A STEP CHANGE IN CALCIUM CARBIDE PRODUCTION TECHNOLOGY

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Abstract

Calcium carbide production volume has been in decline in Western countries for several decades as gas- and oil-based processes have mostly replaced the coal-to-chemicals production route. Correspondingly, there has been no major increase in individual calcium carbide furnace size since the 1960s, when furnaces of up to about 55 MW or 75 MVA were built. Meanwhile China's dramatic industrial development has led to installation there of a large number of often very small furnaces to support its growing coal-to-chemicals industry. China's policymakers mandate that the further development of its calcium carbide industry must maximize equipment scale, minimize water and energy consumption, ensure compliance with stringent environmental standards and utilize full process automation. Workplace safety is also a priority. Furnace designs now in use for decades can be readily improved to meet the future demands.

Hatch has worked with partner Carbide Industries to introduce a step change in furnace capacity and the industry's technology for producing calcium carbide. A process has been developed incorporating a 90 MW rectangular 6-electrode furnace, dry gas cleaning system for fuel gas recovery, and fully automated calcium carbide cooling and handling system. Underpinning these advances are Carbide Industries' proven and robust calcium carbide production process together with Hatch's advanced furnace and other technologies and past history of scale-up in diverse metallurgical industries. This article provides an overview of the new process and equipment, highlighting the advancements relative to the current state-of-the art in the industry. The first application of the system at the Qinghai Salt Lake Industry Co. (QSLIC) smelter in Golmud, China is profiled as a case study.

Introduction

Despite the decline in production of calcium carbide in Western Countries in recent decades, production has exploded in China with capacity reported to be in the range of 20 million t/a. By the 1960s, furnaces of about 50 MW or 70 MVA had been built in Europe and North America. Of course, producers continue to make incremental operational improvements and invest in upgrades to facilities, but no major step change in furnace capacity has been made in recent decades. Technology suppliers have either continued to offer furnaces of conventional design and capacity, or have exited the technology sales business altogether, notably Elkem.

Hatch has worked with partner Carbide Industries (CI) to scale up CI's circular 3-electrode furnace to a rectangular 6-electrode closed furnace design with double the capacity of the previous industry standard. The new furnaces are guaranteed for 90 MW (real power) operation, with a maximum design capacity of 100 MW. The first application of these furnaces is four units for Qinghai Salt Lake Industry Co. Ltd. in Golmud, Qinghai Province, P. R. China. Another furnace is being built for Qinghai Salt Lake Haina Chemical Industry Co. Ltd. (Haina) near Xining, also in Qinghai Province. In addition to the furnaces, associated dry furnace carbon monoxide off-gas cleaning and calcium carbide handling systems have also been designed by Hatch. Further details of the furnace design are given in separate papers [1, 2].

Background

Calcium carbide and acetylene were first produced by Edmund Davy in England in 1836, though their true chemical makeup was not known until much later. Acetylene was given its name by the French chemist Marcelin Berthelot in 1860 and calcium carbide was first identified in 1862 by the German chemist Friedrich Wöhler. However, both materials remained laboratory curiosities until 1892 when Thomas L. Willson, while seeking a more economical process to make aluminum, accidentally discovered the industrial means for producing these materials.

During the latter years of the 19^{th} century the discovery that acetylene, when burned in air, provided a far brighter light than anything else available at the time initially spurred the development of acetylene for home, vehicular and marine illumination, and at the turn of the 20^{th} century, oxy-acetylene cutting and welding processes were developed. However, most important for the development of the calcium carbide industry was the use of carbide for the manufacture of calcium cyanamide, an agricultural fertilizer, and the use of carbide-acetylene as a chemical feedstock in the synthesis of hundreds of aliphatic organic chemicals, particularly solvents, plastics and synthetic rubber. Out of Willson's 1892 discovery in Spray, North Carolina, numerous companies sprang up around the world, most notably Union Carbide Corp in the USA (Niagara Falls, 1898) and Shawinigan Chemicals in Canada (Quebec, 1901).

