10.1 View of the materials collected by Robbins, January 7, 1950. Note the nail barrels for storage. The inset at the upper right is an example of the catalog cards that Robbins used to keep track of artifacts in the collection. (Photograph 141 by Richard Merrill, 1950.)

The Artifacts

Janet Regan and Curtis White

Roland Robbins uncovered thousands of artifacts during his five years of excavation at Saugus Iron Works. This chapter presents a general survey of the artifacts contained in the collection, by Janet Regan, and a thorough examination of the seventeenth-century casting process based upon the artifacts, by Curtis White. This collection has enormous research value for addressing a multitude of issues connected with early colonial ironworking and precontact lifeways. Hopefully, this overview of the collection will inspire those interested in material culture to undertake additional research based on this rich resource.

Thursday, November 20th. Continued excavations at dock site . . . . Among the interesting artifacts being found at dock site excavations, was a heavy lead weight. This weight had an iron pin running through it from top to bottom. The top of the pin had an iron ring through it. The most unusual thing about the weight was interesting Hallmark, or Guild mark found stamped on its top. It should be interesting trying to run down its identity.

Roland Robbins, "Saugus Ironworks Daily Log - 1952," November 20, 1952.

The Roland W. Robbins Collection at Saugus Iron Works

The Roland Wells Robbins Collection (1948–1953) contains more than 4,000 artifacts recovered from the site of the 1646 ironworks known as Hammersmith. In addition to the seventeenth-century artifacts, the collection also contains a significant number of precontact and contact-period artifacts representing more than 7,000 years of Native American activity in the area. The sheer volume of artifacts from these periods makes this collection truly unique and contributes to the site's potential to expand our understanding of these eras.

The extensive historic artifact collection is made all the more valuable by the archival records of the First Iron Works Association (FIWA), which chronicle the site's archeological excavation and reconstruction from 1948–1954. These records include Robbins' daily archeological logs and field note cards, as well as materials compiled by the American Iron and Steel Institute, including correspondence, meeting minutes, maps, architectural drawings, oral histories, 16 millimeter films, and more than 5,000 photographic images. The archive provides invaluable information on the site's complex archeological story and lends special insight into the motives and methods of those involved in reconstructing the ironworks.[1]

Native People Collection

Roland Robbins' mission, as assigned by the Reconstruction Committee, was to locate key features and recover materials associated with the 1646 English colonial ironworks. As a result, he gave only secondary consideration to precontact evidence. In fact, Robbins gave more than 1,000 precontact objects to a neighborhood school boy. Fortunately, the collection was returned to the Saugus Iron Works National Historic Site in 1978; however, Robbins' field notes associated with the collection were lost when water flooded the donor's basement. Despite this loss and research limitations due to provenience problems, the surviving objects themselves hold great value in depicting activities that occurred at this site over thousands of years.

Because the ironworks site was situated immediately below a fall line at the head of the Saugus River estuary, the area was an important fishing ground for Native Americans. The precontact-period collections feature an assortment of lithic tools that date from the Middle Archaic (8,000–5,000 B.P.) to the Contact Period (1500–1620), including grindstones, grooved axes, drills, gouges, pestles, plummets, awls, scrapers, knives, hoes and a variety of projectile point types. Many prehistoric objects in the collection are made from "Saugus Jasper," an easily worked stone that was widely traded as a tool-making material. Ceramic and soapstone sherds and bone objects are also present in the collection.

The Saugus collection is especially valuable for telling the story of Native people during the Contact Period. The people of the Saugus area were called the Pawtuckets (also known as the Penacooks). An Algonkian speaking people, they lived in semi-sedentary communities that moved with the changing seasons from winter longhouse settlements, to spring fishing sites, to summer villages, to fall hunting camps.[2] Contact with Europeans brought epidemics in 1616 and 1633 that devastated Pawtucket communities and depopulated large tracts of their lands.[3] As pressures from English settlement increased, dispossession of Indian land intensified. Some surviving Pawtuckets made alliances with settlers and some even became Christian converts.[4] According to the ironworks' accounting papers, two Native people were employed to cut trees for charcoal production at the ironworks in 1651.[5]

Native Americans were the sole human occupants of the Saugus area for over 10,000 years. The Iron Works Site was an important area during most, if not all of this span.

Eric Johnson, *Archeological Overview and Assessment of the Saugus Iron Works National Historic Site, Saugus, Massachusetts*, p. 25.

The Saugus Iron Works museum collections hold examples of merchandise typically traded to Native Americans, including axes, pots, and "Jew's harps" that were produced by the ironworks. Industrially manufactured trade goods replaced stone, wood, bone, and ceramic items, helping to erode the self-sufficiency of indigenous economic structures and Native Americans' traditional lifeways. With the defeat of Native peoples allied during King Philip's War in 1676, most surviving Pawtucket families moved further inland, joining western tribes such as the Mohegans.[6]

Hammersmith Collections

The majority of the Robbins collection documents the seventeenth-century ironworks and its surrounding community. The collection provides a remarkable record of early iron-making processes, products, and mechanical techniques, as well as a portrait of early colonial settlement life in and around the industrial compound. Exceptional in its scale, degree of preservation, and rarity, this collection is a compel-

10.2 An assortment of net sinkers or plummets (SAIR 4298, 4491, 2507, 4188) provides evidence of fishing at this site. (Photograph by William Griswold.)

ling resource for those interested in seventeenth-century settlement history, industrial archeology, or iron-making tools and machines.

Blast Furnace Site Collection

The remains of the blast furnace overshot waterwheel and its nearly intact 27-foot-long by six-foot-tall hutch enclosure are a centerpiece of this collection. The hutch is comprised of sills, posts, plank sheathing, and decking and several pieces are incised with Roman numerals that colonial millwrights used to guide its assembly. About forty percent of the waterwheel has survived. Its components include soles, bucket boards, rungs, spokes, and shrouds that also bear incised millwright's markings. The blast furnace waterwheel and hutch assemblage and its 31-foot wooden raceway section, complete with staple-shaped iron supports and cow-hair caulking, are outstanding sources of information on colonial water-power technology and millwright construction techniques and designs.

Architectural remains of the furnace include furnace stones, bricks, clay packing, beam pieces, sow bar lintels, and sandstone lining, and the oak sills and wrought-iron tuyere (air nozzle) of its water-driven bellows, along with cams and a cam shoe that closed the furnace bellows. Surviving workers' tools held in the site's collection include crucibles and ladles, which were used to pour molten metal into forms buried in casting sand, and ringer fragments, pointed iron poles that were used to scrape liquid iron from the furnace hearth.

The collection also contains a variety of products manufactured at the colonial furnace including several sow and pig iron bars, ranging in weight from 14 pounds to 290 pounds. Many hollowware fragments that are evidently failed castings (called wasters) are also held in the collection. These fragments illustrate a range of vessel types, including pots, kettles, Dutch ovens, and large cauldrons. Although Robbins' excavations did not unearth a whole cast-iron vessel, the Lynn Public Library holds a complete pot with a lid and bale, known as "the Saugus Pot." The pot's metallurgy matches the pot fragments preserved in the site's collection.[7] Additionally, Robbins recovered cast-iron and lead weights from various areas within the furnace site, some with rings and some without, and some impressed with a stamped design. These may have been sold as "standard weights" to local merchants and/or were used by iron-workers to weigh products or materials at the furnace's steelyard or balance.

Colonial furnace workers also cast replacement equipment for the ironworks itself, such as hammer-heads, cams, cam shoes, etc. The collection holds what seem to be the remains of a shattered trip hammerhead. The site's history object collection also includes a fireback, embellished with the date 1655, the initials "E H," and a handsome pattern of decorative fretwork, that is a metallurgical match to Saugus

[Cast and wrought iron products] helped fuel what has been called [a] "consumer revolution" . . . that had its impact on the material culture of Massachusetts Bay from the very beginning. The English increasingly became leaders in manufacturing cheap but serviceable iron-wares: kettles, skillets, pots, nails, pins, trivets, andirons, wool combs and cards, axletrees, bits, stirrup irons, spurs, grates, locks, and keys. These [wares]. . . helped raise the standard of living for the families of gentlemen, yeomen, and even craftsmen. These were all amenities that the migrants to Massachusetts Bay expected to continue to enjoy in their new homes.

