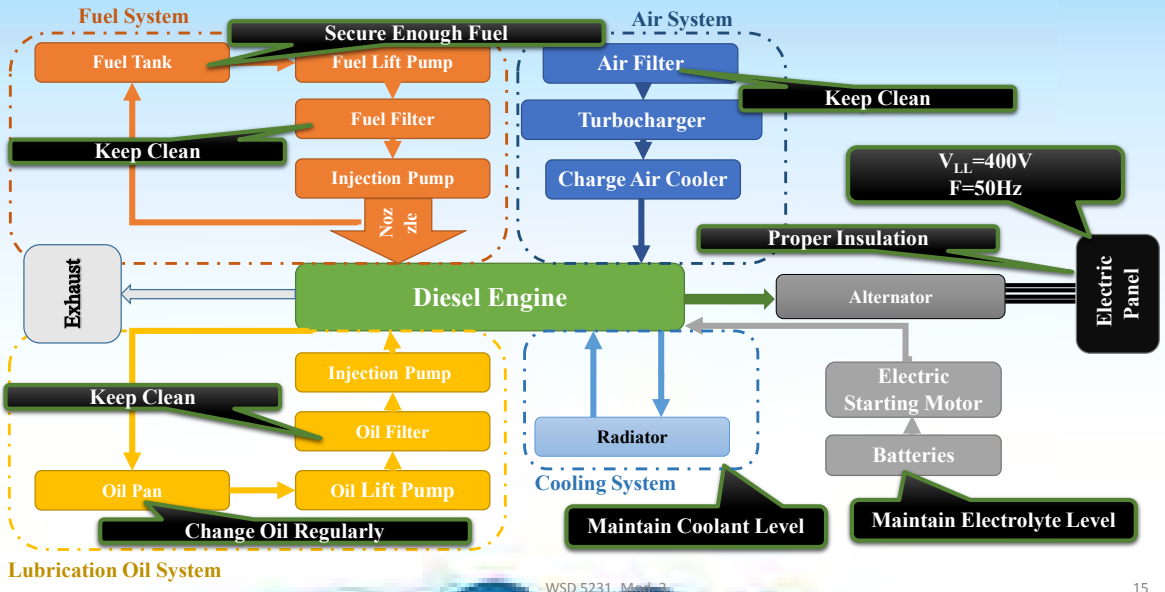
- ✓Reduce uncomfortable operation for main components and increase the lifetime of facility
- ✓Tracking data indicates latent failures in the early stage before it leads to a breakdown
- ✓Fault detection in the early stage contributes to sustainable water supply service

Necessity of Maintenance

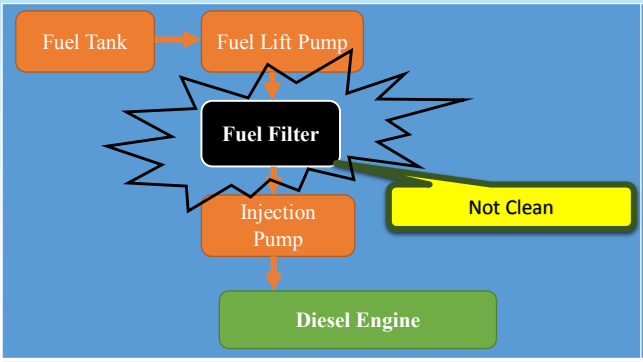
An early warning is generated by the generator before the occurrence of many failure. One should keep special intension to the device during operation, maintenance and regular inspection to avoid major problems. Some of the problem which can be observed during the operation of the device are:

a. Engine misfire
b. Vibration
c. Unusual engine noise
d. Sudden changes in engine operating temperatures
e. Excessive smoke
f. Increase in oil consumption
g. Increase in fuel consumption

How should the generator be?

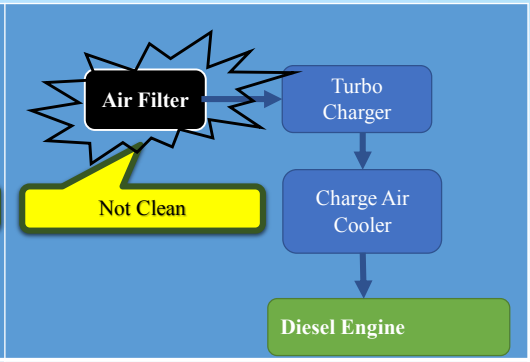


Necessity of maintenance



Problems:
- Engine Misfires
- Engine Runs Rough
- Low Output Power

Remedy:
- **Replace or clean the fuel filter**



Problems:
- Engine Misfires
- Dark Smoke
- Lower Acceleration

Remedy:
- **Replace or clean the air filter**

Daily and Periodic Maintenance Sheet

Sr. No.	Activities	Service Type				Last Activity Date	Year____ Month____				
		Daily	Weekly	Monthly	6 Months		1	2	3	4	5
1	Visual Inspection	●									
2	Check Coolant Level	●									
3	Check Oil Level	●									
4	Check Fuel Level	●									
5	Check Charge Air Piping	●									
6	Check and Clean Air Cleaner		●								
7	Check Battery Charger		●								
8	Drain Fuel Filter		●								
9	Drain Water From Fuel Tank		●								
10	Check Coolant Concentration			●							
11	Check Drive Belt Tension			●							
12	Drain Exhaust Condensate			●							
13	Check Starting Batteries			●							
14	Change Oil and Filter				●						
15	Change Coolant Filter				●						
16	Clean Crankcase Breather				●						
17	Change Air Cleaner Element				●						
18	Check Radiator Hoses				●						
19	Change Fuel Filters				●						
20	Clean Cooling System				●						

17

ITEM	Daily	50 Hrs	300 Hrs	1000 Hrs	2000 Hrs
Inspect, adjust or replace alternator or fan belt	■				
Check cooling system coolant level	■				
Check driven equipment	■				
Inspect engine air cleaner service indicator	■				
Check engine oil level	■				
Drain fuel system primary filter/water separator	■				
Walk around inspection	■				
Drain tank water and sediment		■			
Check battery electrolyte level			■		
Clean/replace engine air cleaner element			■		
Inspect/clean engine ground			■		
Change engine oil and filter			■		
Replace water separator element			■		
Replace fuel system secondary filter			■		
Inspect/replace hoses and clamps			■		
Inspect/adjust engine valve lash				■	
Inspect aftercooler core					■
Inspect alternator					■
Inspect engine mounts					■
Inspect starting motor					■
Inspect turbocharger					■
Inspect water pump					■

18

Daily Operation & Maintenance Record

Daily Operation and Maintenance Record (Generator)

Month/Year : ／

Date : ～

Approved by (Engineer)

Prepared by (Operator)

	Items	Unit	Standard/ Rated	Date ( )	( )	( )	( )	( )	( )	( )	( )	( )	Average	Total
Operation Record	Operating Time	-		: ～					～ :	: ～ :	: ～ :			
	Operating Hours	hrs.												
	Voltage RS	V	400											
	ST	V												
	TR	V	400											
	Frequency	Hz	50											
	Energy Consumption	kWh												
Maintenance Record	Coolant Level	✔										Remarks		
	Fuel Level	L												
	Engine Oil Level													
	Alternator and Fan Belts	✔												
	Driven Equipment	✔												
	Walk Around Inspection	✔												

Operation Record
Operation Time, Operation Hour, Voltage, Frequency, Energy Consumption

Daily Maintenance Record
Coolant Level, Fuel Level, Oil Level, Fan Belt, Driven Parts, Walk-Around Inspection

Daily Maintenance Checks

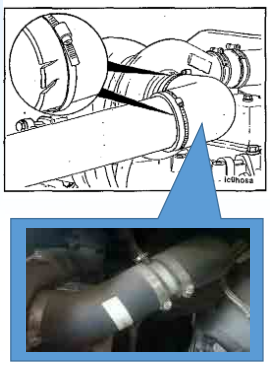
- ***Electric panel***

Electric and control panel must be inspect before operation. There must be no spark or smell etc. In case of spark or smell, check the connections of the devices and rectify the problem immediately.

- ***Air intake piping***

Visual inspect:
- Intake piping wear points
- Damages to piping
- Loose clamps or punctures that can damage the engine

Replace damaged pipe and tighten loose clamps, as necessary, to prevent the air system from leaking.



Daily Maintenance Checks

Walk-around inspection

To look for any…

- Leaks
- Damaged Parts
- Worn of Damaged belts
- Any change in engine appearance
- Odor of fuel

Daily Maintenance Checks

- Maintenance check

Visually inspect piping points for wear points and damage, loose clamps or punctures.

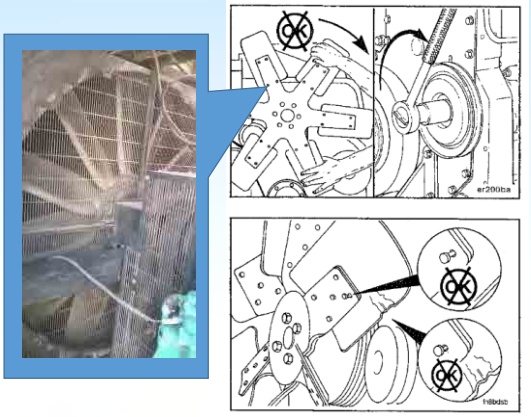
Replace damage piping and replace loose clamps.

Daily Maintenance Checks

Cooling fan

- ✓ A visual inspection is required daily.
  Check for cracks, loose rivets, bent or loose blades.
  Check the fan if it is securely mounted.

- ✓ Do not rotate the engine by pulling or prying on the fan. Use the accessory driveshaft or the crankshaft barring tool to rotate the crank shaft.



Cooling System

- ✓ The charge-air cooler piping and hoses should be inspected regularly for leaks, holes, cracks, or loose connections. Tighten the hose clamps as necessary. In addition, inspect the charge-air cooler for dirt and debris that may be blocking the fins. Check for cracks, holes, or other damage.

Cooling System

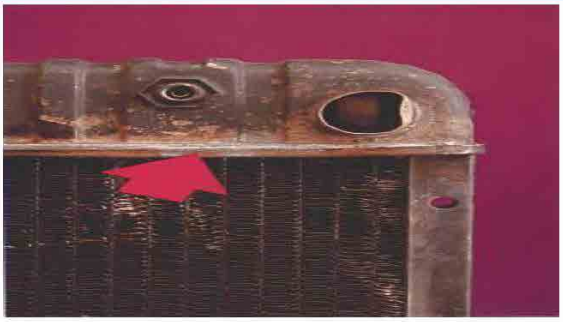
- Inspect for Reuse

Visually inspection is required to check for cracks, loose rivets and bent or loose blades.

Do not rotate the engine by pulling or prying on the fan. Fan blades can be damaged causing the fan to fail and cause personal injury.

