Pouring, Pulling, Spinning, and Pushing:
Various Methods of the Lost Wax Casting of Platinum Both Old and New

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Various methods of the Lost Wax Casting (LWC) process are employed in the casting of platinum with a varying degree of success. We shall concern ourselves with: "pouring" the Gravity Casting Method; "pulling" the Vacuum Assist Casting Method; "spinning" the Centrifugal Casting Method; and "pushing" the Pressure Casting Method.

First, it is important to understand the goals of a "good" casting.

1. No casting defects: deformations, inclusions, misfills.
2. Sufficient mechanical strength throughout the casting.
3. The creation of a good surface for the ease of finishing, plating or brazing.
4. No porosity on the inside or outside of the casting.
5. Homogeneous mix of precious metal and alloy.

We also make the assumption that the preparations prior to casting are done with quality casting in mind. Care must be taken with the creation of the original model, the forming of the rubber mold, the wax pattern, the investing process, and the burnout cycle. In addition, the use of clean and appropriate alloy for the parts cast is essential.

"Pouring" or Gravity Casting

This method, employed for thousands of years, makes use of the basic principle of gravity, all objects fall towards the earth. Molten metal is either poured from a ladle or bottom poured from a special crucible with a stopper and a hole. This method makes use of the principle that objects with heavier specific gravity displace materials of lower specific gravity, hence heavier liquid (molten metal) displaces lighter gas.

However, because of the inherent surface tension between the metal and the refractory and the viscosity of the metal, only larger objects can be cast this way, as in industrial settings. Other disadvantages include the need for a large sprue reservoir and the contamination that exposure to oxygen can bring to the cooling metal.

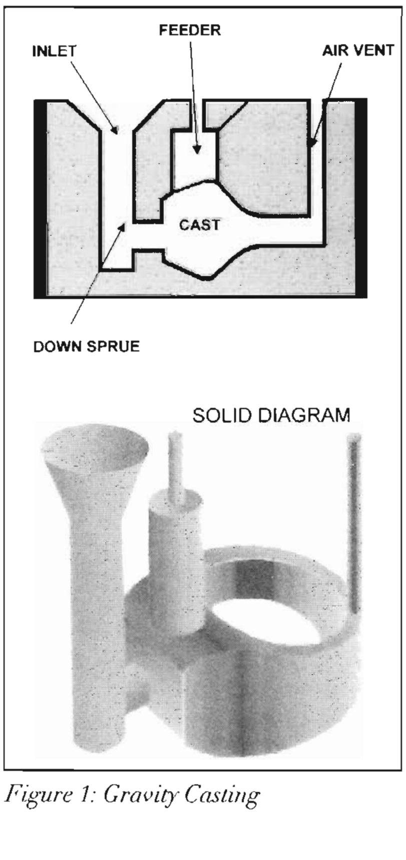

Figure 1: Gravity Casting

"Pulling" or Vacuum Assisted Casting

This method relies on the use of a vacuum pump drawn on the refractory mold while molten metal is poured into it. (*See Figure 2*)

The permeability of the mold allows the creation of a negative pressure in the refractory. The maximum pressure - 1 bar (30" of mercury) or -1.02 kg/cm^2 can only be reached at sea level and relies heavily on the ability for the suction to pass through the micro grains of the refractory material. Gypsum based refractories are suitable for this method, and in fact the casting of gold and silver are done successfully this way. The main advantage to the vacuum method is the removal of back pressure pockets of gas formations by the vacuum.

However, for the casting of platinum we are required to use phosphoric acid bonded refractories because of their ability to withstand greater temperatures than gypsum bonded products and for the strength of the refractory mold they provide. These investments are very poor at allowing a vacuum to be drawn through them and therefore impractical for use in the casting of platinum. Also, a large "feeder head" or button is required to preserve metal temperature and therefore extra metal is being wasted as it is also with centrifugal and gravity methods.

