First Phase Data Collection Required for Cost Benefit Analysis for New Product Development

GMBOND®

Technikon # 1409-140

WBS # 1.4.0

January 2004

THIS PAGE INTENTIONALLY LEFT BLANK

CERP

Casting Emission Reduction Program

Prepared by:
TECHNIKON, LLC
5301 Price Avenue ▼ McClellan, CA, 95652 ▼ (916) 929-8001
www.technikonllc.com

US Army Contract DAAE30-02-C-1095
FY 2002 Tasks

First Phase Data Collection Required for Cost Benefit Analysis for New Product Development
GMBOND®

Technikon # 1409- 140

January 2004

EPA United States Environmental Protection Agency

CISA

AFS American Foundry Society, Inc.

USCAR United States Council for Automotive Research

DaimlerChrysler Ford Motor Company General Motors

THIS PAGE INTENTIONALLY LEFT BLANK

First Phase Data Collection Required for Cost Benefit Analysis for New Product Development GMBOND®

Technikon # 1409-140

This report has been reviewed for completeness and accuracy, and approved for release by the following:

V.P. Operations:	*// Original Signed //* George Crandell	__________ Date
VP Measurement Technologies:	*// Original Signed //* Clifford Glowacki, CIH	__________ Date
President:	*// Original Signed //* William Walden	__________ Date

THIS PAGE INTENTIONALLY LEFT BLANK

Table of Contents

List of Figures

List of Tables

First Phase Data Collection Required for GMBOND® Cost/Benefit Analysis: Overview

This report is Phase One of a cost benefit analysis for GMBOND® Machine. This report provides the data collected to date, explains how this GMBOND® project was established and outlines its importance to the foundry industry. The analysis details the data and information gathered between June 2003 and December 2003. A complete cost benefit analysis will be submitted after core making test results are available (late 2004).

The first section of this report is a description of the process and the binder (GMBOND®). It also describes all the equipment that has been purchased and assembled to provide maximum flexibility for optimizing the process. A discussion of the decision to use pre-coated sand rather than a just-in-time mix system is included.

The product that is the basis for the study is a new generation V8 engine block casting scheduled by General Motors Corporation to go into full production in 2006. This product (the GEN IV block) is going to be produced using a precision sand process. Precision sand refers to molds that are made up of all resin bound sand cores. The current program is scheduled to start-up using ColdBox® or phenolic urethane as the binder for the sand. Tooling has been purchased to allow the GMBOND® machine to make the Gen IV block cover core. This core provides the opportunity to make a direct comparison of ColdBox® and GMBOND® core cost and benefits on a new product.

The second section describes the testing and data procurement process and equipment that have been established to gather the information necessary for comparing the two processes. The parameters to be measured and the equipment necessary to facilitate the data gathering are described.

The third section describes the ColdBox® process along with the production parameters that are being measured. The data that have been developed in ColdBox® core testing is included.

Next, a previous cost study is used to illustrate the potential cost/ benefit of the GMBOND® process. Additional data that is available is used to estimate the potential savings for the GMBOND® process using current costing data. This Phase One study can only estimate a potential range of savings since no actual data on an optimum system has been collected as of the end of 2003. At this time, the system is just completing debugging and initial start-up. The data parameters outlined in this report will allow a final cost/benefit analysis to be completed during the next phase of the program.

Finally, a discussion of what will be completed in Phase Two of the project and some suggestions for additional follow-up phases will complete this Phase One report.

THIS PAGE INTENTIONALLY LEFT BLANK

Background

With the need to maintain a viable foundry industry, the United States government sponsored research to identify ways foundries could comply with environmental regulations while maintaining casting quality and global competitiveness. The Casting Emission Reduction Program (CERP) was formed in 1994 to address these issues. The Cooperative Research and Development Agreement that formed CERP, was drafted between the U.S. Department of Defense, the U.S. Environmental Protection Agency, the California Air Resources Board, and private sector organizations like the American Foundry Society, the Casting Industry Suppliers Association, and the United States Council for Automotive Research.

It is CERP's mission to improve, develop, and/or demonstrate new products, processes, and technologies for the metal casting industry that reduce negative environmental impact and keep the industry competitive in a global economy. The research performed under CERP enables foundries to meet new environmental requirements while insuring an economical supply of quality castings produced in the United States. CERP is operated by Technikon LLC under contract to the DOD.

The Technikon foundry is located at McClellan Park, or the former McClellan Air Force Base, in Sacramento, California. Resulting information and research data is shared with industry, helping to secure American jobs and our national industrial infrastructure.

The project has resulted in a great deal of time and effort being expended in testing and developing new casting processes. A major sector of effort has been the testing of new core processes. One process that has shown great promise but has never been fully developed is the GMBOND® process.

General Motors Research and Development (R&D) started working on finding a new environmentally friendly sand binder system in the early 1990's. During the same time period GM Powertrain was analyzing the lost foam process for the production of future engine castings. After some initial developmental work, the GM R&D team working on the new sand binder formally introduced it to the U.S. metal casting industry in 1994, when they presented the technology to the AFS Casting Congress.

Also in 1994, J. Michael Williams of GM Powertrain Manufacturing announced that "lost foam will be the aluminum engine block and head process of choice" (Modern Casting, Aug. 2000, page 31 "A History in Foam"). Although there were obvious merits to the new sand binder technology, GM Powertrain management had already made a decision to optimize the lost foam process. Nevertheless, between 1994 and 1996 GM's R&D group worked to develop the general process parameters to produce cores with the protein-based sand binder. They realized that despite the Powertrain commitment to lost foam, their suppliers would have a need for this technology because of shakeout and environmental issues related to the phenolic urethane ColdBox® process.

