A 90 MW CALCIUM CARBIDE FURNACE – MECHANICAL DESIGN

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ABSTRACT

Scaling-up a 50 MW, 3-electrode, round calcium carbide furnace, to a 90 MW, 6-electrode, rectangular closed furnace configuration presents a number of mechanical design challenges as well as opportunities. Hearth design, provisions for expansion and binding of the vessel, sealing, access doors and pressure relief, roof (cover) arrangement and support are addressed in this paper.

Carbide Industries' 50 MW furnace in Louisville, KY ran for a 29-year campaign without hearth repairs. Adaptation of its successful design to a 90 MW rectangular furnace presents a number of technical challenges. The rectangular shape also provides the opportunity to incorporate flexible bindings to accommodate thermal expansion/contraction. The resulting design is a world first which is expected to enable the longest possible operating lifetime.

The potential for eruptions is an ever present danger in calcium carbide furnace operation. Environmental demands dictate that any new furnace must be closed. The 90 MW furnace roof arrangement must simultaneously provide for pressure relief, access for operations, gas tight sealing and allow for expansion and contraction of the vessel. These interconnected design challenges and adopted solutions are described.

The first application of the system is at the Qinghai Salt Lake Industry Co. (QSLIC) smelter in Golmud, China. Future application of the 90 MW furnace design for ferroalloy production is a long term objective.

1 INTRODUCTION

Hatch has worked with partner Carbide Industries (CI) to scale up CI's round, 3-electrode furnace to a rectangular, 6-electrode closed furnace design with double the capacity. The new furnace is 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. near Xining, also in Qinghai Province, P.R. China. In addition to the furnaces, the associated dry furnace off-gas cleaning and calcium carbide handling systems have also been designed by Hatch [1][2].

Scaling-up a 50 MW, 3-electrode, round calcium carbide furnace, to a 90 MW, 6-electrode, rectangular closed furnace configuration presents a number of mechanical design challenges as well as opportunities. Hearth design, provisions for expansion and binding of the vessel, sealing, access doors and pressure relief, roof (cover) arrangement and support are addressed in this paper.

2 FURNACE OVERVIEW

2.1 General

The scaled-up calcium carbide furnace is a rectangular six-in-line electrode design with an overall size of 28.7 m x 8.1 m x 7.1 m. The furnace is equipped with a water-cooled roof (cover) that includes an off-gas port at each end. The bottom and sidewalls are cooled by forced air, while the endwalls are not cooled. Molten material is tapped from the furnace through six tapholes, with three located on each sidewall. Isometric three-dimensional models of the furnace are shown in **Figure 1** and **Figure 2**. A transverse cross-section of the furnace is shown in **Figure 3**.

