

oxygen was considered as a palliative for two phase erosion-corrosion at Wylfa. Initial results appeared encouraging with 100 ppb oxygen producing a response. However subsequent tests should that 100 ppb was not always effective in preventing metal loss and more importantly, in the presence of mildly acidic solutions oxygen dosing resulted in an increase in metal loss rate. Thus despite the initial promise the use of oxygen to combat two phase erosion-corrosion was rejected.

Erosion-corrosion has been extensively research within the CEGB and palliatives identified to combat particular problems. Care has been taken to continue monitoring following implementation of the palliatives using either plant data or power station based facilities. All the evidence available to date is that the problems associated with erosion-corrosion are well under control.

ACKNOWLEDGEMENTS

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PLUGGING OF FEED INLET TUBE UPSTANDS WITH Ni/Ti SHAPE MEMORY ALLOY PLUGS — HEYSHAM 1 POWER STATION

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Abstract

The paper contains a description of a new approach for plugging feed inlet tubes of Gas-Cooled Reactors. Instead of utilizing the original explosive method plugging by fitting a shape memory alloy plug into the upstand is being described.

1. INTRODUCTION

The fitting of upstands to the feed inlet tubeplates has made plugging by the original explosive method protracted and difficult. Certain leaks, i.e. those from the bore of the boiler tube/upstand to the gas space could be plugged by fitting a shape memory alloy plug into the upstand.

The upstands consist of a bimetallic 1Cr $\frac{1}{2}$ Mo/Inconel 600 tube bore welded to a buttered spigot on the face of the tubesheet. As shown in Figure 1 the high impedance flow restrictor is screwed into the upstand and this proposal deals with sealing the upstand once the flow restrictor has been removed.

The plug location is shown in Figure 2 and details of the relevant properties and similar applications are appended (Appendix I and II).

2. INSTALLATION PROCEDURE

Once the leaking tubes have been identified and the reactor depressurised the plugging procedure would follow this sequence:-

2.1 Remove the anti-rotation straps from the ferrule and unscrew the ferrule from the upstand.

2.2 Fit a removable plug at the tube plate level in order to prevent debris entering the tube.

2.3 Clean the bore of the Inconel 600 portion of the upstand using a stainless steel wire brush mounted on a flexible drive. The intention is to merely remove any loosely adherent oxide, etc.



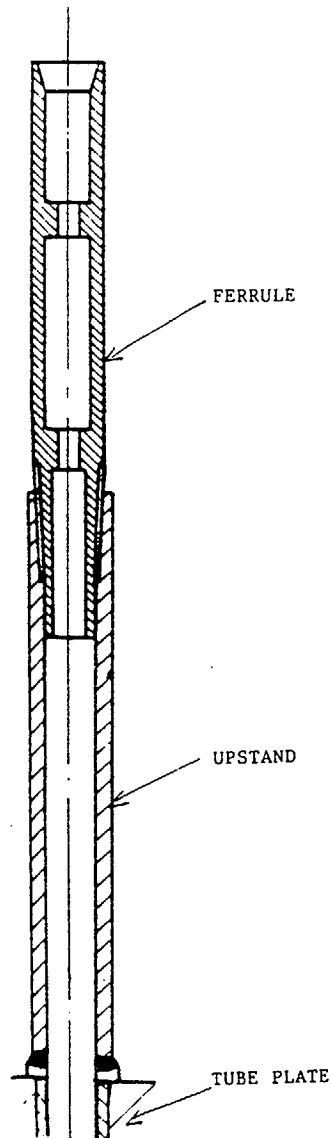


FIG. 1.

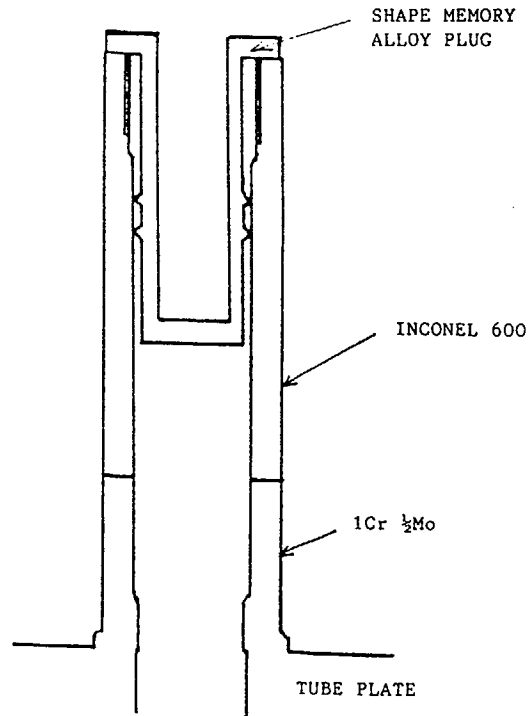


FIG. 2.

