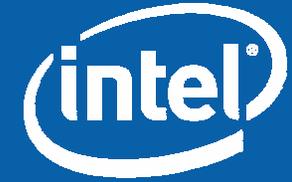


# Process Gas Challenges in a 65nm 300mm CE! Fab

Carl Geisert  
Principal Engineer  
Intel Fab Sort Manufacturing



NSF/SRC Engineering Research  
Center University of Arizona



# Agenda

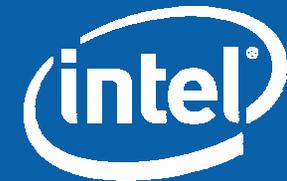
## Background

- ❑ Intel & FSM
- ❑ Process Gases – Bulk & Specialty
- ❑ Gas Distribution

## Challenges in 65nm High Volume Manufacturing

- ❑ Gas Contaminants & Sources (on our radar screen..)
  - Characterization Data Dilemmas
  - Specialty Gas Bottles
  - Environmental Influences
  - Dead Legs
  - Distribution System Construction
  - Quality “Events”
- ❑ Supply Chain Risks
- ❑ Analytical Challenges – Supplier, Delivery, Fab
- ❑ Summary

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## Background

- \* Intel & FSM
- \* Process Gases – Bulk & Specialty
- \* Gas Distribution

# Intel FSM Production Sites



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**FSM**  
Fab Sort Manufacturing



# HVM Process - Organizational

## PTD – Portland Technology Development

- Technology Development, Transfer

## FSM – Fab Sort Manufacturing

- 150mm – 300mm Wafer Fabs Worldwide

## CS – Corporate Services

- Owners of Facilities – Gas, Power, Chems,...

## Materials

- Delivery, Quality, Supply Chain Robustness

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# Process Gases – Bulk & Specialty

## Bulk Gases

- $H_2$ ,  $O_2$ , He, Ar,  $N_2$
- Mix of cryogenic liquid, compressed gas, pipeline gas, and gases generated on site

## Specialty Gases

- $CF_4$ ,  $N_2O$ ,  $CHF_3$ ,  $C_2F_6$ ,  $SF_6$ ,  $NF_3$ ,  $NH_3$ , HCl,  $SiH_4$ .....
- Mix of compressed gas, compressed liquid

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# Gas Distribution



Bulk Tank



Vaporizer

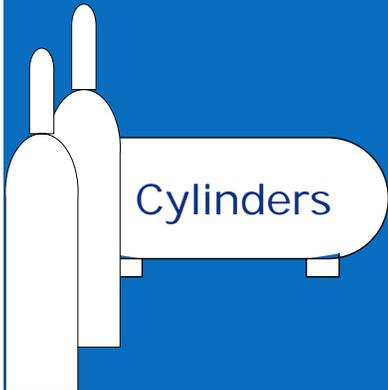


Purifier



Filtration

Fab  
Tools



Cylinders



DVB/VMB

Fab  
Tool

Fab  
Tool

Fab  
Tool

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# Challenges

- \* Gas Contaminants & Sources
  - Characterization Data Dilemmas
  - Specialty Gas Bottles
  - Environmental Influences
  - Dead Legs
  - Distribution System Construction
  - Quality "Events"
- \* Supply Chain Risks
- \* Analytical Challenges – Supplier, Delivery, Fab

FSM

Fab Sort Manufacturing

# The Dilemmas With Contaminant Characterization Data

1. Suppliers will provide  $<100\text{ppb}$  or moisture in a bulk gas, isn't that good enough? Why should I spend \$\$ on purifiers, show me the data..
2. By the time we get around to generating the data, it will probably be 2 generations too late. And I can't spend any money on a mature technology.
3. You want to do **what** with one of my leading technology HVM process tools? Ha!

