RADIODETECTION – Application Note

STREET LIGHTING CABLE FAULT LOCATION USING THE LEXXI T810^{TM} AND THE T272 HIGH RESISTANCE CABLE FAULT LOCATOR

APPLICATION NOTE TO BE READ IN CONJUNCTION WITH DATASHEETS

1 INTRODUCTION

Cable faults take two forms:

a) *Conductor Faults* – Open Circuits, High Resistance Joints.

b) *Insulation Faults* – Insulation Resistance can be any value from a few ohms to hundreds of kilohms.

In this paper two complementary techniques are described which will find most common faults.

They are:

- Conductor Faults and Low Resistance Insulation Faults
- *Lexxi T810^{TM}*
- High Resistance Insulation Faults
- *T272 High Resistance Fault Locator*

Bicotest

2 PRE-TESTINGAND USE OF LEXXI T810

Before commencing fault location on a street lighting network all fuses and neutral links should be removed so that the cable is isolated. The removal of the neutral links is important, since if the neutral is not damaged it can be used as the sound return conductor for T272 bridge location. Also if fuses are left in, the tests referred to in the next paragraph will give misleading results.

Conventionally the first step in fault location is to carry out tests to check insulation, (MEGGERING), and conductor continuity. Whilst it is easy to megger the phases and neutral from the feeder pillar, checking continuity from the feeder pillar to each load on a "teed" network can be time consuming, particularly if there is no record of which phase feeds each load. On a "looped" system checking continuity is obviously simpler. The results of these tests will indicate whether the Lexxi orT272 should be used.

An open circuit is often indicated by the fact that some lamps are not illuminated but no fuse has blown. In this case the Lexxi can be used to "look" for the fault, either from the feeder pillar, or from the lamps on either side of the open circuit, i.e. the last lit lamp and the first unlit lamp on the faulty phase. It is essential to remember that fault diagnosis will give the most important clue to deciding which instrument to apply and testing for continuity is best done with a simple multi meter and not a "megger". TDRs will find low resistance shunt faults up to about 300 ohms and high resistance series faults over about 300ohms. Beyond these limits applytheT272.

Figures 1, 2, 3 and **4** show waveforms when the Lexxi is applied to a cable under various circumstances.

