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## About the T/R set

**The T/R set is a critical component of the ESP power supply. The purpose of the T/R is too accept an AC power Feed from the SCR/CLR control system, and convert the 0 TO 480 VOLTS AC signal to the required level of High Voltage. T/R sets are oil filled tanks with a low voltage junction box and one, or even two high voltage bushings. Single bushing T/R 's are referred to as full wave units, and dual bushing T/R's are referred to as double half wave units. The standard TR described in this presentation is energized by external sources and contains hazardous voltages. Incoming power must be locked off before entering or servicing the equipment. The turns ratio between windings of transformer-rectifier sets makes them capable of transforming low voltages to dangerous levels.**
**Before servicing, the high voltage bushing(s) should be solidly grounded by means of a grounding device supported on an insulated handle, as potentially lethal voltages buildup on the precipitator plates to which the high voltage bushings are connected even when the equipment is de-energized.**

# GENERAL DESCRIPTION

**Transformer-Rectifier Units, operating from a single phase AC source, provide high voltage unidirectional current, rectified by a high voltage silicone rectifier usually of the full wave bridge type circuit, for industrial electrostatic precipitator application. T-R units are available in ratings to meet usual voltage and current requirements for precipitator service.**

**There are two types of T-R units:**

**ONAN and LNAN. The ONAN type uses mineral oil as a cooling fluid, while the LNAN type uses silicone fluid or R-Temp fluid.**

**Range from 20,000 - 75,000 volts DC**

**Range from 250 – 2500 MA**



# BASIC TR SET PRECAUTIONS YOU SHOULD KNOW!

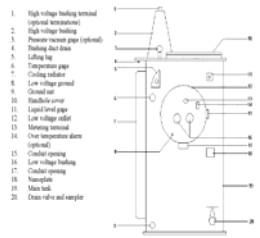
**INSULATING FLUID PRECAUTIONS**

**Mineral oil and silicone are not compatible. The presence of silicone fluid in mineral oil will cause the oil to foam severely when it is vacuum processed. A small amount of transformer mineral oil in silicone fluid will result in a reduction of the flash and fire points of the silicone fluid. R-Temp fluid can be mixed with transformer mineral oil, however small percentages of mineral oil in R-Temp fluid will reduce the flash and fire points of R-Temp fluid. R-Temp or silicone fluid that is known to contain mineral oil should be sampled and tested with respect to fire and flash points to check that these attributes have not been reduced below the minimum levels acceptable for the particular fluid. Units designed to be cooled with transformer mineral oil will, if retro filled with either silicone or R-Temp fluid, operate with a higher conductor temperature rise.**



# MAIN T-R COMPONENTS

**Transformer**



**High voltage supply transformer mounted on the tank bottom and secured in place by guide bars welded to the tank wall. The transformer designed for ESP applications employ design techniques specifically developed for this use. ESP transformer coils must be capable of withstanding repeated sparking and arcing of the load. Disruptions such as these, along with occasional shorted fields, cause current surges well above the systems ratings. These surges cause the winding of the transformer to exert considerable amounts of physical force on the system insulation and support mechanism. If not properly constructed and processed, these over exertions will cause premature destruction and system failure.**

# MAIN T-R COMPONENTS (Cont'd)

**The transformer is typically the longest lasting component of the system itself. Failures of the transformer do occur and can often be placed into two separate categories. The first is degenerative failure that is caused by long term breakdown of component parts. If the transformer is used within it's rated parameters, then degenerative failure is most likely due to a defect of materials and or workmanship.**

**The second failure is overstress failures. This is caused by subjecting the transformer to either excessive voltages, or excessive currents. Overstress failure is usually the case for transformers that fail between 5 and 20 years of service.**

***Internal Inspection***



# MAIN T-R COMPONENTS (Cont'd)

**Bridge rectifier**

Full wave silicon bridge rectifier assembly complete with RC compensation and accessible through the hand-hole or top T-R cover. The diode assembly of the T/R converts the high voltage AC output to a DC signal. The diodes are configured as a full wave bridge as a positive output of the bridge connected to earth ground. The negative output is routed through an air core reactor, and ten to the high voltage bushing. The diode is made up of a series string of many diode junctions. This series string of diodes should be capable of blocking at least twice the peak output voltage of the TR.

A typical 45 KV unit will have a peak output in excess of 75 KV. The diode assembly must have an effective PIV (peak inverse voltage) of 150 KV. Common types of failures are excessive high voltage, or high current. Failure from over current may occur if the power supply is allowed to exceed its rated current output for an extended period of time.