Stephen Innes, *Creating the Commonwealth, the Economic Culture of Puritan New England*, p. 278.

10.3 Analysis being conducted on the "Saugus Pot." (Photograph 279 by Richard Merrill, 1951.)

castings. This piece was discovered in Maine and is one of five surviving firebacks attributed to the Saugus furnace.[8]

Robbins also collected raw materials associated with the ironworks, including samples of gabbro (a local igneous rock used as a flux), bog ore, West Indies coral, and charcoal. Large amounts of slag (a by-product of iron production) were also collected by Robbins and are represented in the collection and on the site; the slag pile, adjacent to the furnace, is one of the last surviving in situ remnants of the original ironworks.

Forge Site Collection

Robbins' investigations uncovered dramatic finds at the forge site. A 500-pound trip hammer and two anvil bases with their supporting crossbeams are impressive objects that speak to the powerful mechanics entailed in the colonial refining process. Stone foundation remains, wooden uprights, pig bars and pig bar ends, casting pieces, wedges, spikes, and heavy slabs of iron are some of the objects found here that may be related to the refining process. The pig ends and possibly the casting pieces would have been melted in the finery hearths to start the refining process; wedges and spikes would have been used to brace equipment or to split lumps of material; and iron slabs may be the "plates"on which the "finers" beat and dragged "loops" (masses of iron that have been "cooked" in the finery hearth). [9] A large clump of fused iron and slag with a wedge stuck in its middle—remaining just as a workman left it more than three centuries ago—may, in fact, be an example of a loop. Regrettably, provenience data is missing for this interesting object.

Hammersmith was a school for ironworkers. Its alumni went forward to build and work many later plants ranging from Massachusetts to New Jersey.

Neal Hartley, "Iron, Steel, and American History," speech, American Iron and Steel Institute regional meeting, Chicago, Illinois, 1953.

Absent from this collection is an example of a "merchant bar," the forge's main commercial product. This valuable sales item would have been sold as a semi-finished commodity to local merchants or as stock to blacksmiths, who would fashion the iron bars into all manner of finished tools and utensils. Colonial workmen may have also forged anchors at this site–an anchor shank was recovered from the Saugus River and 36 anchors are listed in the 1653 ironworks inventory.[10] The collection also holds a jaw piece from a set of large-scale tongs that are without site provenience, but are very likely the remains of a tool used by workmen at the forge.

Slitting Mill Site Collection

About 12 percent of merchant bars traveled to the rolling and slitting mill to be made into flat bars, which were useful as blacksmith stock for hinges, lock plates, and other pieces or as iron bands for wagon wheels. Some of the flat bars were slit into nail rod and sold to blacksmiths for nail production. Objects in the collection associated with the slitting mill include several flat bars, a partially slit flat bar,

10.4 Latch handle, hinges, and door bolt (SAIR 3312, 2084, 2456, 2427.) (Photograph by William Griswold.)

several nail rod pieces, a machine spacer, and a cross-rung from the lantern wheel.[11] Robbins' field notes also mention that fused lime materials, a fire bed, sand, clinker material, and a long notched bar were found in the slitting mill area.

Jenks Site Collection

Robbins' excavation of the Jenks' blacksmithing forge uncovered evidence of water-powered mechanization at this site, including waterwheel remains, a tuyère, an anvil base, and a gear hub. The Jenks blacksmith shop specialized in edge tools and the collection from this area includes knives, a scythe blade, axes, adzes, chisels, a drawshave, a hacksaw, and a pole saw. An extraordinary example of an early sawmill blade was also uncovered here. This blade may have been intended for Richard Leader's water-powered mill in what is now North Berwick, Maine, which operated with "nere 20 saws at once."[12] The Jenks shop also ran a wire-drawing operation, which produced hundreds of brass straight pins and two brass brooches that were recovered during the excavation. Several latten spoons were also found along with sheets of brass. Spades, hoes, a pitchfork fragment, a cow bell, a stirrup, a brass spur, ox shoes, and horseshoes discovered at this site give us a depiction of agriculture and animal husbandry in the Massachusetts Bay Colony. Blacksmithing and other tools found here include tongs, hammers, a die, a rasp, ringer tips, a wrench, and a tool rest.

Dr. Barghoorn, Miss LaCroix and Gerry here at 6:45 (Gerry here at 5:45). We had dinner, then came back to my office and went over details for a new building for storing and cataloguing relics. Also discussed a system for cataloguing our relics. Left here at 11:15 p.m.

Roland Robbins, "Saugus Ironworks Daily Log - 1952," July 1, 1952.

General Tool and Hardware Collection

Robbins recovered an assortment of hardware, including latches, locks, keys, pintles, a variety of hinge styles, and many types of fasteners such as nails, spikes, staples, threaded screws, bolts, rivets, and thatch pins. Among the collection's many woodworking tools are axes, froes, chisels, claw hammers, gouges, pliers, a mallet, and a scribe. One surprising artifact in this category is a beautifully decorated carpenter's claw hammerhead. This utilitarian object, ornamented in the Mannerist style, was discovered in the mud at the waterfront's boat basin, where its owner might have accidentally dropped it into the river. The ironworks existed during the Mannerist period, when designs and flourishes embellished all manner of things, including everyday objects like tools. Historian Jonathan Fairbanks writes in *New England Begins* that "… the people of the 17th-century … could not separate notions of beauty or form of an object from its use. Beauty, significance, utility, and form were all inseparable parts of the whole."[13]

Various trades and industries are represented by objects in the collection, including large rings that were likely used in the production of cast-iron salt pans, an essential piece of equipment for salt makers. Salt making was fundamental to the fishing industry, which shipped huge quantities of salted cod to the Catholic countries of Europe. Other fishing-related items in the collection are fishhooks and a harpoon fragment. Maritime items include a ship's deadeye, an anchor, and a thimble for rigging. These materials

10.5 Claw hammerhead decorated with incised lines that reflect Mannerist aesthetics of seventeenth-century England and New England (SAIR 2533). (Photograph 1029 by Richard Merrill, 1953.)

may have been associated with the company's sailboats. The collection also contains a number of axes that would have supplied shipwrights, housewrights, and colliers. Coopers would have used iron bands for their barrels and soap-makers would have used the ironworks' cauldrons for " boyleing sope in ye River."[14]

Domestic life in and around the ironworks is represented through a variety of material types. Ceramic and glassware fragments are prevalent in the collection and have been useful to researchers interested in charting overseas trade relationships.[15] The ironworks regularly supplied its workers with tobacco and a large number of clay pipe pieces were recovered, including several terra cotta pipes of New England manufacture.[16] Other domestic items include a pair of scissors, several latten spoons, andirons, a variety of kitchen wares, a finger ring, brooches, and a nursing nipple.

The Robbins collection also holds a number of shoe parts that are evidence of a cobbling operation. These objects date to the late or post-ironworks period and include a cobbler's hammer and knife and a pair of cobbler's pliers. An assortment of worn leather shoe pieces, a few unused shoe pieces, cutting scraps, a large leather apron piece, and several stacked heals with wooden pegs are also present.[17] Shoe parts were found in the furnace area, the Jenks site, the slag pile, and the dock site.