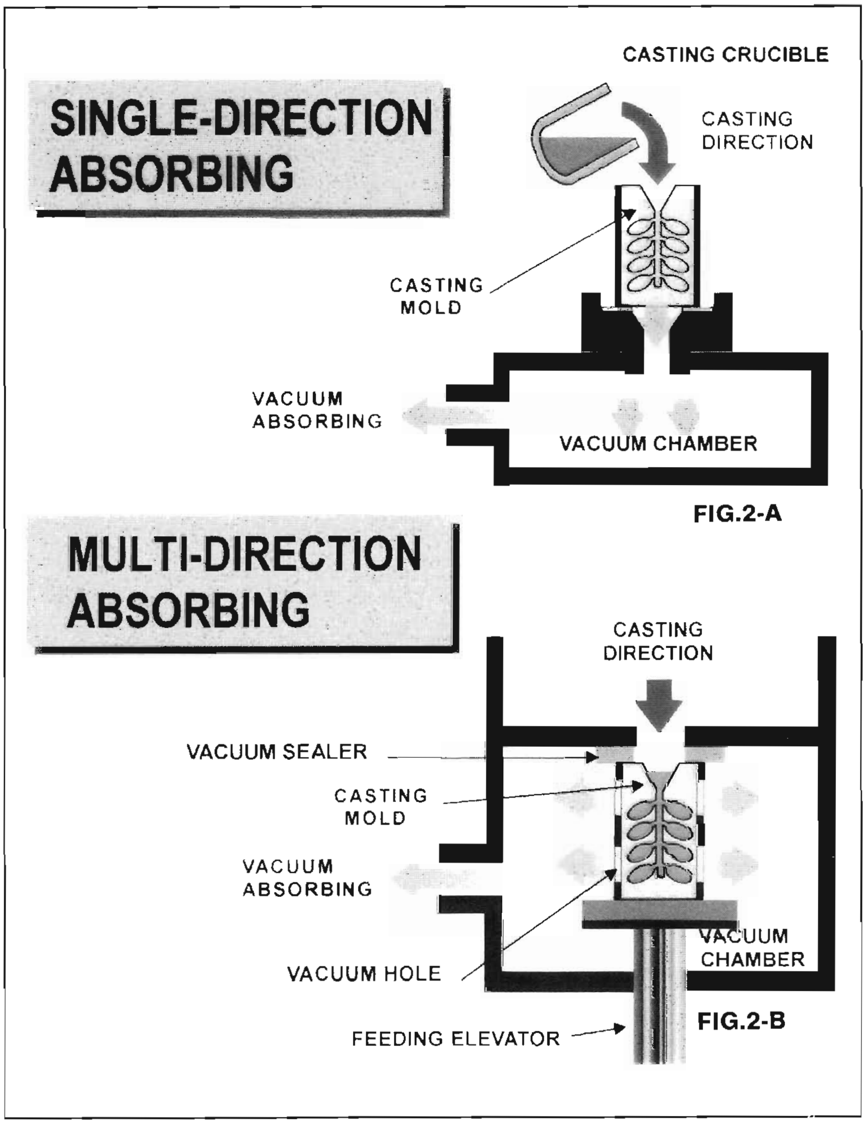

Figure 2: Vacuum-Absorbing Casting

"Spinning" or Centrifugal Casting

Centrifugal casting uses the action of spinning to generate a force for the molten mass of metal entering the refractory mold. This formula applies:

Centrifugal force (mass of metal) x (radius of rotation) x (rpm^2)
There are three methods of using centrifugal force: horizontal rotation, vertical rotation, and slanted rotation, each with its own characteristics. *(See Figure 3)*

Increasing the radius increases the centrifugal force, however space becomes a consideration. To compensate for limits of radius, rotation speed is increased. Spring rotation or motor methods can be used. With spring action, the initial force is sufficient to move the metal into the mold, but without sustained force, inefficiencies occur. In motor driven methods, often the motor does not give sufficient initial boost to cause a proper flow of the metal. Of the motor methods, a transmission using a clutch allows for the motor to increase to proper speed before rotation occurs.[1] However, as speed increases, so do casting deficiencies. These include metal spillage upon entering the refractory, the addition of investment particles in the casted metals brought in by the metal moving into the mold, and most detrimentally, the intense effect of the turbulence of the metal flow and the concomitant gas formations. The various gas formations, having no where else to go, are then forced back into the solidifying metal.

Studies show that this creation of gas formations in centrifugal casting methods may be the most serious detriment to this kind of casting.[2] Minimizing metal thrust to decrease gas formations causes miss fills and no compromise to the centrifugal speed can eliminate this problem.

An additional problem is caused by the various specific gravity and varying solidification rates of the mixed alloys used in casting. The centrifugal force varies according to the specific gravity, the heavier component of the alloy going in the direction of the higher centrifugal force, while the lighter staying in the center. This causes inconsistencies in the homogeneous mix of precious metal and alloy. This becomes a larger concern with alloys of greater differentiation in specific gravity.

