SOFA SOUNDS
SOF&A
SOUTHERN OHIO FORGE & ANVIL
Artist-Blacksmiths Association of North America

APRIL/MAY 1991

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Ken Scharabok (513-258-1389)

MARK YOUR CALENDAR: Unless otherwise noted, all meetings will be held at the Studebaker Frontier Homestead on Rt. 202, about 4 miles north of I-70 near Tipp City. Please don't park on the grass or block access to the production buildings. Donations of items to the newsletter support raffle are always welcome. Please bring your work or tooling for display. The public and guests are welcome. Finger food and cold drinks provided on a break-even donation plate basis. The forges at the homestead are available before and after meetings for individual projects.

APRIL 6th, 1 PM	Demonstration by Doug Fink on forging using structural material.
MAY 4th, 1 PM	Demonstration by Scott Murray on kitchen hardware.
JUNE 1st, 1 PM	Annual workshop to make hardy tools or hand-tools out of jackhammer bits.
JULY 6th, 1 PM	Demonstration by Larry Wood.
AUGUST 3rd, 1 PM	Demonstration by Brian Thompson.
SEPTEMBER 27-29th	1991 Quad-State Round-Up.
NOVEMBER 2nd, 1 PM	Tentitive: Casting powerhammer babbits.

LETTERS TO THE EDITOR:

In the February/March 1991 issue, on page 11, in the article "Removing Zinc Plating", it states, "To remove zinc plating, put the item(s) in Muriatic Acid (used to clean masonry and available in hardware stores) for about ten seconds." While this may work for lightly coated hardware such as hinges, bolts, etc., my experience is that if you are working with galvanized pipe, more like ten minutes are required. Further, if your item is of any size, a piece of pipe 10-12" long for example, several quarts of solution are needed to fill the working container. I prepare a diluted solution, always pouring acid into water. I used about eight ounces of acid to two gallons of water (6¼ percent solution). Pour the acid into the water slowly. The solution will get hot. I store it in a plastic jug in a special cabinet outside of my shop. Most plastics are not attacked by the acid and most plastics, including those bottles which contain acid when you buy them, are porous enough that acid molecules go right through the jug and these fumes will corrode iron and steel badly. I wrecked a set of metal shelves before I learned what was causing it. PVC Schedule 40 4" diameter pipe makes a handy working container. Cut to the length desired and cement a cap to one end. Cut and paste to suit your needs. - Dick Franklin.

VCR TAPE RETURN POLICY:

Denny Bischoff, and several others, have been gracious in making VCR tapes of the monthly meetings and demonstrators at Quad-State. These tapes are loaned out to SOFA members on a one-month basis. If you cannot make the next meeting, you should mail the tapes to Ron Van Vickle, 1121 Central Avenue, Greenville, OH 45331. NOTE: We are missing a number of the tapes. Please check to see if you have any mixed in with your other tapes.

OOPS: In the last newsletter I said the Emmert Studebaker award had been won by Dick Franklin and Larry Gindlesperger. It should have read Dick Franklin and Hans Peot. Sorry Hans! Found out I cannot watch a war live and in color and do the newsletter at the same time.

In Ron Thompson's article on using mild steel for dies: Fourth paragraph, line three, change "about" to "above". Twelfth paragraph, change "Table 2" to "Table 3".

In the write-up of the December 1990 meeting I reported that flaming the spring below the bolt was done to increase the spring action. Larry Wood pointed out the real purpose is to reduce the brittleness in the hacksaw blade piece used as the spring.

MOKUME GAME: (From the newsletter of the Northwest Blacksmiths Ass'n).

Mokume game is a Damascus-pattern effect achieved with brass and copper. Due to the difficulty in fusing the two together, it is often used for smaller items, such as jewelry. To make: 1) cut out 16-gauge brass and copper pieces to 3" x 3"; 2) clean all pieces; 3) make sure pieces are perfectly flat; 4) stack in alternate layers to height desired (but not more than 2"); 5) sandwich stack between 1/2" plates larger than the billet and bolt plates together - it will help if one plate has a handle; 6) heat in reducing fire a minimum of one hour at bright red heat for good fusion; 7) cut bolts and remove billet; 8) leave billet on plate with handle and reheat and forge billet at dull red heat, using flatter until 3" x 3" becomes 4" x 4"; and 9) trim billet sides (bandsaw works best at 8 teeth per inch). Billet can now be ground into shape desired. For a patina for copper-base alloys: Ammonia (pure) plus salt, soap and urea (optional) gives green through blue depending on mixture and amount of contact time and Lime of sulfur (calcium polysulfide) diluted to one percent or less in water will give brown, gray or black depending on mixture and amount of contact time.

1991 SOUTHEASTERN REGIONAL CONFERENCE:

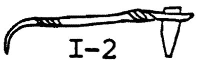
The fifth bi-ennial Southeastern Regional Blacksmithing Conference will be held on May 17th & 18th at the Lion's Club Fairground in Madison, GA. The demonstrators will be Robb Gunter of Edgewood, NM, Hans Peot of New Carlisle, OH, Mike Rose of Pigeon Forge, TN and Brad Silberg of Silver Springs, MD. For a registration package contact Mike Shaffer, 4600-D E. Ponce de Leon Ave., Clarkston, GA 30021 - 404-469-2680.

1991 BLADESMITHING SYMPOSIUM:

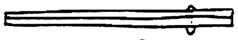
The Third Annual Bladesmithing Symposium will be held on April 19-21 at the Forge of Jim Batson (176 Brentwood Lane, Madison, AL 35758 - 205-837-6160). Demonstrators will be Hugh Bartrug, Bill Moran, Cleston Sinyard, Chuck Patrick, Keith Kilby, James Batson, Cliff Polk, Allan Eldridge, Billy Bates, Trena Polk and Gary Long. The demonstrators will make their own Damascus into truly unique and exceptional blades and knives. They will take you step-by-step through the forging of the blade to the finished knife. From the building of the fire, the making of the Damascus-pattern steel and makume-game to the hafting of the blade. The forging of integral guards and bolsters and the making of folding knives will be demonstrated. Mini-seminars will be taught on scrimshaw, wire inlay, filework and simple engraving. $55.00 per person fee before April 9th - $75 afterwards. This is the premier knife workshop held east of the Mississippi, if not in the entire U.S. Contact Barbara Batson (address above) for registration package. Note this immediately follows the Southeastern Regional Conference. Five total days of blacksmithing/bladesmithing bliss.