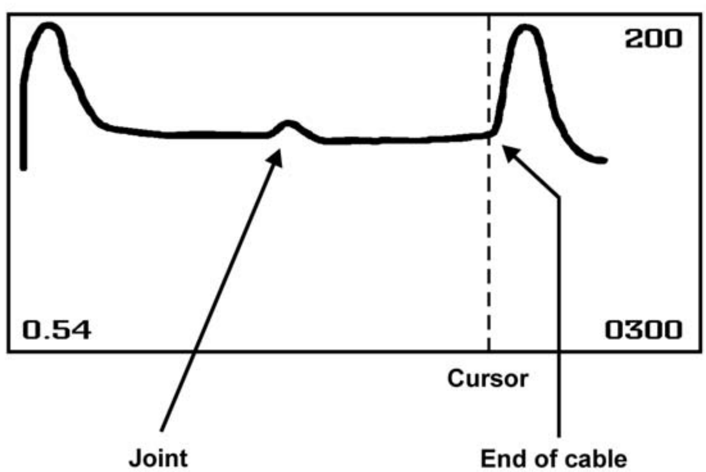


Figure 1 – Straight joint at 100 metres on a 200 metre length of cable

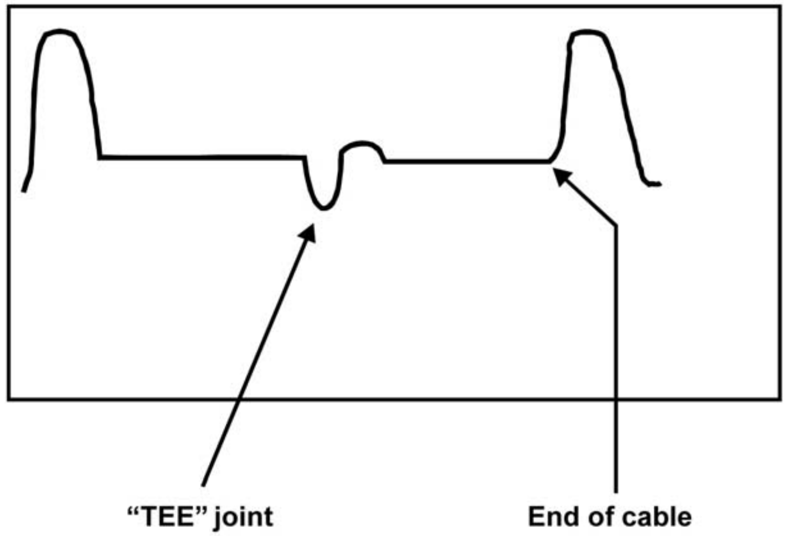


Figure 2 – 5 metre "TEE" at 100 metres on a 200 metre length

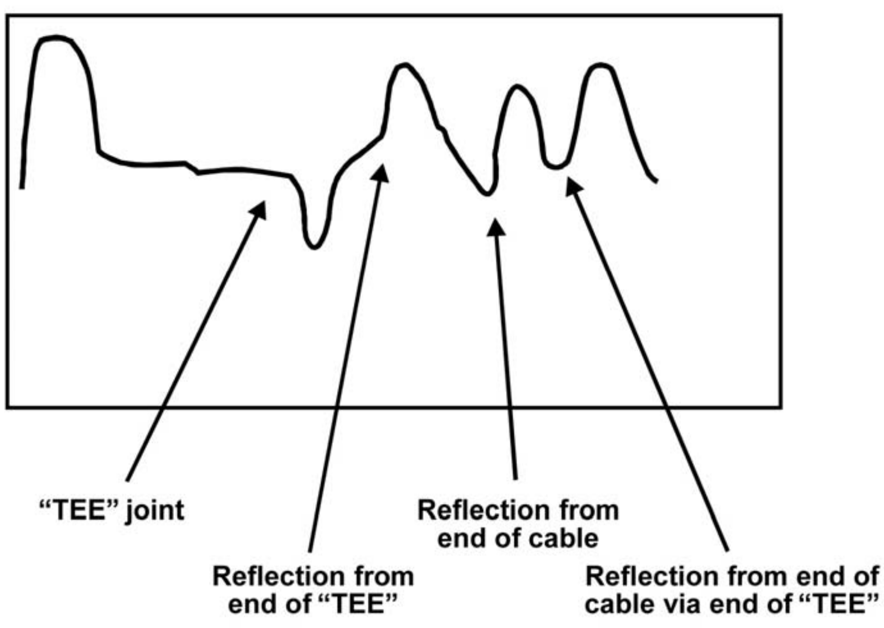
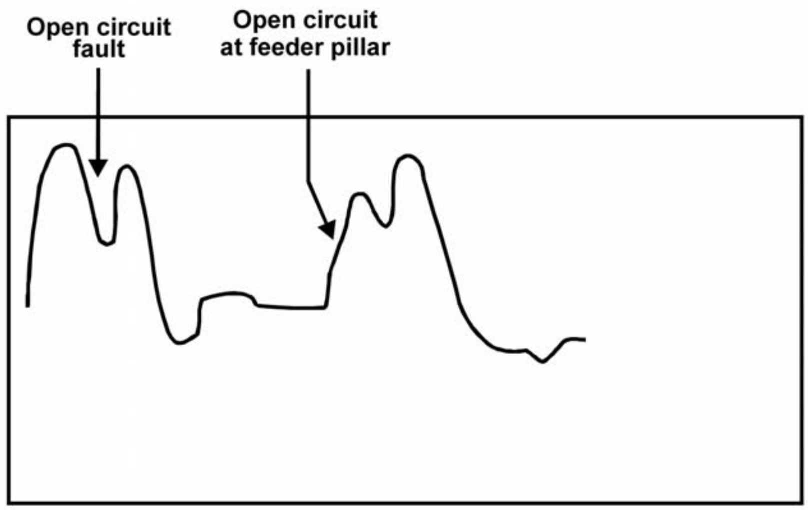
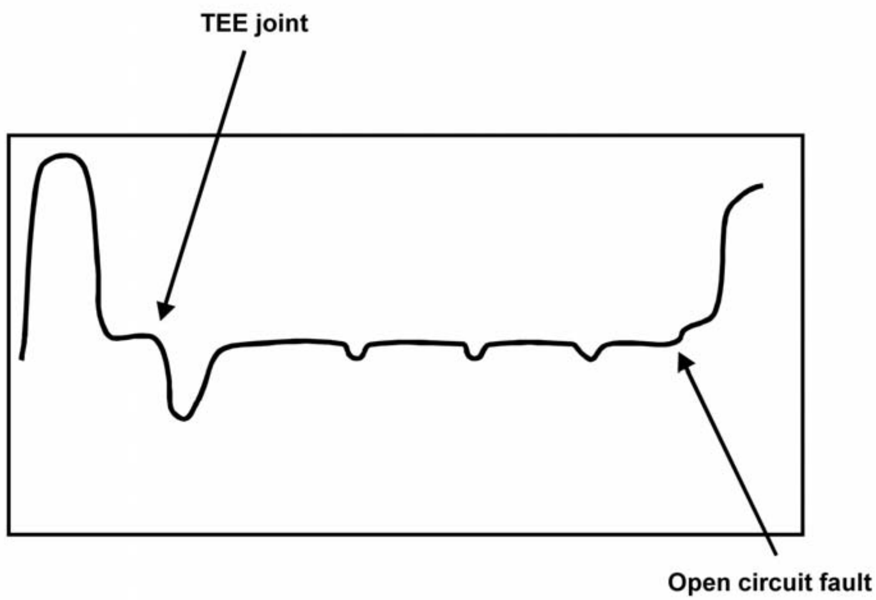