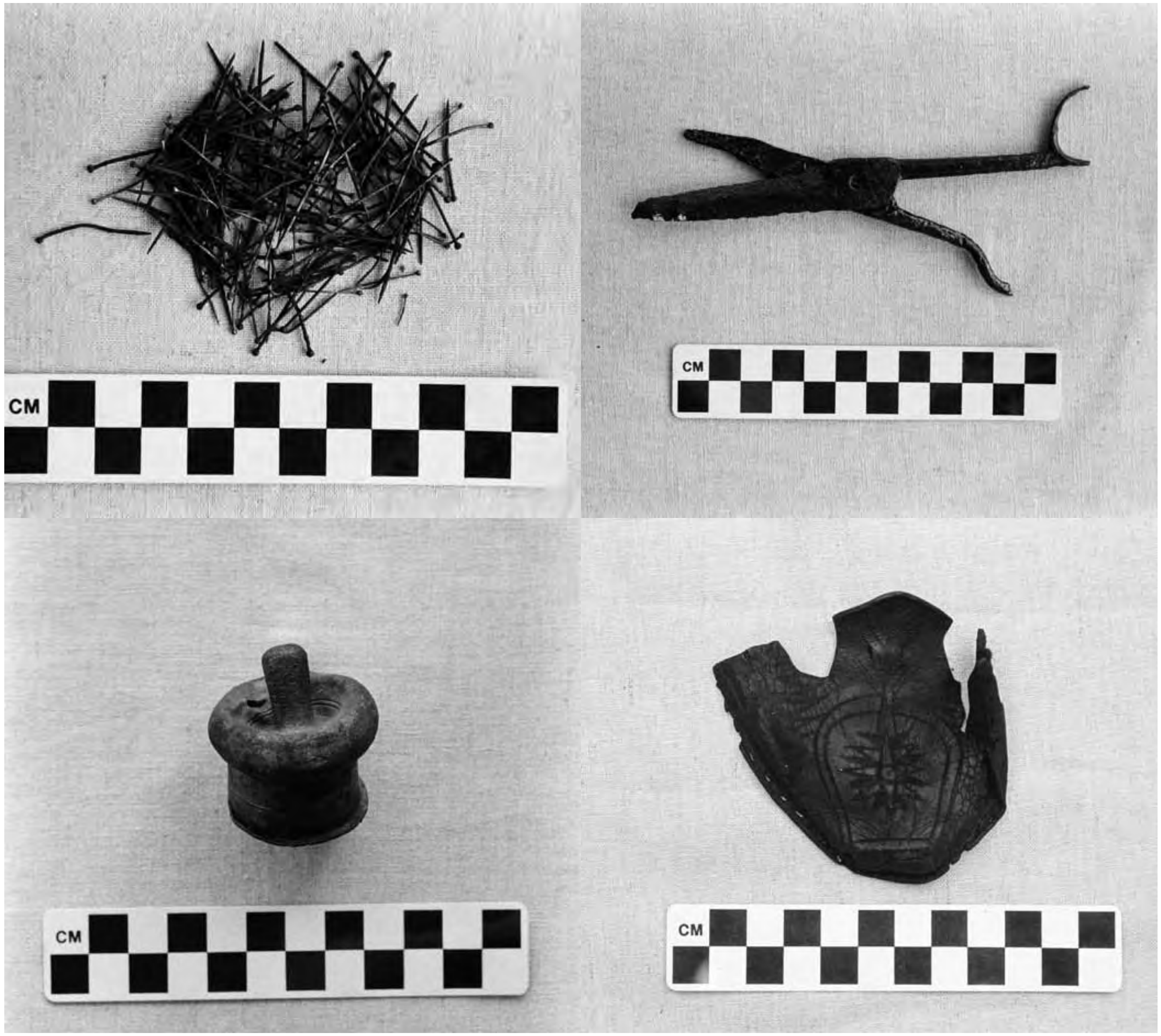
The site's weaponry collection consists of pikes, a musket barrel, a breach plug, shot, cannon balls, bullet molds, a bullet, and a grenade. Although militia service was a requirement for most settlers, ironworkers were exempt from military duty, perhaps because of the importance of their work and its round-the-clock nature once a blast began.

Collection Provenience

Provenience is a significant problem for the Robbins collection. This is a consequence of Robbins' labeling system in combination with circumstances that occurred after he left the project. Robbins, and occasionally his crew members, recorded provenience information for excavated objects on three-by-five-inch index cards, but they also used slips of paper, tags, envelopes, and fragments of cardboard to note in situ object location. Some of Robbins' field note cards plotted the specific location of an artifact by triangulation from two known points and many included diagrams depicting object location. Because Robbins assumed that a physical association between the field note cards and the objects would be maintained, his field note cards often use generic descriptors such as "these artifacts were found . . . ," without identifying specific objects. Unfortunately, collection pieces and field note cards were separated and/or cards were lost or damaged, resulting in the loss of provenience information for the majority of the collection.

Friday, April 24th . . . . Yesterday Fitch showed me a letter from Attwill stating that when we install the clock system for the watchman, there probably will be no need of the A.D.T. System for the old museum building. To my mind, this is ridiculous. If the watchman checks the different buildings once an hour or twice an hour the time between these checks would permit the old buildings to become a raging inferno before the watchman's next check. To my mind, if fire should brake [sic] *out in the old museum building, within five minutes the interior could well be beyond control. In any event, I have made my point, this being the need of utmost precautionary measures where we are exhibiting our original waterwheel, anvil block, other wooden artifacts and hundreds of invaluable relics.*

Roland Robbins, "Saugus Ironworks Daily Log - 1953," April 24, 1953.



10.6 Clockwise from top left: straight pins from the Jenks area (SAIR 9714), wrought iron scissors (SAIR 3310), shoe vamp with decorative toe medallion (SAIR 2699), and a pewter nursing nipple (SAIR 2819). (All photographs by William Griswold.)

Robbins did use a few other systems to identify object provenience. He incorporated data from his field note cards into his notebooks and produced careful sketches illustrating context for some of his finds. His Kodachrome slides and Richard Merrill's black and white photos supplement provenience information. Robbins also applied "relic numbers" (a three- or four-digit number separated by hyphens and often followed by an asterisk) in ink or paint directly onto roughly 140 objects collected from the blast furnace area and annotated the corresponding field note cards with the numbers. Several of these numbered object lots are mentioned in Robbins' report, "Excavations and Artifacts, Record of 1948." He also applied numbered fiberboard tags to wooden pieces from the Jenks shop that are noted on measured drawings drafted by Herb Bogan of the architectural firm Perry, Shaw, and Hepburn, Kehoe and Dean. He inserted numbered window-hanger's buttons to some of the furnace waterwheel hutch pieces, presumably to aid in its reassembly, and attached aluminum tags to other wooden architectural elements. Neither the window-button numbers nor the metal tag identifiers were noted on the field note cards or in any other document that remains with the collection.

In Robbins' museum, his field note cards served as labels for artifacts stored in museum cases. Robbins kept a card file for objects that were displayed without cases. Additionally, he stored a significant quantity of excavated artifacts and materials with their associated field note cards in a variety of containers that he kept beneath exhibit display tables and in the museum attic.

Tuesday, June 16th. Continued work in museum buildings. Had Bill the carpenter build a panel on which to exhibit the largest waterwheel found in the Jenks area. Relocated the exhibit case in the old museum building and arranged a new layout of artifacts in it.

Roland Robbins, Saugus Ironworks Daily Log- 1953," June 16, 1953.

At some point after 1953, portions of the Robbins collection that had been stored in containers were moved to a large, open crawl space beneath an outbuilding on the east side of the Saugus River. There the collection remained until 1972, when the National Park Service undertook a project to inventory this object group. The artifacts were shipped to the Harpers Ferry Center, Harpers Ferry, West Virginia, by truck and the cards and objects shifted during transit.[18] According to NPS Supervising Archeologist John Cotter, the collection arrived in

> . . . an assortment of containers, including over 100 wooden nail kegs, gunny sacks, tubs, oil cans, buckets, cardboard boxes, and other miscellaneous receptacles . . . . Provenience cards, usually 3x5", were scattered in the lots, sometimes more than one to a lot. Some lots lacked data cards or any type of identification.[19]

The overall condition of the note cards for this artifact group is poor to very poor, with cards damaged by tears, dirt, sun bleaching, mold, and water stains; many are simply illegible. Harpers Ferry staff assigned lot numbers to each of Robbins' artifact groupings and attempted to reassociate their field note

10.7 The artifact display cases in the museum. (Photograph 794 by Richard Merrill, 1953.)

cards with limited success. The Harpers Ferry project culled the collection so that "about half of the weight and bulk of the collection" was discarded.

