INSTALLATION MANUAL
CONTOUR APPLICATION

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1 HEALTH AND SAFETY

1.1 Assessments

- Always refer to the COSHH or OSHA assessment before starting work.
- Only start the job is you are clear on how to approach it.
- Brief all those working with you or around you of the processes you will be undertaking and assess whether there are any conflicts with their own activities
- Raise any concerns with your Site Contact.
- Restrict access to the area using a temporary barrier with contact name/ number on. This is especially important when the repair is curing.

1.2 PPE

Make sure all PPE is in good order before use, e.g.

1. Gloves have no rips or tears.
2. Safety glasses, visors etc. are clean.
3. All masks fit correctly.
4. Overalls have no rips.

PPE must be changed when required, e.g.

1. when you can smell iso-propanol even when wearing the appropriate vapour mask.
2. when gloves are ripped.
3. when overalls are resin soaked.

Remove PPE before entering areas used for cleaning, eating or drinking.

1.3 Cleanliness

Good housekeeping is essential during installation of repairs. Identify any potential problems early and address before the resin cures, whilst they are easy to correct:

1. Protect surfaces/equipment around laminating areas.
2. Clean up drips/ runs when you first notice them.
3. Dispose of waste fabric/ peel ply and resin tins as you go.
4. Keep tools clean or dispose of promptly.
5. Wipe up spills immediately.
6. Leave the area as you found it or better.

1.4 Disposal

- Remove waste resin before it cures.
- Mix unused material and leave to cure in a well-ventilated area.
- Mixes of more than 1kg in size will give rise to an exothermic reaction and can release large quantities of fume and smoke if left to stand. Divide unwanted, mixed resin into small quantities (<500g), using empty tins, before the resin heats up (typically 30 mins after mixing).
- Treat cured resin as general waste for disposal.
- Uncured material and containers are considered to be hazardous waste and must be disposed of in accordance with local regulations. Add a small amount of mixed resin to empty hardener tins and mix round thoroughly to neutralise any remaining material and enable the tins can be treated as general waste.

2 REPAIR APPLICATION

2.1 Storage

- All materials must be stored in a clean, dry storage area.
- The resins should be kept in a dry store, in their original containers and at a temperature of between approximately 10-25°C
- When working at site the materials should be handled so that they do not get wet or dirty. They should be kept in the shade when in hot climates.
    - It is acceptable to relax the storage temperature limits when the materials are being used. However, they should not be kept where the temperature could go below 0°C nor above 40°C
- It is quite common for the materials to crystallise when stored. The crystals can be dissolved by standing the resin tin in warm water (~40°C) and stirring. Care should be taken not to prevent water splashing into the tins. Allow the material to cool prior to use (otherwise the pot life will be reduced)
- The resin pot life will be longer at lower temperatures. In cold climates (<10°C) it is advisable to warm the resin and hardener tins before use (e.g. by keeping indoors).
- The resin pot life will be shorter at higher temperatures. In hot climates (>30°C) it is advisable to keep the resin and hardener tins cool (e.g. by keeping indoors or ensuring they are kept in the shade)
- The materials should be confirmed as 'in-date' before use

2.2 Repair Area

- Mark the area to be repaired (e.g. using self-adhesive tape).
- The surface to be repaired must be prepared appropriately, Section 2.3.
- If applying on top of an existing repair then remove peel ply and continue. If no peel ply is present then the surface must be degreased and abraded. Degrease with MEK or isopropanol. Key the surface with clean, 60-grade abrasive paper and remove dust using a clean, lint-free cloth. Make sure the solvent has evaporated before continuing.
- The material will cure at temperatures above 5°C, although 7°C and above is preferable. Do not apply at below 5°C.

2.3 Surface Preparation

Surface preparation is vital if the repair is to work as designed.

