# ESR Supporting Procedure 10

# Capacitors

# SHEQ/HS/TCSESR/SP/010-2.0

**DOCUMENT AUTHORISATION SHEET**

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| | | | | | |

## Contents



## Appendices

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# 1 DEFINITIONS

Terms printed in bold type are as defined in the **TCS** Electrical Safety Rules.

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|---|---|
| *Capacitor Unit* | An assembly of one or more capacitor elements in the same container with terminals brought out by one or more bushings |
| *Capacitor Rack* | An individual framework containing *Capacitor Unit(s)* connected together |
| *Capacitor Stack* | An assembly of *Capacitor Rack(s)* connected together. If the **Equipment** consists of only one *Capacitor Rack* the term *Capacitor Stack* will also apply. A *Capacitor Stack* may contain *Capacitor Unit(s)* from one or more discrete components of the Static *Capacitor Bank*, e.g. the main and auxiliary capacitors, resistors and air cooled reactors |
| *Capacitor Bank* | An assembly of one or more *Capacitor Stack(s)* forming the Static Capacitor installation |
| *Discharge Stick* | An **Approved** device used for discharging a *Capacitor Unit* bushings to earth at a safe distance. |
| *GTO* | Gate Turn-Off thyristor |
| *IGBT* | Insulated Gate Bi-polar Transistor |
| *MOSFET* | Metal Oxide Semi-conducting Field Effect Transistor |
| *Short- Circuiting Lead* | An **Approved** lead used for short-circuiting an individual *Capacitor Unit*. This can be a clip-on short used during the disconnection of a *Capacitor Unit* or a bolt-on short used during the removal. |
| *Technical Specialist* | Any individual within or external to the **Company** with detailed specialist technical knowledge to assist when required in the safe installation, preparation for work, maintenance and removal of *Capacitor Unit(s)*. |


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## 2 PURPOSE AND SCOPE

This procedure sets down the process to be adopted when applying principles established by the **TCS** Electricity Safety Rules (**TCS** ESRs) and Safety Rules Supporting Procedures (SRSP) to achieve **Safety from the System** for personnel working on **High Voltage** *Capacitor Banks*

The SRSPs seek to compliment and apply detail to Approved Code of Practice (ACOP) documents published by the HSE. Although ACOP's are not law if not followed, you will be required to demonstrate that your safe system of work is of an equal or higher standard

## 3 DANGERS

The main **Dangers** to individuals are electric shock, burns and effects on eyes arising from:-

a) The discharge of electrical energy retained by the *Capacitor Unit(s)* after they have been **Isolated**

b) Inadequate precautions to guard against electric shock as a result of any **Charged** conductors or associated fittings

c) **Charged** capacitors inadequately short circuited

d) **Equipment** retaining or re-gaining a charge

## 4 GENERAL REQUIREMENTS

The *Capacitor Bank* shall be **Isolated**, **Point(s) of Isolation** established, **Primary Earth(s)** applied and a **Permit to Work** or **Sanction for Test** *shall* be issued in accordance with the **TCS** Electrical Safety Rules.

The **Senior Authorised Person** issuing the **Safety Document** *shall* ensure the time difference between the completion of the isolation of the *Capacitor Bank* (as recorded on the **Switching Schedule**) and the time of issue of the **Safety Document** to the **Competent Person** *shall* be a minimum of 20 minutes. This is to allow sufficient time for the *Capacitor Bank* to discharge via the *Capacitor Unit* discharge resistors.

Where work is to be performed on any *Capacitor Rack* the **Senior Authorised Person** *shall* produce an **Earthing Schedule** stating:-

- **Drain Earth** *shall* be applied to the connection point between any *Capacitor Bank* and any reactor (refer to figure 4a)
- Application points of discharge stick (refer to figure 4b)
- Location of any shorting leads (refer to figure 4b)

**Drain Earth(s)** *shall* be applied by a **Competent Person**, or by a **Person** under the **Personal Supervision** of a **Competent Person** in accordance with the requirements of SRSP 3 – Earthing of HV Equipment.

Referring to figure 4a, the **Drain Earth** is used to prevent a potentially **High Voltage** being generated by the 50 Hz resonant circuit formed by the capacitor and reactor whilst performing capacitor measurements.