Also the inherent flow characteristic of the metal into the refractory mold causes additional agita-

tion to the metal, The dominant force is the linear movement of the metal towards the outside of its spinning radius. In addition, you have the inertia force which moves the metal away from the rotation direction, as well as the gravity force moving the metal downwards. These forces can be contradictory to the passage the metal is required to take to fill the various components. Further turbulence and gas formations are resultant.
A side issue involves the crucible shapes used in centrifugal casting *(See Figure4)*

Typically an upright or vertical crucible style is used with an induction coil of the high frequency type casting machine, while a horizontal crucible style is more typically used with a manually melting machine (spring type).

The disadvantage to the vertical crucible is that the centrifugal force causes the metal to spiral up the inner walls of the crucible, impacting the roof of the spout it is meant to pass through and therefore cooling occurs. To compensate for the cooling of the metal, a larger sprue volume is typically used, thereby wasting additional metal. Additional problems such as metal spillage and crucible impingement have been mentioned earlier.

"Pushing" or Pressure Casting

The methods of pressure casting are the least known of the various methods of LWC. In the dental trade, in particular, compression caps have been used fitted over the "ring" or mold flask. *(See Figure 5)*

Steam pressure is used inside this closed system to cast small quantities of metal.[3] Pressure techniques are also used in the casting of steel, aluminum, and ceramics.[4]

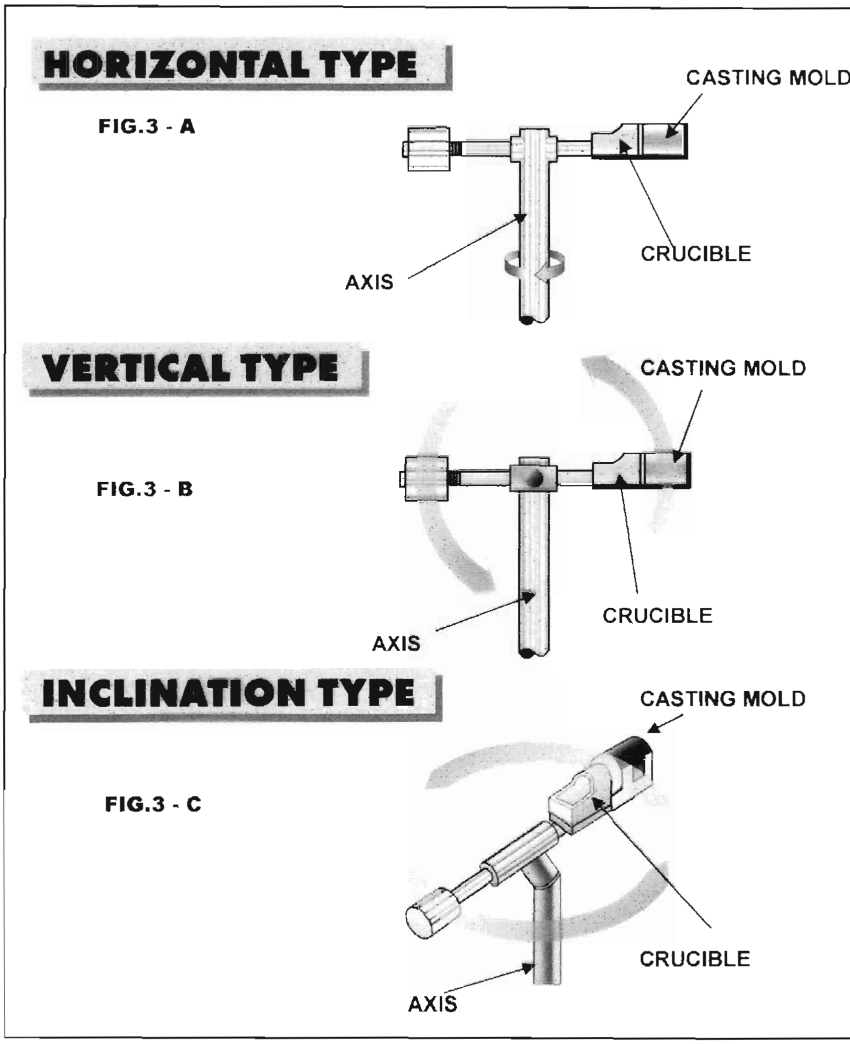

Figure 3: Centrifugal Casting

Simply put, in pressure casting a pressurized force (be it steam, compressed air or inert gas) pushes against the molten metal in order to fill the mold refractory. In some ways it can be argued that centrifugal force is in fact a pressure system in these terms. But I have placed centrifugal action into its own category as the pressure is created through centrifugal force only and not by an external source. This is precisely why centrifugal force is so difficult to control and thereby to minimize the deleterious effects. For the same matter, in fact, vacuum is technically a pressure system, but is, in particular, a negative pressure and therefore belongs in its own category.