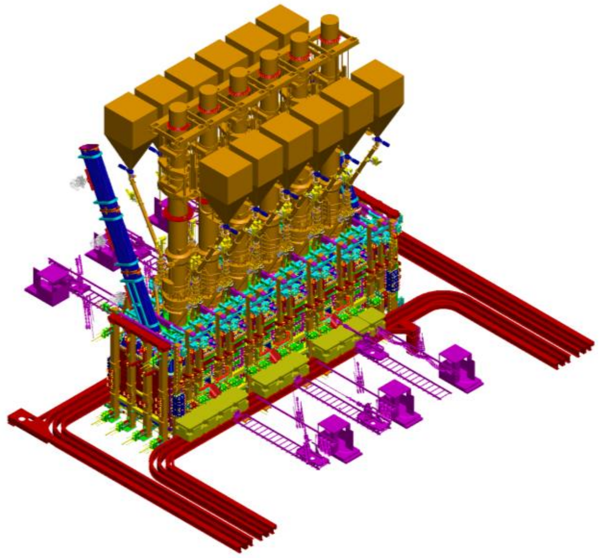

Figure 1: Furnace Overview including Auxiliary Components

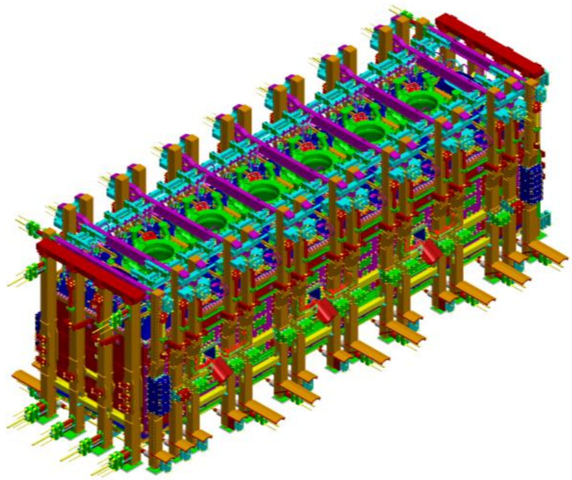

Figure 2: Furnace Overview

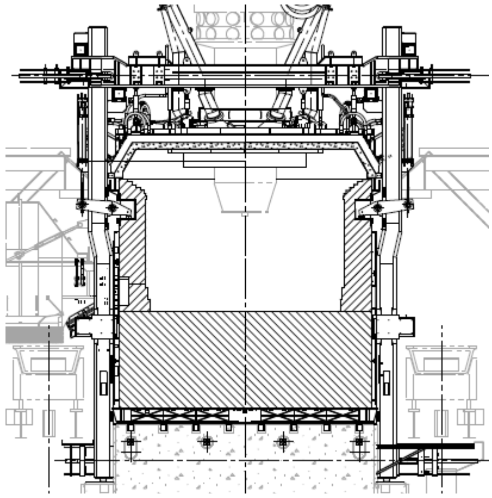

Figure 3: Transverse Cross-Section of Furnace

2.2 Feed System

The pre-mixed coke and lime charge is choke fed to the furnace by gravity from 12 overhead bins, located on both sides of each electrode. The feed system is a fully closed (sealed) design, which is required as the furnace operates between neutral and a slightly positive pressure (up to approximately 100 Pa). This causes small amounts of CO gas produced in the furnace to flow through the material in the feed pipes. CO gas that flows up through the feed pipes is collected at and exhausted from the bins. The CO gas levels in the bins are continuously monitored. The feed pipes include isolating slide gates and nitrogen purges for safety in the event that CO gas levels become excessive or bins run empty. An electrical insulation break is also included in each feed pipe to isolate the feed system from the furnace.

2.3 Furnace Body

The furnace design is scaled and adapted from the CI furnace, including key process parameters such as electrode spacing, reaction zones, electrode tip-to-hearth distance and overall cavity depth. The CI furnace is a hybrid design approximately 9.9 m in diameter and 6.5 metres in height. It includes three tapholes along the hearth elevation (one taphole located the shortest horizontal distance to each electrode) and a water-cooled roof which includes access ports and pressure relief devices.

For the rectangular furnace the steel is designed to accommodate thermal expansion and contraction of the refractory lining during all phases of furnace operation. An adjustable binding system is used to maintain brick compression in both the horizontal and vertical directions. This minimizes the potential for ingress of molten products into the brick joints, which subsequently helps to maximize furnace integrity and minimize contraction/expansion during extended outages and long-term hearth growth.

The binding system is composed of spring loaded tie-rods that transfer compressive forces through the vertical structural members (buckstays) and horizontal members (waler beams) to the hearth. Loads are applied to the hearth at two elevations, in both the transverse and longitudinal directions. Vertical compressive forces are applied to the side and endwalls using Hatch's patented wall hold-down system.

The furnace has a composite carbon/refractory hearth. The hearth has a flat hot-face profile but incorporates an inverted arch to help increase hearth stability under binding loads. The flat design of the hearth allows for the tapholes to be flush with the top of hearth. This permits continuous draining of ferrosilicon with calcium carbide to prevent ferrosilicon accumulation in the furnace. Continuous draining is important to prevent hearth penetration of ferrosilicon and to prevent ferrosilicon taps which damage the tapping and material handling equipment.

Steel shell and bottom plates are used to provide containment to the refractory lining and help to withstand loads generated during furnace operation such as ferrostatic pressure. The shell and bottom plates are divided into sections with expansion joints to allow for movement. The expansion joints are sealed to prevent furnace gas egress or air ingress.