2.4 Using suitable visual aids (boroscope with forward and right angle views) inspect the upstand in the area where the sealing rings will locate. The sealing area must be clean and free from axial score marks.

2.5 Measure the bore diameter in the seal area to confirm that the dimensions are within the allowable limits. The hole tolerances are specified in the Specification Control Drawing supplied by Raychem, which is appended.

Provided that 2.4 and 2.5 are satisfactory then a standard plug can be fitted.

2.6 If the hole is out of tolerance then remedial action is necessary. This will involve either:-

2.6.1 Enlarging the bore of the hole by hand reaming repeating steps 2.4 and 2.5 and manufacturing an appropriate oversize plug, or 2.6.2.

2.6.2 Manufacturing a plug to suit the hole dimensions established in 2.5.

2.7 Remove debris plug.

2.8 Fit shape memory alloy plug. Plugs will be stored under liquid nitrogen in a Dewar Flask. An expanded polystyrene work box will be filled with liquid nitrogen and the plug transferred from it's Dewar Flask into the work box. Handling equipment with a large thermal capacity (copper tongues) will be used to remove the plug from the liquid nitrogen and insert it in the upstand. At any time before the plug is inserted in the upstand it is essential that the shape memory alloy is maintained at a temperature below -70°C to prevent transformation and shape recovery occurring. If these conditions have not been met then the plug will not enter the hole and the plug should be discarded.

The plug will be inserted to its full depth, i.e. with the underside of the head on the top of the upstand and allowed to warm up so that shape recovery occurs.

2.9 It is important to test the efficacy of the seal at the feed inlet end and in order that this may be accomplished the feed inlet should be plugged before the superheater outlet.

With a suitable mechanical seal in the appropriate superheater tube pressurise the tube to 20 psig with Helium and search for the Helium around the shape memory alloy plugs in the Feed Inlet Header. Obviously, this method will only work if the leak in the tube, is small. Other test methods are currently being investigated and these may allow plugging in any sequence.

APPENDIX I

NICKEL-TITANIUM SHAPE MEMORY ALLOY - PROPOSED PLUGGING MATERIAL HEYSHAM I FEED INLET TUBEPLATE

1. Nickel-Titanium Shape Memory Alloy

The alloy adopted for use as a suitable plugging material is designated Alloy J (was previously referred to as "Warm A") by the suppliers Raychem Limited.

It is based (as are all the Ni-Ti S.M.A.) on the equiatomic composition, and the composition is controlled to obtain the shape recovery transformation at approximately -60°C .

A fuller description of the materials in general and this alloy in particular can be obtained from the Annual Progress Reports on S.M.A. Developments produced by N.W.R. S.S.D. (Refs. 1-4 inc).

2. Proposed Application

To plug a leaking boiler tube against full inlet water pressure (design 220 bar) or reactor gas pressure (41 bar). Under normal operation feed water temperature is approximately 160°C . The design accommodates possible transients up to 291°C but it has been postulated that under three-boiler operation the off-load boiler tubeplate could reach up to 370°C .

3. Experience with CEGB using Alloy J Plugs

Since 1983, Midlands Region have used Alloy J plugs to seal leaking h.p. feed heater tubes (approximately 12.5mm bore) at Cottam, Rugeley A and Drakelow (5). Approximately, 500 have been fitted to date. Midlands Region SSD and Stations' experience is favourable but it has been found that success is only guaranteed provided care is taken in the preparation of the bore surface prior to fitting the plug. The problem is generally associated with damage adjacent to the mouth of the tube that may not be completely removed when reaming off minimum material.

This problem should not arise at Heysham where the Inconel 600 upstand should be undamaged and free from thick oxide etc., hence an absolute minimum of preparation will be required.

4. Material Properties of Alloy J

4.1 Tensile Properties

The room temperature and elevated temperature tensile properties have been measured, see Figure A1.