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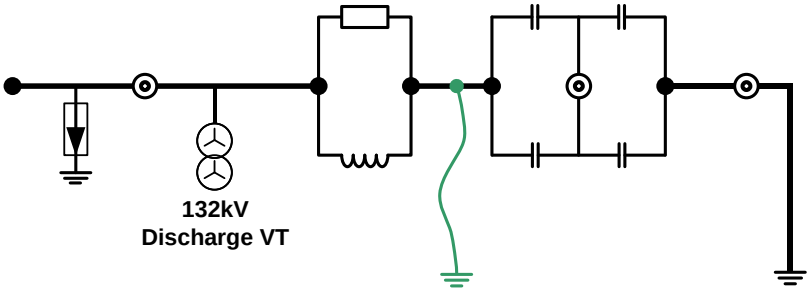


Figure 4a –Harmonic filter incorporating a capacitor bank and reactor. **Drain Earth** shown applied

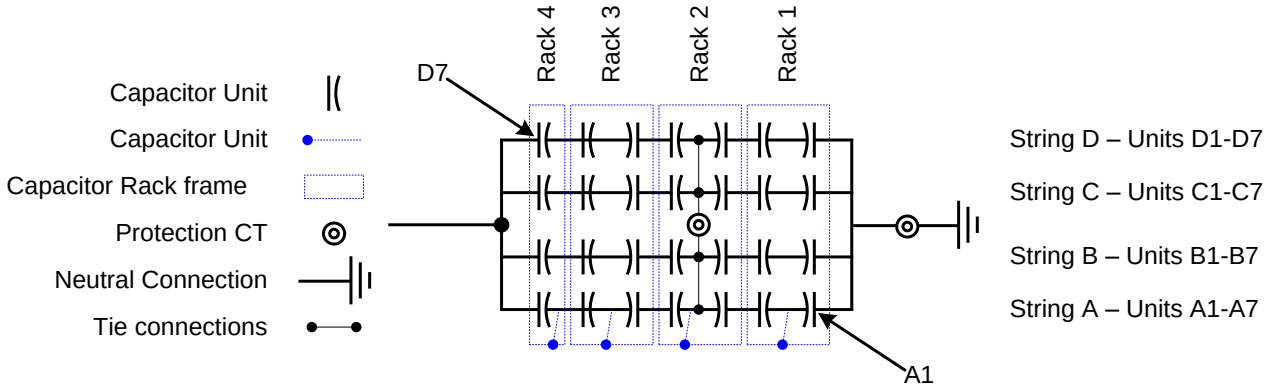


Figure 4b – Circuit layout of one phase of the harmonic filter *Capacitor Bank* (termed *Capacitor Stack*)

# 5 PREPARATION FOR WORK

## 5.1 Inspection

Before performing any work on a *Capacitor Bank* the *Capacitor Unit(s) shall* be visually inspected at a distance greater than the length of the *Discharge Stick* from exposed capacitor bushing in order to identify any abnormal *Capacitor Unit(s).*

Abnormal *Capacitor Unit(s)* are those that show signs of excessive bulging, major leaks or broken bushings. If any abnormal *Capacitor Unit(s)* is found, especially following a fault, then advice from a *Technical Specialist shall* be sought.

## 5.2 Discharging *Capacitor Units*

*Capacitor Unit(s)* by design, dissipate stored voltage via a discharge resistor to a value of approximately 75 V in around 10 minutes (20 minutes for a *Capacitor Bank*).

However, in certain conditions e.g. fuse and discharge resistor failure, there is a potential for the *Capacitor Unit* voltage to remain at a value up to approximately 20 kV, dependant on *Capacitor Bank* type and rating. Hence the requirement to use a *Discharge Stick* on <u>all</u> *Capacitor Unit(s)*.

Figure 5.2 –*Discharge Stick*


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Thus, following inspection a *Discharge Stick,* operated by a **Competent Person** (**Authorised** under this procedure), or by a **Person** under the **Personal Supervision** of the **Competent Person**, *shall* be used on all *Capacitor Unit(s)* to dissipate any potentially **Charged** *Capacitor Unit(s)*.

*Discharge Stick(s) shall* be maintained, and be visually inspected for damage by the **Competent Person** before and after use.

**SAFETY WARNING –** At no time whilst connecting the 'clip-on', or applying the 'crook end' of a *Discharge Stick, shall* any part of the body encroach within a distance shorter than the length of the *Discharge Stick* from exposed **Charged** *Capacitor Unit* bushing, or **Charged** *Capacitor Rack* frame. The *Discharge Stick shall* be applied at arms length.

Discharging is near instantaneous; unless using a Resistor Discharge Stick. Thus, the 'crook end' only needs to be applied to the terminal to be discharged for a short duration (2-3 seconds).

