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TadiVac2000 Analysis Report For Chip[1] Semiconductor CVD1 / CVD2

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[1] Although this report was originally prepared for a real customer, the name Chip semiconductor was selected as a generic and symbolic one.

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Purpose and scope

Tadin was asked by Chip Semiconductor Inc. to analyze process data captured using TaidVac2000 Process and Machine Analyzer to identify the sources for process and machine reliability problems of Chip's CVD1 machine. The dominant nature of the problems was said to be unpredicted high particle counts.
Tadin performed the tests and the analysis and made certain recommendations that are detailed in this report.
In addition to the major particle problem, a number of other machine and process problems were detected, analyzed and recommendations were made.
This report summarizes the work done and the recommendations made.
In addition to CVD1, data collection and tests were carried on CVD2. There are therefore also some comments made regarding CVD2.

General

This analysis uses data recorded by the TadiVac2000 installed on CVD1 at Chip Semiconductor as well as some metrology information that was provided by Chip in a printed list format. We looked into the data to find abnormalities that could be related to the particle counts and that may have caused the particle problem.
We also found some other parameters that can be used to further improve the machine performance, such as bad MFC, control valve drift, poor Load-lock pumping, wafer-arm misalignment, etc.

Important note regarding the data

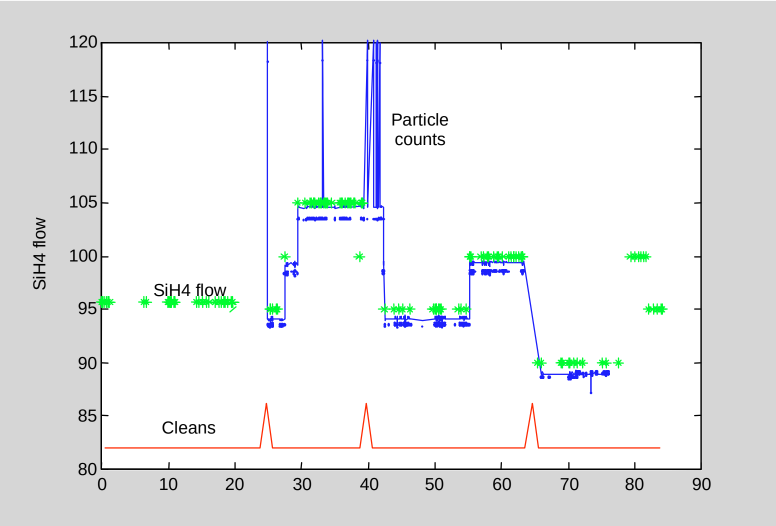
The metrology information such as particle counts, process quality, growth-rate, yields, etc. was used to the best possible extent.
The availability of such information enables to better detect trends and other changes that will help to judge the affect of machine parameters on the process yields.

Methods used for analysis

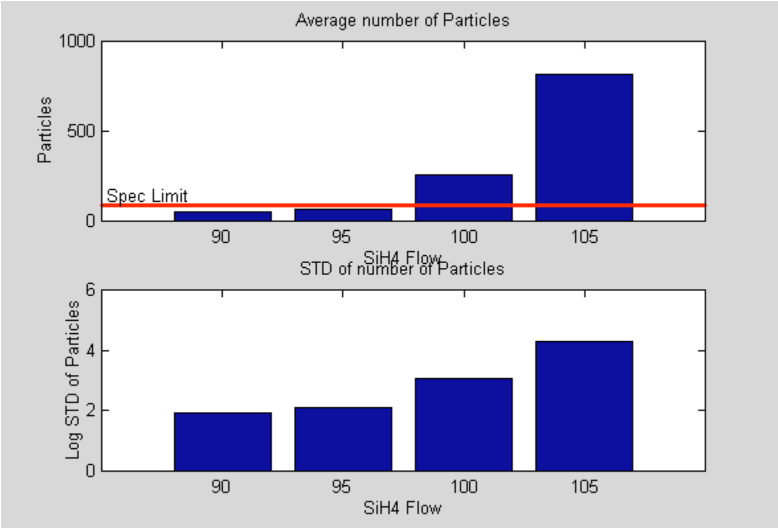
1. The measurable process parameters' magnitudes and trends Vs. the given data time were extracted to identify long-term non-consistence, unstable or abnormal behavior.
2. The dominant unstable parameter (Silane, SiH_4 in this case) was correlated to the particle counts and analyzed.
   (The Silane flow changes were said to have been done manually in an attempt to improve uniformity.)
3. Each parameter was examined carefully and was compared to expected good-process both in the time domain and machine-to-machine.

Results and conclusions

As can be seen on the following graphs, the critical parameter with high correlation to particle-count is the Silane flow-rate. As long as the Silane flow is maintained below 95 SCCM, the particle count is kept under the spec limit. When the flow exceeds 95 SCCM a rapid increase in the particle count is detected. Above 105 SCCM the particle count is occasionally extremely high (More than 10 times the spec limit) and other machine's parameters such as pressure control become highly unstable. Furthermore, it can be seen on most trends that in the period between Feb 5 and Feb. 16 the Silane flow was kept under 90 SCCM (Actually, about 87) the particle counts where very low and ALL parameters where very stable.
See the pressure control valve, the pressure, the RF power, etc.



Silane flow correlated with Particle Counts



Histogram of Particles vs. Silane flow

Conclusions and Recommendations

This report is based on limited metrology information, yet the findings are obvious. Drawing conclusions on the other hand is more difficult because our knowledge of the specific process and yields is limited.
A major question is the reason for the changes in the Silane flow. We have been told that this is done in order to adjust the layer uniformity, but there was no reasonable explanation on how such improvement is achieved.

We can conclude the following:

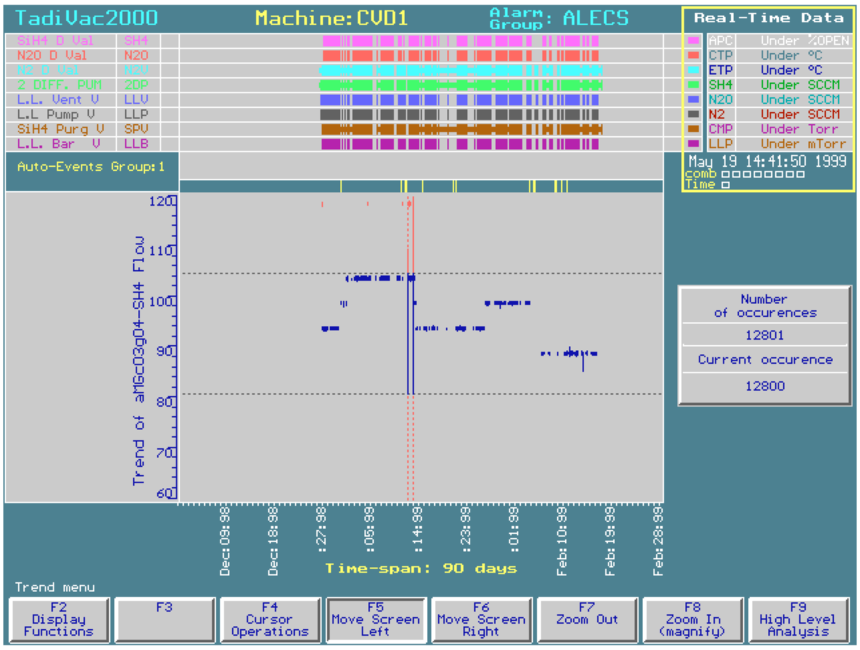
1. The Silane flow-rate is a critical parameter in regards to particle buildup.
2. The Silane flow is set at a critical level with no process latitude. It is recommended that the Silane and N2O flow-rates will be experimented and set to allow for sufficient process latitude.
3. The Silane valve's 'On' time is unstable as can be seen of the Silane Time Trend graph.
4. The particle build-up and the unstable parameters such as pressure and pressure control are suspected to be the result of the chemical reaction of Silane with Oxygen that rapidly converts gas into solid, causing rapid, unpredicted and unstable pressure drops.
5. A leak or insufficient pumping in CVD1 load-lock can be observed. This results in pressure bursts in the chamber that can cause Oxygen (air) in the chamber and particles. (Page #16)
6. In CVD1, an unpredicted opening of the N2 valve or MFC in the middle of the process was observed. It needs to be checked. (Page #12)
7. An arm motor excess current in CVD2 indicates that the arm is probably hitting the inner door. This may cause particles and wafer breakage. Needs to be adjusted. (Page #17)

The checked parameters

Here under are the TadiVac2000 parameter extraction screens. The data was collected in a period of about 2 months using a TadiVac2000. The data analysis and trends were extracted by the use of the TadiVac Trend function.
The TadiVac Trend function is run by first setting up Trend condition for each parameter after which TadiVac automatically searches the historical data and extracts the trends that are displayed and saved to files.
The extracted Trend files can then be exported to other software tools for additional analysis.
The various Trend Conditions setups are shown as TadiVac screens in the appendix at the end of this report.

