MRO Delay Line

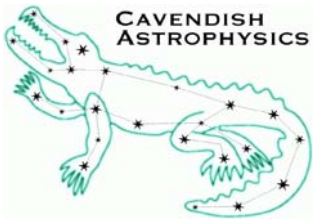
Proposed Delay Line Tools, Jigs and Handling Procedures

Document No. INT-406-VEN-0119

The Cambridge Delay Line Team

rev 1.0

30 Jan 2008



Cavendish Laboratory
JJ Thomson Avenue
Cambridge CB3 0HE
UK

Change Record

Revision	Date	Authors	Changes
0.1	2008-01-30	MF	First draft version
1.0	2008-02-02	MF	Minor edits plus more photographs

Objective

The objective of this document is to describe the jigs, tools and procedures for the installation and maintenance of the delay line pipe and supports for the Magdalena Ridge Observatory Interferometer delay lines.

Scope

This document provides a description of the installation procedures for the delay lines which will be up to 190m in length. It also describes the tools and jigs necessary for installation and maintenance of the delay line including procedures for changing a seal or removing a pipe section. This document does not provide step-by-step instructions; these will be provided with the delivered documentation at the appropriate stage in the contract. The jigs used are descriptions and photographs of those used to assemble the 20m delay line. Appropriate design drawings for manufacture of the jigs will be provided later.

Reference Documents

Applicable Documents

AD01 Pipe and Supports Drawing set

AD02 Delay Line Pipe and supports design description INT-406-VEN-0115

AD03 Risk and hazard Document INT-406-VEN-0121

AD04 MRO Delay Line Documentation Plan INT-406-VEN-0120

AD05 ICD: Delay line to BCF infrastructure (building) INT-406-VEN-0009

Acronyms and Abbreviations

BCA Beam Combining Area

BCF Beam Combining Facility

BRS Beam Relay System

COAST Cambridge Optical Aperture Synthesis Telescope

DL Delay Line

DLA Delay Line Area

ICD Interface Control Document

MROI Magdalena Ridge Observatory Interferometer

MRAO Mullard Radio Astronomy Observatory

NMT New Mexico Tech

OPD Optical Path Delay

SCS Supervisory Control System

TBC To be confirmed

TBD To be determined

Contents

Change Record 1
Change Record 2
Objective 2
Scope 2
Reference Documents 2
Applicable Documents 2
Acronyms and Abbreviations 2
Contents 3
1 Installation of delay line pipes 4
1.1 Preparatory work 4
1.1.1 Defining the delay line axis 4
1.1.2 Marking out support locations 4
1.1.3 Handling 5
1.2 Targets and jigs 5
1.2.1 Support stand target 5
1.2.2 Support stand jig 6
1.2.3 Pipe target 7
1.3 Installation of pipes and supports 8
1.3.1 Installation of anchor section 8
1.3.2 Installation of support 9
1.3.3 Installation of pipe section 9
1.3.4 Installation of a seal 10
1.3.5 Pipe join seal test 11
1.3.6 Further adjustment of pipe supports 11
2 Maintenance 11
2.1 Realignment of the delay line pipe 11
2.2 Replacement of parts 11
2.2.1 Temporary anchor 12
2.2.2 Replacement of a seal 12
2.2.3 Replacement of a pipe section 13

1 Installation of delay line pipes

Detailed instructions on how to install the delay line pipes are provided as part of the documentation package which is outlined in the documentation plan AD04. A description is given here so that the methodology can be reviewed.

1.1 Preparatory work

Preparatory work is that work which is needed to define where the axis of each delay line runs on the DLA slab. This work is expected to be carried out before any assembly of the delay lines can begin and it is assumed that all delay line axes will be marked out for their full length irrespective of the staging of installation of the delay lines. Marking out of the support locations on these defined axes can be done in stages and there may be advantages in doing so in any case.

