Subatmospheric Gas Systems (SAGS)

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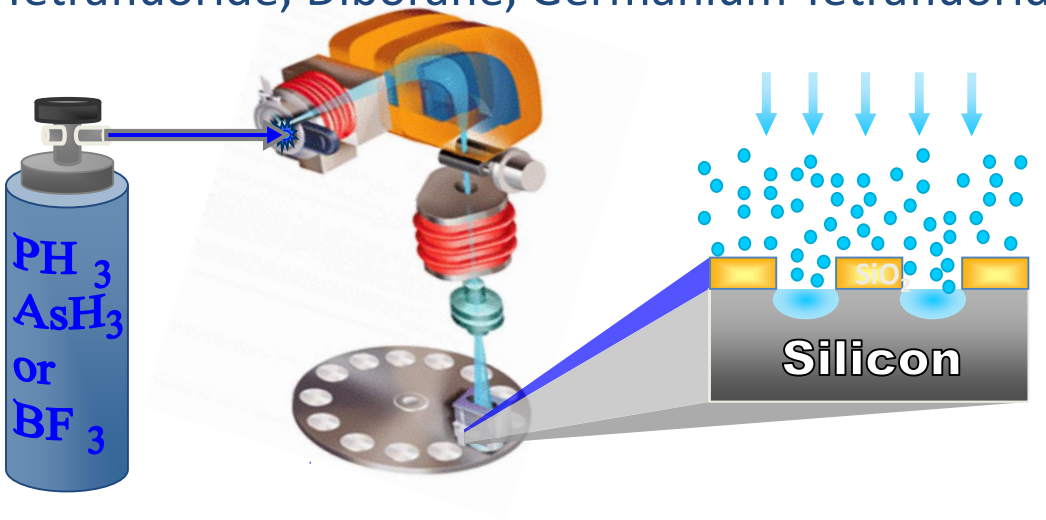
Semiconductor Ion Implant

Ion Implantation is the only method to precisely dope Silicon to a shallow depth and small area

Gas is preferred over solid sources due to the ability to switch over quickly

- Arsine
- Phosphine
- Boron Trifluoride (^{10}B and ^{11}B)
- Silicon Tetrafluoride, Diborane, Germanium Tetrafluoride



Key Fire Code Requirements

- **Since many of these are highly toxic gases, the Fire Codes and Insurance standards have strict guidelines on the system design and use**
  - **Worst case scrubber**
  - **Restrictive Flow Orifices (RFO)**
  - **Automatic Cylinder Shutoff Valve**
  - **Gas monitoring**
  - **Emergency Power**
  - **Ventilation**
  - **Compatible Storage**
- **Many Fabs also require cylinder change while wearing SCBA, area is evacuated and full PPE.**

Subatmospheric Gas Systems (SAGS)

- Gas will flow out of the cylinder only if a vacuum is drawn on the cylinder valve outlet. 4 types of systems are available which operationally meet this criteria
  - Gas adsorbed on a solid
  - Gas complexed with a liquid
  - Mechanical
  - Gas Generator
- Safer than high pressure cylinder. If valve is accidentally opened, little to no gas release

The Beginning of SAGS

- K.O.Knollmueller, Olin Hunt, US Patent #4,744,221). May 17, 1988 describes the use of various molecular sieves to absorb Arsine or Phosphine. at temperatures of –30^{o}C to 30^{o}C
- ATMI licensed the patent and further developed the technology. Expanded it to other gases and included carbon molecular sieves
- Offered as Puragen system which desorbed upon heating or under a vacuum
- Safe Delivery System (SDS^{TM}) was offered shortly afterward. This is ideal for Ion Implantation systems which operate at 5-10 torr and only require a few grams/hour of gas

Subatmospheric Gas System (SAGS) NFPA 318 3.3.28.5 Definition

- Type 1: A gas source package that stores and delivers gas at sub-atmospheric pressure and includes a container (e.g. gas cylinder and outlet valve) that stores and delivers gas at a pressure of less then 14.7psia at NTP
- Type 2: A gas source package that stores compressed gas and delivers gas sub-atmospherically pressure and includes a container (e.g. gas cylinder and outlet valve) that stores gas at a pressure greater then 14.7psia at NTP and delivers gas at a pressure less then 14.7psia at NTP

