Simulation of Vacuum in the Cluster-Jet Line

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A widely used method for pressure-simulation in a high-vacuum system is the calculation of an equivalent electric circuit according to *Kirchhoff's circuit laws.*

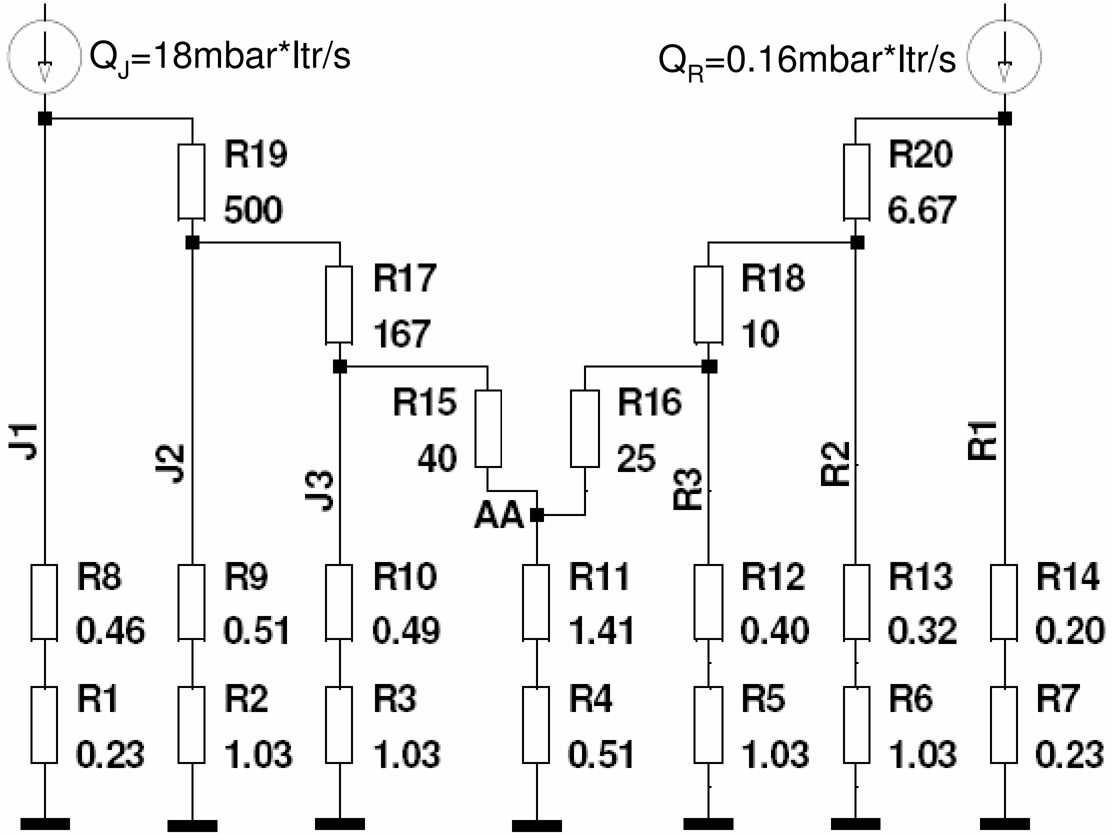
Pumps can be regarded as resistors where one end – the exit – is set to ground. The value of such a resistor is the inverse of the pumping power.

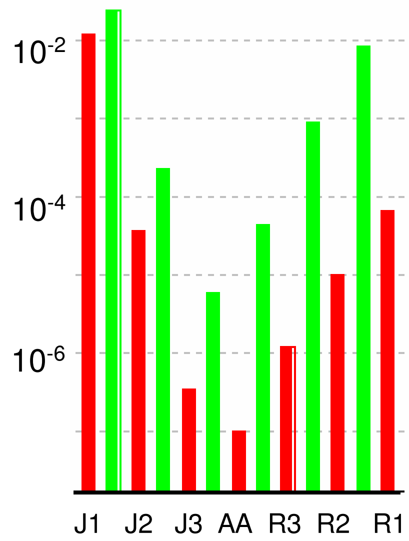
electric circuit	high-vacuum circuit
voltage	pressure
current	gas flow
resistor	flow resistance
capacitor (for transient analysis)	p*V

Circuit simulation of Cluster-Jet

Example: setup built by INFN Genoa and Fermilab for E835

Values taken from preprint *FERMILAB-Pub-97-274-E.* Nozzle fed with hydrogen at p = 7.5 bar and T = 37 K. Resistors R1 to R7 represent the pumps in the respective stages (values in s/m3). R8 to R14 indicate the reduction in pumping speed due to spatial constraints. R15 to R20 are the flow resistances between the stages. Out-gassing of walls and interaction between clusters and background gas are neglected.





red bars: pressure / [mbar] in respective stages

green bars: gas flow / [mbar*ltr/s] between stages (at room temperature)

