

CENTRIFUGAL CASTING AND THE LOST WAX PROCESS
AS A CRAFT MEDIUM

by

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FOREWORD

In 1934, while helping in a dentist's laboratory, it occurred to me that the Lost Wax centrifugal casting process could lead to a most fascinating hobby or even a business. In order to get better acquainted with the various metal casting methods, I enrolled in the course in Foundry Practice at the University of Washington. When centrifugal casting was discussed, I described methods that the dentists use, only to find that the process led to the amusement of the class and the instructor. "No one would try such methods on anything large enough to be worthwhile, for the machine couldn't take the strains. No one ever casts little castings anyway; those are forged."

This shattered dream was put into action by someone else ten years later and became an important factor in the war production of the nation.

It is my hope that now this dream may be used to bring pleasure and introduce new vistas of creative handiwork to those who would explore a new craft.

CENTRIFUGAL CASTING AND THE LOST WAX PROCESS AS A CRAFT MEDIUM

CHAPTER I

INTRODUCTION

Every shop and craft teacher is always on the look-out for new ways to add interest and variety to the work he offers his classes. When this interest-getter can also be a money-saver for his students, the method certainly deserves consideration. If, in addition, the new procedure also teaches the method used in industry without too much modification, it can be considered not only a leisure time project but also a vocational training process. Such a method is the Lost Wax Process with centrifugal casting.

The art has had a remarkable revival, though it has not found its way into the classroom to any extent. One of the oldest methods of making patterns, it became lost in the sixteenth century and was not rediscovered until the end of the nineteenth century, when a dentist saw its application. It took the second World War to make it an industrial process. With this remarkable revival, it is time that it is introduced to the classroom.

This paper will cover briefly this history along with recent developments and their application to the arts and crafts and industrial training program of the schools.

Various applications will be suggested and techniques that have been tried in the classroom of the writer will be explained in the hope that others will similarly experiment in the field.

CHAPTER II

DEVELOPMENT OF PROCESSES

The Lost Wax Process was well named; for not only was the method lost with the death in 1571 of one of its most famous craftsmen, Benvenuto Cellini, but also the wax pattern is destroyed or "lost" before the metal can be cast into the mold.

The history of this process, which first was of value only as an art technique, has become obscure, probably because of the long time the process lay dormant.

Many believed the originator to be Benvenuto Cellini, but earliest specimens of casting show that it was actually in use long before the art of making castings by the ordinary sand mold method was known.¹

There have also been very fine pieces of ancient origin found in the temples of China. It is interesting to note that the process was apparently enough of a craft secret that no one seems to have duplicated it until 1897, when B. F. Philbrook of Iowa, and W. H. Taggart rediscovered the process and used it as a technique in the rebuilding of partially destroyed teeth.² Their work was not kept

¹ "Lost Wax Casting: The Navy and Marine Memorial," Scientific American, CLIII (September 1935), pp. 142-3.

² Robert Neiman, Precision Casting by the Investment Molding Process, (Chicago: American Foundrymen's Association, (April 1944), p. 78.

secret as was that of their predecessors, and soon the process was developed and refined.

The process was essentially a simple one. A pattern was carefully carved or molded in wax. This wax was then invested or enclosed carefully in a special plaster. When the investment was dry, the wax was melted or volatilized and metal was cast in its stead. Undercutting and detail such as had not been seen for years were now possible. The wax could be carefully shaped and then heat "polished" so that no tool marks were left. Cores were not necessary to make delicate carvings in high relief such as those of the great doors of the Milan Cathedral which were cast by Lodovic Pogliachi in 1906.¹

After the Philbrook and Taggart rediscovery, dentists found that they could make finer patterns with wax than they could cast in metal by the conventional methods. The distortion caused by the air pressure method made some of their work unsatisfactory. It was found that if the crucible were designed with a small outlet in the bottom and placed over the sprue of the mold, the surface tension would keep the metal from flowing until it was placed in a bucket and whirled vigorously at arm's length. The metal would thus be forced into the finest crevices that

¹ Karl Baedeker, Italy (Leipzig: Baedeker, 1909), p. 28.

the wax pattern had made in the mold. This led to the development of the centrifugal casting machine. According to George B. Cox of Oregon State College, Dr. Thomas Coyle, a dentist of Orange, Texas, designed a machine that, with slight refinements, became a standard piece of equipment in many dental laboratories.

It was not until World War II that the need for precision castings became so great that dental technicians and engineers combined efforts to develop high speed production methods. Individual castings made by the dentist were replaced by mass production.