Fire Code SAGS Requirement

- **IFC 2703.16** Sub-atmospheric pressure gas systems. Subatmospheric pressure gas systems (SAGS) shall be in accordance with NFPA 318.
- **NFPA 318 Current Annex Note:** Because of its improved built-in safety features, a SAGS **should** be used instead of standard high-pressure cylinder gas wherever process compatibility allows.
- **NFPA 318 Proposed Revision:** 8.8.2 Subatmospheric gas source (SAGS) **shall** be employed unless the process considerations prevent its use.

Flammable or Toxic NFPA 318 8.6.2

- **Due to the inherent safety of SAGS, NFPA 318 allows**
  - **Incompatible SAGS cylinders to be stored together**
  - **Ventilation to 25% of LFL and below IDLH**
  - **Purge gas system can be house system**
  - **Shared purge panels**
  - **Automatic shutoff valves for pyrophoric gas not required**
  - **RFO for pyrophoric gas cylinder not required for Type 1 SAGS**

Absorbent Type (SAGS Type 1)

- Cylinder filled with a liquid or solid media
- Pressure inside the cylinder is < 100 kPa. Vacuum must be drawn to desorb the gas

Safe Delivery System (SDS) Gen 1 SAGS Type 1

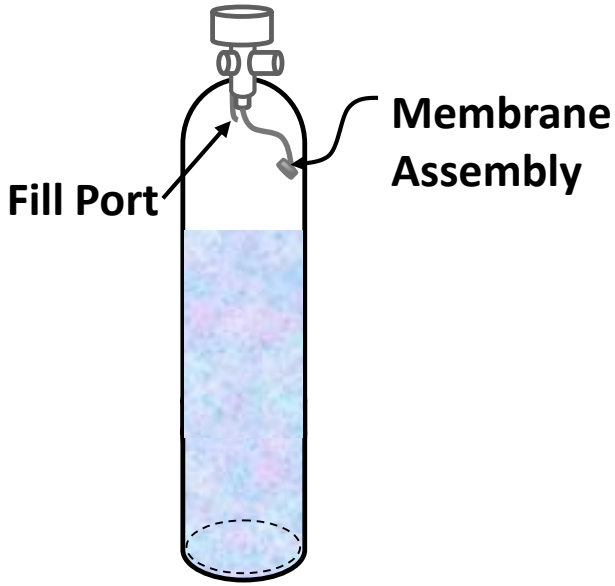
- Carbon molecular sieve absorbs gas
- Packaged in high pressure cylinder
- Carbon molecular sieve is in granular form
- Gen 2 has molded carbon molecular sieve disks and is in low pressure cylinder

Safe Delivery System (SDS) Gen 3 SAGS Type 1

- Low pressure square cylinder design increases capacity by 30%
- Carbon molecular sieve is in square disks
- Can be shipped by air cargo

Linde GENII™ Complexed Gas Technology (CGT) SAGS Type 1

- Gas is complexed (chemically bound) with an ionic liquid. It is only able to be withdrawn by the application of vacuum to valve outlet.