Pressure is applied to the sprue reservoir and continues as the metal is cooling and hardening. Even with the surface apparently hardened, the inner mass of the metal is still molten. As the metal solidifies it is contracting and therefore with pressure continuously applied the density of the hardening metal increases. As the metal is solidifying at different rates, according to the mass of the design and its internal alloy components, the pressure applied to the metal organizes the solidification process and insures an even crystalline pattern.[5]

It is critical at this point to review the nature of pure platinum and platinum alloys as metal for casting.

A. The melting point is very high compared to gold and silver(1700°C or higher).
B. There is a large temperature differential between the molten metal and mold refractory. (1000-1200°C)
C. Surface tension on the molten metal is significant.
D. The addition of impurities, particularly carbon, are easily absorbed into the metal and cause deformations.

It has been largely accepted in the western hemisphere that centrifugal force is the only way to successfully deal with the difficult nature of platinum as a casting metal.[6] A variety of solutions have been taken to ameliorate the problems of casting centrifugal. The addition of vacuum into the centrifugal method has been considered advantageous for the ridding of back pocket air pressure but appears only to accomplish the protection of the metal from oxide formations during its melt. Various configurations have been used to maximize the initial thrust of the centrifugal force including redesigning the traditional swing arm with one or even two breaks in the arm. These solutions appear to minimize the problems of metal

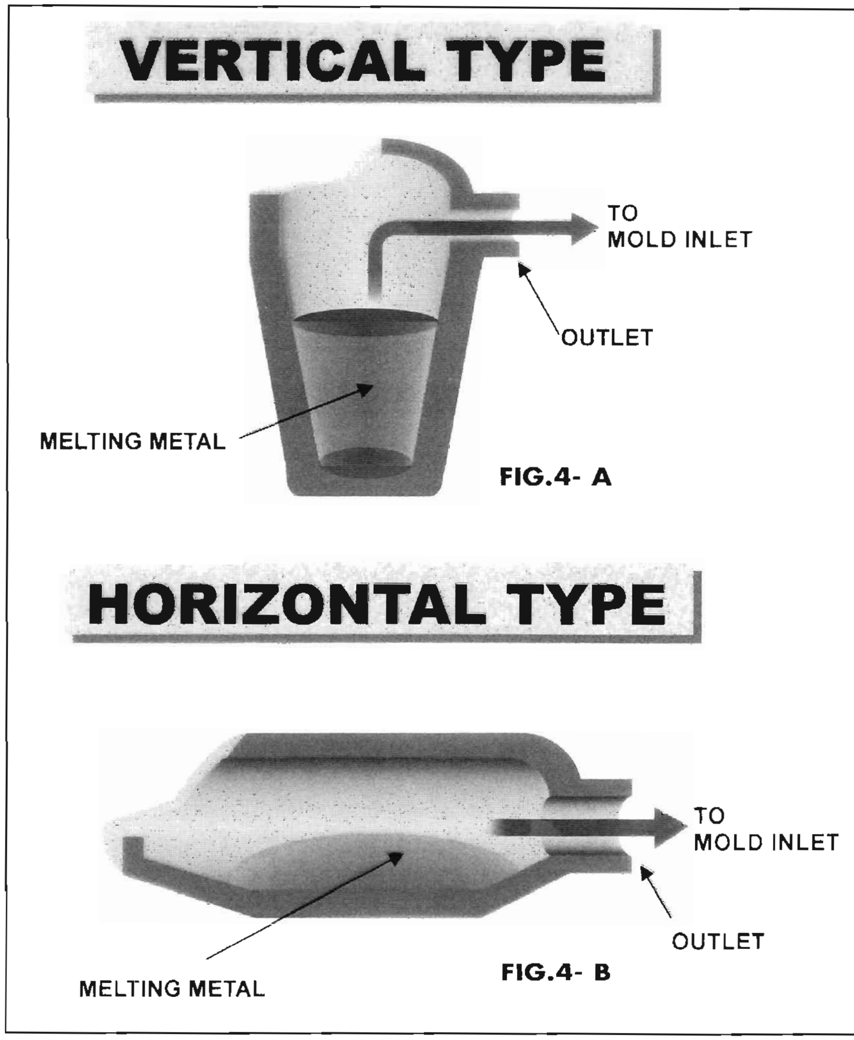

Figure 4: Types Of Casting Crucibles in Centrifugal Casting

spillage and crucible particle embedding.