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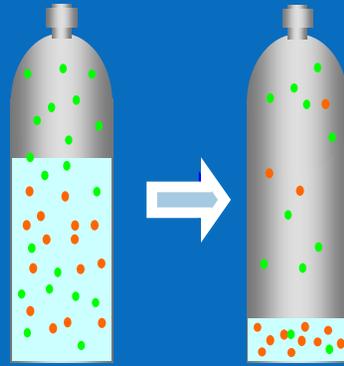
# Contaminants (On Our Radar)

- Moisture
  - Incoming with bulk gas deliveries, specialty gas bottles
  - Desorption from gas lines, valves,..
  - Dead legs in distribution
- $N_2$ ,  $CH_4$ , Ar,  $O_2$ , CO, ....
  - Air Leaks
  - Incoming with bulk delivery (3 events in past few years)
- What levels will impact process steps?
  - “Many processes are sensitive to impurities at the ppb level”
  - Largely anecdotal & theoretical, not much published characterization at the ppb level.

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# Specialty Gas Cylinder Moisture

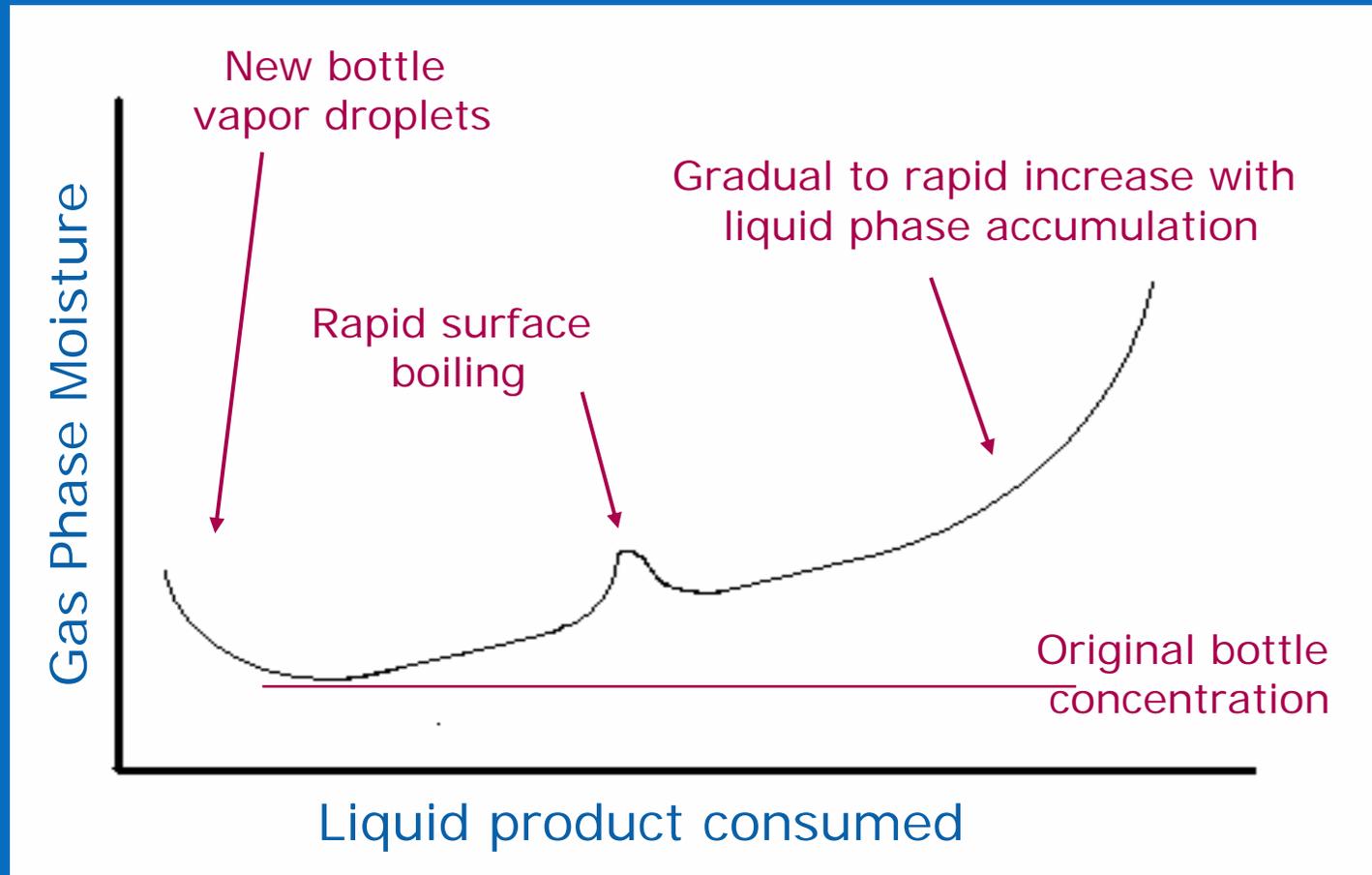
- Liquid phase accumulation of contaminants