1. Degrease the repair area thoroughly before grit blasting using MEK / isopropanol.
2. Wipe the area with a solvent-soaked clean cloth until it no more dirt is picked up.
3. Steel pipes should be grit blast to a white metal finish, termed SA2½
4. Check the surface roughness after grit blasting (e.g. using a Testex instrument). A medium surface roughness is required (segment 2 on ISO comparator gauge). Acceptable levels are between 50μm and 100μm.
5. If the surface roughness is less than this then re-blast until the correct roughness is achieved.
6. Alloys steels and aluminium should be treated with a primer before bonding. If this is not available then apply a layer of resin after cleaning and abrade the surface with e.g. 60-grit silicon carbide paper through the resin. Wipe of any arisings and reapply a layer of resin.

7. Copper-nickel pipes need not be blasted. The material should be thoroughly cleaned with low pressure water (i.e. pressure washed), degreased and primer applied before the repair is started.

- **Do not** apply further isopropanol to the work piece after it has been blasted. It takes at least five minutes (longer in cold temperatures) to fully evaporate from the surface and will reduce bond strength if the repair is applied before it has fully evaporated. MEK and acetone can be used for degreasing after blasting.
- Prevent contamination of prepared surfaces by dirt, grease, water etc. Do not touch surface with bare hands because the oils from your skin will reduce the bond strength.
- Ensure the repair is applied as soon as possible after blasting (the first layer must be applied before any surface corrosion starts to form - the time available reduces as temperature and humidity rise).
- Do not apply the repair if there is condensation forming on the pipe. In general, the pipe temperature should be no more than 3°C below the ambient temperature to avoid condensation.
- If the surface shows signs of degradation it may be necessary to re-blast (a sweep over should be sufficient). Small amounts of 'bloom' can be dislodged by applying resin to the surface and then abrading using Scotchbrite. This has been shown not to affect the bond strength.
- Store and handle all fabric and materials in the correct manner to prevent contamination prior to use.

2.4 Mixing Resin

About 1kg of resin is required per square meter of fabric. Resin is supplied pre-weighed in the proportions required for it to work effectively and entire tins should be mixed. If smaller quantities are needed then mix as follows:

- Standard resin (CS-600) – 4:1 resin (A):hardener (B) by volume
- High temperature resin (CS-700) – 3:1 resin (A):hardener (B) by volume

It is important to measure accurately and graduated containers are supplied for this purpose.

1. Pour the entire contents of the small tin of hardener (CS 600-B) into the larger tin of resin CS 600-A). Use the brown scraper supplied to ensure all the hardener is transferred.
2. Mix the resin and hardener for at least 4 minutes paying particular attention to the bottom and sides of the bucket. Check that the mixture looks homogenous before progressing. Use either the wooden stick or spiral (jiffy) mixer supplied. Mix carefully to avoid trapping air in the resin.
3. The working time of the resin at 25°C is about 40 minutes. Stop using the material once it starts to become too thick.
4. The working time will be reduced at higher temperatures and extended at lower temperatures.

Figure 1. Pre-weighed resin and hardener

Figure 2. Mixing using wooden stick

5. The standard resin takes between 4 and 6 hours to gel (turn solid). Full cure is achieved at ambient temperature in 7 days. Earlier cure can be achieved by post-curing once gelled. Typical cure cycles are:
    - 3 days at 25°C
    - 4 hours at 40°C
    - 4 hours at 40°C followed by 2 hours at 93°C
6. Full cure should be achieved before returning to service if the repair is expected to seal a hole in the pipe (note, if a metal plate has been bonded in place using a fast-curing adhesive then this may not be so critical, please confirm with the repair designer).

2.5 Filling and fairing

- Surfaces must be clean and keyed (abraded). Use either Leak-Stop epoxy putty or thickened resin(see below).
- Consistency of the filler is critical to give a good finish and to prevent sagging.
- Tools used should be clean and have sharp edges.
- Deep holes are best filled by applying small amounts at a time and building up.
- Press filler into corners to eliminate air pockets. A shaped tool should be used, e.g. a wooden spatula.
- Once cured, the filler can be sanded easily to shape. Allow the filler to fully harden before attempting to abrade otherwise it will clog the paper.
- Apply fillets of at least 5mm radius. The fabric must be able to conform to the curve.
- Do let filler extend beyond the boundary of the defect. Use the smallest amount possible. The filler area becomes the ‘defect’ area, and so it needs to be kept as small as possible.