In 1973, the NPS hired contractors Denis Piechota and Russell Barber to conserve and catalog the artifacts and materials that were returned by Harpers Ferry and those that remained at the Saugus on-site museum. Project cataloger Russell Barber found this collection to be in disarray:

> . . . a portion of the materials indicates that the index cards used for recording provenances of lots sometimes were out of place, only partially descriptive, or missing altogether. Discrepancies between the 1972 cards and the materials found in the summer of 1973 suggest further jumbling. As a consequence, a great portion of the collection is without site context; the majority of it is without positive provenience.[20]

Piechota and Barber undertook a second culling of the collection with a qualitative sampling of "the most common artifacts, e.g. nails, utility potsherds, bricks . . . [that] resulted in the discard of approximately one-half, by weight, of the collection."[21]

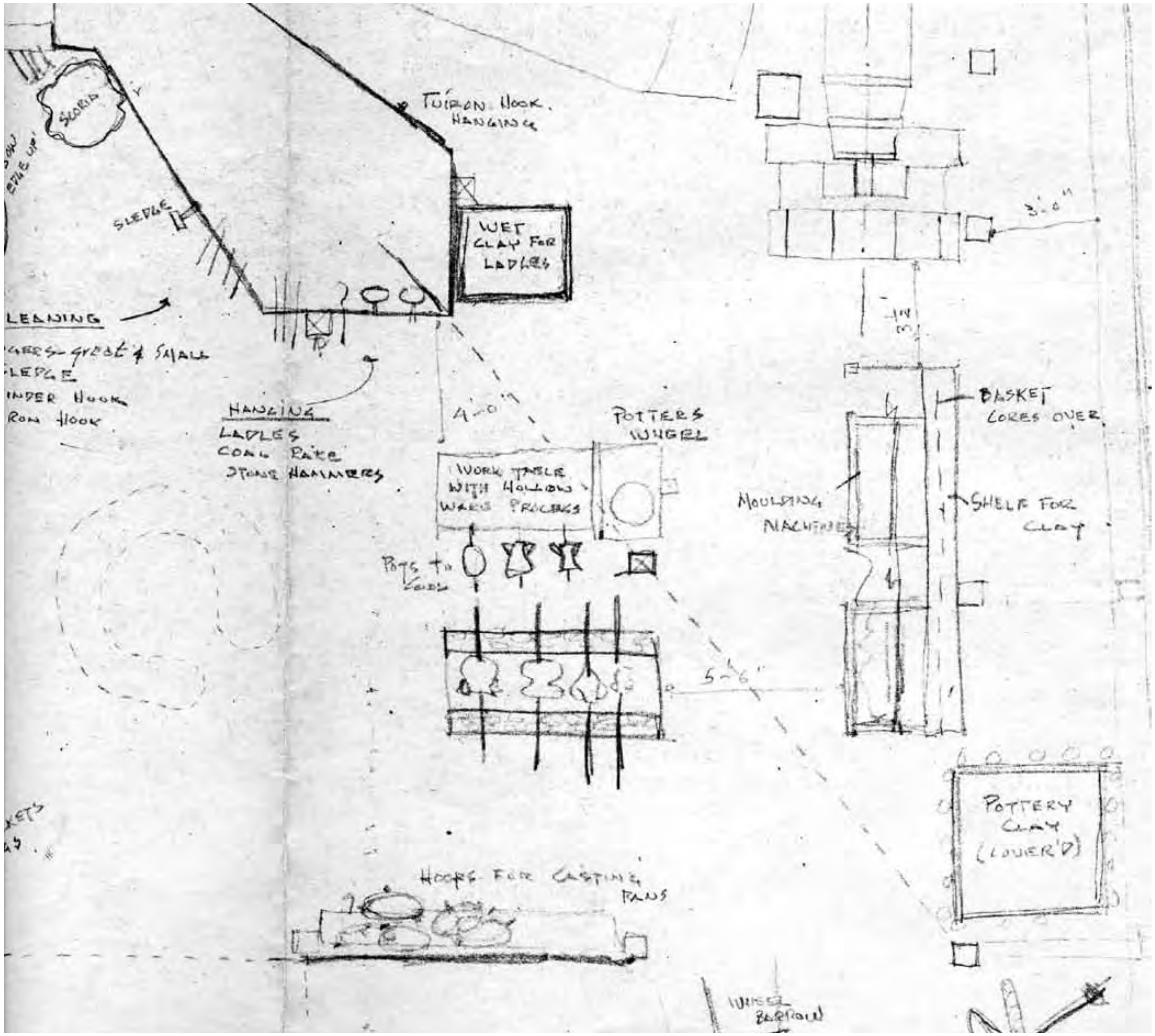
For the past several years, NPS staff and a cadre of dedicated volunteers have invested much effort in organizing, scanning, and transcribing Robbins' field note cards, notebooks, reports, committee meeting minutes, and other documents. Eventually, staff can begin to layer excavation discovery information to help fill in the gaps and hopefully to reestablish provenience for some of the collection. In addition to the thousands of artifacts recovered during the excavations, accounting records, court records, inventories, and some correspondence from the original ironworks have survived and are preserved at several local repositories, including the Baker Library at Harvard Business School, the Massachusetts State Archives, the Lynn Library, the Old Colony Historical Society, and the Peabody Essex (Philips) Library. With these primary sources, it is possible to provide historical context for many museum pieces.

I wonder if it is possible that a trough ran from the hearth through the sow casting bed down into this area where moulds had been placed in this sand? That would have made possible the casting of sows, kettles, etc., all in one operation! Also would help to account for the use of a slope for early operations. Future work here shall reveal more information, I'm sure.

Roland Robbins, "Saugus Ironworks Daily Log - 1949," November 9, 1949.

A Reevaluation of Three Groups of Artifacts Associated with the Blast Furnace

Artifacts discovered during Robbins' excavations inspired a passionate commitment toward an accurate reconstruction, while at the same time creating controversy among the original planners of the Saugus Iron Works restoration. Problems associated with the interpretation of various features and artifacts, such as the existence of a second power hammer in the original Saugus forge, have continued to generate discussion among scholars. The following section offers a reevaluation of three groups of mystifying artifacts produced at the ironworks and excavated at or near the blast furnace site: a collection of 78 notched bars and notched bar fragments made of cast-iron, a collection of cast-iron pot fragments, and two large iron rings and three iron ring fragments. All three groups of objects provide important infor-



10.8 This drawing proposes how molding operations would be represented in the northeast corner of the casting shed. It includes molding machines, a drying furnace, a bin for mixing loam, and hoops for casting pans (bottom). The circle of dashed lines on the left represents the archeological remains of the casting pit. (Perry, Shaw and Hepburn, Kehoe, and Dean, undated drawing.)

mation about seventeenth-century furnace processes and shed light on decision making by the planners and architects of the twentieth-century furnace reconstruction.

"Notched bars" and the Iron Works Operations in Braintree and Saugus: Implications for a "Second Hammer" in the Saugus Forge

Perhaps the artifacts that best illuminate the technical skills of seventeenth-century metallurgists at colonial ironworks are the 78 cast-iron objects that Roland Robbins called "notched bars." Only one notched bar (SAIR 1665) remains unbroken. This intact iron bar measures 29 inches long and gradually tapers to a point at both ends. It has V-shaped notches cast crosswise and uniformly spaced along its underside for its full length. To produce it, the molder at the blast furnace carefully pressed a wooden pattern carved with notches into the sand floor of the casting shed, leaving a negative form of the pattern in the special casting sand. As the molder gently poured molten iron into the void made by the wooden pattern, the glowing liquid iron began to darken and "freeze" into the solid form of the notched bar.

Before casting began, workers would break the notched bar and examine the fractured iron surfaces in cross section to determine whether they had the right type of iron for the desired finished product. Knowledge of the nature and composition of the iron was critical to maximize profits and reduce damage from high furnace temperatures that would "tear the furnace" and increase maintenance costs. Robbins found many sections from these cast-iron bars just a few feet southwest of the stone base of the blast furnace, the location where they would have been used as diagnostic tools for the production of cast iron. Workmen could either direct the iron into sand molds for sows that would be forged into wrought iron or directly cast it in a loam mold that was specially prepared and dried.[22]

While one might argue that most archeologically recovered material is fragmentary, fragmentation of the notched bars at Saugus actually proved diagnostic. The purpose of the notched bar is suggested by the fact that all but one of the bars unearthed by Robbins had been broken. Governor Winthrop described this process to the younger John Winthrop in 1648, noting that "They tried another mine [iron ore], and after 24 hours they had a some [sum?] of about 500: which when they brake [break] they conceived to be a 5th par[t] silver [white iron]."[23] Iron manufactured in the early twenty-first century is still tested and graded by this analytic process called fracture. Metal workers, perhaps for thousands of years, have known that when a V-notch is cut, chiseled, or cast into the metal, this notch can be used to initiate a fissure that promotes complete fracture. Because cast iron is brittle, there is virtually no plastic deformation when it is fractured. Despite their intrinsic brittleness, these cast-iron bars require significant and deliberate force to break at the notch. The resulting newly exposed surface allows examination of the variable crystalline structures within the iron fragment being tested. These visual surface attributes can be compared in much the same way as minerals produced in nature, using terms such as color and luster

Classified relics. Hartley in for two hours in a.m. Neal said that a small book "Pioneer America", by Carl Dreppard has lots of information on 17th century furniture and utensils. Said that it has a picture of a metal bar, similar to the bars we find notched on one side, and it is called 'Cob Iron'. It is used in the fireplace, stretched across a small standard at either end, and wood is set upon end resting against the notched bar which holds it in place.