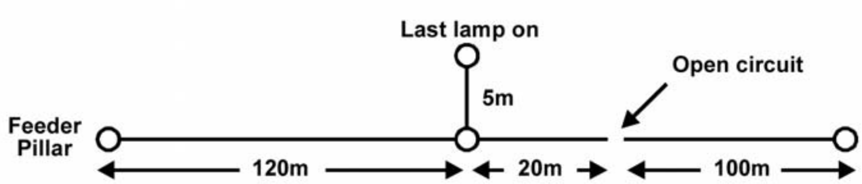
Figure 3 – 40 metre "TEE" at 100 metres on a 200 metre length

a) 300 metre range



b) 30 metre range





CCT Details

Figure 4 – Both waveforms with LEXXI connected at last lamp on

Figure 1 shows the reflection from a straight joint at 100 metres on a 200 metre length of cable and **figure 2** the same cable with a 5 metre long “TEE” at 100 metres. The far end of the cable is easily visible in both cases. In **figure 3** the length of the “TEE” has been extended to 40 metres and it can be seen that the wave form becomes much more complex because of the multiple reflections.

An open circuit with the conditions that apply in **figures 1 and 2** could be located either from the feeder pillar or from the lamps on either side of the break.

For a system like that indicated in **figure 3** the complexity of the network means that the easiest way to locate the fault is to use the Lexxi from the lamps on either side of the fault.

Figures 4a, 4b show waveforms obtained in this way.

Since we are testing from the last lamp ‘on’, the circuit is continuous back to the feeder pillar, thus on the longest range we can see the reflection from the feeder pillar, but there is another reflection close to the transmitted pulse, which is the reflection from the open circuit fault. The range is then reduced as necessary until the reflection from the fault can be clearly seen, in this instance the 30 metre range. Note that there is a substantial reflection from the ‘TEE’ joint.