Between 1996 and 1999 GM conducted several validation trials both internally and with Teksid SpA., a large automotive casting supplier. Castings were made in green sand molds, with GMBOND® cores for cast iron ventilated brake rotors. Aluminum squeeze cast V6 engine blocks were produced in GMBOND® in an effort to determine it's dimensional and shakeout tendencies. Many green sand molded aluminum cylinder heads were produced with GMBOND® cores. Teksid and GM verified the shakeout of the process with a semi-permanent mold aluminum suspension arm. In every case, the casting quality, surface finish, and shakeout were as good as or better than the phenolic urethane ColdBox® process. Despite this, GM was not in any position to commercialize and optimize this technology for the foundry industry.

As a result of their close relationship from past development work, Hormel Foods entered into an agreement with GM in December 1999. This agreement allowed Hormel to attempt to commercialize and develop the new technology. As Hormel has been introducing this technology, they have also been optimizing the core making process.

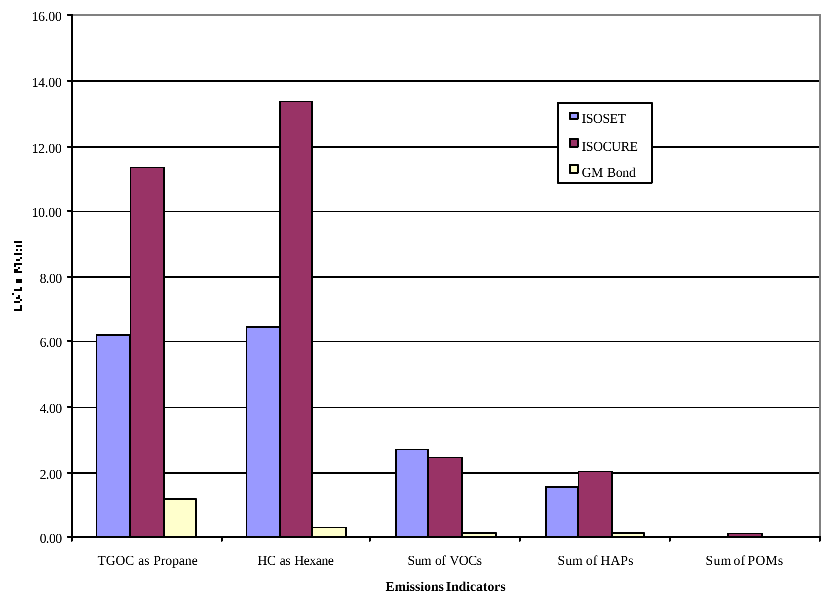
During this same time frame, the air emission testing of various new and improved core binders, including GMBOND®, indicated that GMBOND® produced significantly lower toxic air emissions than all other binders tested. Table 1 and Figure 1 compare GMBOND® with ISOSET®, a sulfur dioxide (SO_2) cured core, and ISOCURE®, a triethylamine (TEA) cured core.

Based on these data, a review of existing work that had been done by both General Motors and Hormel Foods, and the very high potential to recycle the sand that could result in cost benefits to go along with the proven environmental benefits, the US Army (the managers of CERP) and the CERP Steering Committee agreed to direct CERP funding to purchase and install a machine designed specifically for the GMBOND® process at an operating foundry.

Table 1 Comparison Summary Average Results – Pouring/Cooling/Shakeout

Analytes	ISOSET® (Lb/Tn Metal)	ISOCURE ® (Lb/Tn Metal)	GM Bond ® (Lb/Tn Metal)
TGOC as Propane	6.23	11.3	1.21
HC as Hexane	6.47	13.4	0.308
Sum of VOCs	2.71	2.46	0.172
Sum of HAPs	1.58	2.02	0.154
Sum of POMs	0.028	0.119	<0.001
TNC as Aniline	NA	NA	0.459
Individual Organic HAPs			
Phenol	0.930	1.62	0.035
Cumene	0.425	NT	<0.001
Toluene	0.042	0.026	0.070
Ethylbenzene	0.037	0.003	0.005
o,m,p-Cresols	0.025	NT	0.017
Benzene	0.025	0.023	0.004
Methylnaphthalenes	0.024	NT	<0.001
o,m,p-Xylenes	0.014	0.029	0.004
Acetaldehyde	0.010	0.036	0.006
Styrene	0.009	NT	0.004
Naphthalene	0.004	0.119	<0.001
2-Butanone	<0.001	0.006	0.004
Aniline	NT	0.156	<0.001
Hexane	I	NT	0.005
Other VOCs			
a-Methylstyrene	1.01	NT	<0.001
Trimethylbenzenes	0.045	0.392	<0.001
Ethyltoluenes	0.027	NT	<0.001
Dimethylphenols	0.009	NT	<0.001
Butyraldehyde/Methacrolein	0.004	0.044	0.002
Octane	<0.001	0.004	0.007
Other Analytes			
Condensibles	2.45	4.07	1.47
1,6-Hexanediol Diacrylate	<0.001	NT	NT
Trimethylol Propane Triacrylate	<0.001	NT	NT
Methane	NT	NT	0.037
Carbon Dioxide	NT	NT	22.3
Methane (Blank)	NT	NT	0.038
Carbon Dioxide (Blank)	NT	NT	22.3

Figure 1 Comparison of Emission Indicators– Pouring/Cooling/Shakeout



I: Data rejected based on data validation considerations. **NT:** Not Tested. All "**Other Analytes**" are not included in the Sum of VOCs or HAPs.
Individual results constitute >95% of mass of all detected VOCs.
* Blank sample refers to ambient background levels in building at time of test.

