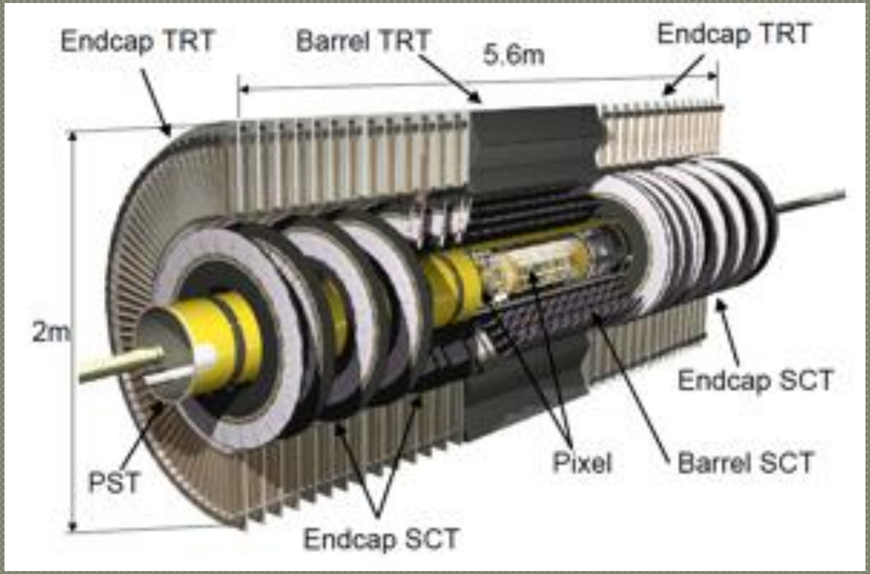
Cooling Tubes-Pipes & their connections from the ATLAS SCT

Richard French – The University of Sheffield

Forum on Tracking Detector Mechanics– CERN 04/07/12

SCT Overview

- SCT = C3F8 fixed mass flow evaporative cooling @ -25°C
- 4x Barrel detectors (2112 modules)
- 2x Endcaps (988 modules per EC)
- Inner PIXEL detector (1744 modules)
- Integrated with TRT detector – all sited inside the LAr cryostat.
- Using predominantly CuNi pipes (Cu from Cryostat flange outwards to PP2 distribution racks)
- Soft soldered joints - a few brazed (hard soldered) for luck.
- Variety of deformable metal seal connectors to on-detector structures