Roland Robbins, "Saugus Ironworks Daily Log - 1950," June 6, 1950.

10.9 Four examples of broken "notched bars." First rust and then artifact conservation have rendered the original fracture surfaces indecipherable. (Photograph by Curtis White.)

to observe the refraction of light. About 1643, while John Winthrop, Jr., was collecting information on smelting ore into iron, he came across and recorded comments from English ironmaker Thomas Cootes about the various types of iron: "... [the ore] yielded great store of Iron and wrought very well and gently, in the furnasse, and would make both gray motly or white sowe Iron."[24] The terms gray, motley, and white are actually standard classifications given to cast iron based upon visible examination of the fracture. Clearly, both Winthrop and his father, Governor Winthrop, were familiar with fracture testing even before the establishment of the Saugus ironworks.

Many commentators have noted that the final cast-iron product can be changed accidentally or, more importantly, deliberately by varying any one or a number of factors. In 1964, G. Reginald Bashforth explained that "the type of iron produced is dependent on three factors: (1) the raw materials charged; (2) the temperature at which the furnace is operated;" and "(3) the type of slag formed."[25] Writing some 200 years earlier in 1775, Pierre Grignon described the effects of factors such as cooling rate and material thickness:

> ... when cast iron that is by nature gray is received in a cold, humid, compact body, it congeals precipitately and becomes white, hard, and brittle, so that if a piece is molded in such a manner as to make it unequal in its thickness, even though it is cast from the same drop of gray cast iron, the thinnest part is white, that which is a little thicker is mottled, and that which has the greatest volume is gray ....[26]

The notched bar's purposeful form provides the key to its function; it serves well as an analytical device precisely because it gradually tapers from the middle to a point at either end. As Grignon states, the iron at the ends freezes quickly into a white iron. As the thickness of iron increases toward the center of the bar, the iron transitions from a mottled gray and white to a gray iron. Depending on the amounts of carbon, iron, and silica, the cooling rate, and the bar thickness, the transition from white to mottled iron would vary both from furnace tapping to furnace tapping and from notched bar to notched bar. To use the notched bar to inform production, the bar would be broken at a thickness similar to the thickness of the planned casting. Workers would then adjust the volume of air blown into the furnace, the iron composition, or the cooling rate in order to obtain the attributes desired for the finished casting. Additional fracture tests could then be made to reanalyze material changes just prior to making the final casting.

Gray, white, and mottled irons all had practical uses in the seventeenth century. All three were cast directly from the furnace into the mold; both this process and its product are now referred to as "direct metal."[27] Gray iron gets its color from carbon, visible in the form of graphite flakes. Graphite is a lubricant that makes it easy to file or saw off flash (the molten metal that has squeezed its way between parting lines of a mold and hardened) and sprues. Sprue refers to metal that remains in a mold's gates,

Among the more striking features of pots made at the ironworks are the feet and the numerous bands or ribs that decorate the body of the pot. The feet are fashioned with five facets, the innermost of which is wider than the other four, and a pronounced toe.

Jonathan Fairbanks, New England Begins, The Seventeenth Century, Vol. 2, p. 354.

10.10 Typically, cast-iron pots were made from gray cast iron cast in a loam mold. (Photograph by Curtis White.)

which control the rate at which a mold cavity is filled.[28] Gray iron at Saugus was used to cast pots, skillets, firebacks, and round and square salt pans used to evaporate sea water for the purpose of extracting salt.[29] The ironworks may have also produced a small number of try pots for rendering whale blubber into oil at shore-based whaling operations, although there are no written references to it. Similarly, iron may have been cast as boiling or reducing vessels, since the 1650 inventory lists a furnace at the river for boiling soap.[30] Presumably the quantity of wood ash generated at ironworking locations facilitated the manufacture of lye, a vital ingredient of soap.[31]

Mottled iron results when part of the carbon occurs as graphite while the rest melds with the iron. An eighteenth-century reference describes its appearance as "the spots on a dogfish or trout."[32] White cast iron results from smaller amounts of carbon and silicates. It is harder than gray iron and therefore more difficult to work with hand tools. Its brittle hardness and resistance to wear make it suitable for machine parts subjected to compression stresses, such as the casting cams and large hammerheads and could be used at the ironworks.[33]

Gray, white, and mottled wrought iron can also be processed from pig iron. Each type of iron requires special treatment in the forge, achieved by manipulating iron plates and the direction of the air blast in the hearth.[34] Knowing whether iron is gray, white, or mottled, therefore, is crucial, making the use of the notched bar for testing a critical step in ironworking.

The notched bar has direct relevance to the discussion of comanagement of the dual English colonial ironmaking operations established by the Company of Undertakers: the 1643 ironworks in Braintree (now in Quincy) and the 1646 ironworks at Lynn (now in Saugus). In an April 1652 letter to the ironworks agent, John Gifford, John Becx and other investors told Gifford how to better manage the company's assets at both Braintree and Lynn: "As concerning the furnace at Braintree, we would have nothing cast in that but pots or other cast ware or salt pans or shot (in the furnace at Lynn nothing but pigs should be cast which will make your pigs better and tear the furnace less)."[35] The investors obviously distinguished the difference between gray and mottled iron and understood the effects of the corresponding manufacturing processes on furnace linings. They strongly suggested to Gifford that he make only mottled iron at Lynn thus extending the life of the furnace lining while improving the quality of pig iron made there. Extending the life of a furnace lining would increase the annual production of pig iron and, by extension, the production of wrought iron.

Clearly, the Company of Undertakers was aware of fracture testing as a vital tool to manage iron production. With the anticipated increase of pig iron at Lynn, Becx proposed the addition of another finery to lower the iron's carbon content. He also suggested building another water-powered hammer to forge

Our desire is that another hammer be set up in Lynn forge and another finery, there being a hutch [wheel pit] for it already and will be done with little cost . . . .

Lynn Iron Works Collection. Baker Library Historical Collections, Harvard Business School, p. 35.

10.11 Fragment (SAIR 2166) showing the misalignment of the two halves of the loam mold. The right side is thicker than the left. The inside of this fragment has no such ridge as the loam core was a single piece with no parting line. (Photograph by Curtis White.)

wrought-iron bars since there was already a tailrace to carry away the water after it had powered the waterwheel and hammer.

Cast-Iron Pots

While the Undertakers apparently pushed John Gifford to manufacture gray iron castings exclusively at Braintree, the archeological collection at Saugus includes the remains of dozens of castings of iron pots. These fragments may have been produced before John Becx's 1652 letter or after the ironwork's bankruptcy in 1653. Of course, all of the pots are broken or have some defect that prevented their sale. Pot legs, ranging in size from a few ounces to a few pounds, illustrate the various sizes of castings produced at Saugus. Pot defects include pock marked castings caused by excess moisture in the mold, a sprue and rim resulting from the use of low-temperature iron or an insufficient quantity of iron, and, in the case of one particular piece, misaligned mold halves. These imperfect castings typically would have been dumped into the furnace and the iron used once again.

