Science and Technology Facilities Council

11TH VACUUM SYMPOSIUM UK

VS11 Technical Meeting

Control and mitigation of particulate transfer within UHV systems

Oliver Poynton, S. Wilde, K. Middleman
STFC, Daresbury Laboratory, Vacuum Solutions Group (UK)

oliver.poynton@stfc.ac.uk

What we will cover

1 ESS High Beta Cavities

2 Radio Frequency & Contamination

3 Controlling Particulate

4 Processing contamination

Science and Technology Facilities Council

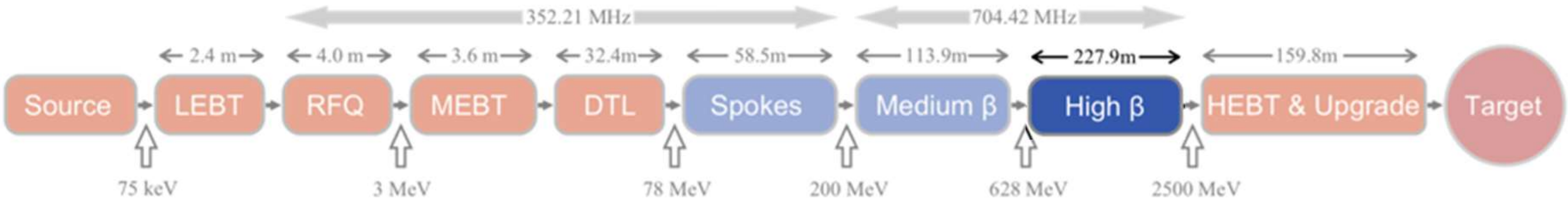
Science and Technology Facilities Council

11TH VACUUM SYMPOSIUM UK

ESS High Beta Cavities

ESS High Beta Cavities

Part of the UK's In Kind Contribution to the ESS, Daresbury is responsible for the manufacture and qualification of 84 high-β SRF cavities

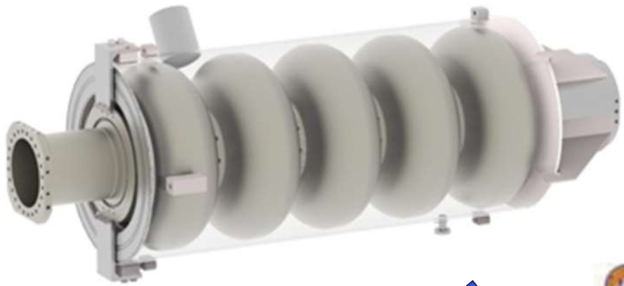


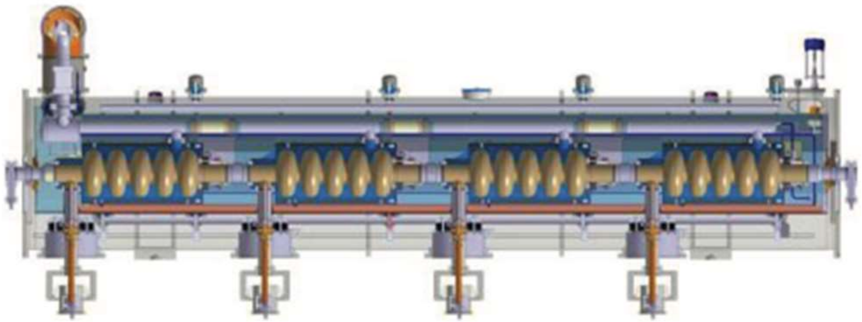
Science and Technology Facilities Council

Credit. M. Pendleton (STFC)