***Transformer / Rectifier Remanufacturing***



# MAIN T-R COMPONENTS (Cont'd)

**Bridge rectifier (Cont'd)**

Most T/R s in service have a source of impedance of about 50%, the TR can actually deliver twice it's rated current. Severe arcs, or shorted output, the system relies upon the controller to maintain the output current to a safe level. When such disruptions occur, the current may instantly rise to twice it's rating but must be reduce QUICKLY by the controller to preclude damage to the T/R. If an over current situation is permitted to continue, excessive heat is generated by the diodes.

Heat related failures. In many cases of TR over current, the heat generated by the diodes cause the diode junction to exceed their maximum operating temperature. When this occurs, the diodes will fail. Occasionally, the heat generated will be sufficient to cause the solder that fastens the diodes to the PC board to melt away. As the solder melts, and it 's displaced with insulating fluid, arcing occurs between the diode lead, and the PC board. This arcing results in the breakdown of insulating fluid. Carbon and cyanide gas are the two resultant components of this breakdown. If the internal arcing continues, then the generated carbon will eventually be attracted to the windings and cause failure of the transformer. If excessive cyanide gas is generated, then the air space between the tank lid and the oil will become explosive.

# MAIN T-R COMPONENTS (Cont'd)

**HV/LV Bushing**

High voltage/low voltage input/output bushing(s) mounted on the cover of the T-R unit or on the wall.

**Air Core Reactor** The ACR provides a means of protecting the diode bridge from high transient voltages that occur within the ESP. ACR's are subject to extreme voltages due to ESP arcing and sparking, and typically will fail before most other components.

**Voltage divider**

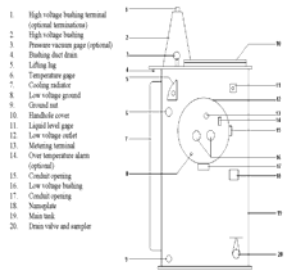
The low voltage divider provides a means of feeding back a low voltage signal that is proportionate to the KV output of the TR. This signal is used for metering, and control of the unit.



# MAIN T-R COMPONENTS (Cont'd)

**Metering bushings/lightning arrestors**

Metering bushings provide current and voltage feedback to the controller. Arrestors protect surges on the systems control.






# INSTALLATION

When the transformer-rectifier unit is installed, the following points must be adhered to:

The unit must be securely attached to a firm foundation at its base. The tank must be securely grounded. High voltage bushing connections of the rigid conduit design should be free floating, under all temperature conditions, to reduce mechanical load and vibration to the bushing. The high voltage bushing terminal must not be rotated for alignment purposes as this will damage the bushing seal.

The primary low voltage terminals must not be used to support heavy loads. The stresses resulting from mechanical loads on the primary bushings can distort the gaskets and possibly other components of the bushings and eventually destroy the seals. Primary cables connected to the low voltage terminals should have restraining clamps at the exit of the conduit to avoid having the weight of the conductor being supported by the bushings.

All connections should be made as indicated on the nameplate. Care should be taken to ensure that all connections are made correctly since wrong connections can cause serious damage to the equipment.

Control or metering leads to monitor the high voltage d.c. current should be connected to the terminals in the low voltage junction box. Refer to control diagrams and nameplate.

Connections for monitoring the high voltage d.c. should be connected to the terminals in the low voltage junction box.

# PRECAUTION

***Importance of utilizing qualified technicians***

**Safety is always first. Lethal and hazardous voltages will be present unless the field is removed, and grounded at the specimen.**



# PRECAUTION (Cont'd)

**After servicing the TR, processing oil, or simply moving the TR set, bubbles of air are apt to be introduced into the insulating fluid in the process of adding additional fluid to the unit or if while moving the T-R, splashing of the fluid occurs. Thus to avoid serious damage to the equipment, the T-R should not be energized until 24 hours settling time has elapsed and not until the condition of the insulating fluid is determined to be satisfactory.**

**The T-R input voltage must NOT exceed 110% rated voltage under any circumstances. The unit must never be energized without a load in the metering circuit(s). FAILURE TO DO SO COULD RESULT IN PERMANENT DAMAGE TO THE ENTIRE T-R SET. A load could be a resistor, a metering control circuit, or a shorting cable connected between the ground terminal in the low voltage junction box and the d.c. positive "plus" bushing(s) and the metering terminal. The surge arrestors are for protection of the metering or control circuit and will be destroyed if subjected to the high voltage d.c.. Refer to nameplate for identification of the terminals.**

**Excessive currents for a prolonged period (ie. more than 15 amperes for 10 cycles) through the rectifier can result in failure.**



# INITIAL START-UP

This applies to newly installed (REMANUFACTURED OR NEW) T-R sets and T-R's that are taken out of service for an extended period of time. This procedure should be carried out in conjunction with the controller start-up procedure.