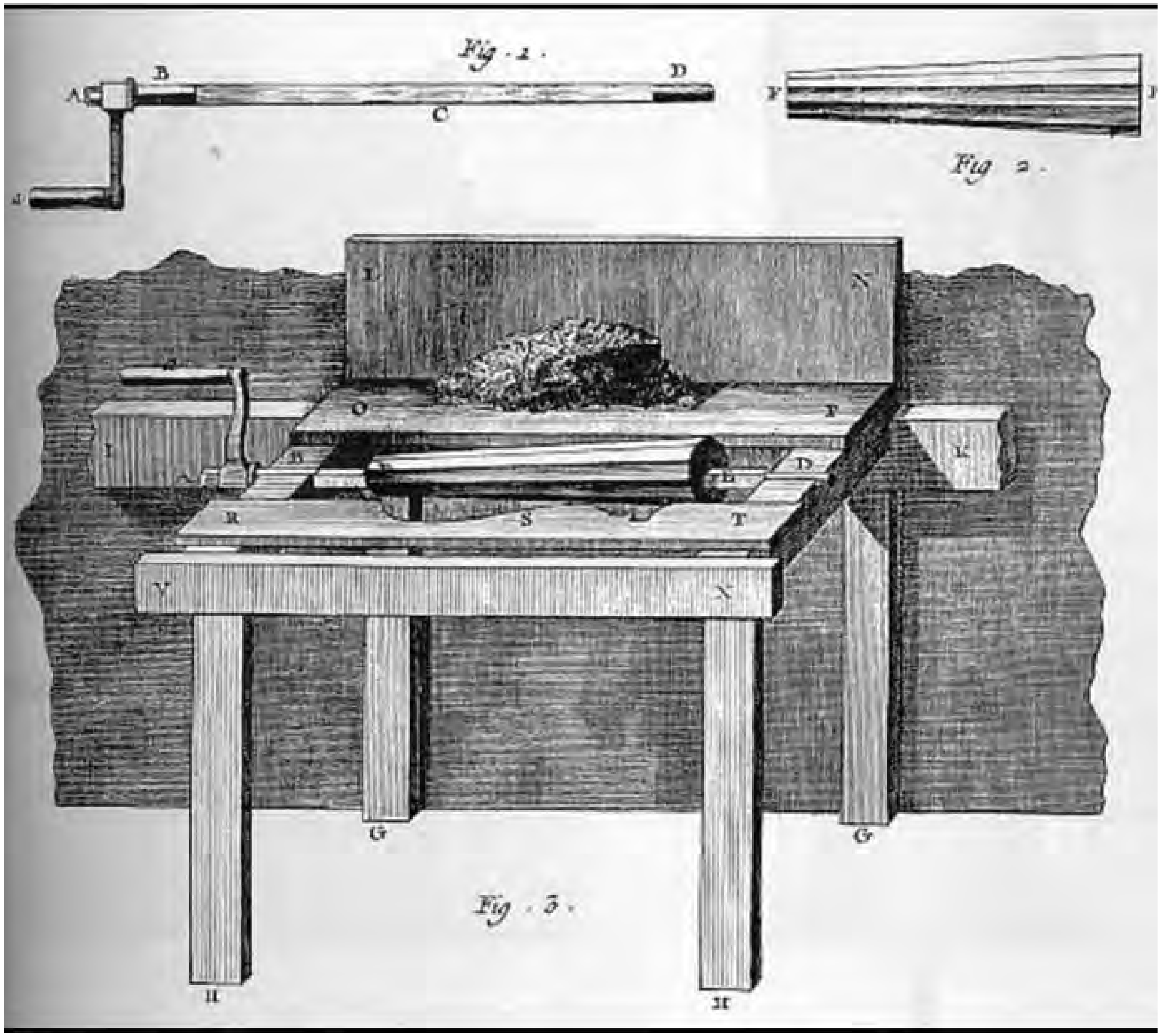
At first glance, a cast-iron pot is a simple form: a single casting that includes a bulbous body, triangular ears, called lugs, to hold the wrought iron bale or handle, and legs with feet that level the pot. Closer examination raises many questions about the production process, including how the legs and lugs were attached and how the molds themselves were made. A careful reading of the surviving pot fragments, such as body fragments, legs, and triangular lugs, and of contemporary literature on iron making may furnish many answers.

Diderot's mid-eighteenth-century ***L'Éncyclopédi***é illustrates two methods of making cast-iron pots: a green, not fired sand method whereby damp sand mixed with a little clay is packed around a wooden pattern to form the shape of the mold and a loam-molding method whereby loam is formed with a series of sweeps or mold boards around a central axis.[36] Analysis of pot fragments recovered by Robbins during the excavations reveals that the ironworks used the loam-molding process. This molding method could employ two approaches, both of which were used at Saugus. The first approach utilized a horizontal bench similar to a lathe around which the mold is built up and revolves; this method was used for making small cast-iron pots. The other method involves digging a pit in the casting house floor; this process was used for making larger castings. Both methods were complicated and time consuming, requiring highly skilled mold makers who understood how the molds interacted with the molten metal that came from the furnace.

The loam-molding process used a mixture of clay, sand, and some sort of binder such as wool fibers, chopped straw, or dung from a horse or cow.[37] Loam was mixed in a trough on the floor of the molding room using tools similar to those for mixing cement, such as a hoe or fodder chopper. Gobs of this

Everyone here agreed that we are faced with the fact that there had been two power hammers at the forge area at Saugus. What was not so clear was whether or not they were ever in use at one and the same time.

Andrew H. Hepburn to H.R. Schubert, September 23, 1952.



10.12 A loam molding bench with a core-bar, loam, and loam board set in place. Using three such loam boards, the molder and his machine scribed loam into the form of a pot mold. (Plate from Recueil de Planches sur les Sciences, les Arts Liberaux, et les Arts Mechaniques, avec Leur Explication, Troisieme Livraison, Paris, 1765, Forges, 3e Section, Forneau en Merchandise, Moulage en Terre, plate III. Saugus Iron Works NHS.)

loam were then placed on the narrow shelf set along the back edge of a molding bench, a heavy wooden framework probably attached to a wall for stability. As seen in Figure 10.12, a half-round wooden channel provided the bearing surface for a square iron bar with cylindrical ends. The iron bar was partially covered with a faceted, conical wooden shaft to form the core bar. The entire assembly was rotated by a hand crank and became the foundation on which the body of a pot mold was built.

Each size of pot required three precision-made mold boards to make the mold for the pot body.[38] Mold boards controlled the application of loam and were a set of masters that produced molds of consistent sizes. The first mold board was used to form the shape of the mold's core or the inside shape of the pot. The second mold board was used to form the outside shape of the pot and the third board left a thick layer of loam that made up the outer shell of the mold.

To make a mold, the first mold board was locked onto its registration pins on the molding bench. Rope was tightly wound around the core bar forming a solid foundation onto which loam was applied. The rope was later removed so that the mold could be dried and poured. The first layer of loam was then applied to the rope foundation; when the hand crank was turned, the profile of the first loam board formed a smooth and almost spherical shell around the rope. This produced the mold's core.