- Droplets in vapor phase with new bottle
- Surface boiling with higher flow rates
- Desorption from cylinder walls, valves, ..
- Moisture vapor pressure changes with liquid temp

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# Specialty Gas Cylinder Moisture



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# Contaminants

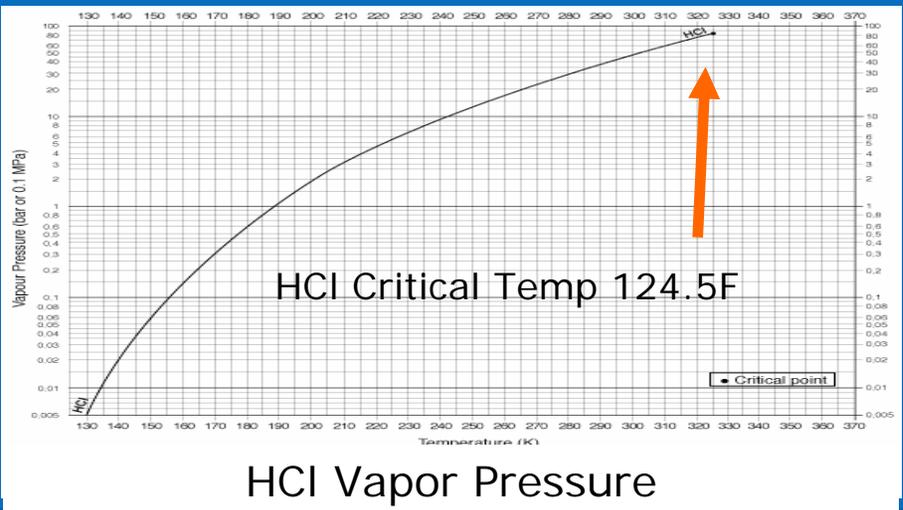
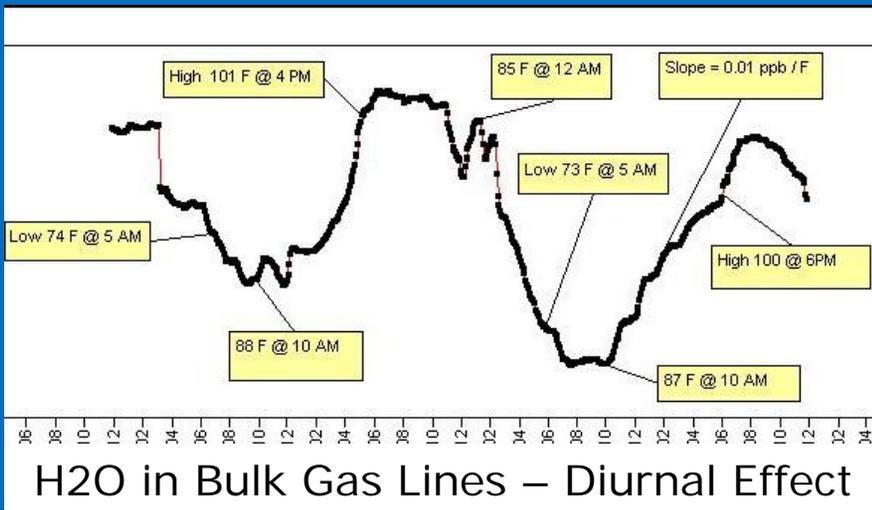