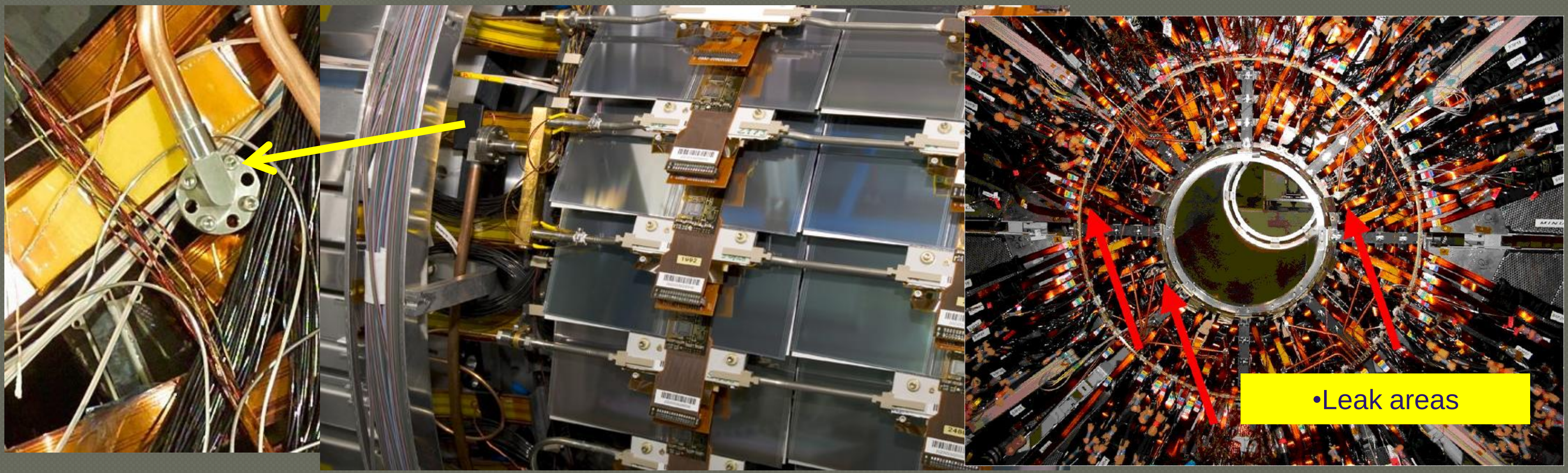


Introduction

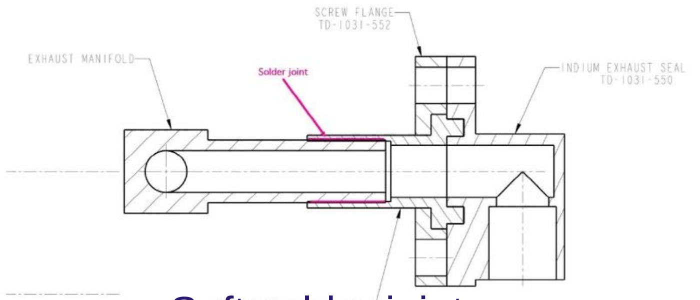
- Writing this presentation was a painful but funny reminder of the past.
- We frequently loose details of how & why components evolve – it's not always obvious why we've made a design choice, let alone materials! It is easy to criticise these choices without the correct understanding.
- I'm a mech. engineer not a physicist (but am slowly turning to the dark side), this influences the way that I view things and present to you today.
- I inherited most of the components to help build the SCT EC-C and later the SCT cooling installation and testing.
- Thankfully avoided most of their design……….

  But had to put them together and make them work.
- My understanding is based on what I have learnt from my ATLAS experience and my attempts to avoid repeating similar problems for ATLAS Upgrade
- Will we be making mistakes again? …… Probably, but hopefully not big ones!

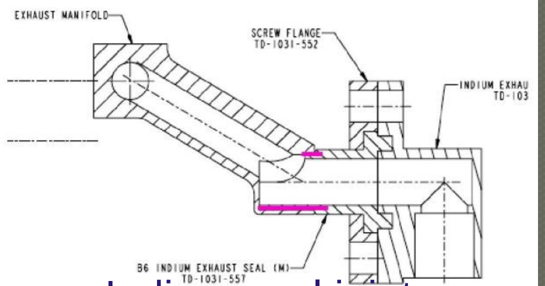
SCT Barrel permanent joints



- •Predominantly CuNi tubes
- •Using mainly solder joints
- •Leaks repaired as found during construction
- •Joint encapsulation required
- •Some scary moments but ok
- •Leak rate defined by vacuum



•Soft solder joint



•Indium seal joint

•© The University of Sheffield

SCT Barrel cooling assembly/testing 1

(Findings from R. Apsimon hunting for leaks in SR1)

- Identified leaks by sealing with alcohol - (temporary) .
- Endoscope used to inspect inside & outside of all leaking joints and some non leaking ones.
  - Some leaking flanges show breaks in external solder ring. Some do not.
  - No evidence of corrosion
  - No sign of delamination of plating
  - No sign of physical damage
  - No evidence of flux remnants
  - No leaks in spiders
  - No dimensional differences between flanges.
  - Leaks present with 1 or 2 indium seals or O-rings. Not present with rubber bungs(??) **Implies that stress is important.**

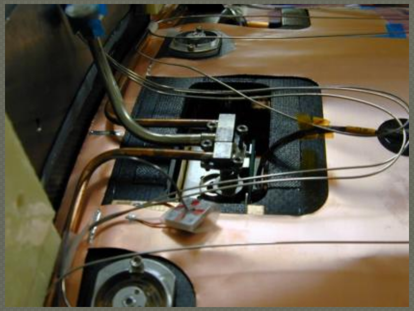
•PROBLEMS

- MUST repair leaking ones - should prevent others
- Assess is not easy! e.g. an "impossible" B5 one
  - Must balance preventative maintenance vs. risk
- Options
  - External
    - Reflow solder - considered too risky
    - Loctite - rad hard, C_3F_8 safe, good penetration. Will not provided additional resistance to stress?
    - Torr Seal. Rad hard, very robust, inert when cured. Will not flow, at room temperature.
    - Araldite 2011. Well known. Not as 'strong' as Torr Seal or as penetrating as Loctite.
    - Hysol 9396. Similar to 2011 but tested by pixels.
  - Internal
    - Glue only. Easy to apply but fully exposed to C_3F_8.
    - Glue + PEEK insert. Protective layer. Can be 'safe'. "Easy" to make. Rad hard. Only B3-B5.
  - Want different glues for internal & external.