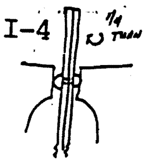
MEETING NOTES:

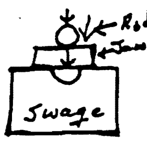

I-1


I-2

For the February demonstration, Chuck Sigler and Bill Vatter did a nifty demo. on making simple tools for the forge.

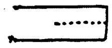

I-3

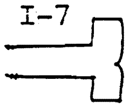

I-4



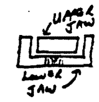
I-5

The first item was a hand-held eye punch. For the punch itself they used a piece of 4150 steel, 3/4" round, 2½" long. A round top and bottom spring swage was used to put a groove about 3/4" from the top and then the other end was drawn out into shape. For a handle they used a length of 3/16" rod about 22" long. It was bent around the punch head, the two rod twisted at the head and then near the end. The remaining two legs were forge welded together and curled slightly. Adding an eye here would allow the punch to hang up. (See I-1 & I-2)


I-6


I-7

For tongs they used two lengths of 3/16" x 3/4" x 12" (size to suit material to be handled). About 8" of one end was tapered to form matching reins, the pieces punched and riveted together about 2½" from the other end, held in a vice at the rivet and the short ends twisted 1/4" in either direction. The jaws were then adjusted to fit 1/4" material, including putting in a groove in both the upper and lower jaw to hold round stock as well as flat or square stock. A neat way to make tongs! (See I-3 - I-5).


I-8

The second pair of tongs was made much like the first except one of the reins stock was longer. It was split in the center about 1" back, the split brought out 90° to the side, and then the end of the ears bent around the other jaw to form a pair of box tongs. The two parts were then riveted together and bent like the first pair. Again, a neat way to make tongs! (See I-6 - I-8).

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For the March demonstration, Ron Thompson proved he could be just as humorous and as informative with Ham Hammond as his partner in crime as with Ron Van Vickle. They did a show-and-tell on various types of casting. Since their demo. was providing information faster than I could note it, you will need to see the VCR tape made of it. However, Ron does have a set of general notes on casting which he will provide if you will send him a business-size or larger self-addressed, envelope with two first class stamps attached (Address: 17166 Mason Rd., Sidney, OH 45365). (I recommend putting in a couple of extra loose stamps for his troubles - ed.) Ham Hammond also provided an informative history of casting contained elsewhere in this issue. On it note the closing paragraphs quoting Biringuccio on the behavior of the casters. I somewhat suspect some of it was due to the fumes they were breathing on a regular basis.

Answers to questions raised at the meeting: 1) How can I harden the faceplate on my Peter Wright anvil? - Larry Wood advises Winston Heat Treating or Dayton Heat Treating (both in Dayton) will do it for about 35¢ per pound; 2) Where can I find insulating wood for inside a gas forge? - Look under the refractory listing in the business-to-business telephone book - two in the Dayton area are Frank W. Schaefer, Inc, 1500 Humphrey Ave (253-3342) and HI-TEQ, INC., 360 Frame Dr. (847-8051); and 3) Where can I find how-to books on casting? - Try Rio Grande Supply, 6901 Washington NE, Albuquerque, NM 87109 - 800-545-6566 and Lindsey Pubs, P.O. Box 12, Bradley, IL 60915 - 815-468-3668. (By the way, Ham mentioned he had taken the casting course offered by the Riverbend Art Center (513-228-1115) and found it very enjoyable and well worth the course cost.)

The Lincoln's New Salem State Historic Site will have Jim Batson on April 6th (people heads) and April 7th (bladesmithing). $10 fee, camping available on site. For further info. contact Jim Patton, RR #1, Box 244-A, Petersburg, IL 62675 - 217-632-7611 (near Springfield).

SAFETY NOTE: In the Jan 91 issue of FARM SHOW, Bill Short of Hamilton, MO reported his neighbor's three-year old portable compressor blew up while being pumped to pressure. Apparently the inside of the tank was not lined and water from the air taken in rusted through the bottom. He recommends you do not purchase an unlined tank and, if you have a compressor now, lined or unlined, add a radiator-type drain to periodically drain out water build-up. FARM SHOW is a bi-monthly newspaper-type report on new farm products, often built by individual farmers or small companies. Cost is $13.95 for six issues - free sample on request - to FARM SHOW, P.O. Box 129, Lakeville, MN 55044-9989.

BLACKSMITHING EQUIPMENT FOR SALE: The following generally have a variety of equipment, including powerhammers, for sale: Neil Brown - 219-724-7554; Russell Cashion - 615-731-3215; Benny Wilson - 615-758-7176; Fred Caylor - 317-769-6351 and David Oliver - 615-878-4969. Locally try Joe Abele - 276-2977 or Steve Roth - 836-8520.

Clifton Ralph will hold two consecutive one-week, hands-on powerhammer clases at Bill Manly's shop near Kingston, TN on March 25-29 and April 1-5. $200 per class, bunkhouse camping available. Contact Clifton at 4041 47th St., Gary, IN 46408 - 214-980-4437. Clifton spent his career forging with powerhammers and if he passes on just a fraction of his knowledge, the class will be well worth the cost.

RECONDITIONED ANVILS FOR SALE: Arm & Hammer, Peter Wright, Hay Budden and others, 150-200 pound sizes, refaced. Contact Jim Campbell at 412-438-5176 (Penn.). Jim attends Quad-States. If you purchase an anvil, perhaps you can arrange delivery there.

A wide variety of small blowers is available from the Surplus Center (P.O. Box 82209, Lincoln, NE 68501-2209 - 800-228-3407, catalog on request). Locally Mendleson's Surplus near downtown Dayton generally has small blowers for under $20.00.

The American Welding Society is seeking 25 metal craftsmen to sell wares during their April 16th - 18th conference in Detroit. For further details contact John Steel at 412-774-6757.

Reprints of "The Edge of the Anvil" by Jack Andrews are available for $18.95 postpaid from Skip-Jack Press, Inc., P.O. Box 2460-MBS, Ocean City, MD 21842.

POWERHAMMER FOR SALE: 50 lb. Mayer, VGC, new bearings, good motor mounts. Contact Bill Sheedy, P.O. Box 3, Palmer, IL 62556 - 217-526-3769. $400.00.