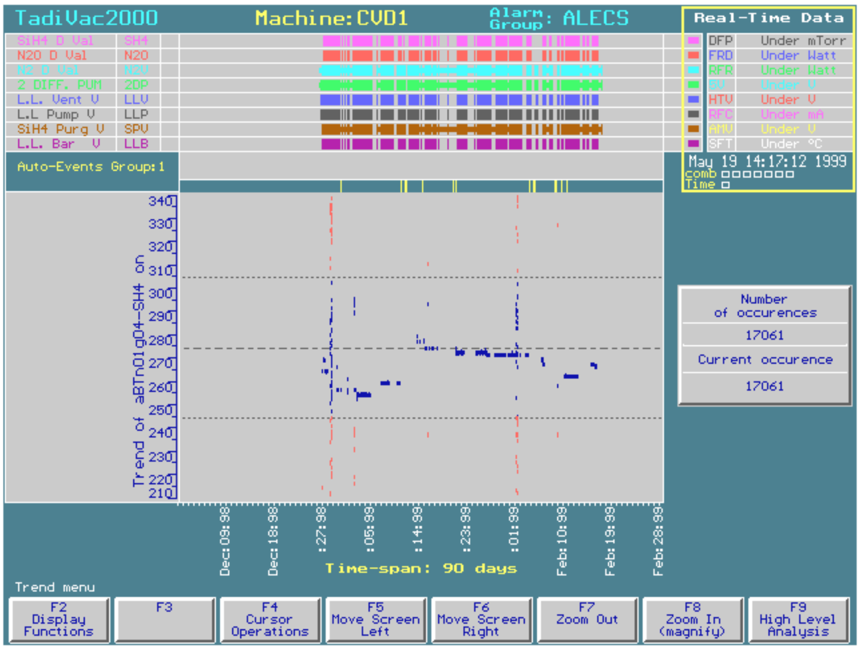
The checked parameters displays

Silane flow parameter trend



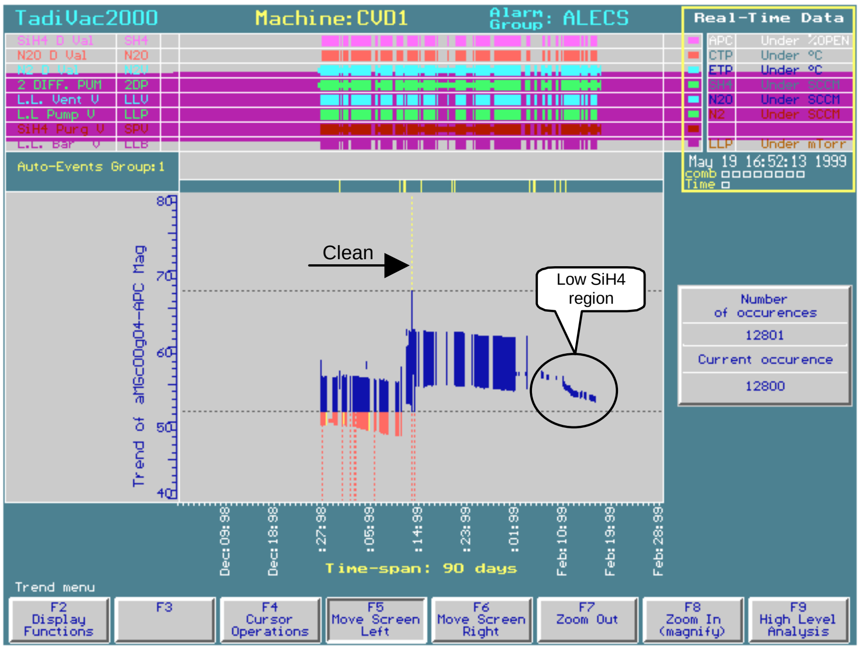
The flow variations were said to be manually set.

Silane 'ON' time parameter trend



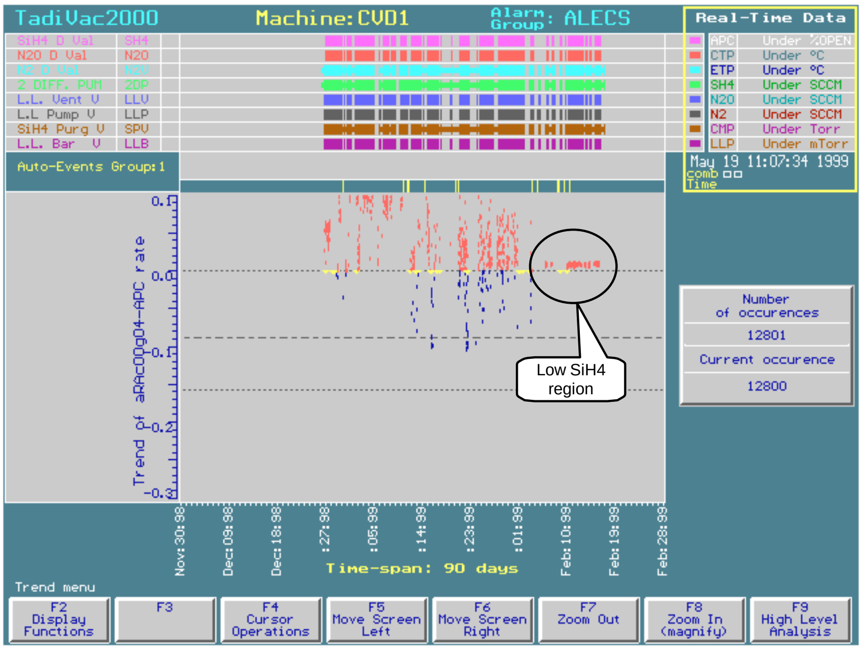
This parameter shows the trend of the Silane valve 'on' time that is very unstable.

APC (Automatic Pressure Control Valve position) vs. time parameter trend



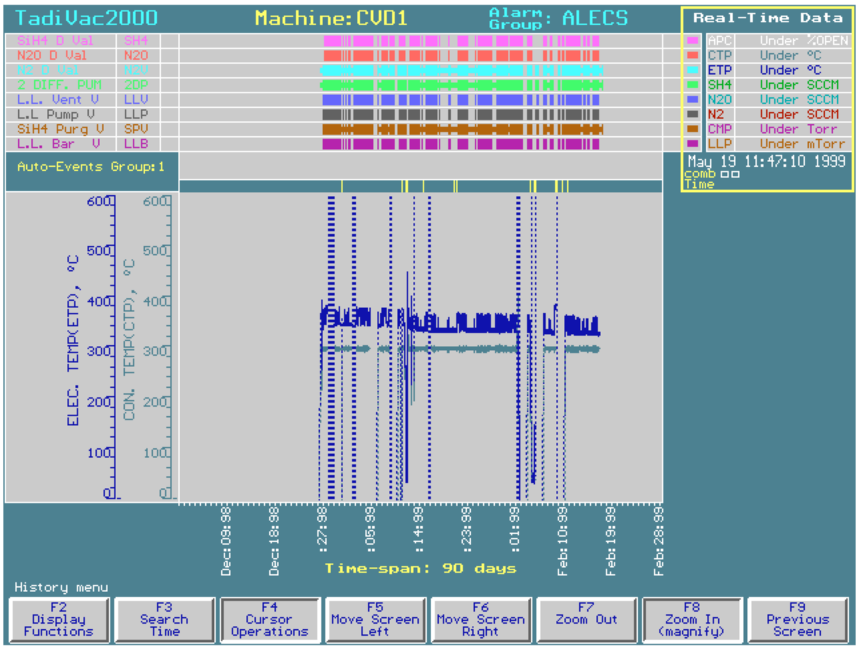
APC Valve position trend. Note trend and clean