The furnace roof is composed of a series of water-cooled panels arranged with a flat top and sloped sides. Feed is directed close to the electrodes and around the electrode perimeter through water-cooled feed distribution cones. The furnace roof load is supported from the furnace binding system using hanger rods, making it independent from the building steel. The furnace roof dimensions are fixed by the water-cooled panels and a sand seal, attached to the furnace shell plates, accommodates relative expansion between the furnace roof and furnace body.

2.4 Electrode Columns and Low Voltage Bus

Power is delivered to the furnace through six 1600 mm diameter electrodes projecting through the furnace roof along its centerline. Hatch designed electrode columns (see **Figure 4**) carry electrical current to the electrodes, position the electrodes based on furnace power requirements, incrementally feed the electrodes into the furnace as they are consumed, and help in the sound baking of the electrodes. The electrode columns feature a simple fail-safe, spring-applied, non-releasing, hydraulically actuated slipping system. The contact pads are a high current, even-pressure design which ensures even baking and minimizes casing bleeders. The slipping assembly is designed for 1.5 m of travel and is capable of both slipping (downward moving) and back-slipping (upward moving) the electrode.

A low-profile electrode seal is used at the furnace roof interface to allow for the lowest possible power clamp elevation as this helps maximize the furnace power factor. The power clamp is situated above the electrode seal (i.e. above the furnace roof line) to allow for external maintenance and a significant improvement over conventional furnace and electrode column designs.

Figure 4: Electrode Columns

A water-cooled low-voltage bus provides the electrical connection between the transformers and the flexible cables connected to the power clamps on the electrode columns. The low-voltage bus is configured as three sets of twenty-four bus tubes, each set carrying current to two electrode columns (twelve bus tubes per electrode). A single-sided bus connection is used on the electrode columns to minimize impedance and maximize furnace power factor. To accommodate the unbalanced loading on the columns from the single-sided flexible connections, reaction devices fixed to the building steel are incorporated into the design.

2.5 Off-Gas Ducts

Furnace off-gas is exhausted through two water-cooled uptake ducts located on each end of the furnace roof. The ducts are obround in shape with fabricated water cooling channels. Features are included to mitigate dust build-up including: orientation at a steep angle, low superficial design gas velocity (approximately 6 m/s), a smooth interior surface and rappers to dislodge accretions. A dry gas cleaning system of a proprietary design by Hatch is employed for cooling, cleaning and recovery of the CO gas [3].

2.6 Tapping

Under normal operation tapping will be continuous with one taphole open on each side and tapping progressing from one taphole to the next approximately every hour. Water-cooled copper taphole frames are provided on each taphole for radiation protection of the furnace shell and cast steel launders are used to direct tapped material into cast iron moulds. The moulds containing molten calcium carbide are transported away from the furnace via a rail system to a cooling area to await further processing.

Tapholes are opened using a stinger electrode. The stingers are connected to a tapping transformer system to adjust the stinger electrode current independently of furnace transformer voltage. Remote Operated Tapping (ROT) machines of a proprietary design are used for taphole rodding, taphole cleanup and taphole plugging.

3 Hearth, Expansion and Binding

3.1 Binding System & Hearth Design

Binding systems are installed in order to maintain the integrity of the furnace during heat up and cooling cycles. During furnace cool down, the refractory will reduce in dimension (contract) and gaps start to form between bricks. The furnace binding system provides adjustable compressive forces in all three dimensions to maintain pressure between brick joints, minimize bath infiltration, ratcheting and significantly reduce the likelihood of leaks. Rectangular furnaces are ideal for the inclusion of spring loaded bindings and Hatch has successfully engineered and implemented binding solutions on over 50 new and rebuilt rectangular furnaces around the world.