FOR SALE: Two Champion 400 firepots, $90 each. Contact Roger Lorance, RR #2, Canton, IL 61520 - 309-647-9242.

FOR SALE: Two large swage blocks, 153 lbs, $150 & $200; 4' floor mandrel, $150; Champion blower, EC, $40. Contact Roy Plumlee, Rt 3, Box 48, Tamaroa, IL 62888 - 618-496-3198.

FOR SALE OR TRADE: Stark Horizontal Milling Machine, 4"x12" table, single phase motor and cast iron base. Rigged for line shaft or motor. $300. Contact Bob Haverstock, RR #1, Box 103, Sullivan, IL 61951 - 217-752-6873.

FOR SALE: Johnson Casting Furnace complete, $600. Contact Herman Leukhardt, 405E. Jamestown Rd., Greenville, PA 16125 - 412-588-0654.

SAFETY ITEM!!! Apparently Fred Cayton suffered from lead poisoning last summer after brushing the paint off a powerhammer burned in a fire. Probably a lot of old machinery and tools were painted with lead paint - BE CAREFUL. (From an item in the newsletter of the Alabama Forge Council.)

WHEELWRIGHT WORKSHOP: A two-day wheelwright workshop will be held at the Old Cowtown Museum. Instructor is Joe De La Ronde from Glorieta, NM. $100 fee. Contact museum at 1871 Sim Park Drive, Wichita, KS 67203 - 316-264-0671. Dates are April 13th & 14th, with a possible second class on April 19th & 20th.

The East Bay Gallery is looking for makers of metal furnishings to sell in their galleries, both production work and one-of-a-kind items. For further information contact them at 636 Coleman Blvd., Mt. Pleasant, SC 29464 - 803-849-9602.

A combination lathe/mill/drill is available for less than $1,000 from Overland Co., 3023 E. 2nd St., The Dalles, OR 97058 - 800-345-6342.

NEW OHIO BLACKSMITHING GROUP FORMED! The Western Reserve Artist-Blacksmiths' Ass'n has been formed to cover northeastern Ohio and northwestern Pennsylvania. Membership $10.00 per year to Jim Irvin, Secretary, P.O. Box 241, Chesterland, OH 44026. Upcoming events include: June 22 - HAMMER-IN at Herman Loukhart's shop near Greenville, PA (412-588-0654) and another HAMMER-IN in July in Ashtabula County, OH (216-771-6095).

Attention Master Smiths! If you have an extra copy of slides of your work, please consider sending them along with a brief description to Sister Claire Basar, Ass'c Professor of Humanities, Barat College, Lake Forest, IL 60045. She would like them to help illustrate her course in "Masterpieces of Decorative Art". Address: 700 East Westleigh Rd.

I am in the process of closing on a 560-acre tract just south of Waverly, TN for when I retire. It turns out one of my neighbors, Hunter Pilkinton, is a member of the Appalachian Area Chapter - ABANA (attends Quad-States), a semi-retired welder and a tool collector for his tool museum. How's that for coincidence.

At the last meeting, Hans Peot mentioned that, since Patterson Scrap Iron on Springfield Street was taken over by new owners, he has been amazed at the wide variety and good quality of the items they are selling for scrap prices (including tool steel). However, they don't keep the scrap around long before shipping it out so you need to check what's there on a regular basis.

A BRIEF HISTORY OF CASTING:

THE BEGINNING

Metallurgy did not begin with casting. The most used metal (iron) was not melted at all until the 16th century A.D. Even today, casting is done mainly to facilitate the making of something that can be wrought.

Man's first use of any metal depended on its ability to be plastically deformed without loss of cohesion. Small pieces of copper were being hammered into decorative objects as early as the ninth millennium B.C. in the Middle East. In North America where copper was abundant in large lumps, weapons and tools were shaped by hammering—with intermediate annealing—by about 3000 B.C.

Copper, which needs a temperature of about 1100°C, was probably the first metal to be melted—not the common, low-melting lead. It is also probable that the first melting occurred in a potter's kiln because potters were the leading users of pyrotechnical means to modify material. Another possibility is that an annealing fire could have provided the condition leading to the discovery. In either case unusual circumstances would have been needed to give a temperature high enough to melt copper.

The first pieces of melted and solidified metals were probably only a supplement to the supply of native metal being hammered into useful shapes. What was demonstrated, however, was that molten metal would take the shape of the surface against which it lay and would preserve this shape after solidification.

Simple cast copper objects appeared around 4000 B.C. From this time on the history of casting is partly the development of mold materials and techniques and partly the discovery of new compositions that could be more easily cast or that could give stronger, cheaper or more decorative castings.

There is a close connection between metallurgy and ceramics. From early times the techniques of the potter in exploiting the plasticity and refractoriness of clay have been the basis of mold making. Sand, which is used to a large extent today, is a very recent material for molds.

The simplest mold is the open groove pressed into clay or cut into stone. It leaves one face of the casting horizontal—exposed to the air and unfinished. A more complex mold is the bivalve and the bivalve with core either transversely or axially. Bivalve mold casting gives a pleasing bilateral symmetry resulting from the joints in the mold which are necessary to allow the shaping of interior surfaces. This is true when stone molds are used where direct cutting is done or when clay is pressed against a preshaped positive.

Early molds seem to have been made by molding around a smooth pattern. The mold would be in sections to allow for easy removal from convex surfaces. Thus, the joints can be often seen as defects on the surface of a finished casting. The pattern itself may have been made of mold clay and then scraped down to serve as a core while separate pieces were incorporated to shape handles and knobs. Smaller clay cores were often left embedded in the casting.

The decorative detail was at first carved directly on the mold surface. Other designs were made positively on the mold. In time the molds became more elaborate. In the eighth century B.C. the Chinese were casting pieces such as legs and handles separately and incorporating them in the mold of the main vessel. These rarely fused into the metal in the body of the vessel. This would have required metal that was too hot to give a good casting and was not needed in a decorative object not subject to high stress.

Later, precast parts were attached to a precast body in a separate joining operation that involved casting an intermediate little ring locking into both. This was the beginning of autogenous welding. The use of true brazing solders in China is uncertain. This "casting on" process came to be used extensively in the West.

The Chinese ceremonial bronze vessels are generally only about two to four millimeters thick. Thus, the positioning of the core in the mold presented a considerable problem. It was commonly solved by the introduction of chaplets (any of various metal devices for holding a core or section of a foundry mold in place) consisting of small, rectangular pieces of previous vessels placed around the mold. They can sometimes be seen on the surface of the finished casting by a difference of patination.

