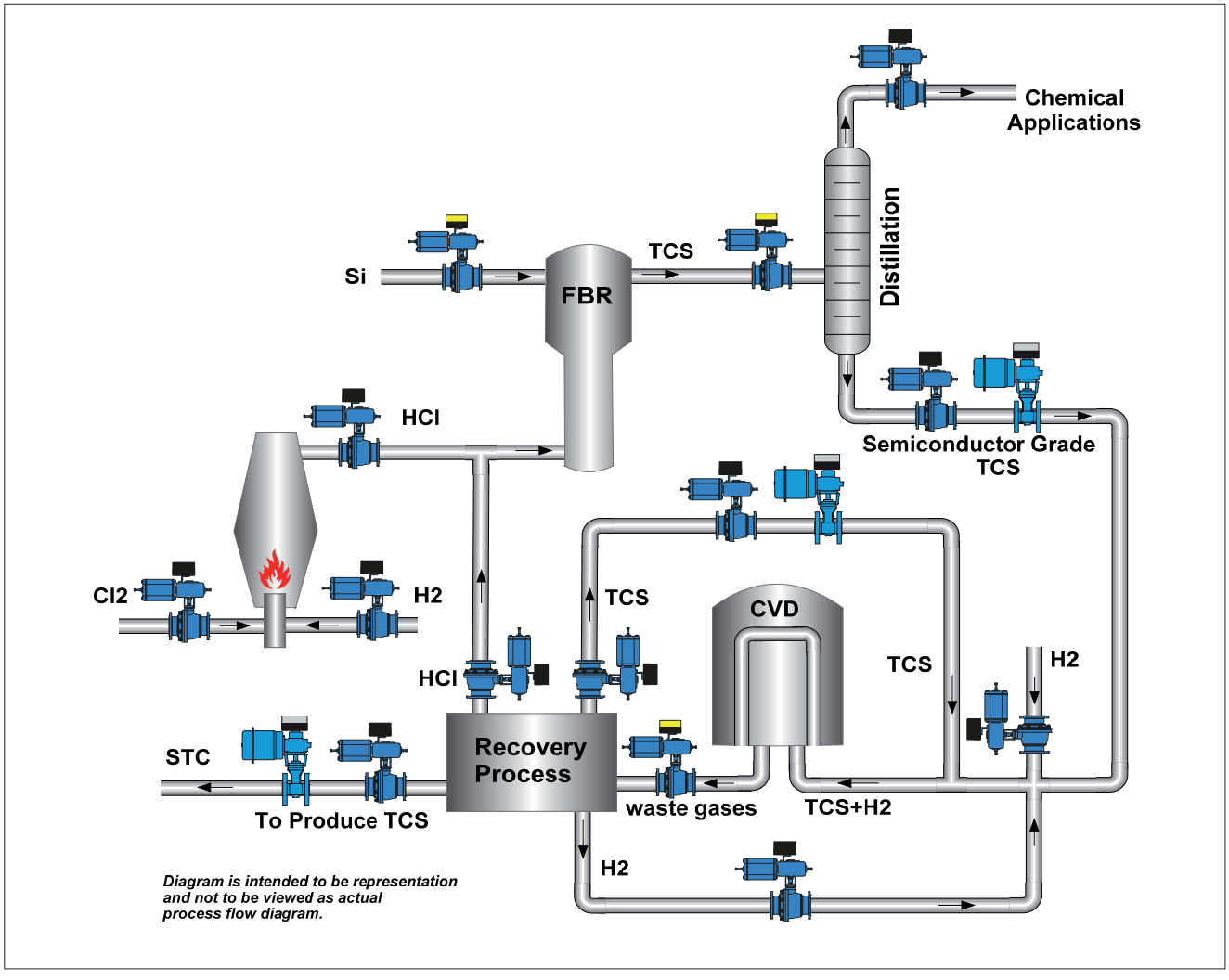
Polysilicon production



Process overview

A typical polysilicon process is using SiO_2 (quartz sand) as raw material to produce metallurgical grade Si, also known as MG-Si. MG-Si is obtained in an arc furnace with existence of carbon.

