Novel, Safe Approach to Process Gas Delivery

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INTRODUCTION

Risk is Proportional to Gas Pressure

Problem:

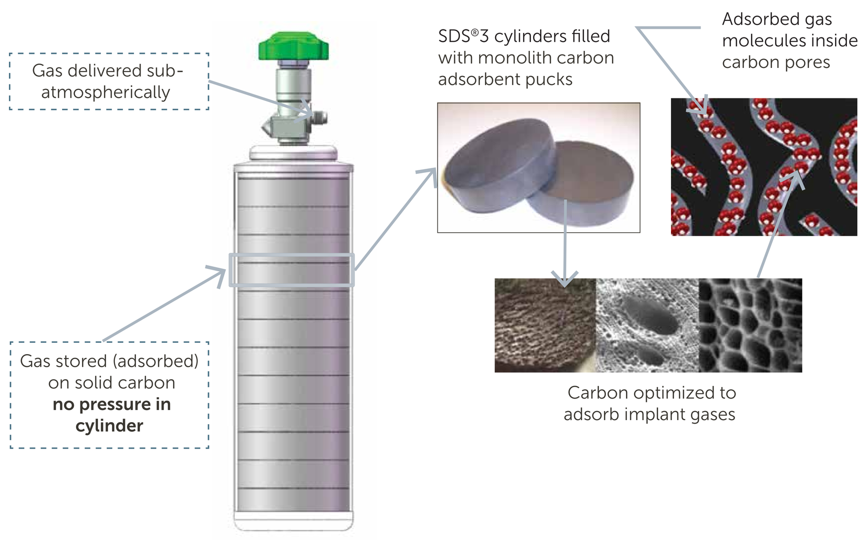
- Many applications use high-pressure, toxic gases which require extensive measures to minimize risk.
- Fire codes, transportation agencies, regulators and safety organizations have focused on procedures for safe use of hazardous process materials.
- Historically, users have implemented approaches to mitigate high pressure: extensive process controls, solid vaporizers, dilute gases, smaller quantities per package, alternative chemistries, etc.
- The industry, as we know it today, is still largely dependent on the use of high-pressure gases.

Addressing the problem:

- This presentation focuses on innovations in gas packaging technology to provide low pressure gas delivery.
- Solutions have been defined and developed to achieve safe storage and delivery of gases and gas mixtures.*
  - SAGS Type 1 definition – Subatmospheric Gas Storage and Delivery Source: A gas source package that stores and delivers gas at subatmospheric pressure and includes a container (e.g., gas cylinder and outlet valve) that stores and delivers gas at a pressure of less than 14.7 psi at NTP.
  - SAGS Type 2 definition – Subatmospheric Gas Delivery Source: A gas source package that stores compressed gas and delivers gas subatmospheric pressure and includes a container (e.g., gas cylinder and outlet valve) that stores gas at a pressure greater than 14.7 psi at NTP and delivers gas at a pressure of less than 14.7 psi at NTP.

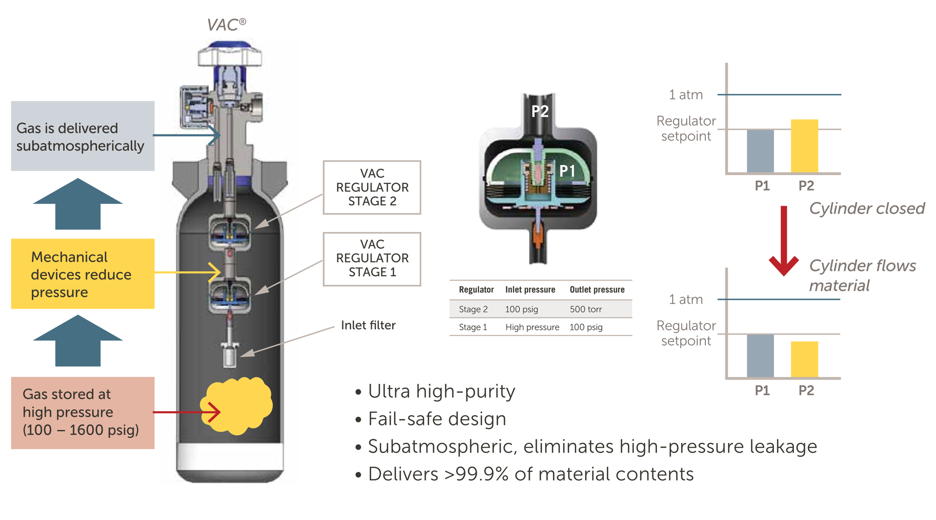
*NFPA 318 – Standard for the Protection of Semiconductor Fabrication Facilities.