Figure 3. Pipe after grit blasting. Note water drip on pipe required surface to be re-blasted before repair application

Figure 4. Fairing – thickened resin being applied around weld beads.

2.6 Fabrics

Two fabric styles are available:

1. Biaxial Fabric. This has the fibre content and orientations optimised to repair pipework carrying hoop and axial loads. It is vital that the fabric is applied so that the roll direction winds around the pipe. This fabric should be used for straight pipe, elbows, and reducers. It should not be used on tees.
2. Quadraxial Fabric. This fabric has equal amounts of fibre in four directions. It does not matter in which orientation it is applied to the pipe, although it is recommended that the roll direction be wound around the pipe. This fabric should be used on tees.

General comments on handling of fabrics:

- Cut fabrics on a clean bench. Always check the area is clean first, it may be necessary to clean up before starting or apply a clean sheet of polythene.
- The best tool to use is a rotary-cutter. When used with a straight edge it will give a good, clean cut. Otherwise use scissors. The rotary cutter can cut four or five layers of fabric in one go.
- Do not use knives for cutting fabric – it is too easy to cut yourself with them.
- Cut between the longitudinal stitching of the fabrics because this will help to stop the fabric falling apart.
- Discard loose fibres from the edges of the cut.
- Always wear gloves to prevent irritation to skin.
- Once cut, fabric and peel ply should be rolled and not folded to avoid creasing. It is best if the fabric can simply be left flat.
- If materials are not to be used immediately they should be covered or put into plastic bags to prevent contamination.
- Unless written instructions detail otherwise, the 0/90 fabric should be applied so that the roll direction is applied around the pipe (i.e. in the hoop direction). *Wind off the roll, and wind in the same direction onto the pipe*.

Figure 5. Glass fibre fabric. Note, the fabric is not woven, and so the fibres are not crimped, but lay in flat sheets, to maximise strength and durability

2.7 Wetting-Out Fabric

Where possible, wet out fabric (impregnate with resin) before applying to the pipe.

1. Prepare a work bench by covering with a polyethylene sheet (this can be replaced when necessary).
2. Mix resin as detailed above, Section 2.4.
3. Apply a generous resin layer to the protected-bench surface using a short-pile roller.
4. Lay the first ply of fabric onto the resin layer and apply further resin to the surface of the fabric using the roller.
5. Work the resin into the fabric (impregnate it) by applying firm pressure with the roller. This forces resin into the fabric through both the top and bottom surfaces.
6. The glass will turn translucent as the resin penetrates the fabric.
7. The weight of resin required to fully impregnate the fabric is approximately the same as the weight of the fabric itself.
8. If it is not possible to see that the whole piece is fully wet out (translucent) then turn the piece of fabric over and check for dry areas, applying further resin as necessary.

Figure 6. Glass fabric place onto layer of resin (on protected table)

Figure 7. Resin wets out cloth when pressure applied with roller

The fabric can be wet out on the pipe if necessary.

1. First, apply a layer of resin to the surface on which the fabric is to be placed.
2. Lay the fabric in place and then apply further resin on top.
3. Work the resin into the fabric using the short-pile roller until the fabric is fully wet-out (and turns translucent).

Figure 8. Apply layer of resin to pipe

Figure 9. Apply dry fabric

Figure 10. Apply more resin to fabric and work in

2.8 Vertical and Overhead Surfaces

The resin may need to be thickened to ensure the fabric conforms and adheres to vertical and overhead services. This is achieved by adding Cabosil (fumed silica thixotrope) to the mixed resin.