THIS PAGE INTENTIONALLY LEFT BLANK

Unique Partnership

This partnership between the private sector and CERP is specifically designed to aid in the ongoing competitiveness of the U.S. foundry industry. It is believed that a successful demonstration of the process at an active foundry will give the process the necessary push to allow viable commercialization with a resulting benefit for the foundry industry and the environment. With the cooperation, effort and active support of General Motors, CERP, Hormel, and the United Auto Workers, the necessary approval and funding for a project to demonstrate the viability of the GMBOND® was obtained from the Department of Defense. It was decided to install the machine at the General Motors Saginaw Malleable Iron operations in Saginaw, Michigan.

The launch ceremony for the first dual-station, production-type, core-shooting machine developed exclusively for use with the GMBOND® process took place at the General Motors Saginaw Malleable Iron operations on August 20, 2003. This machine is unique in that it is designed to accommodate all of the core boxes required for the core package of the General Motors GEN IV engine block. This aluminum block will be manufactured using the precision sand casting process. The current binder selected for the GEN IV engine block is phenolic urethane. This provides a unique opportunity to compare the costs and benefits of the existing accepted binder with the proposed GMBOND® properties. As the precision sand process is being debugged for the GEN IV block, the available tooling will allow GMBOND® cores to be substituted in the core package and direct comparisons evaluated.

The Sand Binder and Process

Studies in the past few years have shown that the new sand binder (GMBOND®) demonstrates several superior characteristics. The goal of the past GM research was to develop a binder that has numerous features: reduced odors and toxic gases, environmentally safe, repeatable recyclability, core strength comparable to current processes, good shelf life, reduced emissions, and easy shakeout from castings. The binder developed has been commercialized as GMBOND®. GMBOND® Sand Binder consists mostly of animal-derived biopolymers that are combinations of amino acids linked together to form long chains called proteins. The binder is a dry, fine, tan, water-soluble powder. In order to make a core for this process, you need the binder, sand, and also water. During the initial development, the amount of binder that will be used to make a batch is 1% of the sands weight. In order to make the binder become adhesive, water (2% of the sand weight) is required. Once water is added to the mixture, it has to be kept at 55°F +/- 5°F. Bonding is accomplished by dehydrating the wet core sand mixture. The biopolymers form covalent bonds as the water is removed from the core to form a crystalline structure. In this process, scrap cores can easily be reused because no chemical reaction has taken place. They just need to be broken down into fine grains again and put back into the system, needing no extra binder.

Previous work indicates GMBOND® sand binder is easy to use, allows for complex core design, and is simple to clean up. Cores made with GMBOND® exhibit high strength and surface finish, and, when properly cured, are easy to handle right out of the core box. Since the binder is completely soluble, water can be used to remove the core from its casting. Because cores dissolve in water, more intricate core geometries are possible. And because acid demand value does not affect overall core strength, GMBOND® can be used with any type of sand.

Another benefit of using this binder is that water can be used to clean the core box because of the binder's water solubility. Material can simply be wiped away using a cloth. GMBOND® dramatically reduces shakeout problems, solid waste, and scrubber costs associated with current commercial binder systems. Phase Two of the project will be to collect the necessary data to prove that a system specifically designed for GMBOND® provides the cost savings and environmental benefits that current data and testing have indicated could be possible.

GEN IV Cover Core

The GMBOND® process at Saginaw Malleable Iron (SMI) foundry currently has tooling to produce the cover core for the GEN IV V-8 engine blocks. This core is the largest in the GEN IV core package which makes up the complete mold for the casting. This core weights approximately 230 pounds. The material being poured is aluminum.

The Core Machine

The core machine was designed as two separate components: the sand system and the GMBOND® core-shooting machine. This design was necessary due to the overhead space constraints that were presented to FATA Aluminum by the Saginaw foundry during the design phase. Both the sand system and the core-shooting machine were designed to be able to function independently to facilitate the myriad of research and development tests required for process optimization.

Core Blower

The sand system contains the different elements required to prepare the GMBOND® coated sand and transport the sand to the core machine. The process begins with coated sand entering from a storage hopper located directly above the mixer. This bin is designed to provide enough sand for approximately thirty (30) minutes of production. It will hold the equivalent of three (3) tons of sand.

Storage bin and hoist

The bags of sand are picked up by the hoist and placed over the bin. They are set on a knife edge located inside the hopper which rips the bag open allowing the sand to drop into the bin.

When the pre-coated sand is required for production, it is introduced into the chiller and then mixed with a metered amount of water. This equipment cools and hydrates the sand to its optimal operating condition. From the chiller, the sand travels into the mixer. The amount of sand required for each cycle will be determined by the specific tooling. Currently, the GMBOND® project only has the tooling for the cover core. When the sand enters the mixer, water (2% of the sand weight) will be added. After water is added to the mixture of sand and binder, the temperature must be maintained at approximately 55°F. To refrigerate the sand, there is a water jacket on the mixing bowl that circulates water to cool the mixture. The mixer disperses the water evenly through the sand increasing the sand's flow-ability.

Due to the limited operating space above the machine, the prepared sand is transported via an enclosed belt conveyor. This specially designed conveyor maintains the sand temperature via cool air from the chiller while it is transported into the receiving hopper elevated above the shooting head loading station. This belt is equipped with a cleaning station to ensure that any sand remaining on the conveyor belt is removed for reuse. Like the sand mixer, the receiving hopper needs to be maintained at 55°F. This is accomplished by a water jacket circulating water from the chilled-water system.

Sand Hopper Over Core Sand Mixer

Enclosed Belt Conveyor

The core-shooting machine consists of the receiving hopper located above the shooting head of the machine, one core shooting station, two purging stations, and one core removal station. The receiving hopper stores the sand until it is ready for production. The receiving hopper acts as a preload station for the shooting head and also facilitates the removal of any unused sand by discharging it into a sand receiving flask. The machine is designed to allow for core unloading and core shooting to take place while a second core is in the air purge, or curing station. This allows for cycle time optimization consistent with customer demand.