Using the controller and with settings adjusted for minimum output voltage and current, energize the T-R set. While observing the controller indicating instruments, adjust the control to slowly increase the output so as to have low level instrument indications.
If the primary or secondary currents do not register or if they are excessive, de-energize the controller and T-R and investigate for an open or shorted condition in the precipitator or for faulty wiring in the instrument circuitry. Repeat step number 1.
If the current and voltage magnitudes being indicated are within the range of the instruments, adjust controller settings so as to allow up to 50% of rated voltage (kV), or 50% of rated current, whichever occurs first. Allow unit to remain energized at this level for one hour.

If the performance is steady, adjust the controller settings to allow 75% of rated voltage (kV), or 75% of rated current, whichever occurs first. Allow unit to remain energized at this level for one hour.

If performance is steady, the controller settings may be adjusted to allow maximum rated current or voltage, whichever occurs first.

# COLD START

**For T-R units with fluid temperature of Zero (0) °C or below, follow steps 1, 2 and 3 above. However, instead of energizing the unit at 50% rated volts or amps for only one hour, maintain this load level until the T-R fluid temperature reaches +5°C or above. Proceed with steps 4 and 5 after the fluid temperature reaches the required limit.**
**If the fluid temperature is still below +5°C after 24 hours at half load, contact CE Power personnel before proceeding any further.**

**Make sure the HV bushing(s) and all wiring connections on the T-R set are clean and dry before start-up.**

**DO NOT EXCEED EITHER THE RATED VOLTAGE OR CURRENT OF THE T-R SET.**



# MAINTENANCE

**In the event of abnormal symptoms such as unusual noises, high or low fluid level, erratic electrical performance, etc. at any time, the transformer-rectifier unit should be taken out of service immediately for a detailed inspection. A regular inspection program should be set and rigidly carried out.**

**The inspection should include the following operations:**
**Check condition of insulating fluid. Draw a sample of fluid from the drain or sampling valve and inspect for color and signs of contamination. Test the sample for dissolved gas (acetylene), neutralization number, dielectric strength, interfacial tension, power factor, color, and water in oil. Discoloration, low dielectric strength, high gas content, high water content and abnormally high dissipation power factor indicates deterioration of the fluid/ and or arcing is occurring. Corrective action MUST BE TAKEN.**

**Acceptable limits:**
Total DGA – Contact CE Power
Acetylene – less than 1 ppm
Neutralization # - .4 mgXOH/gram max
Dielectric strength – 22 kv minimum
Interfacial tension – 18 dynes/DM minimum
Power Factor – 1.0% doble limit
Color – 4.0 max
Moisture in oil – 55 ppm



# MAINTENANCE (Cont'd)

**This test should be carried out every six months after initial start-up. The test interval can be increased up to two years if test results show insignificant change in the fluid over at least two test intervals. What should be done in the event that the oil shows degradation? As long as it's known not to show signs of decomposition in the craft paper, or damaged components, oil processing can be performed. If there are damaged components, they should be replaced, or repaired before processing is performed. Shown below is a de-gas/dehydration machine. This machine will improve the oil back to normal ASTM standards.**

**The transformer windings (step up) is in fact the major component of the T/R system.**

# MAINTENANCE (Cont'd)

All accessories and connections should be inspected for tightness and proper function. The unit, particularly the high voltage bushing(s), should be cleaned to reduce the possibility of flashover. High humidity conditions and certain types of dust make the cleanliness of the bushing quite critical.

A megger test of the high voltage circuit similar to those earlier described should be made. These sections indicate typical readings. A high resistance in the megohm range in both directions indicates an open high voltage circuit. A low resistance in the kilo-ohm range in both directions indicates a faulty rectifier or insulating component. Either of these conditions require that the unit be taken out of service for internal inspection and repair.

The level of the cooling fluid should be checked. A low level may expose some of the high voltage circuit elements and cause excessive voltage stresses and internal damage. An excessive fluid level can cause fluid spillage through the pressure relief device during operation.

If gasket replacement is necessary, a material similar to that originally installed in the T-R set is preferred. Cork neoprene has been used for the handhole and cover. Do not use cork gasket material because of its susceptibility to absorb moisture.



# INTERNAL INSPECTION

Should the previous inspections and tests indicate internal problems, proceed as follows:

Operate the pressure relief valve by pulling the valve ring to relieve any residual internal pressure.

Attempts to maintain near atmospheric pressures inside the T-R by venting for vacuum or pressure conditions can lead the T-R or the tank to take on air containing moisture. Gas volume over the fluid can vary by up to plus or minus fifty percent. During a normal temperature increase the pressure relief device may operate once or twice. This is normal.
Remove the handhole cover or the tank cover (if horizontal HV bushing) on the top of the tank.

