NSW DEPARTMENT OF
PRIMARY INDUSTRIES

EARTHING INTEGRITY & ASSOCIATED PROTECTION

Part 2 - Earth continuity of restrained plugs and receptacles

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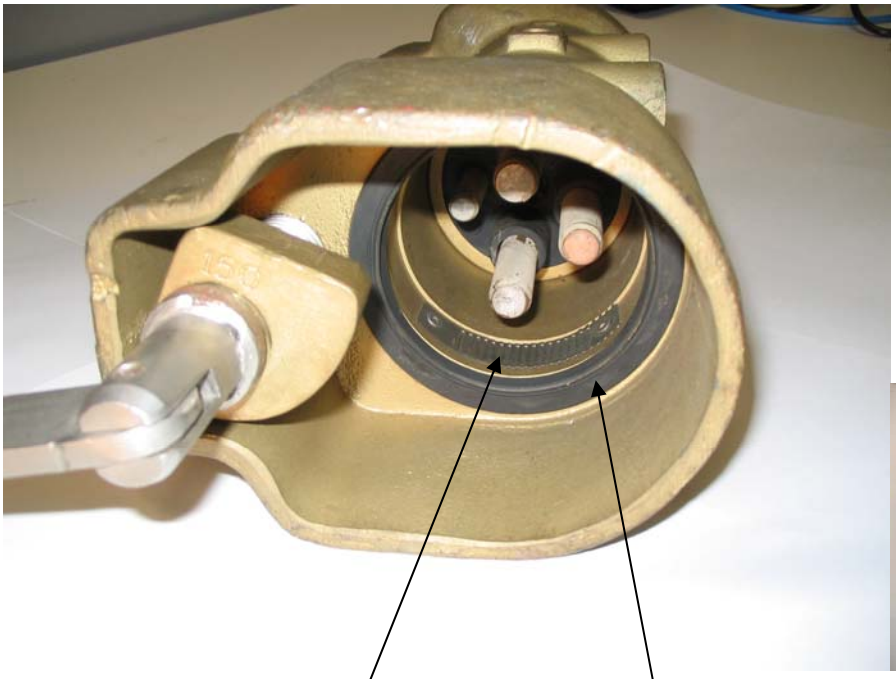
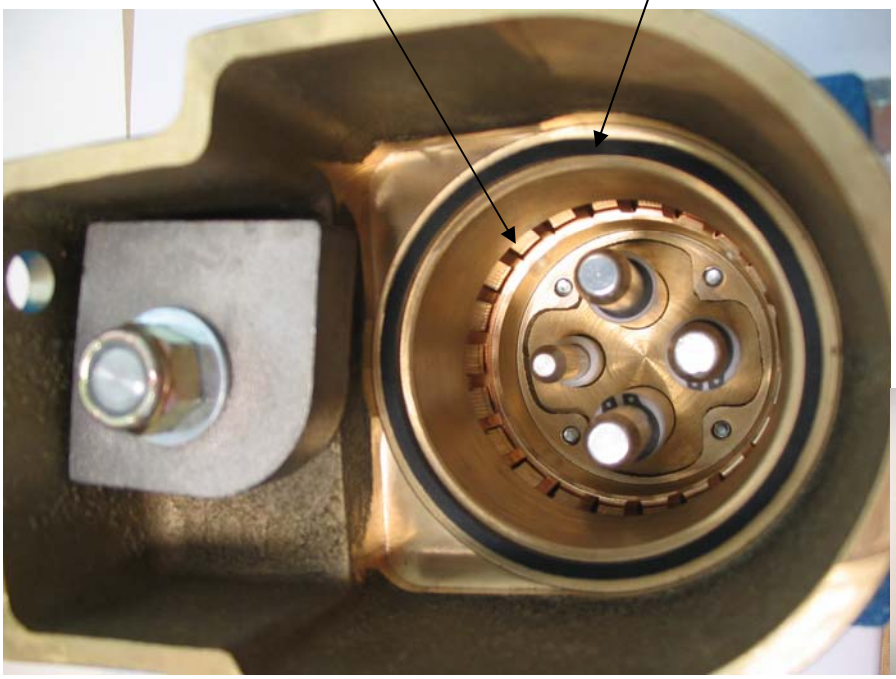
Introduction