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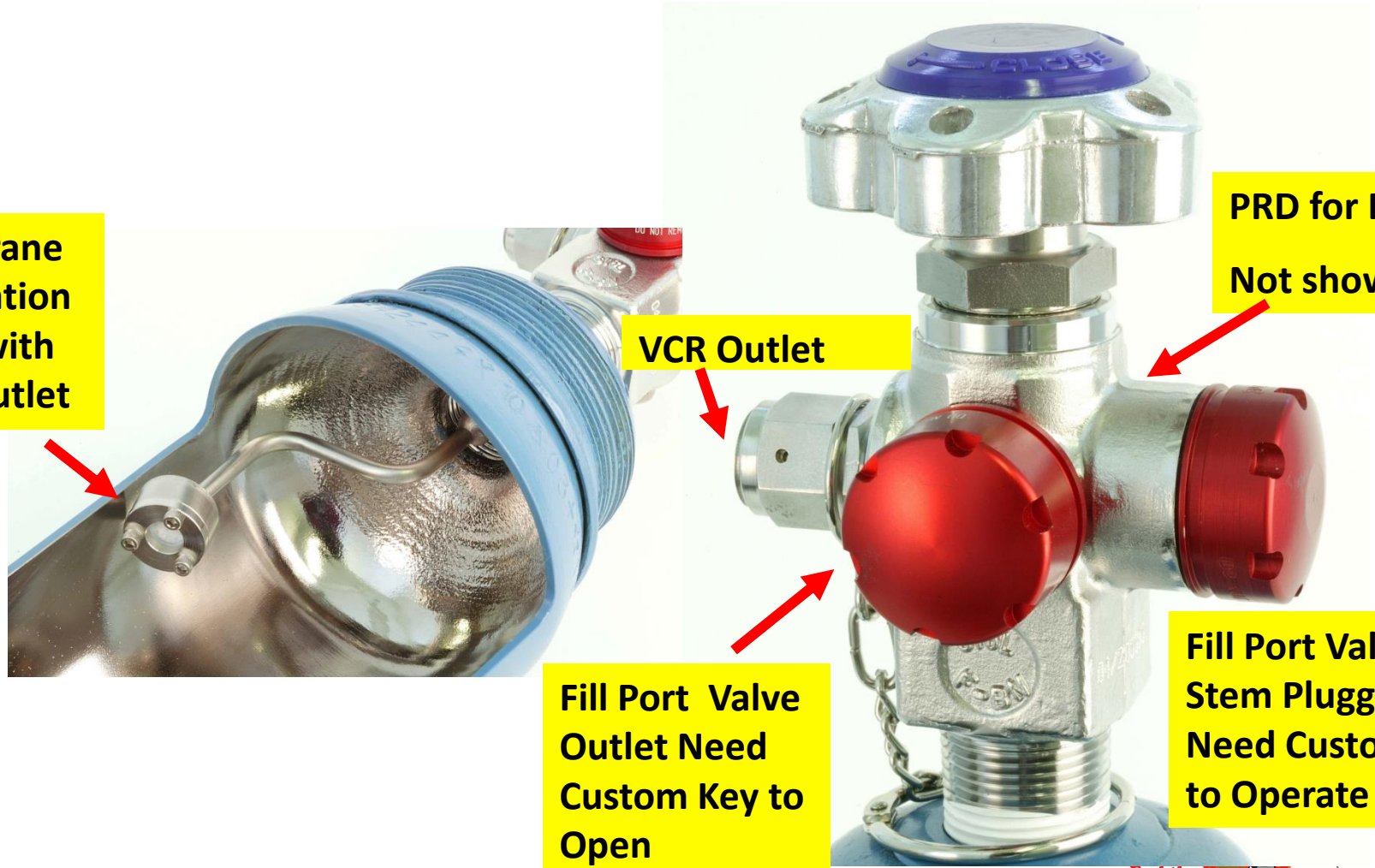
Linde GENII™ Complexed Gas Technology (CGT) SAGS Type 1



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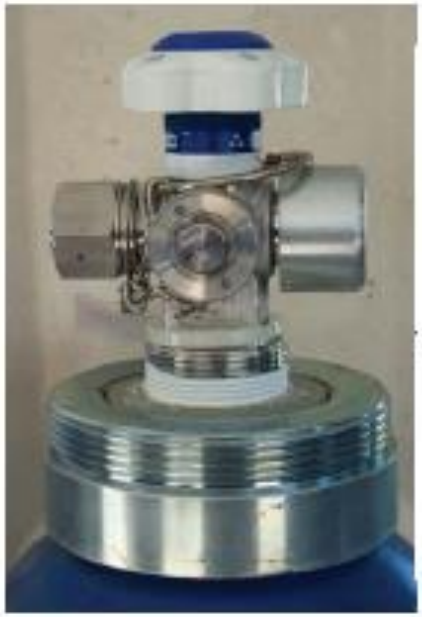
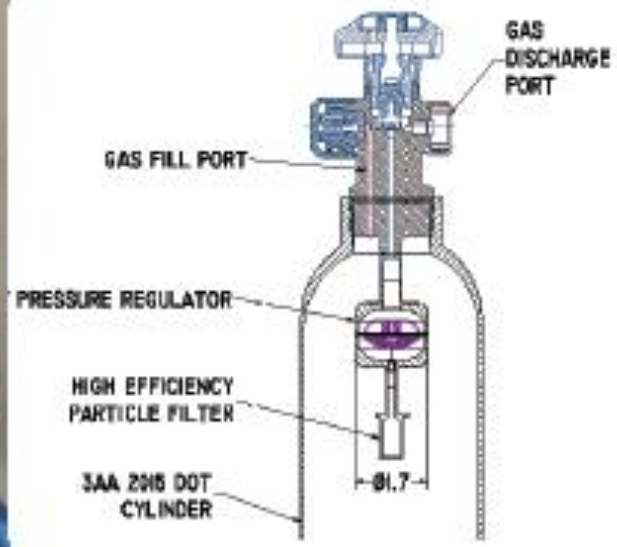
Mechanical Device, SAGS Type 2

