THE BEST LAID SCHEMES ...

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Abstract
A list of recommendations for better vacuum practice is presented in this chapter.

1. INTRODUCTION

"The best laid schemes o'mice and men gang oft a-gley" (Rabbie Burns)

The title of this chapter refers to a poem by the Scottish poet Rabbie Burns, who when farming destroyed a mice nest with his plough. He felt so sorry for this that he wrote the poem. The conclusion we can draw is that even with the best preparations something can, and will often, go wrong because some not so obvious fact was forgotten. Much of the advice in this chapter is certainly available elsewhere in the literature, but some may be compiled here for the first time.

The topics to be covered in this chapter are recommendations concerning the choice of materials with correct properties, corrosion resistance, joining dissimilar material, rolled versus forged material, weld preparation, virtual leaks, inadequate heat treatment, magnetic welds, common errors and design mistakes. The material is presented in the form of recommendations of what to do or not to do. Clearly, deviations from these principles have caused, and will cause, trouble.

2. RECOMMENDATIONS

2.1 Design

- Make sure to match pumping speed and conductance when designing a vacuum system.
- Computer simulations are of great help in optimising the performance of a vacuum system.
- Mechanical stability calculations help to avoid such unwanted surprises as collapsed chambers after the first pumpdown.
- A chamber which can not be made stable enough against deformation during pump down can be reinforced by external bridge-like constructions.

2.2 Choice of materials with correct properties

- Select materials with suitable mechanical properties and good weldability.
- Use 316LN steel where low magnetic permeability and vacuum firing is required.
- Use pyrolytic carbon in UHV (density 2.2). Sintered carbon (density around 1.7) contains a lot of air and must be avoided.
- Materials with too high vapour pressure, Cd (in plated steel screws), Zn (in brass), S and Se (in 303 stainless steel) etc. should never be used in vacuum systems!
- Cast material should be used for flanges since rolled flange material can give rise to virtual leaks. See further below.
- Avoid bare insulating surfaces in an accelerator. Charged structures may deflect the beam. Sparks can cause trouble.
- Charged Vespel may carbonise on the surface when a spark occurs.
- It is possible to coat ceramic tubes by a thin layer of sputtered Au or sublimated Ti to avoid charging of the surface.

2.3 Corrosion resistance

- 304 series steel is not acid proof.
- Certain combinations of metals and chemicals such as fluorine solutions may give rise to corrosion.
- Corrosion of high-voltage feedthroughs (e.g. for ion pumps) in high humidity areas can be avoided by heating the feedthroughs slightly above air temperature.

2.4 Joining dissimilar materials

- Aluminium and stainless steel can be joined by aluminium knife-edge seals, like the LEP seal at CERN. The SMC company has a full range of aluminium Conflat-type seals and aluminium flanges, which is easily combined with standard stainless steel flanges. It is also possible to use spring-loaded seals like Helicoflex.
- Titanium/stainless steel joints can be obtained by explosion welding, performed by special companies. We have, however, bad experience for such welds since three out of four leaked. They were replaced by brazed joints Ti/Cu/stainless steel.

2.5 Machining

- When machining do not use silicon oils. They can not be cleaned away.
- Glass-bead blasting reduces the surface but may bury oil and dirt.
- Glass-bead blasting as well as electropolishing should be followed by vacuum firing.

2.6 Brazing and welding

- Virtual leaks can be created by improper weld preparations.
- Improper welding may create magnetic welds.

2.7 Virtual leaks

- One of the most common sources of virtual leaks is threaded holes for screws which have not been ventilated properly. Drill a 1 mm hole through the centre of the screw or, drill a hole from the bottom, or mill a narrow gap all the way down to the bottom on one side of the hole for the screw as shown in Fig. 1.
- Closed volumes can occur if welds are improperly done. See Section 6 of the Engineering chapter in these proceedings.
- Rolled instead of forged flange material can lead to virtual leaks due to silicate enclosures as shown in Fig. 2.