ESS High Beta Cavities

Cavity to Cryo-Module
step by step

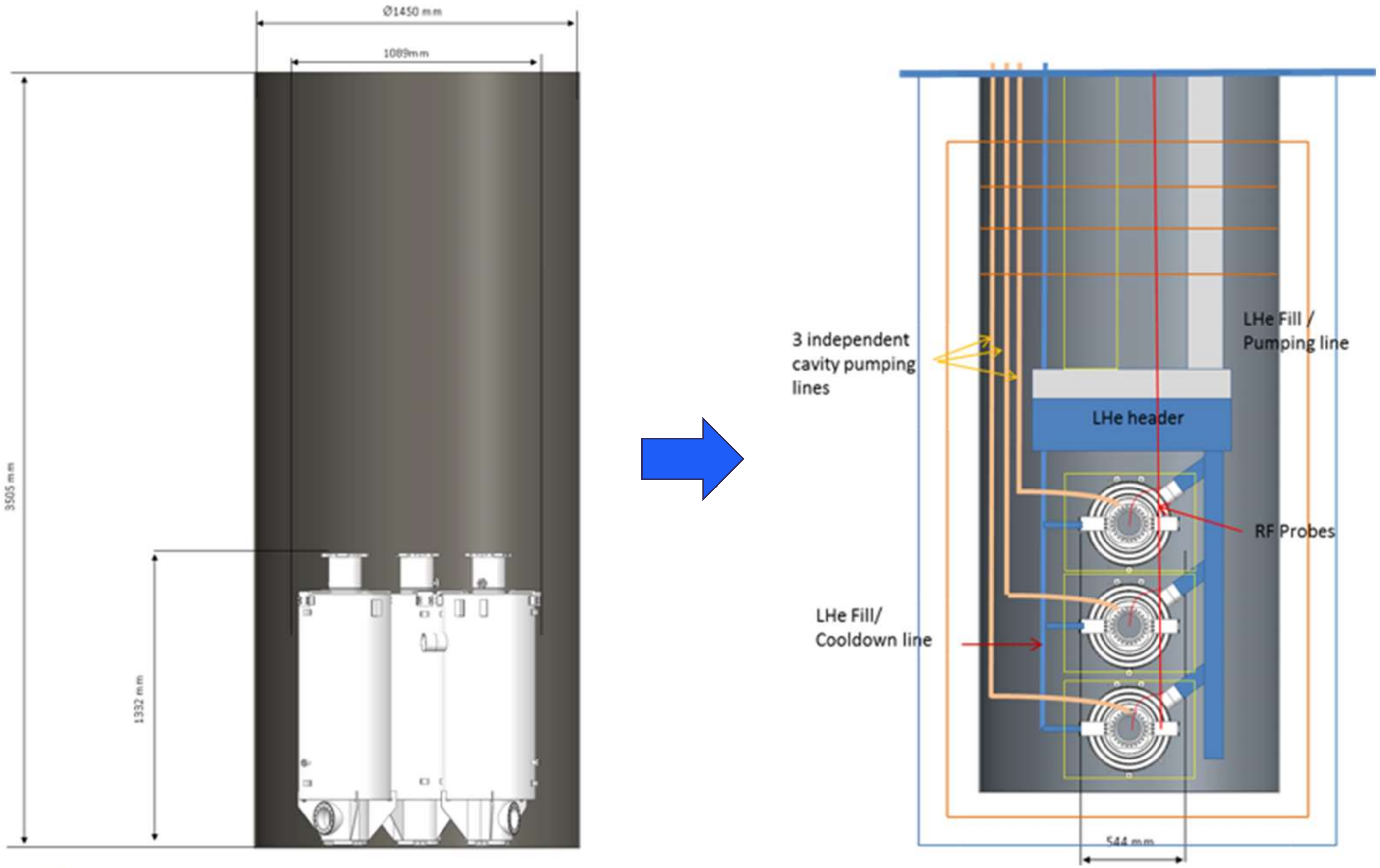




Science and
Technology
Facilities Council

Credit. M. Pendleton (STFC)