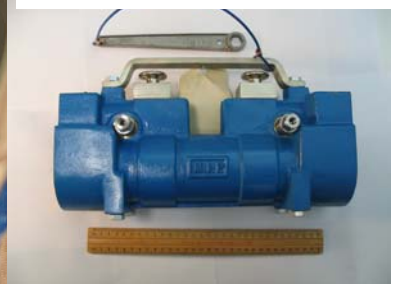
The symmetrical cables used in underground coal mines are constructed with three earth conductors, three-phase conductors and pilot conductor(s). The cable earth conductors are terminated inside the plug to provide continuity to the metallic body of the receptacle. Typical mining restrained plugs and receptacles do not have an earth pin but rely on a scraping earth contact between the metal body of the plug (nose-cone) and scraping earth contact of the receptacle to achieve a continuously effective earth connection. The following photographs of back-to-back couplers show three phase pins and a single pilot pin of a 150 Amp receptacle. This arrangement is also typical for receptacles of other current ratings. Plug and receptacle dimension are prescribed in Australian Standard AS 1299.



Figures 1 and 2:
Crouse Hinds (Macey)
150 Amp Back-to-Back

Earth scraping contact **Weather seal**





Figures 3 and 4:
Minto Industrial Products
150 Amp Back-to-Back

In figure 1 it can be identified that the weather seal causes the inserted plug to centralize in the receptacle but may also cause it to stand-off from physical contact with the scraping earth contact within the receptacle. The scraping earth connection of the receptacle, in figure 1, makes contact to the

plug prior to the flamepath. There is a concern that the scraping earth remains in continuously effective contact with the nose-cone of the inserted plug without damaging the flamepath surface of the nose-cone. Figure 3 shows a reverse arrangement where the scraping earth makes contact to the nose-cone of the plug after traversing the flamepath and therefore is unlikely to damage the flamepath surface of the nose cone. These different arrangements for flamepaths have implications for flameproof properties, in that a plug nose-cone must be considered a flamepath for its entire length if the two brands of receptacles are used. Any damage to the earth sleeve (nose-cone) should be assessed to ensure the flameproof properties of any plug / receptacle combination are not compromised.