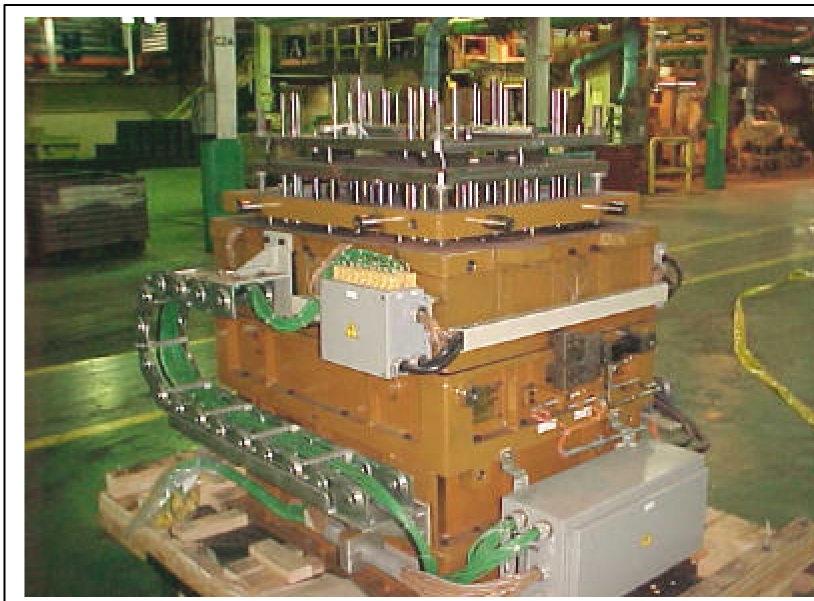
Aging Sand Hopper above Core Machine

Aging Hopper and Screw Conveyor

The shooting head moves transversely underneath the receiving hopper to receive a metered amount of sand necessary for core production. Immediately before entering the shooting head, the sand is augured from the conditioning hopper. As shown in the photograph above, both the aging hopper and screw conveyor are insulated to insure the temperature stays at approximately 55°F. The shooting head is uniquely designed in that the sand is shot into the mold cavity. This is accomplished by forcing a metered amount of sand into the cavity via air pressure applied behind the sand column. This reduces the total amount of air introduced into the cavity resulting in a more uniformly dense sand core.

Core Box

In the core box the specific shape of the individual cores is produced. There are two flasks that make up every pattern, cope and drag. When connected together by clamps or pressure they make up the pattern for the core. For the GMBOND® Core Machine, the core box is heated electrically. This is called a "warm box". The box will reach temperatures ranging from 200-300°F.



Cover Core Box

Once the cavity of the mold is completely filled, the core box is sent to the purging station. At this station the sand core is purged of moisture by the convection of warm air. The warm air that is injected into the core comes from two high powered air dryers. The air reaches an approximate temperature of 250°F.

Air Dryers

Air Dryers

The machine and the corebox are designed to facilitate air purging in different zones, either independently or simultaneously. This machine has been designed to allow the necessary flexibility to optimize the process by varying parameters until minimum cycle time and material use are established. The testing design and parameters to be measured during Phase One will be discussed in the next section.

After purging, the cured core is transferred via the cope to a core unloading station where an operator deposits it onto a pallet for unloading. The operator uses a lifting mechanism to pick up the core and place it into storage. The cope is then transferred back and closed to the drag half of the corebox. Machine and process cycle times are designed to be competitive with current ColdBox® processes.

Auxiliary Equipment

For this attempt to drive the commercial development of the GMBOND® system, equipment not normally used with the ISOCURE® (ColdBox) process was specified for the project. This additional equipment will be evaluated during the initial phase to allow future specification of the optimum system. In addition to some of the equipment previously described, the following components are unique to the GMBOND® process:

Cover Core Lifting Mechanism

Chiller System

The chiller system is essential in the GMBOND® core making process. As noted earlier, once the water is added to the sand and binder mixture, the mixed sand needs to be kept at approximately 55°F. This system supplies chilled water to the sand mixer, transporting conveyor, and to the receiving hopper. Areas that are not cooled with the chilled water are insulated to keep the sand at its operating temperature.

Chilled Water System

Vacuum System

Hormel has provided a set of equipment to produce a vacuum. This equipment will be piped to the purge station on the machine. The vacuum will help the core drying process by helping draw the moisture from the system. By providing this equipment, it is believed the cycle time will be decreased. The benefits of vacuum assist for drying are well documented in the food industry. However, there is considerably less data on the benefit in core manufacturing. Previous GMBOND® tests without this equipment have had cycle times for drying that were not competitive with the current ColdBox® core-making process.