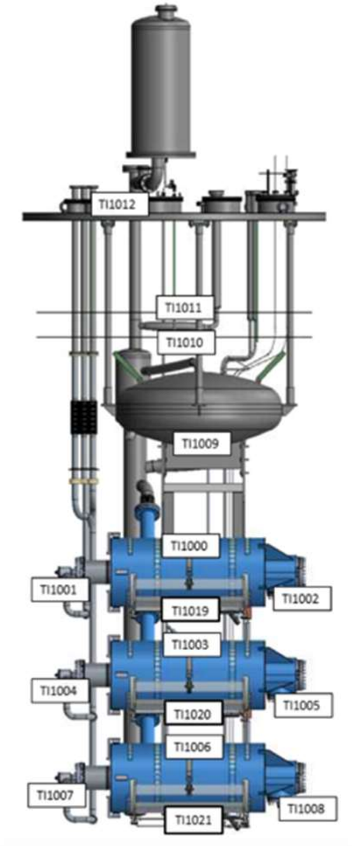
Our Novel Vertical Test Stand



Science and Technology Facilities Council

Credit. M. Pendleton (STFC)

Our Novel Vertical Test Stand



3 cavities tested per run

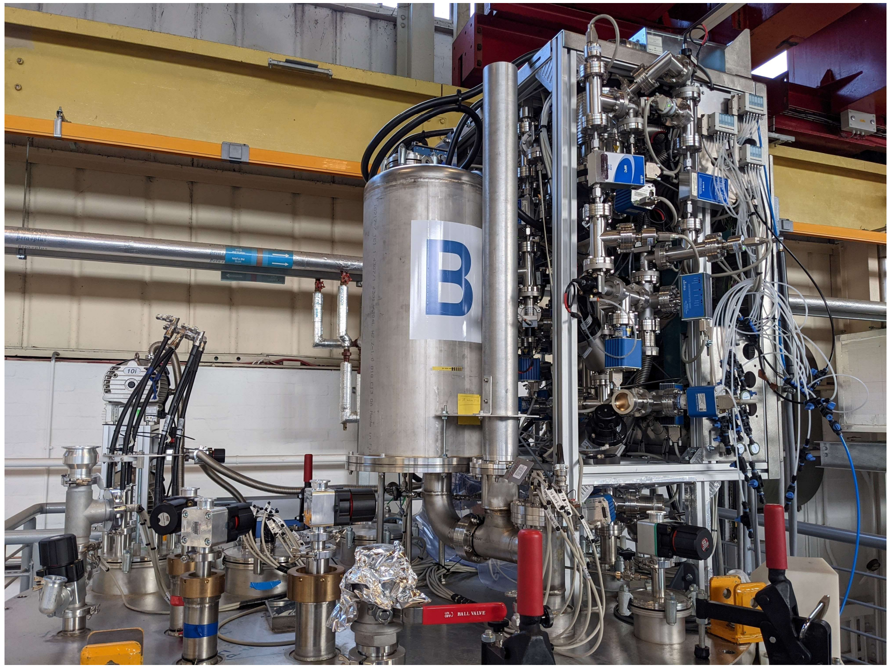
Vacuum system actively pumped

Cavities tested horizontally using helium jackets to better simulate LINAC configuration