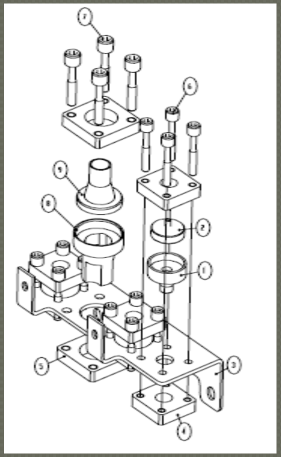
•FALL BACK SOLUTION

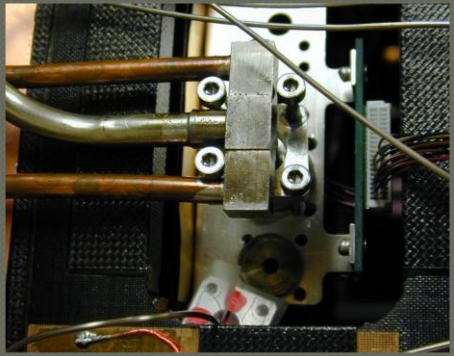
PPF0 or on-detector connections

SCT End Cap connectors.



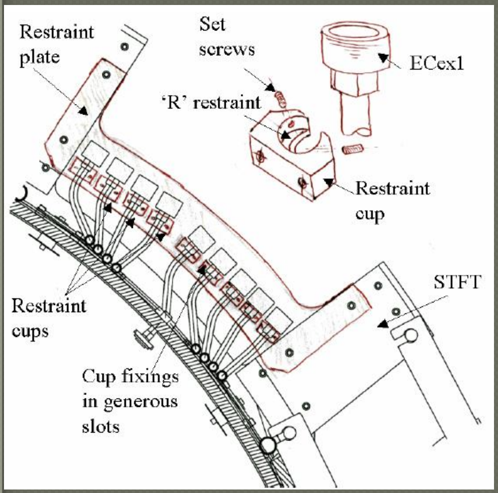
- Helicoflex seal uses plastic deformation of a jacket of greater ductility than the flange materials. Elastic core is close-wound helical spring. The spring is selected to have a specific compression resistance.
- Using Ti bolts to compress seal and to hold PP0 connection in place.