The dentist must produce a single gold casting that will be an exact replica of the missing tooth structure. His object being very small and irregular: he cannot enlarge his wax pattern (by the shrink rule), yet his finished casting must be accurate to better than a thousandth of an inch.¹

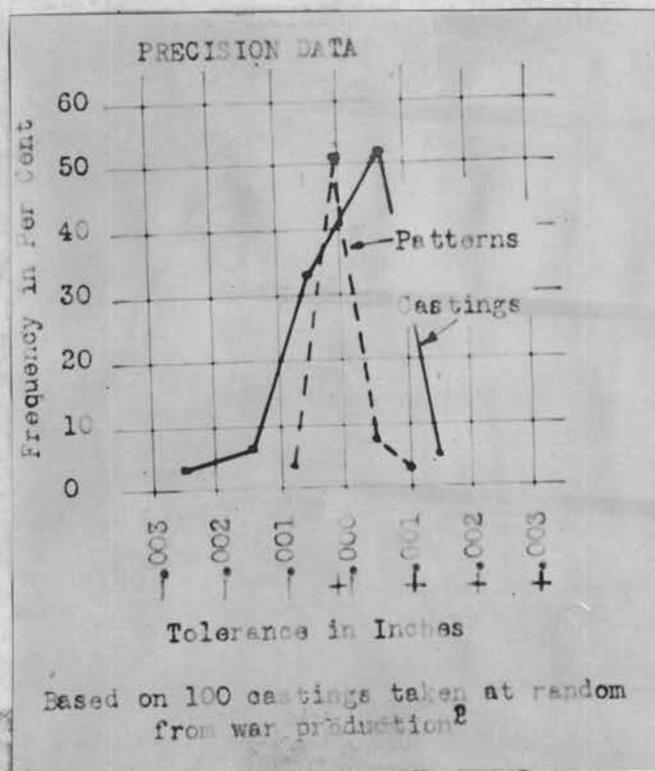
Duplicating methods were devised so that precise wax patterns could be turned out in endless numbers and these in turn were set up in multiple casting machines with automatic induction furnaces so that production was raised amazingly. The Kerr Dental Company developed a special lubricant that helped ease the wax off the pattern mold. Nearly all the dental equipment companies branched into war production.² Parts for airplane engines and small

¹ Neiman, op. cit., p. 81.

² "Precision Casting Practice," Steel, CXVIII (Jan. 28, 1946), p. 116.

munitions were turned out so precisely that machining often was not necessary.

Constant research was conducted on the waxes used and it was soon determined that for long, thin, or slender items some other medium was necessary. Injected plastic patterns were made of polystyrene which, though more costly, stepped up the accuracy to unheard of results.¹ The following table indicates this success:



¹ Charles T. Post, "Precision Casting with Plastic Patterns," Iron Age, LVI, p. 54-59.

² Neiman, op. cit., p. 83.

Size of the castings was still a problem, for the force involved made heavy castings dangerous to handle. Remote controls were used to protect the operators when big pours were made, and the equipment had to be designed carefully to handle the speeds and forces safely.

Perhaps the largest steel casting ever produced by the "spinning" method was poured recently by the Youngstown Alloy Casting Corporation. Weighing 1600 pounds, the casting was a high grade roll made for a Youngstown district steel plant.

It was produced on a 60" diameter spinning table, one of the world's largest, which was built recently at the Alloy Casting Company's plant.

Steel foundries ordinarily get 35-40 per cent from steel poured by the old method, while they get up to 60 per cent (satisfactory castings) by the centrifugal process¹

Not only were the castings more successful but they required far less machining, and the machining costs are an important item in the cost of the finished work.

It should be noted that there are two major types of centrifugal casting. The one with which this paper deals is the more recent development; that is, the use of centrifugal force to drive the metal into the finest parts of the mold without regard to the symmetry of the mold.

¹ "Casting by the Spinning Produced at Youngstown Company," Iron Age, LV (April 26, 1945), p. 124.

The other type has been used for many years and is used in the manufacture of pipe, wheels, pulleys, motor housings and so forth, where the pattern is primarily symmetrical, and the metal is poured in the center and thrown to the rim by spinning the mold about its center.

The practice of centrifugal casting is by no means new. At the break of the century symmetrical shapes, such as flywheels and locomotive wheels were being spun on a center pour basis. Cast iron pipe has been manufactured centrifugally for a number of years. The types of centrifugal castings have been briefly classified into three groups: (1) Die molds, (2) Semi-centrifugal-center pour, (3) True centrifugal cylindrical shapes, the inside diameter of which is governed by the volume of the metal poured . . .¹

This symmetrical type of casting is very important in industry, but its application to the school is so limited that it need not be considered further. It is with the other types or asymmetrical castings that all manner of enrichment may be added to art-metal projects, or delicate projects from the simplest to the most complex can be made.

¹ Peter Blackwood and John Perkins, Centrifugal Casting (Chicago: American Foundrymen's Association, April 1944), p. 1.

CHAPTER III

THE LOST WAX PROCESS

In order to present clearly the development of the Lost Wax Process, it was necessary to describe the process briefly. To understand the process thoroughly, it will be necessary to repeat; and it is hoped that this repetition will lend clarity.