1.1.1 Defining the delay line axis

The axis of the delay lines is constrained by the geometry of the DLA slab. In the horizontal plane the delay lines will occupy an envelope which is the 'best fit' for the length of the slab so that support anchor bolts are not too close to either edge. In the vertical plane the slab has a small gradient but the vertical adjustment range of the supports allows the delay line to be set horizontal along a nominal axis such that the science beam axis is 1.6m above grade. It is expected that the defined height will be chosen once the characteristics of the slab in the DLA are known.

The axes of the delay lines are the defining axes for the interferometer array and therefore surveying of the site must be adequately referenced to these axes. On the basis of surveying already undertaken to establish preliminary monumentation inside the BCF a set of ten monuments will be defined at the far end of the DLA so that a target can be placed with repeatable precision on the nominal axis of each delay line. A similar set of monuments in the BCA at which to mount a theodolite provides the line of sight necessary for sufficiently accurate positioning of the support locations across the slab and for aligning the pipe centres using the support adjustments when the pipes are installed.

1.1.2 Marking out support locations

The support locations on the DLA slab must be marked out accurately so that they lie sufficiently close to the axis for each delay line that any required adjustments are small. The distance between support locations will depend on the length of pipe chosen and the thickness of the washer providing the pivot point between pipes. The temperature at which the pipes are manufactured and the temperature at which they are installed are important factors in ensuring that there is no build-up of error between the position of pipe joints and the position of support locations. The pipe specification AD01 defines the tolerance on pipe lengths as 1mm in 5m, allowing for a maximum build-up of 37mm over the length of the delay line following the anchor.

Establish a line on the floor – a number of methods can be used - wire or line tensioned just above surface – spray paint produces permanent mark.

Marking out locations along the line can be done by a jig set to a precise length and with a hole pattern at either end laid out to match a support stand base-plate. The jig automatically provides the correct hole-pattern and ensures that it is normal to the axis. Alternatively a laser

theodolite could be used in conjunction with a suitable target plate but this may require levelling for every position.

It is only necessary to mark out and install chemical anchors for the portion of delay line to be erected. There are two advantages in phasing build in this way:

(i) The remaining delay line floor is not covered in tripping points if chemical anchors are not installed until needed.

(ii) It is less likely that setting out the support locations will lead to a large accumulated error if delay lines are built up in, say, 50m stages. Even if a 190m delay line was to be installed in one phase, it would still be advisable to stage the build to 50m lengths at a time.

1.1.3 Handling

There are to be facilities within the DLA for transporting and handling pipes. Although they are not provided as part of the Delay Line contract we have advised MROI as to what is required for the purposes of installing and maintaining the delay line. We have proposed that the following should be available for the purposes of handling lengths of pipe and lifting them into position.

- Overhead gantry crane: This must span the ten delay lines and able to move the whole length of the DLA. The height should be sufficient to allow a pipe section to be lifted over existing installed delay lines.
- Pipe trolley: This is a ‘dolly’ (a low two-wheeled platform) or a short low four-wheeled cart onto which a pipe section can be placed for manoeuvring easily into position.
- A small floor crane: either an engine crane or preferably a counterbalanced floor crane.
- An appropriate sling or lifting beam.

The floor crane can be used to lift the pipes onto the dolly which is then wheeled to the install area so that they can be brought into a position where the overhead gantry crane is then used to hoist the pipes onto the support stand cradles.

1.2 Targets and jigs

The targets and jigs required to install the pipes and supports are described here. Preliminary versions of these have been used to install the 20m test rig in the COAST facility.

1.2.1 Support stand target

The initial installation and alignment of the support stands requires that a target representing the centre of the delay line pipe be fitted to the support stand. The arrangement used for this is depicted in the photographs in Figure 1 and is the arrangement used for erecting the 20m test rig at COAST. The assembly seats on the cradle of the stand in a kinematic fashion, defining the four degrees of freedom necessary. A support jig, described below, is used to steady the stand and stop the cradle from tilting. The theodolite in the inner BCA, set up on the delay line axis is now able to view the target and adjustments made to the support stand to bring the target onto the line-of-site.

Figure 1: Two views of the support stand alignment jig. The separation of the two pipes places the pin-hole target on the pipe axis when the jig is supported on the cradle tabs.

