Vacuum Processing and Control on COSY Beam Lines

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1. INTRODUCTION

The complet COSY-systems consists out of the Injection Beam Line, the COSY Beam Line Ring and the Extraction Beam Line System, distributing the extracted beam to three different locations for experiments.

The actual status shows the Injection Beam Line being in commissioning. The Extraction Beam Lines are in construction, so mounting will start this year in may. The COSY Beam Line Ring is mounted up for more than 95 %, and all beam chambers are ready for mounting at the site /1/. Heater and vacuum control systems as well as vacuum pumps, gauges and heater jackets are installed, cabled and mainly commissioned.

The vacuum chambers are general manufactured from steel typ SS316LN ESR (DIN 1.4429 ESU), except of for three extra wide chambers with tangential extensions for special use. These extra wide and bended chambers had to be constructed out of Inconel 625 and were welded by laser beam technic instead of the normal TIG-welding. All vacuum chambers are hydrogen annealed by use of vacuum furnaces.

Every hardware component was checked in a separate test field by a special acceptance-working group before mounting in the COSY-system.

2. CALCULATIONS OF PRESSURE PROFILE

Overview

To predict the pressure distribution in the COSY vacuum chambers a suitable software was developed: the interactive computer code *Netzwerk* generates a mathematical model of the vacuum system in analogy to an electrical network of direct current. The resultant equations system can be solved by the program code *Vakuspek*. The results form the partial pressure on the net nodes in equilibrium between the surface desorption rates and the pumping speeds of the vacuum pumps.

Preprocessing

First, the molecular conductances of the system parts must be determined. For components of relatively simple geometry (e.g. cylindrical tubes) the Knudsen-Dushman-formula may be applicated in connection with published correcting factors. For more complicated geometries a Monte-Carlo-Simulation of the molecular flow with the program code *Molecular Conductance* from A.Pace (CERN) is made on a powerfull vector computer (CRAY).

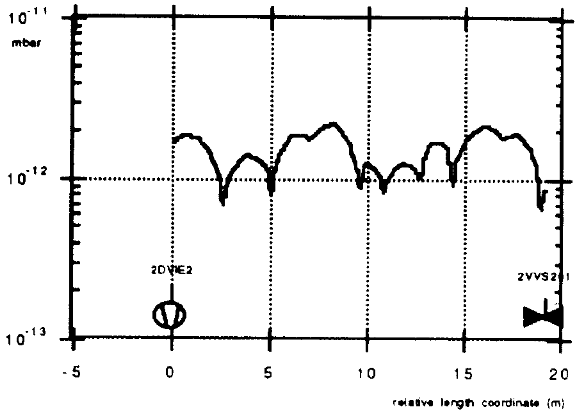

Figure 1

Accuracy

The values of molecular conductance can be determined with high accuracy by the described programs respectively formulas and are easy to convert for arbitrary gas components.

The gas dependency of pumping speed of the vacuum pumps is generally delivered by the producer and is based on experimental results.

The main influence of error comes from the desorption rates. They are get by global measurements on the applied materials (NiCr-steels) which are specially treated (annealing). The gas dependency of the desorption rates can be gained by analysis of the residual gas spectra.

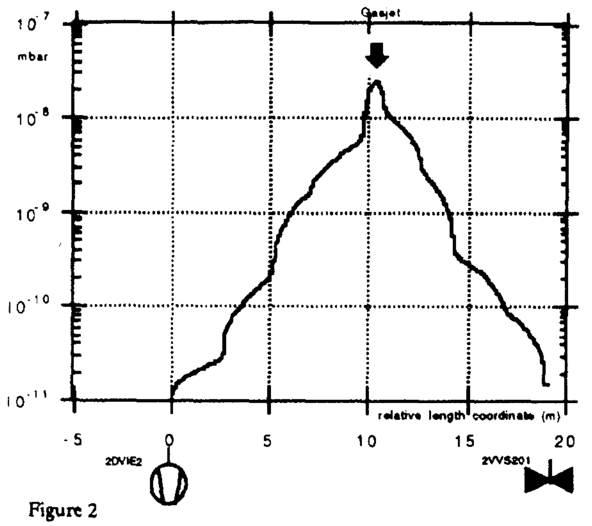

Figure 2

Example

The pressure distribution of the COSY ring on the "target station 2" was studied. Figure 1 shows the equilibrium pressure of the first stage (projected stochastic cooler replaced by a dummy tube of 150 mm diameter). The section was modelled and analysed between the Viewer 2DVIE2 (position 20.58 m) and the valve 2VVS201 (position 1.38 m). Only hydrogen partial pressure is outlined, because the other residual gases are neglectable. On the regarded section we find 22 vacuum pumps recognizable by the relatives minima in the diagram.

Figure 2 gives the result of the second stage. In this case an additional gas jet target is invoked at beamline position 10.0 m. A hydrogen gas stream of $1 \cdot 10^{15}$ molecules/sec enters the vacuum chamber. This facility is theoretically handled in the manner of a desorption rate and corresponds to a gas throughput of $4.14 \cdot 10^{-5}$ mbar ltr/sec. The pressure increases up to 10^{-8} mbar and influences considerably the adjacent sections. Not before a distance of 10 meters on both sides of the gas jet the pressure level is decreased on 10^{-11} mbar.