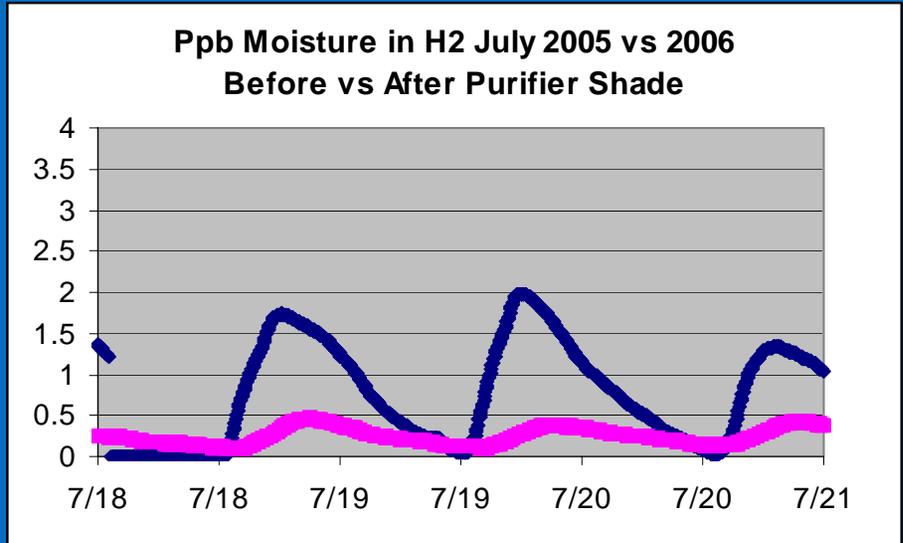
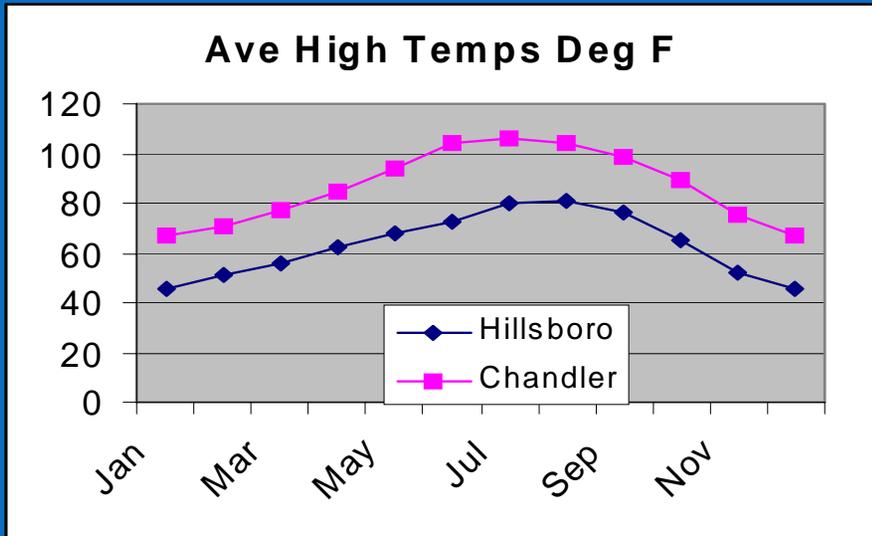
## Environmental Influences

- Process Development in Portland, HVM in Az, NM,...
- Gas cylinders sitting outside in sun or shade
- Hundreds of yards of 1" – 3" gas lines outside
- Higher ambient temps, more intense sun..
  - Several ppb higher moisture in gas lines
  - Several hundred ppb higher moisture from cylinders?