APC rate-of-change after SiH4 is applied parameter trend

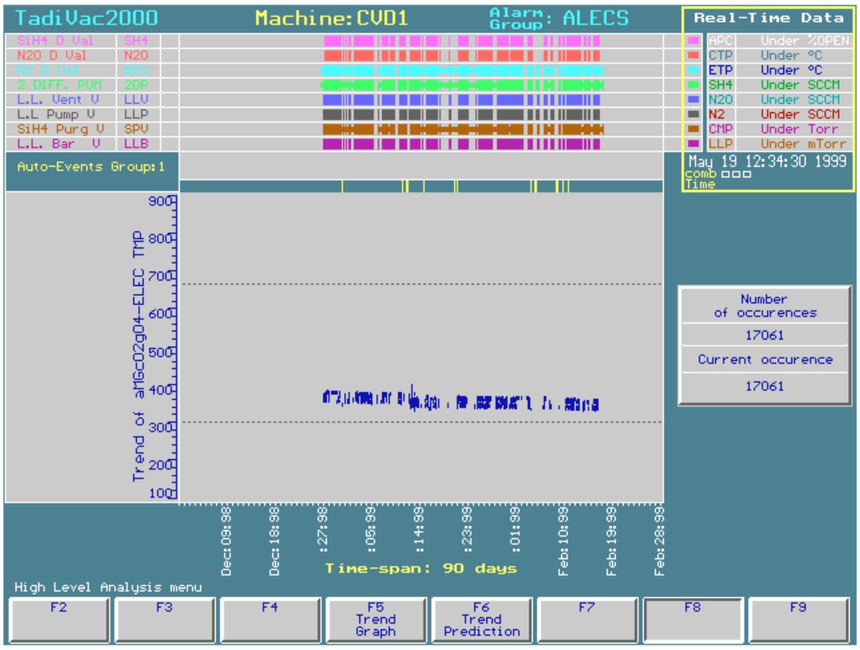


The APC valve rate. Note stability at low SiH4 flow.

Electrode Temperature #1 parameter trend

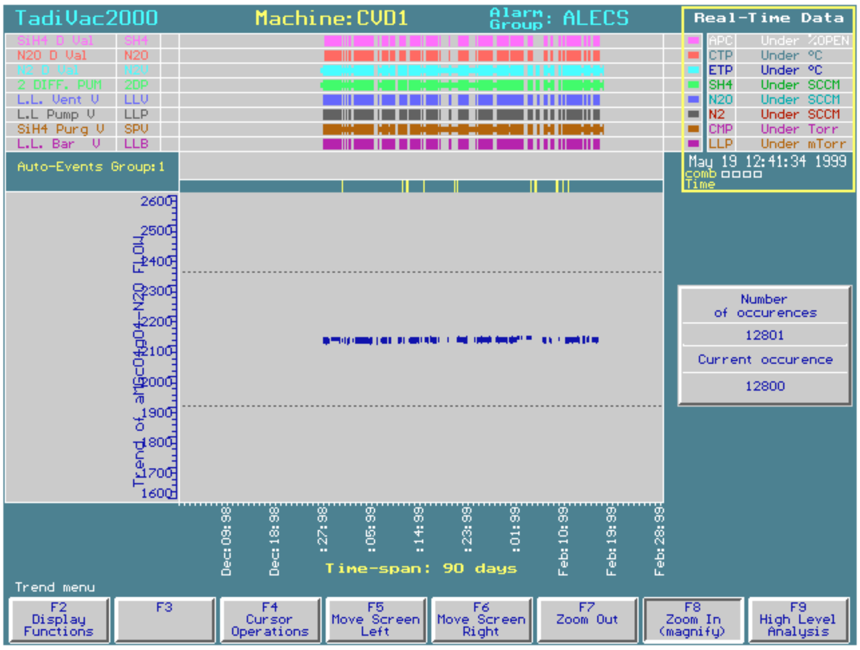


Electrode Temperature #2 parameter trend

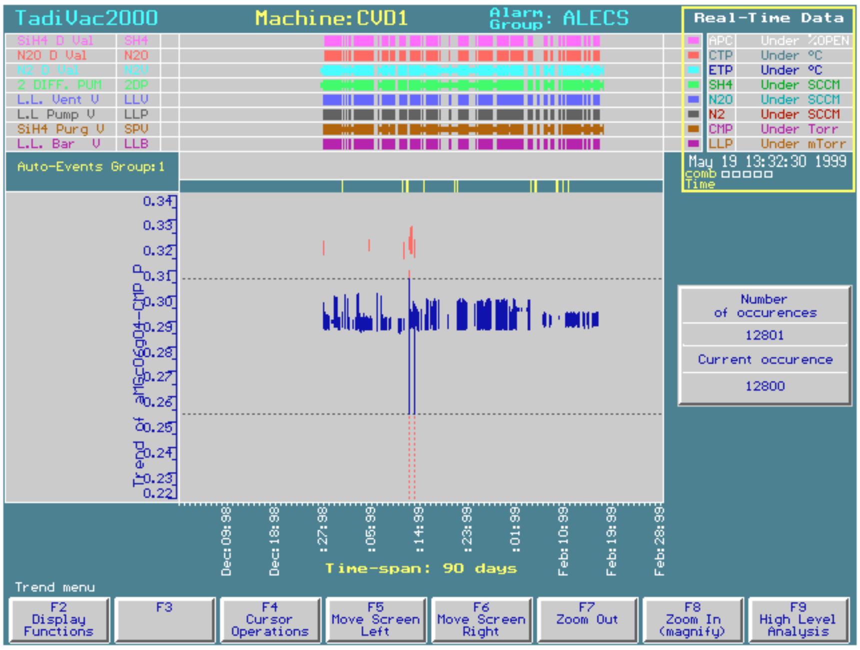


Note slight trend.

N2O flow parameter trend

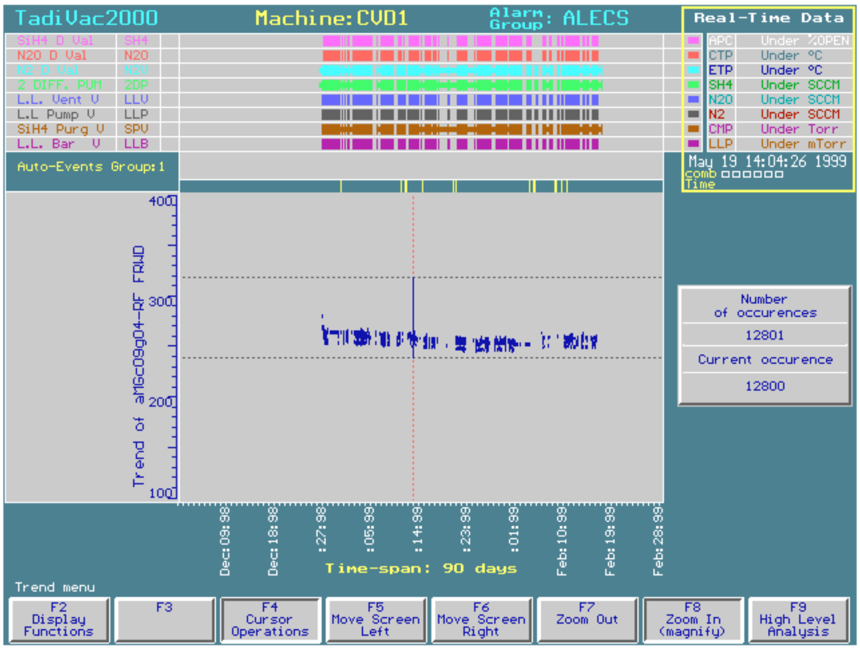


Chamber pressure parameter trend



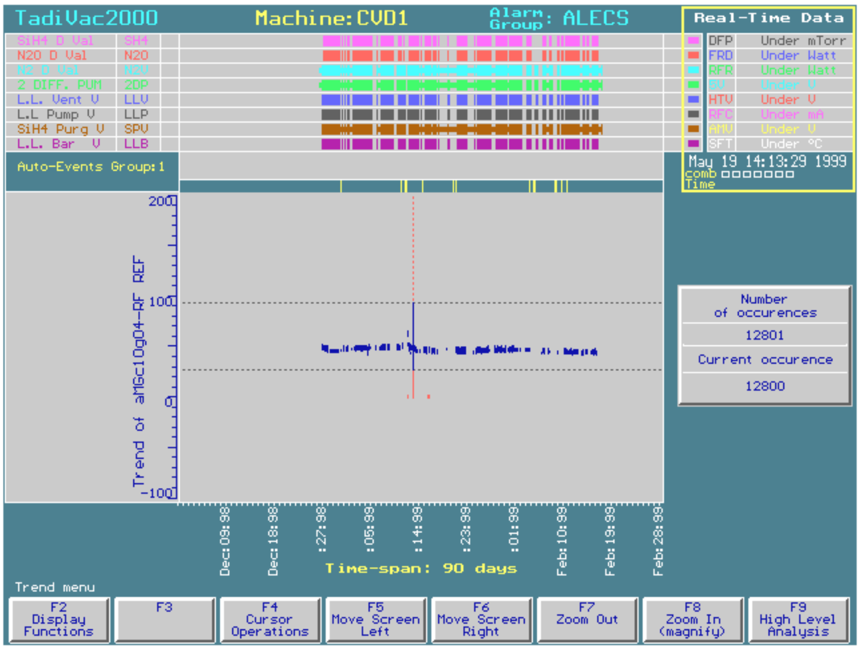
Note: When SiH4 is high, the Pressure has wide range.
At low SiH4 flow the pressure is stable.