If this reflection is not there but the feeder pillar can be seen, this would indicate that the fault was very close to the ‘TEE’ joint on the leg towards the first lamp ‘off’. Similarly if the Lexxi was being used from the first lamp ‘off’ and the ‘TEE’ joint reflection was missing but lamps towards the far end of the cable, or the far end of the cable itself could be seen, this would indicate a fault near the‘ TEE’ joint feeding the first lamp‘ off’.

If a reflection is observed at about 1 metre it might only be due to the mismatch between the test lead and the cable, so double check before excavating

It is always a good idea to ‘look’ at the cable using the longest range first. The range can then be reduced as necessary to make the required measurement.

For an insulation fault the Lexxi is only effective if the fault resistance is quite low. In the circuits indicated in **figures 1 and2,** (i.e. minimum reflection from joints), it should be possible to see faults with a resistance upto300ohms.

On a circuit where there are major ‘TEE’ joints, and hence complex wave forms, it might be difficult to see a fault with a resistance of only a few ohms, depending on its position relative to the instrument, i.e. if the fault is between the test point and the first major ‘TEE’ then there will be no problem. If there are several ‘TEES’ between the test point and the fault it will be very difficult to interpret the waveform.

In all instances it is vital that the insulation resistance is measured with a low voltage instrument, (e.g. AVO or DVM), rather than a MEGGER. On a complex network with a low resistance fault it might be possible to find the fault by looking at the cable from the ends of the various ‘TEE’ joints, but this will be time-consuming.

3 FAULT LOCATION USING THE T272

For an insulation fault that cannot be ‘seen’ by the Lexxi, the fault location procedure will be dictated by the fault conditions.

a) ONE OR MORE PHASES“DOWN”, BUT NEUTRAL“HEALTHY”

In this instance a conventional MURRAY loop test can be carried out using the T272. The test can be made from the feeder pillar with the faulty phase and neutral solidly connected at the furthest lamp on that phases **(See figure 5)**. When the T272 is ‘balanced’, the distance to the fault will be indicated as a percentage of the loop length, (2L). Normally where a cable consists of lengths of different cross-sectional area, allowances have to be made for the difference in resistance per unit length of the cables. On a street lighting network advantage can be taken of the access to the phase afforded at the ‘TEE’ joints to over come this problem.

For example, in **figure 5** the fault might be indicated at 46%L. Examination of the cable records or cable route would indicate that this was somewhere between lamps R7 and R10. By leaving the bridge set up as it is and applying a solid earth to the phase only at lamp R7and repeating the bridge test would yield an answer of 41%L.

Similarly, removing this earth and applying it to the phase at lamp R10 would give an answer of 47.5%L. This would confirm that the fault was between R7 and R10, and the numbers would indicate that the fault was closer to R10 than R7. The bridge test could then be carried out with phase and neutral looped at R10 rather than R19, the bridge reading would then give a percentage of the loop length between the feeder pillar and R10.

When carrying out a bridge test a fault anywhere along a ‘TEE’ will appear to be at the ‘TEE’ joint. Thus if a bridge indicates that a fault is close to a major ‘TEE’ the bridge test should be repeated with a loop at the end of that ‘TEE’ to prove whether the fault is in fact at the ‘TEE’ joint or some where along the ‘TEE’.

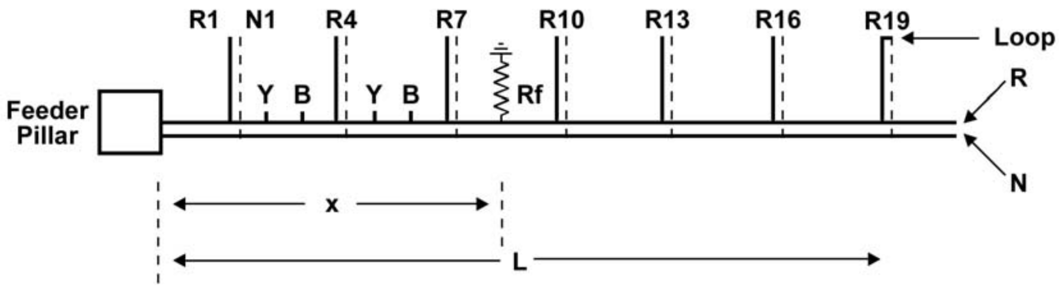
This procedure can be carried out on other faulty phases to ascertain whether there is more than one fault.