In other cases, instead of a chaplet, a small pyramidal or roof-shaped projection was left on the clay core to rest against the mold body. This left a fine unfilled line on the casting. This was a refinement of earlier cruciform clay spacers which could leave holes as large as eight millimeters across.

By 750 B.C. the Chinese provided decorative detail by premolding clay against a flat master pattern and then cutting out little slabs that were joined into a larger assembly, which in turn formed a section of the main mold. The master pattern itself was made by repeating some units. Many of the surfaces of castings from this period contain detail where the mold parts were probably bent over a smooth curved surface, when soft, immediately after molding.

The elaborate development of mold making and bronze casting in China was in large measure due to the local potter's long and successful acquaintance with the technology of clay.

LOST-WAX CASTING

Long before there were any Chinese bronze founders more elaborate castings were being made by the lost-wax method in the West. In this process a wax model is completely invested (i.e. covered) in clay or other refractory material and is then melted and burned away leaving its space to be filled with molten metal. These castings show no mold joints and the process allows for greater freedom of shape.

Castings produced by this method first appear in Mesopotamia around 3000 B.C. The actual "wax" used is not known, but any easily shapeable material that was fusible or volatile or that left a light removable ash on combustion would serve. Some possibilities are: animal fat, beeswax, rosin, some forms of bitumin, or a light, tow-ash wood.

With this technique the sculptor is free from any restraint arising in the negative or undercut parts of the mold because the pattern does not have to be withdrawn and the mold surfaces (however complex) reproduce all the details of the wax. The artist could model in clay and have the object reproduced exactly.

At first these castings were solid, but later a method of molding the wax over a sandy core was devised. Pierced areas in the design were needed to keep the mold and core the right distance apart. Metal spacers were also sometimes used. They remained embedded in the final casting. The large, life-size bronze castings of Classical Greece were probably made by this method.

The lost-wax method of casting was used by founders in many countries—including Syria, Nigeria and Colombia—over many centuries. The Japanese founders in the 19th century used the lost-wax technique to produce the most exquisite detailed surface finish that has ever been achieved by casting. The Japanese realized that a hot mold is needed to produce fine detail.

The lost-wax casting was used for centuries to produce works of art. In recent times the method has been used in the precision shaping of dental metalwork. The process has had a modern revival in the making of accurately shaped castings for engineering use.

A modern variant of the principle of the disposable pattern is the use by sculptors of a styrofoam model. It is embedded in a sand mold into which molten metal is directly poured, evaporating the low-density foam and taking its place. Thus, a lightweight, fragile pattern or form is transformed into permanent metal.

SLUSH CASTING

Slush casting is the method of

making hollow castings without using cores. This is done by filling a mold and pouring out the still-molten metal after a layer of the desired thickness has solidified. This process has been used for cheap decorative objects in pewter, zinc and lead. The slip casting of ceramics in porous plaster molds is a somewhat similar process.

The principles involved in slush casting were used much earlier in the casting of thin sheets of tin and lead for roofing and for organ pipes. In this process an inclined board was covered with a half-inch layer of sand or ashes, spread out and smoothed flat. A bottomless wooden box was then fitted to slide over the board. Then the molten metal was poured in the box, which was moved slowly down to the foot of the board, leaving behind a layer of solid metal of uniform thickness and width.

The thickness was determined by the thermal diffusivity of the sand bed and the time the molten metal was in contact with it. When thicker ingots of lead were required for rolling into sheet, the molds were made horizontal and the sliding section became a skimming operation. This process began in the 17th century with the development of ingenious reversible mills in Europe.

Organ pipes are today still made of sheet cast in open horizontal beds. Those made of "spotted metal" are of special metallurgical interest. They are supposed to have superior tone. They are easily identified by their surface pattern. The "spots" occur only with lead-tin alloys containing between 35 and 65 percent lead. It is believed that the two-dimensional cellular pattern is produced by equiaxed growth of crystals from random nuclei.

Microscopic examination of "spotted" organ pipes shows that the lead dendrites (a branching figure resembling a tree produced on or in a mineral or stone by an oxide of manganese or other foreign material) are very much smaller than the pattern spots. It is the irregularity of the lead dendrites in the shrinkage troughs that are responsible for the pattern. The cells are eutectic (an alloy or solution having its components in such proportions that the melting point is the lowest possible with those components) colonies nucleated at random—but infrequently—which have grown through the liquid interstices of a spongy mass of lead dendrites concentrating all the solidification shrinkage to form depressions along the lines where they meet.

CASTING IN SAND

Green sand molding is a simple process, yet in the history of casting, it was late in being developed. Nearly all molds—until about 1500 A.D.—were made of metal or stone or, if complex, of foundryman's clay that was dried and baked before being used. The use of these molds, however, did not prevent mass production. Clay molds for Roman coins have been found in multiple layers. Also, in an early foundry in Milan, 1200 small castings of everyday objects were made by a single mold composed of 20 superimposed layers of clay—each junction surface in succession being molded against a metal pattern complete with gates and runners.

In England a foundry was making 6000 brass thimbles a day. The molds used were made of a mixture of sand and red clay. Each mold contained 72 thimbles which were finished by turning and stamping on special machinery.

Jewelry and medallions were usually molded in a fine powder made from ground pebbles and brick, ashes or similar refractory material bonded with sodium silicate made by heating salt in clay crucibles. These powders were pressed against the pattern in split metal or wooden flasks and dried before being used. These molds were often hard enough to be used for more than one casting. Many renaissance medallions which have very fine detail were made using this type of mold.

Casting in green sand (compressed moist sand) seems to have begun between 1500 and 1550 A.D. in Europe. The renaissance scholar, Biringuccio, who wrote extensively on the art and science of casting, had the following to say about sand casting in 1540: "It has been discovered, contrary to the natural order of art, how to cast in moist earth in order to save labor and expense. This is truly a thing that many desire and few practice because it is not as smooth a way or as easy to effect as it apparently seems." In his description of the sand casting method, Biringuccio describes frames or boxes similar to the flasks used in foundries today. The mixture used at the time consisted of ground yellow tuff (or fine washed sand) mixed with urine or wine, and the mold surface was smoked.