RF Forward power parameter trend



Note slight RF power drift.

RF Reflected power parameter trend

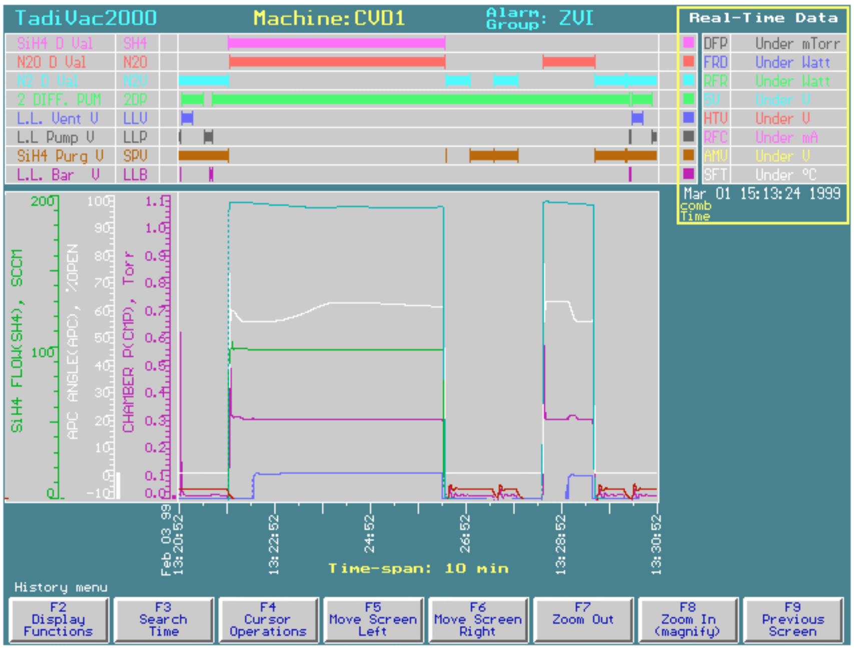


Note: The RF Reflected has some variation correlated to the RF Forward.

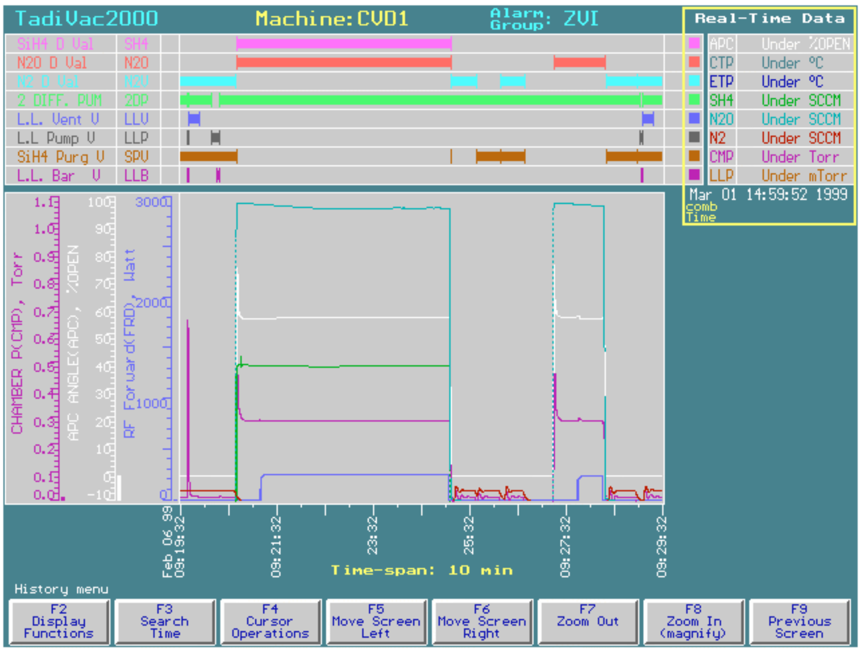
Detailed Process Parameter Analysis

APC Valve

Viewing critical parameters of the process will reveal, lack of repeatability and stability during and in-between the processes.

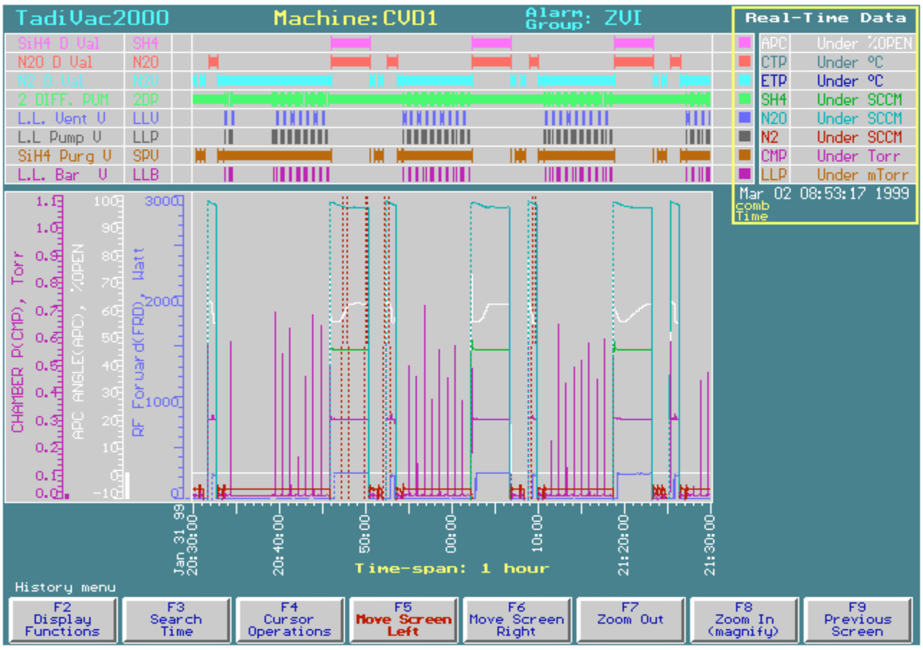


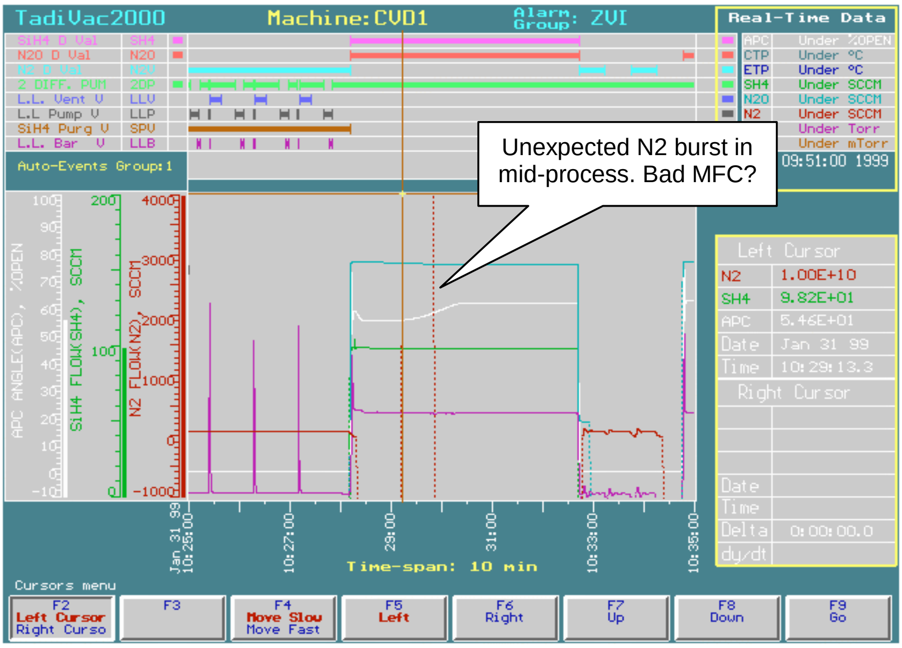
At high Silane flows, the APC valve is unstable.