~1500 L lHe required per test (vs 7500 L), Helium recycled in closed loop system

UKRI Science and Technology Facilities Council

The UHV System



Science and
Technology
Facilities Council

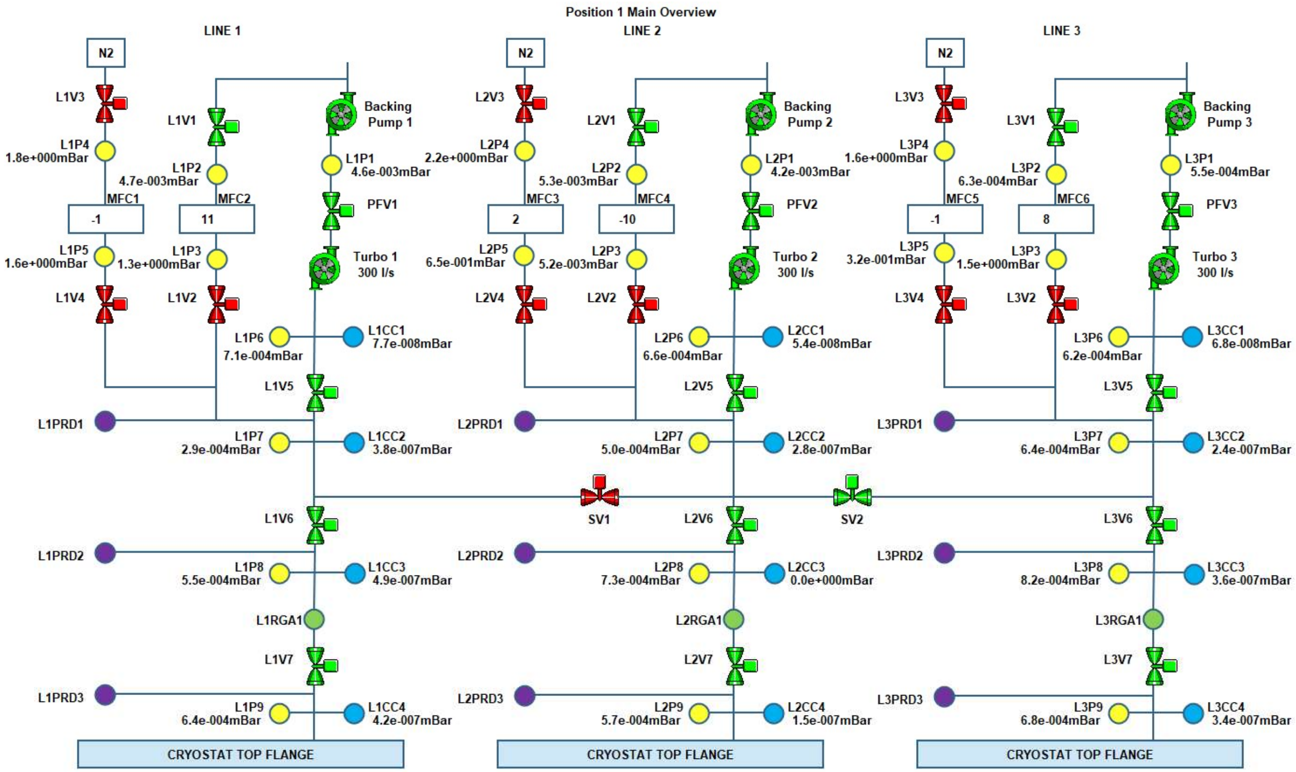
The UHV System

3 Individual UHV lines

Operating down within the 10^{-7} mbar range

Cavities are actively pumped during testing

Each line consists of:
1 x Scroll pump
1 x Turbomolecular Pump
1 x Residual Gas Analyser
2 x Mass Flow Control units*



Science and Technology Facilities Council

Science and Technology Facilities Council

11TH VACUUM SYMPOSIUM UK

Radio Frequency & Contamination

Overview of an RF cavity

Think of cavity as a mechanical resonator like a child on a swing

Cavity stores electromagnetic energy in the same way a child stores kinetic energy

Quality Factor or Q is a measure of how well a resonator stores energy

Q=(ώ *Energy stored)/Power Dissipated

If the Q is very high, then when we stop pushing, the child takes a long time to come to a standstill

Superconducting cavities can have Q's over 10,000 million.