Calcium carbide production continued to expand rapidly into the 20th century and by the late 1950s and into the early 1960s the carbide chemicals industry was at its peak, with world production of calcium carbide estimated at well over eight (8) million tonnes per year (1962), with more than 90% of this in North America, Europe and the Soviet Union [3]. However, the advent of other routes for the manufacture of acetylene and the development of the petrochemicals industry, during the 1960s and 1970s, led to a rapid decline in calcium carbide production, especially in both North America and Western Europe.

Often, calcium carbide production was accompanied by ferroalloy production, since both require economically attractive access to electric power and utilize similar furnaces. By the 1960s, submerged arc furnaces for both calcium carbide and ferroalloy production had reached their historical peak capacity, up to about 55 MW or 75 MVA. Examples of large calcium carbide furnaces included Carbide Industries' 50 MW furnace in Louisville, Kentucky (1968), Cyanamid's 50MW furnace in Canada, BOC's 55MW furnace at ODDA in Norway (1979), Sentrachem's 50MW furnace in RSA and SKW's 50MW furnace in Germany. Up until today, there have been no larger calcium carbide furnaces put into service. Additionally, very few larger ferroalloy furnaces have been built; examples of these include Samancor's 60 MW DC furnaces at Middelburg in South Africa, and Nikopol's 75 MVA 6-electrode rectangular ferroalloy furnace in Ukraine.

Since the 1960s, calcium carbide production has declined in Europe, North America and the former Soviet Union as alternative processes using oil and gas feed stocks have become predominant for acetylene (or substitutes) production. As of 2015, the only operating calcium carbide furnace in operation in North America is Carbide Industries' in Louisville, KY, while in Europe, carbide continues to be produced in Germany, Austria, Sweden, Spain, Poland, Romania and Slovakia. Calcium carbide also continues to be produced in the Republic of South Africa and in quantity in Japan, primarily for captive chemical use.

Meanwhile, China's rapid industrial development has led to a dramatic increase in production. A first 1.75 MVA furnace was installed in Jilin in 1948 [4]. Chinese production was 210,000 t/a by 1962,**Ошибка! Закладка не определена.** and had grown to approximately 16,000,000 t/a in 2010, with installed capacity reported to be 22,000,000 t/a at that time.**Ошибка! Закладка не определена.** Domestically designed furnaces of 30 MVA (approximately 22 MW real power) based on older Elkem designs had become commonplace by 2010. By 2012, SMS Siemag had won orders to supply technology and equipment from two customers in China, each building four 46.5 MW calcium carbide furnaces. [5, 6]

Hatch and Carbide Industries were awarded contracts to supply technology and equipment for five 90 MW furnaces to QSLIC in 2010.

China is by far the most active area for investment in new calcium carbide production capacity at the time of writing, however, there are indications of renewed interest in other countries.

China's Conditions of Access

Development of the calcium carbide industry in China is required by the government there to be according to its Calcium Carbide Industry Conditions of Access (2014) [7]. Hatch and CI partnered to meet the technological challenges required to satisfy these conditions (and those in a 2007 revision of the Conditions of Access). The 90 MW Hatch CaC_2 Production System fulfills this goal.

Key points arising from Conditions of Access include the following:

- New calcium carbide production facilities must be co-located with other industry in order to enable the full reuse of calcium carbide coproducts such as furnace off-gas and recovered dusts, and the lime hydrate ($Ca(OH)_2$) coproduct from associated acetylene generation operations. Emissions controls must meet relevant Chinese standards for gaseous and solid wastes. – The 90 MW Hatch CaC_2 Production System is designed for full recovery of furnace carbon monoxide off-gas and dust and collection of all fugitive emissions. Additionally, fully automated mechanical systems for calcium carbide product cooling and handling virtually eliminate the generation of fugitive emissions of calcium carbide prior to the downstream crushing plant. In contrast, most existing calcium carbide plants in China have major off-gas and fugitive emissions. Fugitive emissions in these applications are often a consequence of manual handling of feed and especially the fume emanating from the calcium carbide tapping operation. These operations are typically a source also of significant safety hazards.
- The minimum capacity (power) of new individual furnaces must be 40 MVA, and of any new plant must be 150 MVA. – The 90 MW Hatch CaC_2 Production System furnace is rated for 195 MVA total power, is designed for 100 MW of real (active) power and is guaranteed for 90 MW of real (active power). A single Hatch process line satisfies the minimum capacity requirement not only for a furnace, but also for a new plant, while four furnaces of Chinese design, or two of European design are otherwise required.
- Automatic controls and sophisticated process monitoring are required throughout the process. – The 90 MW Hatch CaC_2 Production System is fully automated and remotely controlled using a Siemens PCS7