Daily Maintenance Checks

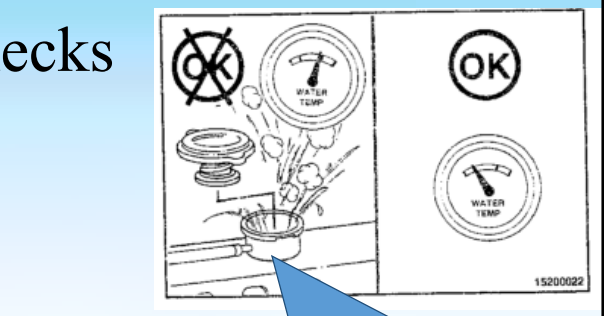
- ✓ External coolant leaks
- ✓ Belt condition-cracked or loose
- ✓ Block heater – on constantly or leaking
- ✓ Hoses – leaking, soft, brittle, bulging
- ✓ Radiator – Leaking, plugged, broken fan shroud

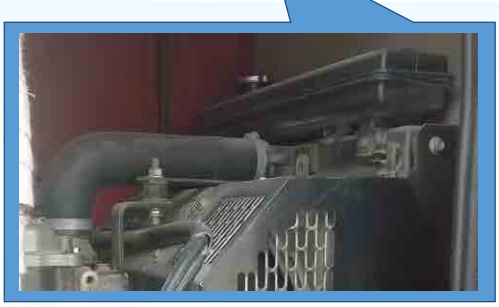


Daily Maintenance Checks

Engine coolant level

- ✓ Do not remove the pressure cap from the hot generator. Wait until the coolant temperature is below 50 ℃ before removing the pressure cap.
- ✓ To add coolant, the ratio of coolant and anti-freeze must be according to the recommended weather conditions.



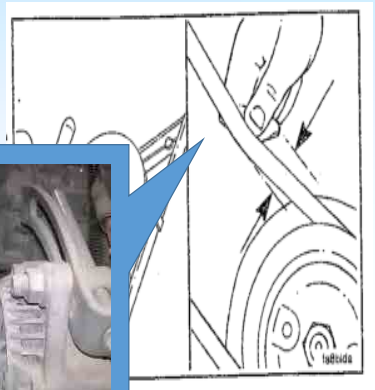


Daily Maintenance Checks

Drive belts

Inspect the belt daily. Check the belt for intersecting cracks. Replace the belt if it is frayed or has pieces of material missing.
Belt damage can be caused by:

- •Incorrect tension, size or length
- •Pulley misalignment
- •Severe operating environment
- •Oil or grease on the side of the belt
- •Aging degradation



Checking the belt tension

- Use a ruler to find the midway point on the belt's longest run between pulleys. Hold the belt between finger and thumb at this point and move it from side to side.
- See how much it deflects at the center of the run.
- If it moves more than 1/2 in. (13 mm) it is too slack - any less movement and it is too tight. Check the exact deflection recommended in the car handbook.

Fuel System Check

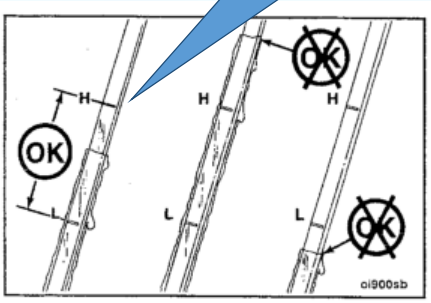
- ✓ With the generator set operating, inspect the fuel supply lines, return lines, filters, and fittings for cracks or abrasions.
- ✓ Make sure the lines are not rubbing against anything that could cause an eventual failure.
- ✓ Repair any leaks or alter line routing to eliminate wear immediately.

Fuel System

Daily Maintenance Checks

Engine lubrication oil level

- ✓ The engine must be level to check the lubrication oil level.
- ✓ Shut off the engine for an accurate reading. Wait at least 15 minutes after shutting off the engine to check the oil level. This allows oil the time to drain into the oil pan.



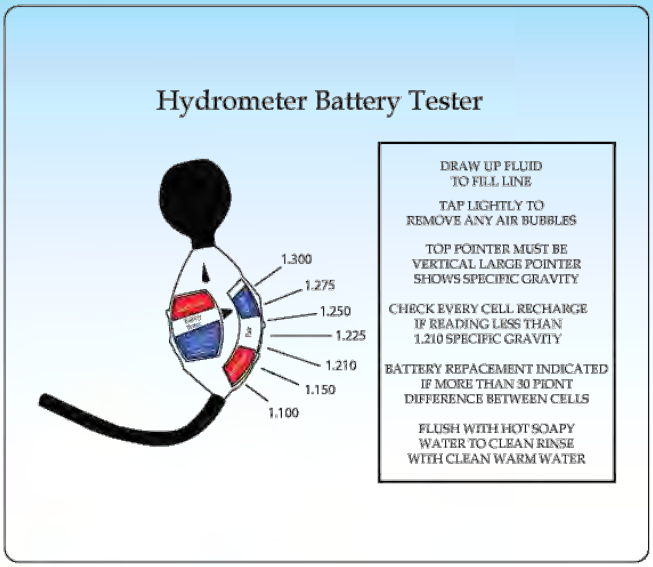
DC Electrical- Areas of concern

DC electrical system: Check the terminals on the starting batteries to make sure the connections are clean and tight. Loose or corroded connections create resistance, which can hinder starting.

1. Battery Charger - voltage and amperage
2. Condition of batteries-Change every 24-36mths
3. Wiring - connections
4. D/C Alternator – Belts, connections

Battery maintenance check

- ✓ Avoid starting failures by making sure the starting batteries are fully charged and tested regularly under a load.

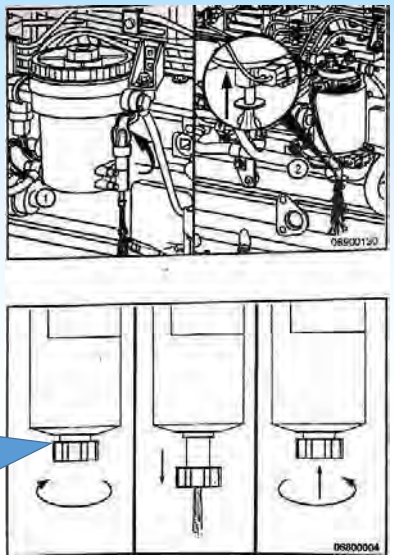


Daily Maintenance Checks

Fuel water separator/ filter

Drain the water and sediments from the separator daily. But before draining, shut off the engine. Use hand to open the drain valve. Drain the filter sump until the clear fuel is visible.

After that close the valve
and turn it until it is hand-tight.
Do not over tighten the valve.
It can cause the damage of the threads.

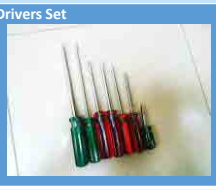
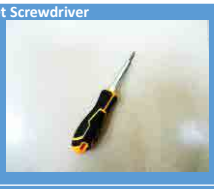
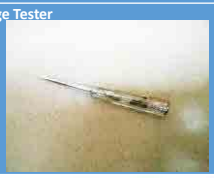


Engine Operation Report

Report any of the following issues:

- Low lubrication oil pressure
- Low Power
- Power increases or Engine surge
- Erratic or no accelerator response or control
- Warning lights
- Unusual Engine noise
- Excessive Smoke

Necessary Tools

1. Insulated Rubber Glove 	2. Screw Drivers Set 	3.Helmet 
4.Ratchet Screwdriver 	5. Ratchet Socket Wrench Set 	6. Adjustable Wench 
7. Voltage Tester 	8. Clamp Type Multi-meter 	

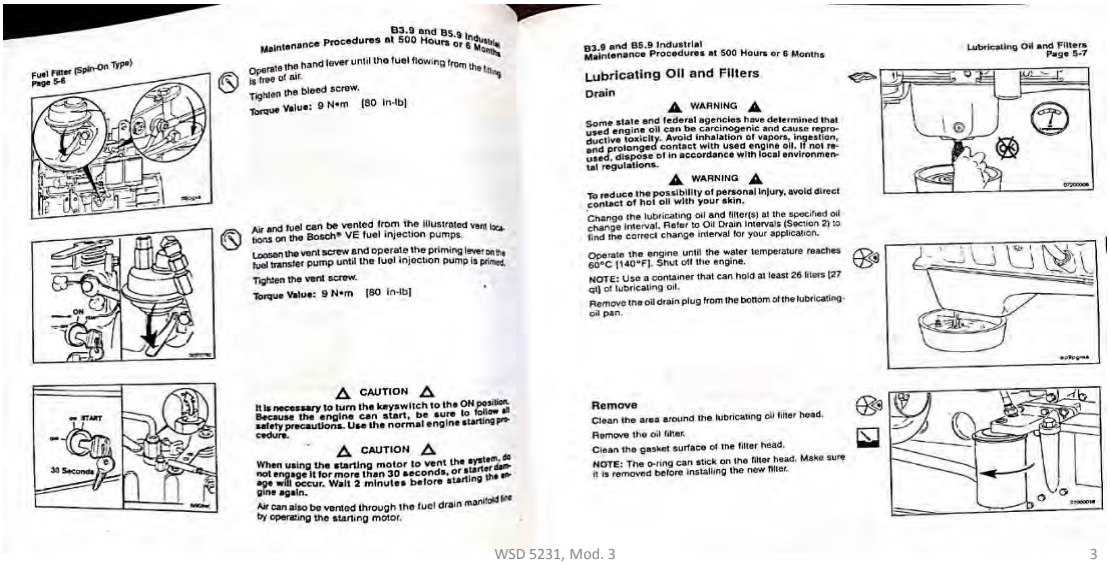
O&M Manual & Specification

Introduction of manufacturer's O&M manual

Depending upon the power rating, design and manufacturer, different generators may have different flow of maintenance. So O&M manual of each device must always be available at the site.

You have to keep O&M Manual of **YOUR** Generator with you

Introduction of manufacturer's O&M manual



B3.9 and B5.9 Industrial
Maintenance Procedures at 500 Hours or 6 Months

Fuel Filter (Spin-On Type)
Page 5-6

Operate the hand lever until the fuel flowing from the fitting is free of air.

Tighten the bleed screw.

Torque Value: 9 N•m [80 in-lb]

Air and fuel can be vented from the illustrated vent locations on the Bosch® VE fuel injection pumps.

Loosen the vent screw and operate the priming lever on the fuel transfer pump until the fuel injection pump is primed.

Tighten the vent screw.

Torque Value: 9 N•m [80 in-lb]

CAUTION

It is necessary to turn the keyswitch to the ON position. Because the engine can start, be sure to follow all safety precautions. Use the normal engine starting procedure.