- Add the silica slowly until the resin reaches the consistency required.
- Mix vigorously to eliminate lumps.
- Ensure that it is thoroughly mixed, and of even appearance.

The resin can be used to fill and fair discontinuities in the pipe surface when thickened sufficiently. Apply the thickened resin as a thin layer to the pipe and smooth out using a paint brush.

To prevent resin draining out from vertical or overhead surfaces then it may be necessary to add thixotrope.

- Typical volumes required are shown below (note, it is very low density, so the mass added is minimal).
- Continue to add filler until the consistency required is achieved (more will be required as the application temperature increases).

- A 2kg tin of resin can be thickened by adding either one or two scoopfuls of thixotrope (200-400ml), .

Resin Type	Approximate addition per tin of resin	
	Filler (mix small amounts in hardener tin)	*Thickened resin*
Standard	1-2 scoops	1-2 scoops
High Temperature	2-3 scoops	2-4 scoops

Table 1. Typical amounts of Cabosil required to thicken resin

Figure 11. Adding cabosil to resin. Hardener tin was half filled with mixed resin

Figure 12. Resin thickened for use as filler

Figure 13.. Filler applied to fair in uneven edge

Figure 14. Filler smoothed using a paint brush

Note!
Resin thickened for filler quickly becomes hot as the resin cures.
Use within 10 to 15 minutes of mixing and take care when picking up the tin as it may become very hot.

2.9 Consolidation

The fabric must be pushed down onto the layer below (or the substrate below), and all air removed. This can be achieved using the short-pile roller or brush

Figure 15. Consolidation using a roller

Figure 16. Consolidation using a paint brush

Figure 17. Consolidation by hand

2.10 Application to the pipe

For large diameter pipes it is easies to apply single layers, one at a time. The fabric should be cut about 10-20mm longer than the circumference of the pipe so that a complete encirclement is completed by each layer. The joints should be staggered around the pipe, and the joint in the first layer must be diametrically opposite any defect (where possible). For small diameter pipes it is possible to spiral the fabric around the pipe to make the repair.

1. Apply a layer of resin over the surface to be repaired using a short-pile roller.
2. Apply the first layer to the repair. Consolidate it onto the surface using a roller. Ensure the fabric lies flat over the entire surface; it can be pushed down onto uneven areas using a brush.
3. Wet out the second and subsequent plies on the bench in the same manner.
4. Apply subsequent plies on top of the first layer consolidating using the short-pile roller or by hand as preferred. Remove all air bubbles by pushing to joints/edges.
5. Check that all layers are fully wet out, applying more resin where required, and that no foreign matter is trapped

Figure 18. Apply a layer of resin to pipe surface first

Figure 19. Pipe with resin applied prior to application of glass

- Each layer should be wound in the same direction around the pipe. However, ensure joints (start points) in layers are staggered around the pipe in subsequent layers. This is to prevent a line of weakness being built into the composite.
- Ensure that the subsequent layers of fabric are fully in contact with the ply below.
- Work out any trapped air by carefully pushing it to the joints in the fabric using the rollers or by hand.
- Work on each layer until it lays flat. If you don't then subsequent layers will magnify any discontinuities.
- A gentle touch is sufficient. The epoxy resin enables the layers to work together – there is no need to force the layers onto each other, only to ensure there is no air gaps between them – when the epoxy cures it will provide the bond.
- Do not lean on the repair or apply significant pressure because this will cause dents in the fabric which cannot then be removed (the wet repair will behave like a dough).
- Peel-ply should be applied when the required layers have all been applied (or when an overnight break is required), Section 2.12.

2.11 Joins between Pieces of Fabric

Plan ahead where joints are to be made and stagger between layers. Avoid placing joints on corners. Overlaps should be at least 10mm but ideally no more than 25mm (to ensure a visually smooth finish).

This example shows the concept of the overlap. However, the extent shown in the photograph is outside of recommended levels.