- Regulator inside of the cylinder attached to the cylinder valve
- Vacuum must be drawn on the valve outlet for gas to flow out
- High pressure seamless cylinders
- Pressure within the cylinder is above atmospheric pressure, typically >100 psig

ATMI VAC, SAGS Type 2





ATMI VAC™

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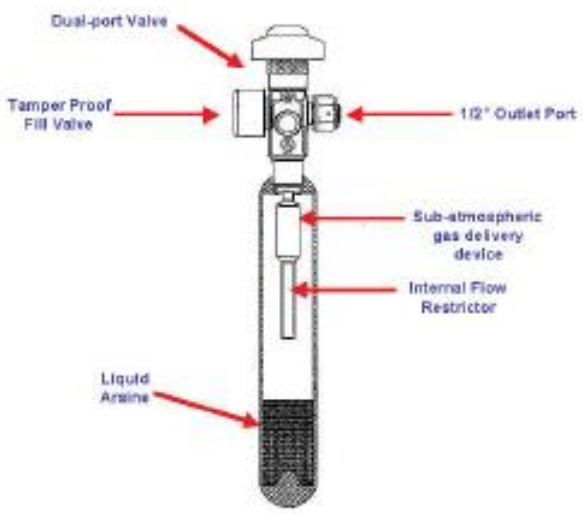
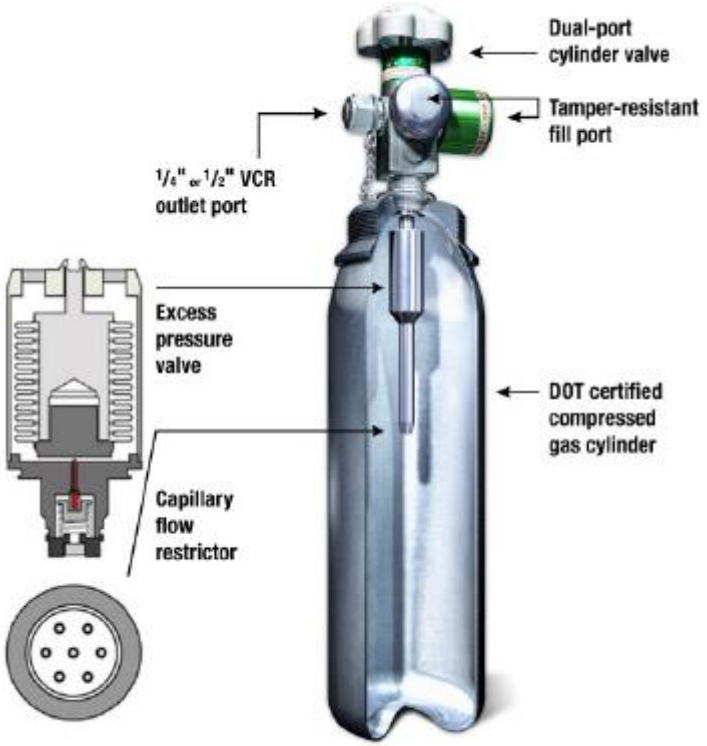
Praxair Uptime, SAGS Type 2