The drawbacks of the centrifugal method, however, specifically, the gas formations caused by the excessive turbulence in the filling of the mold, as well as alloy separation giving rise to the mixing of gas and metal have been well known in the casting of gold and silver.[7] In fact the centrifugal casting of gold and silver is done less and less.[8]
The use of vacuum casting, while proving successful in the casting of gold and silver, is impractical for casting of platinum because of the density of the refractory used, and additionally, it would appear that the force of the vacuum is too limited for the characteristics of platinum.

Given the difficulties in casting platinum centrifugal or with vacuum, it is no wonder that the impression has been created (we are speaking of the western jewelry manufacturing market) that working with platinum is so difficult and that the accepting of high

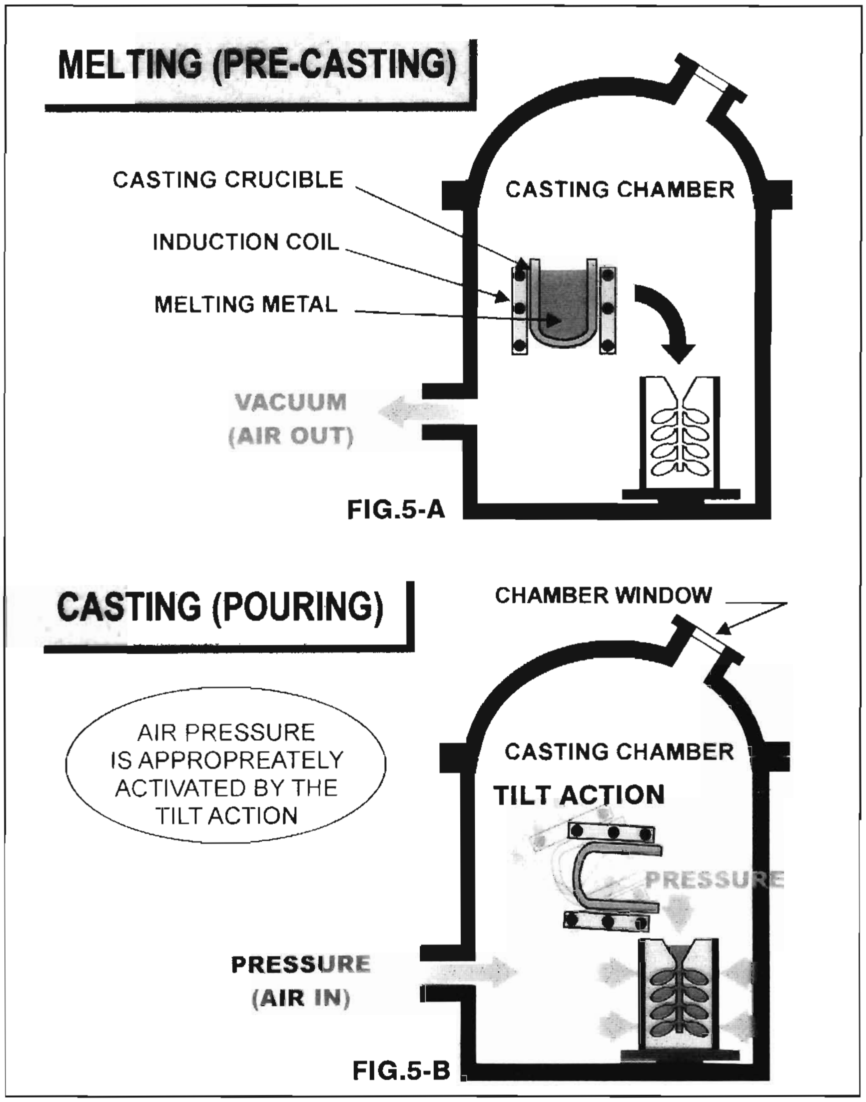

Figure 5: Pressure Casting by Tilt-pouring

failure rates is unavoidable. However, if we consider the advantages of working with a pressure system for the casting of platinum, the problems inherent in centrifugal and vacuum methods can be avoided.

The introduction of pressure in the casting of platinum began in Japan in 1966. Its integration with more modern methods of induction melting began in 1985. This process was introduced in North America at the MJSA Expo NY in 1998.

The means by which the metal enters the mold refractory during the pressure casting process is smoother than with centrifugal. First, the metal enters the refractory mold by the force of gravity, and then pressure is applied to the solidifying sprue as well as throughout the mold chamber. The metal is pushed into the various intricacies of the mold while pressure is maintained. The force is adequate to accomplish the filling of the mold without the excessive conflict caused by centrifugal filling.