The famous renaissance artist and scientist, Leonardo da-Vinci, had previously mentioned the use of a box of river sand moistened with vinegar to make castings. Cellini, another Italian renaissance sculptor, wrote the following in 1568 regarding his use of sand as a mold material: "By the bye, as I write I am minded of a very rare kind of tufa (a porous rock formed as a deposit from springs or streams) which is found in the bed of the Seine in Paris. While there I used to take what I wanted from hard by the Sainte Chapelle, which stands on an island in Paris in the middle of the Seine. It is very soft and has the property, quite different from other clays used for moulding purposes, of not needing to be dried, but when you have made from it the shape you want, you can pour into it while it is still moist your gold, silver, brass or any other metal. This is a very rare thing, and I have never heard of it occurring anywhere else in the world."

In 1722 iron waterpipes were being cast in sand molds. This was an important technical development for the growth of cities. The casting was done in cored sand molds and cooking pots in both loam and sand. From this time on the use of sand molds became more popular and the process became more and more mechanized. The method, however, remained basically the same. One new development was the use of jointed sand molds in the production of bronze cannons in France in the later decades of the 18th century.

The casting of metal into ingots for further use was, from the earliest times, usually carried out in permanent molds of metal or stone. Long iron molds were used for casting H-section lead cames (a slender grooved rod of cast lead used to hold together panes of glass in a window) used for glazing. A clamped-together mold of plates and rings was used to produce a disc of silver for hammering into desired shapes. From the 16th to the 18th century brass slabs to be hammered into sheet and cauldrons were cast between thick slabs of stone.

During this time bars of gold and silver were being cast in sand molds to later be made into coins. An unusual method of casting copper ingots was developed in Japan. The metal cloth draped over a wooden rack immersed in a tub of hot water. The ingot acquires a beautiful pink oxidized surface that is very resistant to tarnish.

Many compounds have been used in metal molds to prevent sticking and give a good surface. Wax and clay have been used, and in the casting of brass ingots, organic material such as tallow or oil with a filler such as lampblack or graphite was used. Until very recently the smell of burning lard oil was common in a brass ingot casting foundry.

ALLOYS FOR THE FOUNDRY

An important step in the history of metallurgy was the transition from a pure metal to an alloy. An early—or perhaps the first—alloy was the transition of copper to copper-arsenic and then to copper-antimony. These alloys were easier to melt and cast and were harder than pure copper. Next came the discovery of bronze which dominated the casting scene for 4000 years.

Cast iron appeared in China about 400 B.C. Thus, it was natural that the Chinese began to appreciate and exploit the casting properties of high-carbon iron. In Europe the brittleness of cast iron made it little used until the late 14th century. It was used mainly as a stage in the production of wrought iron. By the middle of the 15th century, however, it was used for simple decorative items. By the early 16th century, cast iron was also used in making cannons, although bronze remained the favorite cannon metal until the middle of the 19th century.

The use of cast iron as a building material began in England towards the end of the 18th century. The Coalbrookdale bridge over the Severn river in Shropshire, which was made of cast iron, was built in 1779. It is the first important cast iron structure. The use of cast iron beams in construction led to studies of the strength of iron and other materials. It also led to the mathematical theory of design.

The art and technology of casting improved, but it was largely a trial and error (empirical) process. Productivity increased and the product (castings) became cheaper, but the process of transferring molten metal to a solid has remained basically the same. Also, the properties of castings are still usually inferior to wrought metal. The growth of scientific metallurgy, however, is opening up new casting possibilities.

EARLY SPECULATIONS ON SOLIDIFICATION

In the past attempts to understand the structure of castings and the mechanisms of solidification have involved three different aspects: (1) understanding of the transition from liquid to solid state, (2) understanding the local changes of chemical compositions that accompany crystallization, and (3) the analysis of heat flux in mold and metal. Also, the manner of the growth and impingement of the crystals to give the structures and compositions that are found in different parts of castings having different thermal and mechanical histories had to be understood.

Early fracture tests of castings showed that metals were composed of grains. The fact that the grains were crystalline, however, does not appear until the 19th century. In 1644 Descartes, the French philosopher, discussed crystallization in terms of his corpuscular theory. He observed the "coming of nature" of iron in a refining hearth. He surmised that the subparticles that composed one "drop" or grain of iron were more closely bound to each other than those in other grains. Descartes attributed this to differing directions of coordination rather than to orientation. To him the shape of the crystal was incidental to the shape of the parts.

Robert Boyle, the English scientist, experimented in 1672 with the solidification of bismuth in a spherical bullet mold. He saw that the parts—no matter how disordered in the liquid state—rearrange themselves into smooth planes on cooling. The arrangement, he noted, was "more uniform and regular than almost anyone would expect in a concretion so hastily made; not withstanding which their internal contexture will be much diversified by circumstance as particularly the figure of the vessel mold wherein fluid matter concretes."

In the 18th century many attempts were made to grow crystals from liquids. The first observations of metal-crystal growth was in the shrinkage cavities of large castings. The fact that metals solidify in the form of dendrites was of interest to both scientists and foundrymen.

The scientific history of the dendrite and crystallography begins with Johannes Kepler's *New Year's Letter on the Hexagonal Snow Flake.* Much was written on snowflake formation by meteorologists, and later, crystals in iron were referred to as "iron snowflakes."

In 1775 another ironmaster, Pierre C. Grignon, made drawings of dendrites from a shrinkage cavity in a large mass of cast iron in a blast furnace that was allowed to cool over a period of fifteen days. He described the geometry of dendrites in detail and also noted the roles of heat and slag as solvents for metallic crystallization. Grignon also studied the directions of solidification of white cast iron. He explained the phenomenon as follows: "To the degree that the heat retires to the center, the molecules accumulate one on the other, following the progress of cooling right up to the center, which is the point towards which they all tend."

The first 18th century metallurgist to state that shrinkage lines—the "trees" or dendrites on the surface of frozen metal—were related to structural details displayed on fracture was Guyton de Morveau in 1777. He assumed that the crystallization of metals was analagous to the crystallization of salts. He reasoned that both were due to the evaporation of solvent . . . that the ingenous matter in melts acted in the same way as water in other solutions.

It was Mongez, in 1781, who first showed how to produce well-shaped crystals by draining partly solidified melt. David Musher, the developer of Mushet steel for metal cutting, also studied crystal growth in metals at this time. He wrote detailed descriptions of growth direction and successive branching of dendrite arms.