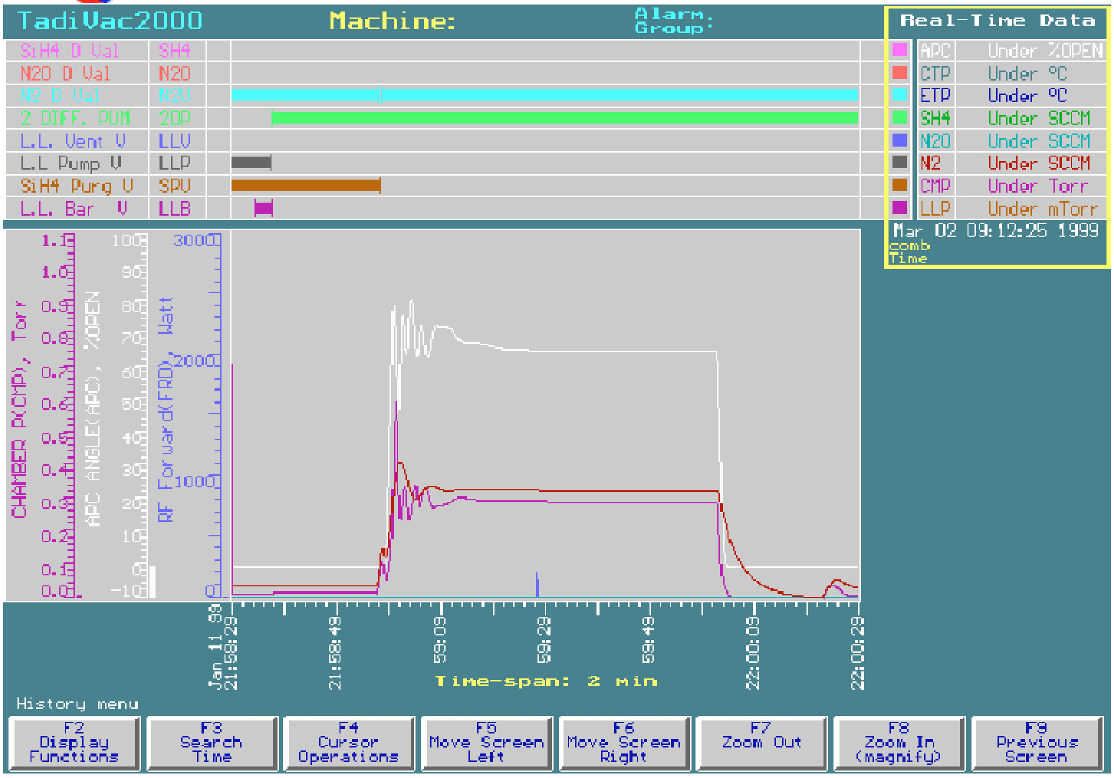
At low Silane flow, the APC valve is stable. (With slight overshoot)

Unstable and irregular process can be observed both in the time-domain trends and regular historical data display.



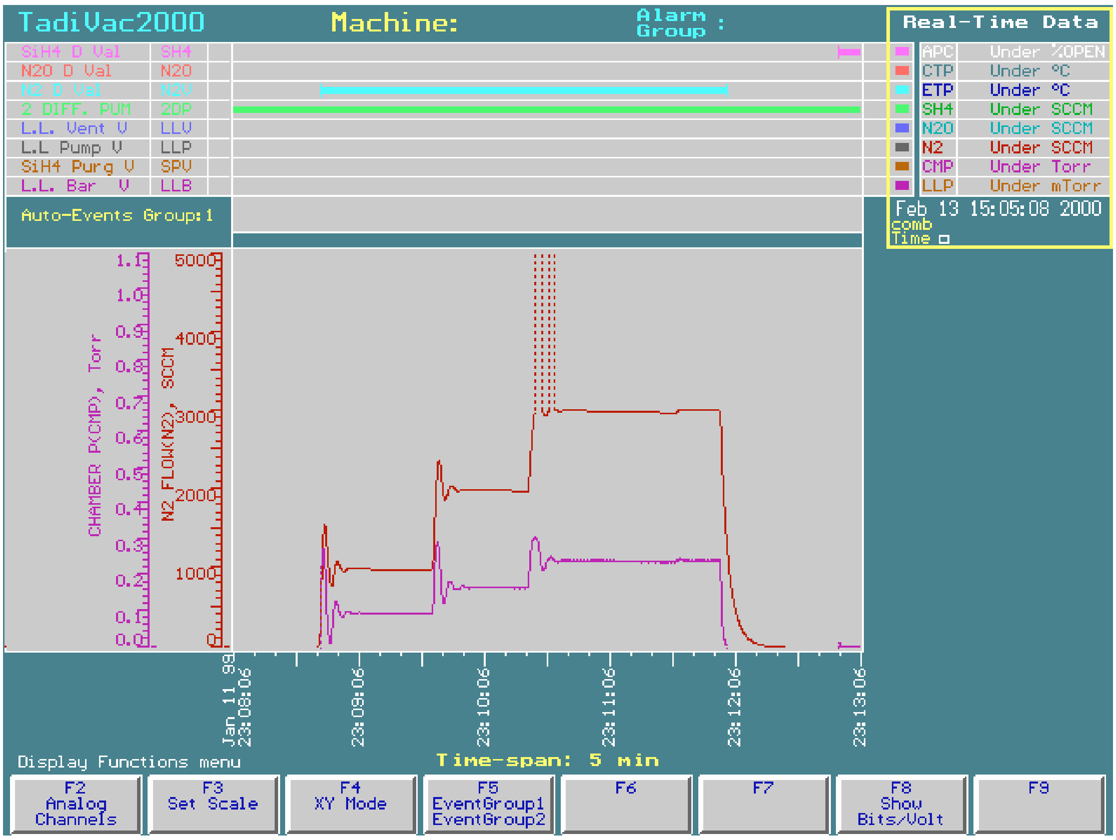


During a regular process, an unexpected opening of the N2 MFC was observed,



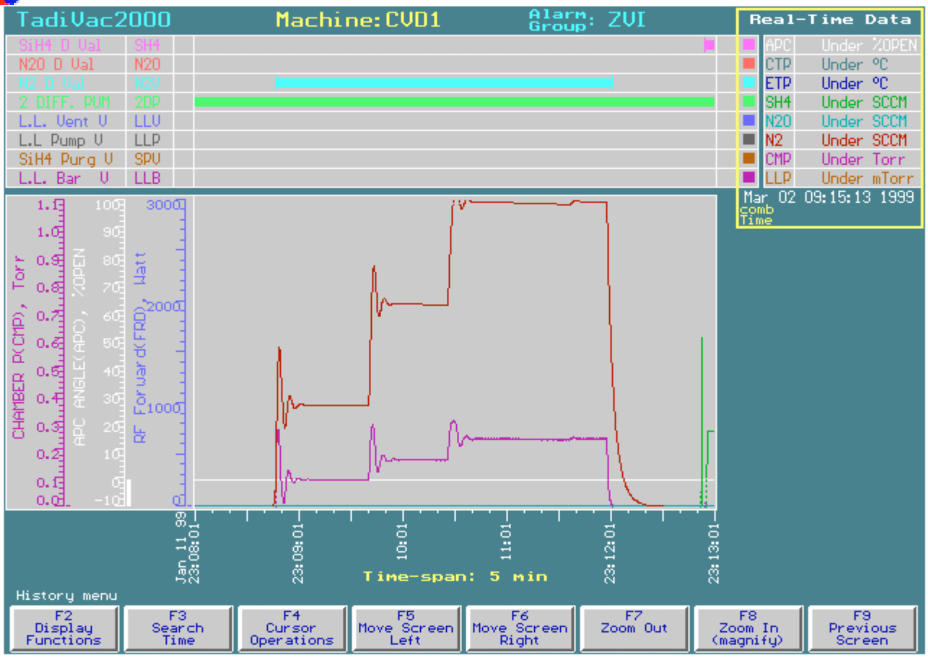
CVD1, Trikon

Poor Pressure control.