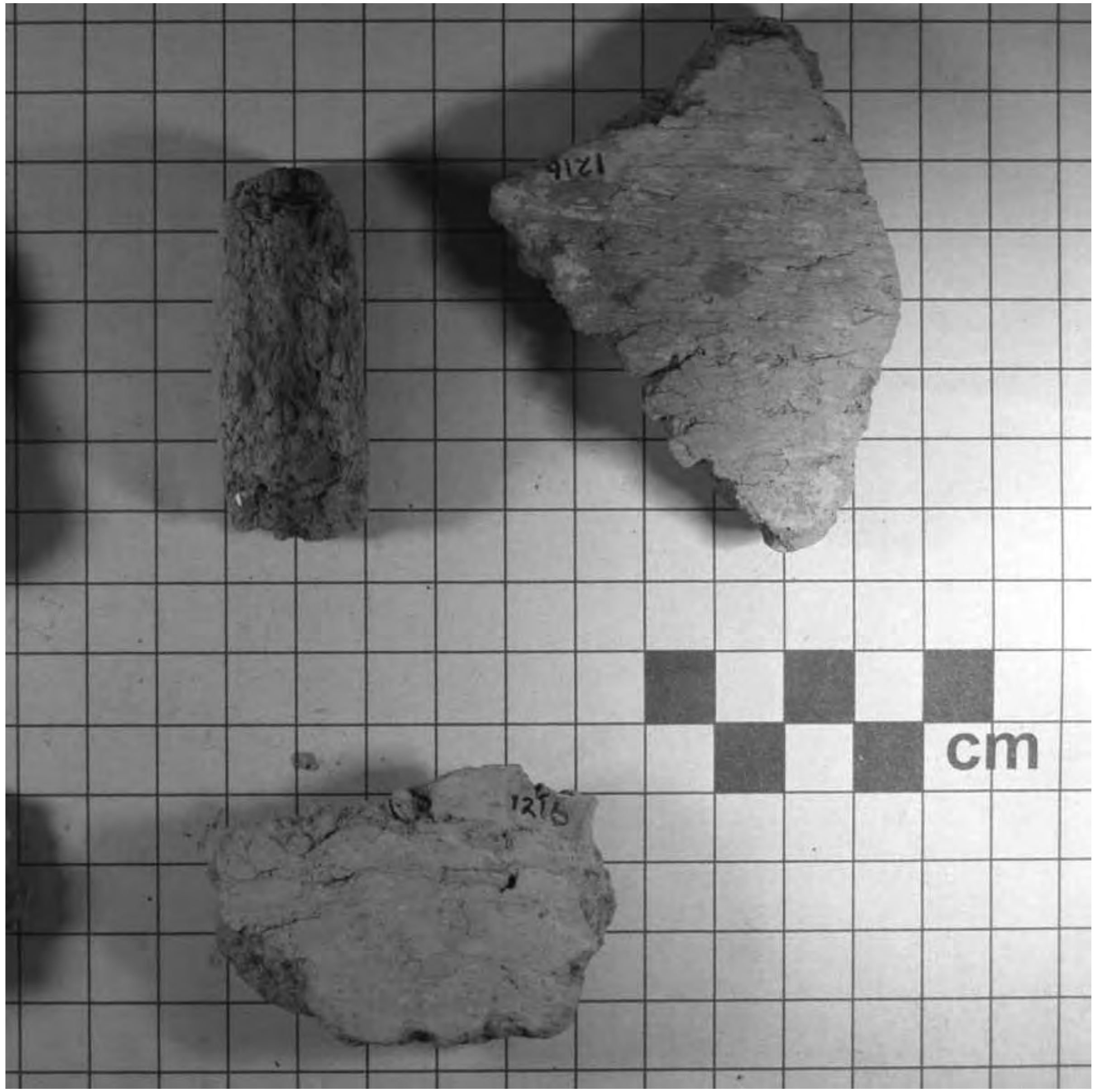
[A]ll manner of earth, stoanes, turfe, clay, & other materials for buildings & reparations of any of their works, forges, mills, or houses, built or to be built, or for the making or moulding any manner of guns, potts, & all other cast iron ware.

Massachusetts Records, Vol. II, p. 126.

After the first mold board was removed, a thin layer of parting compound was applied to the core. The second mold board was attached to the registration pins and a thin second shell was applied over the first. This second loam board applied a very precise layer of loam that formed the outside shape of the pot. The second layer was physically removed before the pot was cast, but in the interim the outer portion of the mold took on the impressions of the rings that went around the pot's exterior. These rings helped to place the ear molds and leg molds. An additional layer of parting compound was applied over the second shell of loam.

Finally, with the third board attached, a third, thicker shell of loam was applied to form the outer shell of the mold. The three layers of loam, still on the core bar, were dried over a low fire. Each of these molding processes left a visible mark on body fragments of cast pots from Saugus. For example, the inner wall of SAIR 2609, a pot body fragment, has score marks left by the mold sand as the core was turned against the mold boards.

After drying, the mold was slid off the end of the core bar and the rope was pulled from the inside of the core. The molder set the pot mold with the flat side down on the molding bench and carefully cut the third shell in half. He then separated those two hemispheres from the two inner shells and put them aside.[39] The second layer of loam was broken away from the first layer and discarded. The loam core



10.13 Pot mold fragments (SAIR 1216) were analyzed by the National Park Service and found to be composed of five parts sand to four parts clay. Drying heat has made the gray clay's outer surfaces a light salmon color. (Photograph by Curtis White.)

contained a hole where the core bar had passed through. This hole was patched with loam and the core set aside to await later reassembly.

Next, molds were made for the two lugs that held the bale and for the three legs which would be attached to the main body of the pot. Four wooden patterns were used to make these mold parts: two for the lugs and two for the legs.[40] Once the lug mold was finished, the molder drilled two holes through one hemisphere of the third layer of loam and affixed the two ends of the lug mold, then did the same on the other hemisphere. The process for creating the leg molds was similar to the lugs.[41] Many pot legs retrieved from the Saugus excavations (SAIR 9477, 1950, 9729) are five sided, reflecting the pattern used to form the mold. The leg molds were installed with two legs on one hemisphere and one leg on the other, all located about 120 degrees apart.

With the lug and leg molds complete, the hole where the core bar originally passed through the two outer hemispheres was patched and holes were drilled through the bottom of the outer shell to form gates for filling the mold. Conical risers were made using loam that was wrapped around a wood pattern in much the same way as the leg molds were crafted. The risers were attached to the mold, the two hemispheres were reassembled around the core, and all cracks were sealed with loam.[42]

Besides a parcel of molds for pots left, that were ready to cast, the furnace newly repaired, etc., new beam and wheel, furnace filled with Coals ready to blow which molds would have been worth about 700 pounds, proper for me to have.

Lynn Iron Works Collection. Baker Library Historical Collections, Harvard Business School, p. 252.

The assembled mold was then dried and buried upside down in the sand with the risers and legs sticking up out of the ground. The pot mold was then filled through the risers with molten iron. Excess iron flowed out of the riser onto the sand floor of the casting shed and sometimes formed a roughly cast iron ring (SAIR 1880).[43] Once cooled, the sprue of cast iron was broken off (SAIR 2892), the mold was opened, and the finished casting was inspected.

Salt Pan Rings

Although the Saugus collection contains two complete and three broken iron rings, on September 6, 1951, Robbins found the first of three large rings lying east of the slag pile and downhill of the furnace casting beds and refinery forge. The ring, SAIR 2930, was 42 inches in diameter, three and one-quarter inches wide, and about three-quarters to one inch thick. On October 5, he discovered a 34-inch section of a broken ring of similar construction, standing on its edge at the Jenks site along the furnace tailrace. Several days later, he found a second complete ring lying in slag fill just south of the dock (SAIR 2929).[44] The rings appeared to have been made by welding together a number of short, flat wrought-iron bars to form a large circle. One of two complete rings fits inside the other. On November 26, Robbins had a few holes drilled in one of the broken rings. The shavings were collected and sent out for testing, but the results of that test are unknown.

10.14 Leg mold (SAIR 2493) made of two pieces, the leg and the foot. The swell where the leg meets the body of the pot is where the body mold was pierced to attach the leg mold. Patterns (A-leg and E-foot) are used to form each leg mold assembly (F). (Plate from Recueil de Planches sur les Sciences, les Arts Liberaux, et les Arts Mechaniques, avec Leur Explication, Troisieme Livraison, Paris, 1765, Forges, 3e Section, Forneau en Merchandise, Moulage en Terre, plate IV. Saugus Iron Works NHS.)

Undoubtedly, the large rings that Robbins found were two of eight cast rings listed on the 1653 inventory as “8 hoops for casting pans.” There may have been a single set of eight rings, each fitting inside another so that the molder could make a wide range of pan sizes or a number of pairs so that multiple rings could be cast at the same time.