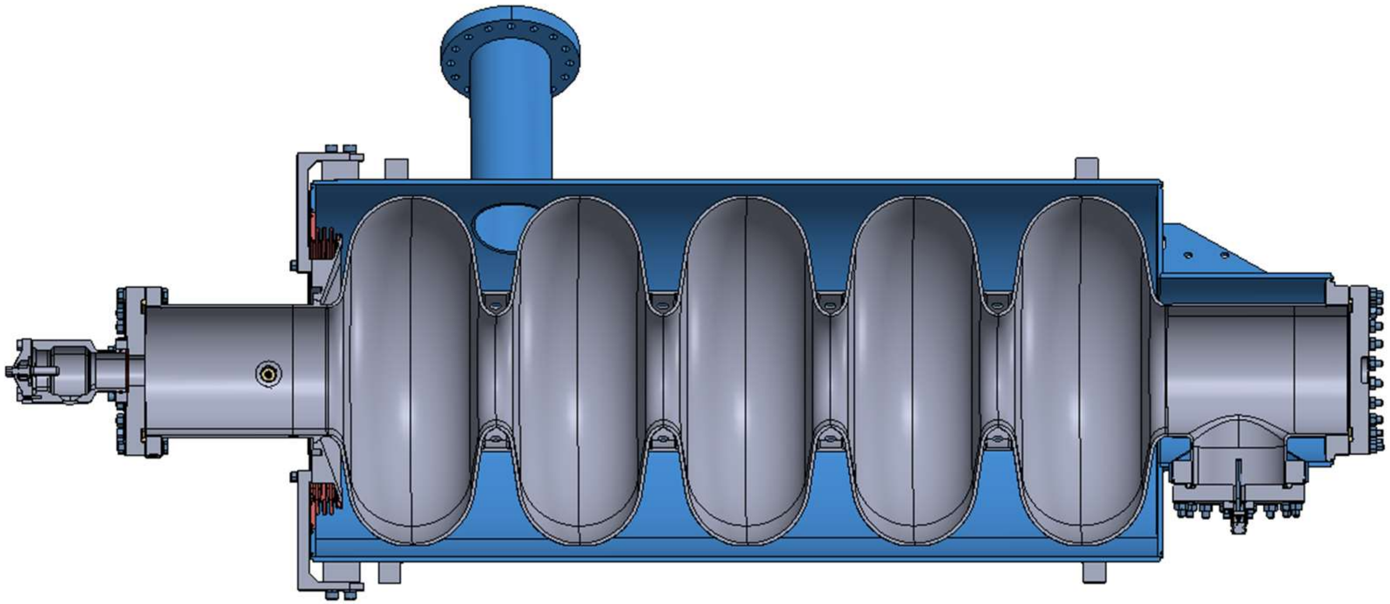
Q of 10,000 Million means the child takes over 300 years to come to a standstill!

Poor child!

Science and Technology Facilities Council

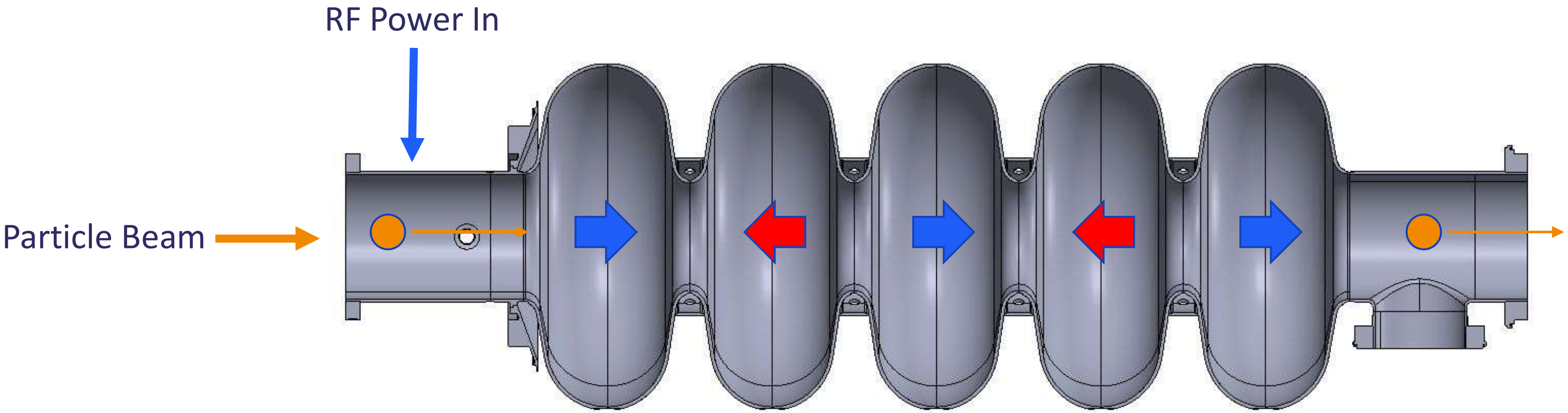
Credit. Dr P. Smith (STFC – RF & Cryogenics Group)