Historically most traditional carbide furnaces have hearth lives in the range of 3 to 12 years as they do not have an active binding system, relying instead on a combination of carbon paste and compression blanket between the lining and steel shell to take up the furnace expansion during heat up. Without binding forces the furnaces tend to be more prone to gaps forming between bricks during furnace cool down, which leads to ratcheting from infiltration of material between the gaps, ferrosilicon penetration and overall premature failure. CI’s circular furnace had outstanding performance without a hearth run-out during a continuous operation period from 1982 into 2011 (almost 29 years) until a major rebuild was undertaken. The rebuild was initiated prior to the hearth having reached the end of its useful service life as a result of an explosion. The perceived success factors of CI’s design consisted of the overall hearth design, high manufacturing quality of the materials used, superb installation methodology to achieve tight tolerances and a very good maintenance program. Consistent and steady operation by an experienced and reputable company to limit the number of thermal cycles as well as the continuous tapping across the hearth to reduce the opportunity for ferrosilicon accumulation and penetration also led to an extended hearth campaign life. The addition of a binding system to CI’s outstanding reference hearth design can significantly improve the campaign lives of calcium carbide furnaces.

Converting the CI furnace to a rectangular furnace with a binding system posed a number of technical challenges. In light of CI’s successful operation, the following key elements are retained in the design:

- Maintaining the main carbon working hearth lining and back-up refractory brick arrangement;
- Maintaining the flat hearth surface for ferrosilicon benefits (as mentioned in previous section);
- Maintaining tight tolerances and fit of carbon blocks;

The addition of a binding system enables the operator to control the growth of the furnace by ensuring pressure between bricks is sufficient at all times and does not need to solely rely on good initial installation and steady operation. As typical binding systems on rectangular furnaces use an inverted arch shaped hearth to maximize the effectiveness, maintaining a flat hearth surface created a significant technical challenge. The design uses the first of its kind jack arch arrangement to allow for the flat hearth surface to be retained; however this feature creates complexity in the manufacturing process since most carbon blocks are supplied in cube or rectangular shapes. The unique series of carbon block shapes forming the arch require multiple shapes with at least two machined tapered surfaces and very tight tolerances.

The use of two different materials for the construction of the hearth creates a scenario where the application of varying amounts of binding force is required. Carbon blocks can resist very high process temperatures; however, the compressive strength is relatively lower than that of the refractory hearth meaning the application of high compressive forces from the binding system might lead to damage of the carbon lining. In order to provide adequate binding forces for the carbon hearth, a secondary binding system (lower force) is introduced to maintain the brick pressure and prevent flotation within the carbon layers. The primary (higher force) binding loads are directed into the refractory hearth which then acts as a back-up lining to maintain furnace integrity. **Figure 5** illustrates the binding loading arrangement through a typical transverse hearth cross-section.

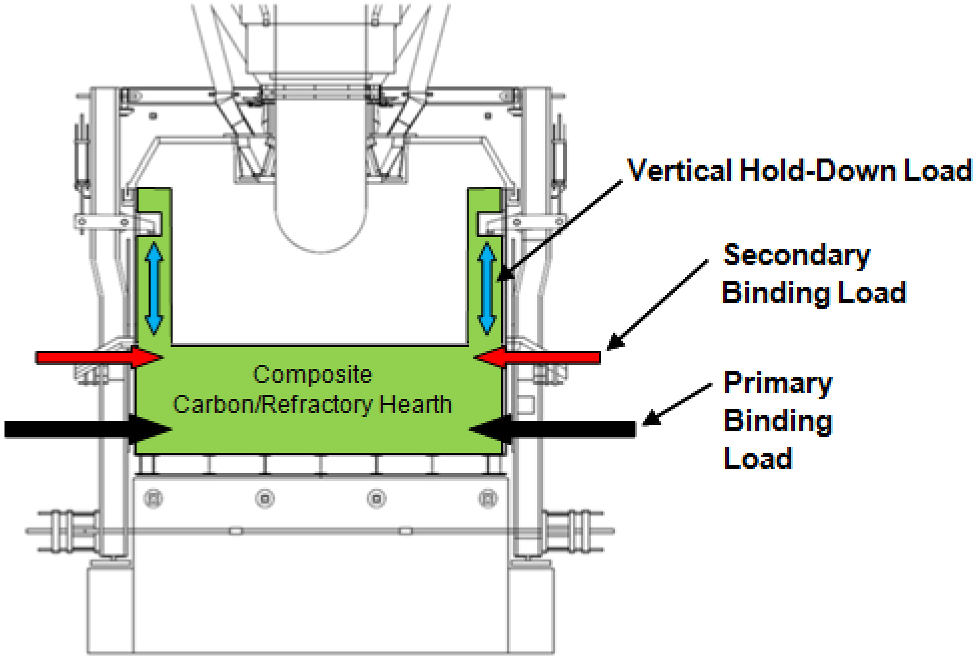

Figure 5: Furnace Binding System Loading Locations

The differential thermal expansion of the two hearth materials is also accounted for in the furnace design. The carbon hearth will expand rather uniformly in the transverse direction of the furnace, so neither expansion boards nor expansion papers are required. The longitudinal growth of the furnace is set by the maximum longitudinal carbon expansion after the compression of the expansion boards against the furnace shell. The differential expansion between the carbon and refractory layers is controlled and compensated for by the binding system.