**Note: -** Resistor Discharge Sticks are only used in special circumstances e.g. SVC modules where the *Capacitor Unit* and power electronics (IGBT / MOSFET / GTO) are in the same module in similar size to a *Capacitor Unit*.

### 5.2.1 *Capacitor Banks* with single bushing *Capacitor Units*

The *Discharge Stick shall* be used by first connecting the clip-on end of the *Discharge Stick* to the **LV** terminal of the first *Capacitor Unit* (usually the *Capacitor Rack* frame metalwork) and applying the crook-end of the *Discharge Stick* to the first *Capacitor Unit* **HV** bushing. See figure 5.2.1b.

Figure 5.2.1a – Single Bushing *Capacitor Unit*

The *Discharge Stick shall* be applied to each **HV** bushing of a *Capacitor Unit* in the *Capacitor Rack* e.g. all *Capacitor Units* who's **LV** terminal is connected to the *Capacitor Rack* frame which the *Discharge Stick* clip-on is connected to.

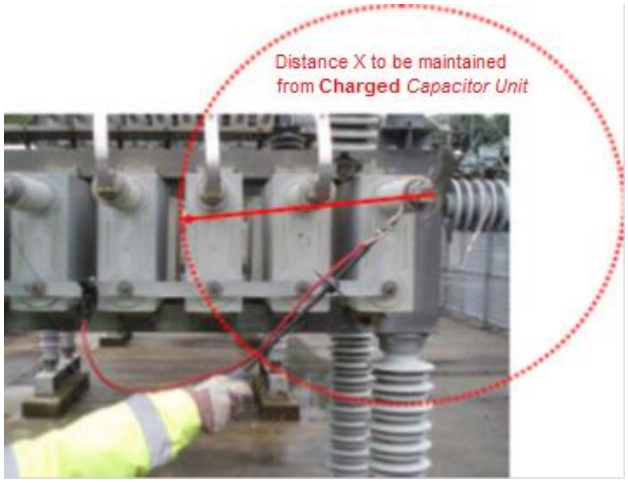


Figure 5.2.1b – Discharging single bushing *Capacitor Units* with **LV** terminal on *Capacitor Rack* frame


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Once all *Capacitor Units* in the *Capacitor Rack* have been discharged, the **LV** terminal of the next *Capacitor Rack shall* be discharged to earth to allow the clip-on to be attached, and the **HV** bushing discharging process repeated through the next *Capacitor Rack* until the whole *Capacitor Stack* is discharged, and *Capacitor Bank* if appropriate.

### 5.2.2 *Capacitor Banks* with two bushing *Capacitor Units*

If the *Capacitor Unit* has two bushings (see figure 5.2.2a), then a second *Discharge Stick* is required to ensure the distance between an individual's body and an exposed **Charged** *Capacitor Unit* bushing is greater than the *Discharge Stick* length.

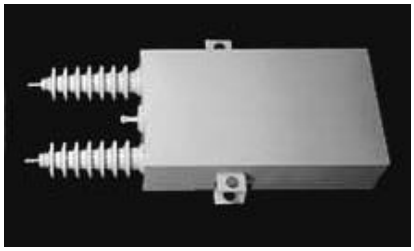

Figure 5.2.2a – Two Bushing *Capacitor Unit*

For two bushing *Capacitor Units* the clip-on of both *Discharge Sticks shall* be connected to the earthing system first. The 'crook end' of one *Discharge Stick* is then applied to the **HV** bushing of the first *Capacitor Unit* up the string from neutral. Once applied, continue and apply the 'crook end' of the second Discharge Stick to the **HV** bushing of the second *Capacitor Unit*.

Using a 'leap frog' approach apply the 'crook end' of the *Discharge Sticks* on each of the **HV** bushings of each *Capacitor Unit* on the string (refer to figure 5.2.2b) . This 'leap-frogging' ensures all *Capacitor Unit* bushings are discharged to earth (via the clip-on) in a methodical sequence.

**Note: -** The **HV** bushing is connected to the **LV** bushing of the next *Capacitor Unit* up the string, so you're always are shorting each bushing to earth and across the *Capacitor Units*.