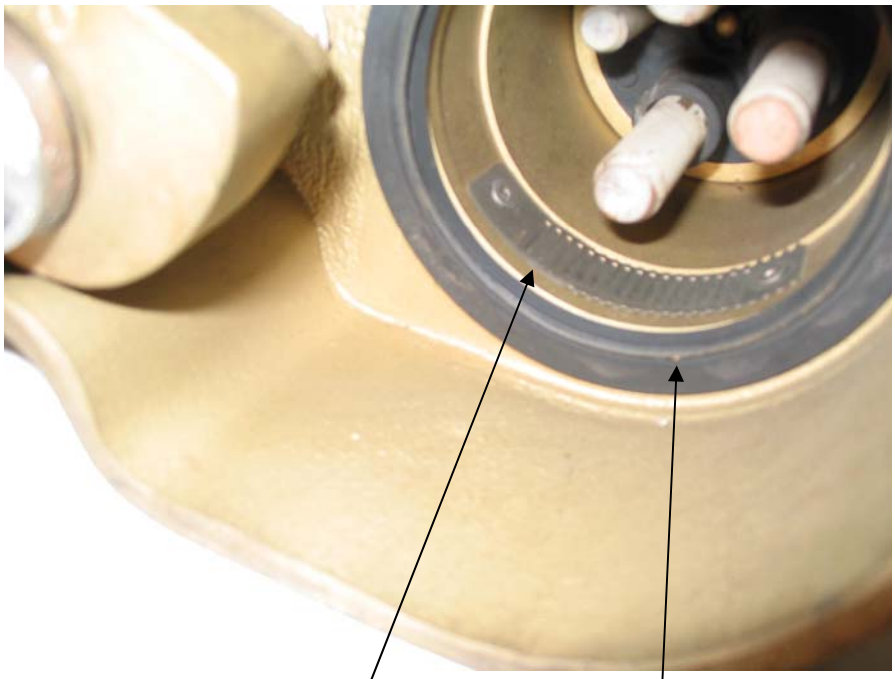


Figure 5:
Magnified view of Macey 150 Amp Back-to-Back

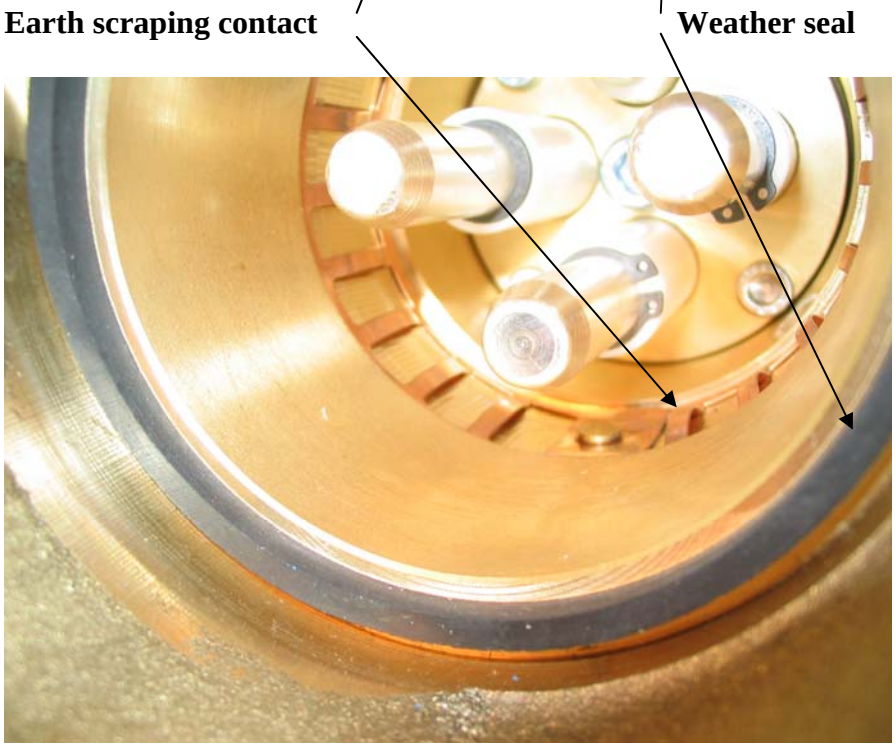


Figure 6:
Magnified view of Minto Industrial Product 150 Amp Back-to-Back

Figure 5 shows a magnified view of the one of the scraping earth contacts assembled into the Macey receptacle. There are two scraping earth contacts in this type of receptacle, arranged to be diametrically opposite in location. The weather seal may prevent accurate determination of the mechanical resistance of the scraping earth contacts. Therefore the seal needs to be removed to determine the insertion and withdrawal forces for scraping earth contacts of the Macey receptacles.

Figure 6 shows that the insertion and withdrawal force of the scraping earth contacts can be tested without removing the weather seal in the Minto receptacle. Clause 3.2.6 of Australian Standard AS 1299-1993 *Electrical equipment for coal mines-Flameproof restrained plugs and receptacles*, nominates the limits of axial force necessary to insert into and withdrawal from an earthing contacts. If the axial force to insert into and withdraw from a scraping earth is near the upper permitted limit it is more likely that the scraping earth will remain continuously effective whilst in service.

Detailed examination of earth contact arrangements within plugs:

The following photographs assist in depicting the construction and earth transfer path arrangements of the restrained plugs. Also detailed are various potential failure modes in the earth transfer path.

Figure 7 depicts a nose-cone on an insulated plug core and separated from the earth ring by an o-ring.

Figures 7 and 8:
Crouse Hinds (Macey)
150 Amp Restrained Plug

Nose cone **Earth (connection) ring**

Figure 9 depicts an alternate arrangement where the nose-cone slides over contact fingers of the earth ring.

Figures 9 and 10:
Minto Industrial Products
150 Amp Restrained Plug

Figure 11: Stripped down view of the Macey 150 Amp Restrained Plug

Voltage polarizing slot on Macey 150 Amp plug

Voltage polarizing pin on Macey 300 Amp plug

Nose cone **O-ring** **Insulated plug core** **Earth ring**

Figure 12a: Magnified view of the part-assembled Macey 300 Amp Restrained Plug

The Macey 150 Amp and 300 Amp plugs are equivalent in design except for voltage polarization locator and overall size. Figures 11 to 13 show the physical earth contact points for the Macey restrained plugs. An earth continuity path occurs through the thread contact when the nose-cone is screwed to the plug body. In addition the nose-cone applies pressure to the o-ring and in turn the earth ring is pressed against the internal lip of the plug body to form an earth transfer path. A missing or deteriorated o-ring, loose nose-cone or dirty contact surfaces may degrade the earth continuity.

