Future Performance Expectations for Foundry Bentonite

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Introduction:

The green sand molding process has been used in the foundry industry for many years! The challenge of this proven foundry methodology is to meet the future requirements of the modern foundries that have to produce a product that meets or exceeds the requirements of the casting consumer. Tomorrow's casting consumer is requiring improved dimensional tolerances to the cast part, at a reduced cost, and just in time delivery, to minimize inventory. Simultaneously, the foundry that is producing the cast part is required to improve casting quality, increase production to meet the casting consumer requirements, improve working conditions in the foundry, meet or exceed current and future environmental regulations, and an overall reduction in the cost of metal castings produced.

A metal casting facility is made up of various functional areas; these include "melting" capability, molding operation (green sand or other processes), core making, and various mechanical methodologies to separate the metal cast part from the molding media. Simply referred to as "Pouring, Molding, Cooling, and Shakeout" in a foundry. This publication will focus primarily on the molding process to produce a cast part. A traditional molding media for the metal casting process is made up of the aggregate (in most foundries Silica Sand); bentonite is utilized as the "perfect inorganic binder", and in addition to the bentonite specifically designed/selected organic/inorganic additives. Since the topic of this publication is "**Future Performance Expectations for Foundry Bentonite**", the selection of the aggregate will not be reviewed in this discussion. However, the consideration and selection of the bentonite/ selected additives will be discussed.

Main Characteristics of Bentonite for the Foundry Industry:

One of the reasons that bentonite is considered the perfect inorganic binder is because it can be reused many times (often referred to as "a recirculating" sand system). It is generally understood that 90% of the bentonite and selected additives are readily available to be rehydrated and molded to the desired shape to produce another metal casting. Because of the high temperatures generated during the metal casting process, montmorillonite dehydroxilation will occur. When the dehydroxilation occurs, two hydroxyl (OH) groups will form water vapor and irreversible deformation of the montmorillonite crystal will occur. High quality bentonites show higher dehydroxation temperatures. It is important to note that bentonites containing impurities (for this example a higher level of iron) have poorer dehydroxation behavior (Figure 1). Other impurities may have similar results.

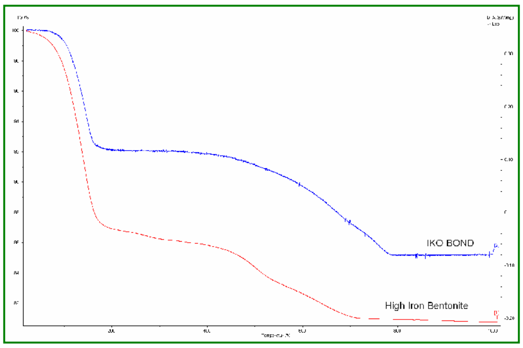

Figure 1, differences in dehydroxilation of two bentonites

Since each cycle of the returned molding media (green sand) requires rehydration and the addition of up to 10% bentonite to replace material that is not available for bonding, the future performance expectations of foundry bentonites must be considered. The primary performance indicators include; consumption/economics, mold strength, moldability, logistics and consistent quality.

Consumption of the bentonites is one of the most commonly discussed considerations of the current and future expectations of materials utilized in the foundry industry. Low grade materials can be consumed at levels of two to three times higher than materials with higher montmorillonite content and impurities that occur within the geological deposits (one example given is the iron content). As a result of this consideration, a desirable bentonite for the foundry industry is not limited to only the consideration of the montmorillonite content. To be specific, when a selected bentonite that is utilized in the metal casting process results in an increase consumption the recirculating molding sand will generated an increase in fines that will require more moisture to be added to the molding sand that will result in specific casting defects (e.g. porosity, water explosion, and scabbing) rendering the casting unusable. In addition to the foundry application of the bentonite, the economics of purchasing a bentonite will increase with the increase in the quantity of material consumed.

The next consideration is the mold strength and moldability (sometimes referred to as mold integrity) of the prepared molding sand. When a lower grade bentonite is utilized in the prepared molding sand it is not possible to produce the high quality molds that are required. This is generally reflected in the quantity of molds that can be produced in a desired length of time to meet the quantity of castings required by the casting consumer. This will result in increased costs to the foundry and reduced profitability. In addition, foundries also discover that specific casting defects increase/occur when lower grade bentonites are consumed. The casting defects that are usually observed include: porosity, water explosion, inclusions, and scabbing.