Pattern and
shrink-preventing
ball mounted on
sprue base



Invested



(Cut away view)
Mold ready
for
burn-out

The Pattern. The Lost Wax Process, more recently called the precision method of casting, is one that can easily be handled in the high school. An exact pattern of a project is made in wax or other volatile substance. There is no need of allowing for draft, as in patterns which are used in sand molds. There need be no limit to undercuts; in fact, the pattern should be made exactly as

the final casting is to be. The wax pattern can be flame-polished or rubbed with the fingers or a cloth to remove all tool marks. Allowance for shrinkage of the metal should be made only if the casting must meet certain specific measurements. There has been a great deal of study in the problem of shrinkage, and certain investment compounds have been found especially successful. The shrinkage can be compensated for very accurately as shown in the table of "Precision Data" on page 6 of this paper.

One of the especially interesting features of this process is that wax need not be the only pattern material. A heavy-petaled flower, leaves, short-legged insect, cotton cord, or any other material that can be burned out may be used if the material is thick enough. When these other materials are used, the burn-out period must be longer, because the substance first must carbonize and then oxidize. If long burn-out periods are necessary, a durable investment must be used.

Mounting the Pattern. The pattern may be mounted on the sprue set in the sprue base in order to handle the pattern conveniently while the carving is being done; or this mounting can be delayed until just before investment. This mounting is done by heating the sprue former, a small finishing nail, and touching it to one of the larger parts of the pattern where not too much detail

will be lost. When this cools, the sprue can be built up to a size sufficient to allow the flow of the metal. For the type of work being discussed, there seems to be no set rule or guide as to what size this is. To be on the safe side, the larger the sprue, the more certain the success of the casting; but more is lost in detail where the sprue is attached. Wherever possible, sharp corners should be avoided at the point of sprue attachment, so that the metal will flow smoothly into the mold. Intricate or delicate patterns such as flower blossoms may require venting or extra support. Small rods of wax attached to the sprue base and to each part usually suffice. To avoid large sprues and still get good castings, a standard dental practice should be considered.

To prevent pits in castings a "shrink spot" reservoir should be provided by placing a ball of wax on the sprue. The ball of wax is conveniently made by cutting off the end of a stick of inlay wax or by wrapping a strip of base plate wax around the sprue. The wax should be sealed to the sprue not more than 1/16 inch from the pattern and the sprue, between the ball and the pattern, should be slightly thickened with wax.¹

The Metal Ring. The mounted pattern is now ready for investment. A metal ring is trial-fitted to the sprue base so that the uppermost part of the pattern will be

¹ Horace M. Miller, *The Dental Office Guide* (Oswego, Oregon: 1934), p. 81.

about one-fourth inch below the top of the ring. Metal rings can be made from various sizes of electrical conduit cut to the desired length. The sprue base can be turned from wood or cast from a pattern but should have ridges that fit the various size rings that will be used. Probably several bases will be desired to handle varying types of castings.

Investments. The investment can be made of many different compounds at the discretion of the worker. Cristabolite and the all-purpose gray compound available at dental supply houses seem to be the most successful for the work of the writer, but there are industrial compounds that were not tried. Plaster of Paris was not very successful because shrinkage due to drying as the wax was burned out made so many cracks that the mold would not stand up.

Investing the Pattern. The investment should be mixed according to its specific instructions but should not be too thick to flow into all the details. On the other hand, too much water will make a weak mold. Just before the investment is mixed, the pattern should be dipped in a soapy solution to remove any grease, and then rinsed. The investment is then placed on the pattern and carefully spread with an artist's brush. When it is covered, a slightly rough file may be rubbed against the

base to vibrate the air bubbles to the surface. The ring is then set in place and the rest of the mixed investment is poured around the pattern and the base again vibrated. Dental and industrial laboratories use an electric vibrator, but this is not a necessity to make satisfactory castings. The excess investment material is scraped off, and the mold is left to set and harden.

Burning out. When the investment has set at least a half hour, the base may be removed by tapping it sharply and the sprue former carefully withdrawn. The mold is then slowly heated in a soldering furnace or over a bunsen burner. In order to get sufficient heat with the bunsen burner it will be necessary to encircle the mold with a band of asbestos. Here again the industrial electric furnace with heat controls can be used if available, but it is not necessary. After a half hour of low heat, the flame may be turned up until finally the entire investment is heated through, and there is a rosy glow in the sprue. The temperature should be kept at this point for five to ten minutes for wax patterns or thirty minutes for flowers, etc., and then should be cast. The mold should not be allowed to cool before it is put in the casting machine, as this is likely to crack the investment.

CHAPTER IV

THE CENTRIFUGAL CASTING MACHINE

The simplest method of casting, and the one used in the foundries of the world, is the gravity-pour method. The metal is simply poured from the ladle into a mold and then flows to its outer reaches. Such a method works very satisfactorily in most cases, though, as noted before, steel foundries expect only thirty-five to forty per cent successful castings.

In the manufacture of toys, ornaments, and hardware the slush method is often used. Low-melting alloys are poured into a mold and allowed to chill on the outside and then the still-liquid center portion is poured out. Such castings use little metal and require no core.

To increase this yield, die casting was developed in which the metal is forced, by air pressure or by action of a plunger on the molten metal, into the outer reaches of the metal mold. When the metal has solidified but not contracted too much, ejector pins force the casting out of the mold.