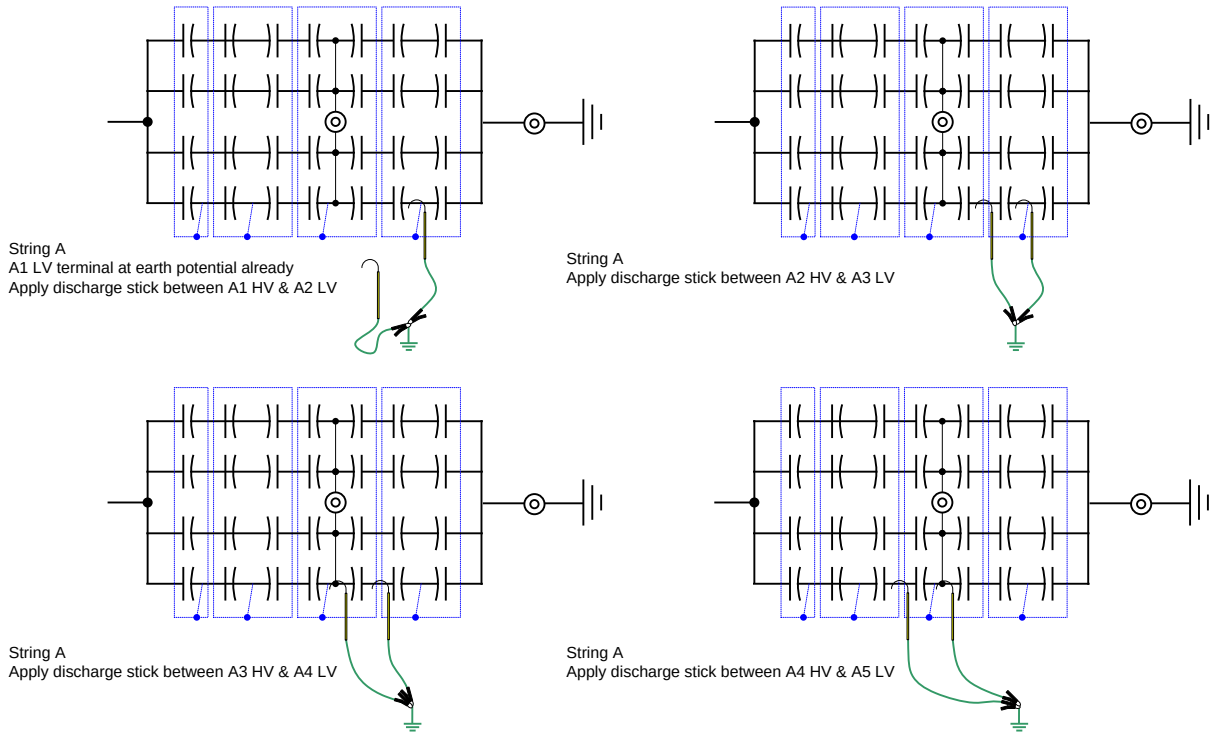


Figure 5.2.2b – Two Bushing *Capacitor Unit* discharging sequence


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The sequence may be varied slightly to discharge adjacent strings in a zig-zag formation if it is impractical to complete a single string (up one side of a *Capacitor Stack*) without encroaching distances, to **Charged** *Capacitor Units* on adjacent strings, shorter than the *Discharge Stick* length. An example sequence is given in figure 5.2.2c below where string A and B are adjacent on the same side of a *Capacitor Stack*.