No discussion would be complete without considering logistics and consistent quality of the bentonite consumed by a foundry. In the world today it costs money to transport materials. In many instances a lower grade bentonite may be readily available to a foundry, but when the foundry considers the fact that it is transporting twice or three times as much material the cost of the product including transportation becomes uneconomical. In addition, consistent quality in the bentonite produced is usually a stronger consideration to the previously reviewed economical/logistics consideration. To produce a constant quality over an extended period of time the mining company is required to have a lot of experience and knowledge of the requirements of the foundry industry. A bentonite that is suitable for other application is mostly not the best product for the foundry industry!

Comparison of Bentonite as a Molding Media Compared to Chemical Binders:

In today's modern foundries there are two popular molding methods. These include the green sand molding process (utilizes bentonite) and the other is referred to as chemical binders (sometimes referred to as nobake molding). The comparison of these processes usually include; quantity (level) and types of materials consumed, environmental consideration (emissions at pouring, cooling and shakeout of the metal casting process), energy level requirements of the foundry, economics, and process considerations.

The quantity (level) and types of materials consumed is important. A typical green sand molding process will maintain a level at 8% bentonite by weight. Considering the fact that the green sand molding process is recirculating, typically 7.5% of the bentonite will be available to reuse (with 0.5% bentonite required to replace bentonite that has been consumed). A typical chemical binder molding system will maintain a 1 to 3% level in the prepared molding sand. Since the chemical binder molding system can not be reused, the entire quantity of chemical binder has to be replaced. This consideration has a big impact on the economics of the process.

Environmental considerations have a strong impact on the selection of the desired molding process. When considering the impact that bentonite has on the environmental considerations, the only contribution that bentonite has is the evaporation of water and carbon dioxide. The negative environmental considerations from the green sand molding process at pouring, cooling, and shakeout is the result of the addition of organic additives. In comparison, the emission characteristics at pouring, cooling, and shakeout of chemical binders result in very different emissions and odors that occur from the "cracking and burning" of the organic binders.

Another topic for this discussion is the understanding and application of energy demands and economics (since economics is heavily impacted by energy costs). The green sand molding process has a relatively low energy demand compared to the chemical binders. In most mining locations, a large quantity of the necessary drying of the raw ore can be facilitated by the "sun" and local conditions. In comparison, chemical processes that are required to produce the complex organic materials has a large demand upon energy which results in higher economics. As discussed earlier on the subject of economics, the cost of the finished product and transportation of the product will have an additional impact on the foundry consuming these products.

The final discussion in this section will review the process considerations of the two methods of mold production. Green sand molding can take advantage of two areas; it is a less critical process to control and the potential for less expensive pattern equipment in the molding operation. When considering process control for the chemical binder process, it is critical that the correct binder level is maintained for cost, technical and environmental reasons. The green sand molding process usually require less critical process variables which result in fewer control requirements and as previously stated a lower cost for pattern equipment.

Bentonite Modification:

Bentonite modification is a major element to the successful implementation of the future performance for foundry bentonites. The key element to the successful implementation of bentonite modification is based upon the concept of taking a bentonite from the market to the mine. Figure 2 is a graphical representation of this concept.