PRAXAIR UpTime™



Feel the Heat!
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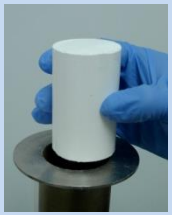
Gas Generators

- Gas is generated on demand
- Currently the following are used in the Semiconductor Industry
  - Arsine
  - Fluorine
  - Hydrogen
  - Methylsilane
  - Ozone
- NFPA 55 has gas generator section reserved

Sixtron Methylsilane Generator PECVD-based Process

- **Polymer-based on-site "proprietary mixture of methylsilanes" generation**



Solid polymer source

Safe to handle, ship and store – lower cost supply chain

On-site continuous gas generation and delivery

Proprietary Mixture of methylsilanes delivered to PECVD

Patents granted (US, Canada, PCT) on Apparatus, Process, and Material

Feel the Heat!

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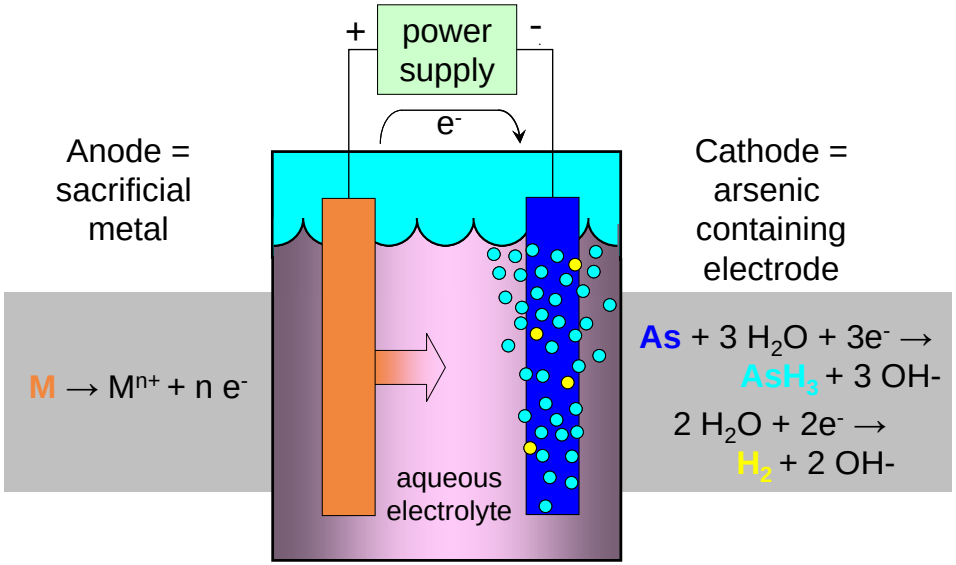
Linde Genii™ Generated Gas (AsH_3) Technology (GGT) SAGS Type 1

- Generates arsine under vacuum on-demand using an electric current
- 316 Stainless Steel Cylinder
- 316 ss Cylinder designed to a working pressure of 160 psig (11 barg)