Keep overlap between 10mm and 25mm where possible.

Figure 20. Exaggerated overlap shown

2.12 Peel Ply Finishing Layer

Apply peel-ply when laminating is complete as shown in Figure 21 to Figure 23. For pipes, it is best to apply it in a spiral around the pipe, each piece overlapping the next by about 10mm.

Check the following points:

1. The peel ply should extend past the edge of the fabric and onto the pipe.
2. Wrap in the same direction as the fabric so that the 'pull' causes the fabric to coil around the pipe, not uncoil. Apply light pressure only.
3. Confirm no foreign matter is trapped (if so, remove the peel ply, then the contaminant and re-apply the peel ply).
4. The peel ply will soak up any excess resin on the surface – ensure there are no 'dry' areas. Apply more resin using a brush to any areas that appear dry.
5. Make sure the peel ply does not bridge over high points. If it does, push it onto the surface using a brush.
6. Make sure all areas are covered by the peel ply, adding more where necessary.
7. Make sure there are no air voids, indentations, rucks or dry patches visible.
8. Leave a corner of the peel ply dry (ensure this is above a first layer of peel ply!) to enable it to be removed when the resin has cured.

Figure 21. Peel ply

Figure 22. Application of peel ply. Resin can be seen to be coming through fabric

Figure 23. Apply more resin where required

Figure 24. Repair after peel ply has been removed. Overlaps can be seen.

Figure 25. Using peel ply to consolidate fabric in tee

Figure 26. Application around intersection of branch and header

2.13 Finishing laminates

1. Remove all peel ply.
   - The material is prone to splitting, and all traces must be removed. It is often easiest to lift a corner using a flat blade to start stripping it off.
   - A gentle touch works better than force.
2. Complete a visual inspection of the laminate (compare to allowables in procedures). Check for:
   - foreign matter
   - pits/scores
   - de-lamination
   - unconsolidated areas
   - remaining peel ply
   - exposed/cut edges (seal and cut edges with further resin)
   - dry areas
   - blisters
3. Tidy the repair as necessary
   - Remove any protruding fibres from the edges of the laminate. This may require use of a file, grinder, or scissors.
   - Any ridges of resin formed under the peel ply can be filed off.
   - Dry areas can be coated with resin

2.14 Examples of Poor Repairs

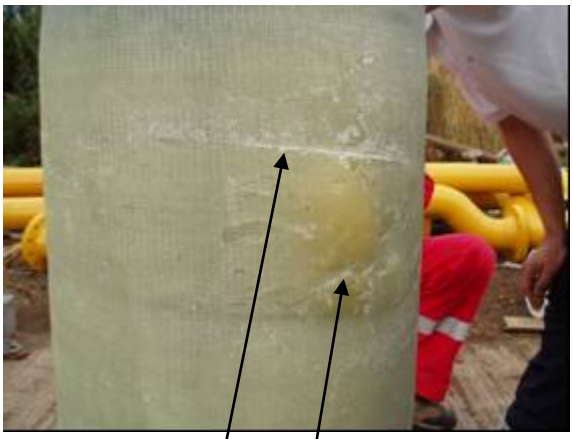


Figure 27. Poor application of peel ply leading to resin uneven surface. Draining resin has created a 'bulge' when trapped in loose peel ply.

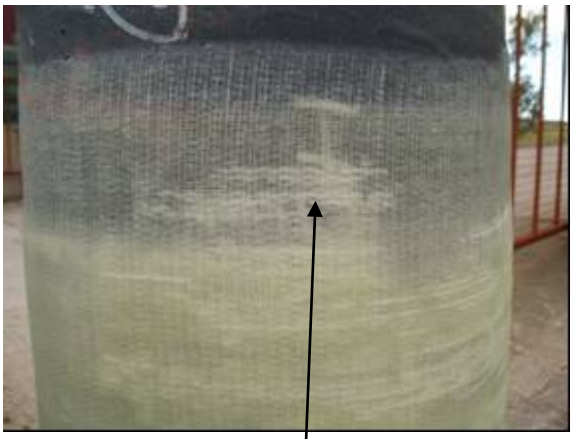


Figure 28. Surface irregularity caused poor wet out and scraping of surface whilst resins till wet

2.15 Post Cure

- Apply a layer of dry E-glass under trace heating to protect the repair.
- Position thermocouples towards centre of the repair and in-between coils of heating cable.
- Monitor temperature during cure cycle.