based PLC control system with proprietary controls developed by Hatch. The system is used to control and monitor furnace raw material feeding, furnace power supply, electrode regulation, automatic calcium carbide handling, furnace off-gas cooling and cleaning, and all associated utilities systems such as cooling water, nitrogen and hydraulics systems. In contrast, conventional plants in China are normally manually controlled with few monitoring and safety systems.

- Furnace energy utilization must be less than 3.2 MWh/t when producing calcium carbide with 300 L/kg acetylene gas yield. (The gas yield refers to the Chinese standard [8].) – The 90 MW Hatch CaC_2 Production System will achieve 3.0 MWh/t when utilizing good quality feeds. (Note that equipment design cannot change the thermodynamic energy requirements of the smelting reactions, so if poor quality feeds are used, undesirable side reactions will increase energy consumption beyond the target.)
- Comprehensive safety management practices and procedures are required. – The 90 MW Hatch CaC_2 Production System includes extensive safety features within the design of the process, equipment and control system. Of course, the whole design has been subjected to a formal HAZOP review with actions arising from the HAZOP addressed both in the design and in operating and maintenance procedures.

While the Conditions of Access are specific to the Chinese context, they reflect targets which are broadly desirable throughout modern industry in all countries. The 90 MW Hatch CaC_2 Production System is a fully modern plant design reflecting the highest global standards.

Process Overview

Process Flowsheet, Layout and Material and Energy Flows

Figure 12 illustrates the process flows and equipment layout for the Hatch 90 MW Calcium Carbide Production System. The diagram is constructed from 3D views of the core process equipment separated to show process interconnections. The arrangement is indicative of the actual plant layout. The diagram shows the three core process areas: furnace, off-gas and CaC_2 handling. The equipment in each of these three areas is mainly located in its own building, one for each area. Not shown in the diagram are raw material feeding, power factor correction, crushing plant, utilities and fugitive dust collection systems which lie outside of the scope of this paper.

With good quality raw materials, furnace energy consumption will be about 3.0 MWh/t calcium carbide for a grade in the range of 300-320 L/kg gas yield or around 80 weight % contained CaC_2. (Again, gas yield refers to the Chinese standard.) Good quality feed refers to metallurgical coke with 88% or higher fixed carbon (moisture free basis) and burned lime with 96% or higher CaO content. Deleterious constituents such as MgO, alkalis and iron compounds should be a minimum to avoid unwanted side reactions which increase energy consumption and result in operational problems. With real (active) furnace power of 90 MW, calcium carbide production is 30 t/h and lime and coke consumption are approximately 26-28 t/h and 16-18 t/hб respectively. Coproduct furnace off-gas production is roughly 11,000 Nm^3/h, mostly as CO.

Furnace Plant

Coke and lime are supplied to the intermediate storage bins of roughly 10 hours operating capacity within the furnace building via conveyors from external storage and preparation facilities. From each intermediate storage bin two weigh feeders meter precisely controlled quantities of coke and lime to make a charge mix in the range of 0.6-0.65 coke:lime ratio depending on raw materials characteristics. Properly weighed coke and lime as a charge mixture are delivered to furnace feed conveyors located on each side of the furnace. Each furnace feed conveyor satisfies the inventory needs for six bins arranged in-line on each side of the furnace adjacent to the electrodes. From the furnace feed bins, charge mix is choke fed to each furnace closely around the electrodes.