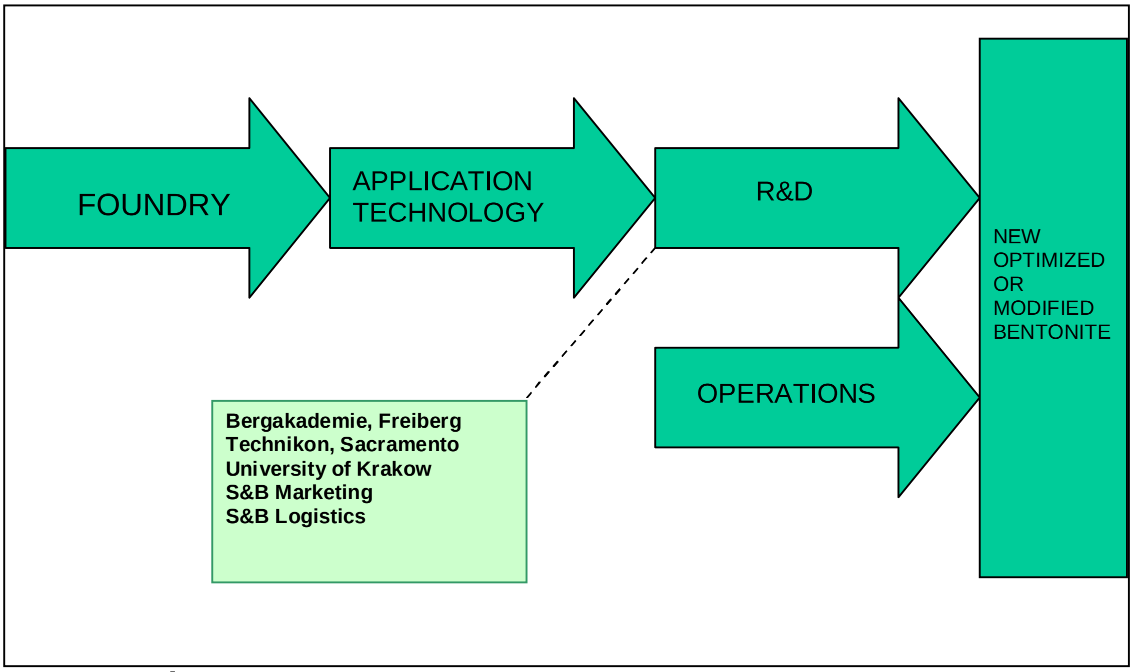

Figure 2, market to mine

The entire process begins with the customer (foundry) reviewing their future expectations of the bentonite with the bentonite supplier. The open communication between the foundry and the bentonite producer is critical. The foundry must supply measurable information that will allow the bentonite producer to develop a product that meets or exceeds the expectations of the foundry. The successful application of the information depends heavily on the application engineer that will interface with the research and development team that utilizes universities and technical support facilities. Next, with cooperative efforts from Universities and technical support facilities a product will emerge. These efforts usually result in a “prototype” that can be trialed at the foundry with input from manufacturing operation that will ultimately producing the product for the foundry industry. With all of the supporting efforts in place, a newly developed and optimized or modified bentonite is the result.

A question that is usually asked: Why modify bentonites? The foundries that consume bentonites usually ask for materials that result in higher production rates. This is usually measured in an increase in molds per hour, reduced production stops (down time), and improved casting quality. This can accomplished with shorter mixer/mulling time for the prepared molding sand, and less time required for the modified bentonite to re-hydrate. The “return on investment” to the foundries that purchase modified bentonites take advantage of improved casting quality. The measurable to this consideration is that modified bentonites have proven to allow foundries to produce castings more effectively because these bentonites allow for the casting to be produced with complex geometry. Another advantage to the improvement in the application of utilizing complex geometry that can be realized is that a greater number of castings can be produced per mold (measured with an increase in metal to greensand in the mold). An added consideration is the realization that bentonite modifications can result in less bentonite consumed and a reduction in the carbonaceous additives, this results in lower emissions during the metal casting process.

The second question that is usually asked concerning bentonite modification is: How does the application of bentonite modification apply to foundry molding sand? One of the first observations that are seen by the foundry person is the enhanced flowability of the prepared molding sand. Foundry molding sands that have been enhanced with bentonites that have been modified are more homogeneous compacted. This characteristic can be measured quite easily in the foundry by measuring the mold density. This “mechanical” characteristic of the molding sand is the result of better dispensability. Additional characteristics that can be observed in the foundry are an increase in strength properties of the prepared molding sand. The final consideration to the application of bentonite modification is the improved casting quality. The casting defects that are usually reduced are; erosion, penetration, and increase casting dimensional accuracy.

As discussed previously, bentonite modification will allow for a reduction of organic additives. One of the most effective bentonite modifiers is process carbon (figure 3).