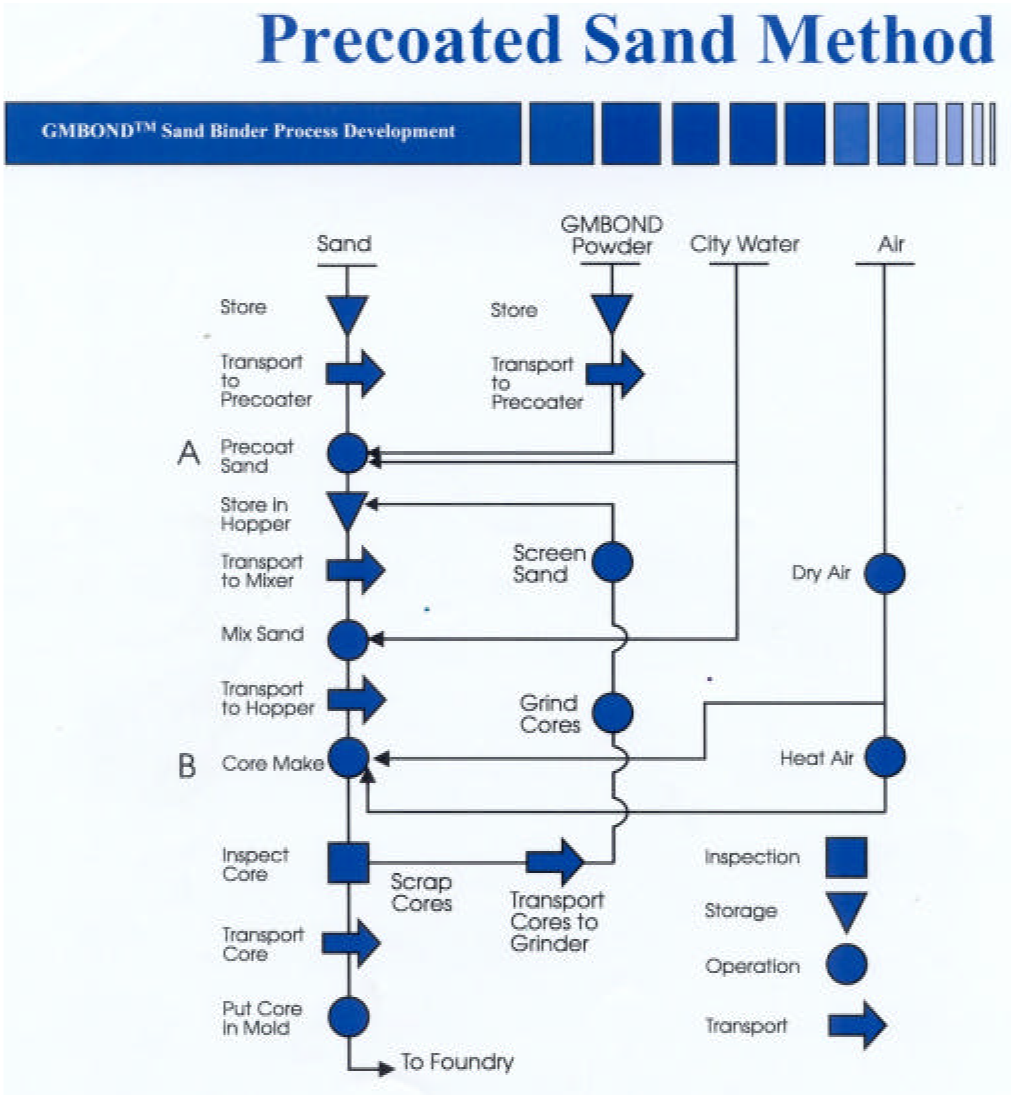
Hormel Vacuum Assist System

Sand Coating

Hormel Foods Corporation produces the sand binder that is used in the GMBOND® core process. It is manufactured in two ways: pre-coated sand or just-in-time mixing. Pre-coated sand is provided with the binder already mixed as a percentage of the sand weight. Just-in-time mixing is the more typical system where the binder is by itself, not mixed with sand. The company receiving the binder then has to have machinery that will correctly mix the binder with the correct sand quantity. To remove one variable from the GMBOND® study at the Saginaw Malleable Iron Facility, it was decided to receive pre-

Coated GMBOND® Sand Delivered in Bags

coated sand, in bags. These bags weigh between 2,900-3,000 pounds. The figure below illustrates the pre-coating and use of GMBOND® sand in core making.



Sand Preparation Flow Chart

Although tests have been successfully performed with GMBOND®, binder-levels as low as 0.75%, the initial Phase One binder, will be applied at 1.00%. This is the same binder percentage being used for the new Gen IV ColdBox® precision sand project.

As the project continues, one of the goals will be to determine the binder formulation and the most efficient percentage of binder to use to produce properties as good or better then the ColdBox® binder at a lower cost and greater environmental benefit.

Testing and Data Procurement

After the installation and debugging of the equipment, producing and testing the cores is the next step in putting the GMBOND® process into production. In Phase Two, analysis testing will be done on the cores, and the equipment operating parameters. The core tests that will be performed are: Loss of Ignition (LOI), shell thickness versus purge time, tensile test, core scratch hardness tests, and shelf life.

Machine and Sand Parameters

The machine and sand parameters for the GMBOND® process will be in comparison with the ISOCURE® process for the cover core. The parameters that will be recorded are as follows:

~ Batch size:
~ Blow time:
~ Core box temperature:
~ Purge pressure:
~ % Binder vs. Sand weight:
~ Mixed sand price/ton:
~ Air quantity per cycle:
~ Cycle time:
~ Mix time:
~ Blow pressure:
~ Purge time:
~ Purge temperature:
~ Binder cost per bag:
~ Sand temperature:
~ Core weight:
~ Core shelf life

These parameters are changeable to insure the production of a quality, competitive core, and have the cycle time as short as possible. Each time a parameter is changed, tests will be performed on the cores to see how the changes affect the cycle time and the quality.

Tests and Equipment

The cores will be tested for the various parameters listed above. The tests that will be performed are: Loss of Ignition (LOI), shell thickness versus purge time, tensile test, core scratch hardness test, and shelf life.