Pressure at Panda Cluster-Jet, Raw Guess

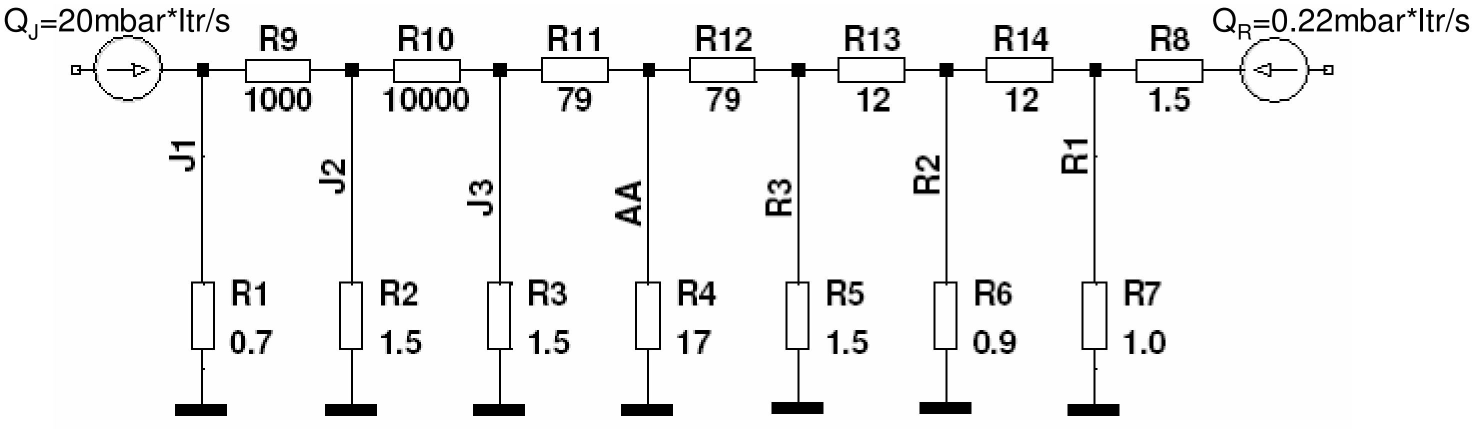
A lot of the following assumptions are based on the diploma theses of Jennyfer Otte and Tobias Rausmann, WWU Münster.

Resistors R1 to R7 represent the effective pumping in the respective stages (values in s/m^3) of the present Panda design. R8 gives consideration to the fact that the cluster-jet can be dumped directly into the blades of the last turbo-pump (R7, in the beam-dump stage). R4 represents the effective pumping in the beam line (about 59 ltr/s).

R9 to R14 are the flow resistances between the stages. R9 represents a skimmer, R10 a collimator with a smaller diameter of 0.53mm. R11 to R14 are calculated from the diameters and lengths of the tubes between the stages. These values are not quite accurate since the flow characteristics at the exits of the tubes are neglected. For a raw guess, however, they should be sufficient. R11 and R12 represent the relatively long and narrow tubes (diameter 20mm) next to the IP.

In order to achieve an atom density of $n=2*10^{14}cm^{-3}$, a gas load of Q_R=0.22mbar*ltr/s (at room temperature) has to be removed by the turbo pumps in the dump stage (assumption: T_0=28K, p_0=18bar, spot diameter 1cm, jet velocity v=700m/s, $Q_R=n*1.67*10^{-27}kg*A*v*R_s*T_r$, with R_s*T_r=1.208MJ/kg).

The value for Q_J is assumed to be 1200 sccm (*standard cubic centimeter per minute*). This is a rough guess. But this value does not directly have a big influence on the vacuum at the IP (AA), as will be shown.



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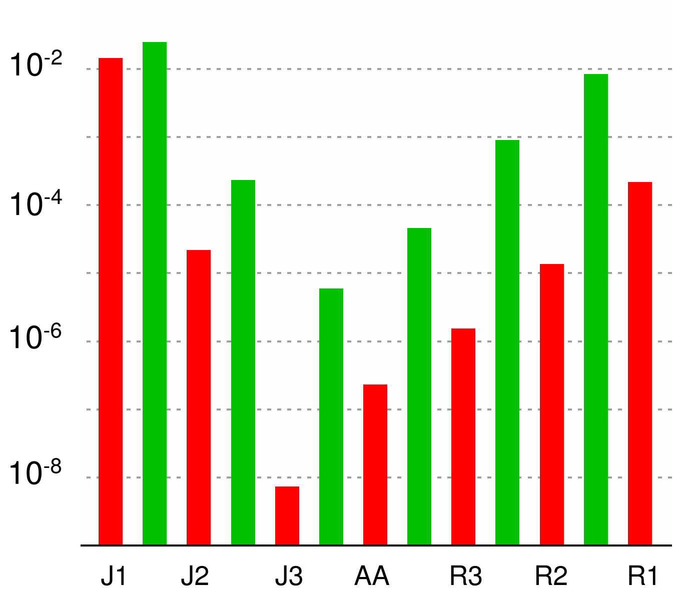

red bars: pressure / [mbar] in respective stages
green bars: gas flow / [mbar*ltr/s] between stages

Conclusion:

A pressure below 10^{-6}mbar can be achieved in the IP region.

Although the gas load in the skimmer stage is usually 2 orders of magnitude higher than in the dump stage, the latter one contributes more to the background gas in the IP region since the flow resistances (R9,R10 compared to R13,R14) are more than 2 orders of magnitude apart.

Remarks on neglected gas loads

• Out-gassing of the tube walls which cannot be baked:

For a very clean metallic surface a rate in the order of 10^{-6}mbar*ltr/(s^1*m^2) can be expected after a pumping time of 10 hours (100 hours for a normal metallic surface)*. The tube wall area near the IP is far below $1m^2$, so its influence on the background gas in that region is rather small.

• Leaks in the sealing:

At the outer diameter of the central tracker the connection between the separate target tubes has to be sealed by a good gasket. This region is hard to access, therefore the sealing might not be very good. But even a leak rate as big as 10^{-4}mbar*ltr/s would hardly increase the amount of background gas in the IP region.

* M. Wutz, H. Adam, and W. Walcher. Theorie und Praxis der Vakuumtechnik. Vieweg-Verlag, 1988