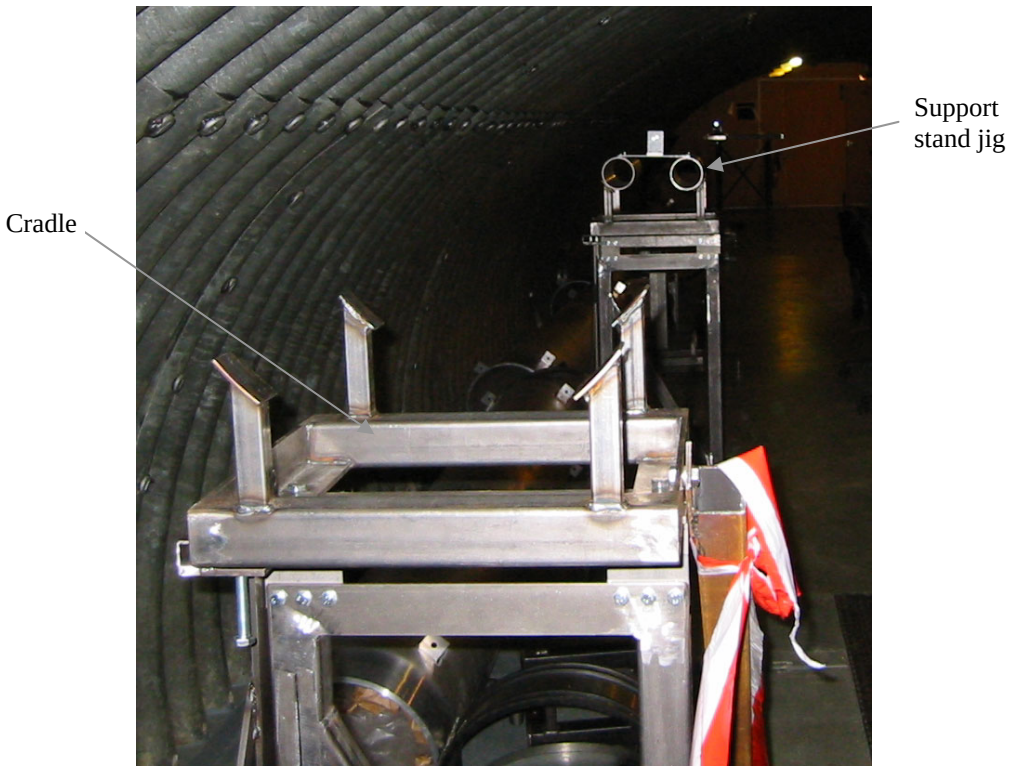


Figure 2: A support stand and cradle is in the foreground and the support stand target is mounted on a stand and cradle in the background

1.2.2 Support stand jig

A support stand is self-supporting providing not too much weight is placed on it and the cradle may tilt easily. So in order for the support stand to be able to support a pipe it must be locked approximately vertical with the cradle locked approximately horizontal otherwise the stand would collapse. The support stand jig stabilises the stand and cradle, allowing a pipe section to be held on one half of the cradle before the other pipe section is brought into place. It can also be used to stabilise the support stand when the support stand target is placed upon it. The jig, shown inFigure 3 and Figure 4, is an ‘A-frame’ whose apex locates on the centre of one side of the cradle. Adjusters on outrigger arms prevent the cradle from tilting while allowing it to be levelled. Adjusters at the base of the A-frame allow the support stand to be set and held upright or adjusted to an angle if thermal expansion is to be taken into account.

Figure 3: The support stand jig used to stabilize the stand during assembly of the delay line test rig.