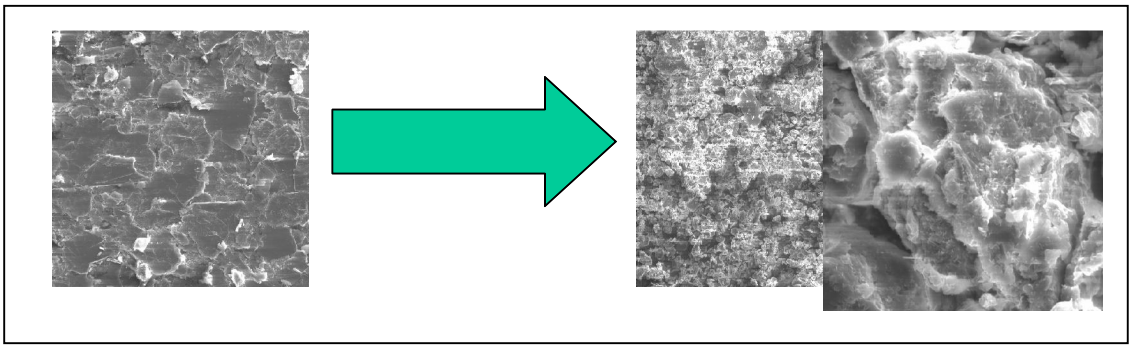

Figure 3, macro crystalline graphite when it is processed with bentonite creates a new bentonite (QUICKBOND) (pictures graphite left – QUICKBOND right)

The addition of macro crystalline graphite when it is processed with bentonite has the distinct advantage to develop a new bentonite that produces higher mold strength, increase greensand flowability, and fewer emissions when added to molding sand in a green sand foundry (less required organic additives)
A testing method that can be used to measure the increased in green sand flowability of foundry molding sand as a result of the addition of macro crystalline graphite when it is processed with bentonite can found in figure 4.

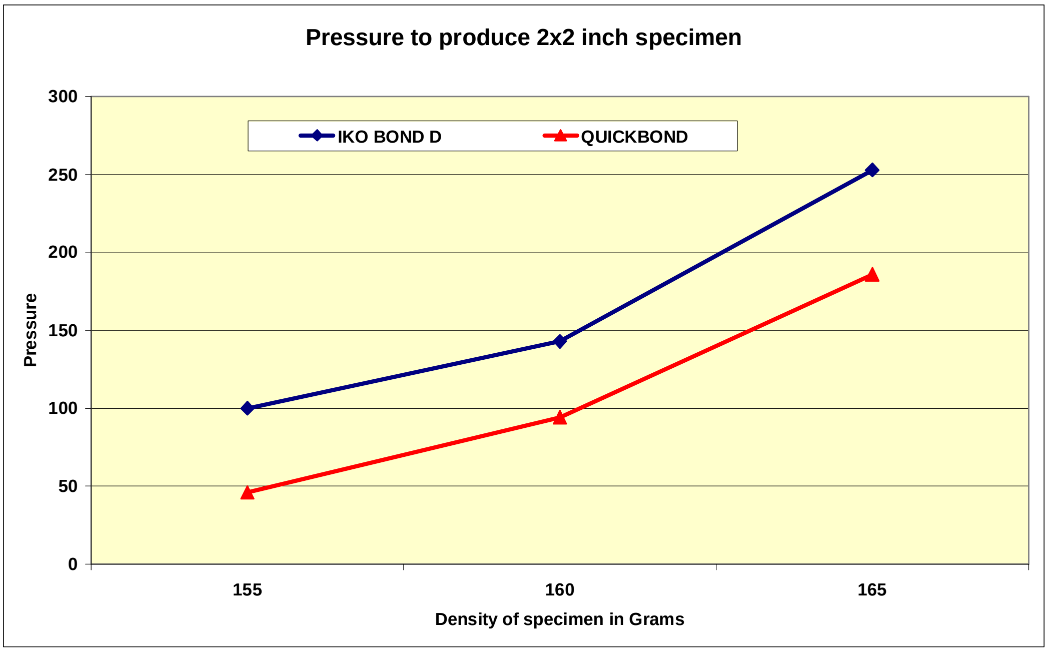

Figure 4, to achieve same density with process carbon modified bentonite (QUICKBOND) jess pressure is required.

This graphical representation compares two bentonites that have been evaluated in a laboratory environment with varying sand density versus the squeeze pressure required for molding (IKO BOND D (bentonite without processed carbon) and QUICKBOND (same bentonite with processed carbon)). It can be observed that; with the addition of processed carbon, less pressure is required for “molding” sand (improved flowability).