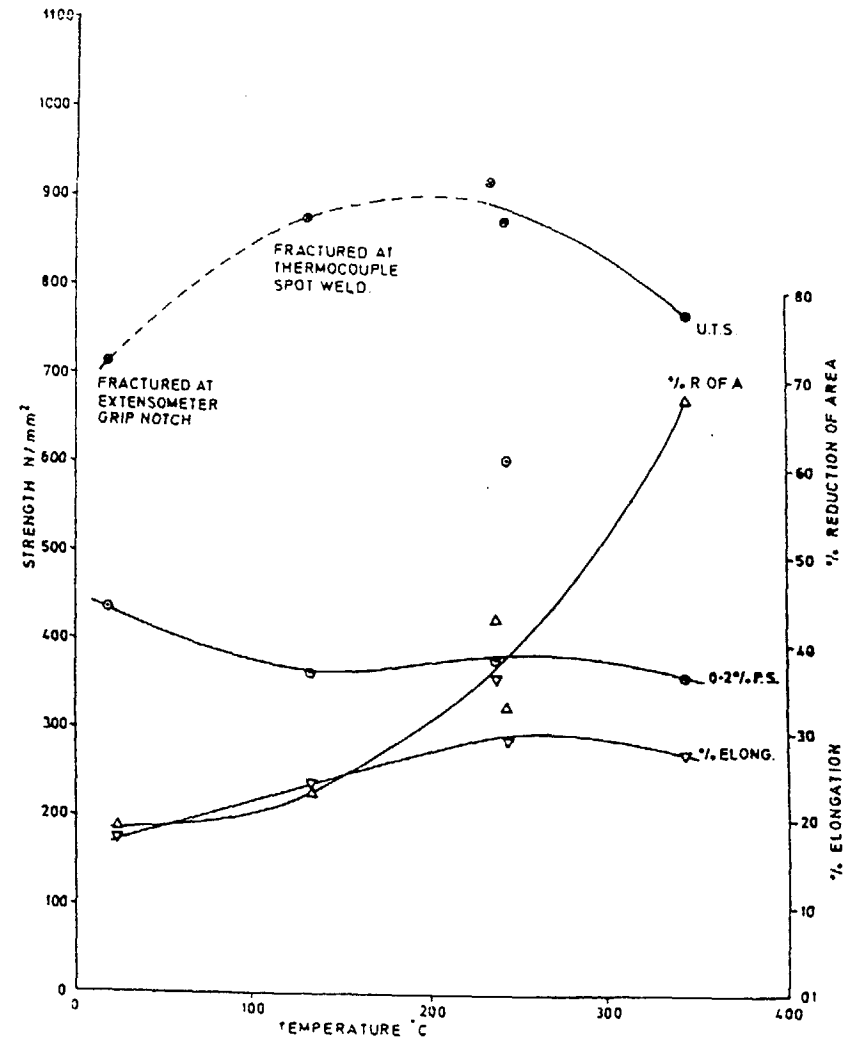


Fig. A1 - WARM A ALLOY TENSILE PROPERTIES

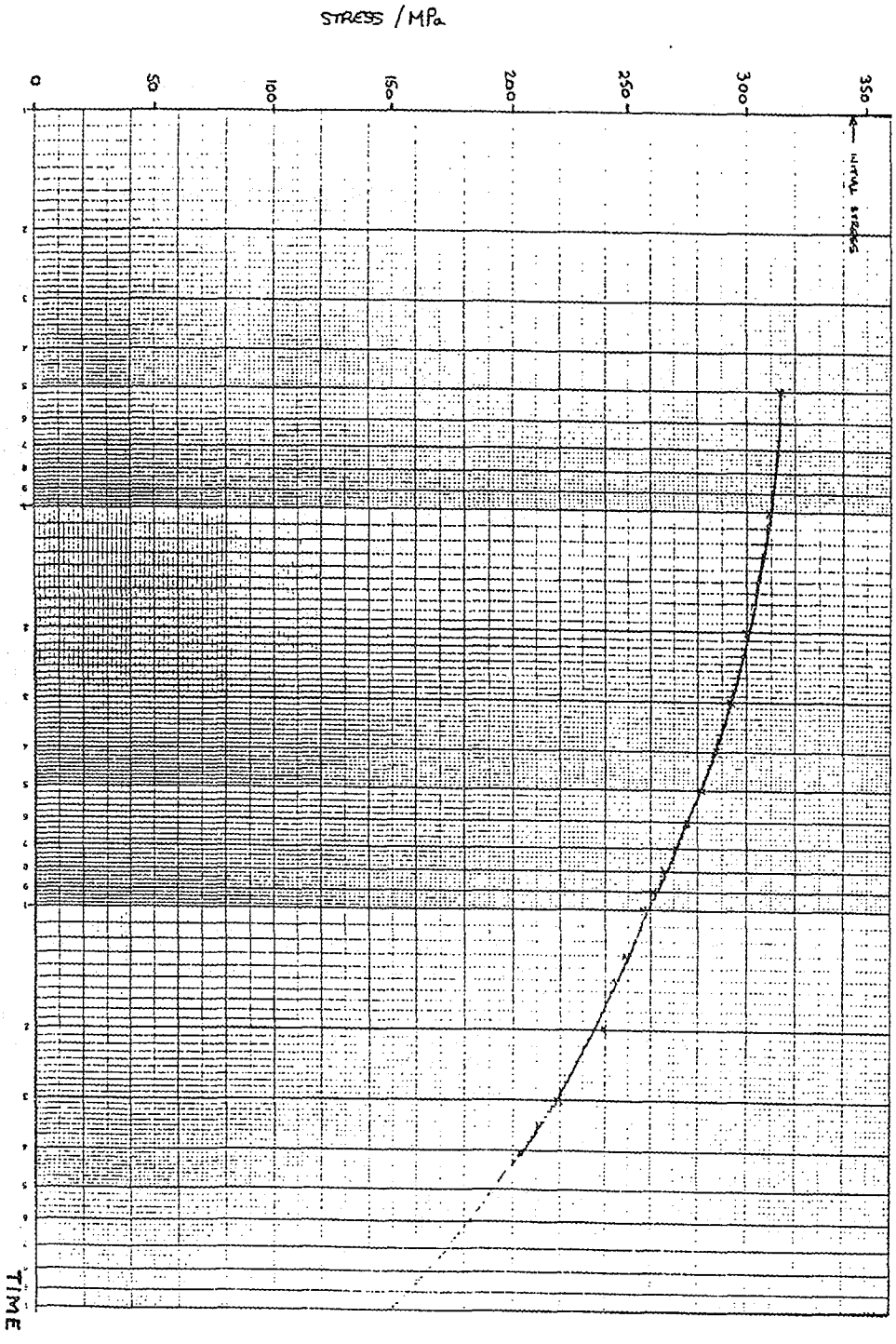


Fig. A3 - INITIAL STRESS CORRESPONDING TO 0.2% PROOF STRESS

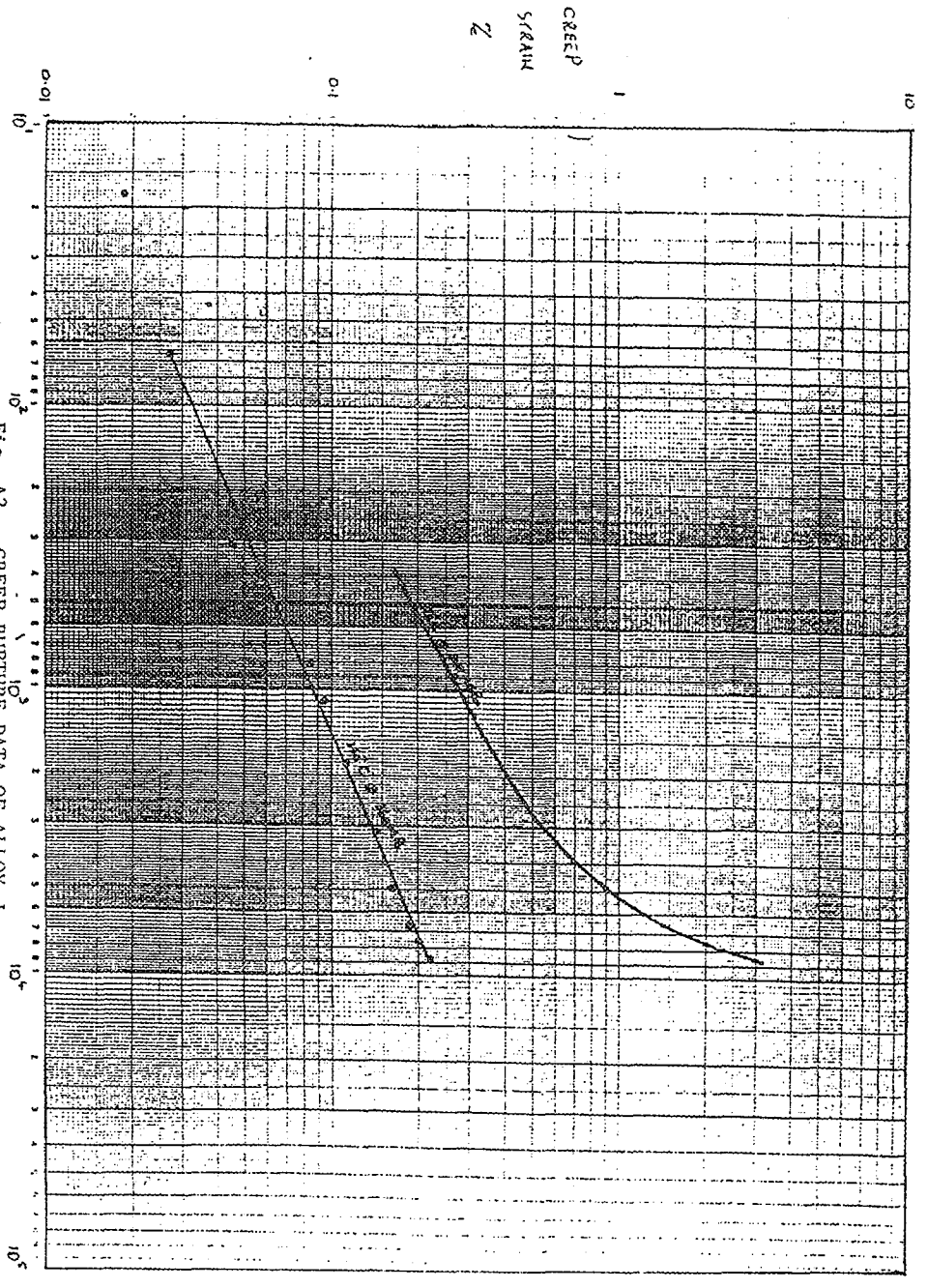


Fig. A2 - CREEP RUPTURE DATA OF ALLOY J

4.2 Creep Rupture Properties

Constant load creep testing at 350°C and 370°C is in progress at present and the results to date are shown in Figure A2. The applied load selected in each case is that equivalent to the 0.2% proof stress for the original cross sectional area.

4.3 Stress Relaxation Properties

A stress relaxation test is currently in progress at 370°C using an initial stress equivalent to the 0.2% proof stress at the test temperature. The results to date (shown in Figure A3) indicate an approximate halving of stress after 10,000 hours at temperature.

4.4 Thermal Cycling Testing