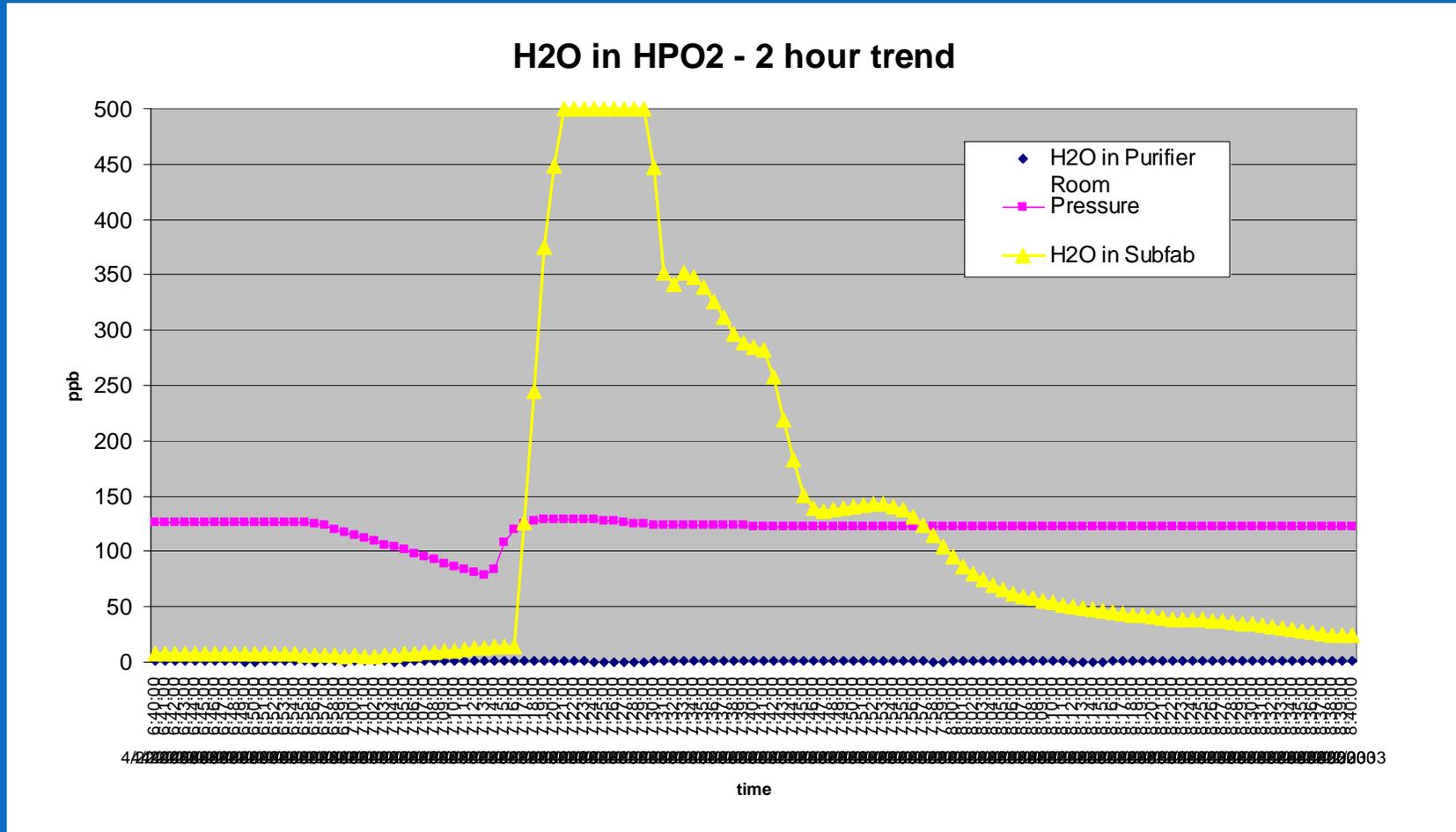
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# Contaminants – Environmental Influences