b) ONE PHASE AND NEUTRAL“DOWN”,TWO PHASES HEALTHY

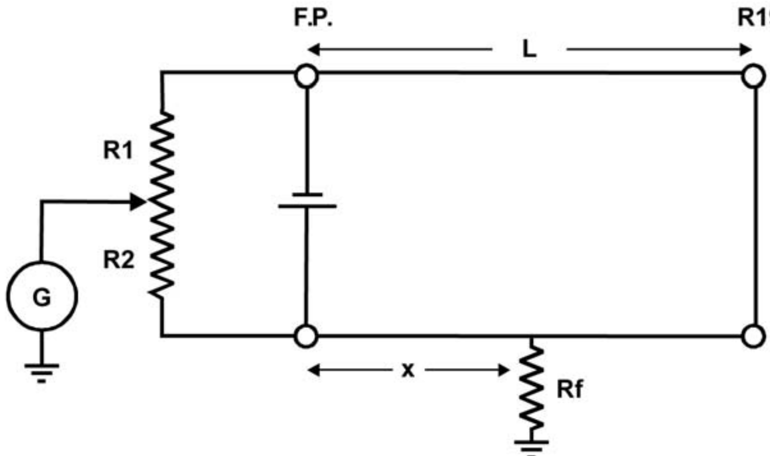
A variation of the MURRAY loop - the HILBORN loop – can be used in this situation. If we assume standard phase rotation in **figure 5**, then lamp 18 will be on the Blue Phase (B18) and lamp 20 on the Yellow Phase (Y20). A single insulated wire, (cross-section unimportant), is runfromB18to R19and a similar wire fromY20toR19.At the feeder pillar the red bridge terminal is connected to the faulty phase, (in this case also red), the black bridge terminal is connected to one of the healthy phases and the battery is connected between the other healthy phase and the faulty phase. This time, when the bridge is balanced, the reading will give the fault position as a percentage of the cable length (L) between the feeder pillar and R19. Again, by applying a solid earth to the faulty phase at a lamp, the ‘TEE’ joint feeding this lamp can be identified relative to the fault.

c) ALL PHASES AND NEUTRAL“DOWN”

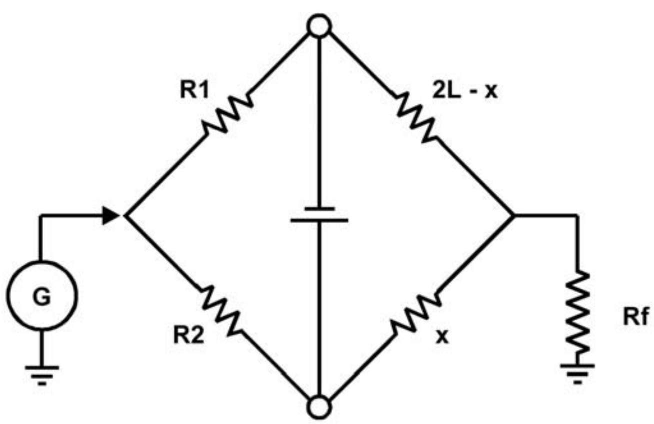
In this case we again utilise the HILBORN loop but, since there are no sound conductors, a special ‘overland’ lead is used. This is a twin lead which is used to span the gap between two lamps on the same phase. The conductor cross-section should be about 1 square mm. ($1mm^2$). The more lamps that can be spanned at one go, the easier the fault location will be, but practical limitations with respect to handling the ‘overland’ lead means that 200-300metres is probably the maximum length.