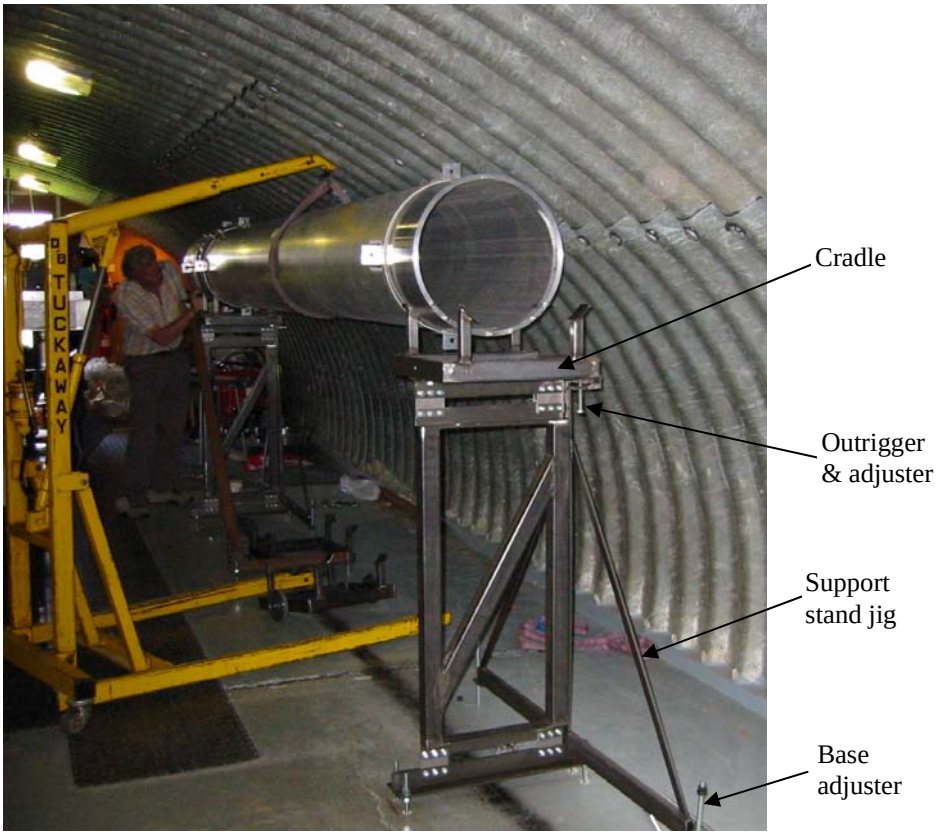


Figure 4 Photograph of a pipe being positioned on a cradle with the support stand jig applied to the support stand to stabilize both the stand and the cradle.

1.2.3 Pipe target

This is a thin target plate with a small hole to mark the centre of the pipe end as defined with respect to the dowels linking the pipes. The target plate (Figure 5) is slid between the two pipes at a joint and lowered so that it is defined both horizontally and vertically by the four

dowels which are used to align the pipe sections to each other. As the dowels are placed where the wheels of the trolley run they can be used as a reference to define the trolley centre and hence, by design, the pipe centre. With the target plate in position the support stand can now be adjusted to place the target on (or relative to) the line-of-site defined by the theodolite. After the stand is adjusted the target can be removed, the pipes drawn together and the seal slid into place over the join.

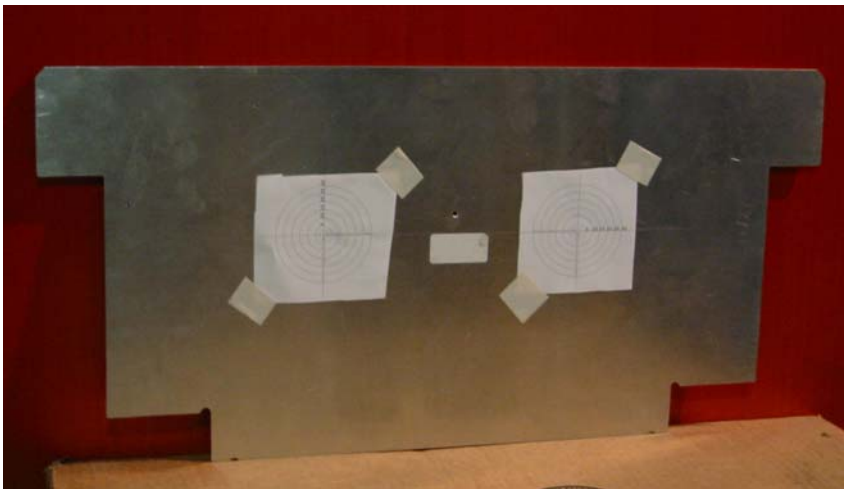


Figure 5 Photograph of the pipe target used to erect the delay line test rig at COAST. Additional paper targets were added to assist in alignment of the laser metrology system.