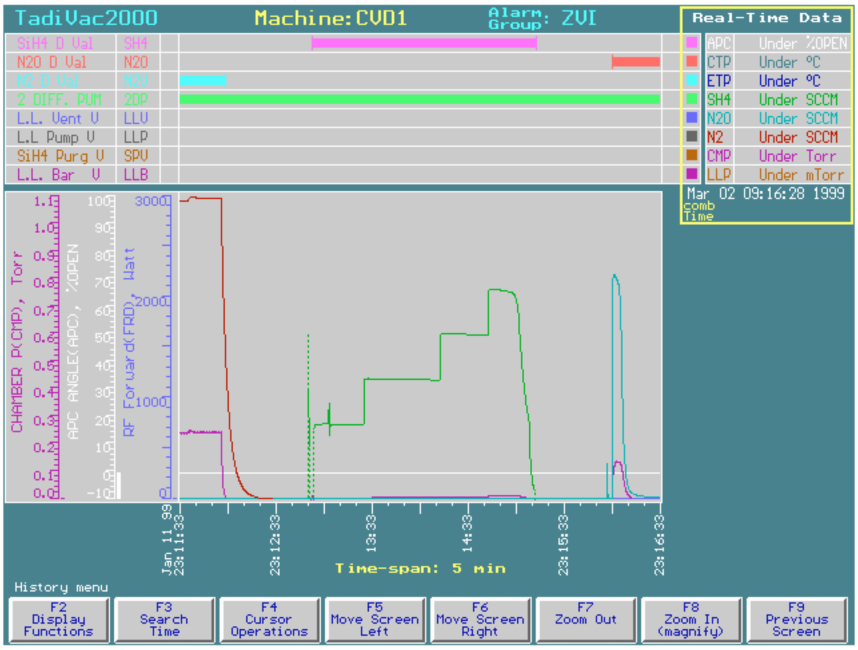
CVD1

After clean, the machine goes trough an unstable period. we can see difficulty in pressure stabilization.



Testing the N2O MFC shows unstable operation. May indicate excess N2O pressure and / or a need for MFC adjustment.

MFC Stabilization



N2O and SiH4 MFC ramp up tests show proper operation

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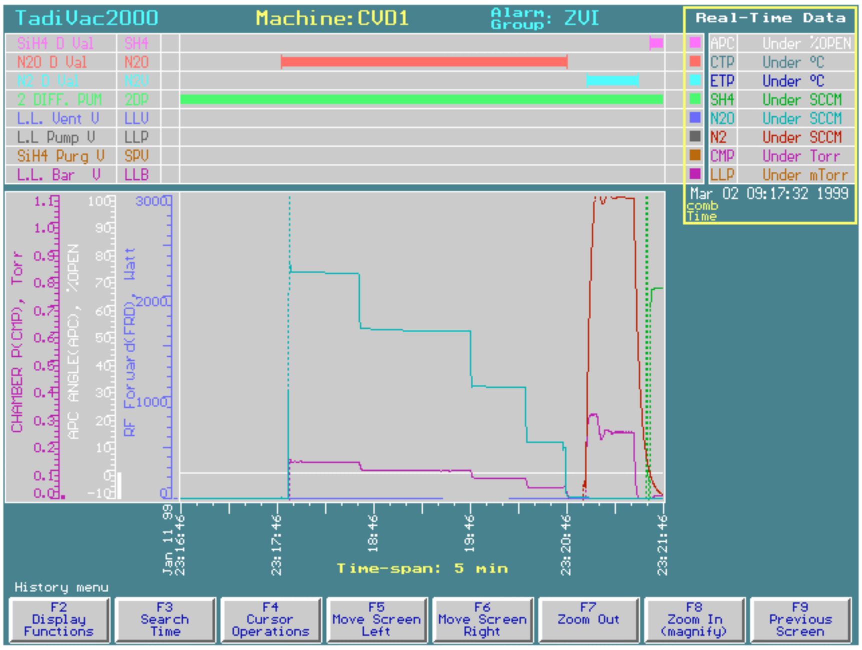
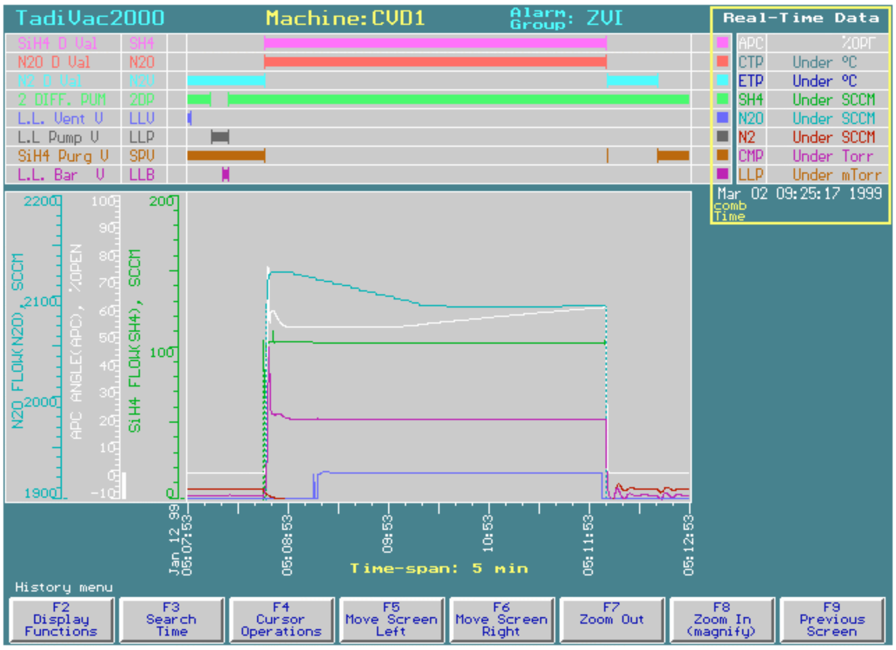
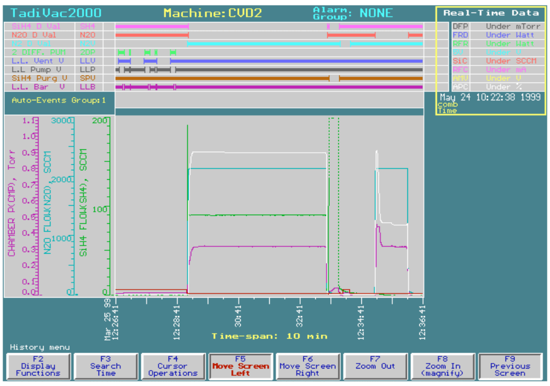


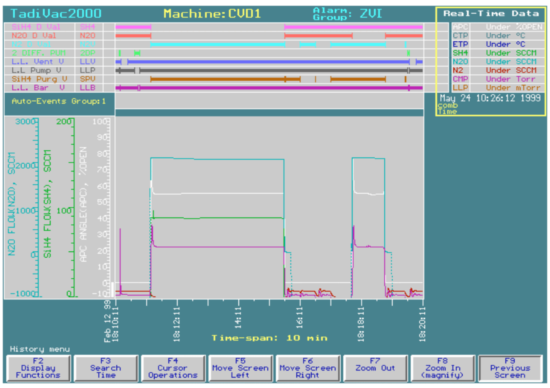
N2O and SiH4 MFC ramp down tests show proper operation

A more careful observation of N20 MFC operation after clean reveals that a drift of flow is present during process. This drift might not be a cause for problems in this process, but in general it is recommended to have a stable flow.



Process after clean. N2O MFC has drift from 2130 to 2090 SCCM. The SiH4 flow is 103 SCCM (too high).



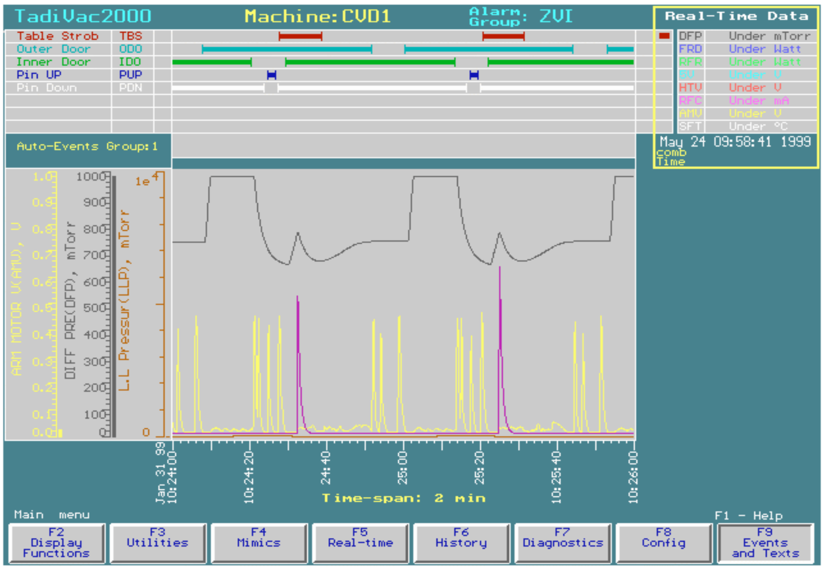


By comparing the fingerprint of CVD1 and CVD2 one can easily see that the two machines work differently.
Although the flow and pressure levels are almost the same the process sequence and APC operation are very different.