The integrity of earth continuity of an assembled plug should be tested (with power isolated) from the phase barrier to the nose-cone and plug body.

Figure 12b: Repeated view of the part- assembled Macey 300 Amp Restrained Plug

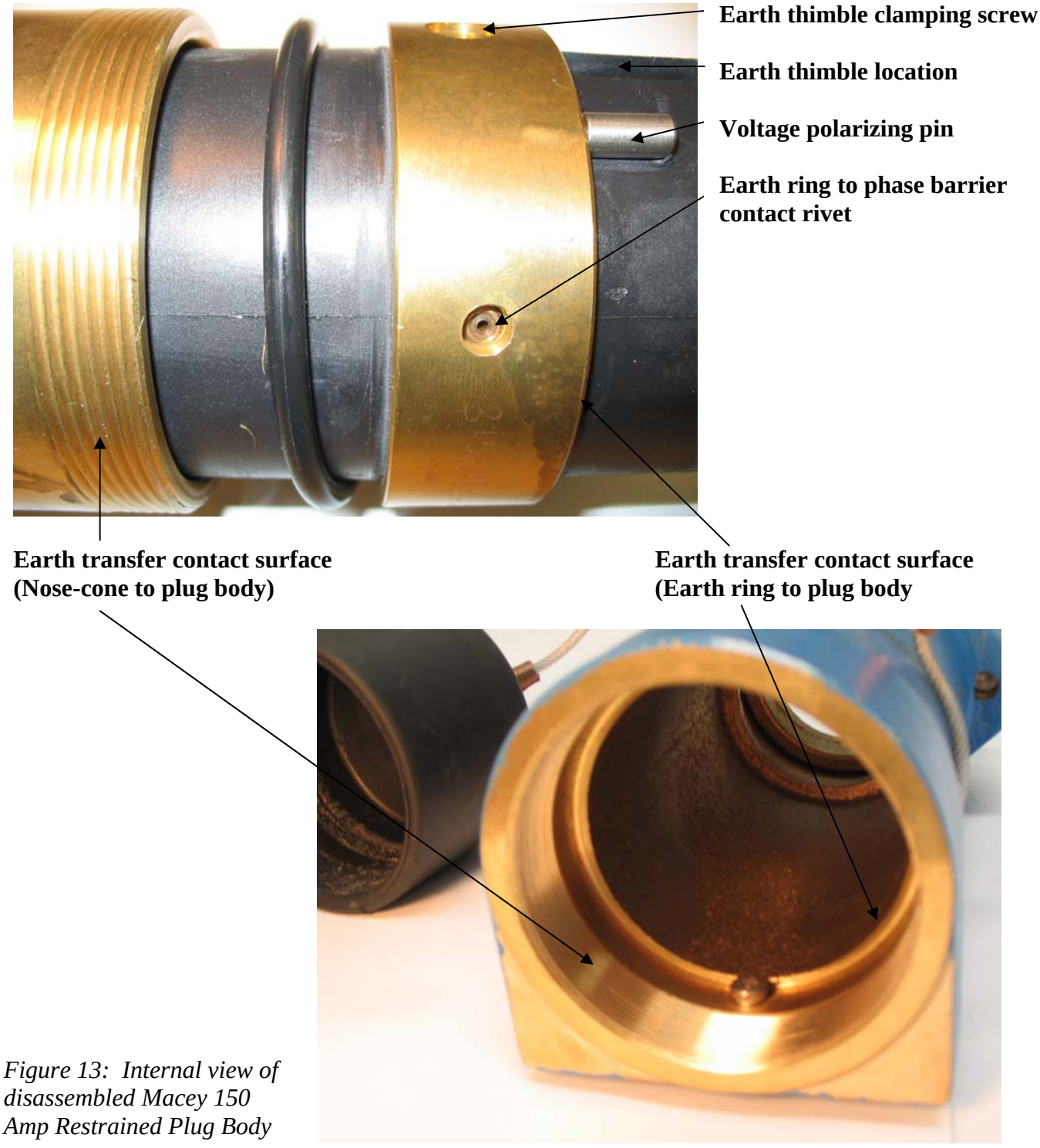


Figure 13: Internal view of disassembled Macey 150 Amp Restrained Plug Body

Figure 14: Stripped down view of the Minto Industrial Products 150 Amp Restrained Plug