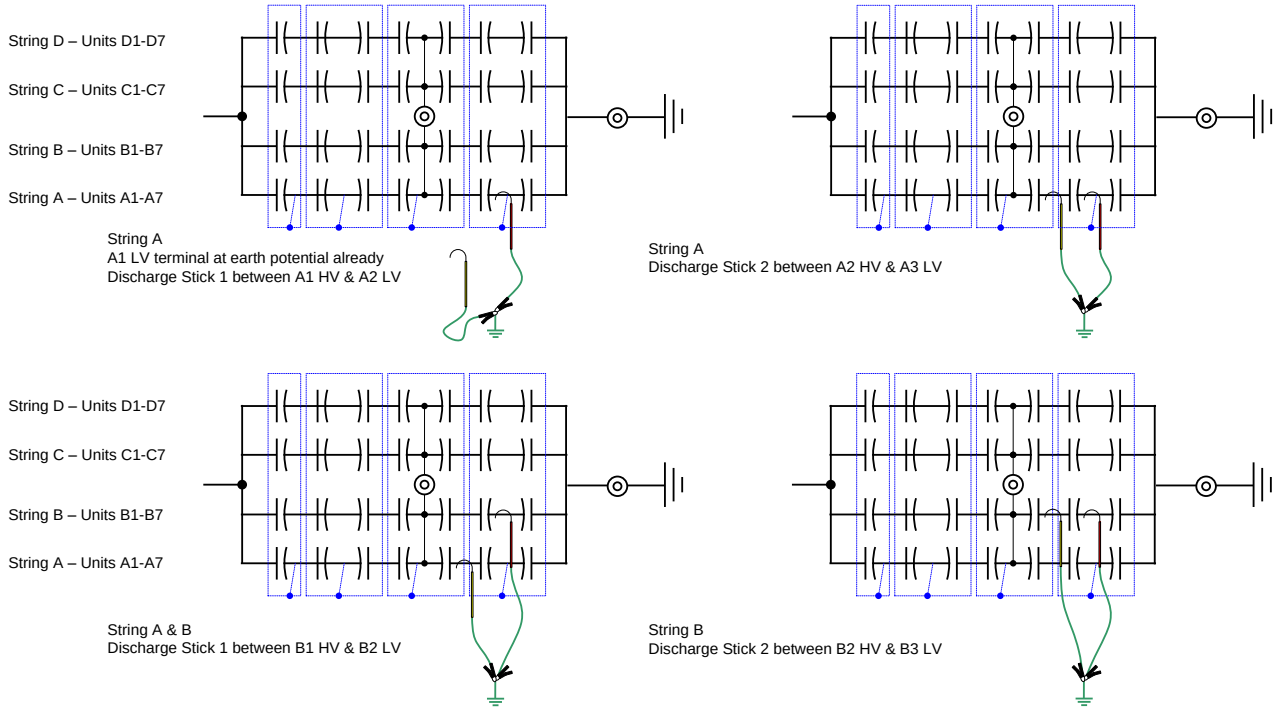


Figure 5.2.2c – Two Bushing *Capacitor Unit* discharging sequence on adjacent strings