During the 19th century the belief that the solidification of metal was analagous to the crystallization of salt continued to grow. It was not until nearly the end of the 19th century, however, that the idea that metals were *always* crystalline was accepted. Then, it was in a paper by Savant in 1829 that the conclusion was reached that metals consist of groups of crystals in which each one considered individually presents a regular structure, while the mass as a whole is confused.

In 1856 Robert Mallet provided a picture of the thinking at the time on the problems of solidification. He wrote that "It is a law (though one which I do not find noticed by writers on physics) of the molecular aggregation of crystalline solids that when their particles consolidate under the influence of heat and motion, their crystals arrange and group themselves with their principal axes, in lines perpendicular to the cooling or heating surfaces of the solid."

Relative to casting, Mallet related the planes of weakness to the meeting of opposing zones of crystallization moving in from different surfaces. He also showed how the problem could be solved by attention to mold shape.

In 1878 D. K. Tschernoff, in a paper on the making of steel ingots, dealt with nearly every aspect of solidification including: shrinkage, blowholes, cracking, columnar and equiaxed granular crystallization, plus segregation. He also reported finding dendrites so small that they could only be seen under a 150-magnification microscope. Tschernoff also noted that dendritic growth caused numerous locked-in spaces in which contraction cavities would form, and he advocated forging to improve the grain size of a steel casting and close up the many gas bubbles and shrink cavities.

The study of the structure of matter became a subject of wide interest in the 19th century. Two important books relative to this field of inquiry were O. Lehmann's *Molekularphysik* and D'Aroy Thompson's *Growth and Form.* Lehmann describes a wide range of phenomena and covers the diversity of form in which inorganic matter can appear. He discusses the growth of dendrites in terms of the enhanced availability of material by diffusion or by convection at apexes.

Another scientist, Quincke, did pioneer work on liquid crystals. He proved that there could be some degree of structure in a liquid system. In 1903 he pointed out that the formation of foam in the liquid state was an essential preliminary to solidification. He observed that the crystals in some solidified liquids such as benzene can be seen to form a foam with a network of boundaries meeting always at any angle of 120 degrees—exactly as in a soap froth. What Quincke was proving was the nearly universal cell-like structure of matter.

The reference to "grains" appears early in the speculations on the structure of metals. The reference, however, is in the more natural form of granular matter such as grains of wheat which have an individual skin. It requires a new way of thinking to view a grain boundary of purely geometric origin. The study and understanding of grain boundaries is one of the more interesting aspects of metallurgy.

In the 20th century important studies have been done on the question of ingot design and ingot solidification. A great deal was learned by bleeding the liquid from partly solidified ingots, and when the thermocouple came into use, temperature measurements were made in different parts of solidifying ingots. Mathematical models have been used in the study of heat flow in castings

DEOXIDATION

The first and very early use of a minor element to prevent oxidation of a major element—and the evolution of gas by reaction during solidification—was probably the use of arsenic and iron in the smelting of copper. Zinc also appeared in bronze as a minor addition before it became a major component in brass. The effectiveness of phosphorus in creating fluidity and soundness in bronze, however, was not discovered until 1870.

The deoxidation of cast iron was not a problem because smelting always reduced enough silicon to serve as a deoxidizer. When crucible steel began to be produced, however, good ingots were produced only by "killing." This meant holding the molten metal for an extra hour in the furnace. This resulted in the reduction of small amounts of silicon from the clay crucible. The addition of silicon to molten steel in commercial castings was done first in Prussia in 1860.

In 1839 manganese began to be added to crucible steel. It served as both a deoxidizer and as a neutralizer of hot-shortness (short or brittle when heated beyond a red heat) due to sulphur. The use of silicon and manganese was crucial to the commercial success of the new methods of making low-carbon steel by the Bessemer process in 1856 and the Siemens-Martin process a short time later.

Many metallurgists experimented with aluminum in steel when that metal became available. A factory was established in 1885 in Sweden for the production of Mitis castings. They were ductile castings with thin sections and fine detail made by melting carbon-free wrought iron in a crucible and adding aluminum before casting in dry sand molds. Aluminum was also used later in the production of pure ingot iron from metal melted in open hearth furnaces.

LIQUATION (to heat (a metal etc.) in order to separate a fusible substance from one less fuscible) AND SEGREGATION IN CASTING

The early bronze founders probably noticed that their hot metal passed through a long mushy stage of solidification. Later, when men's minds began to be chemically oriented, they probably began to suspect that the process of solidification was accompanied by local variation in composition.

A very old example of chemical separation during phase change is the purification of salts by crystallization from a liquid solution. The separation of melting metal into slag and metal, and the purification of tin and lead by drossing (skimming off the scum on top) are other examples.

Segregation by partial solidification is the basis of the process of removing silver from copper. This process was a great source of wealth in Europe from the 15th century on. It involved the preparation of large cakes of an alloy containing three times as much lead as copper. When the cakes were heated to a dull red heat, the lead could be drained off carrying with it most of the silver. Then, the silver could be separated from the lead. The process was fully developed in Europe by 1574. It was replaced by a sulphuric acid process in the middle of the 19th century and today is done by electrolysis.

The phenomenon of segregation in a casting seems to have been recognized in 1540. The Italian metallurgist, Biringuccio, mentions the "leanless" of the bronze at the top of a gun casting in a manuscript from that year. He also tells how this can be corrected by adding more tin to the metal that is the last to run into the mold.

The first quantitative measurements on segregation were done on the alloys of the precious metals—gold and silver. The minting of coins required a purity of the metal used to establish its value. Regarding the assaying of copper-silver alloys, the metallurgist, Ercker, in 1574, noted that the sample should be cut neither from the center of the cake (ingot) nor from near the rim "for the silver follows the cold . . . so that the rim of a cake of matte is richer than the center." In casting black copper, Ercker writes that "the mold has to stand level lest the copper ingot become thick at one end and thin at the other, for you may be sure that wherever the copper flows with a rush and the ingot becomes thicker, there will be more silver in the ingot, especially when the copper is rich."

Instructions on assaying continued to instruct on the selection of samples to compensate for segregation, and attempts were made to explain it. In 1739 A. J. Cramer knew that silver, gold and copper were not evenly distributed throughout every part of a mass of lead. He noted that the effect depended upon casting temperature—that there could be composition differences due to insufficient stirring of the liquid, especially if there was partial immiscibility (cannot be mixed) as with lead in alloys of gold, silver and copper. Regarding a copper ingot containing lead, Cramer observed that it should not be quenched in water for the copper in growing cold contracts and "repels the lead still in fusion to the outside, and toward that part of the ingot which is immersed the last into the water. Likewise, the ingot is always richer in silver and gold in the thicker place where the mold has been inclined toward the horizon than it is in the opposite extremity, which is especially true of those mixtures in which lead and copper enter together."