This can be redrawn:



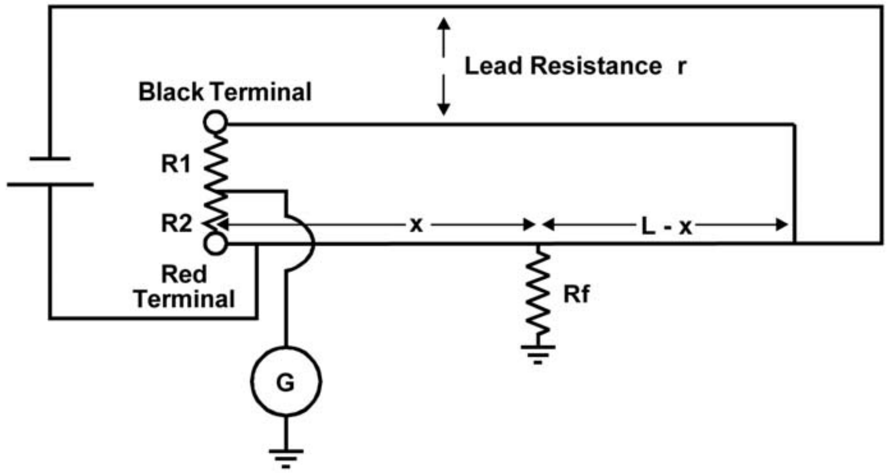
This in turn can be drawn as a Wheatstone Bridge circuit.

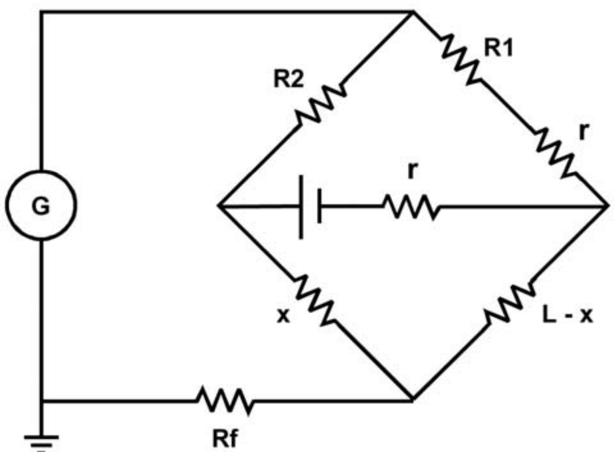


At balance

$$x = \frac{R2}{R1 + R2} .2L$$

Figure 5 – MURRAY Loop Test





From this at balance

$$x = \frac{R2}{R1 + R2 + r} \times L$$

Since R1 + R2 = 1000 ohms, small values of r will not make much difference.

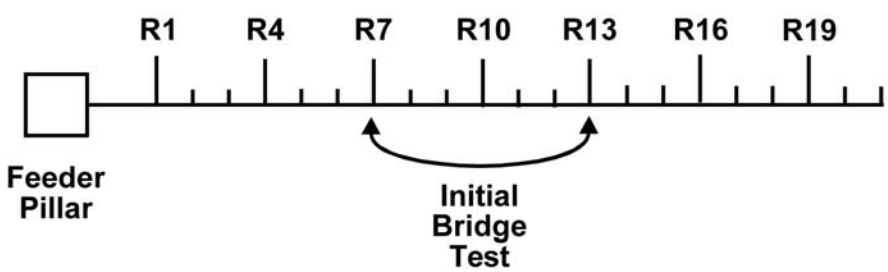


Figure 6 – HILBORN Loop Tests

Figure 6 shows how the location would proceed for the fault on the Red phase. It is assumed that the ‘overland’ lead is long enough to span between a lamp and the next but one on the Red phase and the initial test is carried out somewhere near the middle of the run. The two cores of the ‘overland’ lead are connected to the faulty phase at R13 and the bridge is set up at R7, faulty phase to red bridge terminal and one conductor from the ‘overland’ lead to the black terminal, the battery is connected between the other conductor in the ‘overland’ lead and the faulty phase.