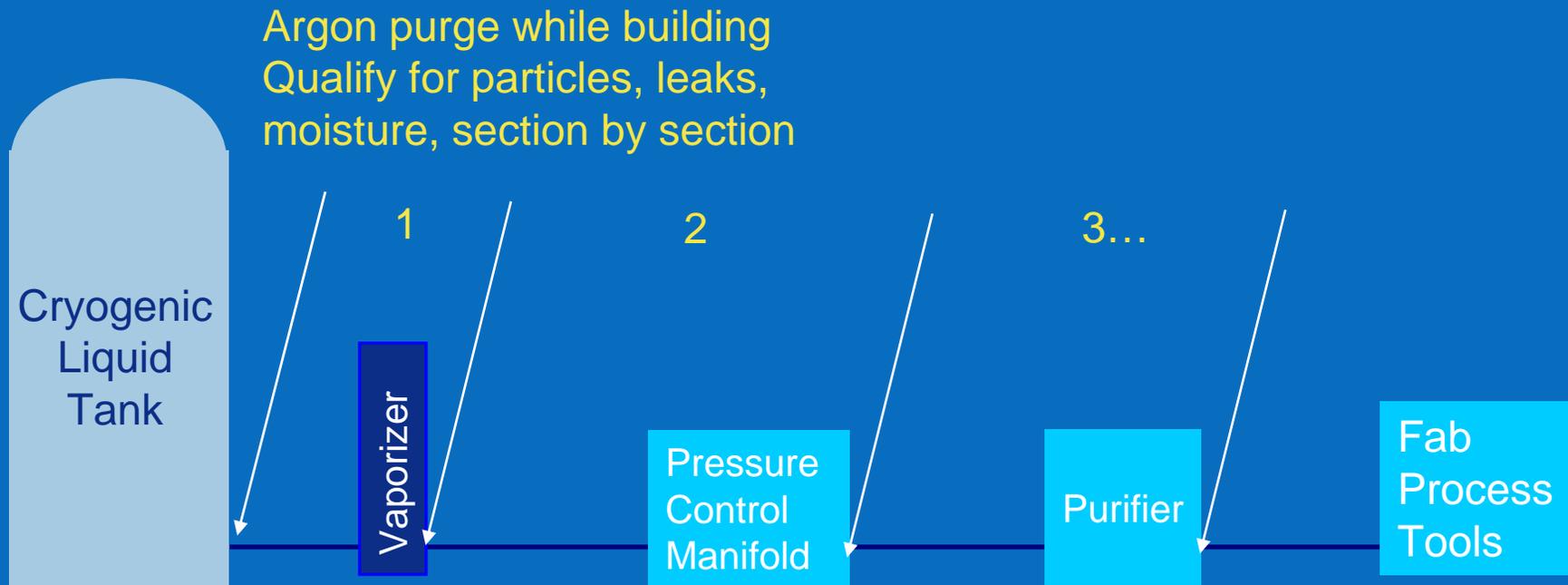
# Contaminant Sources – Dead legs



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# Progressive Dry-Down

Gas lines are capped, bagged in inert gas prior to construction



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# The Cost of Gas Quality Issues

- Bulk (O<sub>2</sub>, H<sub>2</sub>,...) gas lines can be connected to 100-250 process tools at once.
- Incoming contaminants can saturate a purifier, then show up as an OOC (out of control) process monitor
- An event can shut down a fab for weeks, impact thousands of wafers (some obvious, others not)
- Cost can range from tens of thousands to millions \$.
- Clean Up...purge the lines, vent the X000 gal tank, schedule another delivery (fast)

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# Gas Supply Risks – Increasing?