Furnace feed and intermediate storage bins as well as associated conveyor transfer points are ventilated to a dust collection baghouse. Recovered dust containing coke and lime is well suited to reuse in a cement or lime kiln. Because the furnace feed bins are connected directly to the furnace freeboard through the feed pipes, there will be a continuous small emission of freeboard gas (mostly CO) to the feed bins. This is extracted with a large excess of air from the feed bins to ensure that the CO content remains well below the lower explosion limit. CO gas composition monitoring is interlocked with slide gates for feed pipe shutoff and nitrogen for purging to ensure safety.

The furnace is a rectangular, refractory lined, vessel with a composite carbon and refractory hearth. It is approximately 6.5 m across and 27 m long at the shell. Its roof (cover) is water cooled and includes openings for electrodes, off-gas connections, inspection ports and for feeding charge mix. Six in-line Soderberg electrodes are employed to supply the electrical energy for the calcium carbide production reactions. Tapping is from six sidewall tapholes adjacent to the electrodes with three in the 1, 3 and 5 positions on one side and three in the 2, 4 and 6 positions on the other side. The furnace is designed to accommodate thermal expansion during operation with the inclusion of an adjustable, spring-loaded binding system. Mechanical aspects of the design of the furnace are described in more detail in a separate paper.[Ошибка! Закладка не определена.]