This relates to actual foundry molding production from the standpoint that molding operations regardless of the molding equipment (DISA, Impact, Floor Molding, etc.) require improved flowability which results in improved casting quality, production of castings with complex geometry, and a greater number of castings produced per mold.

The other previously discussed benefit to the addition of processed carbon into foundry molding sand can be observed in the reduction in emissions. To demonstrate this conclusion a prepared foundry molding sand utilizing a bentonite modification product with processed carbon to take advantage of a reduction in the quantity of seacoal required for casting production. Figure 5 is an excerpt from a CERP report (Technikon in Sacramento California) that demonstrates a significant reduction in hazardous emissions from test casting produced at the facility (a complete report is available upon request).

Analyte Name	Reference Test FK Average	HE Average	Percent Change from Test FK
Selected Target Organic HAPs and POMs			
Benzene	0.1450	0.0248	-83
Toluene	0.0744	0.0138	-81
Xylenes	0.0506	0.0084	-84

Figure 5, emission reduction by using modified bentonite instead of bentonite + sea coal

In addition to the previously discussed processed carbon that had been added for bentonite modification, additional organic additives, not coal, can be added to enhance the performance properties of molding sand. These additives are generally organic in nature and neutralized. The primary reason for these additions is to enhance the flowability characteristics and green sand properties of foundry molding sand without negatively impacting the emission characteristics that has been discussed previously. Figure 6 is a representation of the improvement in the green sand properties (reflected in Green Compression Strength).

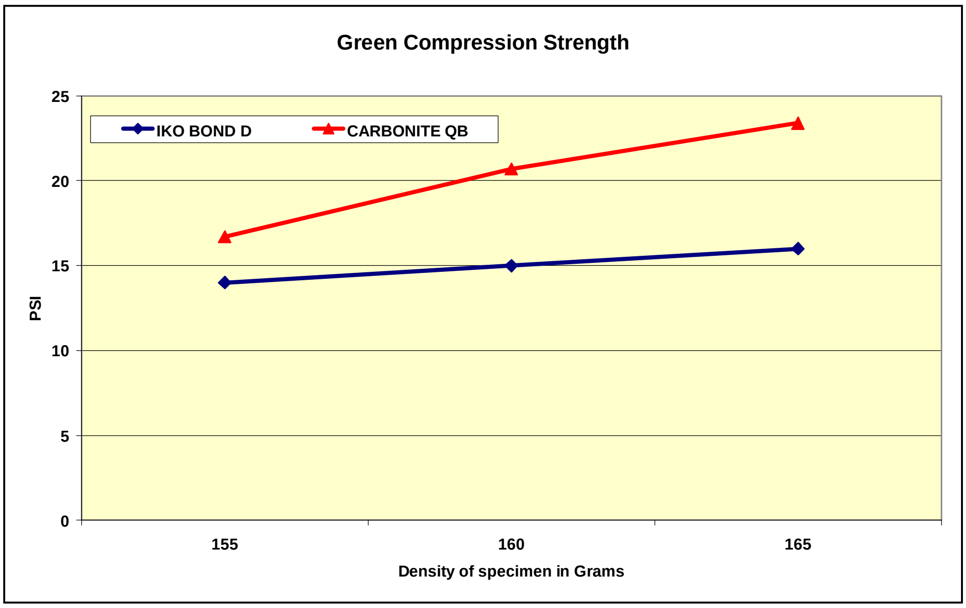

Figure 6, increased strength by using a “semi” organic modified bentonite (CARBONITE)

In this graphical representation the addition of both process carbon and organic additives has resulted in a significant increase in green compression strength. Additionally, other green sand properties were also evaluated with similar improvements.

In addition to processed carbon other additives can be added to the bentonite modification products to enhance the physical properties and environmental considerations. These additional materials could include zeolite and expending minerals. Figure 7 is a visual characterization of the benefits determined by the addition of these materials with the process carbon.