- 2005 Hurricane Katrina & Rita
  - New Orleans H2 plant underwater
  - Texas coast Ar supply challenged for weeks
  - Manufacturing sites not necessarily “geographically diverse” with no obvious intent to improve the situation.
- 2005 Steel Workers Strike in BC impacts Ar supply
- 2005 Nasa testing Shuttle engines consumes H2 supply
- 2005 Supplier (H2) feedstock shortages

We had to find & qualify alternate sources & reduce consumption significantly at several sites

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# Analytical Challenges - Suppliers

- We (SC Industry) are not the biggest bulk gas customers..but we may be the most demanding from a quality perspective
- Analytical capability Idl may vary significantly site to site
  - How to qualify new supplier if Idl >> existing baseline level
- Higher precision analysis takes time, not interested or costly
- Typically get < spec vs 1.7 ppb

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# CERTIFICATE OF ANALYSIS

Material <b>Liquid Hydrogen</b>	Grade <b>Special</b>	Total Purity <b>&gt;= 99.9998%</b>
------------------------------------	-------------------------	---------------------------------------

CUSTOMER INFORMATION
Company Name <b>INTEL CORPORATION</b>
Address

AIR PRODUCTS INFORMATION
Company Name
Address

ANALYSIS INFORMATION			
IMPURITY	ANALYSIS RESULTS	SPECIFICATIONS	QUALITY VERIFICATION
THC (as Methane)	$< .1 \text{ PPM}$	PPM	Each Lot
Carbon Dioxide/Carbon Monoxide	$< .1 \text{ PPM}$	PPM	Each Lot
Water	$< .1 \text{ PPM}$	PPM	Each Lot
Nitrogen	$< .1 \text{ PPM}$	PPM	Each Lot
Oxygen	$< .1 \text{ PPM}$	PPM	Each Lot
Argon	$< .1 \text{ PPM}$	PPM	Each Lot

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By \_\_\_\_\_

# Analytical Challenges – At the Fab Site

- Incoming check prior to cryogenic liquid off load?
  - N<sub>2</sub>, O<sub>2</sub>, Ar, CH<sub>4</sub>, HC, H<sub>2</sub>O,...
  - Do we trust the C of A, how about from a new supplier?
  - If you have purifiers you rest easier, but they don't cover everything, and they can saturate quickly.
  - 3 Gas contaminated delivery incidents in the past few years
  - CG, RGA, how long will it take (while the driver waits..)

Analysis needs to be inexpensive, fast & cover a wide range of gases & contaminants Dedicated is ok..

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# Analytical Challenges – At the Fab Site

- Troubleshooting excursion issues, “Task Forces”
  - Gases show up as a commonality in many fab issues
  - Main line moisture analysis is helpful, but what about other contaminants in the line or a more local issue in that specific lateral or connection..
  - Some process tools may have dedicated RGAs, but that’s ppm analysis to that specific tool set, and they probably want to run production rather than running your experiments..

Analysis needs to be inexpensive, fast & cover a wide range of gases & contaminants      Mobile is mandatory

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# Organizational & Educational Challenges

- Fab Engineering level of understanding of gas manufacture, delivery, contamination
- CS/Facilities Engineering understanding of the fab process & it's sensitivities
- Materials organization getting anyone's attention as to the supply chain risk and the need to take business continuity action. Nobody wants to open the big black box.
- Technical competency, ownership related to suppliers owning and/or operating the on site storage & distribution equipment

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# Summary

Our recent experiences would suggest

1. Gas related infrastructure, technical competency, training, analytical capability, process characterization is lagging the needs of newer technologies
2. Gas supply chain risks, changes have increased significantly in the past few years
3. Suppliers are largely catering to the needs of their larger customers, and they don't make semiconductors..
4. We may have a large opportunity for sharing information, but how to proceed...

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