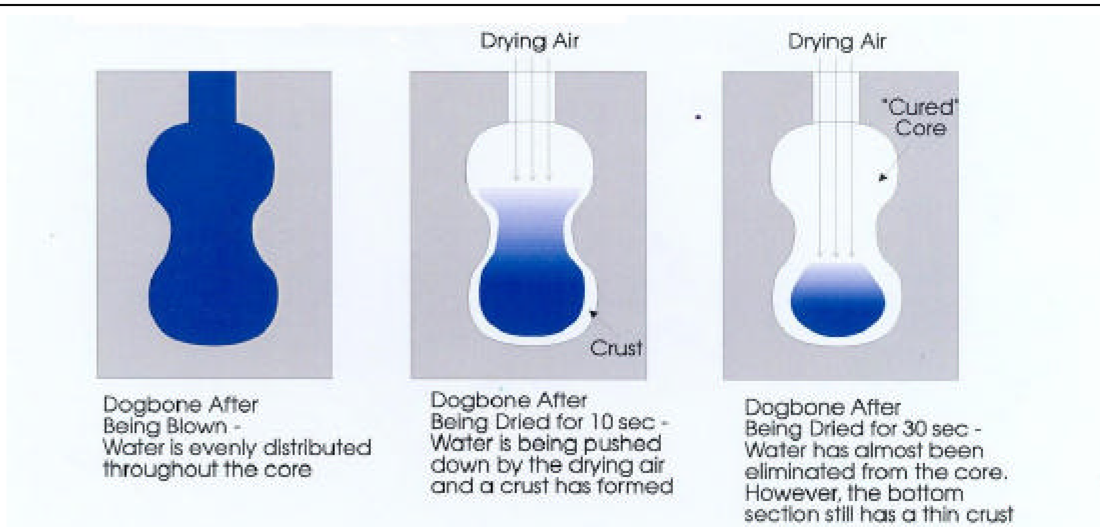
LOI Furnace

The Loss of Ignition test determines the percentage of binder that is present on the sand. A sample of sand is taken out of the sand system and brought up to the Metallurgy Lab. Fifty grams of the sand-binder mixture is weighed on a scale, and put into a cup. The cup is then put into the furnace where it is heated to approximately 1,800°F. The mixture is kept in the furnace for approximately two hours. Once the time has elapsed, the cup is removed from the furnace and set aside until cooled. After it is cooled and can be handled, it is put back on the scale and weighed. The difference between the two weights, multiplied by two is the amount of binder that is burned off of the sand and will be recorded on a graph.

One of the most crucial test parameters on this core is going to be the shell thickness, a measure of curing versus purge time. This test is going to have a great impact on determining the overall cycle time. Once the core is out of the machine, it will be cut open to determine how thick the shell of the core is. The shell is then going to be measured and charted on a graph to determine the least amount of purge time that has acceptable qualities. The shell is the part of the core that is completely dehydrated of water and has the core strength properties.

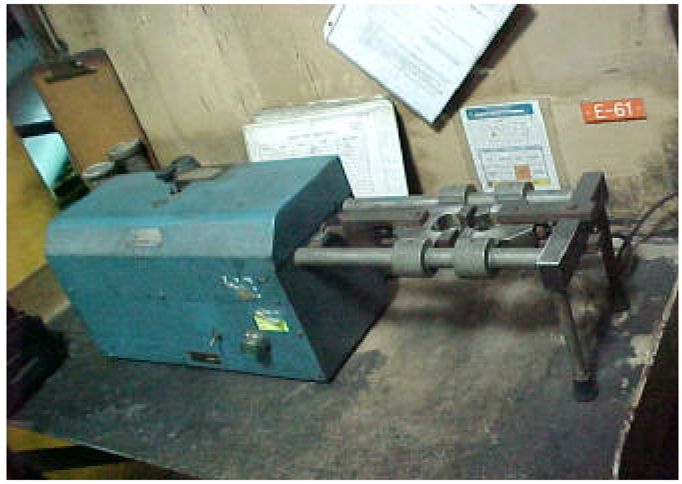
Sand Blower Equipment

The tensile test will determine the strength of the sand-binder mixture. A sample of the sand mixture will be taken out of the system and put into a sand blower device. The device blows the sand into a dog bone shape. The device dehydrates the water from the sand to give its strength. Once the cycle time for this machine is completed, the operator will take the dog bone out of the machine and put into the tensile test device. The dog bone is placed into the tensile test device and is pulled horizontally until the core fails. The operator will then record the strength from reading the indicator on top of the equipment.



Dog Bone Curing and Testing Process (Hormel)

The core scratch hardness test will also be performed on the cores. This will determine the strength of the cores outer surface. The equipment that is used is set on the surface of the core. Next, the gauge is zeroed out. To use the device, the knob on the top of the equipment is rotated one revolution. A gauge then provides a reading of the hardness of the core. A certain standard of scratch resistance will be determined to classify a core as good.



Tensile Test Device

To determine the bench life of the core, using GMBOND®, testing will take place by setting the core in storage. Cores at various times in storage will be tested to see if humidity has an effect on the cores strength. The core scratch hardness test will be performed on them as well as cutting them open to see if the inside has deteriorated. These tests will be repeated until the ultimate core shelf life is determined.

All these tests will be compared to similar data for the ColdBox® (ISOCURE®) process. The goal of the GMBOND® process will be to equal or surpass the standards set by the current process. Once the testing stage is complete, GMBOND® can produce cores. The cores will then be used in production to see how they react once aluminum comes into contact with there surface. Modifications will be made, if needed.

Core Hardness Device

Current Core Making Process

The current core making process at Saginaw Metal Casting Operations (SMCO) is called ISOCURE® (ColdBox). This is the process against which GMBOND® process is being compared. Both processes are used for what is called Precision Sand, which means the entire mold package is made up of cores instead of the combination of cores set in green sand molds. The ISOCURE® process has the tooling for all of the cores in the V-8 engine block core package. The cover core that is produced at SMCO will be the focus of this section. This section will discuss the binder, sand and machine parameters, as well as the process that is currently under development for the GEN IV ISOCURE® (ColdBox) equipment.

Binder

In the ISOCURE® process, the binder is a resin that consists of two liquid parts. The two liquids are labeled Part I and Part II. Like the GMBOND® process, this binder is currently being tested at 1% of the sands weight. To make up that one percent, the ratio of part I to part II is 55/45 for every batch. This binder has to be mixed with the sand just before making it into a core. Once mixed with sand, it must be made into a core within approximately 12 hours (depending on the humidity) or its characteristics as a binder diminish and cannot be used to make a quality core. This is very different from the GMBOND® process where the binder can be present in the sand for an indefinite period of time until water is added.