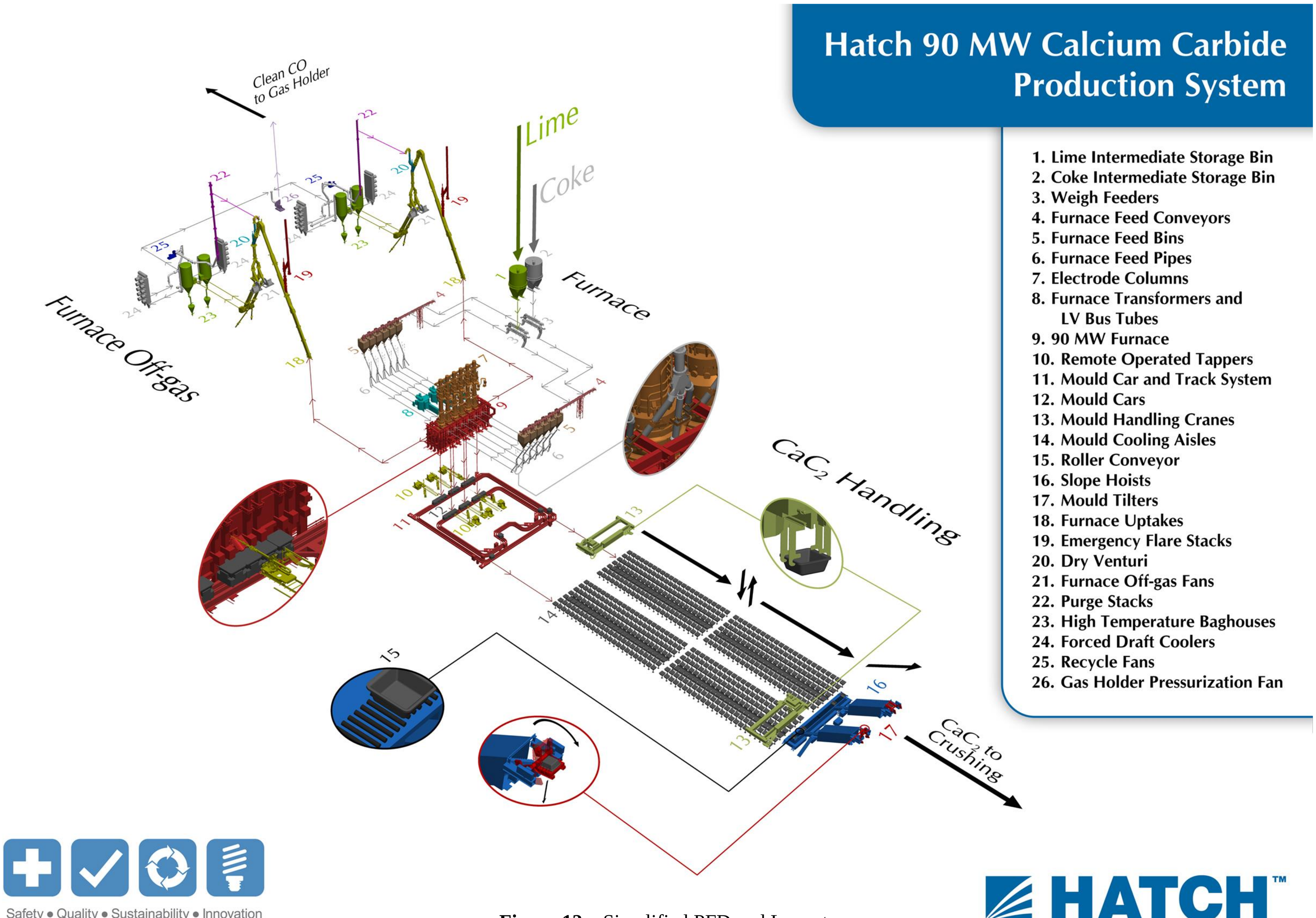

Figure 12 – Simplified PFD and Layout

Electrical energy for the furnace is supplied at 110 kV to the furnace switchgear and transformers. Three single-phase furnace transformers, each rated for 65 MVA and 150 kA, step down to between 250 to 500 V. Each transformer is connected to an electrode pair. At a 90 MW real power furnace load, target secondary voltage and current are roughly 390 V and 115 kA for each transformer. Process and electrical aspects of the furnace operation are discussed in more detail in a separate paper. [2]

Within the furnace, molten calcium carbide is produced according to the following reaction at about 2,000°C:

$$CaO + 3C \rightarrow CaC_2 + CO_{(g)}.$$

Side reactions reduce iron and silicon contained in the feed to produce liquid ferrosilicon alloy which is tapped with the calcium carbide. The quantity of ferrosilicon produced varies with the raw materials quality, but for typical raw material feedstocks it is in the range of 1-2% of the mass of the calcium carbide produced. Other impurities such as magnesium, alkalis and other metal oxides are also reduced in the furnace. Magnesium and alkali reduction lead to metal vapour production which vents from the reaction zone of the furnace along with the carbon monoxide. Metal vapours tend to reoxidise at lower temperatures, either in the furnace charge above the reaction zone, or in the furnace freeboard and off-gas system. These reactions can be a significant drain on electrical energy from the furnace. Also, oxidation products may result in buildups within the furnace which can lead to upset or even hazardous conditions.

Liquid calcium carbide is tapped from the furnace by burning a taphole through the sidewall using graphite stinger electrodes. Each stinger electrode is connected to a furnace transformer and diverts a portion of its current through the taphole to melt frozen calcium carbide in the taphole. The stinger electrodes are also connected to a tapping transformer system which regulates current to the stingers to a target value, regardless for furnace transformer secondary voltage. The tapped calcium carbide pours into 1.8 t capacity cast iron moulds. During tapping, hydraulically driven, remotely operated tapping machines (ROTs) of a proprietary design are used to keep tapholes open by rodding, to clean frozen carbide crusts from the taphole areas, and to plug the tapholes with clay when tapping is finished. The ROTs are operated by tappers from safe enclosures located on the tapping platform. Tapping fume (mostly oxidized calcium metal vapour, i.e. CaO) is contained within taphole hoods which are vented to a tapping gas baghouse.

The furnace roof, taphole frames, transformers, low voltage busbars, electrode contact clamps and furnace off-gas ducts are all water cooled. A closed loop system is used which includes features for water leak detection including tank level (total water inventory), circuit inlet and outlet flow measurement comparison, circuit pressure test capability and off-gas hydrogen and moisture content detection. In critically exposed furnace roof components, redundant water passages enable safe and orderly shutdown for repairs in case leaks are detected.

Calcium Carbide Handling

Moulds containing calcium carbide are transported away from the furnace on cars located on two parallel tracks operating on each side of the furnace. When a mould is filled, the tapper remotely activates the track system to push through an empty mould under the taphole, thus displacing the full mould. From this point through cooling, discharge to crushing and finally return to the track, the mould's movements are all automatically controlled, with no operator intervention.