3. VACUUM CONTROLSYSTEM

From the three parts of COSY, as there are Injektion, Storage- Ring and Extraction, in this paper is presented mainly the vacuumsystem of the COSY-Ring.

The design pressure of $< 10^{-10}$ mbar requires baking out the entire ring at 300 °C. All over the ring are mounted ca. 1600 electrical heating jackets.

Dividing the ring by gate valves into 8 sections and restriction to heating only one section at a time reduces the effort for the heating control system. Additional valves at the target places give a total of 12 separatly pumped sections.

The typical vacuum equipment of one section is shown in fig. 3.

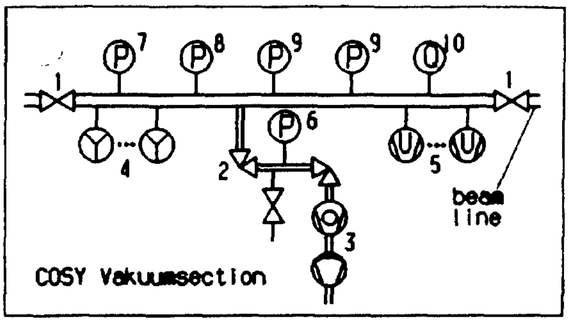

Figure 3

Valves and Vacuumpumps

1. Slide valves, metallic sealed, bakeable
2. Valve, metallic sealed, bakeable
3. Turbomolekular pump, "wide range"-version, with membrane rough pump for nearly hydrocarbon-free pumping
4. Ion sputter pumps (ca. 10 units per section) Power supply from crates each having 7 independently switchable outputs. Supply voltage 6kV, DC
5. Titanium sublimation pumps (ca. 15 units per section). Up to 10 pumps are fed by one powersupply. A transformer, delivering up to 50 Amps, is fitted close to the vacuum pumps and is switched serially to one of the Titanium filaments by relais. At the assigned control unit one of three preadjusted current values can be selected.

Pressure Measurement

6. Pirani gage, $10^{3}...10^{-3}$ mbar, non bakeable version
7. Pirani gage, $10^{3}...10^{-3}$ mbar, bakeable version
8. Penning gage (cold catode ionisation gage, "inverted magnetron"), $10^{-3}...10^{-7}$ mbar
9. Penning (Same gages like 8.), $10^{-7}...10^{-11}$ mbar
10. Quadrupol mass spectrometer

At each vacuum section the first Penning gage is switched on automatically at $6 \cdot 10^{-3}$ mbar, controlled by the Pirani gage. The other Penning gages go into operation at 10^{-7} mbar. By these methode the gages are protected from impurities as far as possible, and we expect high accuracy of measurement in the range of 10^{-10} mbar.

Requirements on the Controlsystem

1. During the bake-out process the temperature of all components in the vacuum section has to be rised ore reduced simultaneously with an adjustable maximum gradient of 50 K/h.

2. In order to make possible degassing of components during the bakeout procedure, all power and measuring cables have to withstand the high temperature.
3. The request for free accessability of the most control components for reason of maintenance even during operation of the beam leads to installation of the controlsystem outside the COSY-ring.

Realisation

Programmable controllers, type SIMATIC S5-135U, are used. All data transfers between the different crates and the two operator consols are handled by one master-PC, which is linked by Ethernet-bus with two PC-crates of the bakeout system and the two crates of the vacuum control.
All critical parameters are supervised and trigger control commands and/or fault indications. Necessary interlocks to other subsystems are hardwired.
As isolating materials for the different connectors and cables were used PEEK, silicon rubber, PTFE or Polyimid.
A data connection to the main controlsystem of COSY is available, but not necessary for operating the vacuum and bakeout system.

Arrangement in the Building

The operator consol with the master-PC, the PC-crates for the vacuum system and 16 cabinets (2 for each section) containing powersupplies and vacuummeters are placed at a platform besides the storage ring. The length of cables reach up to 130 m.
Two mobile cabinets contain the PC's for the bakeout system with 208 temperature control loops and solid-state relais. They are placed in the center of the storage ring, close to the section to be heated (fig. 4).

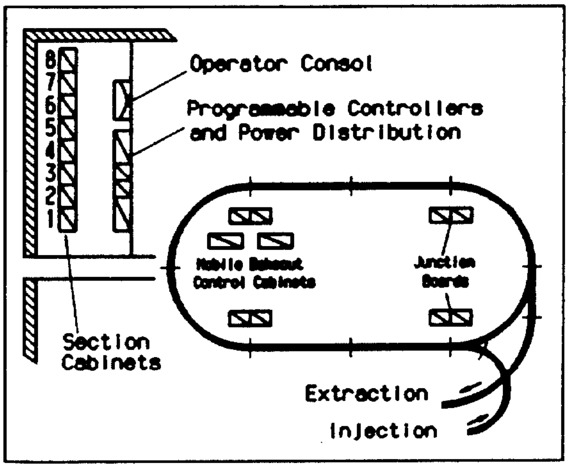

Figure 4

4. Summary

Layout and design of the different components for the COSY-vacuumsystem /2/, /3/ has been proven as satisfying on all aspects of the technical realisation as well as of fullfilling the requirements of an ultra high vacuumsystem. The application of programmable logic controllers for the bake-out system and the vacuum generating system as subsystems to the COSY main control led to a very handy operation, especially during the commissioning phase.
For the pre-investigation of the influence of more complex structural parts to the pressure distribution in the beam lines a suitable software was developed.

5. References

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