Overview of an RF cavity



Science and Technology Facilities Council

Overview of an RF cavity



Power applied to the cavity walls generates an oscillating electromagnetic field – The child on the swing

Science and Technology Facilities Council

What is "Contamination"

Contamination is particulate, metallic or organic, on the internal surface of the cavity

Surface contamination effects the cavity through:

- increases surface resistance (remember Q) and subsequently power & cooling requirements
- Generates Field Emission in the form of X-Ray radiation

Radiation is the most common cause for rejection of cavities during testing

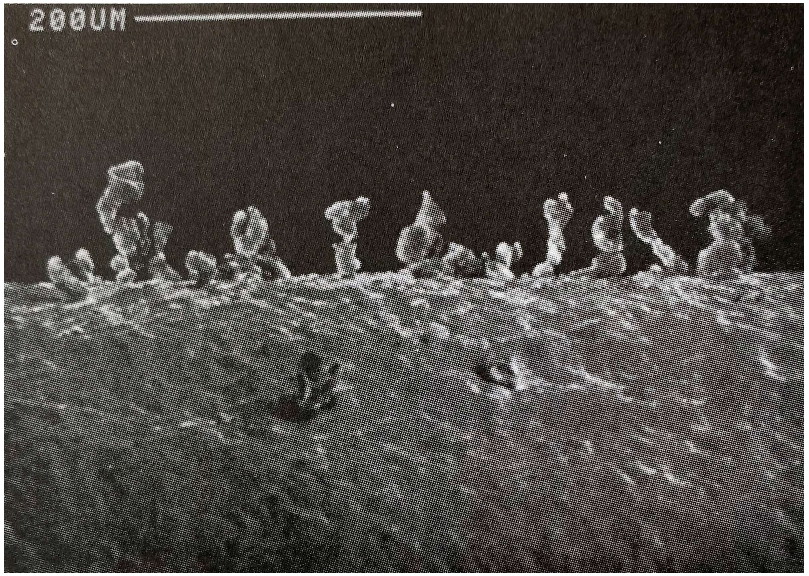


Figure 1. SEM micrograph of iron particulate on a niobium surface (Padamsee, Knobloch and Hays, 1998)

Science and Technology Facilities Council

Basic Mechanics of Field Emission

Conducting & semiconducting contaminants on the surface generates additional electric fields

This charge excites electrons allowing them to escape the surface of the material and into the vacuum space.