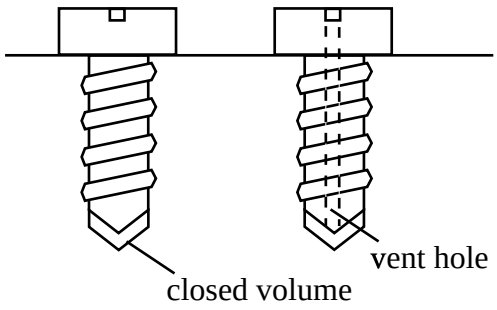

Fig 1 The screw to the right has a bored through ventilation hole to prevent virtual leaks and slow pump-down

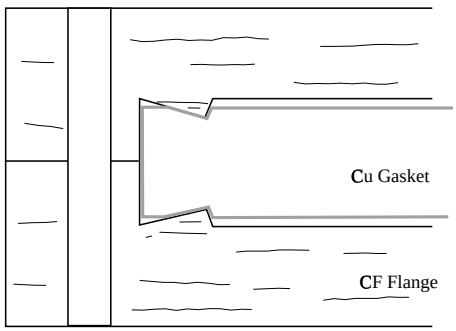

Fig. 2 Possible virtual leaks at the knife edge of a Conflat flange

2.8 Flanges and gaskets

- Improper torque applied to the bolts of a Conflat flange may cause a leak. Use a torque wrench and apply the recommended torque stepwise after completing a full turn of all the bolts.
- Do not re-use Conflat-type gaskets.

2.9 Vacuum furnace heat treatment

- It is important to have a sufficiently low pressure in the furnace, at least 10^{-3} Pa.
- Magnetic welds can occur if, during the heat treatment (vacuum firing), the temperature does not rise fast enough in the temperature range 500 – 800 ˚C.
- If a leak occurs during baking to 450 ºC the chamber can be coated internally by copper oxides if OFHC copper seals are use. Use instead silver plated OFHC copper or Oxygen-Free Silver (OFS) seals

2.10 Baking

- Inadequate bakeout temperature will not give significantly improved vacuum.
- Non-baked areas defeat the purpose of the bakeout due to the large difference in outgassing rate between baked and unbaked stainless steel.
- Crossed heating tapes give a too-high temperature spot and will eventually cause a short circuit.
- Magnetic baking equipment will move in a magnetic field when the field is cycled and will eventually be damaged.
- Poor contact between the thermocouple and the chamber will result in excessive bakeout temperature, which can cause severe damage.
- Inadequate heat insulation gives too low temperature.
- Not degassing filaments of sublimation pumps results in excessive outgassing when the pump is operated and therefore very fast saturation of the sublimated layer.

2.11 Vacuum pumps

- Diaphragm or membrane pumps an cause damage when the membrane beaks down. Ask the manufacturer for the recommended interval between membrane replacements.
- Ion pumps exposed to a high noble-gas load release previously pumped gases.

2.12 Contamination

- Cleanliness is a must! No fingerprints. Use clean gloves! Use head cover.
- Mount equipment in a clean tent where an overpressure is established by using a sufficiently large air cleaner with HEPA filter. A movable clean bench can easily be combined with a tent. The tent is made from metal bars and clean plastic sheets. The over pressure prevents dust from entering.
- When transporting or storing vacuum chambers protect sensitive parts such as bellows from damage.
- Protect sealing surfaces by covering flanges with Al foil and protective covers after cleaning. Do not dismount until installation.
- Beware of dust particles!
- Beware of metal particles! They can stick in the seal of an all-metal gate valve resulting in expensive repairs.
- Ventilate vacuum chambers with clean nitrogen gas. Air contains water.
- During leak detection connect the leak detector between the turbo pump and the fore pump for lowest contamination risk and highest leak sensitivity. This can be done without stopping the turbo pump if two manual valves are installed in this position.

3. REFERENCES FOR FURTHER INFORMATION

The International Union of Vacuum Science Technique and Applications (IUVSTA) is an international organisation with 30 member national vacuum societies all over the world. It has eight divisions: Applied Surface Science, Electronic Materials & Processing, Nanometer Structures, Plasma Science and Technology, Surface Science, Thin Films, Vacuum Metallurgy and Vacuum Science. On IUVSTA's home page, http://www.vacumm.org/iuvsta you find information about its vacuum congress (IVC), conference series like ECOSS, ICTF and EVC as well as workshops and schools. On the Vacuum Science division page (http://www.vacumm.org/iuvsta/vsd/biblio.htm) you find a list of vacuum books, both historical and modern ones. There are links to national vacuum societies where you can find information about meetings, and courses they organise. Most vacuum societies publish a journal or a news letter. By joining your national vacuum society you can find very useful contacts.

Good Luck!