3 REPAIR OF SPECIFIC COMPONENTS

3.1 Elbow repair

There a number of ways elbows can be wrapped:

1. Spiral wrap. Easy to apply to smaller diameter pipes (<24”).
2. Template. The fabric is cut to fit the outer dimension of the elbow and small cut-outs made to give fingers which wrap around the pipe to repair the inside. This gives the neatest looking repair, but is more demanding and slower to apply relies on a large number of overlaps.
3. Lobster-Back. Mimics how steel pipes are cut and fabricated to give an elbow and works well on large diameter pipe (>1m (36”))

3.1.1 Spiral Wrap

- Start at one end of elbow and wind fabric around, moving along the elbow a little each wrap.
- The precession should be calculated in conjunction with the fabric width so that the required number of layers are applied.
- For example, if 6 layers are required and the fabric is cut 120mm wide then step along 20mm for each successive layer (measured on the extrados of the bend). This creates a long taper.
- Whatever the width of fabric cut, precess 1/6th of the width each wrap on the extrados and start the repair 5/6th of the width away from the damaged area to create the taper.
- Mark the steps on the extrados before applying the fabric

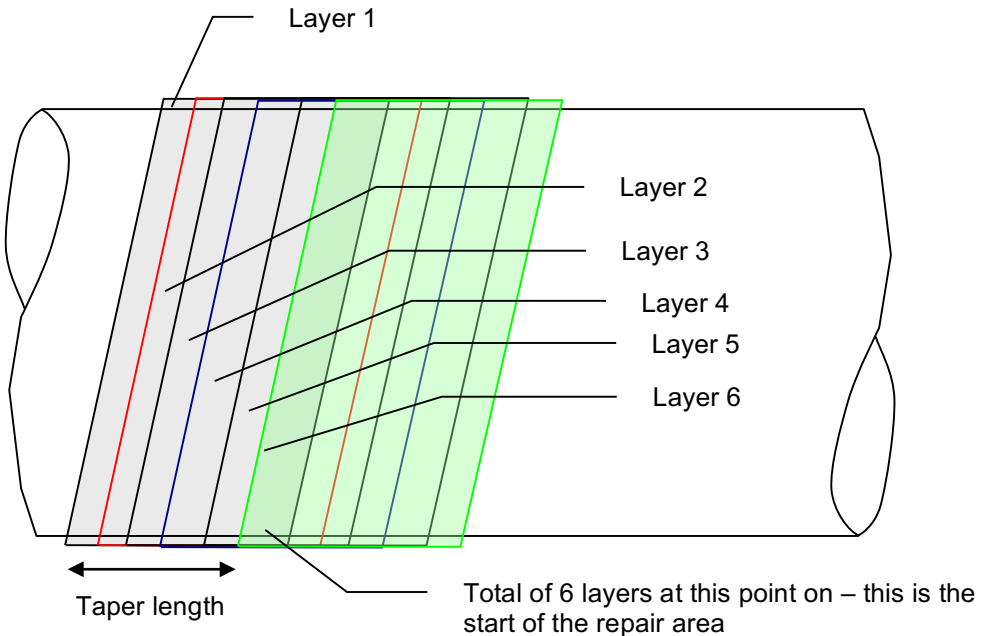


Figure 29. Spiral wrap geometry. Each layer moves on by 1/6th of the fabric width. Repair starts 5/6^{ths} back from damaged area.