One benefit of the ColdBox® binder is that it is not dependent on the sand being held to a cool temperature (55°F) as is the GMBOND® process. Since this is the case, a chiller system is not required.

Process

The process of the ISOCURE® Core Machine is very similar to the GMBOND® Core Machine. The sand starts in a storage hopper. From the hopper the sand travels into the mixer where the resin is added. Resin (1% of the sand weight) is then metered into the sand and mixes for 60 seconds. Since water is not a part of the binder system, none is added. From the mixer, the sand travels to the blow hopper where it is ready to be blown into the core box. The core box is called a "ColdBox" since no external energy is required to heat it. Using a ColdBox® reduces the energy cost. Because the cover core is very large, the previous steps have to be repeated twice to complete one cycle. The core weighs approximately 230 pounds. With the existing machine for this process, a batch of sand is limited to approximately 150 pounds requiring two consecutive blows per core. Once the core is fully blown the core box stays in its position and the shooting head rotates to allow the purging head to get into place. Unlike the GMBOND® process where it purges with hot air, this process purges with triethylamine (TEA) gas. The TEA gas is blown through the core, hardening it to make it usable for production. Once the core is through purging, it is released from the core box similar to the GMBOND® process. A lifting device is used to set the cores onto boards for storage.

Unlike the GMBOND® process, a chemical reaction takes place once the TEA gas is pushed through the sand. Since a reaction takes place, sand reclamation is very difficult to do. It is very expensive and time consuming. Since this is the case, every scrap core that is produced is thrown away instead of being reused. Sand reclamation is one of the benefits of the GMBOND® process and will reduce the cost dramatically of the sand and binder.

Other factors that are involved with this process are toxic emissions and additional ventilation costs. In order to run this machine, ventilation has to present for the operator and the surroundings. This equipment is very expensive and takes a great amount of time to obtain the necessary permits for installation. The GMBOND® process does not appear to require this equipment, thereby reducing the initial cost.

Machine and Sand Parameters

The machine and sand parameters for the ISOCURE® core process for the cover core are as follows:

- ~ Batch size: 146 lbs.
- ~ Mix time: 60 seconds
- ~ Blow time: 6 seconds (total)
- ~ Blow pressure: 3 bar
- ~ Core box temperature: not required (ColdBox)
- ~ Purge time: 90 seconds
- ~ Purge pressure: 4 bar
- ~ Purge temperature: not required
- ~ % Binder vs. Sand weight: 1%
- ~ Sand temperature: not required
- ~ Gas type: TEA gas
- ~ Gas quantity per cycle: 90 cubic centimeter (cc)
- ~ Core weight: 230 lb.
- ~ Cycle time: 109 seconds
- ~ Core shelf life: 4-6 wks
- ~ Historical Part 1 plus Part 2 cost is \$0.75-0.85/ lb.
- ~ Gas cost: \$0.89 per lb.
- ~ Mixed sand price/ton: \$45-72

Current research and testing of this process has provided these parameters to produce the cover core. When all of the data is available, a more comprehensive cost/benefit comparison of GMBOND® versus ColdBox® will help evaluate the potential for GMBOND®.

Cost Comparison

During the initial development of the GMBOND® process, a cost analysis was performed by GM Powertrain Group and GM Research and Development. This study indicates that GMBOND® is competitive and provides a savings when used in an all core package.

The following chart, Table 2 tabulates the results of this pervious study:

Table 2 Cost Comparisons – GMBOND® & Silica Sand

GMBOND V8 Blocks (Silica Sand)

Volume (pts/year)	500,000	SUBTOTAL $/ton PUCB BINDER	$18.00
Casting Weight (LB):	90	SUBTOTAL $/ton PUCB Amine*	$19.48
Sand to Metal Ratio:	5.5	TOTAL PUCB $/TON	$37.48
Binder Addition (%BOS) PUCB	1.20%	Cost/ton GMBOND	$74.25
Binder Cost ($/LB) PUCB	$0.75	Sand (LBS/YR)	247,500,000
Binder Addition (%BOS) GMBOND	0.75%	Sand (TONS/YR)	123,750
Binder Cost ($/LB) GMBOND	$4.95	Binder PUCB (LBS/YR)	2,970,000
Sand Cost ($/TON)	$60.00	Binder GMBOND (LBS/YR1)	946,688
Reclamation ($/TON)	$25.00	Binder GMBOND (LBS/YR2+)	928,125
Sand Loss (% BOS reclamation)	10.00%	Scrap Cores % PUCB	5.00%
Scrap Rate (% of Shakeout)	0.00%	Scrap Cores % GMBOND	0.10%
Casting Cost ($/CASTING)	$150.00	Reuse GMBOND %	50.00%

Cost Breakdown GMBOND YEAR 1		Cost Breakdown GMBOND YEAR 2	
Sand ONE WEEK SUPPLY	$148,500	Sand ONE WEEK SUPPLY	$0
Binder REUSE AFTER WK 1	$4,686,103	Binder	$4,594,219
Reclamation	$1,048,134	Reclamation	$1,048,056
Sand Loss	$371,250	Sand Loss	$371,250
Scrap Cores	$9,188	Scrap Cores	$9,188
TOTAL GMBOND	$6,263,175	TOTAL GMBOND	$6,022,713

PUCB V8 Blocks (Silica Sand)

