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STEP RESPONSE OF VACUUM SENSORS – A PRELIMINARY STUDY

Fredrik Arrhén

SP Technical Research Institute of Sweden, Boras, Sweden, fredrik.arrhen@sp.se

Abstract: The development of a system for determining step response of total vacuum gauges is described as well as results for some typical vacuum gauges. The system is mainly suitable for steps from atmospheric pressure down to around 50 Pa. Step response times reached with the system are (with reasonable sizes of DUT internal volumes) about 20ms.

Keywords: Vacuum gauge, dynamic pressure, step response

1. INTRODUCTION

In many applications the time for evacuation of atmospheric pressure down to suitable process vacuum is essential. The time needed from start of pumping until opening of valves for turbo pumping and/or start of processing is many times one of the limits for process time. The equipment was set up as a preliminary test to evaluate the limiting parameters for such a system.

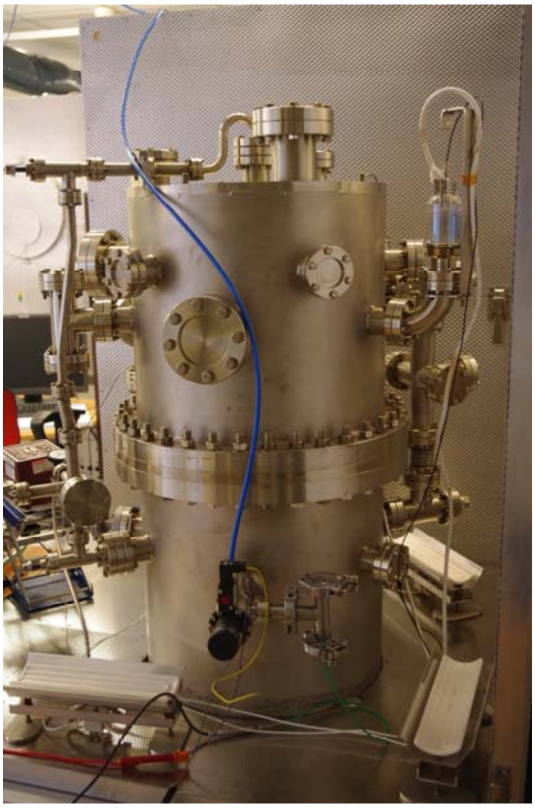
3. SYSTEM DESCRIPTION

In principle the system consists of a large expansion volume, a valve and a small test volume to which the reference gauge and the device under test (DUT) is connected. The expansion volume is evacuated while the test volume is at atmospheric pressure. The valve is opened and the gas is expanded. The expansion volume can be either closed or continuously pumped during the expansion.

In the present system the expansion volume is about 130 liters, the test volume (without DUT) less than 0.04 liters and the volume ratio is about 3500. There are also a CDG, a pirani sensor and an ion gauge mounted on the expansion volume to monitor the vacuum level. The system is pumped by a turbo pump with the capacity of 1000 liter/s and a roughening pump.

The test volume consists of a T-piece on which a reference sensor is mounted. Nearby the reference sensor is the mounting flange for the device under test (DUT).

The reference sensor is a piezoresistive sensor which has a resonance frequency well above 100kHz. The DUT and the reference sensor are mounted in such a way that the gas path between the valve and the sensors are equal.



Picture 1, Test system

4. SIGNAL CONDITION

For signal condition and aqusition a PXI system with multiple inputs was used. The sampling frequency was for all presented tests 20kHz which was considered well above the demands. The system uses simultaneous sampling for all used channels. The evaluation was made using FlexPro.

5. SYSTEM TEST RESULTS

Initially some results were made to see the effect of the test volume on the step response. These were made with and without the T-piece mounted. Unfortunately there are no conductance data available for the valve. Since the final pressure during all test are between 10Pa and 100Pa we have actually not reached below transition region and the conductance should not be any problem.

All tests supported this idea. As seen from fig 1, the step time as measured by the reference sensor is around 0.03s.

This time is not significantly affected by the volume added to the test volume by the DUTs.

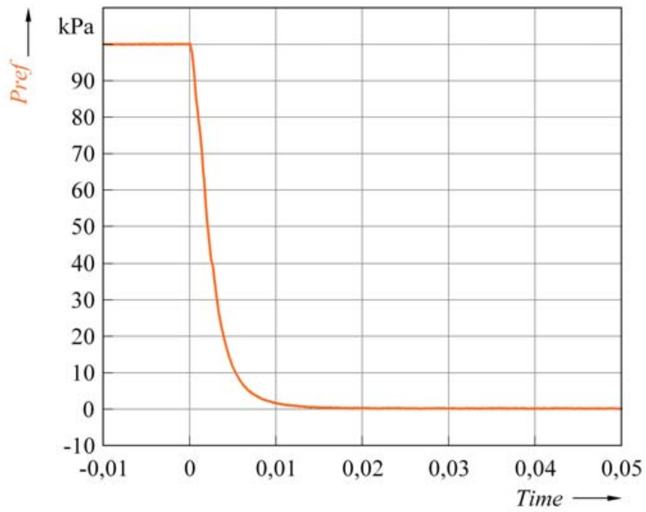


Fig 1. System Step response

6. SAMPLE DUT RESULTS

A few different DUTs was tested to examine their performance and also compare with their specifications. First an active pirani gauge, used in conjunction with a signal conditioner was tested. The specified response time was “fast”. According to the test the response time is about 0.2s, see figure 2 below.

It is also very clear that it has an internal processing time of about 0.05s, a typical behavior for sensors with digital internal signal conditioning. Also the small peaks with an interval of about 50ms in the curve indicate this processing time.