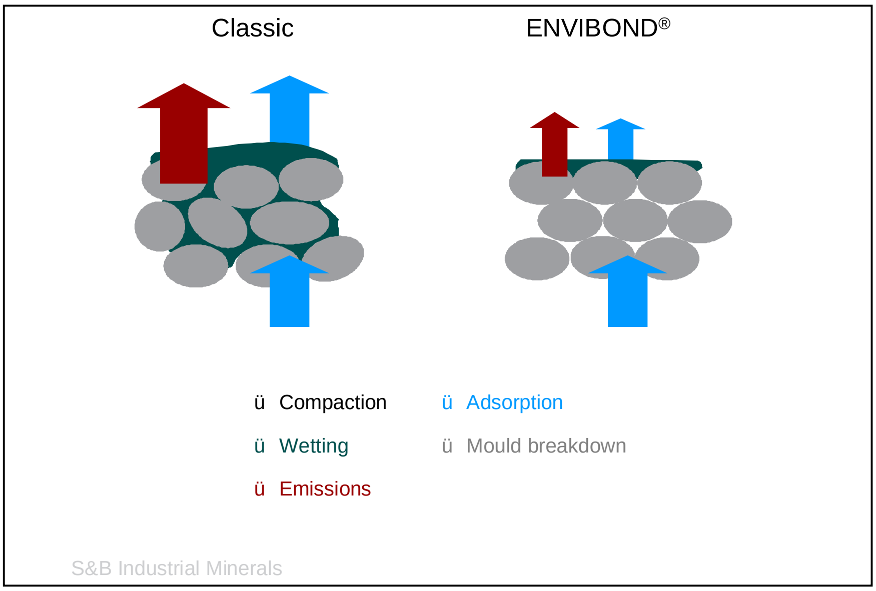

Figure 7, mechanism of ENVIBOND, higher compacted (less pores), less wetting by liquid metal, less carbonaceous additives (emissions), more adsorption (core binder gasses), good mold collapsing (shake out)

The basic concept to the performance of the mechanism of the product ENVIBOND® is the benefit that results for the creation of highly compacted molds in the molding process with less porosity. In addition to the highly compacted molds, the addition of the previously discussed process carbons benefits the casting solidification properties by developing less wetting of the liquid metal, also the process develops a closed mold that results in no emissions, and the zeolite will adsorb odors. In addition to the previously discussed improvements, the addition of zeolite, processed carbon in bentonite modification, and the addition of expending minerals will promote mold breakdown during shakeout in the metalcasting processes. The combination of bentonite modified products and these additional materials have resulted in a reduction in measured emissions.

<u>Application</u>:

As previously discussed, the key element to the successful implementation of bentonite modification is the concept of taking a bentonite material from market to the mine (reviewed in figure 2). One of the elements to the successful implementation of technology is the utilization of cooperative efforts from Universities and technical support facilities. To demonstrate this effective methodology, S&B has measured the emission characteristics of these processes at testing facilities (Technikon – US, University of Krakow-Europe). Figure 8 is an example of the testing methodology at the University of Krakow.