CAUTION

When using the starting motor to vent the system, do not engage it for more than 30 seconds, or starter damage will occur. Wait 2 minutes before starting the engine again.

Air can also be vented through the fuel drain manifold line by operating the starting motor.

B3.9 and B5.9 Industrial
Maintenance Procedures at 500 Hours or 6 Months

Lubricating Oil and Filters
Page 5-7

Lubricating Oil and Filters

Drain

WARNING

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

WARNING

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

Change the lubricating oil and filter(s) at the specified oil change interval. Refer to Oil Drain Intervals (Section 2) to find the correct change interval for your application.

Operate the engine until the water temperature reaches 60°C [140°F]. Shut off the engine.

NOTE: Use a container that can hold at least 26 liters [27 qt] of lubricating oil.

Remove the oil drain plug from the bottom of the lubricating oil pan.

Remove

Clean the area around the lubricating oil filter head.

Remove the oil filter.

Clean the gasket surface of the filter head.

NOTE: The o-ring can stick on the filter head. Make sure it is removed before installing the new filter.

Specifications

Example: Generator at Aljazari Academy

GENERATING SET MODEL (PZ65)		
Output Ratings	**Prime**	**Standby**
380-415 V, 3 ph, 50 Hz, 1500 rpm	60 KVA	66 KVA
	48 KW	53 KW

Specifications

ALTERNATOR DATA	
Make	Stamford
Model	**UC224E**
No. of bearings	1
Insulation class	H
Total Harmonic Content	at no load <3% - on load <2%
Wires	12
Ingress Protection	IP23
Excitation System	SHUNT
Winding Pitch	2/3 (wdg 6)
AVR Model	R220
Overspeed	2250 mn^{-1}
Voltage Regulation (steady)	± 0.5%
Short Circuit Capacity	-

CONTROL PANEL	
Make	Deep Sea
Model	**7120**

The **DSE7120** is an Auto Start Control Module for single genset applications. It includes a backlit LCD display which clearly shows the status of the engine all the times. This module can either be programmed using the front panel or by using the DSE configuration suite PC software.

Metering and Alarm indications:

- Generator frequency
- Underspeed, Overspeed
- Generator volts (L-L, L-N)
- Generator current
- Engine oil pressure
- Engine coolant temperature
- Fuel level (Warning or shutdown) - Optional
- Hours run counter
- Battery volts
- Fail to start/stop
- Emergency stop
- Failed to reach loading voltage/frequency
- Charge fail
- Loss of magnetic pick-up signal - Optional
- Low DC voltage
- CAN diagnostics and CAN fail/error

Specifications

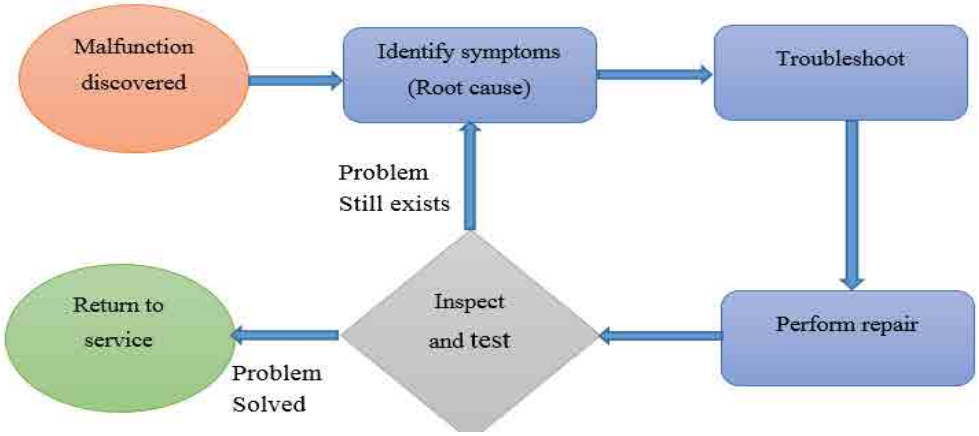
ENGINE / TECHNICAL DATA

Ratings at 0.8 Power Factor

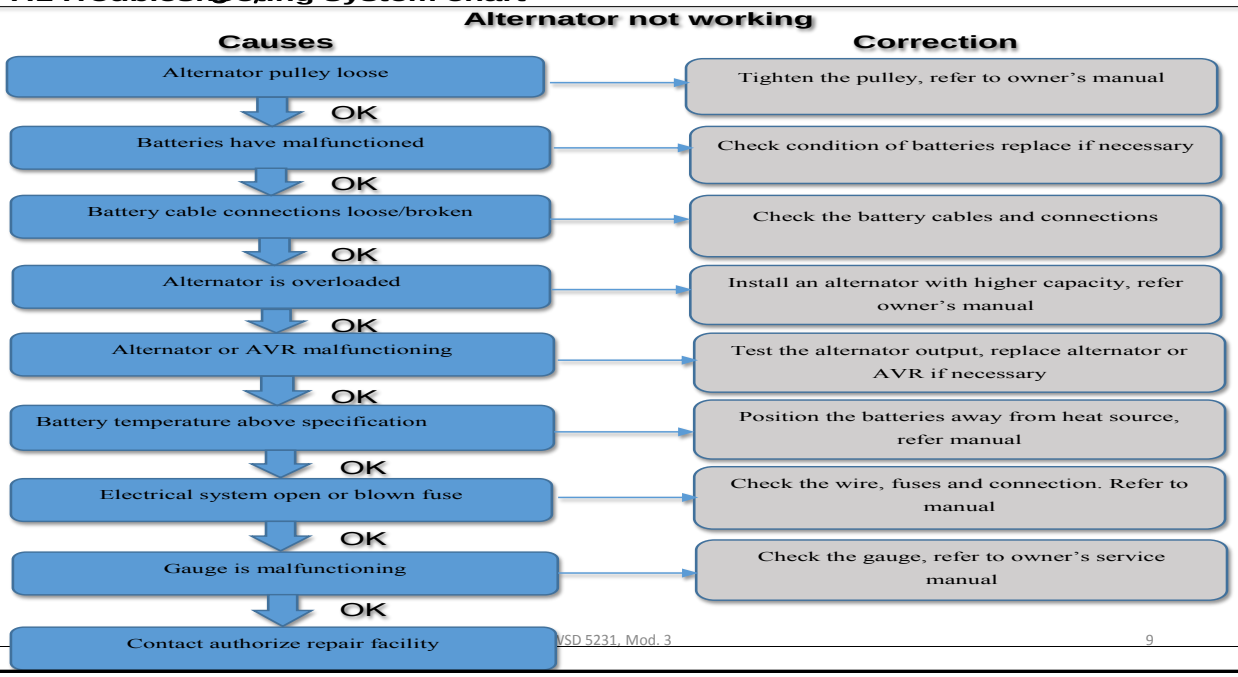
	50Hz & 1500rpm		60Hz & 1800rpm	
	Prime	**Standby**	**Prime**	**Standby**
Engine Make	Perkins			
Engine Model	1103A-33TG2			
Governing Type	Mechanical			
Number of Cylinders	3			
Cylinder Arrangement	Vertical in line			
Bore and Stroke mm	105 x 127			
Displacement / Cubic Capacity litres	3.3			
Induction System	Turbocharged			
Cycle	4 stroke			
Combustion System	Direct Injection			
Compression Ratio	17.25:1			
Rotation	Anti-clockwise, viewed from flywheel			
Cooling System	Water - cooled			
Gross Engine Power kW (hp)	55 (73.8)	60.5 (81.1)	63.3 (84.9)	69.6 (93.3)
Fuel Consumption @ 50% load L/hr	7.2	-	8.8	-
@ 75% load L/hr	10.4	-	12.5	-
@ 100% load L/hr	13.9	15.4	16.6	18.2
Total Lubrication System Capacity litres	7.9	7.9	7.9	7.9
Total Coolant Capacity (inc. radiator) litres	10.2	10.2	10.2	10.2
Exhaust Temperature: °C	557	571	534	564
Radiator Cooling Air Flow (Min): m^3/sec	1.48	1.48	1.85	1.85
Combustion Air Flow: m^3/min	3.8	3.9	4.7	4.9
Exhaust Gas Flow: m^3/min	10.1	10.4	11.8	12.5
Fuel Tank Capacity: litres	87	87	87	87

Troubleshooting

General Repair Process

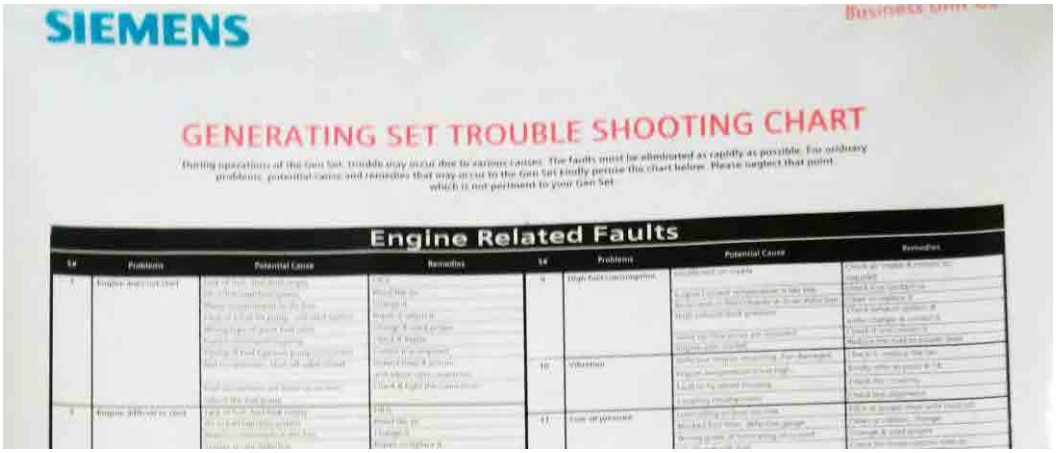


Trouble shooting system chart



Possible Fault Situation

Many faults can be occurred due to over use of generators,
in addition to the user manual, troubleshooting charts are also provided by the manufacturer i.e. M/S Siemens for guidance in possible fault situation.