Additionally, the various factors in terms of delivery of the force for filling the mold is much more easily controlled in pressure casting. Variations on the amount of force, when the force is applied in relationship to the timing of the metal cooling, and the duration of the force are all much more controllable with the method of pressure.

One difficulty that still needs to be addressed is the problem of gas formations and back pressure pockets inside the refractory mold. As mentioned before, the application of a vacuum on the mold would be ideal, but because of the nature of the refractory used in platinum casting and the difficulty of balancing the forces of positive and negative pressure in this very brief act of casting, other methods must be pursued. The use of mold rotation on its own axis (the centrifugal force mentioned earlier) is an interesting addition to the casting cycle. The refractory mold spins at a low rpm (75-100 rpm) while the molten metal is poured into a funnel shaped opening (a different method of sprueing is required). A vortex of negative pressure is created forming a center column that may be used for the exiting of remaining air and gases within the mold that would normally embed into the metal.

This principle can be seen with the use of a bottle of liquid which has a narrow opening. In turning upside down the bottle, the exiting of the liquid is slow because of the narrow opening When the

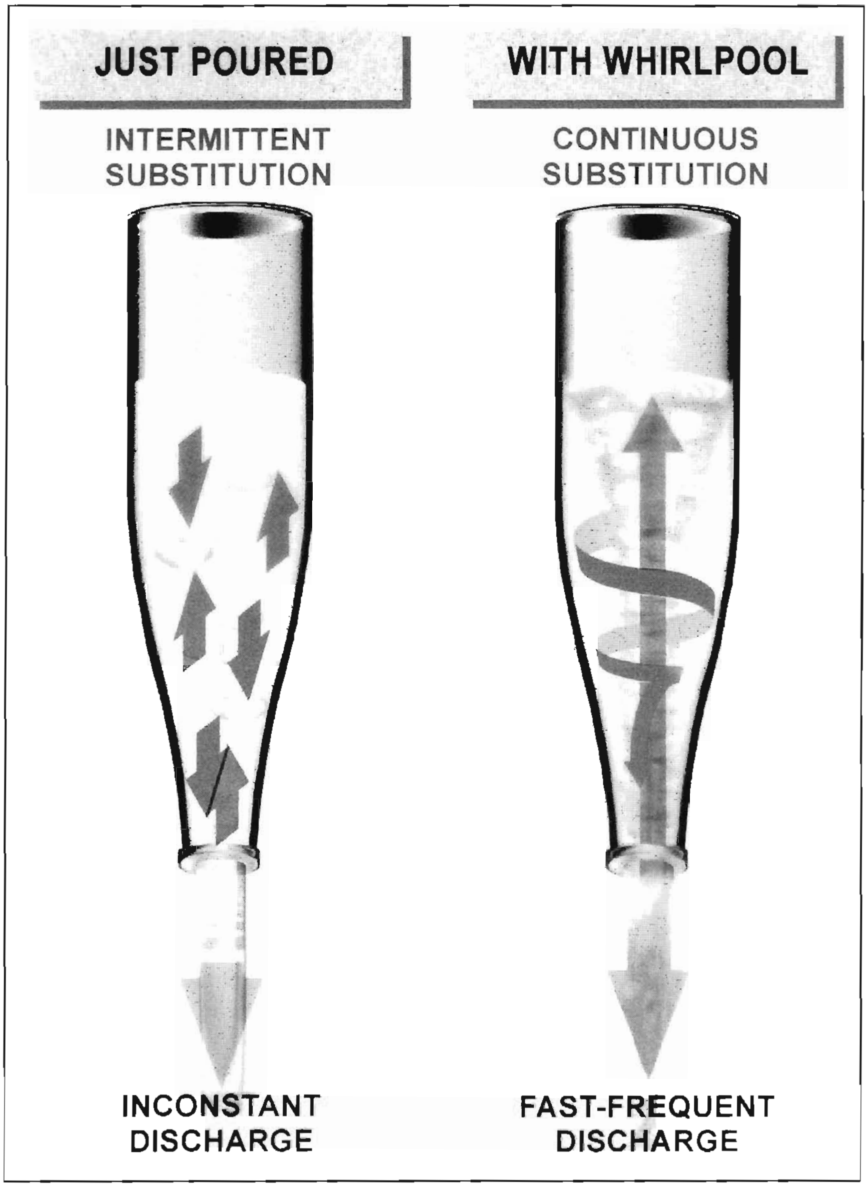

Figure 6: Efficient substitution by fluid whirlpool

bottle is rotated, a negative pressure is created by the centrifugal force sending the liquid to the sides of the bottle. This creates a center air column allowing easier access of air into the bottle and thereby creating a better flow for the liquid. *(See Figure 6)*

