SAGS TYPE 1: SUBATMOSPHERIC PRESSURE STORAGE AND DELIVERY

- Solutions have been defined and developed to achieve safe storage and delivery of gases and gas mixtures.
- These technologies replace high pressure cylinders
- Enables safe delivery of toxic gases for high-flow/high-usage rate toxic gas applications
- Proven field performance of SDS® and VAC based technology packages
- Reduces stress and failure of gas system components
- 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

**Introduce**

Risk is Proportional to Gas Pressure

- 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: 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 greater than 14.7 psig 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 psig at NTP and delivers gas at a pressure less than or equal to 14.7 psig at NTP.

**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.

**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 psig, 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 applications.

**Benefits of Novel SAGS-Based and Near-Atomospheric 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 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

**Summary**

- These technologies replace high pressure cylinders
- Enables safe delivery of toxic gases for high-flow/high-usage rate toxic gas applications
- Proven field performance of SDS® and VAC based technology packages
- Reduces stress and failure of gas system components
- Focus on reduced-risk gas delivery solutions
- These technologies replace high pressure cylinders
- NFPA — use SAGS whenever able
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**Results:**

<table>
<thead>
<tr>
<th>Description</th>
<th>Savings per tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment changes</td>
<td>$400,000/yr</td>
</tr>
<tr>
<td>Operating/variable cost savings by recirculating the heat (backed exhaust to the sub-atm)</td>
<td>$50,000/yr</td>
</tr>
<tr>
<td>Gas loss air exhaust, now being vented to general and non-related exhaust approx. 5000 hou rs/year</td>
<td>$5000/yr</td>
</tr>
<tr>
<td>Total Operating Expenses Savings</td>
<td>$55,000/yr</td>
</tr>
<tr>
<td>A one-time capital cost savings was realized through not having to &quot;ship&quot; the gas box exhaust to an abatement system</td>
<td>$450,000</td>
</tr>
<tr>
<td>Total Capital Expense Savings</td>
<td>$540,000/yr</td>
</tr>
</tbody>
</table>

**Case Study — Operational Efficiencies and Improved Process Results**

- User was allowed to adopt 20 Kg 100% phosphine due to safety concerns
- Was disallowed to implement high pressure 100% PH₃ 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% PH₃ would yield improved results

**Solution:**

- User was allowed to adopt 20 Kg 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

**Reducing Delivery Pressure Reduces Risk**