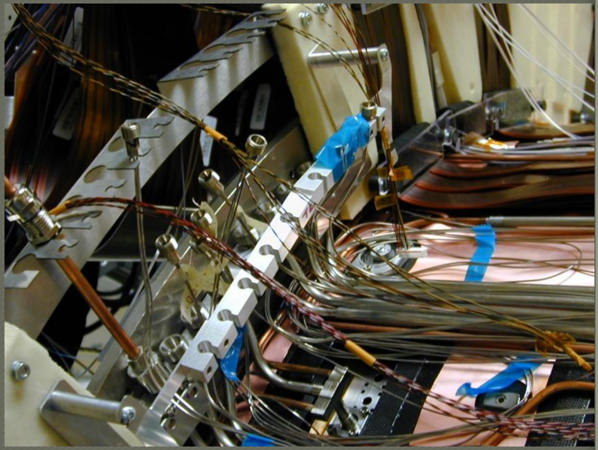


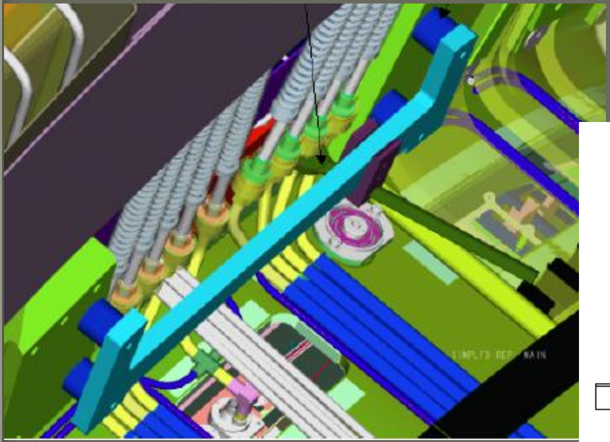
- So, what faults did we observe?
  - The Helicoflex seal faces were Aluminium, concerns grew about corrosion issues (CuNi to Al) so changed to a Cu seal material
  - The Cu seal was too tough to compress fully and leaked
  - The Ti bolts suffered from creep and stretched.
- We kept the Cu seal, selecting a softer spring & switched the Ti bolts to 316L stainless.

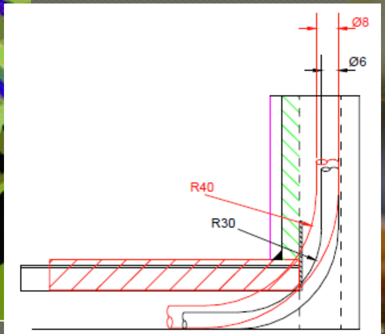
On cylinder cooling (STFT)

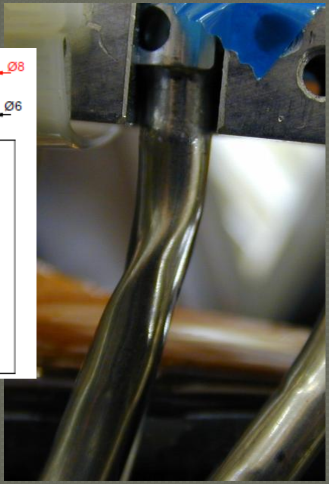


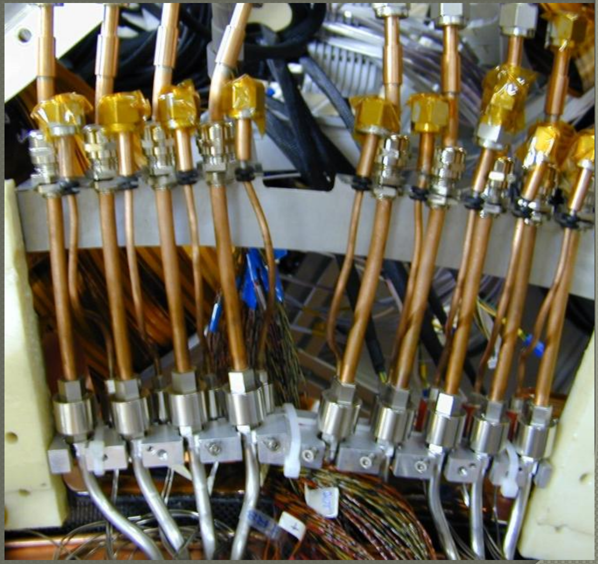
- Services Thermal Feed-through
- Design of restraint problematic
- Torque from fitting damages either:
  - Restraint device or
  - Cooling circuit
- Circuits not ideal fit in area.
- Eventually "made to work"
  - Schedule prevents alternative