After displacement from the taphole area, the mould and its car are advanced around the track to a mould pick-up station. The mould is removed from the car with a crane and is taken to the cooling aisle. The car then advances to a mould drop off station where a crane places an empty mould on the car. The car eventually returns to the taphole. Approximately 20 cars circulate on each track and there are provisions for accumulation of cars before the tapholes and before the pick-up station to allow for imbalances between tapping rates and crane transport rates. By design, the crane cycle (5.5 minutes) is faster than the average mould filling frequency (7.2 minutes) at 90 MW operation to allow for upset conditions and to ensure that the furnace is the bottleneck, not the mould handling.

Moulds are allowed to cool for 36 hours in two parallel cooling aisles, each of which contains 48 rows and 7 columns of mould cooling stands (672 cooling stands total). A fully automatic cooling aisle crane works in each aisle and each is normally dedicated to one track system, however either crane can access either track system. The normal crane cycle is as follows:

- Pick up a full hot mould from track system and transport to cooling aisle.
- Pick up adjacent full cold mould and transport to roller table.
- Pick up empty mould from roller table and transport to track system.

Alternate cycles are used to accumulate calcium carbide in the cooling aisle in case of a crusher shutdown, or to deplete cooling aisle inventories in case of a furnace shutdown.

Calcium carbide cools in the moulds to an average temperature of below 400°C before it is transported to crushing. Axial fans blow and fins divert air towards the bottom of the moulds to enhance cooling. Heat is exhausted below the cooling aisle roof.

Full moulds placed on the roller table are positioned in line with a slope hoist, one for each cooling aisle. The hoist lifts the mould from the roller table and transports it up to a mould tilter in the adjacent crushing building. The mould tilter grasps the mould and rotates it 150° to discharge the ingot of calcium carbide into the downstream crushing plant. The tilter returns the empty mould to the hoist which returns it to the roller table for crane pick-up. By design, the crusher feeding cycle is about 3 minutes and the roller table allows for cross-feeding between cooling aisles. This allows for processing of both cooling aisles' product through a single downstream crusher. (Normal crusher availability is expected to be lower than that of the furnace plant. So the ability to process all furnace production through a single crusher prevents crushing from being a process bottleneck.)

Note that the calcium carbide remains at all times in the mould until it is discharged into the crusher. This is in contrast to conventional plants which typically discharge the ingot from the mould onto the floor in the cooling aisle and then have some form of mobile equipment handling of the calcium carbide for transport to crushing. Although the Hatch system involves more mechanical handling equipment and more moulds in circulation; there are major advantages to this approach, including:

- Exposure of the calcium carbide to atmospheric moisture and consequent acetylene losses is significantly reduced since only the top surface of the ingot is ever exposed to the air. This is estimated to reduce acetylene losses in handling by 0.5%.
- There is no chance of water or snow on the floor contacting the calcium carbide. If this is allowed in a conventional operation, acetylene losses could be very high. It also creates significant safety risks.
- There are no fugitive emissions generated in the handling of the calcium carbide since it remains at all times in the moulds. (Of course the tilter and crusher must be located in a properly ventilated dust enclosure.)
- There are no operator exposures to either fugitive emissions, hot calcium carbide or mobile equipment hazards. Operation is fully automatic and remotely controlled.

Furnace Off-Gas Handling

The Hatch dry positive-pressure furnace off-gas cleaning system uses baghouses operating at ~200°C for particulate cleaning. The flowsheet is presented schematically in Figure 13 to simplify its presentation relative to Figure 12. The hot gas exiting the furnace remains slightly positive pressure due to stack effect. The initial cooling prior to entering the furnace off-gas fan is achieved by a water-cooled duct followed by recycling cool cleaned gas from downstream of the forced draft cooler. The cooled gas is injected using a custom-designed dry educator (venturi) to simultaneously pressurize and cool the furnace off-gas. This maintains positive pressure at the inlet of the furnace off-gas fan. The fan discharges the gas through a baghouse and forced draft cooler, keeping the entire gas handling system under positive pressure.