3.2 Monitoring and Maintenance

Monitoring and maintenance of the binding system is a key factor to enable a binding system to perform efficiently at all times and new designs are incorporated to facilitate these activities. Load cells and displacement transducers are installed at each main binding spring set and buckstay. The loads cells present real time binding force values while the displacement transducers provide buckstay plumbness information to the operators. Both systems are integrated to the plant control system and data is made accessible in the control room. This effectively minimizes the field activities and the associated down time required for actual measurement with only essential adjustments to the components requiring field measurements.

As field activities close to hot material and equipment pose high safety risks, the above mentioned automated binding force and buckstay alignment reporting system can enhance the overall level of safety for site personnel. The system helps to eliminate some field tasks that are often neglected due to unsafe access or difficulty in performing the actual task.

4 Furnace Sealing

One of the main problems associated with calcium carbide furnaces is the workplace hygiene issues associated with the leakage of CO gas into the areas surrounding the furnace. This leakage is primarily a result of the need to operate with suppressed combustion in the freeboard; this means that the furnace cannot be kept under significant suction (since this would draw oxygen into the freeboard leading to combustion). As a result, leakage and 'puffing' often occurs at openings.

For a calcium carbide furnace, this problem is further exacerbated by the need to accommodate intermittent furnace over-pressurizations caused by charge slipping and the abrupt generation of CO gas. With some furnaces, such as the CI furnace, openings are often left around the electrodes to more quickly relieve these over-pressurizations from the furnace roof; however, this has led to greater CO gas emissions and worsening plant conditions if efficient secondary exhaust systems are not in place.

The Hatch calcium carbide furnace is designed as a fully closed furnace. This not only prevents unwanted gas egress into the working environment but also allows for the effective recovery of the chemical value of the CO gas without its dilution or combustion with air. Creating a fully closed furnace, while making accommodations for thermal growth, presented a number of unique challenges. A discussion of the key areas requiring gas sealing and the mechanisms used for providing seals follows.

4.1 Furnace Body/Roof Interface

While the furnace body is designed to accommodate growth, the furnace roof is considered to retain a fixed size based on the use of water-cooled panels. This arrangement creates a critical sealing interface that needs to: accommodate the movement of the walls in three planes of motion – vertical, transverse and longitudinal; withstand exposure to the furnace headspace which can see temperatures in excess of 1000^{o}C; accommodate any slight over pressurizations of the headspace; fit into the space constraints created by the furnace binding components in the area; and not impede access to the furnace roof for inspection and maintenance activities.

To provide a seal in this area, a sand seal is used, which consists of a sand filled trough attached to the furnace shell and a blade attached to the furnace roof (see **Figure 6**). The sand provides a maintainable medium that creates a gas tight seal at elevated temperatures while not losing any of its ability to accommodate movement. As the space available for the sealing connection did not permit designing a seal to permit the full amount of expansion expected over the life of the furnace, a modular sealing blade design is installed, which can be easily replaced as needed.