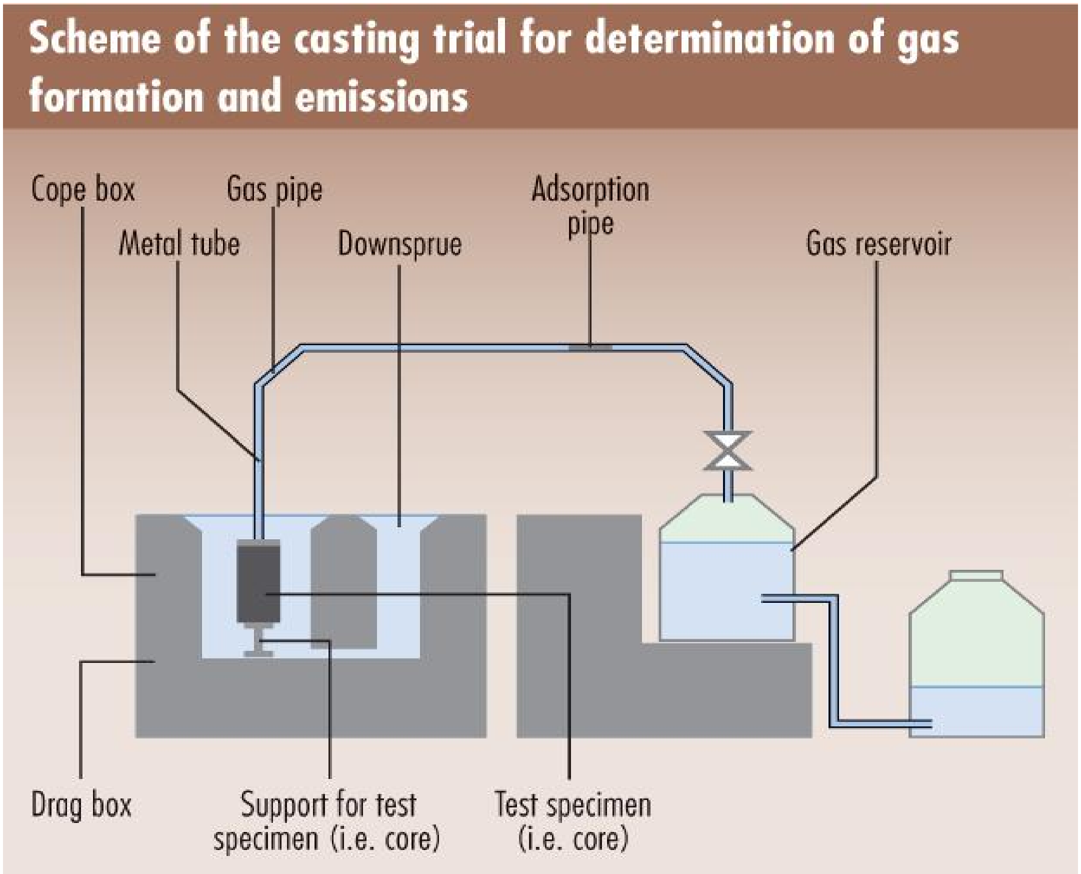

Figure 8, measurement of emissions, with adsorption pipe or filter to collect selected hazardous components, dust or condensates.

This laboratory set up has resulted in the development of a methodology for the successful application of technology to be applied to product development and then to the foundry consumer of materials for the green sand process.

In addition to the collected emission data from the University, one of the most visual comparisons that can be found when evaluating the various materials applied in foundries is the differences observed in the filter that is collected in adsorption pipe in the Figure 8 design. Figure 9 is a comparison of these observations. In this series of investigations a comparisons of three tests was completed. The first example shown is a new filter before evaluation, the second is a filter after evaluating ENVIBOND® in the equipment set up, and final example is a comparison to a classic (traditional) sample evaluation.

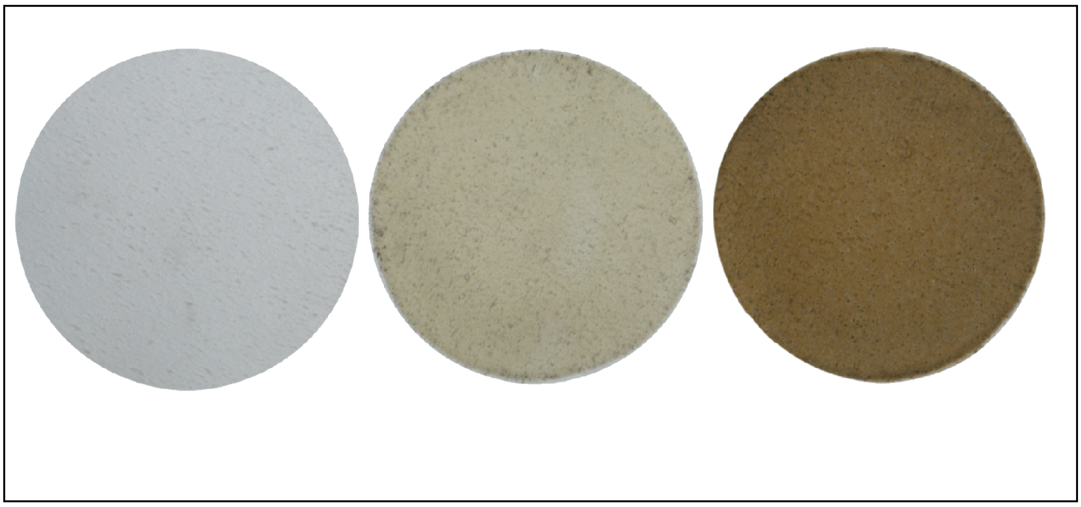

Figure 9, Foundry greensand, filters after test casting, left original, middle ENVIBOND, right classical foundry.