Possible Fault Situation

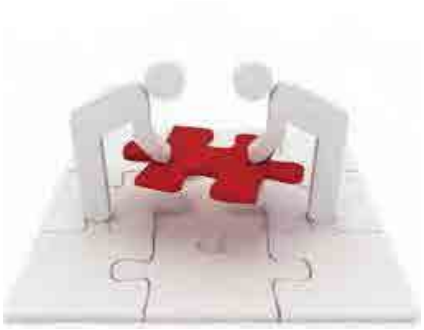
Engine Relate Faults			
Sr. #	**Problem**	**Potential Cause**	**Remedies**
1	Engine does not start	Lack of fuel., Fuel tank empty	Fill it
		Air in fuel injection system	Bleed the air
		Check Battery with Multi-meter	Replace or Charge battery
		Water contaminants in the fuel	Change it
		Fault in the fuel lift pump, cold stat system	Repair and adjust it
		Wrong type of grade fuel used	Change & use proper
		Fault in fuel injection pump	Check & repair
		Timing of fuel injection pump is incorrect	Correct is as required
		Bad compression, Shut-off valve closed	Inspect rings & pistons and adjust valve clearances
		Fuel connections are loose on suction side of the fuel pump	Check & tight the connections
2	Engine difficult to start	Lack of fuel., Fuel tank empty	Fill it
		Air in fuel injection system	Bleed the air
		Water contaminants in the fuel	Change it
		Starter motor defective	Repair or replace it
		Restriction in filter/ cleaner or in air induction system	clean or replace it
		Restriction in fuel vent	Remove & clean
		Restriction in exhaust pipe	Remove & clean exhaust system

Possible Fault Situation

Alternator Related Faults			
Sr. #	**Problem**	**Potential Cause**	**Remedies**
1	If Generator voltage below 400V & not adjustable via potentiometer	Drive speed too low	Check speed control of drive engine
		Voltage regulator defective	Replace voltage
2	Generator voltage too low (say less than 100V)	Interuption of excitor circuit	Tighten connections according to connection diagram
		Surge supressor faulty	Replace the supressor
		Rotating rectifier faulty	Repair the diaodes of the rectifier
3	If Generator voltage above 450 V & not adjustable via potentiometer	Drive spped too high	Check engine speed and adjust it to 1500 rpm
		Interruption of reference valve of AVR	Check AVR Connections
		Voltange regulator defective	Replace voltage regulator

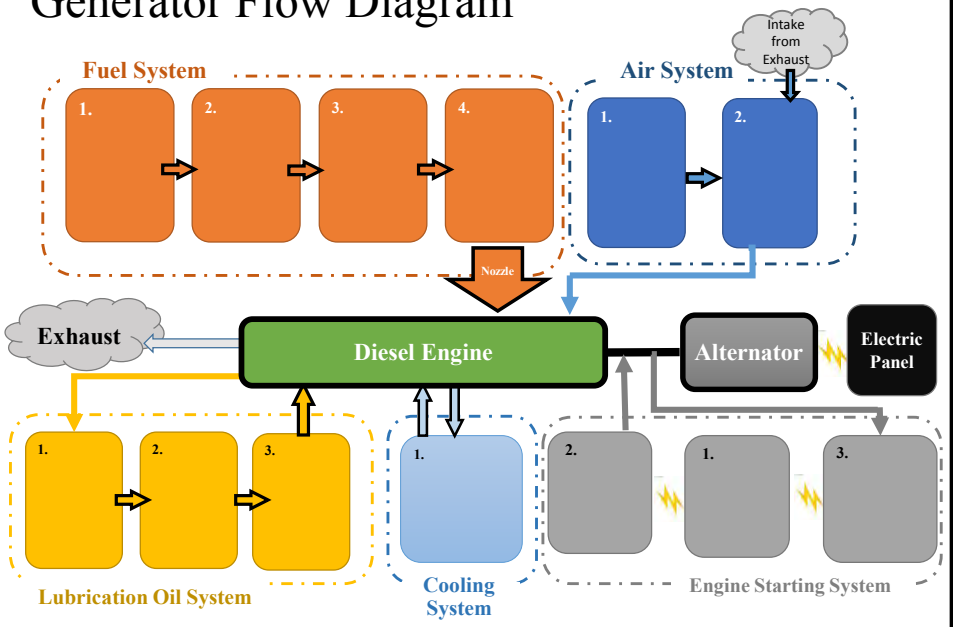
Wrap-up

- Things to take home…
- Generators drive your Operation.
- Always do a root cause analysis
- Repair is not preventive maintenance
- Keep records, always !!!



Generator Flow Diagram

EC-M2-01



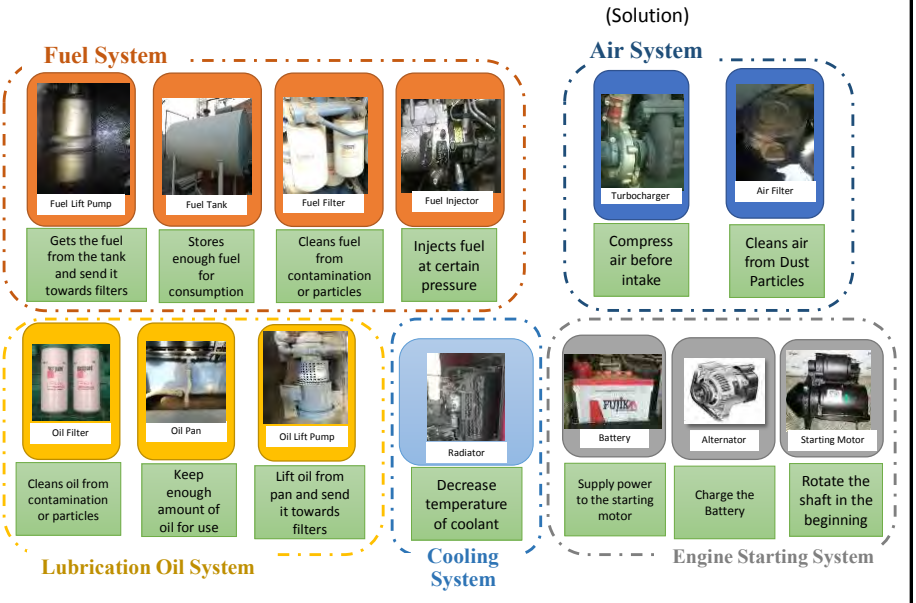
Name of Participant: _____

08/12/17

Components for Engine

EC-M2-02

(Solution)



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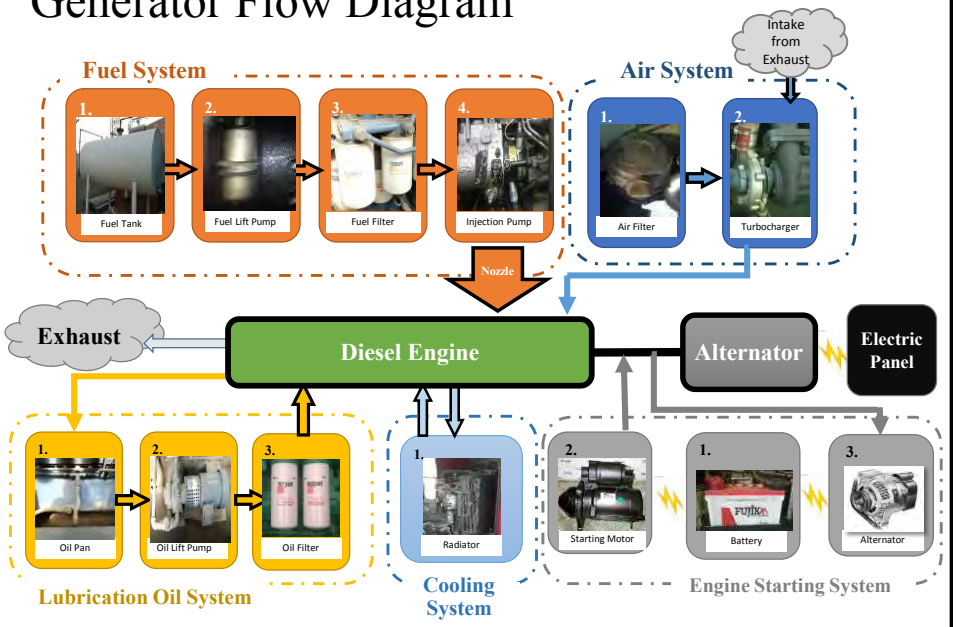
Generator Flow Diagram

EC-M2-03



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Maintenance Interval Schedule
(Sample for Practice)

Daily

- Alternator and Fan Belts – Inspect/Adjust/Replace
- Cooling System Coolant Level – Check
- Driven Equipment – Check
- Engine Oil Level – Check
- Fuel System Primary Filter/Water Separator – Drain
- Walk Around Inspection

Every 50 Service Hours or Weekly

- Fuel Tank Water and Sediment – Drain

Every 500 Service Hours or 1 Year

- Battery Electrolyte Condition & Level – Check
- Engine Air Cleaner Element – Clean/Replace
- Engine Oil and Filter – Change
- Fuel System Filter Element - Replace
- Hoses and Clamps – Inspect/Replace

Every 1000 Service Hours or 1 Year

- Engine Valve Lash – Inspect/Adjust

Every 2000 Service Hours or 1 Year

- Alternator – Inspect
- Engine Mounts – Inspect
- Starting Motor – Inspect

Every 2 Year

- Cooling System Coolant – Change

Generaotr Annual Maintenace Plan (Sample) -Year 2017-

Legend : Plan "●", Done "✓"

First Setting for Trial Activity

Average Operation Time per day	5	hours/day
Average Operation Time per month (※30days)	150	hours/month

※Days for each month are considered as 30days for ease.

Item	2017	2018									
	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
Operation Hours of the Month	150	150	150	150	150	150	150	150	150	150	150	150
Total Operation Hours	**150**	**300**	**450**	**600**	**750**	**900**	**1050**	**1200**	**1350**	**1500**	**1650**	**1800**

Item	Required maintenance cycle	Product to be required	DEC		JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV	
			Plan	Done	Plan	Done	Plan	Done	Plan	Done	Plan	Done	Plan	Done	Plan	Done	Plan	Done	Plan	Done	Plan	Done	Plan	Done	Plan	Done
Fuel Tank Water and Sediment Drain	Every 50 hours	None	●		●		●		●		●		●		●		●		●		●		●		●	
Battery Electrolyte Level – Check	Every 500 hours	**Electrolyte**							●																	
Engine Air Cleaner Element – Clean/Replace	Every 500 hours	**Air Cleaner Element**							●																	
Engine Oil and Filter – Change	Every 500 hours	**Engine Oil Filter**							●																	
Fuel System Filter Element - Replace	Every 500 hours	**Fuel Filter**							●																	
Hoses and Clamps – Inspect/Replace	Every 500 hours	**Hoses, Clamps**							●																	
Engine Valve Lash – Inspect/Adjust	Every 1000 hours														●											
Alternator – Inspect	Every 2000 hours																									
Engine Mounts – Inspect	Every 2000 hours																									
Starting Motor – Inspect	Every 2000 hours																									
Cooling System Coolant – Change	Every 2 Years																									

12/08/2017

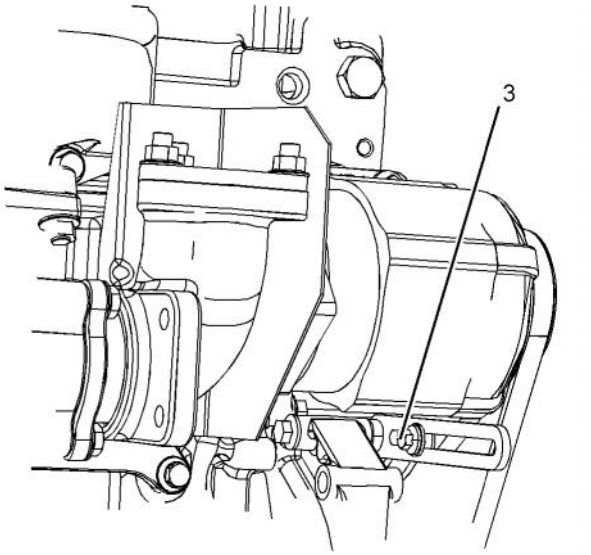

Illustration 31 g03716558

2. loosen the link bolt (3). Move the alternator in order to increase or decrease the belt tension. Tighten the alternator pivot bolt and the link bolt to 22 N·m (16 lb ft).(1).