The use of the asymmetrical type of centrifugal casting machine (see page 7) is confined generally to small castings where precision is a necessity. The terrific force available with this method of casting must be

carefully controlled so as not to overload the machine or have the molten metal break through the mold. But in spite of this need for caution, this method turned out such large numbers of perfect castings during its first two years of industrial use that it will undoubtedly be a most important method of small-parts manufacture in the future.

Because of this growing field, and because of the essentially small size of these castings, this machine is especially adaptable to the school shop. The hazards involved can easily be removed by simple safeguards, so that the machine need be considered no more dangerous than any of the common power tools found in the shop. Such a safe machine can easily be built in the school's metal shop and then used to make unusually fine castings.

A School Casting Machine

In order to make a practical casting machine for the school shop it was necessary to examine the machines in general use to discover what the true needs were and what embellishments could be ignored without losing the necessary characteristics. Simplification was a major consideration, for the costs must be kept low when introducing a new craft. The entire cost of the materials to make the machine can be kept below two dollars, and there is no complicated part that a student in a machine shop could

not handle.

The essential parts of a casting machine are described below, with details as to their construction. The drawing on the following page, and the photographs, should clarify the details.

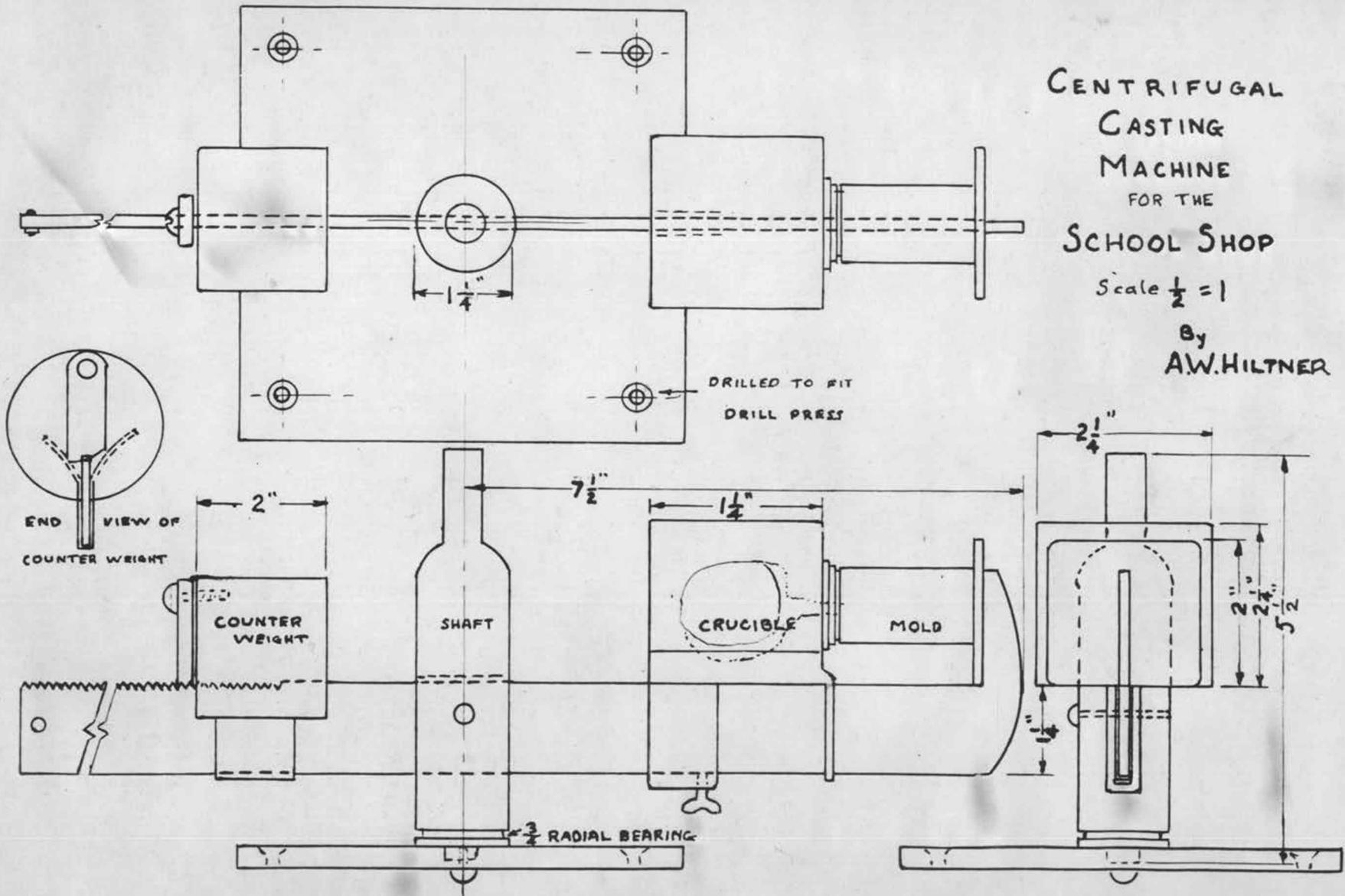
Bearings and Shaft. The bearings of the conventional machines are usually both in the base, so as to eliminate the frame necessary to hold the upper bearing above the spinning arm. The dental machines are generally driven by a spring,¹ but this seemed likely to be unsatisfactory when large castings were to be made in which the melt would not congeal immediately. With these two points in mind, it was decided to use the drill press to support the upper end of the shaft and drive the machine. To insure smooth action and to support the load, a tapered roller bearing that was on hand was used to support the shaft on the drill press table. Such a fine bearing was not necessary, for during the first several trials with large and small molds and at higher speeds than are necessary, the shaft had been so long that it merely rested on the bearing plate, with the set screw taking all the radial thrust. There was no apparent wear; so it might be assumed that a simple bearing would be satisfactory.