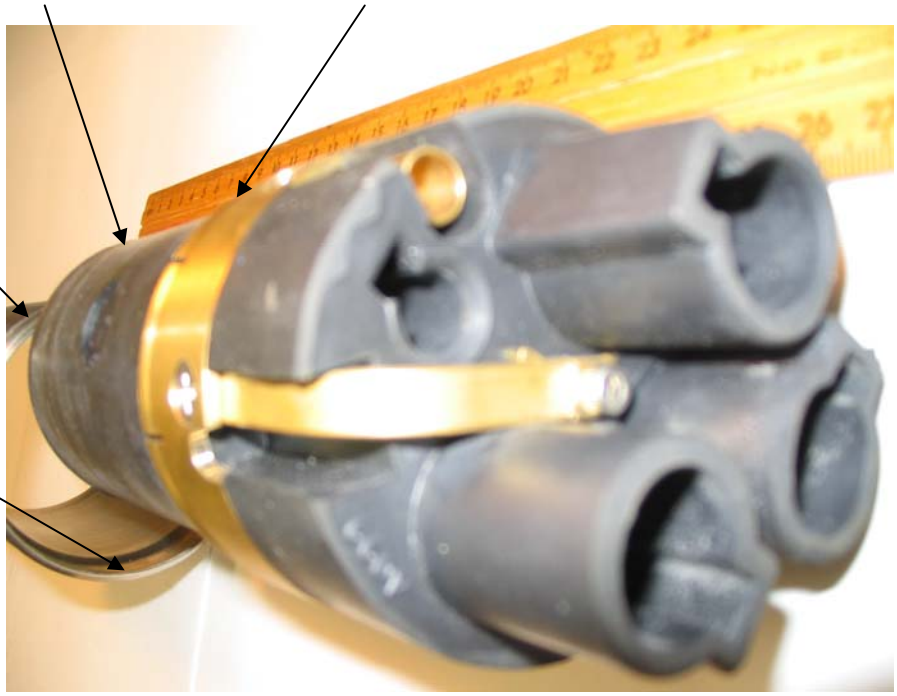


Figure 15: Rear view of the disassembled Minto Industrial Products 150 Amp Restrained Plug

Figures 14 to 15 show the physical contact points for the restrained plug. An earth transfer path occurs from the three earth conductors to individual thimbles which are screwed to the earth ring. The fingers of the earth ring are required to make physical contact with the nose cone. A further physical connection occurs between the nose-cone thread and the plug body when assembled.

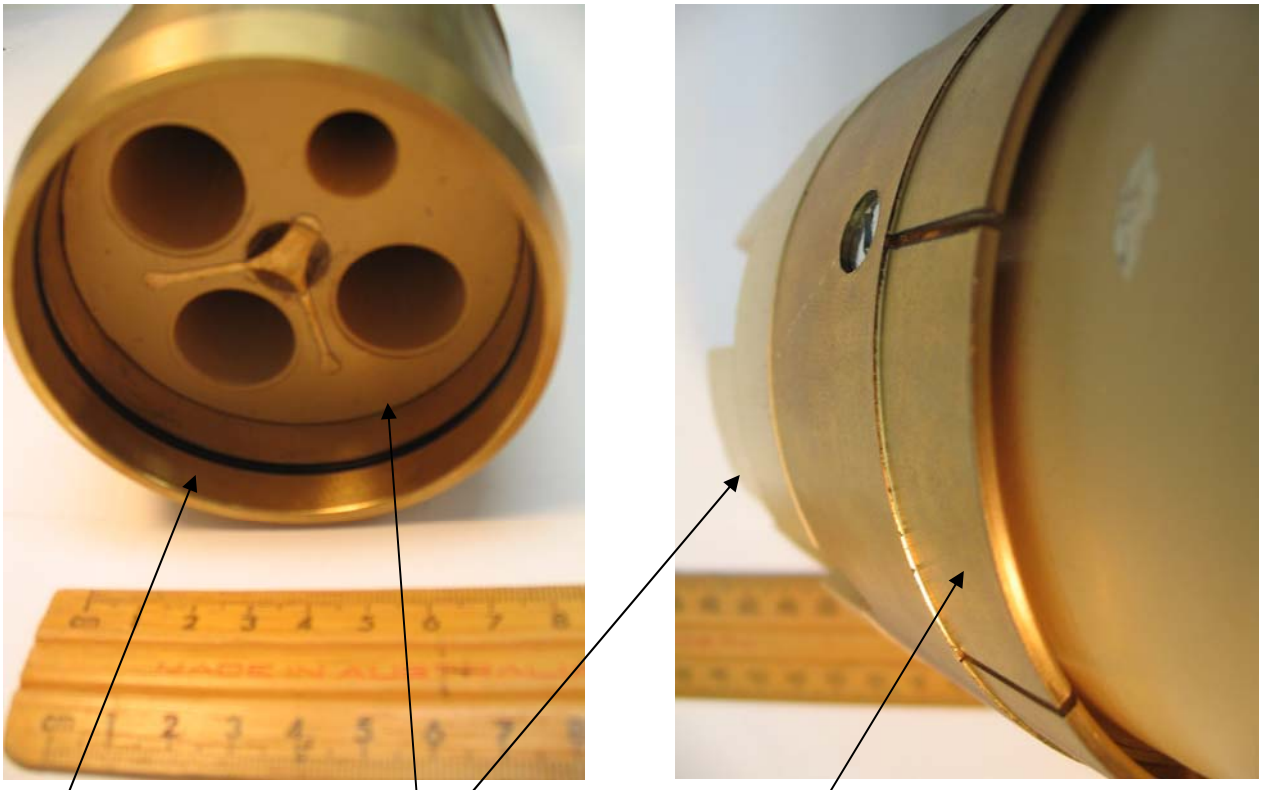
A slightly increased molding diameter on the extreme front of the insulated plug core for improved IP rating, offers physical resistance when inserting the nose cone onto the scraping earth contact fingers, so it becomes difficult to judge the force of contact fingers onto the nose cone. Bent, broken or deteriorated contact fingers, or dirty contact surfaces may degrade the earth continuity. Also the rear of the insulated plug core is slightly proud of the earth ring, so physical contact between the earth ring and plug body cannot be guaranteed.