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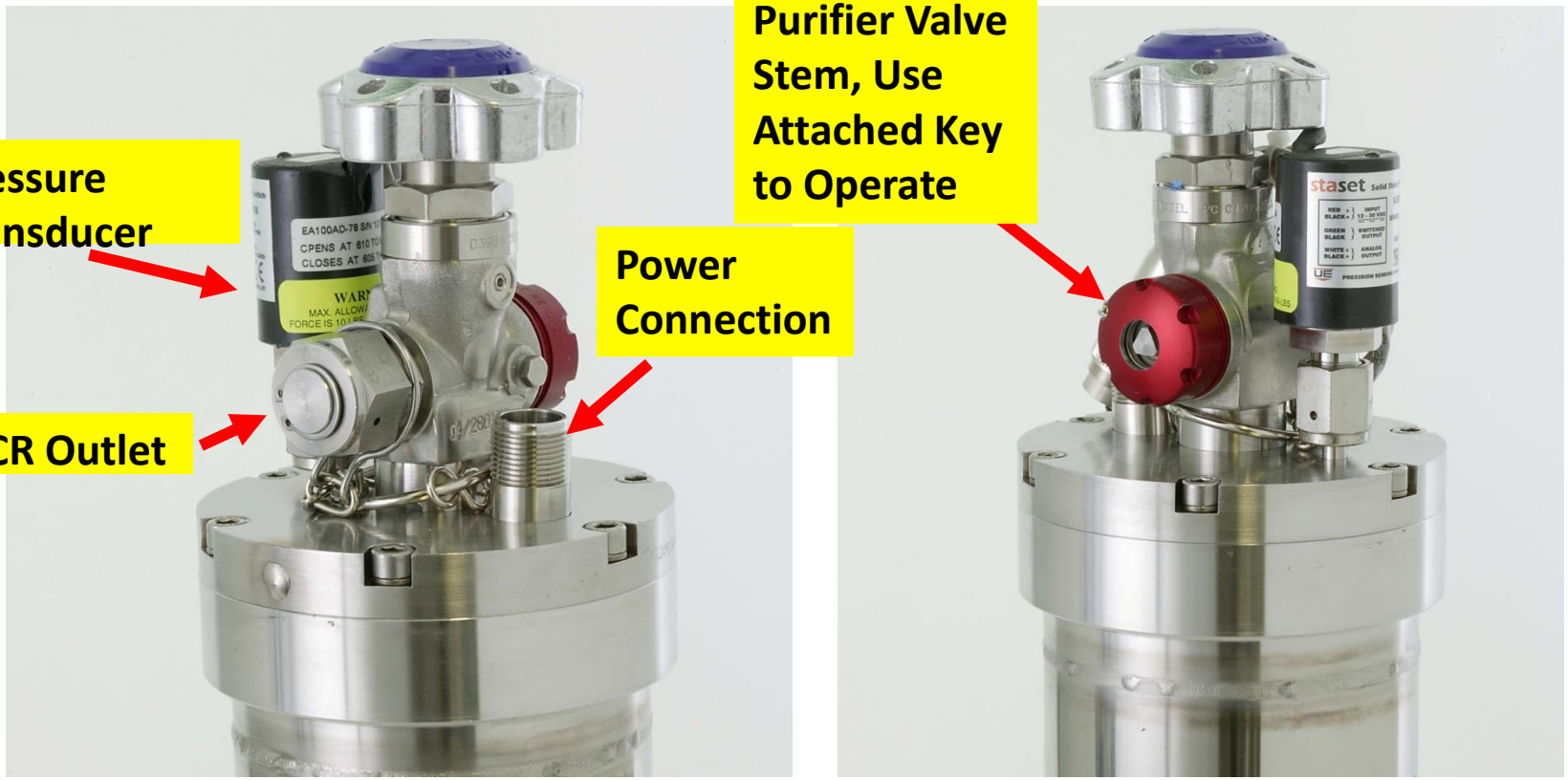
Linde Genii™ Generated Gas (AsH_3) Technology (GGT) SAGS Type 1