SAGS TYPE 1: SUBATMOSPHERIC PRESSURE STORAGE AND DELIVERY



SDS is the safest gas package available in the industry for highly toxic, pyrophoric, or corrosive gases

SAGS TYPE 2: SUBATMOSPHERIC PRESSURE DELIVERY



Mechanical packages provide a safer alternative to high pressure and can be used for gases and gas mixtures

SAGS TYPE 2 OPERATION – RELIABILITY AND SAFETY

- The Vacuum Actuated Cylinder (VAC®) operates as its name implies, allowing flow only when a demand pressure below a subatmospheric threshold pressure has been achieved. Its basis is the incorporation of set pressure regulators (SPR) embedded within the cylinder body and located upstream of the primary cylinder valve. Thus, while the pressure inside the storage cylinder can exceed 1500 psi, the gas leaving the VAC cylinder is 500 torr, nominal.
- The orientation of the regulators relative to the cylinder valve is shown in Figure 1. The gas stick assembly, which includes a particle filter, is welded to the base of the cylinder valve and resides completely within the cylinder body. Gas is introduced into the cylinder using a separate dedicated fill port.
- The heart of the SPR is an internal pressure sensing assembly (PSA) used to both actuate and attenuate gas flow and control discharge pressure, as illustrated in Figure 2. The PSA is a sealed, edge welded bellows unit, which is calibrated by back filling with an inert gas to a preset pressure. When pressure less than the PSA setpoint is applied downstream, the welded bellows expands unseating a poppet and allowing gas to flow through the regulator and around the PSA. With flow initiated, the bellows expands and contracts accordingly to limit gas flow and control the downstream pressure. An added benefit to this design is that the contents of the cylinder cannot be contaminated if the delivery port is exposed to other materials.
- As the poppet is normally closed, its design will leave it closed in the unlikely event of a failure. Should the PSA lose its calibrated charge pressure, the system will require a stronger applied vacuum (i.e., lower absolute pressure) to operate or it will ultimately fail in the closed position.

Figure 1. Gas stick assembly.

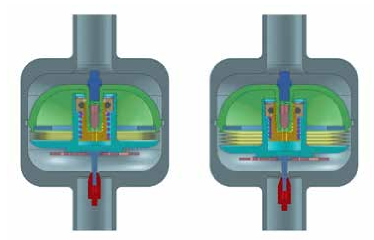


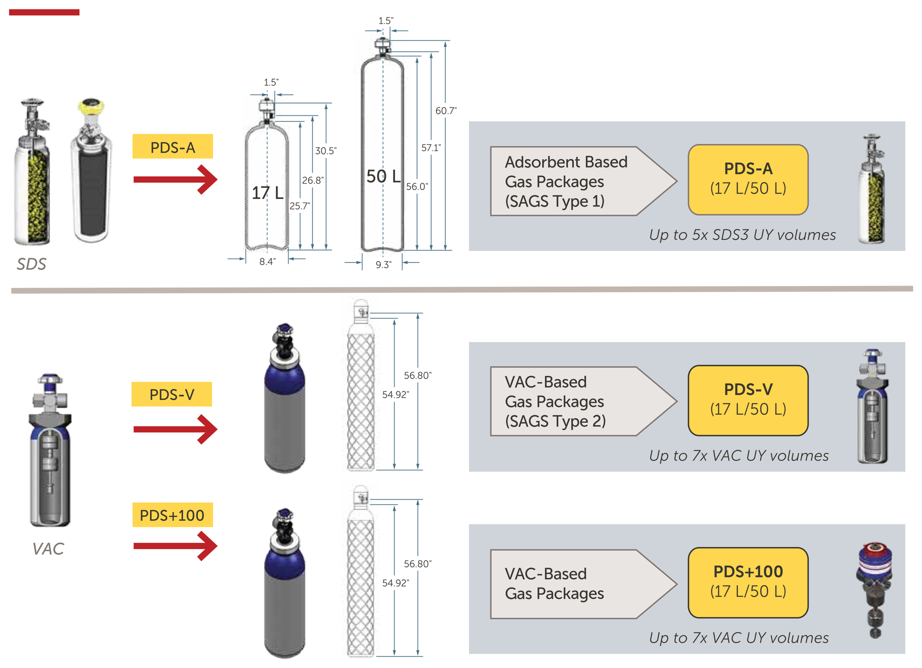
Figure 2. Section view of the SPR. Left image flowing, right image no flow.