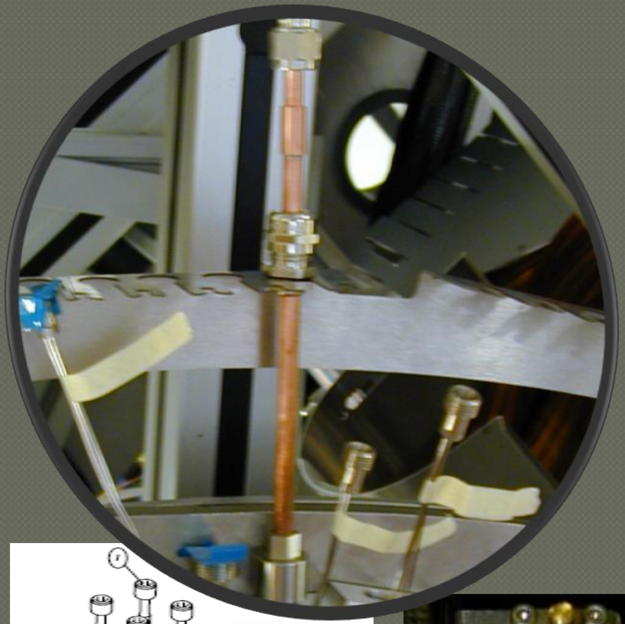








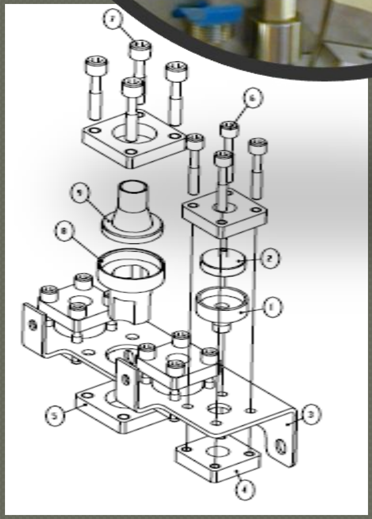
Temporary Connectors

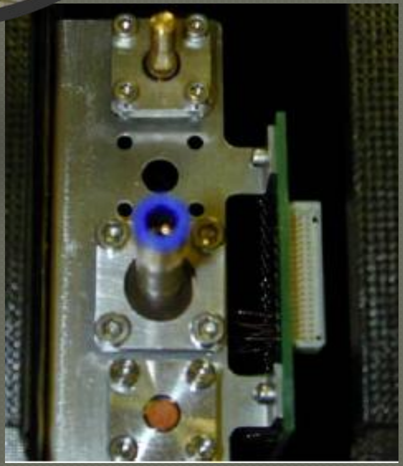


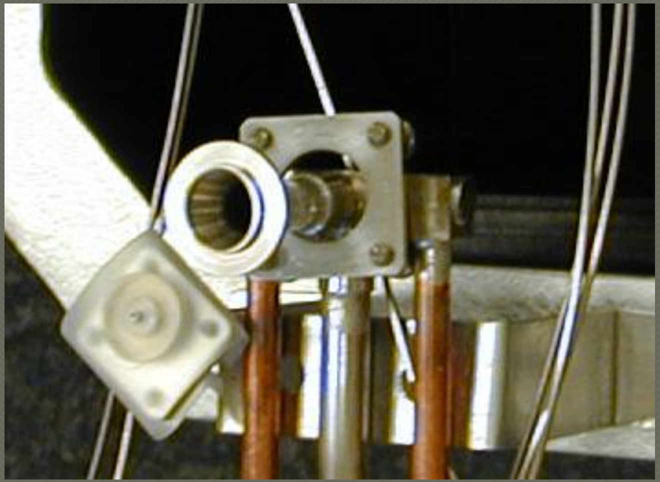
•Temporary pipe extensions to remove wear and minimise damage to the permanent connections was at time troublesome but overall worth it.

•You never realise how fragile a connector is until you've broken it.

•Testing will cause the majority of failures through simple errors, especially HANDLING.

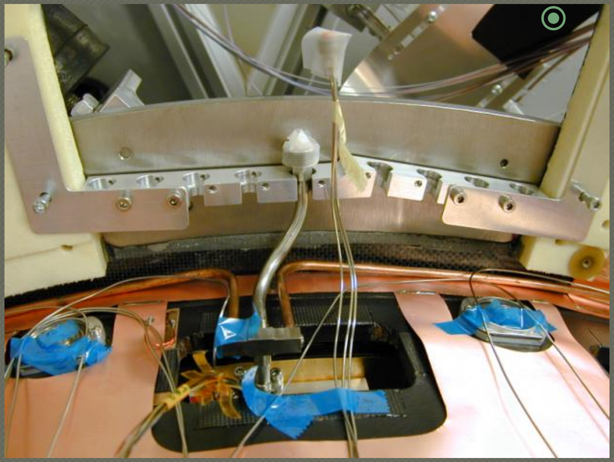






D9 leak after cavern installation

- EC-C D9 testing phases:
  - Disc construction
  - Post module assembly to disc
  - Disc to test box connection tests
  - Disc testing in thermal chamber
  - [On cylinder cooling added]
  - Post support cylinder assembly
  - Full EC thermal testing
  - Pre shipping testing
  - Post shipping testing
  - Testing in SR1for the sake of testing
  - SR1 thermal test box testing
  - Early HEX installation + testing
  - HEX removal NO TESTING on
  - Post TRT integration testing
  - Combined cosmic run tests in SR1
  - HEX assembly leak testing in cavern
  - UNRECOVERABLE LEAK FOUND