Replacement

Refer to the Disassembly and Assembly Manual for the installation procedure and the removal procedure for the belt.

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Battery - Replace

⚠ WARNING

Batteries give off combustible gases which can explode. A spark can cause the combustible gases to ignite. This can result in severe personal injury or death.

Ensure proper ventilation for batteries that are in an enclosure. Follow the proper procedures in order to help prevent electrical arcs and/or sparks near batteries. Do not smoke when batteries are serviced.

⚠ WARNING

The battery cables or the batteries should not be removed with the battery cover in place. The battery cover should be removed before any servicing is attempted.

Removing the battery cables or the batteries with the cover in place may cause a battery explosion resulting in personal injury.

1. Switch the engine to the OFF position. Remove all electrical loads.

2. Turn off any battery chargers. Disconnect any battery chargers.

3. The NEGATIVE "-" cable connects the NEGATIVE "-" battery terminal to the NEGATIVE "-" terminal on the starting motor. Disconnect the cable from the NEGATIVE "-" battery terminal.

4. The POSITIVE "+" cable connects the POSITIVE "+" battery terminal to the POSITIVE "+" terminal on the starting motor. Disconnect the cable from the POSITIVE "+" battery terminal.

Note: Always recycle a battery. Never discard a battery. Dispose of used batteries to an appropriate recycling facility.

5. Remove the used battery.

6. Install the new battery.

Note: Before the cables are connected, ensure that the engine start switch is OFF.

7. Connect the cable from the starting motor to the POSITIVE "+" battery terminal.

8. Connect the NEGATIVE "-" cable to the NEGATIVE "-" battery terminal.

i02747977

Battery Electrolyte Level - Check

When the engine is not run for long periods of time or when the engine is run for short periods, the batteries may not fully recharge. Ensure a full charge in order to help prevent the battery from freezing. If batteries are correctly charged, the ammeter reading should be very near zero, when the engine is in operation.

⚠ WARNING

All lead-acid batteries contain sulfuric acid which can burn the skin and clothing. Always wear a face shield and protective clothing when working on or near batteries.

1. Remove the filler caps. Maintain the electrolyte level to the "FULL" mark on the battery.

   If the addition of water is necessary, use distilled water. If distilled water is not available use clean water that is low in minerals. Do not use artificially softened water.

2. Check the condition of the electrolyte with a suitable battery tester.

3. Install the caps.

4. Keep the batteries clean.

   Clean the battery case with one of the following cleaning solutions:

   - Use a solution of 0.1 kg (0.2 lb) baking soda and 1 L (1 qt) of clean water.
   - Use a solution of ammonium hydroxide.

   Thoroughly rinse the battery case with clean water.

i02323088

Battery or Battery Cable - Disconnect

⚠ WARNING

The battery cables or the batteries should not be removed with the battery cover in place. The battery cover should be removed before any servicing is attempted.

Removing the battery cables or the batteries with the cover in place may cause a battery explosion resulting in personal injury.

1. Turn the start switch to the OFF position. Turn the ignition switch (if equipped) to the OFF position and remove the key and all electrical loads.

2. Disconnect the negative battery terminal. Ensure that the cable cannot contact the terminal. When four 12 volt batteries are involved, two negative connection must be disconnected.

3. Remove the positive connection.

4. Clean all disconnected connection and battery terminals.

5. Use a fine grade of sandpaper to clean the terminals and the cable clamps. Clean the items until the surfaces are bright or shiny. DO NOT remove material excessively. Excessive removal of material can cause the clamps to not fit correctly. Coat the clamps and the terminals with a suitable silicone lubricant or petroleum jelly.

6. Tape the cable connections in order to help prevent accidental starting.

7. Proceed with necessary system repairs.

8. In order to connect the battery, connect the positive connection before the negative connector.

i05901701

Cooling System Coolant (Commercial Heavy-Duty) - Change

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to Local regulations and mandates.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Clean the cooling system and flush the cooling system before the recommended maintenance interval if the following conditions exist:

- The engine overheats frequently.
- Foaming is observed.
- The oil has entered the cooling system and the coolant is contaminated.
- The fuel has entered the cooling system and the coolant is contaminated.

Cleaning the Primary Air Cleaner Elements

NOTICE
Observe the following guidelines if you attempt to clean the filter element:

Do not tap or strike the filter element in order to remove dust.

Do not wash the filter element.

Use low pressure compressed air in order to remove the dust from the filter element. Air pressure must not exceed 207 kPa (30 psi). Direct the air flow up the pleats and down the pleats from the inside of the filter element. Take extreme care in order to avoid damage to the pleats.

Do not use air filters with damaged pleats, gaskets, or seals. Dirt entering the engine will cause damage to engine components.

Refer to the OEM information in order to determine the number of times that the primary filter element can be cleaned. When the primary air cleaner element is cleaned, check for rips or tears in the filter material. The primary air cleaner element should be replaced at least one time per year. This replacement should be performed regardless of the number of cleanings.

NOTICE
Do not clean the air cleaner elements by bumping or tapping. This could damage the seals. Do not use elements with damaged pleats, gaskets or seals. Damaged elements will allow dirt to pass through. Engine damage could result.

Visually inspect the primary air cleaner elements before cleaning. Inspect the air cleaner elements for damage to the seal, the gaskets, and the outer cover. Discard any damaged air cleaner elements.

There are two common methods that are used to clean primary air cleaner elements:

- Pressurized air
- Vacuum cleaning

Pressurized Air

Pressurized air can be used to clean primary air cleaner elements that have not been cleaned more than two times. Pressurized air will not remove deposits of carbon and oil. Use filtered, dry air with a maximum pressure of 207 kPa (30 psi).

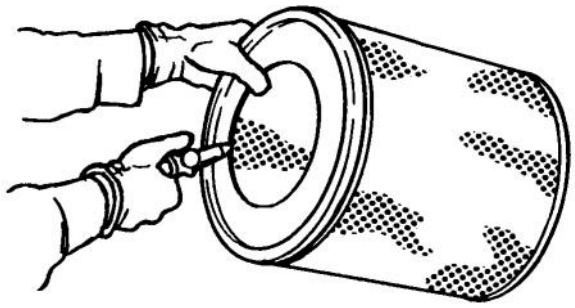


Illustration 38 g00281692

Note: When the primary air cleaner elements are cleaned, always begin with the clean side (inside) in order to force dirt particles toward the dirty side (outside).

Aim the hose so that the air flows inside the element along the length of the filter in order to help prevent damage to the paper pleats. Do not aim the stream of air directly at the primary air cleaner element. Dirt could be forced further into the pleats.

Note: Refer to “Inspecting the Primary Air Cleaner Elements”.

Vacuum Cleaning

Vacuum cleaning is a good method for cleaning primary air cleaner elements which require daily cleaning because of a dry, dusty environment. Cleaning with pressurized air is recommended prior to vacuum cleaning. Vacuum cleaning will not remove deposits of carbon and oil.

Note: Refer to “Inspecting the Primary Air Cleaner Elements”.

Inspecting the Primary Air Cleaner Elements

Illustration 39 g00281693

Inspect the clean, dry primary air cleaner element. Use a 60 watt blue light in a dark room or in a similar facility. Place the blue light in the primary air cleaner element. Rotate the primary air cleaner element. Inspect the primary air cleaner element for tears and/or holes. Inspect the primary air cleaner element for light that may show through the filter material. If it is necessary in order to confirm the result, compare the primary air cleaner element to a new primary air cleaner element that has the same part number.

Do not use a primary air cleaner element that has any tears and/or holes in the filter material. Do not use a primary air cleaner element with damaged pleats, gaskets or seals. Discard damaged primary air cleaner elements.

i02152042

Engine Air Cleaner Element (Single Element) - Inspect/ Replace

Refer to Operation and Maintenance Manual, “Engine Air Cleaner Service Indicator-Inspect”.

NOTICE
Never run the engine without an air cleaner element installed. Never run the engine with a damaged air cleaner element. Do not use air cleaner elements with damaged pleats, gaskets or seals. Dirt entering the engine causes premature wear and damage to engine components. Air cleaner elements help to prevent airborne debris from entering the air inlet.

NOTICE
Never service the air cleaner element with the engine running since this will allow dirt to enter the engine.

A wide variety of air cleaners may be installed for use with this engine. Consult the OEM information for the correct procedure to replace the air cleaner.

i01909507

Engine Air Cleaner Service Indicator - Inspect

Some engines may be equipped with a different service indicator.

Some engines are equipped with a differential gauge for inlet air pressure. The differential gauge for inlet air pressure displays the difference in the pressure that is measured before the air cleaner element and the pressure that is measured after the air cleaner element. As the air cleaner element becomes dirty, the pressure differential rises. If your engine is equipped with a different type of service indicator, follow the OEM recommendations in order to service the air cleaner service indicator.

The service indicator may be mounted on the air cleaner element or in a remote location.

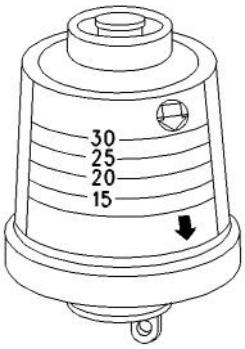


Illustration 40 g00103777
Typical service indicator

Observe the service indicator. The air cleaner element should be cleaned or the air cleaner element should be replaced when one of the following conditions occur:

- The yellow diaphragm enters the red zone.
- The red piston locks in the visible position.

Test the Service Indicator

Service indicators are important instruments.