SUPER-ATMOSPHERIC OPERATION WITH HIGHER RELIABILITY AND SAFETY

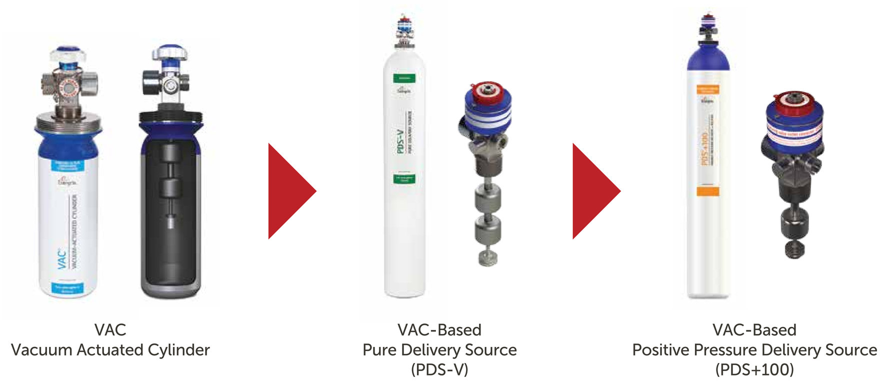
- While initially designed to operate at subatmospheric pressure, the VAC SPR can also be calibrated to operate at a nominally low super-atmospheric pressure, e.g. 50–100 psi, to meet application requirements. This implementation of the VAC technology, as in PDS+100 shown here, has enabled users that require super-atmospheric gas delivery pressure for their application.
- Users and gas component suppliers recognize the benefit of a low positive pressure for safety as well as equipment reliability purposes. Higher pressure within the gas delivery system typically reduces component lifetimes. One valve supplier has conducted a study and reported that cylinder valve lifetimes are significantly increased when operating pressure is capped at 100 psi.

Gas stick assembly

HISTORY/DEVELOPMENT



PACKAGE EVOLUTION ENABLING PDS®-V AND PDS+100



GAS MIXTURES ENHANCING PRODUCT RESULTS AND ENABLING NEW PROCESSES

VAC-based cylinders have been adapted to supply specialized gas mixtures while limiting risk:

- Consistent mixture ratio due to cylinder design and precision pre-mixed gases
  - Consistent over varying gas flow rates
  - Consistent over cylinder deliverable-gas lifetime
  - Consistent process results and resulting end-product performance
  - Not subject to mixture ratio variability of co-flowing from multiple cylinders with MFCs that are subject to mis-calibration, drift, and tool-to-tool mismatching
- Enhanced process performance
- Improved product results
- Enables new processes
- Improved reliability and safety over traditional high pressure cylinders

BENEFITS OF NOVEL SAGS-BASED AND NEAR-ATMOSPHERIC GAS DELIVERY

- A drastically improved risk profile
  - Reduces gas accidents/gas releases
  - Reduces risk and scale of a worst-case-release
  - A gas package that is more forgiving in the case of human error or gas manifold leak
- New gas/package opportunities while meeting safety/regulatory compliance requirements
- Opportunity for more deliverable grams per package while maximizing safety
- Minimizes gas line system/component failures
- Higher gas system reliability and uptime
- Enables use of 100% gas instead of a dilute gas
- Replace safety-mandated dilute gases with safe 100% gas solution
  - Known to improve process/device performance

CASE STUDY – CAPITAL AND OPERATIONAL EXPENSE SAVINGS

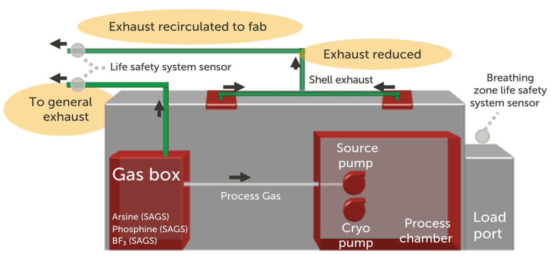
- Ventilation rate for toxic exhaust is based on worst-case-release