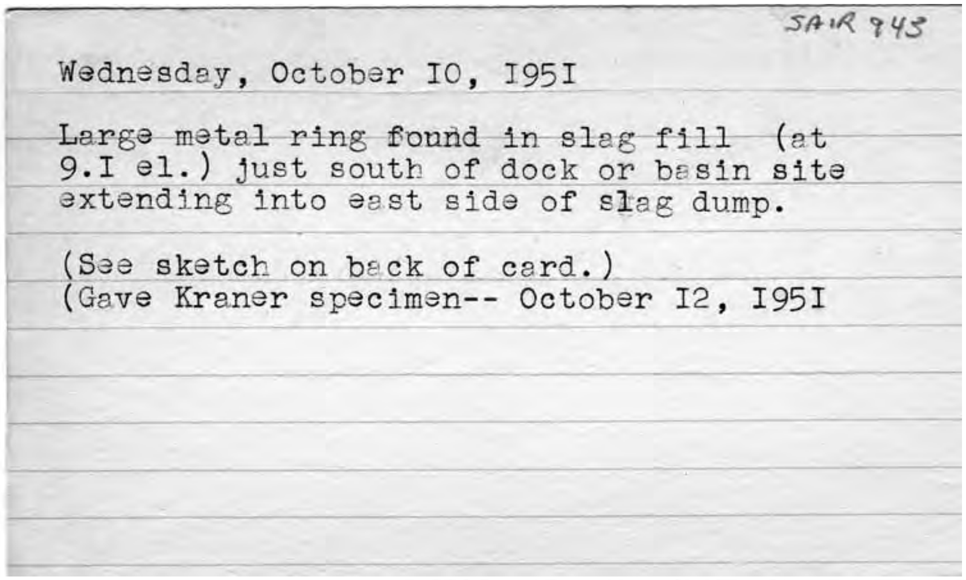
The clean and sharp edges of the fractured iron ring show no bending or deformation, confirming that it is composed of cast iron rather than wrought iron. On close inspection, one can tell that the rings were cast in open sand molds. To set up the casting, the molder might have first marked a center point in the casting sand and then used a string and scribe to delineate a circle. By pressing a short wooden board into the casting sand while following the marked circle, he could neatly displace the sand to make the roughly round circular void that would serve as the mold for the iron ring. This mold was then carefully filled with molten cast iron. When the iron hardened and was removed from the sand, its bottom edge bore in fine detail the irregular impressions of the board that had been pressed into the sand. The top surface of the completed iron casting would have been consistently flat with just a few visible gas bubbles, the result of the molten iron freezing in a sand mold that had a wide surface exposed to the open air.

Unlike most of the tools listed in the 1653 inventory, the rings have a fairly complete description: “8 hoops for casting pans.” Properly defined, a pan is a shallow, wide, open container. Since salt pans were used to evaporate water from sea water to leave the salt behind, a wide pan shape provided a great deal of surface area where water could evaporate quickly. From the bottom of the pan the sides flared out toward the rim. Molds for large castings were cast in the hole at the forehearth in the casting shed, below the seventeenth-century ground surface. Large molds were made in much the way that smaller pot molds were made but rather than working horizontally and turning the mold, the molder had a vertical shaft, and a series of three sweep boards. The sweep boards were attached to the center shaft and walked around the stationary loam mold.

Molders used concentric rings or “hoops” rather than a single, solid mold with a base in order to form the flared, concave shape of a pan. A pair of nested rings sat upon bricks at the bottom of the pit. Instead of building up a core around a core bar and coil of rope, the mold was constructed of loam applied with a sweep board around a foundation of brick atop the inner cast-iron ring. Just as it does in the smaller pot, the core defined the inner shape of the pan. A second sweep board replaced the first and, just like with the smaller cast-iron pot, the sweep board formed the loam into a pattern that simulated the thickness of the casting. The outer shell of the large mold was built over the second layer but was supported by the outer cast-iron ring. Because the mold was made upside-down, the concave shape of the third shell allowed it to be lifted in one piece from the core using a crane or winch mechanism rigged with hooks that fastened under the outer ring.[45] When the outer shell was lifted from the core, the second thickness of loam that was sandwiched between the core and the outer shell could be removed, thus cre-

On these pages are shown some of the interesting activities of the Committee. Above they are shown admiring the latest discovery unearthed by Archeologist Roland Robbins. It is an iron ring, 3 feet 8 inches in diameter. Preliminary conjecture i[s] that it may have been a ring at the top of the furnace, around the charging hole.

“First Iron Works Gazette,” October 1951.

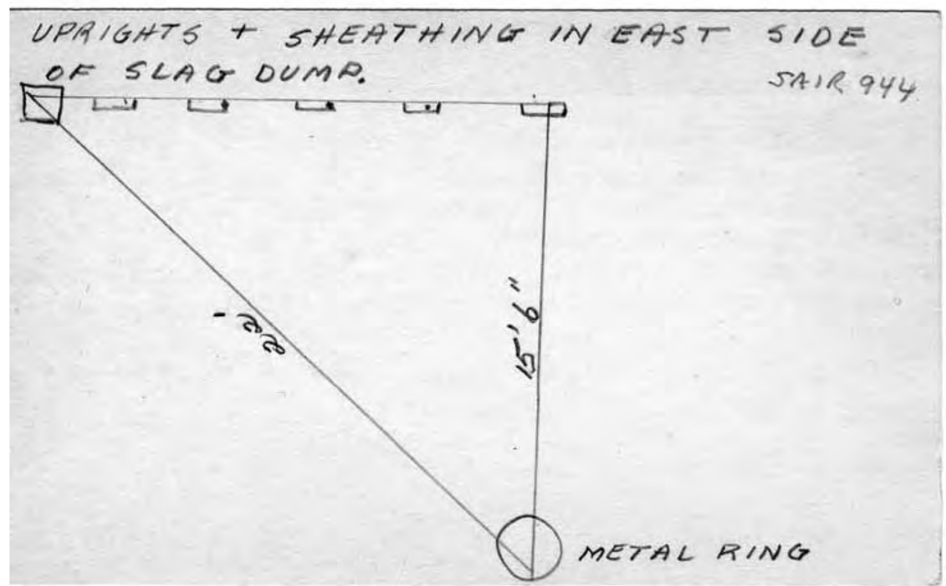


SAIR 943

Wednesday, October IO, I95I

Large metal ring found in slag fill (at 9.I el.) just south of dock or basin site extending into east side of slag dump.

(See sketch on back of card.)
(Gave Kraner specimen-- October I2, I95I



10.15 The front and back of Robbins' notecard indicating the location where the smaller cast iron ring (SAIR 2929) was found. (Robbins notecard scans numbered 943 and 944.)

ating the cavity into which the iron was poured. If the large casting was to be a large form of a cast-iron pot (with a bulbous shape) the third shell would need to be split as it was in the smaller cast-iron pot mold, as the outer shell could not be lifted from the core.

In the October 1951 issue of the *First Iron Works Gazette,* one writer speculates that these rings had been used to encircle the charging hole of the blast furnace.[46] As interesting and practical as this idea sounds, iron rings of this type were not integrated into the design of the reconstructed blast furnace. Instead, the charging hole was surrounded by eight separate cast-iron plates, each about two inches thick. Apparently the Reconstruction Committee or the architects did not agree that the iron rings had been used around the charging hole. In the late 1970s, the National Park Service added two cast-iron rings to the forge exhibit and one broken cast-iron ring to the blast furnace exhibit as examples of the use of wrought iron.

As time drew closer to the grand opening date of September 17, 1954, a concerted effort was made to outfit the reconstructed ironworks with iron-making tools of the trade. In June 1954, historian Neal Hartley and architect Conover Fitch assembled “a list of tools and implements” used at the blast furnace, forge, and slitting mill based on the 1650 and 1653 Iron Works inventories. They referred to works by Agricola, Diderot, and Hilestrom to understand the size, shape, and function of each tool and approved or disapproved its reproduction[47] The blast furnace exhibit featured tools to move slag, make molds for iron pots and pans, and tap the furnace. Pig-iron bars, molding benches, rakes, ringers, wheelbarrows, ladles, patterns, sieves, baskets, hammers, a box of molding clay, a box for drying molds by the fire, and “8 hoops for casting pans” were all included in a hand-drawn sketch showing the placement of each item.[48] Hartley and Fitch decided to omit the reproduction of the salt pan rings due to “insufficient information on these hoops to determine size and function at present.”[49]

The physically and emotionally engaging ironworks complex, reconstructed as the Saugus Iron Works Restoration by 1954, can overshadow the thousands of original artifacts in the site’s museum collections. Artifacts are primary cultural resources that, when combined with documentary evidence, tell an important story about the founding of North America’s iron and steel industry and its importance to the history of the United States. The archeologically recovered artifacts in park collections provide tangible evidence of the Company of Undertakers’ venture in iron making in the Massachusetts Bay Colony. Some artifacts have excellent provenance, which provides the best cultural context, while others unfortunately do not. Even the latter, however, contribute to the interpretation of our shared American heritage.