Another European metallurgist, Gabriel Jars, in a 1769 paper on the reworking of base silver-copper coinage wrote that "the common belief that the heavier metal sank to the bottom of the alloy ingot was not true whenever the degree of heat was strong enough to hold the two metals in fusion." The separation occurred during cooling. He attributed segregation to differential repulsion in the cold mold.

"Metals in fusion have a strong tendency to jump up in the air with a great deal of commotion when they come in contact with cold or humid material. Lead is less sensitive to this reaction than silver, and silver is less so than copper," Jars continued, "so from this I concluded that on pouring an alloy of silver and copper into an ingot, the mass, meeting a body less hot than itself, seeks to withdraw from the walls as soon as it touches them. Copper receives stronger impulses by virture of its greater sensitivity and tends to approach the center from all sides."

The 19th century was the age of steam and every steam engine needs a boiler. The problem was that either through faulty design or poor material, boilers were exploding at an alarming rate and killing people. Part of the problem was the quality of the steel used. In the 1880s the steel industry was making larger and larger ingots and began to discover that they were more heterogeneous than expected. The examination of the debris from a boiler explosion revealed a large variation of carbon content in a rolled steel plate.

In 1881 a metallurgist named Stubbs traced some "very peculiar results" in the analysis of a 90-inch ingot of steel. It was not homogeneous. In it and other similar ingots examined, the carbon content varied from 0.37 to 0.92 percent; the sulphur from 0.025 to 0.161; and the phosphorus from 0.096 to 0.261 percent. Stubbs noted that "sulphur, phosphorus and carbon went to that part which remained the most fluid, so that in the center of the ingot which remained fluid the longest they had a very impure sample of the metal."

The segregation of metallic and nonmetallic elements plus impurities in steel ingots has continued to be a subject of an enormous amount of study. Also, the formation of inclusions, cracks and intercrystalline weaknesses have been given attention by the metallurgist.

Segregation of carbon toward the center of an ingot of steel is what one would expect because the lower-melting alloys should concentrate in the part that solidifies last. Thus, it came as a surprise when research around 1900 showed that segregation occurred in exactly the opposite direction. In fact, inverse segregation turned out to be the most common form.

There has been no unanimous agreement on the mechanism of solidification of a casting. Most of the scenarios proposed to account for segregation are involved in some degree in the very complicated system of happenings as metal cools in a mold. The factors to be considered are many . . . including: the balance of heat flow in the mold (in a liquid and solid state; convection movements of both liquid and solid; crystal nucleation and the growth of crystals with and without dendritic branches; volume changes occurring in spaces of varying geometry and connectivity; composition gradients on both sides of the solid-liquid interface; and the production of gases, immiscible liquids and major or minor solid phases as a consequence of changes of constitution during cooling. The interaction of all of these complexities makes the operation beyond computation . . . so far.

In the early 1950s mathematical models were created, however, representing the growth of crystals. This new attack on the problem of solidification is now permitting an estimate of the relative importance of the different models, and much more is now known, which gives the metallurgist more control.

The story of casting—presented in capsule form here—covers thousands of years. Contributors to the technology include artists, philosophers, scientists, engineers, metallurgists and foundrymen. In the past casting has been used as the simplest means of shaping metal. The defects of the method have been accepted or corrected by subsequent working. In the future the mechanisms and complexities of casting may be so well understood that the defects and reworking can be eliminated.

This would mean the production of castings accurately shaped, containing no shrinkage or embrittling impurities or grain boundaries, hardened by precipitation, and matching their wrought competitors in every way. Considering the present use of computers in product design and manufacture, one can imagine a programmed computer running a foundry as it mathematically measures and controls the movement of heat and matter in a mold.

A breakthrough in the technology of casting was reached in 1966. It was the production of single crystals in complex shapes for engineering purposes. The process was used by Pratt & Whitney Company to make turbine engine blades. They also report that parts of a complex shape over five inches ~~long and two inches wide have~~ been made by this process.

Today, besides single crystal growing, continuous casting and zone melting have expanded the frontiers of casting. Thus, the foundryman has come a long way from the description of him in 1540 by Biringuccio. He said that the foundryman is "like a chimney sweep, covered with charcoal and distasteful sooty smoke, his clothing dusty and half-burned, his hands and face all plastered with mud, his fearful, and his spirit distur and almost continually an ious." Biringuccio goes on say that the foundryman e dures all this because of "a certain expectancy of novelty and as if ensnared, he is often unable to leave his place of work for he finds it a profitable and skillful art and in large part delightful."

The "delight" of casting and the challenges it makes are still with the foundryman/metallurgist of today, although the conditions of his work are better. He no longer looks like a chimney sweep while practicing his skill in his foundry.

This short survey gives only an overview of the history of casting. For further reading on the subject, the following books are suggested:

Notes on the Prehistoric Metallurgy of Copper and Bronze, H.H. Cohlan, Oxford, 1951.

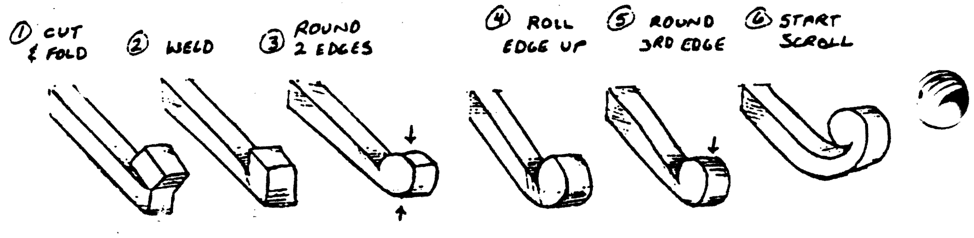
A History of Metals, L. Aitchison, 2 Vol., London, 1960.

Bronze Casting and Bronze Alloys in Ancient China, N. Barnard, Canberra and Nagoya, 1961.