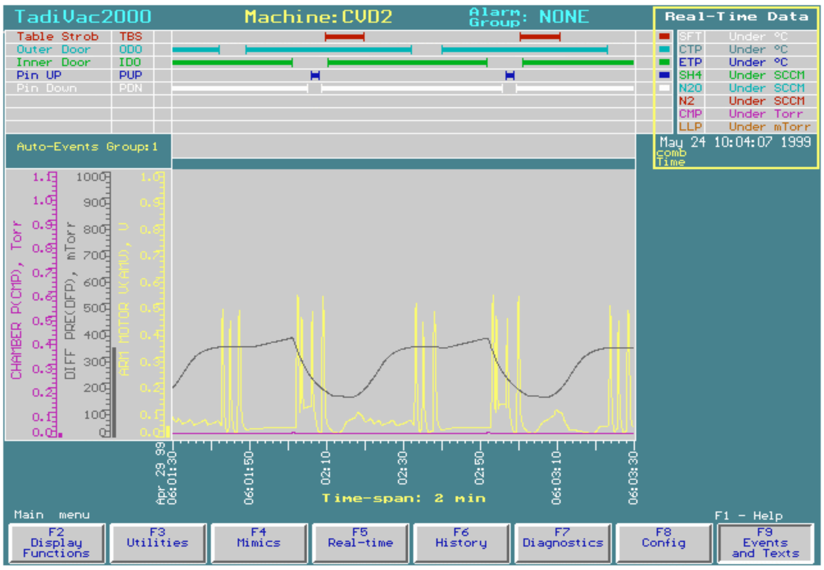
Load-lock vacuum problem

The data shows clearly that CVD1 differential pressure it too high, causing pressure bursts in the chamber each time the inner door is opened to load a new wafer. There might be a leak or insufficient vacuum pumping at the load lock chamber.

The pressure bursts can cause high Oxygen level in the chamber that can be the reason to many if not most process problems.



CVD1 Load-lock pressure. Note the high level of pressure and the chamber pressure bursts when the inner door opens.



As a reference, CVD2 Load-Lock pumping seems normal. The LL pressure level is sufficiently low, there is no pressure increase in the chamber when the inner door is opened.

A closer observation of the Arm operation, using the TadiVac2000, reveals that CVD2 might have a wafer-handling problem. Since that data shows that the Arm is moving while the inner door be closed, which means that the Arm hits the door while loading and unloading the wafers.

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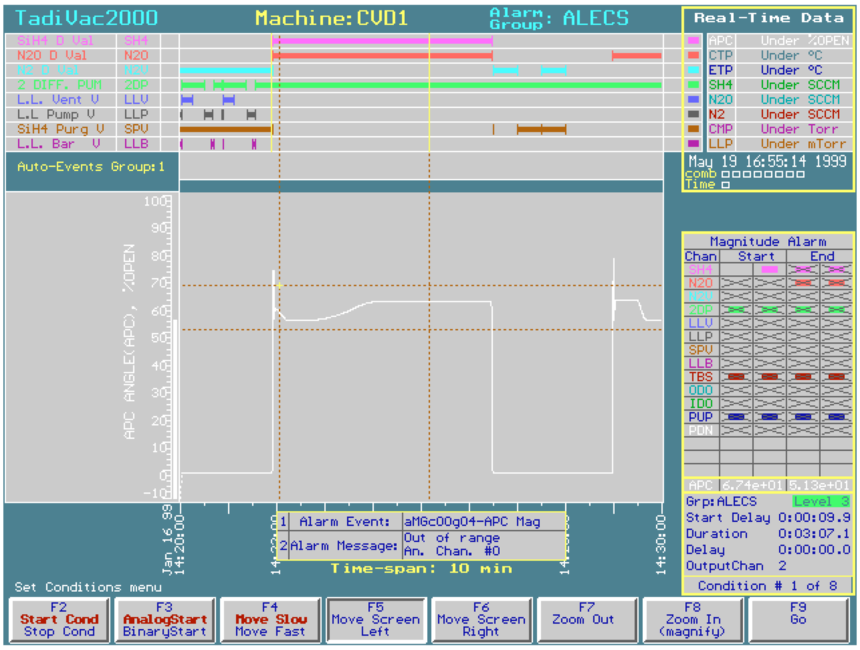
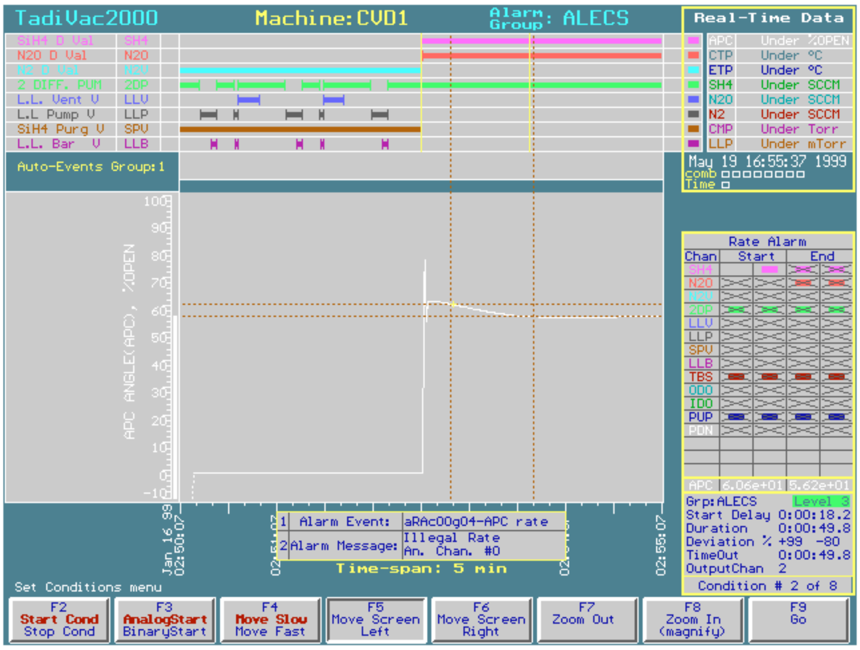
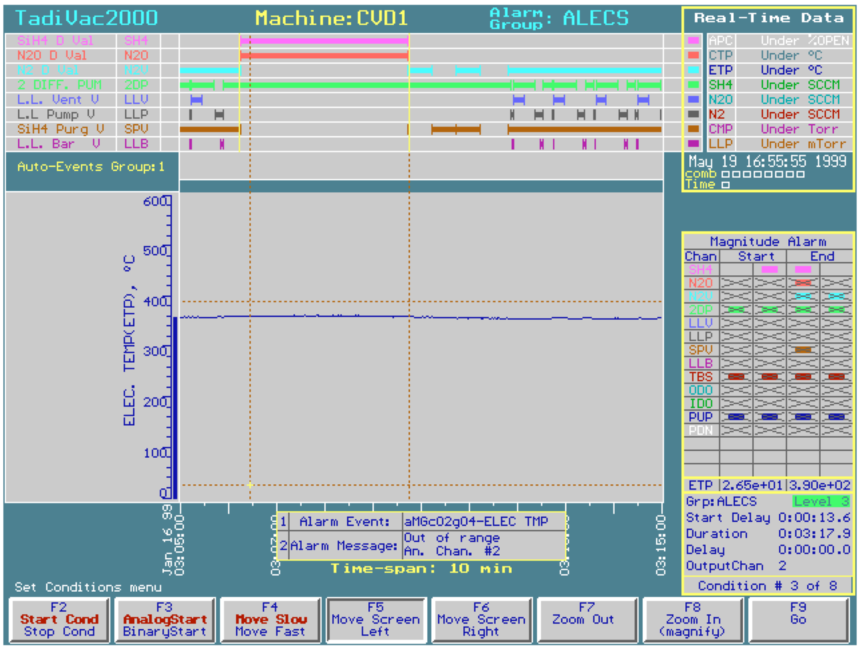
Appendix: Test conditions Setup for the various trends