1.3 Installation of pipes and supports

Installation of a delay line at MROI would proceed once the delay line axis has been determined as described in section 1.1 and a theodolite set up in the BCA area to define the line-of-sight. The following sections present a brief explanation of the installation process (not the detailed procedure that would be provided with the deliverable documentation) and assumes that support stands are assembled ready to receive the cradles.

1.3.1 Installation of anchor section

The following list is a brief explanation of the installation process for the first piece of delay line (refer to Figure 6):

1. Mark out, drill the holes and install the chemical anchors for the support stands and the anchor.
2. Install the support stands either side of the anchor position on the chemical anchor studs using a support stand jig to stabilise each stand.
3. Place the support stand alignment jig on the cradle of one stand and adjust the base height and tilt so that the target is centred when viewed through the theodolite. Repeat this for the other stand.
4. Install the anchor frame (with a temporary pipe axis target) on its anchor studs using the four adjusters to set the anchor height.
5. Grout under the anchor according to the system used and allow the appropriate length of time.
6. Lift the special anchor pipe into position onto the two support stands.
7. Insert the anchor bars through the pipe brackets and the anchor, temporarily tightening the nuts so that the pipe is held by the anchor.

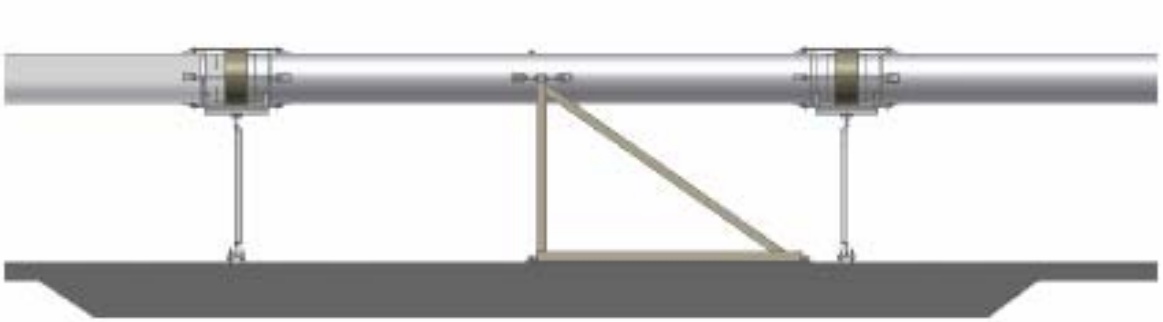


Figure 6 The anchor is positioned between two supports.

1.3.2 Installation of support

The delay line is now anchored and further pipes can be installed on either side once the support stand is in place and stabilised with the support stand jig.

1. Install the next support stand on the chemical anchor studs using a support stand jig to stabilise the stand and fit the cradle to the top of the stand without tightening the connecting bolts too much.
2. Place the support stand alignment jig on the cradle of the stand and adjust the base height and tilt so that the target is centred when viewed through the theodolite. Remove the target once the stand is aligned.

1.3.3 Installation of pipe section

The pipe section can now be installed, always ensuring that the support stands which it is to straddle are both stabilised by support stand jigs and a draw wire is passed through the pipe..

1. Insert dowel pins into the pipe end to be joined (on the already fixed pipe) and include the pipe washer on the lowest dowel.
2. Fit the clamp band and the pipe seal over the fixed pipe. Fit a clamp band over the end of the free pipe to be joined.
3. Lift the new pipe section into place on the two support stands and ensure that the dowels and holes are aligned.
4. Insert the draw bars and nuts through the four pipe brackets on each pipe.
5. Draw the pipes together using the draw bars and ensuring the dowels maintain alignment. Do not close up completely. The cradle is not tightly bolted to the stand during this process and so is allowed to rotate if necessary to accommodate the different shapes of pipe ends and achieve a kinematic seating.
6. Insert the pipe alignment target in the narrow gap between the pipes and seat it on the dowels (Figure 8).
7. Adjust the stand and cradle, if necessary, to bring the pipe target approximately onto the theodolite line of sight and tighten the cradle bolts. Then remove the target, draw the pipes together and tighten the pipe strap clamps.
8. The next support stand can now be set up using the support stand jig from the stand before the one just completed.