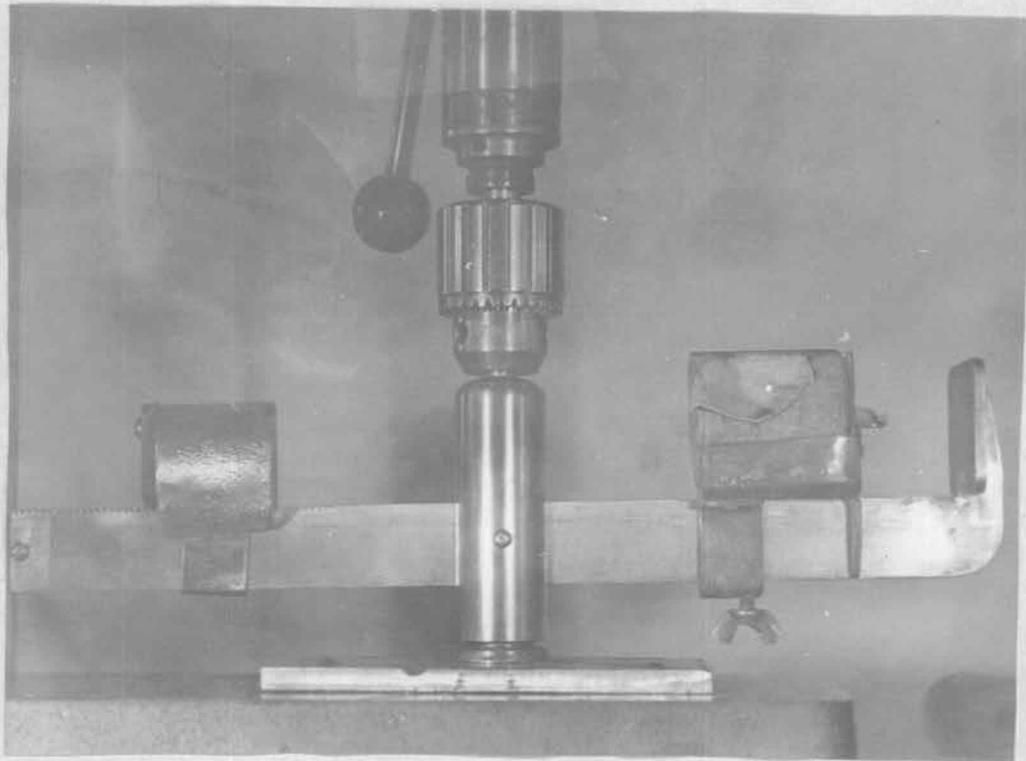
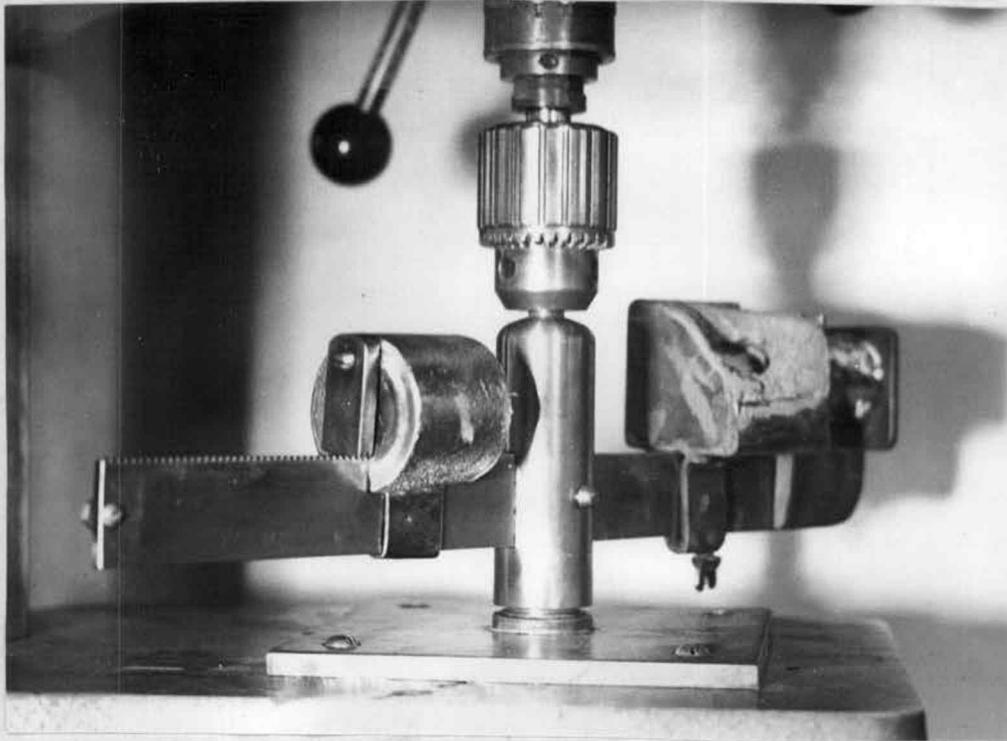
¹ Pictures of several commercially-built machines will be found in the appendix.