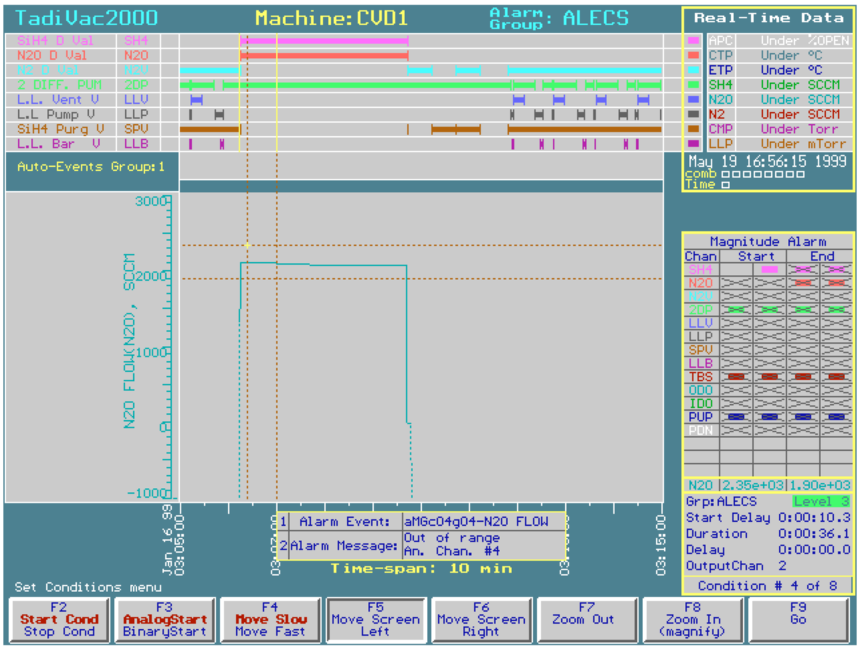
APC Valve opening magnitude (% open)



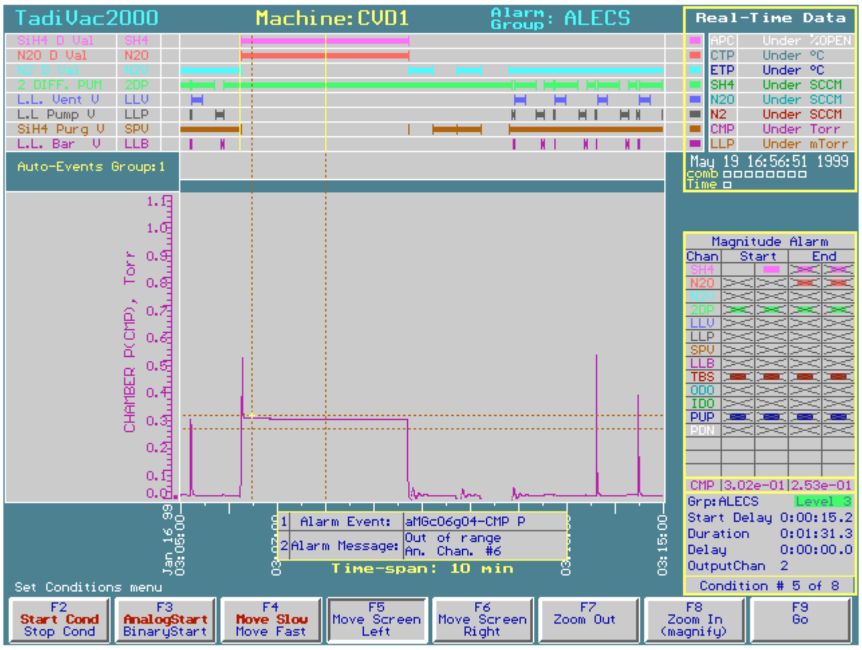
APC Valve Rate-of-change



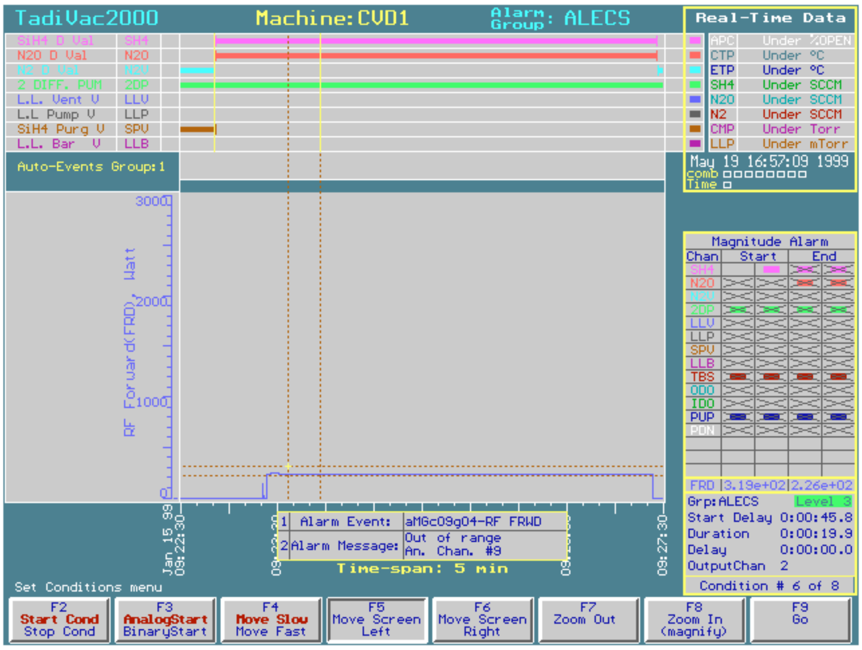
Electrode temperature trend condition



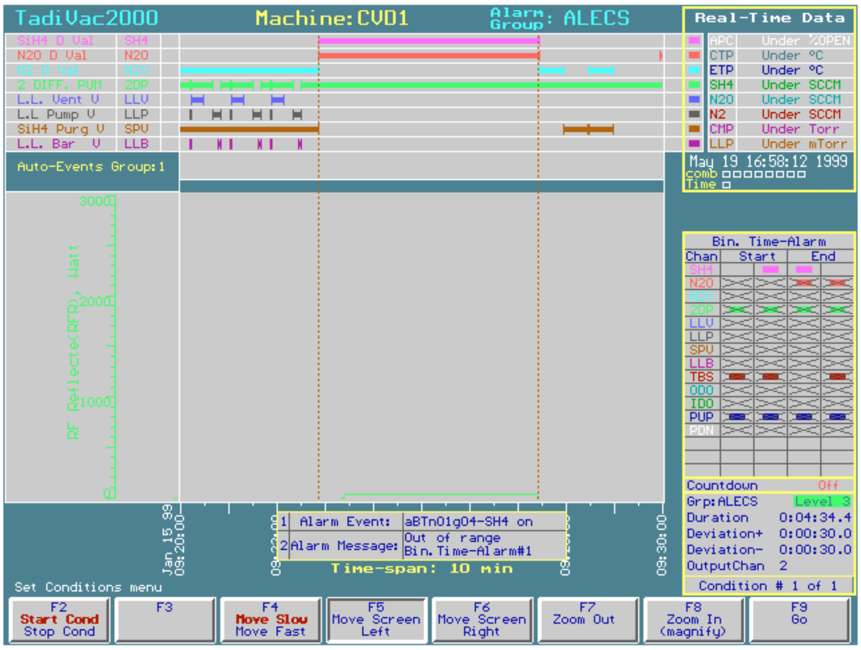
N2O flow trend condition



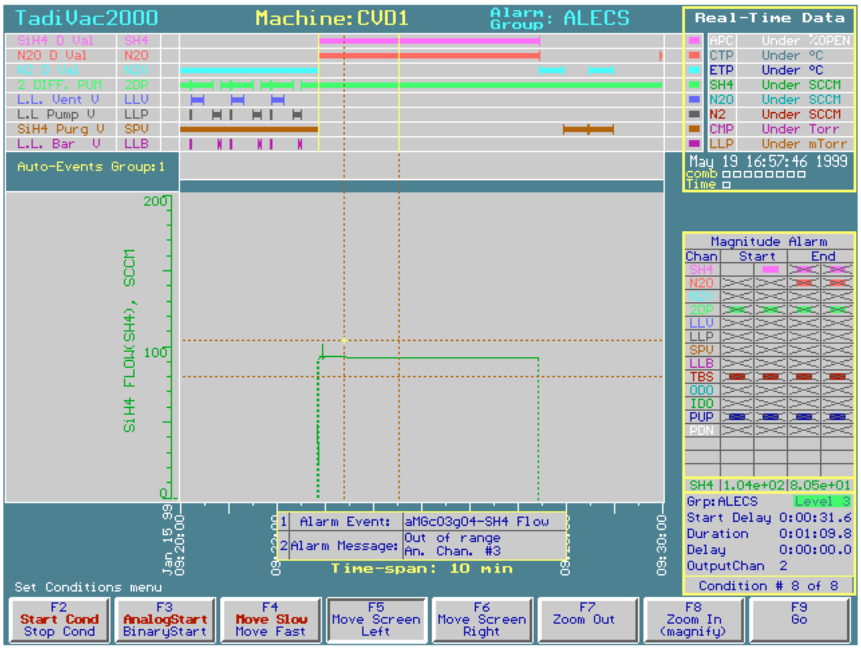
Chamber pressure parameter condition



RF forward parameter condition



Silane valve open time trend condition



Silane flow rate trend condition