Figure 7 Lifting a pipe section into place. In this case the seal is on the pipe being fitted. The stand at the other end is not yet erected because maneuverability of the pipe is restricted by ceiling height

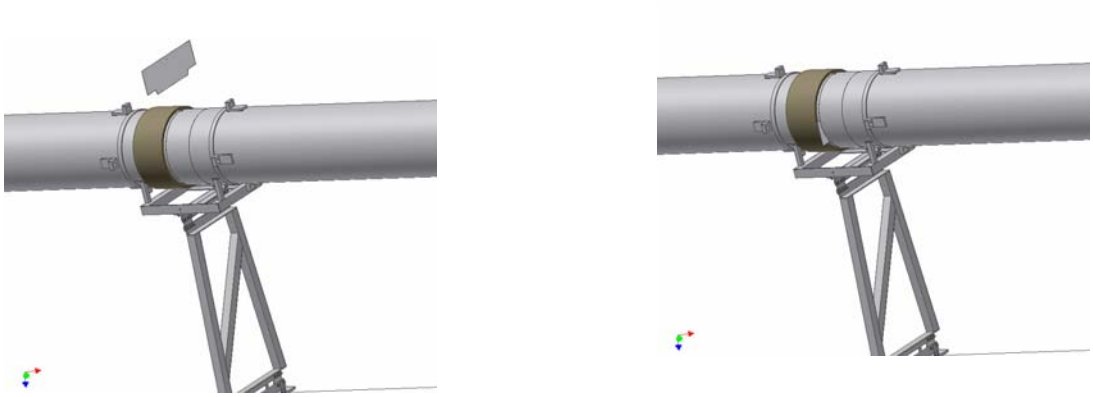


Figure 8: Installation of a pipe onto a stand showing the seal displaced to allow the pipe target to be inserted. (The pipe draw bars are not shown).

1.3.4 Installation of a seal

The seal is very lightly smeared with vacuum grease before it is placed over the fixed pipe. Once the pipe alignment jig is removed the seal can be centred over the join and the seal band clamps tightened (Figure 9). All but the lower draw bars are then un-tensioned.

Figure 9: Completed pipe joint with seal and draw bars in position and the pipe clamped to the cradle.

1.3.5 Pipe join seal test

It is proposed that a method of testing each pipe seal as the delay line installation progresses could be undertaken using a device called a 'pipe pig'. This comprises two inflatable bags which are tied together between their centres so that they can be positioned on either side of the join and then inflated to form a sealed cavity. Test gas is then introduced into the cavity under a small pressure and the seal checked for leaks. Once testing is complete the bags are deflated and pulled to the open end of the pipe ready for the next join.

This method of testing may save much time in seeking for faulty seals in a complete delay line pipe and uses much less test gas.

1.3.6 Further adjustment of pipe supports

As the installation proceeds the pipe alignment target is used to put the pipe centres at each join in approximately the right position. The right position may not be the line of sight of the theodolite because the deviation in the straightness of the pipe being laid could be taken into account at this stage by placing the centre of the end of the pipe in a more optimal position i.e. the pipe centre at a join may need to be displaced in order to ensure that the total pipe deviation is kept within the allowed deviation from the delay line axis. This offset can be arrived at by dead-reckoning to begin with if the pipe deviation is known. Measuring and marking this deviation is part of the pipe procurement process and so it should be possible to set the pipes in approximately the right position at each join.

Once the delay line has been erected and the laser metrology system aligned and set to work the trolley can be installed and the shear sensor used to measure its lateral deviation as it traverses up and down the pipe. The actual pipe deviations are obtained from this and the support stands adjusted to optimise them.