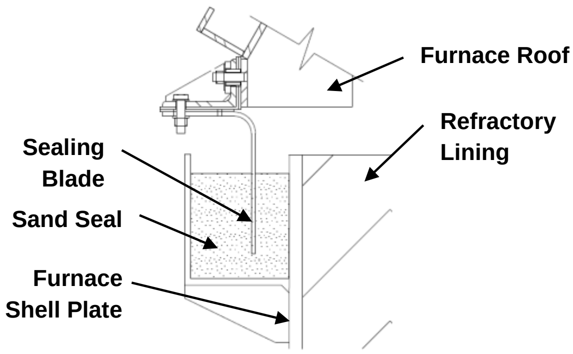

Figure 6: Furnace Roof-Wall Sand Seal Simplified Cross-Section

4.2 Furnace Roof Panel Connections

The furnace roof is constructed from a series of 50 panels which are joined together by bolted connections. Bolted connections are used to allow for modular installation and future replacement of individual panels in the event of wear or the development of leaks; however these present numerous potential leak paths for headspace gas. Similar to the interface between the roof and wall these seals must also be capable of withstanding the hot headspace conditions. In order to seal the panel joints, each connection is provided with a compliant ceramic refractory membrane to act as a gasket.

4.3 Furnace Roof Openings and Ports

Numerous openings are required in the furnace roof for a variety of reasons, ranging from inspection of the furnace interior to installation of instrumentation. For openings that remain fixed in place, with little to no movement expected during operation, sealing is accomplished through the use of high temperature gaskets with bolted connections. For openings which incorporate movable components, such as inspection doors, an additional level of complexity is added as these seals require a high degree of resiliency to withstand repeated use. The pressure relief doors offered yet another complication of requiring opening and closing while not being secured with any force other than their own weight. In these locations, designs incorporating a number of compliant ceramic refractory sealing membranes, including rope and moldable products, are used.

4.4 Off-Gas Connections

The interface between the furnace roof and the off-gas uptake connections also require a seal that allows for relative movement between the two components as the uptake ducts are supported independently from the furnace using building steel. A sand seal is installed in this location for similar reasons as those cited for use at the furnace roof-wall interface.

4.5 Electrode Openings

Electrode seals are provided to prevent gas leakage at the interface between the furnace roof and the electrodes. This area is a critical sealing location due to the high volume of gas typically generated around the electrodes. Sealing is made especially difficult by the harsh operating environment created by the movement and high temperatures at the electrodes.

The electrode seals sit on top of the water-cooled feed cone and have sealing elements in direct contact with the electrode casing to block process gases from leaking out of the furnace. The seal design consists of a double seal arrangement with pressurized inert gas introduced between seals. The use of purge gas creates a seal area that is at a higher pressure than the headspace, which forces the purging gas into the headspace and prevents headspace gas from escaping. The back pressure and flow of the purge gas is continuously monitored to assess the condition of the seal and allow for preemptive maintenance.

The seal elements are constructed out of both soft and hard ceramic materials to withstand the high temperature service. The entire seal assembly is designed to float laterally to accommodate electrode misalignment. Springs are used to press sealing elements against the electrode surface to allow accommodation of variations in electrode geometry (e.g. out of round, oversize, undersize, not straight, etc.). The seal frame is designed to allow for replacement of the unit and incorporates access doors for wear material replacement. **Figure 7** shows an illustration of the electrode seal design.

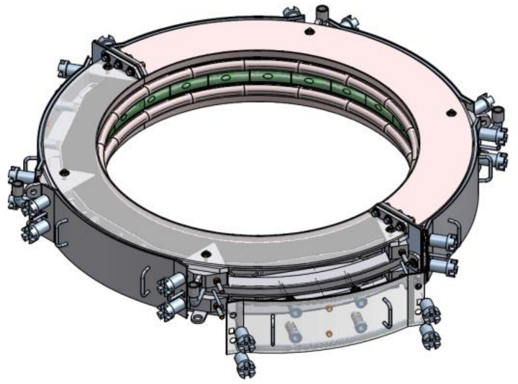

Figure 7: Electrode Seal

4.6 Furnace Steel Joints

All openings in the furnace steel must also be provided with a gas tight seal in order to maintain a closed furnace design as the positive pressure of the furnace forces gas out through any gaps that may open. Adding to the difficulty of maintaining a tight seal for the furnace body is the requirement to accommodate thermal growth over the life of the furnace. In many cases, such as the shell and bottom plates, this requires decoupling components to allow for relative movement between them. As the components move due to thermal loads gaps are created at the joints that become potential leak paths.

Various sealing mechanisms are incorporated due to the variety of joints and openings. In most locations, including the shell panel joints, bottom panel joints, wall hold-down openings and corners, a lap joint connection is used to act as an expansion joint. A sealing plate or angle is fixed on one side of the joint and allowed to slide against the mating plate. The sliding side of the joint is provided with a low friction sealing compound to ensure it does not limit movement.