Volume (pts/year)	500,000	SUBTOTAL $/ton PUCB BINDER	$18.00
Casting Weight (LB):	90	SUBTOTAL $/ton PUCB Amine*	$19.48
Sand to Metal Ratio:	5.5	TOTAL PUCB $/TON	$37.48
Binder Addition (%BOS) PUCB	1.20%	Cost/ton GMBOND	$74.25
Binder Cost ($/LB) PUCB	$0.75	Sand (LBS/YR)	247,500,000
Binder Addition (%BOS) GMBOND	0.75%	Sand (TONS/YR)	123,750
Binder Cost ($/LB) GMBOND	$4.95	Binder PUCB (LBS/YR)	2,970,000
Sand Cost ($/TON)	$60.00	Binder GMBOND (LBS/YR1)	946,688
Reclamation ($/TON)	$25.00	Binder GMBOND (LBS/YR2+)	928,125
Sand Loss (% BOS reclamation)	10.00%	Scrap Cores % PUCB	5.00%
Scrap Rate (% of Shakeout)	0.00%	Scrap Cores % GMBOND	0.10%
Casting Cost ($/CASTING)	$150.00	Reuse GMBOND %	50.00%

Cost Breakdown PUCB YEAR 1		Cost Breakdown PUCB YEAR 2	
Sand ONE WEEK SUPPLY	$148,500	Sand ONE WEEK SUPPLY	$0
Binder	$4,637,655	Binder	$4,637,655
Reclamation	$3,757,050	Reclamation	$3,757,050
Sand Loss	$742,500	Sand Loss	$742,500
Scrap Cores	$231,833	Scrap Cores	$231,833
Scrap Castings	$0	Scrap Castings	$0
TOTAL	$9,517,538	TOTAL	$9,369,038

Based on this study, GMBOND® would provide approximately a $3,000,000 per year cost benefit over the ColdBox® precision sand process. As noted in the study, this savings is based on using silica sand and producing 500,000 castings per year.

The current plan is to use lake sand instead of silica sand for both the ColdBox® and the GMBOND® processes. The same production level of 500,000 units will be used in calculating the cost benefit of GMBOND® versus ColdBox. The other difference is that, at the present time, the only tooling available for GMBOND® is for the cover core. Therefore, the calculation will be based on a comparison of costs for the cover core only. Ranges of prices will be used since the optimum formulation and binder percentage are not known at this time. Table 3 indicates that, based on the ability to reclaim 80-90% of the cover core sand and reuse it with only the addition of water, an annual cost savings in material usage and disposal is in the range of $1,968,225-$2,490,325.

Table 3 Cost Comparison GMBOND® vs. ColdBox® (ISOCURE®) - GM GEN IV Project

	Product	GMBOND®	Sub total	Total	ColdBox	Sub total	Total
Cost of Reclamation	**Pounds Sand/Casting**	230			230		
	Total Sand Usage	57,500 tons		57,500 tons	57,500 tons		57,500 tons
	% Sand Loss						
	Reclaim	0%			0%		
	Disposal	10%	5750 tons	5750 tons	100%	57,500 tons	57,500 tons
	Basis for Binder Usage	63,250 tons		63,250 tons	57,500 tons		57,500 tons
	Sand Cost/Ton	$15-$25		$948,750-$1,581,250	$15-$25		$862,2500-$1,437,500
	Sand Disposal Cost/Ton	$15-$30		$948,750-$1,897,500	$15-$30		$862,500-$1,725,00
	Reclaim (GMBOND®) [1] ***Disposal Cost (ColdBox)***	***$3***		***$189,750***	***$23***		***$1,322,500***
Cost of Sand & Making Cores	**Binder Cost**	$2.75-$3.25/lb.	$55-$65/ton	$3,478,750-$4,111,250	$0.75-$0.85/lb	$15-$17/ton	$862,500-$977,500
	Amine TEA Cost	0		0	$0.85/lb	$17/ton	$977,500
	Description	GMBOND®			ColdBox		
	Relative Tonnage for Cost Basis (Sand)	10-20%	6,325-12,650 tons	$948,750-$1,581,250	100%	57,500 tons	$862,500-$1,437,500
	% Sand Reclaimed	80-90 % cover core	50,600-57,150 tons	$151,800-$170,775	100% disposal	0	$1,322,500
	Relative Tonnage For Cost Basis (Transportation)	10-20%	6,325-12,650	$948,750-$1,897,500	100%	57,500 tons	$862,500-$1,725,000
Savings Potential	***Cost Range for GMBOND® vs. ColdBox***			***$2,397,175-$4,471,775***			***$4,887,500-$6,440,00***
	Cost Benefit for GMBOND® vs. ColdBox				***— $1,968,225-$2,490,325 —***		

[1] The cost for disposal of remaining GMBOND® material compared to ColdBox® is low because GMBOND® is crushed and recycled back into the system where the residual ColdBox® product must be transported to landfill.

Phase Two and Beyond

During Phase One of the project, a machine designed specifically for GMBOND® was purchased and installed and partial debugging was completed. In addition, the parameters to be tested and compared to the existing ColdBox® process were determined and test protocol developed. During Phase Two of the project, the various steps in the core making process will be optimized and data collected to provide an accurate cost/benefit analysis of the GMBOND®

Phase Two of this report will analyze the core making process and compare the cost of making cover cores in GMBOND® and ColdBox. This will allow a cost benefit analysis to be completed on core making.

Phase Two of the project will not provide data on reclamation of mixed sand which has been exposed to molten metal temperatures. For a proper evaluation of this parameter, additional tooling will have to be purchased to provide cores which have a greater exposure to heat. The cover core has very little exposure to molten metal and as a result will be relatively easy to reclaim simply by crushing and adding water. The other cores in the package have a greater exposure to temperature and will require additional handling and processing to allow reclamation. Another benefit of having the necessary tooling to provide interchangeable cores would be an optimization of the costing process. The core package makeup could be varied from just the cover core all the way to 100% GMBOND® until the least cost most efficient core package is developed.

Another area which needs investigation is the cost benefit of lower emission control requirements. Additional testing will be required to validate less equipment is required and to establish actual cost savings. These additional projects will be subject to the availability of funding either from the CERP program or the foundry community.