- Check for ease of resetting. The service indicator should reset in less than three pushes.
- Check the movement of the yellow core when the engine is accelerated to the engine rated speed. The yellow core should latch approximately at the greatest vacuum that is attained.

If the service indicator does not reset easily, or if the yellow core does not latch at the greatest vacuum, the service indicator should be replaced. If the new service indicator will not reset, the hole for the service indicator may be restricted.

The service indicator may need to be replaced frequently in environments that are severely dusty.

i01941505

Engine Ground - Inspect/Clean

Inspect the wiring harness for good connections.

Perkins use the starter motor in order to ground the engine. Check the connection on the starter motor at every oil change. Ground wires and straps should be combined at engine grounds. All grounds should be tight and free of corrosion.

- Clean the grounding stud on the starter motor and the terminals with a clean cloth.
- If the connections are corroded, clean the connections with a solution of baking soda and water.
- Keep the grounding stud and the strap clean and coated with suitable grease or petroleum jelly.

i02323089

Engine Mounts - Inspect

Note: The engine mounts may not have been supplied by Perkins. Refer to the OEM information for further information on the engine mounts and the correct bolt torque.

Inspect the engine mounts for deterioration and for correct bolt torque. Engine vibration can be caused by the following conditions:

- Incorrect mounting of the engine
- Deterioration of the engine mounts
- Loose engine mounts

Any engine mount that shows deterioration should be replaced. Refer to the OEM information for the recommended torques.

i05909059

Engine Oil Level - Check

⚠ WARNING

Hot oil and hot components can cause personal injury. Do not allow hot oil or hot components to contact the skin.

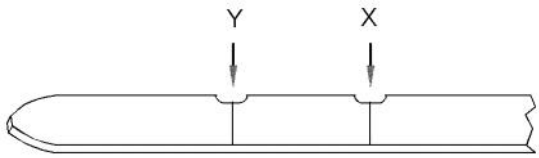


Illustration 41 g01165836
(Y) “Min” mark. (X) “Max” mark.

Illustration 42 g02173847
(L) “Min” mark. (H) “Max” mark.

NOTICE
Perform this maintenance with the engine stopped.

Note: Ensure that the engine is either level or that the engine is in the normal operating position in order to obtain a true level indication.

Note: After the engine has been switched OFF, wait for 10 minutes in order to allow the engine oil to drain to the oil pan. Then, check the oil level.

Name of Participant: _____

Q1: Write down the procedure of cleaning air cleaner element in your own words

Q2: Write down the procedure of checking electrolyte level and condition of battery in your own words

Operations and Maintenance of Electrical Equipment

Application of 5S

Quality Tool for Operational Excellence

Objectives of Application of 5S

❖ ***Application of 5S for enhancing:***

- Productivity
- Efficiency
- Quality
- Safety



3/30

What is 5S?

Seiri (Sort)	Distinguish between necessary and unnecessary items.
Seiton (Set in order)	Enforce the dictum 'a place for everything and everything in its place'.
Seiso (Shine)	Clean up the demarcated area.
Seiketsu (Standardize)	Maintain and monitor adherence to the first three Ss.
Shitsuke (Sustain)	Follow the rule to keep the workplace 5S-right. Hold the gain.

4/22

5S – A Quality, Productivity, Efficiency and Safety Tool

- 5S is an approach to eliminate waste, organize work place to save time and effort to achieve operational efficiency.
- Implementation of 5S improves operational quality and efficiency.
- It enhances safety by reducing hazards, which may occur due to an unorganized work place.

1. Sort (Seiri)

- Necessary items are separated from unnecessary items and removed.
- *Unnecessary items' accumulation makes it difficult to find and keep important items organized.*
- Red tag campaign is conducted to evaluate items based on their usefulness and frequency of use.
- Items can include obsolete equipment and inventory, broken tools, scrap, old files, etc.
- Safety and productivity are improved as a result of an organized work place.

1. Sort (Seiri) For wavering items

- Place un-necessary items in the red tag area
- Allow course participants to re-evaluate the needed items
- At the end of evaluation, required items should be returned to proper area

PRIORITY	FREQUENCY OF USE	HOW TO USE
Low	Less than once per year Once per year	Discard Store away from the workplace
Average	Once per month Once per week	Store together
High	Once per day	Locate at the workplace

7/22

2. Set-in-order (Seiton)

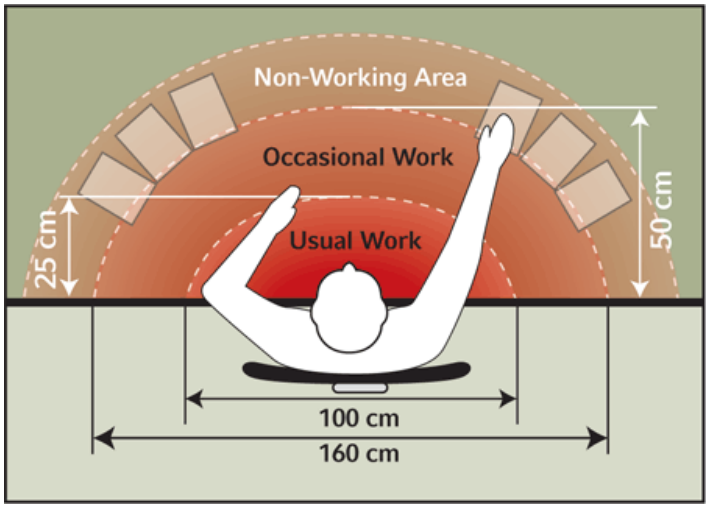
- It involves setting of necessary items, which are always located in logically predetermined locations.
- Based on the inventory classification of the red tag campaign, items are placed in locations based on frequency of use.
- Frequently used items are placed at or near the work place.
- Infrequently used items are stored in store.
- Items in store would help employees save time, otherwise wasted in trying to locate scattered items.

8/22

3. Shine (Seiso)

- It is a regular cleaning activity at and near the work area.
- Removing unnecessary stickers, posters, pictures and other items.
- During operations and maintenance **ergonomically** establishing the positions for tools and equipment.
- Continuously achieve better level of organized and efficient work place through brainstorming.

3. Shine (Seiso)



4. Standardize (Seiketsu)

- The goal of this step is to set a standard work place (organized)
- This is achieved by providing visual labels and signs
- Work place is marked and labeled so that organization is made simple and easy
- Organized and marked tool boards etc.

5. Sustain (Shitsuke)

- It involves developing habits to implement the 5S philosophy on an ongoing basis.
- If 5S is to be successful, a regular appraisal of the electrical panel is required.
- This ensures the focus remains on maintaining the electrical panel.
- It is a housekeeping and a structured program.
- **5S activity is conducted systematically and regularly.**
- **5S activity is tracked through a visual control board.**

Before

After

13/22

WASA Outfall Workshop, Lahore

Before

After

14/22

WASA South Yard, Lahore

Before

After

SCBA equipment was buried under this

15/25

16/25

5S is a continuous improvement tool !!!

- Create necessary documents or forms to support/optimize your operations
  - ✓ Process flow charts
  - ✓ Contact lists
  - ✓ Emergency response procedures
  - ✓ SOPs
  - ✓ Post job instructions
  - ✓ Label equipment for operators

Panel without Labels

Panel with Labels

19/25

Panel with Labels

20/25

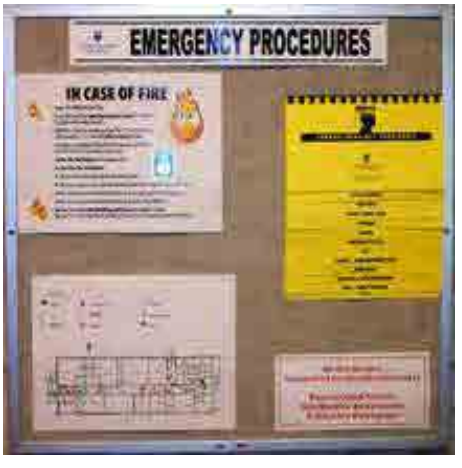
Panel with Instructions

21/25

Panel with Drawings

22/25

Post important forms here !



Emergency Procedures

Emergency Contact List

25/25

1

OJT

Operation and Maintenance of Electrical Equipment

Health Safety & Environment for Electrical Components

Ihsan Ul Haque Javed
Sr. Instructor (HSE)

2

Activities for On-the-Job Training

1. Electrical Panel
2. Generator

- Introduction of PPE
- Job safety analysis (JSA)
- Firefighting
- Low Voltage Rescue Kit
- Electrical Safety Rules
- Cardiopulmonary Resuscitation
- First Aid Box
- Accident or Incident Reporting

3

Personal Protective Equipment (PPE)

Equipment worn by employee to minimize exposure to hazards.

Criteria to choose PPE

1. PPE should eliminate risk associated with hazard
2. Should be physically comfortable
3. Should be in compliance to OSHA, ILO or local standards
4. Should be right fit for the user
5. Should be in good working condition
6. Should be easily accessible

4

Identified Personal Protective Equipment (PPE)

1. Safety Vest
2. Apron (for repair & maintenance)
3. Insulated gloves (Electrical Safety)
4. Heat insulated gloves
5. Safety helmet
6. Safety shoes
7. Face mask







5

Maintenance of PPE

Effective procedure of maintenance & cleaning

1. Manufacturer's maintenance schedule
2. Inspection of PPE before each use (for any breaks, tears and visible signs of stress or damage)

Maintenance include:

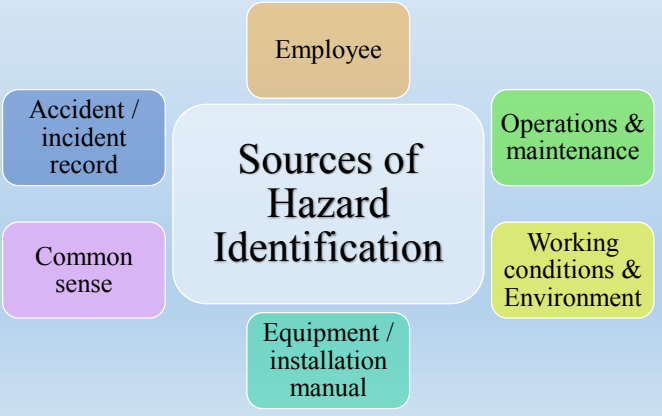
1. Ease of access and availability
2. Validation (not expired)
3. In good working condition
4. Ample stock

6

Hazard Identification

What is Hazard?

Situation that poses a level of threat to Life, Health Property or Environment for example, Electric shock, Electric fire etc.