The integrity of earth continuity of an assembled plug should be tested with power isolated and from the exposed phase barrier to the nose cone and plug body.

Figure 16: Stripped down view of the Minto Industrial Products 300 Amp Restrained Plug

Figure 17: Front view of the disassembled Minto Industrial Products 300 Amp Restrained Plug

Figure 18: Side view of the disassembled Minto Industrial Products 300 Amp Restrained Plug



Nose cone & o-ring

Insulated plug core

Scraping earth contact fingers

Figures 16 to 18 show the physical contact points for the 300 Ampere restrained plug, these are equivalent to the 150 Ampere restrained plug in Figures 14 and 15. The O-ring in Figure 16 increases physical assembly resistance so it may be difficult to gauge the force applied to nose-cone by the fingers of the earth-ring. The nose cone for the 300 Amp plug slides inside the fingers of the earth contact ring. Direct physical contact between the earth ring and plug body cannot be guaranteed due to the slight increased molding diameter on the rear of the insulated plug core, just visible in Figure 18 at rear of the earth ring.

Recommended routine tests to verify earth continuity of installed cables with inline restrained plugs and receptacles

As a potential for degraded earth continuity exists within restrained plugs and between receptacles and restrained plug a test method is required to verify earth continuity. To verify earth continuity of installed cables with inline restrained plugs and receptacles, from the distribution and control box (DCB) to a face machine, mines are advised to run a temporary test wire of known (measured) resistance from the DCB to the face machine. As alternate paths exist through the strata from the body of electrical enclosures and face machines, it will be necessary to conduct the test in two parts.

It will be necessary insulate all plug and receptacles from ground by suspension or chocking. Then remove the restrained plug from the DCB (Test point 1) and measure the resistance to the frame of the face machine. Then to confirm earth continuity from the DCB receptacle, return the plug to the DCB receptacle and remove the restrained plug from the face machine. Then measure resistance from the face machine restrained plug (Test point 2) to the frame of the DCB.

The test wire is to be attached to a clean section of frame metal work. A low resistance contact between the test lead and frame surface is essential. An accurate Ohmmeter can then be used to test the earth continuity through the power supply cables, restrained plugs and receptacles and the test wire loop resistance.

The above recommended test will verify the condition of earth continuity at that instant in time, but only quality manufactured and Australian Standard compliant plugs and receptacles will give complete confidence of continuously effective earth connection. Therefore it is essential that tripping times for earth leakage and earth continuity relays are set to minimum values to minimize exposure time to excessive prospective touch voltages.