CENTRIFUGAL
CASTING
MACHINE
FOR THE
SCHOOL SHOP

Scale $\frac{1}{2} = 1$

By
AW. HILTNER





Shop Centrifugal Casting Machine

The shaft was machined from one and one quarter inch cold-rolled steel so as to fit the chuck of the drill press and the base bearing. A slot was made by drilling and filing so as to fit the spinning arm snugly, but a little long in order to allow the arm to rock slightly on the balance pin.

The base bearing was set into a piece of one-fourth inch iron plate which was attached firmly to the drill press table.

Spinning Arm. This arm was made of one-quarter inch by one- and one-quarter inch cold-rolled steel just short enough to clear the drill press post when set in the shaft. If a larger press were used, it would be possible to have a longer arm, but a 15-inch arm is adequate. The end of the arm was notched so as to allow for the adjustment of the counterweight. As a safety precaution, a machine screw was set in the end of the arm in case the adjustment slipped. On the other end, a plate with a stiffener was welded to act as the mold holder.

Crucible. From a piece of eleven-gage sheet iron a box without top, one end, and only one third of one side was formed and welded. To the bottom a strap with a locking screw was attached to permit the box to slide freely on the spinning arm. A hole was drilled in the end opposite the open end to permit the spout of the

crucible to protrude. Furnace cement¹ was then formed into a bowl-shaped crucible with an overhanging wall and funnel-shaped end so that the metal would not be thrown free. If crucibles available from dental supply houses are to be used, the box should be made to fit. The crucible should be lined with a piece of asbestos sheet. This may be easily done by wetting the asbestos and slipping it into place. Any wrinkles should be made so that they will spill the metal freely toward the outlet.

Counter-Weight. A piece of sheet-iron strip two inches by four-and-one-half inches with one-fourth inch holes drilled in the ends as shown in the drawing was bent to fit the spinning arm and then spread out on the ends. It was then set in a plaster mold and filled with lead, the spread ends serving to make a firm anchorage for the strap. A small piece of bar stock was grooved on the bottom to fit the notched spinning arm. The bar was attached to the lead so that it would swing into the spinning arm and prevent the weight from flying off the arm.

Guard. A piece of sheet-iron seven inches wide, with a half-inch edge turned in to catch any spattering metal, was bent to encircle the machine and was fastened to the

¹ Tharco Asbestos Furnace Cement manufactured by the Armstrong Company of Detroit, Michigan was used. At least 24 hours should be allowed for the cement to dry before it is slowly fired.

drill press table. (Not shown in the picture or drawing.)

Operation of the Casting Machine

When the mold is ready to be burned out, it should first be placed against the mold holder and the crucible slipped firmly into the gate of the mold and secured. The counter-weight should then be slipped to the position on the spinning arm where it just balances the crucible and mold. When metals other than aluminum are to be cast, the metal should be placed on the mold at about the distance it will be from the center when the casting is made. This will not prove to be in exact balance when the casting is made, but it is close enough to give vibration. The mold should now be burned out. If there are several molds to be made at one time, this balancing process may be done with the burned out mold but will have to be done rapidly to prevent chilling of the mold.

While the mold is being burned out, the machine should be checked to see that all is ready. The belts should be set to give the correct speed. With a fifteen-inch spinning arm, four hundred revolutions per minute work very successfully. The arm should be turned by hand through a full revolution to be sure that all is clear. If a large mold is to be used, it is necessary to allow

ample clearance above the arm. If the guard is secure, the crucible properly lined, and the metal in place, the machine is ready for the mold.

When ample time to burn out the pattern has been allowed, the mold should be transferred to its place on the spinning arm and the crucible secured firmly. The metal is quickly melted, sparingly fluxed if necessary, stirred, and the slag skimmed off the surface. Then as all is clear, the machine is turned and allowed to spin freely until the metal has congealed. Fluxing should be avoided if possible when using aluminum; but if scrap is to be used, a mixture of thirty per cent potassium chloride and seventy per cent cryolite may help to clear the melt. Borax works well with gold, silver, and brass.