7

Current conditions of generator rooms

8

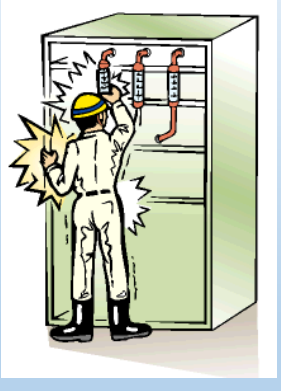
Current Conditions of Electrical Panels






9

Major hazards related to Electrical Facility



Electric shock

Electric fire

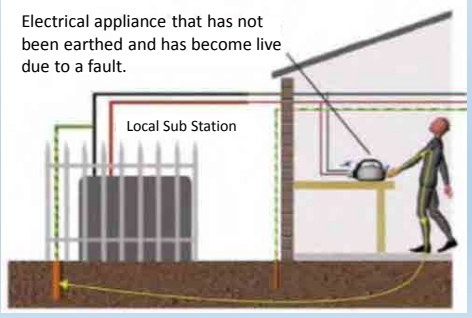
10

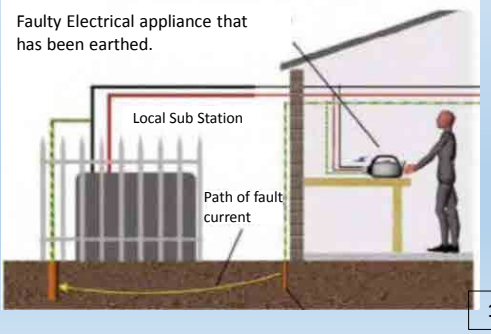
Safety measures for electrical panel room

Grounding

Electrical panel Earthing helps protect the operator.

It helps if a malfunction causes the metal frame to become energized.





11

Safety measures for generators

Protective Fence

Protective fence is used to secure the generator area to prevent unauthorized access

- **To avoid high voltage effects**
- **Theft & vandalism**
- **Physical contact of thermal parts**

12

Probability

Extent to which a hazard may cause harm.

Probability Rating

Probability	Rating	Comments
Frequent	5	**Workers are frequently at risk**
Probable	4	**The hazard is likely to cause harm**
Occasional	3	**Workers are occasionally at risk**
Possible/remote	2	**The hazard could cause harm, but is unlikely to do so.**
Improbable	1	**The hazard is unlikely to cause harm.**

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Severity

Seriousness of the harm that could result from contact with a hazard.

Severity	Rating	Comments
Catastrophic	5	Death and/ or severe destruction
Critical	4	Serious illness, injury, disability and significant property damage
Serious	3	Lost time injury and property damage
Marginal	2	Minor injury and property damage
Negligible	1	No injury and/or property damages

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Priority level of Hazard is obtained from multiplication of the Probability and Severity ratings

Priority Level of Hazard = Probability x Severity

Probability	Severity	Priority level
2	3	6
2	2	4
3	1	3

Hazard Coding

Obtained from product of probability and severity.

Priority rating	Hazard Level	Hazard Code
11 – 25	High	H
5 – 10	Medium	M
1 – 4	Low	L

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Job Safety Analysis (JSA)

It helps integrate accepted HSE principles and practices into a particular job.

Evaluating probability of occurrence of hazard during in terms of priority rating and the hazard coding

- Potential hazards are identified & evaluated
- Control measures are recommended

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Example : Electrical Facility - Job Safety Analysis (JSA)

Location:	Tube well 4-D1, Green Town Sub Division
Date:	December 9th, 2016
Conducted By:	Sub Engineer, Electrician and Tube well Operator

Sr. No.	Hazards Identified	Hazards Type	Probability Ratings	Severity Ratings	Priority Rating	Action Needed	Assigned to	Due Date/ Time	Date Completed	Comments
1	Thermal Relay Bypass	Motor winding damage	3	4	12	Replace relay and adjust values as per design	Electrician	8-12-16	9-12-16	New relay purchased and installed
2										
3										
4										
5										

Priority rating is obtained from multiplication of the Probability and Severity ratings (Hazard = Probability x Severity) (range is between 1 -25, 1 being the lowest and 25 is highest priority)
JSAs are done for a specific task prior to the commencement of all major tasks involving any hazards or risks.

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Hazard Control During Operations & Maintenance

1. **Elimination :** Remove unsafe conditions
2. **Substitution:** Replacement of faulty or damaged electrical components
3. **Isolation:** Protection of electrical components from water leakage
4. **Engineering Control:** Install Earthing to prevent electric shock
5. **Administrative Control:** Lock out / Tag out methods before any maintenance work
6. **PPE:** Use PPE, i.e. wear insulated gloves, Shoes with insulated sole and toe protection

More Effective

Less Effective

18

CLASSES OF FIRE

Class A – For Ordinary combustibles such as wood, paper, and trash

Class B – For Flammable liquids such as gasoline, xylene, and alcohol

Class C – For Burning gases such as propane, methane, butane

Class D – For Metals such as Aluminum, Magnesium, Titanium

Class E – Fire involving potentially energized electrical equipment

Class F – For Cooking Oil

19

Firefighting

Fire prevention practices are attained by:

- **Keep passage ways and exits clear**
- **Ensure fire extinguishers and fire alarm pull stations are accessible**
- **Place trash in proper receptacles**
- **Ensure that fire doors are not blocked**
- **Enforce No Smoking policy**

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Firefighting

If Fire extinguisher containing carbon dioxide or halon are not available then

- Sand buckets may be used.
- Sand may cause a lot of mess.
- If sand buckets are not available then
- As a last resort sand may be kept in a polythene bags

21

In case of Fire . . . .

- Remain calm. Don't panic.
- Shout "Fire".
- Proceed safely to nearest passage
- Check passage carefully and leave
- Crawl to leave if smoke is present in area
- Shut off the power supply

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Electrical Fire Safety

☠Do not use water to Extinguish electrical fire

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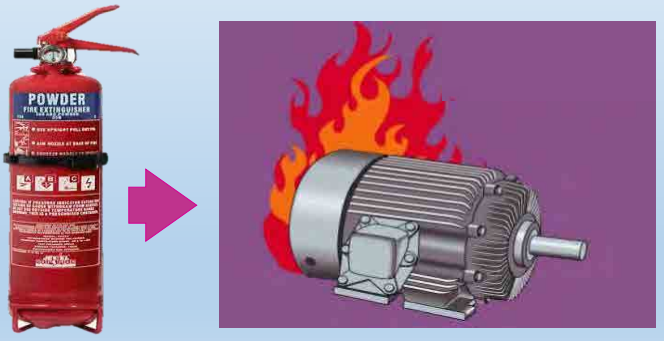
Always remember

To use **"Class "E"** fire extinguisher in case of energized electric equipment.



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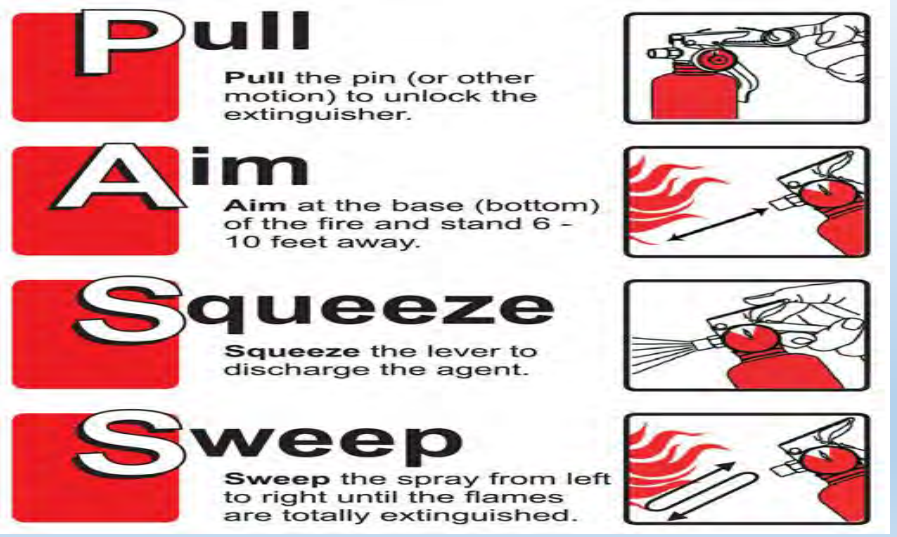
Steps of using fire Extinguisher



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Low Voltage Rescue Kit

Safety kit for technician working on electrical panel is good protection.

Following are the components :-

- **Fire blanket**
- **Low voltage rescue crook**
- **Isolation tag**
- **Trauma dressing ***
- **High resolution torch**
- **Insulation mat**
- **Bag**

*** Always examine expiry date before use.**

26

Electric Shock

- Human body is a good conductor of Electricity
- Direct contact with electric current can kill
- Electric current destroys muscles, nerves & tissues
- Cause burns or even affect the functioning of heart
- Ensure isolation by switching off the mains

Do not use a wet object or metal object for detachment of Electric shock victim

- If current can not be turned-off, use low voltage crook or a non-conducting objects such as broom, rug or rubber mat to push the victim away from source of current
- Once the victim is free from source of electricity, check victim if in smoldering state then put fire blanket starting from the skull and moving towards the legs
- Check victim's breathing & pulse
- Apply CPR
- If the victim has a burn, remove any clothing that comes off easily & apply burn cream or trauma dressing upon burnt area
- Call RESUE 1122

27

Effects of Electrical Current On the Human Body

Current in mAmp	Effects
1 or less	No sensation; probably not noticed
1 to 3	Mild sensation not painful
3 to 10	Painful shock.
10 to 30	Muscular control could be lost or muscle clamping
30 to 75	Respiratory paralysis
75mA to 4 Amps	Ventricular Fibrillation
Over 4 Amps	Tissue begins to burns. Heart muscles clamp and heart stops beating

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Electric Shock Video

29

Electrical Safety Rules

- ✓ Read & follow standard operating procedure for the function of each electrical component
- ✓ Prior turning on inspect electrical component for damage
- ✓ Never work alone
- ✓ Turn off the main supply and confirm with your own eyes
- ✓ Damaged or defective components must be removed
- ✓ Do not forget to check the presence of electricity using probe tester before O&M
- ✓ Maintain sufficient access around electrical equipment for O&M
- ✓ Always wear insulation gloves and use insulation sheet working with electrical components

30

First Aid Box

Accessories

- Panadol
- Dichloron
- Sterile gauze pads
- Adhesive tape
- Dressings (3″ & 6″)
- Zinc Oxide Adhesive Plaster
- Antiseptic cream
- Antibiotic ointment
- Piodine solution
- Quench cream for burn
- Tweezers
- Splint
- Scissors
- Thermometer
- Eye wash solution

Always examine expiry date before use.

31

Accident or Incident Report

Accidents or incidents are the part of repair and maintenance of Electrical installations.

- May be minor for example bruising or minor cut or major.
- May need hospitalization or compensation

Recording and documentation of accident and incident is necessary.