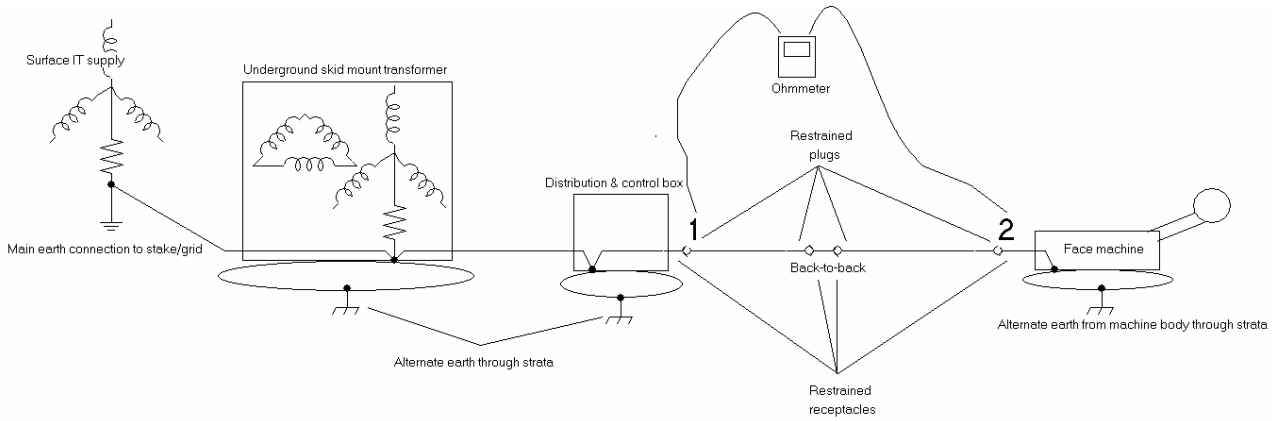


Figure 19: Earth continuity test configuration and underground mine supply earthing arrangement

Note: Electrical systems are designed so that earth leakage and fault currents are carried through cabled earths when a break down in insulation occurs. This minimizes damage, prevents arcing and raised touch potentials associated with the fault. Alternate or false earth paths through the machine body and strata are dangerous in that they are intermittent, cannot be rated for fault currents, and can produce incendive arcing.

Recommended routine tests to verify earth continuity in restrained plugs

The Macey and Minto Industrial Product plug designs have high integrity earth connections from earth conductors in the cable to the earth ring within the plug. The Minto plug has a bolted connection from the earth ring to the phase barrier and the Macey plug has a riveted connection to the phase barrier. Both generally give a good connection from the earth ring to the phase barrier Therefore it is possible to use the exposed face of the phase barrier as a reference to check earth continuity to other metallic parts of the plug.

Because of the potential for the earth connections within the plug body to deteriorate in service due to handling (withdrawal, insertion and transport, vibration and contamination). The mine electrical engineer will need to implement tests at regular intervals and specify that these tests are done at the time of any cable repair service.

A good quality, accurate Ohmmeter with a low resistance scale will be required to conduct the test. Essentially two routine earth continuity tests are recommended, but it is essential to short the test probes together and zero check the meter.

Figures 19: Low Ohm range meter for testing

Figures 20: Zero check for Ohmmeter

The two routine earth continuity tests recommended for restrained plugs involve resistance measurement from the phase barrier to the nose-cone and from the phase barrier to the plug body. The contact surface of the phase barrier, nose-cone and plug body points of contact for the test probes will need to be cleaned to assure low resistance probe contract.

Each earth continuity test should return an extremely low result, less that 0.05 Ohm. Higher test resistances will require further investigation; check the Ohmmeter probe contact integrity and re-measure the earth continuity, and if > 0.1 Ohm or if the reading is erratic, then the cable needs to be tagged out-of-service and sent to an approved cable repair shop for detailed inspection.

Figure 21: Earth continuity test from phase barrier to nose-cone for a typical 300 Amp restrained plug

Figure 22: Earth continuity test from phase barrier to plug body for a typical 300 Amp restrained plug

Figure 23: Earth continuity test from phase barrier to nose-cone for a typical 150 Amp restrained plug

Figure 24: Earth continuity test from phase barrier to plug body for a typical 150 Amp restrained plug

It is useful to repeat the tests using a meter that gives an audible tone during Ohms measurements. Securely connect the test circuit then move the cable-under-test at the gland-end to test for tell-tale signs of intermittent earth connection indicated by a break in the Ohmmeter tone.