This sprueing method is unique in that the metal enters the top of the refractory mold, spiraling down the center funnel, filling a thin donut shape at the bottom and then entering through the sprues to the jewelry forms. There is no need of a heavy sprue reservoir as the pressure force acts directly upon the metal. A minimum amount of metal is wasted and a larger volume of finished forms can be cast by allowing pieces to be setup both above and below the donut reservoir. *(See Figure 9)* This combination of a more gentle entrance of the molten metal into the refractory, while at the same time creating a means for entrapped gasses to escape, is a successful formula for the casting of platinum. Cross sections of pressure cast platinum forms show remarkably dense formations without the porous problems typically associated with other means of casting platinum *(See Figure 10)*. While the use of pressure in the casting of platinum is relatively recent, at least in this country, the potential for success with this method is much greater than with the other methods we have discussed.

This paper: "Pouring, Pulling, Spinning, and Pushing: Various Methods of the Lost Wax Casting of Platinum Both Old and New" was presented by Roger Greene during Platinum Day IV, sponsored by the Platinum Guild International on March 27, 1999 with the direct collaboration of Minoru Yoshida.

Mr. Roger Greene is the president of Eisinger Enterprises, a jewelry supply company located in Newark, NJ, USA. Eisinger Enterprises has been actively investigating new casting technologies, particularly for platinum.

The Yoshida Cast Industry of Japan has been pioneers in casting by the pressure casting method since early 1966. A pressure casting machine using induction heating was introduced in Japan in 1985. The Yoshida company began to export its technology into China, India and Thailand during the early 90s. Pressure casting was introduced to North America in 1998.

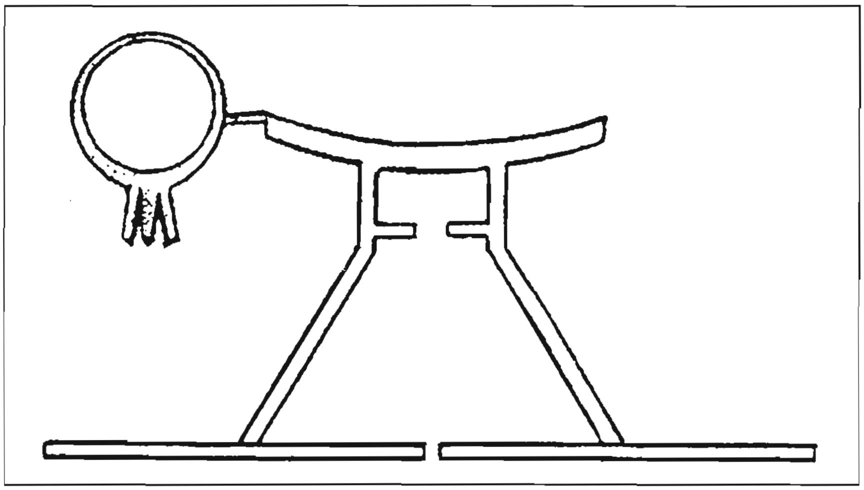

Figure 7: Our unique spruing method makes the best use of your precious metal: less for the button, more pieces sprued per flask. Our funnel feed form creates a whirlpool fill, allowing gases to escape.

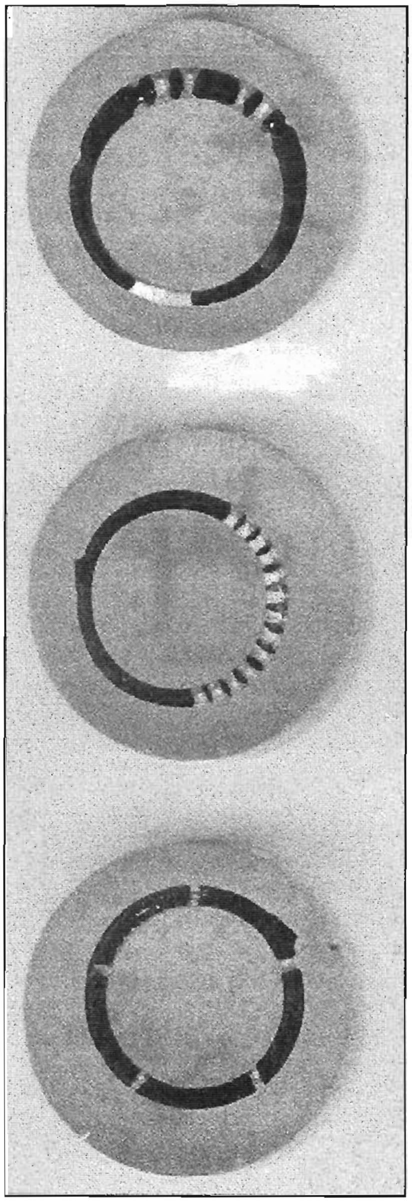

Figure 8: Microphotography of cross-section of pressure-cast platinum. (Photo courtesy of Tiffany & Co.)