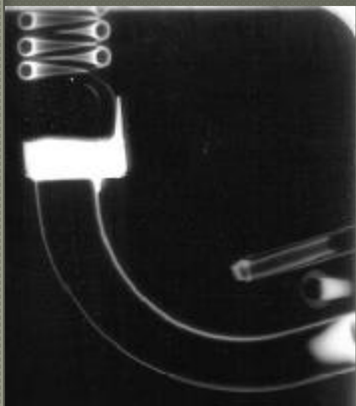


- What happened?:
  - Pre-installation of HEX in SR1 altered original plan
  - HEXs installed but fouled on integration frame
  - HEX's removed by mystery people to proceed with tests.
  - Loop 186 never rechecked until after installation as combined cosmic run used opposite quad

- D9 first to install both disc & loop on detector
- D9 last to connect in cavern
- Loop 186 was 2nd to last connection made
- Strain relief on ECex3 to STFT questionable
- LMT cooling acts as lever arm on manifold
- D9 main pipe uncomfortable fit in feed-through
- Connection torque easily transmitted to solder joint.

Off detector – Heat Exchanger

Too much to say in one slide, I'll concentrate on the mechanics only.



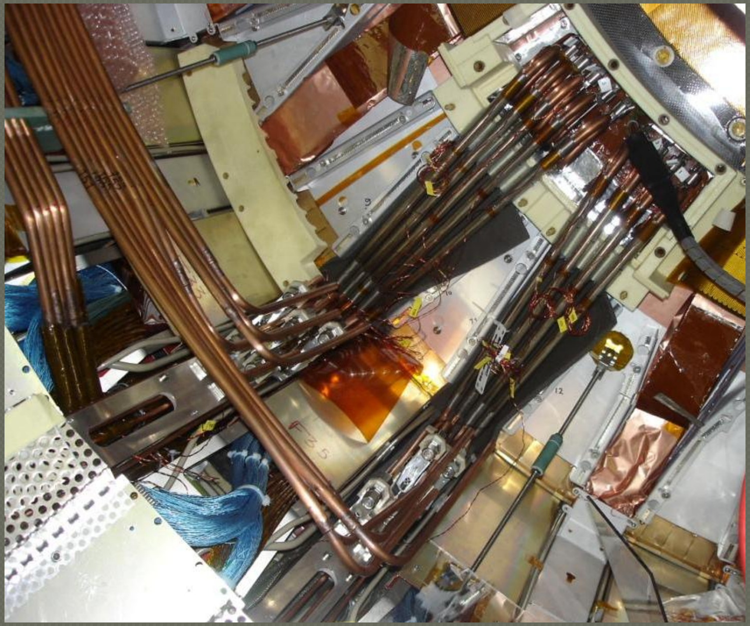
- •3mm OD tube to 4.6mm ID tube brazed sleeve joint -
- •Faults = POOR DEISGN due to gap size in sleeve joint
- • Found - porous joints - asymmetric alignment - lack of penetration into joint = Rework time (again) and this time 100% PRESSURE TESTING.
- •Q:How did they even manage to make this joint??
- •A: By building a jig and getting very clever with low temp solder.
- •Repaired by crimping 5mm tube and reducing gap – brazed ok.

- •We use highly skilled people to construct & assemble components.
- •When something is not quite right – bad design is viewed as a challenge to be made to work
- • We should listen more to the people working with the components to make sure what is designed not only can be built, but be built to last.
- •We have to bury the political culture and kudos of who makes what where, but funding mechanisms will continue to dictate this for some time.