MG-Si is purified through the following processes:

First, Si is converted to $SiHCl_3$ (trichlorsilane, also known as TCS) via below reaction:

$Si + 3HCl \rightarrow SiHCl_3 + H_2$

The reaction takes place at around 300 °C in a fluid bed reactor with forming possible byproduct such as $SiCl_4$ and SiH_2Cl_2. Secondly, the $SiHCl_3$ is distilled, resulting in extremely pure $SiHCl_3$.

Finally, a chemical reaction takes place in a chemical vapor deposition (CVD) reactor under a high temperature around 1000°C, when high-purity electronic grade (>99.9999%) Si is produced through converting $SiHCl_3$ to Si and forming HCl (hydrogen chloride) as a new compound:

$SiHCl_3 + H_2 \rightarrow Si + 3\,HCl$

Meanwhile, some byproduct such as $SiCl_4$ (silicon tetrachloride, also known as STC) may form in the CVD reactor too. The mixture ($SiHCl_3$, $SiCl_4$, H_2, HCl) leaving the CVD reactor must be separated and recovered as much as possible to meet tight environmental regulations and reduce raw material consumption.

In the first generation process, neither $SiCl_4$ nor HCl is recovered. In the second generation process, only HCl is not recovered. Nowadays close loop production has been achieved in the third generation process, which means all the intermediate products and byproducts are captured and recovered to increase the whole process efficiency remarkably.

Polysilicon Production Challenges

During the process, raw material, intermediate products and byproducts include Si powder, Cl_2, H_2, HCl, $SiHCl_3$, SiH_2Cl_2 and $SiCl_4$, therefore valve's design must be able to deal with these medium, especially the highly abrasive Si powder.

The chemical compounds are extremely dangerous. H_2 and $SiHCl_3$ are easily combustible, HCl is dangerous and extremely corrosive, $SiHCl_4$ is a highly toxic substance that poses environmental hazards, which makes it necessary to recover these substances, and bring them back into the production process. Handling these chemicals, including the safe and environmentally sound disposal as well as emission control at the same time is not easy. All these chemicals should be captured and recovered to decrease raw material consumption and increase the whole process efficiency.

$SiHCl_3$ production is a complex reaction equilibrium system, different products and by-products form in the fluid bed reactor. Reaction condition should be controlled precisely to maximize $SiHCl_3$ yield.

Health, Safety, Environment – Valve leaking poses both an environmental and safety issue due to risk of fire, toxicity and volatility of gases. Emergency shutdown and on/off valves must be able to perform their action in a process or equipment failure.

Top-class products at maximum yield – The market calls for clean products and high quality. It is important that the process is stable, flexible and under control. Proper valve performance in fluid bed reactor, CVD reactor and recovery system improves the accuracy of throughput control and adversely affects to the plant performance and also the downstream processes.

Maintenance costs –Valves play an extremely important role in successful polysilicon producing performance. Poorly performing valves in the process must be serviced because they will have a direct impact on the efficiency of the process.

Plant run-time – Silicon plants are looking for longer plant run-times since downtime means production losses and is a remarkable cost including maintenance costs. This requires reliable equipment.

Neles™ solutions

We are all tuned up to answer these challenges through our polysilicon application experience and product offering for control, safety and automated on/off duty that ensure high valve performance. Neles valves have proven performance history and are designed for efficient and reliable process operation.

Safety - We are the only single source emergency shutdown valve supplier who has the experience and knowledge to combine intelligence with most reliable valves and actuators. Technology selections like rotary stem operation and inherently fire safe design ensure that latest emission and fire safety standards can be applied. Reliable valves with first intelligent, SIL3 approved safety valve controller and partial stroke testing system Neles ValvGuard™ will ensure that plant emergency shutdown valves will always perform properly when needed.

Efficiency - Throughput losses and poor control performance will be avoided with high performance rotary valves. Flow through the process unit may be changed as the need arises with rangeability of 150:1 and further with full bore ball valves. Our advanced intelligent digital valve controllers for control, on-off and ESD applications ensure high positioning accuracy and fast response. Correct valve selection and sizing with our Nelprof™-program we can assure the best valve performance and process control.

Availability - Simple rotary designs, same face-to-face dimensions, and global service network and inventory management will help you to optimize your maintenance activities. Rotary valves have been in service for several years without requiring maintenance and show no sign of leakage. The proven performance of Neles valves with long lasting metal seat tightness and shut-off capabilities makes them an ideal solution for on-off, control and critical catalyst handling applications.