Footnotes

1. A newer method of centrifugal rotation exists which uses the spinning of a refractory on its own axis. But this method is employed using the pressure cast method and will be discussed later.

2. "High turbulence increases the probability of gas entrapment and favors the formation of gas porosity." Igor Shersher Platinum Manufacturing Process, Vol. II, PGI.

3. "Another one is a kind of static pressure casting, where the pressure generated by the steam produced by an application of a potato is used to improve mold filling." Dr. Valeno Faccenda, GOLD TECHNOLOGY Issue #23, April 1998, pg. 21

4. There is a great deal of information available on pressure casting of steel, aluminum, and ceramics. For an excellent article on ceramic pressure casting consult: "Ceramic Technology" Chalmers School of Chemical Engineering Dec 23,1998, see http: //www. chalmers. se/ researchprofile/ceramic. Html

5. "The results show that pressure accelerates the solidification process, reassigned to the crystal structure and increases the formation of steel castings under pressure" E.D. Taranov. CASTING PROCESSES No.1 1997, pg. 22-28

6. "A Primer for Platinum Casting" Elaine Corwin, American Jewelry Magazine August 1998 pg. 28-35

7. "Investment casting: Centrifugal or static vacuum assist?" Dr. Valeno Faccenda, GOLD TECHNOLOGY Issue#23, April 1998, pg. 21

8. Although a definitive source for this information could not be documented, I am deducing this based on the diminishing sales of centrifugal equipment over vacuum that we have seen. Also much discussion of this issue can be found on the Internet, particularly at: "orchid~ganoksin. com"

Composition % of Alloying Elements	Pt/PGM Fineness	Melt Range solid	liquid	Hardness Hv	Ductility % elongn	Density g/cm^3	Application Notes	Countries of Main Interest
	999	1773	1773	50	40	21.1	Stamped Pt 1,000	JAP
	990	1773	1773	50	40	21.4	990 Fine CHUK PAK GAM	HK; FU^2
5% Copper	950	1725	1745	120 108(C)	29	20.0	General Purpose, Medium Hard, Can be cast	GER; HK; EUR
5% Cobalt	950	1750	1765	135	20	20.8	Fluid for hard castings	GER; HK; EUR
3% Cobalt/7% Palladium	900	1730	1740	125(C)		20.4	Hard castings	JAP
5% Cobalt/10% Palladium	850	1710	1730	150(C)		19.9	Harder castings	JAP
1 .5% Indium/3% Gallium	950	1550	1650	225	26	19.3	Hard, springy, can be cast	HK; FUR
5% Iridium	950	1780	1790	80	30	21.4	High work-hardenability for	GER, JAP
10% Iridium	900	1780	1800	110	25	21.5	Safety catches, pins	GER, JAP, USA
15% Iridium	850	1800	1820	160	15	21 5	Springs, watch backs	JAP
20% Iridium	800	1815	1830	200	10	21.6	Fine wire work, chain, mesh	GER
5%Palladium	950	1755	1765	60 68(C)	22 22(C)	20.6	Castings, delicate settings	HK; JAP; EUR
10%Palladium	900	1740	1755	80 72(C)	22 22(C)	19.8	General purpose in Japan	HK; JAP
15%Palladium	850	1730	1760	90 64(C)	22 22(C)		Chain making for Japan	HK; JAP
36.5% Pd/5% Copper	585 Pt 950 PGM	1580	1650	160		15.4	Typical 14ct Platinum	USA
5% Ruthenium	950	1780	1795	135	32	20.7	General purpose, good machining properties.	HK; EUR; USA
5% Tungsten	950	1830	1845	135	20	21.3	Hardenable for springiness	EUR; GER

Notes:

1. Hardnesses and Ductilities in table are for the annealed state except those marked (C), which are for as-cast state.
2. Under Countries of Main interest (last column):
   EUR refers to most European countries but Germany (GER) has additional alloy interests.
   EU^2 refers to most European countries who would stamp higher grade alloys as standard 950 Fine.
3. Pt/PGMs fineness are in parts per thousand.