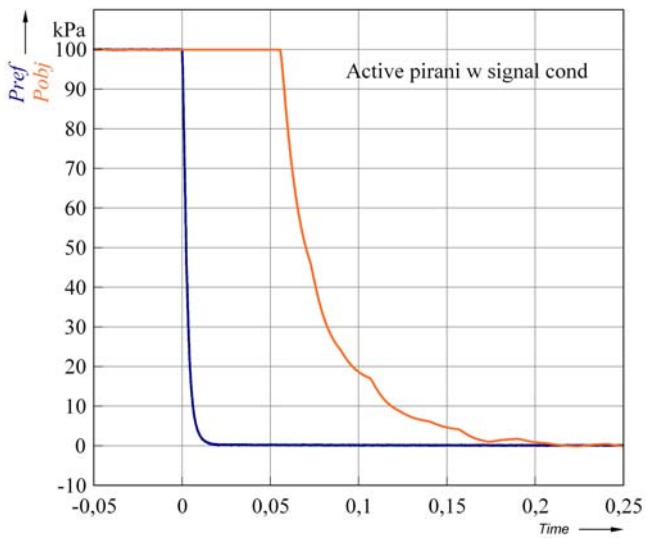


Fig 2. Response time for active pirani

Another sensor tested was an active ceramic CDG. In the specifications the response time was said to be 30ms. On this sensor it was possible to measure either the signal after conditioner or directly from the sensor. These both measurements showed similar behavior as the previous but with faster response. In fig 3 the delay is about 20ms and the signal quite nice looking even if the total time until it reaches a reasonable level is almost 75ms compared to the specified 20ms.

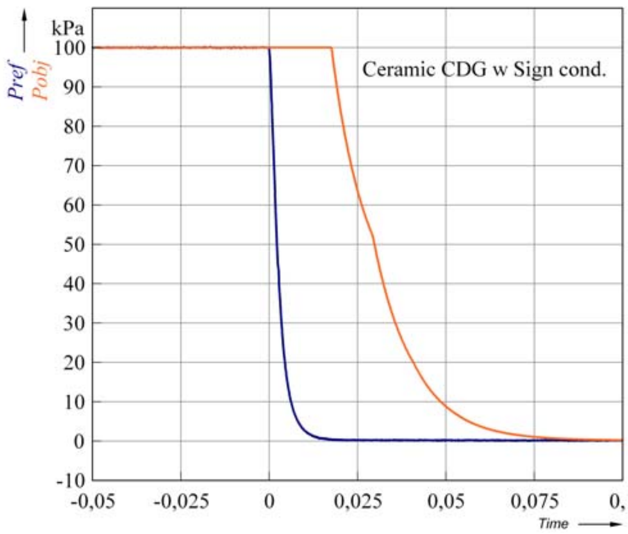


Fig 3. CDG with signal conditioner

If we compare this output with the raw signal from the sensor directly the digital output becomes very clear. The output is changed stepwise after each processing cycle and the signal does not look as nice as after the conditioner.

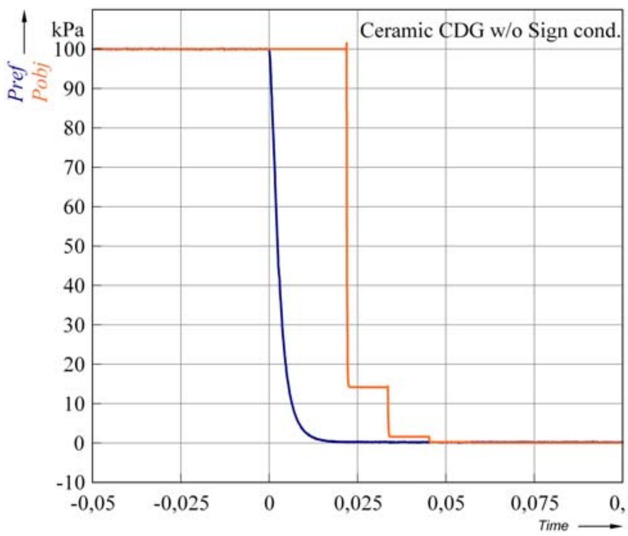


Fig 3. CDG without signal conditioner

7. DISCUSSION

These tests show a big need for further investigation of the dynamic behavior of vacuum gauges. It is both a question of measurement or test setup but also a question of how to specify results and performance of sensors. Sensor characteristics like in fig 3 can hardly be used in feedback loops without special considerations for the stepwise behavior. On the other hand, using signal condition like in fig 3 gives a delayed response which might be too slow for some processes.

The results also points out the problem with generating step responses in the vacuum range. To generate steps from 100kPa down to 100Pa and step times well below 0.1 second is not a problem but to reach further down the conductance of the vale is a big issue. Also the expansion volume becomes a major problem. To reach step sizes below the transition region the expansion volume has to be at least 10 times bigger than the one here used if the step is to start at atmospheric pressure. Even if the system is continuously being pumped, a pump with reasonable size cannot evacuate fast enough. A solution might be to measure the response in several steps, for example start pressure 100kPa to 100Pa, next step 1kPa down to 1Pa and so on. This will give other problems like reducing hysteresis and similar effects of the sensor.

For pressures well below 100Pa the conductance of the valve will be a major issue. Unfortunately a large-area valve with high conductance will also mean relatively large volume on the test side giving slower response.

On the other hand, the same problems arise when using these sensors in industrial processes. It is not probable that the industrial applications reach further than in the laboratory tests showed and planned.

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