The comparison is dramatic. This comparison demonstrates the benefit to utilizing research and test facilities in development of bentonite modification products. Once a product has proven to be successful and a "prototype" project has been complete, a bentonite modification product is available to the foundry industry. An example of a foundry that has successfully implemented this technology can be found in Figure 10.

Figure 10, clean foundry, no visible smoke during casting

In this picture it is important to note that when the metal is being poured into the mold there are no visual emissions (usually observed as smoke). This is a very important issue with most foundries. In addition to no visual emissions, actual emission measurements were take at the foundry to determine the actual reduction in percent VOC and a reduction in BTEX in mg/kg of the molding sand. This comparison can be found in figure 11.

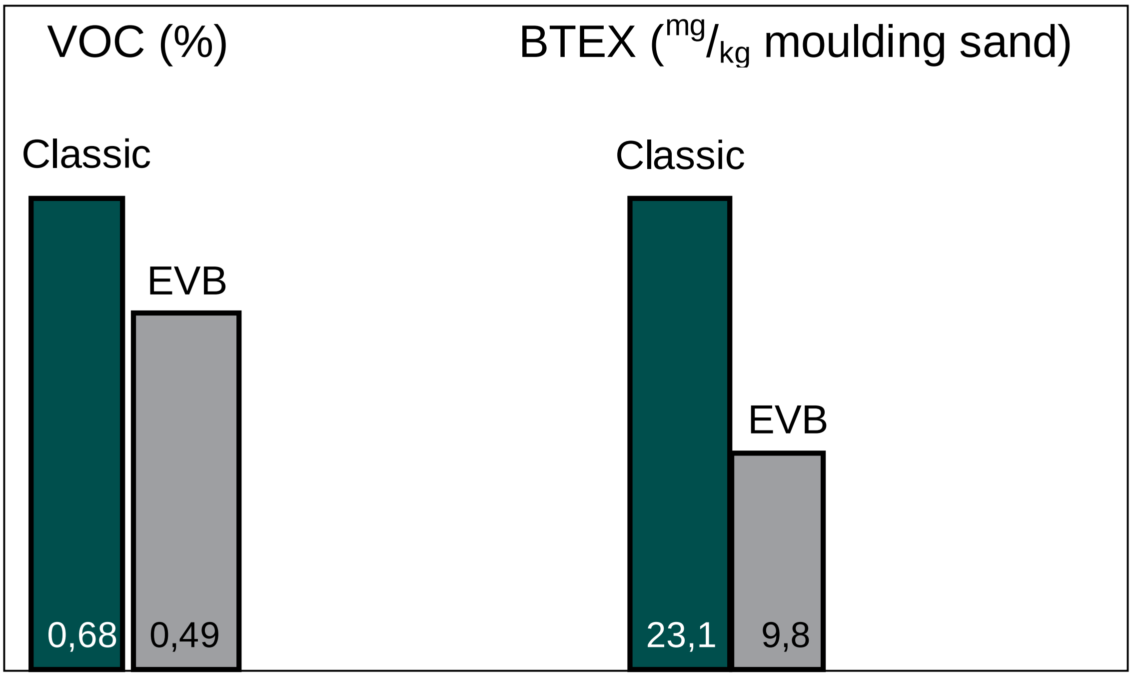

Figure 11, Emission reduction after introduction of ENVIBOND. Foundry is “core intensive”

<u>Cost Benefits for Modified Bentonites</u>:

Bentonite modifications have been successfully utilized in foundries in both Europe and North America. These foundries have observed:

- Improved Casting Quality
- Higher Production Rates
- Lower Emissions and Lower Emission Control Costs
- Lower Consumption of Materials by Foundries
- Improved Working Conditions in the Foundry

The only negative consideration is the cost for special additives.

Future Performance Expectations for the Foundry:

In the future, foundries will continue to have an increased requirement for greater productivity, higher production speed of molding machines, enlarged mold sizes (capabilities), and environmental friendly products.

To achieve this:

- A greater quantity of high grade bentonite will be used and modified for foundry applications.
- These modified bentonites will partly replace organic additives (e.g. Seacoal) in greensand molding systems.

The bentonites of tomorrow will therefore continue to offer benefits to foundries, meeting their future expectations!