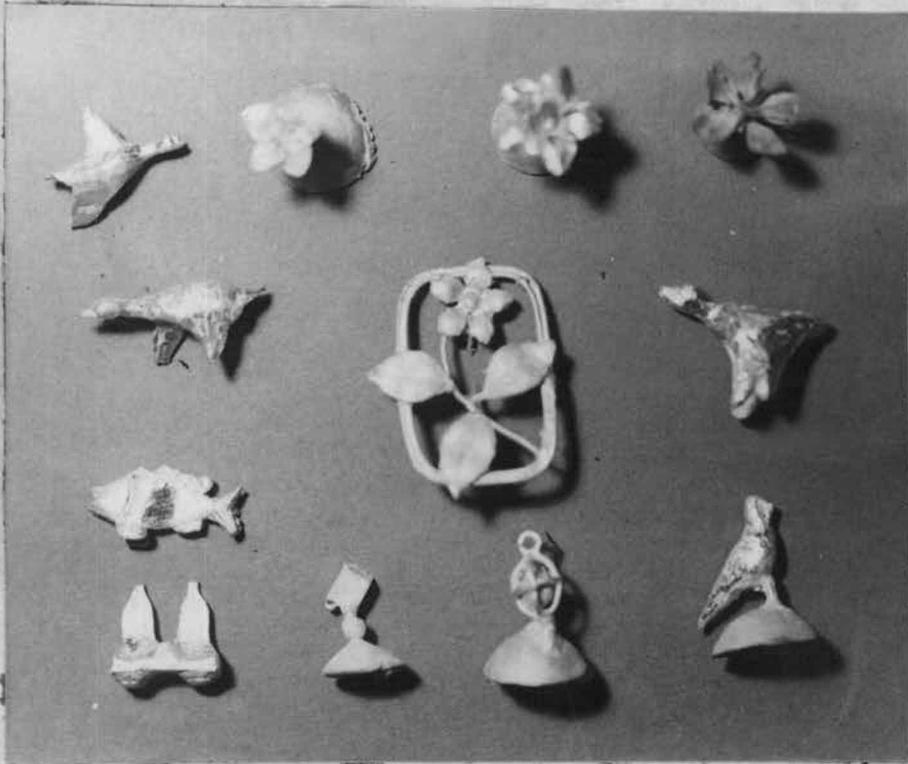
The mold can now be quenched in water or allowed to cool in air, depending on the type of investment material and the delicacy of the casting. Some investments will soften without danger to the casting while others will practically explode with quenching. Delicate castings may be broken by sudden cooling. When the investment material has been removed, the casting process may be considered complete. The sprue and button were found very satisfactory mounts for display or handling the castings but may be removed if desired.

CHAPTER V

PROJECTS

When one realizes that the Lost Wax Process with centrifugal casting is limited only by size, it is hard to suggest just what projects should be attempted by the interested craftsman. If the operator is a model builder, parts of airplanes, railroads, engines, coaches, automobiles or whatever the interest is, will suggest many applications. The jewelry hobbier will immediately think of rings, tie clasps, charms, ear rings, buttons or belt clasps, pins or all manner of ways to apply his interest. The carver will find an easy medium in which to work which can in turn be cast in several different types of material. Even the practical handy-man will be able to cast a new part to repair the worn-out gadget that demands attention.

On the following page is a photograph of some of the experiments attempted and brief hints as to why they were successful or why they failed.



Specimens of Castings

The first duck was mounted head straight up so that there would be no danger of having the metal fail to flow to the tips of the wings. The other two ducks were mounted wings up. The tail of one did not cast completely and the head of the other did not vent sufficiently to give a perfect casting.

The blossoms were mounted directly to the sprue base, the cherry blossom petals being supported by slender rods of wax. The cherry blossom was tried several times but

the petal is apparently too thin to cast with assurance. The one shown is so thin that it is lace-like as the aluminum only flowed into the thickened portions of the petals. The other flowers, weigela, were apparently thicker, for they cast with little difficulty.

The center pin, a built-up wax pattern casting, was mounted in six sprues to assure complete flowing of the metal. Because the pin was mounted face up, a large number of air bubbles were trapped on the bottom surface, so there were many tiny balls stuck to the surface. If mounted with more slope so that the bubbles could have flowed off, this would not have happened.

The fish was mounted on the dorsal fin. A gas bubble prevented a perfect casting which would indicate that all such bulky castings should be vented to the sprue base.

The anchor head was mounted on the fluke tips and was a very successful casting from a carved wax pattern.

The sample block, still mounted on the sprue base with its "shrink spot reservoir," shows a bubble on the left corner.

The ball in a cage was a built-up pattern with a sprue for both the cage and the ball.

The bird was successful without any extra sprue, though the sprue was rather large.

CHAPTER VI

CONCLUSIONS

The value of these processes to the educational program, like that of any other process, depends on the presentation to the students and the actual participation that the students make. The worker's skill is the only limit to the accuracy and delicacy that can be attained. Each attempt leads the student toward higher goals. Those who have tried their luck have been hard to discourage. Everywhere new possibilities appear. The process as used in the classroom is exactly the same as that used in a new and expanding industry; thus it gives vocational training to those who are interested in that aspect of the work.