Figure 30. Start of spiral wrap

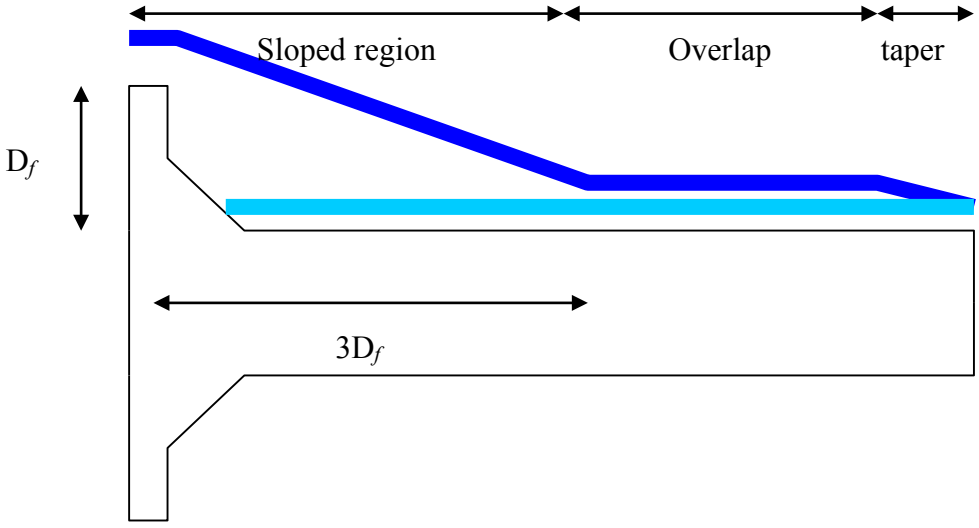
Figure 31. Completed spiral wrap repair

3.2 Flanges and valves

- The approach is to create a surface on which it is straight forward to apply the repair
- This is achieved by filling hollows and gaps and tapering steps using an appropriate filler or foam.

The composite is applied in two parts:

1. First apply fabric right up to the flange faces
   - Allow to cure (gel) and then apply a foam collar
   - The foam is formed from a two-part mix, ratio of 1:1, and poured into a former around the flange. The liquid then foams. Small mixes are recommended in case there are any leaks in the former. The former can be made using cardboard, or strips of duck tape.
   - The foam is worked to its final shape using handsaws, files and sandpaper.
   - Keep the foam collar to a minimum, so it just covers the bolts. It should rise at an angle of about 30°, or a slope of 1:3, as shown below.
2. Cut fabric to the size of the OD of the flange. The fabric will need to be slit so that it lays down on the collar.
   - On a difficult geometry the fabric may have to be laid in narrow strips to enable it to conform to the surface. Ensure each strip overlaps the next by between 10 and 25mm.