2 Maintenance

The deliverables for the delay line contract include full documentation of the design, parts lists and suppliers etc. and procedures for the installation and maintenance of the delay line pipe, the metrology system, the trolley and ancillary electronics. This section briefly addresses the maintenance of the delay line pipe including replacement of parts.

2.1 Realignment of the delay line pipe

Realignment of the delay line may be necessary if the DLA slab moves or tilts sufficiently or an earthquake disturbs the setting of the support stands. If this happens the procedure for realigning is the same as that for optimising the alignment after installation. That is the use of the trolley and shear camera system to record the deviations of the pipe and calculating the correction required, if any, for each support stand. After applying the corrections the trolley can be used again to check the result and produce further corrections if necessary.

2.2 Replacement of parts

It is not thought that any delay line parts except for the seals will require replacing over the lifetime of the facility. A severe earthquake may cause misalignment but is unlikely to result in anything other than minor damage. The two cases considered below require that the delay line be parted at some point in which case the part that is not stabilised by the anchor must be stabilised by a temporary anchor.

2.2.1 Temporary anchor

The method proposed for temporarily anchoring a portion of delay line separated from the main anchor is similar to the anchor used on the test rig at COAST (see Figure 10). Two struts are installed at the final support leg at the far end of the delay line and fixed to anchor bolts provided in the floor slab. The struts are adjustable in length so that they can be fitted for any expansion condition of the delay line. Once fitted the pipe draw bars may be disconnected at the desired location or used as push bars and the pipes drawn apart by adjustment of the temporary anchor struts.

2.2.2 Replacement of a seal

The replacement of a seal involves separating the pipe at the seal location withdrawing the seal and fitting the new one. The pipes would need to be separated by at least the width of the seal which would require too much displacement of the un-anchored section of pipe. Therefore the procedure for replacing a seal involves the temporary removal of a length of pipe.

Figure 10: Test rig installed at COAST showing the anchor struts being used to stabilize the nearest support.

2.2.3 Replacement of a pipe section

The procedure for replacing a seal or a whole length of pipe is outlined here. It is not the detailed procedure that would be supplied with the maintenance documentation. This procedure can be followed in the unlikely event that a trolley cannot be extracted from the pipe by any other method.

1. The delay line is brought up to atmospheric pressure.
2. The temporary anchor is fitted to the far end of the delay line.
3. A support stand jig is fitted the support where the pipe is to be parted.
4. Loosen the seal straps and the pipe clamp bands. Pull the seal back onto the fixed pipe section.
5. Loosen the pipe draw bars and then arrange for them to push the joint apart.
6. Draw the pipe apart using the anchor adjusters, assisted by the pipe push bars.
7. When the pipe is separated by 50mm place a second support stand jig at the next support in the temporarily anchored part of the pipe line. This will prevent the cradle from tilting when the pipe section is removed.
8. Loosen the seal straps and the pipe clamp bands at the next support. Pull the seal back onto the fixed pipe section.
9. Use the pipe draw bars to push the pipe apart at the next join. The pipe is now resting on the stabilised cradles ready to be lifted out.
10. If replacing a seal, lift the pipe sufficiently using the gantry crane to allow removal and replacement of the seal. Remove the seal, inspect the polished pipe surface and if OK fit a new seal (lightly greased). Draw the pipes back together as described in point 13 onwards.
11. If replacing a pipe section, then continue to remove pipe to a safe location. Replace any dowel pins missing from the fixed pipes either side of the removed section.
12. Lift the new section of pipe into position on the cradle, checking its orientation. Loosen the cradle bolts on each support stand to allow the cradle to conform to the pipe.
13. Draw the pipe section on to the fixed part of the delay line, following the install procedure.
14. Remove the support stand jigs and draw the temporarily anchored pipes onto the re-fitted pipe section using drawbars and the temporary anchor adjusters, following the install procedure as appropriate.
15. Ensure that seals are in position and strapped, that the pipes are clamped to the cradle using the band clamps.
16. Remove the temporary anchor.
17. Adjust the support stands (if a new pipe section has been fitted) as necessary.