The process requires little and inexpensive equipment, and the detail-work and effort are done on wax at small cost so that lost or stolen projects are unlikely until the cast is made. Very attractive castings can be made from scrap aluminum or brass; or if the student can afford silver or gold, these can be cast with practically no waste. To add to these values, there is an excellent opportunity for the student to build a practical machine for the school or for himself. Even with some failures in the first castings, the writer feels that these

successful attainments were worth the effort.

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APPENDIX

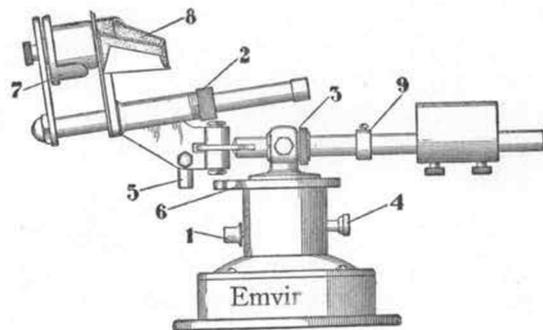
SPINER
BOND
MADE IN U.S.A.

DENTAL CASTING MACHINES

Most dental casting machines are sold through agents at dental clinics where actual demonstrations are made. If a machine is to be purchased for a school, it would be well to visit such a clinic and thereby see all the latest improvements.

The following are advertisements furnished by various Portland dental supply houses.

EMVIR
Floating-Arm
CASTING MACHINE



This Finer Casting Machine
 Gives You—

1. Crossbar Lock
2. Ring Lock
3. Crossbar Balance
4. Crossbar Brake
5. Floating-arm Control
6. Floating-arm Lock
7. Ring Cradles
8. True Flow Crucible
9. Counterbalance Lock
10. Many Other Exclusive Features

Handled by L. O. Sandin Dental Supply Co., Portland, Oregon

TORIT*Casting
Machines*

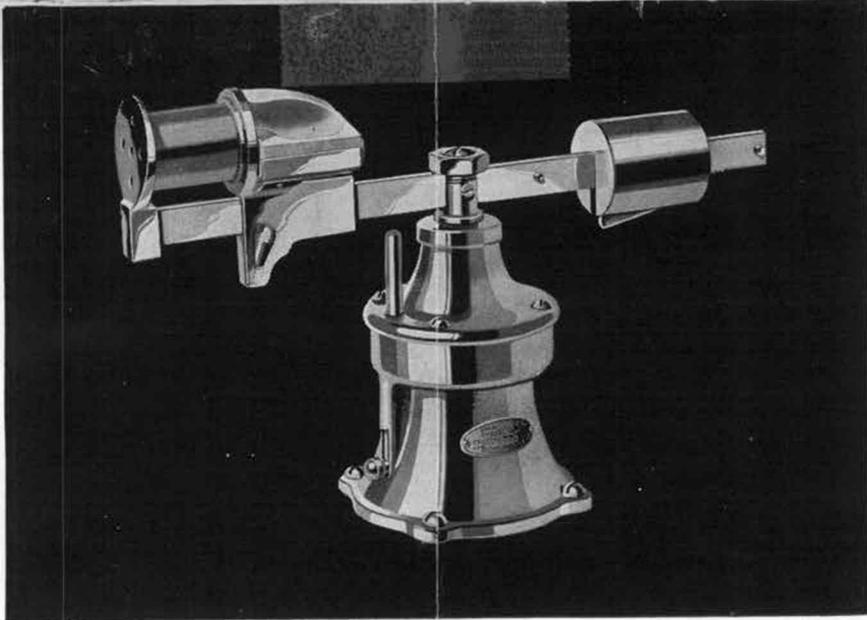
**TORIT vertical-centrifugal casting machines
produce better castings with no metal loss**

TORIT Casting Machines are spring operated. Crucible and flask revolve vertically at constant speed. Metal flows direct into the mold, with no loss. Castings with perfect margins are assured.

TORIT Casting Machines are manufactured in two sizes. No. 7 is designed for casting inlays, small bridges and crowns. No. 10 will handle all casting work including full dentures. Both are becoming available in ever increasing numbers. For complete information and latest TORIT Dental Catalog write: TORIT MANUFACTURING COMPANY, 279 Walnut Street, St. Paul 2, Minnesota.

Torit Dental Products

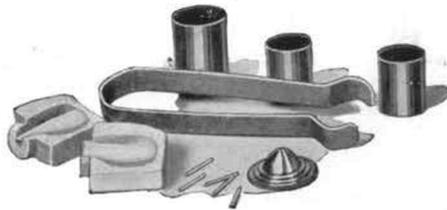
Handled by John Welsh Dental Depot, Portland, Oregon



CENTRIFUGAL FORCE, definite, accurate and easily controlled, is the motive power which operates the Perfection Casting Machine. The pressure exerted on the gold is positive, immediate and direct, and may be exactly duplicated for any subsequent operation.

The crucible carrier and counterweight of the Perfection Casting Machine are easily moved and adjusted.

The separate crucible gives the operator complete control of the gold, prevents overheating the mold, and economizes investment.



THE CLEVELAND DENTAL MFG. CO. Cleveland, Ohio, U. S. A.

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