When the bridge is balanced, the fault position will be indicated as a percentage of L, (the cable length between R7 and R13). A reading close to 0%* would indicate that the fault is between the feeder pillar and R7, (or in ‘TEE’ joint R7), a reading close to100%* would indicate that the fault is between R13 and the far end, (or in ‘TEE’ joint R13).

The ‘TEE’ joints can be identified as before, i.e. a solid earth at R4 would show the position of ‘TEE’ joint R7 and an earth at R16 would indicate ‘TEE’ joint R13. If the fault reading indicates that the fault is between R7 and R13, then an earth at R10 would enable its position to be established relative to the fault. If the indication was that the fault was between the feeder pillar and R7 or between R13 and the far end, then further bridge tests would have to be carried out between the appropriate points.

** It is difficult to put exact values on these two figures, since the tails to the lamps at each end are included and the fact that the cross-section of these cables is smaller than the main feeder means that their “effective” or “equivalent” length will be greater than their physical length.*

Example:

Main feeder 4c 75 mm, tails to lamps 2c 16 mm, spacing between lamps 40Êm, total length of main R7-R13 = 240Êm, tails 4Êm long but since they are only 16 mm, effective length = 4 x / = 19Êm, total length presented to bridge=240+19+19=278m, so ‘TEE’ joint 7= / x 100%=7%, similarly, ‘TEE’ joint 13=93%.

The actual position of the ‘TEE’ joints could be found as explained above.

4 FAULT LOCATION ON A LOOPED NETWORK

A looped network is one where a single phase cable is used. The cable runs from the feeder pillar into the first lamp and then from first lamp to second lamp and so on. The cable thus “loops” in and out of each lamp, rather than having a ‘TEE’ joint from a main cable to each lamp, often there are subsidiary loops to illuminated bollards and signs.

An open circuit could be located from the feeder pillar or from the lamps on either side (last on, first off as before).

If the neutral is healthy, an insulation fault location could be carried out using a MURRAY loop on the complete cable length in the same way as on a ‘TEED’ network, using earths to identify the position of intermediate lamps relative to the fault.

If both phase and neutral are faulty, then it is best to 'sectionalise' the cable to find which length is faulty. This is done by 'breaking' the connection at approximately halfway and meggering both lengths of cable and repeating this until the fault is known to lie between two lamps. A HILBORN loop could then be carried out on this short length of cable.

Many looped systems use a split core concentric cable, where the neutral consists of a number of individually insulated conductors. Often by separating the neutral wires at both ends of the faulty section, a fault location can be made without the need for an over land lead. Sometimes a check on each individual neutral toearthwiththeT810 will indicate an obvious difference on some wires. If this is not successful then a check on the insulation resistance between the individual neutrals and earth will often show that one or two have a much higher resistance than the rest. This will allow a MURRAY loop location to be carried out on one of the faulty neutral wires or if two neutrals have a high insulation resistance, a HILBORN loop location can be carried out on the line conductor.

IMPORTANT POINTS WHEN CARRYING OUT BRIDGE TESTS

1 After the overland lead has been run out, MEGGER it before connecting it to the cable. If it is faulty it will affect the bridge measurement.

2 Before carrying out a bridge test, check that the loop is continuous. If carrying out a MURRAY loop test, the connection at the far end must be a low resistance connection. If possible, put Land N into a terminal block in the cut out.

3 Connections from bridge to cable and battery to cable must be made with separate cables, otherwise the lead resistance will be included in the cable circuit, where it could have a marked effect on the accuracy of the location.

4 Tails from the main cable to the cut out in a lamp are of much smaller cross section, therefore their effective length is greater than their physical length.

5 If applying a temporary earth to identify a 'TEE' joint, use an AVO, (or other low voltage instrument), to make sure that a low resistance earth exists.

OTHER INSTRUMENTS WHICH MAYBE USED ON STREET LIGHTING SYSTEMS:

a) M225 Cable and Pipe Locator – useful where the route of the cable is not known.

b) S5000 AXXIS – for locating Sheath Faults.