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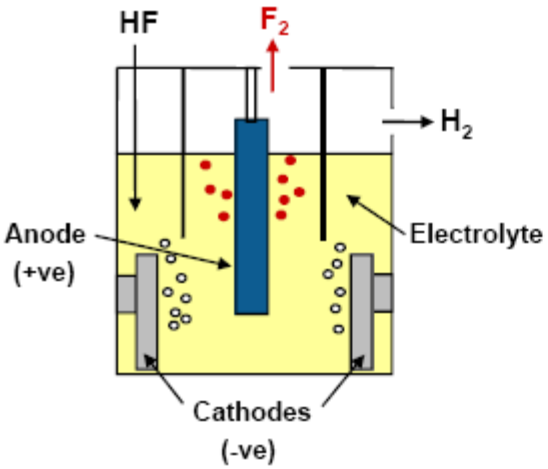
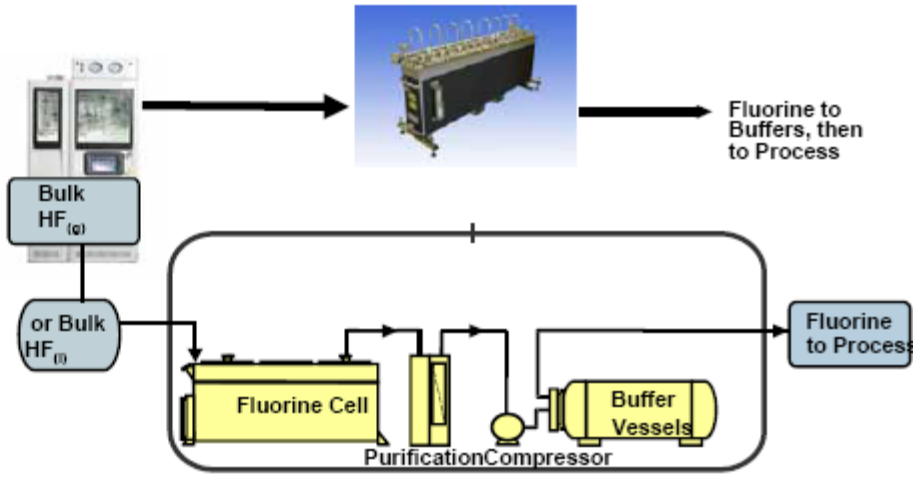
Linde Genii™ Generated Gas (F_2) Technology (GGT) SAGS Type 1

Fluorine Electrolysis



$$2HF \xrightarrow[90^oC]{KF.2HF} F_2 + H_2$$

On-Site Fluorine Generation



Stockman, Paul, "Going Green with On-Site Generated Fluorine: Sustainable Cleaning Agent for PECVD Processes", Photon's 4thProduction Equipment Conference, Munich, Germany, March 2009

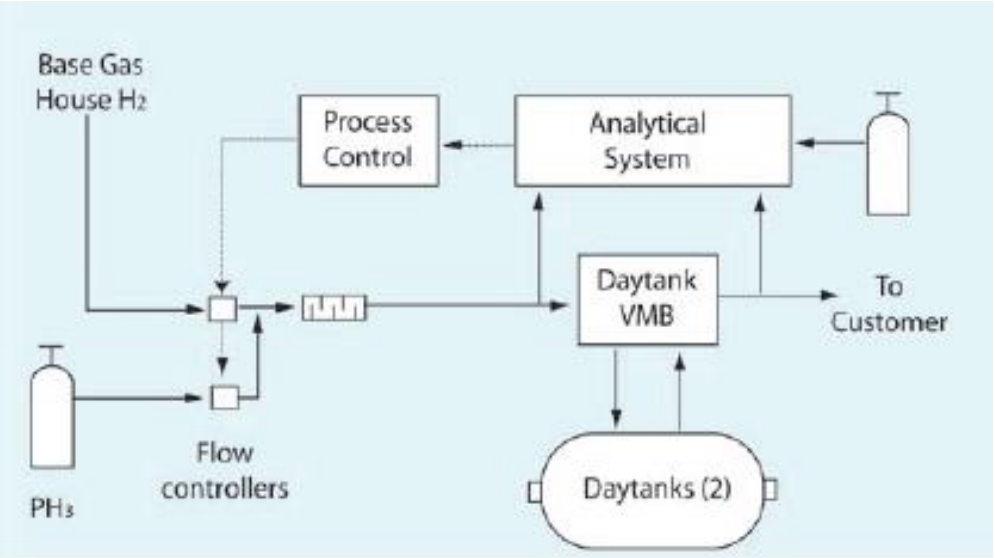
Linde Genii™ Generated Gas (F_2) Technology (GGT) SAGS Type 1

- Generates Fluorine for reactor cleaning
- Uses anhydrous HF as the raw material generating pure F_2 at 1 – 1.4 bar
- Because of its reactivity, pure F_2 has 0 global warming potential due to atmospheric life of 0.

Greg Shuttleworth “Sub-atmospheric gas delivery systemsIonic liquids + electrolysis”, 2010 Electronic Specialty Gas Safety Seminar, Korea

Gas Mixing Systems, Air Products

- Reduced cost
- Reduced cylinder changes
- One pure Phosphine cylinder can make 200 0.5% mixtures



Thank You

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