Using a flashlight, inspect all internal connections, check the level of the cooling fluid and look for any signs of contamination or failure.
Inspect the rectifier stacks for any evidence of burning or broken connections. Replace or repair the faulty part. Check wiring and make sure all connections are secure. Check fluid level and top up if necessary. Bolt cover back on and re-seal the unit.

Follow the initial start-up procedure if the unit was repaired, topped-up or left open for more than 3 to 4 hours total.

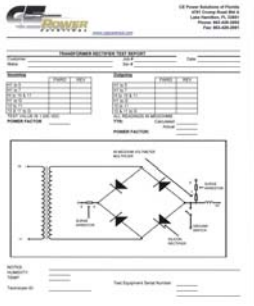


# INTERNAL INSPECTION (Cont'd)

If, in this inspection procedure, evidence of malfunction is found that cannot be immediately repaired, it is recommended that the cover be replaced and resealed. CE Power personnel should then be contacted for advice and assistance.

Internal inspection and/or repair time should be kept as short as possible. Do not expose the core, coil or choke to air unless absolutely necessary. If repair work is needed on parts other than core and coil, remove the part from the tank to repair. Replace the cover and re-seal the unit during repair. Take care not to contaminate the coolant with any foreign materials. Do not let any metal particles fall inside the tank.

# MEGGER TEST LEAD CONNECTIONS



The meggering device used should have a high enough voltage to "turn on" the diodes. A 1000 volt megger is recommended. Connections for "REVERSE" and "FORWARD" measurements are as follows:

REVERSE MEGGER READING obtained with -
Megger NEGATIVE terminal connected to H1or H2 if applicable.

Megger PLUS terminal connected to ground.
FORWARD MEGGER READINGS obtained with -
Megger PLUS terminal connected to H1 or H2 if applicable.

Megger NEGATIVE terminal connected to ground.



# MEGGER TEST LEAD CONNECTIONS (Cont'd)

The meggering device used should have a high enough voltage to "turn on" the diodes. A 1000 volt megger is recommended. Connections for "REVERSE" and "FORWARD" measurements are as follows:

REVERSE MEGGER READING obtained with -
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FORWARD MEGGER READINGS obtained with -
Megger PLUS terminal connected to H1 or H2 if applicable.
Megger NEGATIVE terminal connected to ground.
Restore wiring connections to original wiring arrangement.
Megger measurement of voltage divider.

(a) Disconnect rectifier from ground in junction box and any control wires being used for monitoring the current signal.
(b) Disconnect Control wiring that is used for monitoring the voltage signal. (c) (c) Voltage divider must be connected to ground either through external voltage divider resistors or connections shorting out the surge arrestor.

Test H1 to ground with megger. The readings should be in agreement with the values indicated on the nameplate.

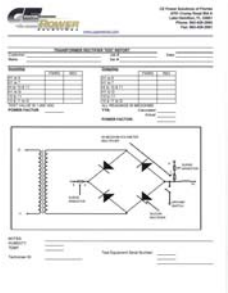
Restore wiring connections to original wiring arrangement.



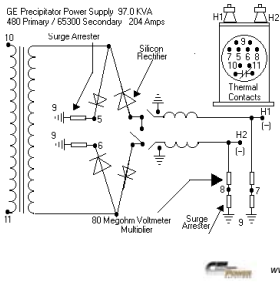
# MEGGER TEST OF FULL WAVE T-R SET

The following procedure tests full wave T-R set diode stacks. Included also in the procedure is a check of the voltage divider. The ground switch, if supplied, must be in the ungrounded position. Arrange connection in junction box as follows: Rectifier must be connected to ground. Control wires used for monitoring the current signal should be disconnected. The voltage divider ground in junction box and control wires connected to the voltage divider terminals must be disconnected.

Refer to the test report for the specific order. Measure forward and reverse resistance of diode stacks. The megger readings should be plus or minus 5% of the values on the test report.



# MEGGER TEST OF DOUBLE HALF WAVE T-R SET




**The following procedure is for checking out T-R set diode stacks which are arranged for double half wave output. Included also in the procedure is a check of the voltage divider.**
**Arrange connections in junction box as follows: One half of rectifier bridge must be disconnected from ground while the other half remains grounded for each of the measurements, H1 to ground and H2 to ground. Any control wires used for monitoring the current signal should be disconnected. If voltage dividers are supplied, the voltage divider grounds in the LV junction box and any control wires connected to the voltage divider terminals must be disconnected. Refer to the test report for the specific order. Measure forward and reverse resistance of diode stacks. The megger readings should be plus or minus 5% of the values on the test report.**