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Accident / Incident Report

Reported to XEN (Operations)

Reported Date 5th Dec 2017

Reported by Ihsan Ul Haque Javed

1. Status of Accident / Trouble

Date of Accident	4th Dec 2017
Place	Lift pump room, Academy Disposal Station
Person involved	Operator: Fahad Qureshi
Equipment involved	Electrical Panel for No.3 Lifting Pump
Current Condition (Person/Equipment)	・No persons injured ・1 magnetic contactor of the starter circuit is burnt out even though No.3 pump is operational somehow.
Incident in detail	Several minutes after the operator starts the pump as usual in the afternoon, he found some smoke and burnt smell around the panel. He immediately stopped the pump by emergency stop button.
Possible Causes	・Setting value of the thermal relay was set at maximum. ・Loosen terminals ・Continuous low voltage from WAPDA

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2. Countermeasure

Action to be taken	・Replace the burnt magnetic contactor with new one. ・Check the availability of the other 2 contactors and cables, then replace them if necessary ・Change the setting value of thermal relay from maximum value to 160A, which is the rated current of motor. ・Check the setting value of U/O voltage relay and adjust it if necessary ・After the work above, confirm retightening of all bolts in the panel
Resources required	・Electrician for the panel arrangement ・1 magnetic contactors If necessary: 2 more magnetic contactors, thermal relay
Due Date	15/12/2017
Person in charge	Jawad Shahid

3. Remarks

Already arranged the repair working day with the electrician. We will confirm the availability of the devices mentioned above on 13th Dec. I will finalize and report the required item list to you by 15th Dec 2017.

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Contact Information

Faculty Names	Contact Information
JICA Expert **Takeo Maruyama (Electrical)**	
Course Leader **Mubasher Ahmad Cheema**	
Sr. Instructor (HSE) **Ihsan-ul-haque Javed**	
Sr. Instructor (Electrical) **Jawad Shahid**	
Young Professional **Tanveer Shahzad**	

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Cardiopulmonary Resuscitation

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What is CPR?

- A sequence of techniques used to sustain life in the absence of spontaneous breathing and heart beat
- Chest compressions and rescue breath are called cardiopulmonary resuscitation
- Objective is to maintain victim's breathing and circulation until emergency aid arrives.

Important steps for CPR

Check
Call
&
Care

Check, Call & Care

Once followed the first two C's, you may need to give care until **Rescue 1122** personnel arrive.

Follow guidelines:

- ✓ **Move injured person ONLY if the scene is unsafe**
- ✓ **You need to reach someone more seriously injured, or need to move the person to give care.**
- ✓ **If a person is in shock, DO NOT give water or any drinkable.**
- ✓ **Help the person rest in the most comfortable position.**

3

Is person responsive?

Check the victim for a response

If no response

CALL Rescue 1122

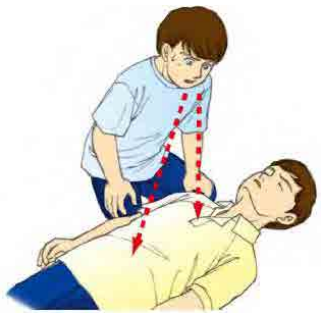
4

Open the airway &
Maintain the airway open

Head tilt and chin lift

5

Check for breathing



Look listen and feel for normal breathing
&
LOOK FOR SIGNS OF LIFE for more than 10 seconds.

6

If no signs of life are present

Start Chest Compression

20/2

push hard and push fast

Continue for 2 minutes
100 to 120 total compressions

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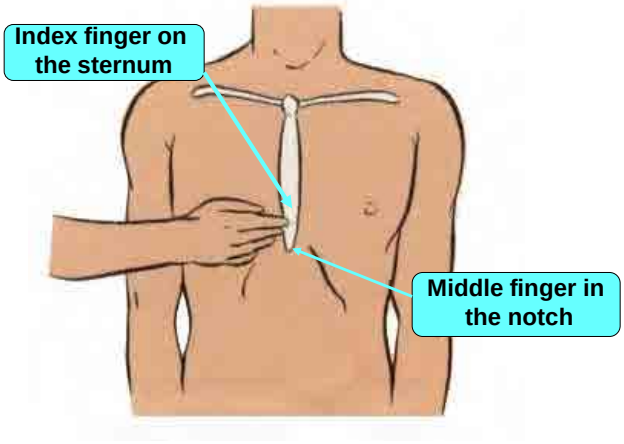
Land mark



- Place the heel of on the center of the victim's chest
- Place the heel of your other hand on top of the first hand
- Press down on the sternum 1 ½ to 2 inches

8

20 / 2

- ✓ After 20 compressions open the airway again using head tilt and chin lift give two breaths while watching the chest rise
- ✓ Rescue Breaths should last for 1 second.

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ABC'S OR CAB'S???

Change in CPR guidelines: no more ABC's but rather…CAB's

C= Circulation

A= Airway

B= Breathing

The CAB's are your priority management steps to life-saving

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CPR Demonstration

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Handling of Manikin

- For handling and demonstration purpose wear rubber gloves
- For demonstration at site use spare nylon sheet as underlay
- In case of more number of trainees separate mouth protector be provided.

Cleaning of Manikin

- Use Soap and water for dirty materials swiping gently
- Cleaners containing wax, oil or citrus are not recommended
- The face skin may also be sanitized with alcohol wipes or soaked in a solution of ¼ cup bleach mixed with one gallon of water for 10 minutes

Storage of Manikin

- Always store and transport the manikin in nylon carry bag
- Store the manikin in a cool dry area at temperature between 50-70 °F and 50% relative humidity
- For storage longer than one month, the batteries should be removed from the CPR rate monitor
- The manikin head should be removed for the protection of the facial features, specifically the nose

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Job Safety Analysis (JSA)

Location:										
Date:										
Conducted By:										
Sr.#	Hazards Identified	Hazards Type	Probability Ratings	Severity Ratings	Priority Rating	Action Needed	Assigned to	Due Date/Time	Date Completed	Comments

Priority rating is obtained from multiplication of the Probability and Severity ratings (Hazard = Probability x Severity)
(range is between 1 -25, 1 being the lowest and 25 is highest priority)
JSAs are done for a specific task prior to the commencement of all major tasks involving any hazards or risks.

Firefighting Preparedness Questionnaire

Small Fire Involving Motors	
What facilities you need for firefighting?	
In case You are the First Finder, What You Can do or should not do to extinguish fire?	
To Whom You may contact in case of a fire emergency?	
Propose firefighting preparedness actions for Your work site?	
Suggest PPE and Equipment for firefighting?	

Accident or Incident Report

Reported to _____ Reported Date _____

Reported by _____

1. Status of Accident / Trouble

Date of Accident	
Place	
Person involved	
Equipment involved	
Current Condition (Person/Equipment)	
Incident in detail	
Possible Causes	

2. Countermeasure

Action to be taken	
Resources required	
Due Date	
Person in charge	

3. Remarks

_____

_____

_____

Permit to Work

Valid only for work described on the permit

Permit valid for: Date _____ Time_____

Permit expires: Date _____ Time _____

Number of Workers _____

Work Description

_____

_____

Work Location _____

Shift supervisor's signature _____

Hazards Identified/Precautions	**Done (initials)**	**Comments**
Pre-work requirements		
Equipment locked out?	_____	_____
Atmospheric conditions tested for safety?	_____	_____
Guarding for moving parts?	_____	_____
Safety guidelines reviewed?	_____	_____
Work requirements		
Area barricaded, roped off, signs posted?	_____	_____
Personal protective equipment adequate?	_____	_____
First aid readily available?	_____	_____
Post-work requirements		
Tools and equipment removed from work area?	_____	_____

Where atmospheric tests are required, indicate results of tests:

Oxygen _____% Comments _____

CO_2 _____% Comments _____

H_2S _____

Signature of tester _____ Date _____ Time _____

Permit approved by

Signature (Sub Engr) _____Date _____ Time _____

Signature (SDO) _____Date _____ Time _____

Worker

I have read the permit and understand the nature and extent of the work. I agree to comply with safety precautions.

Name _____ Signature_____

Date _____

Name _____ Signature_____

Date _____

Completion

Work completed? Yes/No (Comments _____)

All safeguards returned to normal? Yes/No (Comments _____)

Requirements after work complied with? Yes/No (Comments _____)

Verified by Supervisor

Signature _____ Date _____ Time _____

Emergency Information for WASA Sites

WASA Tube Well / Disposal Station Address			
First Aider			
Name		Contact	
Rescuer			
Name		Contact	
Helper			
Name		Contact	
SDO			
Name		Contact	
Rescue 1122 Contact No.			
Fire Brigade Contact No.			
Nearest Hospital and Contact No.			
Nearest Police Station and Contact No.			

Action Plan

Name of Participant: _____ Date of Training: _____

Name of Organization: _____

1. Please focus on and list up the any actions you can actually apply at your sites. It should NOT be like just saying "SOP" "Preventive Maintenance", Please write down the possible actions as detail as possible such as including device name.

Electrical Panel

Generator

➡ ***Please choose some prioritized actions from the list above and put them into the attached format "OJT Implementation Procedure".***

2. Please share the problems or issues you are facing with in your sites and organizations
3.Other Comments or Notes:

Output Challenge 1: Wiring Diagram of Pump Control Panel

Name of Participant: **Date:**

Name of Organization:

1. Please draw the general wiring diagram of the pump control panel.
2. Please add anything you learnt through this training.

Output Challenge 2: General Flow Diagram of Diesel Generator

Name of Participant: _____ **Date:** _____

Name of Organization: _____

1. Please draw the general flow diagram of the diesel generator.
2. Please add anything you learnt through this training.

WASA: _____ *Division:* _____ *Sub Division:* _____

Approved by: _____

Prepared by: _____

OJT Implementation Plan for Record Keeping, SOP & Device Inspection Activity of Electrical Panel

Administrative Information						Contents of Activity	Planning Date	Completed	Planning Date	Completed
Site No.	Site Name	Name of the Persons in Charge								
		XEN	SDO	Sub Engineer	Operator					
1.						Daily Operation Record				
						SOP Check List				
						Device Inspection Sheet				
2.						Daily Operation Record				
						SOP Check List				
						Device Inspection Sheet				

-Remarks-

OJT Implementation Procedure for O&M Manual, Record Keeping and Preventive Maintenance Activity of Diesel Generator

Administrative Information						Contents of Activity	Planning Date	Completed	Planning Date	Completed
Site No.	Site Name	Name of the Persons in Charge								
		XEN	SDO	Sub Engineer	Operator					
1.						1. O&M Manual				
						2. Basic Specifications				
						3. Daily O&M Record				
						4. Preventive Maintenance Plan				

-Remarks-