  SAGS Type 1
  - In case of failure at valve or cylinder breach, solid-diffusive release

  SAGS Type 2
  - In case of failure at valve, possible extremely small diffusive release up to volume from valve seat to regulator
  - In case of catastrophic cylinder breach, full contents of cylinder
- Ventilation may be rerouted, reallocated or reduced based on reduced risk
- Results:

Engineered changes	Savings per tool
Operating/variable cost savings by recirculating the heat load/shell exhaust to the sub-fab.	$10,000/year
Gas box air exhaust, now being sent to general and non-abated exhaust saving approx. $500/tool/yr.	$500/year
Total Operating Expense Savings	$10,500/year
A one time capital cost savings was realized through not having to “pipe” the gas box exhaust to an abatement system, just general exhaust.	>$400,000
Total Capital Expense Savings	>$400,000

SAGS 1 Enabled



Actual implementation: Texas Instruments 300 mm Semiconductor Fab*

* Steve Russo, *Generating Variable and Capital Cost Reduction in Implant Modules*, Solid State Technology, August 2009

CASE STUDY – OPERATIONAL EFFICIENCIES AND IMPROVED PROCESS RESULTS

Problem:

- User had historically implemented dilute phosphine (20% PH_3 in 80% H_2) due to safety concerns
  - 1.5 Kg deliverable grams phosphine
  - Cylinder (internal and outlet) pressure >1500 psi at installation
- Was disallowed to implement high pressure 100% PH_3 due to safety concerns by internal EHS and reported concerns due to local jurisdiction
- Was not achieving desired process results
- Also performing frequent cylinder changes
- Wanted to explore whether converting to 100% PH_3 would yield improved results

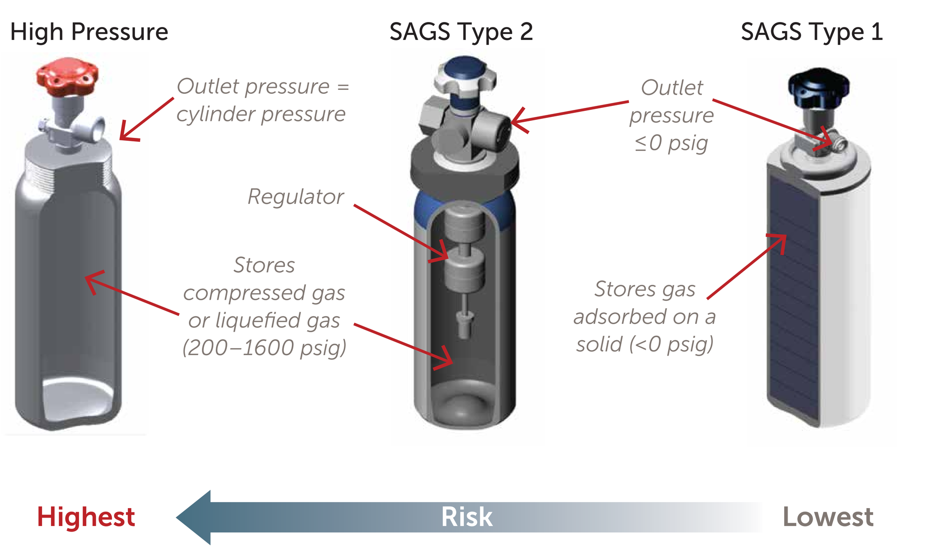
Solution:

- User was allowed to adopt 20Kg 100% phosphine due to the favorable risk profile
- User adopted 100% phosphine in the SAGS Type 2 (PDS-V) package
  - User achieving desired process results, exceeding expectations
  - Significantly fewer cylinder changes also reduces risk

SUMMARY

- These technologies replace high pressure cylinders
- Enables safe delivery of toxic gases for high-flow/high-usage rate toxic gases applications
- Proven field performance of SDS® and VAC based technology packages
- Reduces stress and failure of gas system components
- A focus on reduced-risk gas delivery solutions
- These technologies replace high pressure cylinders
- NFPA — use SAGS whenever able
- Offers a more secure and safe package to contain hazardous materials on site

REDUCING DELIVERY PRESSURE REDUCES RISK



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