5 Furnace Roof Design

The furnace roof (see **Figure 8**) is required to fulfill a number of essential functions while still adhering to a number of basic design principles. These functions include: providing a source of electrical insulation between the electrodes and ground; providing access for maintenance and inspection; and providing a means for pressure relief. When coupled with the design requirements of being completely sealed against gas egress/ingress and allowing for maintainability this presented a number of design challenges.

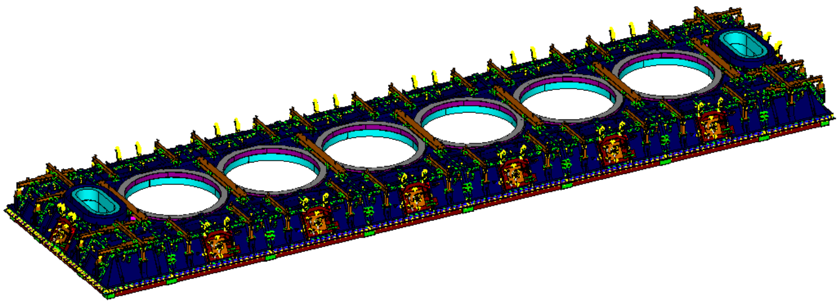

Figure 8: Furnace Roof

5.1 Electrical Insulation

The furnace roof is required to act as an electrical insulator between the electrodes, which operate at approximate 500 V, and ground. Achieving proper electrical insulation is a critical aspect in the design of any high voltage electric arc furnace to ensure the safety of personnel and equipment. An added challenge in calcium carbide furnaces is that the feed material is very conductive in nature and electrical flow paths through it must also be controlled.

Breaks to achieve both voltage insulation, which prevents flashover from energized (live) equipment adjacent to non-energized equipment, and current insulation, which prevents induced heating of materials due to circulating currents developed from the magnetic fields generated by the electrodes, are incorporated into the furnace roof design. A voltage break is provided between the electrode seals, which are in direct contact with the electrodes, and the furnace roof. Current breaks are included between the electrode seals and feed distribution cones as well as between adjacent furnace roof panels.

In addition to these measures, non-cooled furnace roof components within the area of high magnetic field intensity are equipped with shielding or are constructed from non-magnetic materials in order to reduce the level of induced heating. A potential monitoring system is also included in the design to detect when an isolation break has been compromised.

5.2 Access and Maintainability

The furnace roof is designed to allow for access to perform maintenance and inspection activities of various furnace components, while also incorporating features to allow for its own maintainability. While the water-cooled panel arrangement helps to provide a sealed design, its use dictates that a means to monitor for damage to the panels and detect leaks be incorporated. Several features are included to prevent, detect and minimize the impact of water leaks on the furnace operation.

Dual circuit pipe coil water passages provide redundancy in cooling capacity and circuits can be individually isolated and pressure tested in the event a leak is suspected. Each individual water circuit is equipped with flow monitoring and leak detection instrumentation. Pipes are used in place of the flooded channel design often found in calcium carbide furnaces as they offer numerous benefits including improved thermal and maintenance performance due to increased water velocities as well as more straightforward fabrication.

The sectional arrangement offers the benefit of allowing for replacement of individual panels in the event of a leak or refractory wear. Panel sizes and configurations are designed to allow maneuvering between binding steelwork when replacement is needed.

To allow for interior inspections of the furnace, access doors are provided around the perimeter of the furnace. Checks are routinely performed on the condition of the charge bed and the underside of the furnace roof. The access doors are also used for stoking the charge bed and breaking up crusting and boil-ups that may have occurred. Ports are included across from each electrode to enable electrode depth measurements to be performed.

Furnace roof support hangers are arranged as far away from the centre of the furnace to reduce the potential for induced currents and to maximize the space available to perform maintenance activities on the electrode seals.