When an electron is slowed or impacts a surface (eg tungsten targets) it produces X-rays

On a surface only 10% of 100 particles/cm2 emit – Little is known about why or exactly what surface-contaminant interface makes conductive material emit

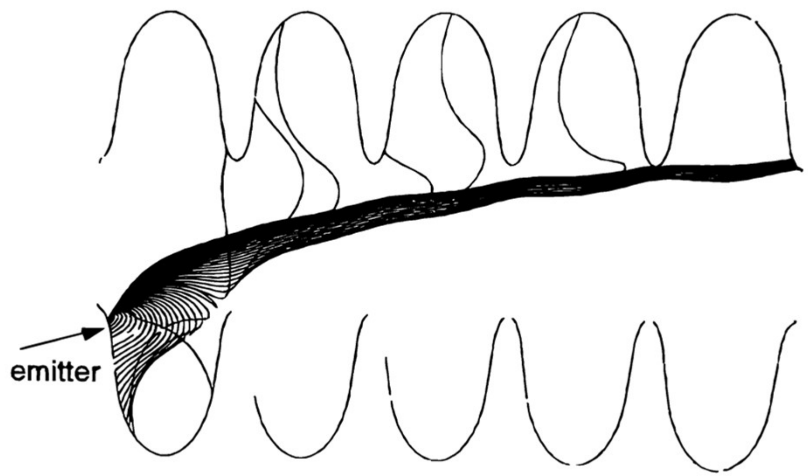


Figure 2. Calculated electron trajectories in a 5 cell cavity (Padamsee, Knobloch and Hays, 1998)

Controlling Particulate

Within the vacuum system and with external measures

UHV system control measures

There are two key sources of particulate contamination for your vacuum chamber:

- **Particulate introduction**
  - From outside sources & atmosphere
  - Venting gases
  - New components mounted to system

- **Particulate migration**
  - Airflow from pumping
  - Turbulent flow from gas injection and venting

Science and Technology Facilities Council

Controlling Particulate Introduction

Particulate can be easily become suspended in gas, from ambient air to injection and venting gases.

Control Measures:

- Inline gas filters – 0.01µm filter
- Particle counting venting gases prior to use
- Only expose vacuum system within cleanroom environment
- Purge with filtered nitrogen if exposed to air

Science and Technology Facilities Council

Controlling Particulate Introduction

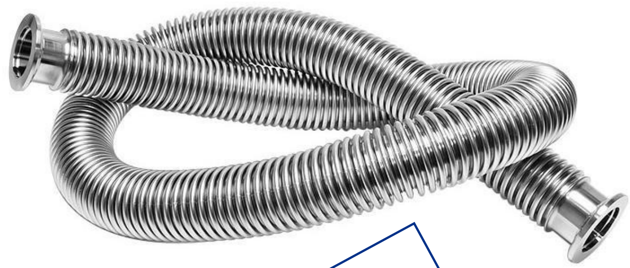
Much like vacuum cleanliness, contamination can be transferred from “dirty components”

Unless manufactured and stored in a cleanroom, components will ALWAYS require cleaning prior to use

Filtered nitrogen blown through an ionising gun should be used to clean

Ionised gas neutralises static charge of particulate

Prior to assembly all items should be particle counted



Think about the components you’re adding!

Science and Technology Facilities Council

Controlling Particulate Migration

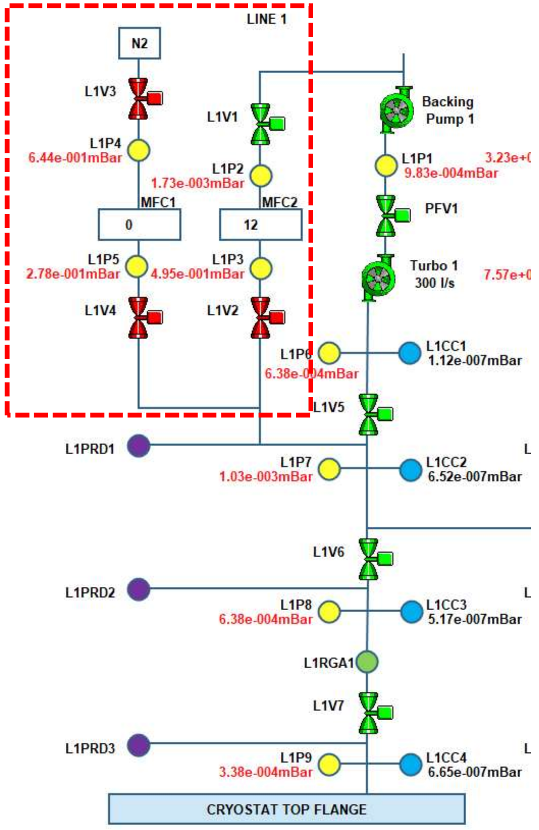
Particulate migration occurs when a turbulent gas flow picks up particulate and transfers it through the flow of gas, IE through pumping, gas injection or venting.