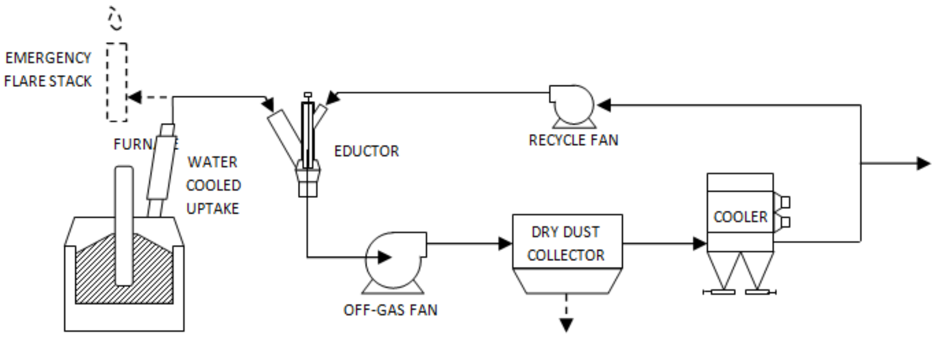

Figure 13 – Schematic of Hatch Dry Gas Handling System (One uptake, one train configuration shown)

Numerous safety improvements relative to existing processes have been incorporated in the design, including especially a fully pressurized system which prevents potential and dangerous air ingress, flange sealing with leak detection, a dust wash system to remove entrained CO gas, and fully automatic process controls including all start-up, shutdown, purging and operation sequences. This system is described comprehensively in another paper [9].

Furnace off-gas dust contains coke and lime from the charge mix, as well as reoxidised fume and carbon which have evolved in the furnace. It may be reprocessed in a cement or lime kiln to recover the calcium oxide and burn any carbon or other deleterious species present.

Water Usage

Water consumption in the Hatch 90 MW Calcium Carbide Production System is absolutely minimized. Water is used for two purposes only in the process:

- Closed loop cooling water for furnace, electrical equipment and off-gas duct cooling. Consumption of water is negligible, limited to first fill of the closed loop and make-up in case of leaks. Heat rejection from the closed loop can be directly to the atmosphere with air-cooled heat exchangers, or can be to an open loop with cooling towers if water consumption and discharge is tolerated. (For the QSLIC projects, one site uses cooling towers and the other air-cooled heat exchangers for reasons which are site-specific.)

- The furnace off-gas system incorporates a water seal for positive isolation for maintenance from downstream processes. A small and continuous flow of 1 m^3/h of water is required to maintain the seal in working condition during normal operation.

Safe Plant Layout

A number of steps were taken in the design to ensure safety through the plant layout and access:

- Remote location of the central control room is enabled by the use of a modern control system and CCTV. This removes all non-essential operator actions and time from the field to the safety of the control room.
- Furnace blows and eruptions from the furnace roof in case of operational upsets are an ever-present danger with a calcium carbide furnace. Access to the roof area is prohibited while it is in operation and there is no maintainable equipment in this area, except the furnace roof and electrodes. Maintenance of this equipment requires a shutdown for maintenance in any case.
- The only furnace off-gas equipment located in the enclosed furnace building is the duct exiting the furnace. Building ventilation and CO gas monitoring are employed on operating floors in the furnace building where CO emission from the ducts is a risk. All other furnace off-gas equipment is located outdoors for natural ventilation.
- The cooling aisles are a restricted area with gates interlocked to shift cooling aisles cranes from automatic to manual mode in case of personnel entry.
- The calcium carbide crushing plant is remote from the cooling aisle, and the furnace off-gas is remote from the furnace building, thus separating the areas and their respective hazards.

Advantages of the Hatch 90 MW Calcium Carbide Production System

Key advantages of the Hatch 90 MW Calcium Carbide Production System are summarized as follows:

- Efficiency:
  - Furnace energy consumption of 3.0 MWh/t can be achieved with good quality raw materials.
  - Labour involvement is minimized as a result of automatic controls and the reduced number of furnaces required for a specified capacity.
  - Product (acetylene) losses are minimized by handling of calcium carbide in moulds.
  - Fully automatic operation enables consistency in operation and will lead to high operating factor.
- Environmental protection:
  - The furnace is closed-type, with no emissions in normal operation.
  - Furnace off-gas (primarily CO) is fully recovered as a clean cool pressurised gas stream for reuse in other processes.
  - Furnace off-gas and fugitive dust sources are all captured and recovered as dry dust streams suitable for processing in cement or lime kilns.
  - Water consumption and discharge are minimised.
- Safety:
  - Remote control and fully automatic operation minimizes field operator exposures. This is especially relevant in the calcium carbide handling systems.
  - Extensive process and equipment monitoring systems are interlocked to protection devices to ensure safety and prevent damage to equipment.
  - Water leak detection systems enable determination of potentially dangerous conditions. Redundant circuits in critical areas as well as circuit isolation facilitate safe work during any necessary repairs.
  - A positive pressure furnace off-gas system provides inherent safety by preventing air ingress and explosion risks.
  - Numerous other safety features in the off-gas are incorporated to prevent worker exposure to potential carbon monoxide emissions.

QSLIC's Magnesium Integration Project

Contracts were awarded to Hatch and Carbide Industries for engineering, technology and equipment supply for the calcium carbide plant within QSLIC's Magnesium Integration Project at Golmud in Qinghai Province in Western China in 2010. The calcium carbide plant is one of several large industrial plants in an integrated production chain which will produce primarily magnesium metal (100,000 t/a) and polyvinyl chloride (PVC – 500,000 t/a) plus byproducts using magnesium chloride resources originating in the Chaerhan Salt Lake, plus locally available coal and limestone. As part of the Magnesium Integration Project, coal is coked and then converted to calcium carbide by smelting with lime. Calcium carbide is used to produce acetylene which is converted to PVC along with chlorine sourced from electrolysis of magnesium chloride in magnesium metal production. The calcium carbide plant includes four process lines of the Hatch 90 MW Calcium Carbide Production System and has a capacity of 950,000 t/a calcium carbide of 300-320 L/kg acetylene gas yield.

Contracts were also awarded for an additional process line by QSLIC's subsidiary Haina at Xining, also in Qinghai Province. Haina's project entails limestone mining, cement production, and serial production of burned lime, calcium carbide, acetylene and PVC. Byproduct lime hydrate ($Ca(OH)_2$) from acetylene generation as well as collected dusts from calcium carbide production are recycled for cement production. Coke for calcium carbide production is obtained from external sources.

At the time of writing in early 2015, construction of the QSLIC calcium carbide plant at Golmud is well advanced as illustrated in

Figure **14**. This photo, taken in January 2015, shows Furnace Buildings #1 through #4 from left to right as viewed from the upstream raw materials area. Furnace off-gas buildings for Furnaces #1 and #3 are started, visible in front of the furnace buildings. Tapping Gas Baghouses #3 and #4 are visible in the foreground, as is the Power Factor Correction Building #4. Cooling buildings are behind the furnace buildings and are not visible in the photo. Commissioning will commence in mid-2015 with start-up to follow promptly.

Figure 14 – View of QSLIC's Golmud Calcium Carbide Plant Showing Furnace Buildings' Construction Progress

Hatch and Carbide Industries jointly licensed the companies' respective technologies, while Hatch designed the scaled-up plant and equipment based on these technologies. Hatch supplied electrode columns and process control software. Hatch also provided assistance in purchasing and quality assurance of other equipment and is currently engaged in field technical support. Carbide Industries' personnel will join the field team for the start-up.

Hatch's engineering included basic design of the whole plant, and detailed design of the core process equipment and its control system. Important engineering contributions were made by China Tianchen Engineering Corporation (TCC) and Baosteel Engineering for detailed engineering of the calcium carbide plant buildings and other facilities at Golmud and Xining respectively.

QSLIC's Magnesium Integration Project is a major investment and can fairly be described as a highly ambitious megaproject given the number and capacity of the plants involved. More than this, internal recycle of byproducts among the facilities makes effective use of available resources. Further, QSLIC has shown strong industry leadership with adoption of advanced technology throughout its facilities, including especially the calcium carbide project. In adopting the 90 MW furnaces along with advances mechanization, automation, environmental protection and safety, QSLIC sets a new benchmark for the industry. This is also the first significant increase in furnace capacity attempted for submerged arc furnaces in more than 50 years.

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