5.3 Pressure Relief

The furnace roof is required to provide a means for relieving pressure in the event of an eruption or blow within the furnace. Furnace "eruptions" are a phenomenon observed in many submerged arc furnaces. While eruptions are a rare occurrence they are by far the most serious type of furnace event as they usually result in significant damage to the furnace and its surroundings. An eruption involves the ejection of a significant fraction of the furnace contents (solid, liquid and gases) from deep within the furnace interior. These events are believed to involve the very rapid evolution of large volumes of CO and calcium vapour from deep within the furnace cavity [4]. In the most severe cases, these events are thought to be caused by a "cave-in" of hanging charge into a pool of superheated liquid carbide in the void space formed under a crust that develops in the charge. Furnace "blows" result from a rapid over-pressurization of the furnace at, or near to, the charge surface and cause ejection of charge particulates; usually from around the charge funnels, up the sides of the electrodes.

Many previous calcium carbide furnaces utilize a semi-closed configuration to help reduce the impact of such pressure events; however with a closed furnace design this strategy cannot be employed and dedicated pressure relief openings must be included. These openings must be capable of rapid opening and exhausting a high volume of gas in order to minimize the actual overpressure for any given event and therefore minimize the extent of collateral damage. The Hatch furnace roof design maximizes the amount of area dedicated to pressure relief, providing nearly three times as much area as on the CI design, while still maintaining a relatively low activation pressure. A ventilation "smoke" hood located above the furnace ensures that emissions resulting from furnace over pressurizations are mechanically exhausted outdoors.

Fourteen relief doors, hinged along the bottom, are provided around the sloped sidewalls of the furnace roof. Locating the doors on the sloped sidewalls provides an arrangement that minimizes the gravitational inertia resisting opening during an over-pressurization event resulting in a quicker response time. Spring loaded restraints are used to limit the door opening angle allowing the door to help prevent damage to the surrounding area by directing flames and hot gases upward to the fume containment system. Due to the relatively large area of the door that is exposed to the interior of the furnace, and the necessity to avoid distortion in order to retain a proper sealing surface, water-cooling of the door is required.

Allocating a large area of the furnace roof to the pressure relief system impacts the design of the furnace inspection and electrode measurement ports. These ports require smaller openings and are conventionally restricted to being placed directly across from the electrodes. To accommodate these requirements a relief door design incorporating both a measurement port and inspection door is installed as shown in **Figure 9**.

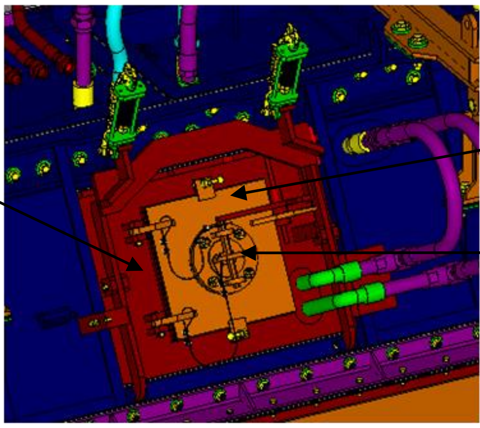

Figure 9: Pressure Relief Door Design

Engagement of furnace operating personnel from CI during the design phase enabled the design team to discuss ideas and weigh trade-offs with the benefit of a strong operational experience base.

6 Conclusion

The opportunity to scale up CI's proven and reliable 50 MW furnace to a 90 MW, 6-electrode, rectangular furnace presented a number of design challenges and opportunities. The result is the world's highest power calcium carbide furnace with a design that is robust, efficient, maintainable and the safest in the industry. The furnace builds on the strengths of both CI's furnace design and decades of operating experience while taking advantage of the rectangular configuration and modern design developments adapted from Hatch's experiences in building high powered furnaces for other industries.

7 REFERENCES

[1] McCaffrey, M., et. al., "A Step Change in Calcium Carbide Production Technology", Hatch, 2015.
[2] McCaffrey, M., et. al., "A 90 MW Calcium Carbide Furnace – Process and Electrical Scale-Up", Hatch, 2015.
[3] Trovant, M., et. al., "A Novel Dry-Based System for Safe, Hygienic Energy Recovery from Ferro-Alloy Furnace Exhaust", Hatch, 2015.
[4] Healy, G.W., "Why a Carbide Furnace Erupts", Journal of Metals, May 1966, pp. 643-647.