To assess the sensitivity of Alloy J vent tube couplings (components likely to be more thermally responsive than plugs) to temperature transients a rig was constructed to subject these components to thermal cycling from ambient - 220°C - ambient. A total of 82 cycles were completed without loss of seal integrity as demonstrated by pressure testing at 90 bar. This test on a relatively massive mild steel tubeplate would have been more severe than the plug-in - Inconel 600 upstand where the discrepancies in thermal mass and coefficients of thermal expansion are less great.

5. Corrosion and Oxidation Resistance of Alloy J

5.1 Boiler Quality Water

Since 1982, 30 Alloy J components have been exposed to Wylfa boiler water. After 3200 hours the Alloy J was unaffected (6). There is no information on any galvanic or crevice corrosion effects between Alloy J and Inconel 600.

The similar Alloy A material was unaffected after 7877 hours at 315°C in PWR quality water (7).

5.2 Acid Cleaning Solution

Six Alloy J specimens were exposed for 8 hours at 90°C at a mass flow rate of 0.066 kg/second to a solution of 3% citric acid + 0.5% formic acid ammoniated to pH 3.5 and inhibited with 0.05% stannine LTP. No measurable loss of material nor deterioration in the quality of surface finish was recorded (8).

No information exists on any galvanic or crevice corrosion effects between these two couples in this solution.

5.3 Stress Corrosion Cracking

No evidence of stress corrosion cracking was observed when Ni-Ti alloy (either Alloy A or Alloy J) was exposed to 5% NaCl solution, boiler quality water (2-8 ppm O₂), sea water, saturated boiling MgCl₂ or 10% NaOH solution.

Greater details are given in Ref. 4.