<u>SHOP TIPS & TECHNIQUES</u>: The following were, for the most part, paraphrased from other ABANA Chapter or affiliated group newsletters. While the information presented herein, and elsewhere in this newsletter, is believed to be accurate, neither SOF&A nor ABANA assume any responsibility for the accuracy, fitness, proper design, safety or safe use of any information, technique, material, tool design, use, etc. <u>USE IS SOLELY AT THE USER'S OWN RISK!</u>

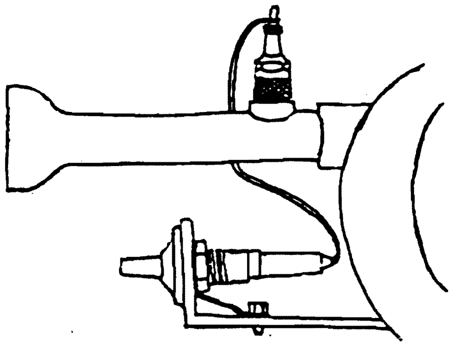
- <u>DEALING WITH RUST</u>: The March 1991 issue of Cars and Parts Magazine has an article by Matt Joseph describing ways to combat rust on autos. You might want to read the article if you need to rustproof new or old work. Read about etching epoxy-type primers, hot-dip galvanizing, high zinc primers, conversion coatings, rust converters and converting primers, anti-rust enamels, and moisture-cure urethanes. Available on the newstands for $2.50 or from Amos Press, P.O. Box 4129, Sidney, OH 45365-4129 for $3.50. (From the newsletter of the Blacksmiths' Guild of the Potomac).

- <u>WELDED BUTT END SCROLL</u>: (From the newsletter of the Blacksmith's Ass'n of Missouri).

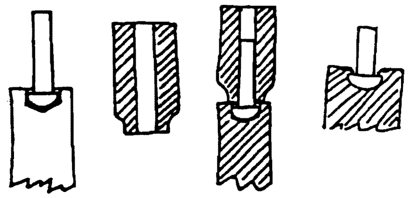


- DRILLING OIL: WD-40 seems to improve the cutting ability and life expectancy of drill bits versus standard cutting oil considerably! (From the newsletter of the Pittsburgh Area Artist Blacksmith Ass'n).

- GAS FORGE LIGHTER: This lighter was made by James Lavender. The B-B-Q gas grill replacement ignitor came from Wal-Mart (about $7) and the steel automobile anti-fouler plug, 14 mm, came from AutoZone. He drilled a hole and welded in the plug, but the hole can also be tapped. Make sure the electrodes are sticking into the pipe and are not shorted out. Set gap to 3/16". Check with the ignitor to be sure you get a good hot blue spark. Mount ignitor to side of forge. (From the newsletter of the Alabama Forge Council).



- ANYWHERE YOU WANT IT TENON: Stan Strickland showed me this method of putting on tenons on the ends or sides of bars or on plates. A rivet is used. Drill a hole so the rivet heat is recessed about 1/8". Make a set tool so the bottom diameter is 3/16" wider than the rivet head - hollow jackhammer bits work excellent for this. This set tool should be at least 1/2" longer than the longest rivet you expect to use in that size. Put the rivet head in the hole, the set tool on top and upset the stock around the rivet head. Heat the area around the rivet head as required. Stan says these rivets will break rather than tear out, so apparently they will hold. (By Clay Spencer from the newsletter of the Alabama Forge Council).



- ON FORGING NON-FERROUS METALS: (From a demonstration by Jack Brubaker as reported in the newsletter of the Upper Mid-West Blacksmiths Ass'n)

-- Aluminum. To find the correct forging heat, rub the hot bar with a pine stick (or other soft wood). When it makes a black mark like a greasy crayon, the heat is right. Too hot and you will just melt the metal off and when you hit it, it just disappears. Make sure the black mark stays in place for a few seconds. If it goes away, the heat is not right.

-- Bronze (more accurately aluminum silicone bronze - 642 alloy). Has a maximum forging temperature which is a color judgement. To find out the true color, heat rod in the forge, holding one end up and resting the other in the fire. When the rod starts to droop, pull it out and look at the color. This color is the maximum forging heat. Easier to control in the gas forge.

-- Naval Brass (no lead content). Has a very limited range of forging temperature. A few degrees too hot or a few degrees to cold and you hit it once too often and it breaks. It has a very high structural strength, but hard to work with.

-- Copper. Gets dead soft with red heat - that means no hammer rebound - just dead soft. You can hit it hot or cold for a long time. It takes a lot of abuse before it work hardens. It has no structural strength.

-- Stainless. Jack uses 304 and tells us stainless steel is hard to forge. It just doesn't move like mild steel, or any of the non-ferrous metals which he was demonstrating. It has to be really hot to work.

- POSITIVE PRESSURE VENTILATION: To reduce the smoke in your shop, and to help your chimney draw better, pressurize it by leaving doors and windows closed, except for one fan blowing in air from outside. (By Ken Roby in the Fall 90 issue of The Anvil's Ring).

1991 I.B.A. SPRING CONFERENCE:

The 1991 Indiana Blacksmith Ass'n Spring Conference will be June 1st and 2nd at the Stoney Creek Farm, 11366 St. Rd. 38E, Noblesville, IN. For further information contact Clifton Ralph, 4041 W. 47th Ave., Gary, IN 46408 - 219-980-4437. Demonstrators will be Bob Becker, Bob Ferguson and Hans Peot.

1991 N.O.B. SPRING CONFERENCE:

The 1991 Northwest Ohio Blacksmiths Spring Conference will be May 4th and 5th at Auglaze Village, Defiance, OH. Demostrators will be Gary Ameling (advanced blacksmithing), Bill Hahn (intermediate-level blacksmithing) and Ken Scharabok (beginning blacksmithing). Spouses programs scheduled. Saturday evening meal catered. Camping available and motels in the area. For further information contact Pam Raker, P.O. Box 344, Temperence, MI 48182 - 313-847-1248.

1991 QUAD-STATE BLACKSMITHING ROUND-UP:

This year's line up includes: Joe Keeslar (Kentucky Black Powder Rifle Production and Bladesmithing), Bill Callaway (Southwest Ironworking Techniques), Doug Henderickson (Beginning and Intermediate-level Blacksmithing), Bob Becker (Quadifoils, etc.) and Clay Spencer (Treadle Hammer Construction and Use and Hands-on People Heads). Display competition will be inovative tooling and the Chapter Challenge on Saturday evening will be chainlinks. We are trying to arrange for the same spouses program as last year due to popular request. Registration packages will be mailed in July.

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