Reliability - Valve performance trend data collected by our smart valve controllers and analyzed by open FDT/DTM technology based configuration and condition monitoring software, makes it possible to predict and respond to maintenance requirements and reduce unscheduled downtime. This gives full transparency to the valve performance in process control.

Polysilicon production applications

1. Chlorine and hydrogen addition valves
Chlorine and hydrogen are added into HCl oven to produce HCl, which will be further used to produce $SiHCl_3$.

Valve requirements

- Bubble-tight shut-off
- Low emissions packing and gaskets
- Oxygen degreasing required

Neles solution – Jamesbury™ 9000 series soft-seated ball valve with Xtreme™ seats and live loaded packing has proven to be the right choice as chlorine and hydrogen addition valves. The patented polymeric flexible-lip seat design offers tight shut-off in either direction and extended cycle life with minimum maintenance. Xtreme is a unique material that resulted from a technological break-through in our polymer research lab. The stem sealing design is made for long term and high cycle life that meet highest environmental requirements in a most economical way. Jamesbury 9000 series provides superior quarter-turn performance.

Fig. 1. Jamesbury 9000 series ball valve

2. Abrasive powder applications

Silicon powder addition valves
Silicon powder is added into a fluid bed reactor and reacts with HCl to produce $SiHCl_3$ as product and sometimes $SiCl_4$, SiH_2Cl_2 as by-products.

Silicon powder is highly abrasive.
$SiHCl_3$ production is a complex reaction equilibrium system, different products and by-products form in the fluid bed reactor. Reaction condition include silicon powder level should be controlled precisely to maximize $SiHCl_3$ yield.
The silicon powder in the fluid bed reactor should keep in a proper level to optimize fluidization and get enough contact with HCl gas to maximize $SiHCl_3$ yield.

Reducing furnace isolating valve

A chemical reaction takes place in Chemical Vapor Deposition (CVD) reactor under a high temperature around 1000°C, when high-purity electronic grade Si is produced through reducing $SiHCl_3$ to Si and forming HCl (hydrogen chloride) as a new compound. Meanwhile, some $SiHCl_3$ will decompose into $SiCl_4$ and Si.

The tail gas from the reducing furnace could contain some silicon powder, which is highly abrasive.

By-products recycling valve

The by-products from the Chemical Vapor Deposition reactor include H_2, HCl, $SiHCl_3$, $SiCl_4$, and sometimes entrain silicon powder, valve should be able to deal with all these possible mediums. Oxygen degreasing might be needed.

The recycling medium includes $SiCl_4$ (silicon tetrachloride), which will make hydrogen chloride and SiO_2 if it leaks from packing and mixes with water, then hydrogen chloride will lead to corrosion and SiO_2 in packing will lead to jam. High demanding emission control is required.

Neles solution – Neles metal seated ball valve X-series equipped with pneumatic B-series actuator, and intelligent on-off valve controller Neles SwitchGuard™ (SG9000) as an option for the most critical applications. Neles dust proof seat has proven to be the right choice as high erosion application such as silicon powder addition valve. The seat prevents silicon powder from penetrating behind the seat and seizing the valve, and its anti-abrasive feature makes it a perfect choice for silicon powder. The seat has continuous contact with the ball, wiping the seat surfaces with every cycle to prevent silicon powder build-up. Double packing with nitrogen purging could be used to eliminate emission from packing especially when medium include silicon tetrachloride ($SiCl_4$).

SG9000 gives the possibility to set the on-off valve stroking times and profiles according to the process needs. Its high pneumatics capacity also gives the possibility to reach fast stroking times without the need for any additional accessories such as volume boosters or quick exhaust valves. In addition, predictive maintenance can be practised with the help of the diagnostics that SG9000 provides on valve performance. To simplify the installation, different mechanical or inductive proximity switches can be installed inside the SG9000 housing. As an option for SG9000, we can also provide traditional control solution based on separate solenoid valve and limit switches.

Benefits

- Safety, long lasting tightness and cycle life
- Reliable operation with wiping seat design
- Emission proofing with rotary technology and standard live loaded packing
- Field proven performance
- Dust proof seat prevents silicon powder from penetrating behind the seat.

Fig. 2. Neles metal seated ball valve

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