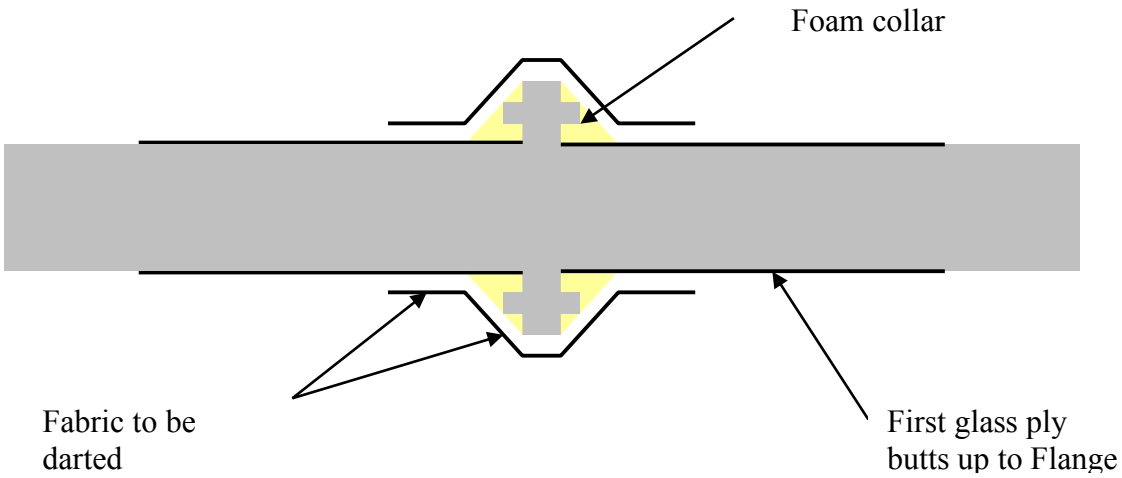


Figure 32. Schematic of flange repair

The build up of the foam former is shown below

	
Flexible sheet used for mould	Mould in place
	
Foam poured into mould	Foam expands and fills mould

	
Mould removed	Former left in place
	
Example of mould	Completed repair

3.3 Small Bore Connections and Tee's

- Use filler material to radius tight corners, for example at the connection of the branch to the trunk on a tee and at weld beads.
- Keep fillets to a minimum, but at least approximately 5mm radius
- Coat surface with resin first, as normal.
- Apply fabric to trunk, centred on the 6 o'clock position, and cutting out sections so that the fabric lays around the branch, with fingers reaching up onto it.
- Smooth the fabric onto the surface of the pipe.
- Cut a piece of fabric to wrap the branch so that it will extend at least 50mm beyond the weld and onto the trunk.
- Place the fabric around the branch and make cuts up to the line of the weld so that it lays flat. Smooth fabric onto tee and ensure it is properly wet out, laying the fingers out onto the trunk.
- Interleave layers on the branch and the trunk, and continue until the required number of plies have been applied.
- Cuts made in subsequent layers should be staggered around the branch so that the joints do not overlap and the entire area of the intersection is completely covered.

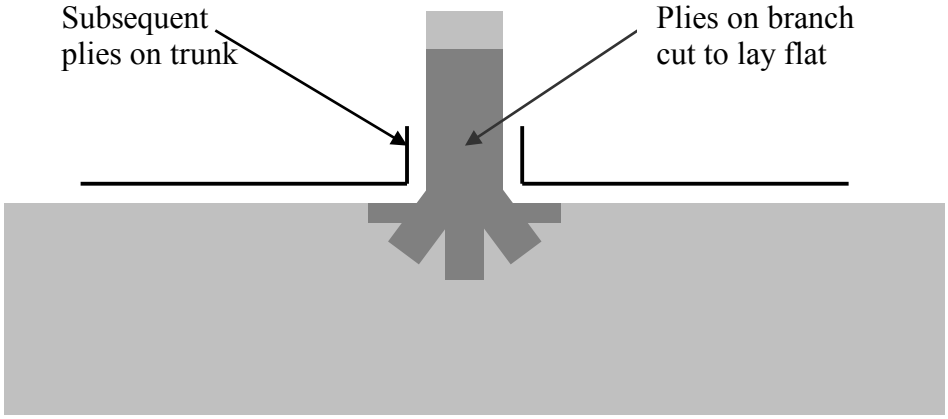


Figure 33. Schematic of repair of tee

Figure 34. Repair of small bore take off, showing fairing and over-wrap

Figure 35. Fair connection to 5mm radius minimum.

Figure 36. Wrap fabric around branch and slit fabric back to connection so that it lays flat on the surface.

Figure 37. Cut fabric so that tabs of material extend onto trunk.

Figure 38. Apply fabric to trunk and slit to form overlap onto branch.

Figure 39. Build up layers alternating between trunk and branch.

Figure 40. Build up layers alternating between trunk and branch (remember to allow for tapers on both).

Figure 41. Apply peel ply.

Figure 42. Cover entire surface.

Figure 43. Ensure surface is fully 'wet' with resin and peel ply is flat over all surfaces.

Figure 44. Completed repair.