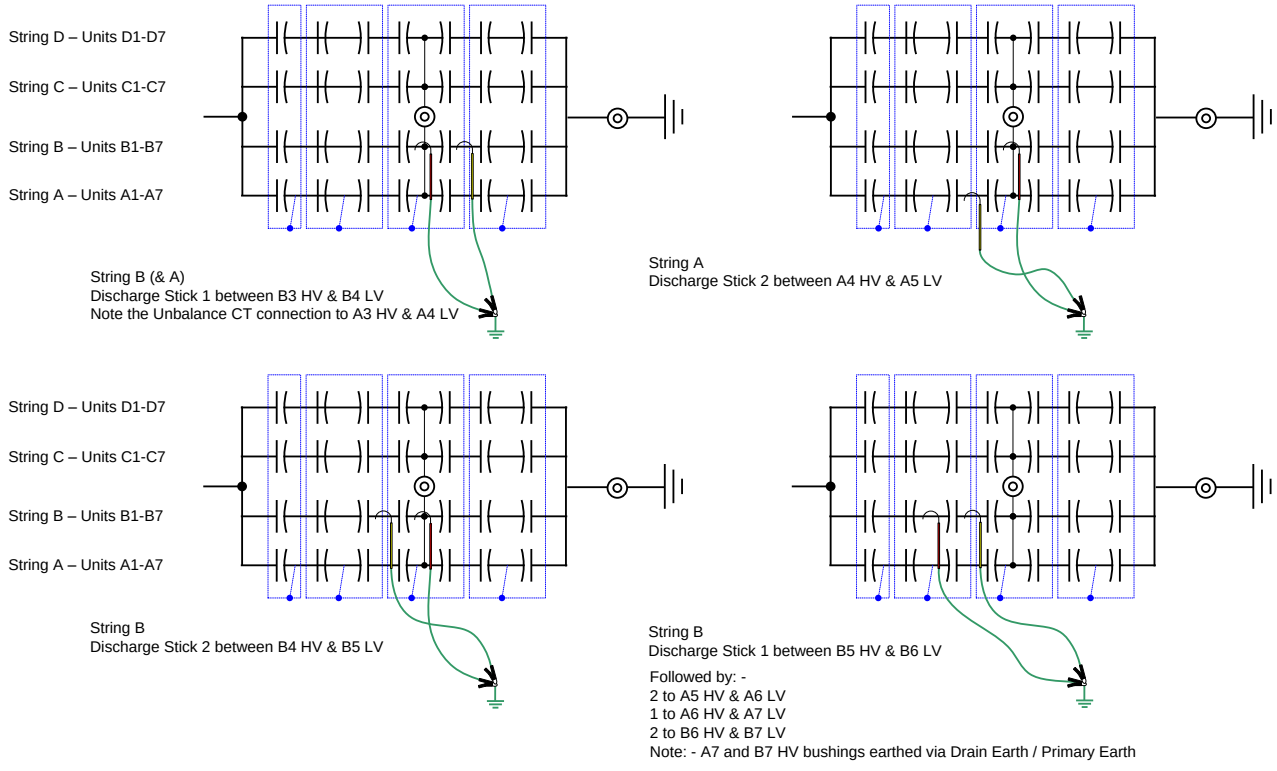


Figure 5.2.2c (continued) – Two Bushing *Capacitor Unit* discharging sequence on adjacent strings


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# 6 CAPACITANCE MEASUREMENTS

Before and after performing capacitance measurements, the *Capacitor Unit or Capacitor Unit(s)* in a parallel group *shall* be discharged using a *Discharge Stick* by a **Competent Person**, or by a **Person** under the **Personal Supervision** of a **Competent Person**. Refer to guidance Section 5 for discharging *Capacitor Unit(s)* using a *Discharge Stick*.

## 6.1 Performing Capacitance Measurement

Connect the capacitance bridge to a series group of *Capacitor Unit(s)* starting at the low voltage end of the *Capacitor Stack.*

Perform capacitance measurements as required on *Capacitor Unit(s)* in that series group. Continue capacitor measurements working on the next series group of *Capacitor Unit(s)* towards the high voltage end of the *Capacitor Stack*.

In exceptional circumstances an individual may be used for technical expertise e.g. third party SVC *Technical Specialists*. A **Competent Person** *shall* provide **Personal Supervision** to the individual.

# 7 HANDLING, STORAGE AND TRANSPORT OF CAPACITOR UNITS

Where there is a potential for a *Capacitor Unit* to become **Charged** e.g. within an **HV** compound it *shall* not be handled unless discharged and shorted.

Following Discharging the *Capacitor Unit shall* be short-circuited by connecting a clip-on *Short Circuiting Lead* between the capacitor **LV** terminal and bushings. If the capacitor unit has two bushings, a second *Short-Circuiting Lead shall* be connected between a bushing terminal and the *Capacitor Unit* metal case.

Only a **Competent Person** (**Authorised** under this procedure), or a **Person** under the **Personal Supervision** of that **Competent Person**, *shall* discharge the *Capacitor Unit* using a *Discharge Stick* and apply a *Short-Circuiting Lead*.

Before removing a *Capacitor Unit* from a *Capacitor Rack* the clip-on *Short-Circuiting Lead* connections *shall* be immediately replaced by a bolt-on *Short-Circuiting Lead*, or shorted by copper wire. The *Short Circuiting Lead* or copper wire shall connect both *Capacitor Unit* terminals together, and connect to the *Capacitor Unit* metal case in the case of a two bushing capacitor.

If using a shorting copper wire it *shall* be at least 1.0mm in diameter and have at least two complete turns on each *Capacitor Unit* terminal/bushing and metal case connection in the case of a two bushing capacitor. Only a **Competent Person**, or by a **Person** under the **Personal Supervision** of a **Competent Person**, *shall* apply the *Short-Circuiting Lead* or shorting copper wire.

A failed *Capacitor Unit(s) shall* remain shorted due to the potential for the bushing to become **Charged**. This is due to the possibility of a trapped internal charge within the failed unit re-connecting to the bushing during movement.

Figure 7a – Clip-on Short-Circuiting Lead

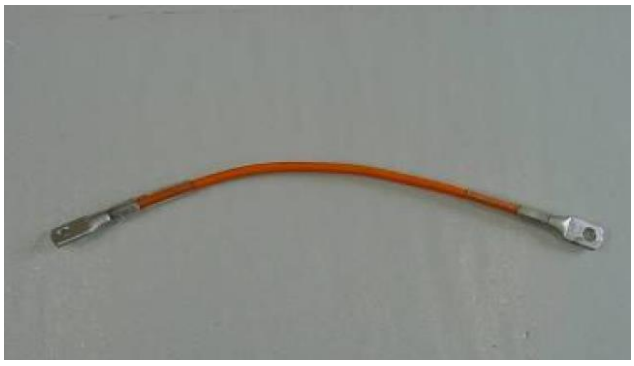

Figure 7b – Bolt-on Short-Circuiting Lead


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# 8 NOTES

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