6. Summary

6.1 Experiences at Midlands Region Stations show that Alloy J plugs can seal reliably at temperatures of the order of 250°C, which is in excess of Heysham I feed inlet water temperature under normal operation conditions. (There is in addition extensive supportive information on the reliability of this type of material (Alloy A) at temperatures up to 315°C).

6.2 The effect of prolonged exposure to temperatures of the order of 370°C will result in stress relaxation taking place which in turn will probably result in the reduction of the sealing force. The direct extrapolation of the stress relaxation data would indicate an approximate halving of the sealing force after 10,000 hours at 370°C. The practical effect of this reduction on the seal integrity cannot be quantified, as yet. (It is hoped that a rig currently under design will clarify the position).

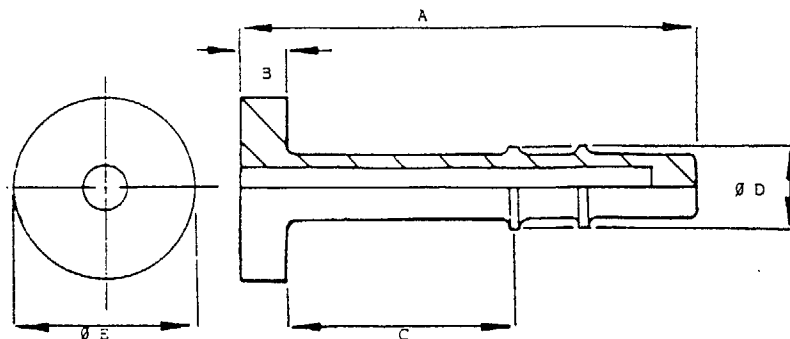
6.3 All available corrosion and oxidation data indicates that the Ni-Ti shape memory alloys are chemically inert to the environments likely to be encountered in this application. Galvanic and crevice corrosion effects between Inconel 600 and Alloy J require determination.

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1. DESCRIPTION AND INTENDED USE

This self-expanding plug is made from 'Tinel' Alloy J, Raychem's nickel-titanium shape memory alloy. It is shipped in a contracted state (dimensions - Fig. A4) in liquid nitrogen (LN) and will maintain this dimension as long as it remains stored so. When removed from LN, placed in a suitably sized hole, and allowed to warm it will expand to its larger memory shape due to its shape memory effect. The plug diameter will try to increase by about 3% and the force developed is concentrated on the sealing lands on the outside diameter of the plug where it brings about a secure leakproof seal. It is intended to be installed into a bore of between 10.20 and 10.24mm so as to seal a tube against the ingress or egress of fluid under pressure.

DIMENSIONS

A = 50.5	
B = 4	Tolerances ± 0.5
C = 25	Unless Stated.
$\varnothing D$ = Max. contracted 10.13	
Min. freely recovered 10.38	
$\varnothing E$ = 15.79 \pm 0.01	

Fig. A4 - CRYOPLUG FOR CEGB UPSTAND (Provisional)2. BORE MATERIAL AND DIMENSIONS

Performance of the plug is influenced by the mechanical properties of any bore into which they are fitted. Similar plugs have given good results with carbon steel, stainless steel, copper-nickel and aluminium alloys.

Size limits also influence plug performance and bore surface defects may reduce the chances of a good seal.

Mating bore diameter maximum = 10.24mm

Mating bore diameter minimum = 10.20mm

3. BORE PREPARATION

Performance and reliability are dependant upon size, finish and soundness of bores into which these plugs are installed.

Boring, reaming and in "difficult" metals, honing have proved successful. All traces of swarf, reaming compound, etc., must be removed prior to plug installation.

4. INSTALLATION

Tools used for installation may depend on the accessibility of bore to be plugged. Any special tools needed to prolong installation time may be designed in conjunction with Raychem.

To install, remove plug from LN using pre-chilled handling tool and fit immediately into the prepared bore.

Ensure that the head is fully seated against the top of the bore. Expansion will complete in 60 seconds or less.

5. SAFETY PRECAUTIONS

Liquid Nitrogen (LN) is the only recommended coolant for installation of this plug. Avoid contact with exposed skin. Although non-flammable, non-poisonous and non-corrosive LN can cause frost bite or cold burns. Do not touch chilled metal objects. Always wear eye shields especially when pouring LN. Check there is adequate ventilation before taking LN into confined areas.

Further information concerning LN is available from Raychem.