SCT HEX problem of Autumn/Fall 2007 taken from 124th ATLAS EB notes 30/11/2007

"A new problem has been observed: at the transition from a 3mm pipe to 5 mm of a heat exchanger (HEX) a leak had occurred. Further investigations revealed that for 70% of the HEX the soldering at this point is faulty and that all HEX have to be reworked. By now 60% of the HEX have been repaired and re-installed. This has however further impact on the schedule, which foresees now to seal the end-caps before Christmas." "Because of all these problems much work is being carried out in parallel. The teams work 2 shifts per day and over the weekend, but the schedule is still extremely tight and requires much interleaving of installation and commissioning work."

Far Heater Solution



- Due to many failures and worry over the performance of the heaters, they were relocated to the cryostat face.
- Compression fittings with reducing ferrules were used to join pipe OD changes to minimise space usage.
- Compressing the larger OD tube ferrules proved to be highly problematic.

Teams of people spent 100’s of hours trying to make these fittings seal.

They were not suitable for the way we were trying to use them

Fortunately using hydraulic equipment and lots of experience making them work properly – we were able to get reasonable reproducibility (eventually)

Conclusions

Apologies now if I offend people, this is my opinion only…….

Soft soldering?

- We can see that the majority of SCT permanent joints were made by soldering of one type or other. Was it a good idea?

- Ultimately, easy to repair if you have **time and access**.
- Failures were spotted either by testing or testing of a related component then repaired when possible.
- Attention to risk management and serviceability was raised
- The idea that 100% QA on cooling components became reasonable
- One or two really stupid things were done and un-recoverable due to lack of spares and knock on effects to the installation schedule for other disasters occurring in parallel soaking up both manpower and resources.

- I believe that there is greater potential for disaster than other solutions available to us.

- Most of the main solder joints on the SCT coupled to a lever arm that caused stress in the joint and sometimes failure.
- The sheer number of problems surrounding cleanliness, preparation and the lack of repeatability is an issue common to all material joining.
- Low temperature electrical solder should not be used for tube joints –
- Use a proper brazing alloy

- YOU WILL NEVER HAVE THE TIME OR ACCESS TO MAKE REPAIRS especially in a radioactive environment.

Generic fittings?

- Most of the off detector SCT joints fro PP1 to PP2 etc were made by compression fittings. Was it a good idea?

- If we did not use the compression fittings, adopting many of the new pipe routings may have taken much longer.
- If the TRT C wheels were in place I think we would be in a significantly worse situation today.
- Failures were tricky to find and we often flooded the cryostat environment with Argon so it was impossible to sniff for leaks for the remainder of the day.
- All repairs were carried out on the fly.
- Big compression fittings do a lot of damage when dropped.
- Big spanners do even more damage
- Copper washers get lost everywhere and are not magnetic to pick up.
- We took many risks to make these work and got away with it..
- Once you have used Torr Seal – it does not come off – ever.!!

- Most "experts" know what works well with what material/OD.
- It takes about 2 years for these views to be listened to……………
- 2 days if something has been damaged!
- Modify at your own risk.

- Select the fittings wisely and **<u>make prototypes!!!!!!!</u>**
- Weld on fittings are a sensible alternative to minimise torque damage available from Parker, Staubli and Swagelok to name a few.

Custom fittings?

- Eventually the custom fittings (especially ECex1 and ECcap3) were made to work well.
- The time invested was significant and maybe not worth it.
- Poor materials choices caused majority of problems
- Routing issues, conflicts with other services and alignment contribute significantly to all failures observed.
- Due to routing and lack of space, torque control of tooling was exceptionally difficult.

- I'm convinced there is no real need for custom fittings if you think about your design long enough.

- Prototyping will save HUGE amounts of trouble.

Summery

- The problems with other components deflected attention from the cooling system pipes and fittings.
- Multiple disasters occurred in 2007 that no one could have foreseen with any type of planning.
- We were short of manpower and resources.
- Risks were taken
- Schedule changes forced many stupid errors
- I feel if the original plan was maintained then some problems would have never happened.
- Testing with vacuum was a waste of time.
- Testing with pressure highlighted many flaws
- Sniffing with Argon saved a huge amount of time to track a leak down to source and make a crude repair.
- 100% QA took time but saved more in retrospect.
- Lever arms directly to a soldered joint are trouble waiting
- Attempting to bend and make pipes fit to high tolerances needs carefully thinking about in the future.
- Space envelopes in the services were breached by other sub-systems resulting in many alignment difficulties.