This risk can be mitigated through the use of mass flow controllers.

Flow rates <20 mbar/min can be used to prevent particulate migration through pumping or venting

Both venting and pumping MFC's are used on our ESS system

ALWAYS blow nitrogen through your vent lines for several seconds before connection to a clean system or clean chamber



Science and Technology Facilities Council

Cleanrooms for particulate control

We use both modular cleanrooms and large cleanrooms certified to the ISO class 4 standard

We use a modular cleanroom solution where the connection of UHV line to cavity is made

Initial particle count with a 1 bar purge, 3 x 1 min 50L count

If the count fails, a 3 bar purge for 3 mins is made to clean the line

All purges use filtered nitrogen

Science and Technology Facilities Council

Key Points

- Cleanrooms are essential
- Always purge into a cleanroom
- **Filtered** nitrogen or filtered gasses
- Approach particulate contamination like you do vacuum contamination; gloves, procedures, general cleanliness.
- Vacuum clean does NOT mean particulate clean – further cleaning for particulate is almost always required

Science and Technology Facilities Council

Processing Particulate contamination

HPR & Chemical Polishing

Even with our control measures cavities can fail from contamination from other sources before they arrive with us for this we can take further corrective action:

High Pressure Rinse:
The cavity core is removed in a cleanroom and through the use of high pressure water jets, particulate is cleaned from the cavity surface

Chemical Polishing:
A last resort if HPR did not improve the field emission. Chemical agents are used to remove surface layers of the bulk niobium, also containing the contamination.

Costly and time consuming.

Science and Technology Facilities Council

Science and Technology Facilities Council

Questions?

Science and Technology Facilities Council

Thank you

Science and Technology Facilities Council @STFC_matters Science and Technology Facilities Council

References

Padamsee, H., Knobloch, J. and Hays, T., 1998. *RF superconductivity for accelerators*.

Science and Technology Facilities Council

Airborne Particulate Cleanliness Classes (by cubic meter):

CLASS	Number of Particles per Cubic Meter by Micrometer Size					
	0.1 micron	0.2 micron	0.3 micron	0.5 micron	1 micron	5 microns
ISO1	10	2				
ISO2	100	24	10	4		
ISO3	1,000	237	102	35	8	
ISO4	10,000	2,370	1,020	352	83	
ISO5	100,000	23,700	10,200	3,520	832	29
ISO6	1,000,000	237,000	102,000	35,200	8,320	293
ISO7				352,000	83,200	2,930
ISO8				3,520,000	832,000	29,300
ISO9				35,200,000	8,320,000	293,000

Table 2: Selected airborne particulate cleanliness classes for cleanrooms and clean zones. Classification Parameters from ISO 14644-1.

ISO 14644-1 Cleanroom Standards
In 1999 Cleanrooms and associated controlled environments-Part 1: Certification of Air Cleanliness was created to replace the old Federal Standard 209-E. Within this document the various classification systems are based upon the requirements for counts associated with non-viable particulates. The limits stated in this document are depicted in Table 1.

Learn more about cleanroom-related ISO standards:

ISO 14644-1:2015
Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness by particle concentration

ISO 14644-2:2015
Cleanrooms and associated controlled environments — Part 2: Monitoring to provide evidence of cleanroom performance related to air cleanliness by particle concentration