Platinum Fabrication Processes

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Platinum is today enjoying a renaissance in modern jewelry design that began in the early 1990s. Jewelry articles fabricated in the early part of this century invariably had platinum as a component, mostly for gemstone setting. With the advent of nickel-based white gold substitutes and supply restrictions when the catalytic properties of platinum made it a strategic metal during the 1940s, applications for jewelry in the U.S. diminished. Renewed interest in platinum has created an increased demand for a broad range of feedstocks that facilitate more rapid and economical manufacturing. Primary manufacturing is considered to encompass the processes that provide feedstocks to jewelry design and manufacturing. This would include melting stocks, sheet, strip, wire and seamless tubing. Within this broad scope of products, the processes necessary to shape platinum will be explored, limitations of the metal outlined and areas for further research defined.

A certain number of basic processes are executed to produce any primary platinum product. Table 1 summarizes these processes and provides corresponding products as they evolve along an increasing complex manufacturing path descending down the scale.

Topics such as jewelry assembly through finishing, grinding, polishing, stone setting or soldering and welding are not considered primary processes. Fig. 1 captures the variety of products covered in Table 1. Each of the primary manufacturing processes deserves separate consideration.

Platinum Melting

Platinum feedstock for melting is available primarily as sponge. Besides being the final product of chemical refining, the inherent nobility of platinum and its application as a catalyst dictates that a powder or sponge is the most convenient form for further processing. Melting sponge also avoids the rather difficult procedure of producing shot, commonly employed for lower melting point precious metals such as silver or gold. Bars produced from rolled ingots are also common. Nominal commercial purity is in the range from 99.90% to 99.98% as opposed to the standard 99.99% purity of fine gold. This is a reflection of the difficulty involved in separating the principal impurities, fellow platinum group metal elements—iridium, ruthenium, palladium and rhodium. Their trace presence does not adversely affect properties. Principal alloying elements from the platinum group metals are also available as sponge. Iridium and ruthenium cannot be melted with conventional equipment and have such poor physical properties that their main application as alloying additions is most easily facilitated in sponge form. Base metal alloying additions such as cobalt are usually obtained as electrolytic nodules.

While pure platinum melts at 1773°C, most commercial jewelry alloys melt in the range of 1700°C to 1800°C. This range exceeds the 1400°C to 1500°C commonly employed for iron and steel production. A sufficiently intense

TABLE 1: PRIMARY PLATINUM PRODUCTS AS A FUNCTION OF MANUFACTURING PROCESSES

Manufacturing Process Product	Typical Primary
1. Melting and alloying to shot or ingot	
2. Assaying	Melt feedstocks
3. Cold working by rolling mill or rod mill section reductions	Melt feedstocks
4. Annealing to soften and recrystallize	
5. Drawing, rolling, shaping	Sheet, round wire, square wire, 1/2 round wire, rectangular wire
6. Thin gauge rolling and slitting	Strip
7. Stamping	Findings or ring blank production
8. Welding of strip	
9. Mandrel or plug drawing to diameter with control of wall thickness	Seamless tube

Table 1

heat source for melting cannot be obtained by mixing ambient air with a fuel source or employing common electrical resistance. Oxy-fuel melting, preferably with hydrogen to avoid detrimental reactions with carbon, is required to render platinum molten. Platinum sponge and high velocity torch gasses do not interact well. Electric induction heating is the preferred melting method for any significant amount of platinum. A typical setup is shown in Fig. 2.

Ceramic melting crucibles and implements are required because graphite and silicon carbide react with platinum to cause embrittlement. Primary candidates for melting platinum include magnesium oxide, aluminum oxide, thorium oxide or zirconium oxide crucibles. Zirconium silicate or alumina silica mixtures will not withstand temperatures in excess of 2000°C that could be encountered during melting. Ceramic crucibles are typically backed with rammed ceramic powder plus additional protective sleeve to counteract their inherent tendency towards thermal shock cracking. Such precautions are necessary because high levels of electrical power, induction cooling water and molten metal at 2000°C are a dangerous mixture. Slow preheating and cooling cycles maximize the ceramic life cycle, but impair melting productivity. Thermal shock properties of most ceramics are generally poor. This inherent limitation comes with the high melting point required to withstand molten platinum.

Platinum is very susceptible to contamination when it is molten. Most materials will melt when they come into contact with anything at 2000°C. Platinum is also susceptible to embrittlement by silicon and phosphorous by virtue of reactions that form intermetallics. This behavior is similar to reactions with gold and silver with a notable difference: the temperatures encountered with molten gold and silver alloys are not sufficiently high to promote any reduction of silica or phosphate present in combination with any reducing agent. When melting platinum at 1700°C to 2000°C, if reducing conditions are encountered, silicon dioxide common in virtually all ceramics as a stabilizer or binder, can be reduced to elemental silicon and react with the molten pool. To minimize the chance of these types of reactions, it is important to employ oxidizing conditions when melting platinum. Any iron, silicon or phosphorous present will combine with free oxygen available from the air and form oxides that remain stable to join the flux or slag layer.

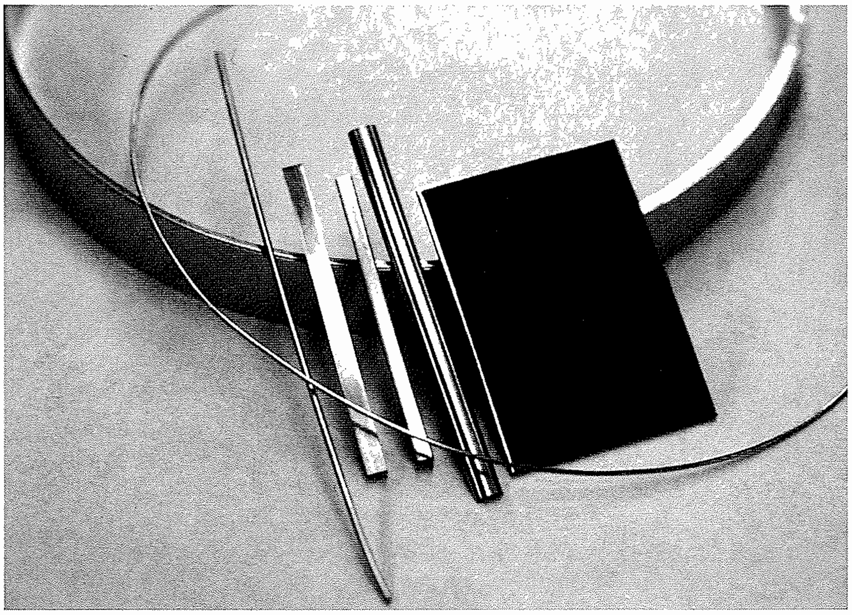
Figure 1: Platinum alloy sizing stock, sheet and wire.

Platinum is also susceptible to the detrimental effects of excessive grain size during ingot pouring procedures. This behavior is a consequence of the high purity levels associated with 90% to 95% platinum and the complete solubility of the binary relationships between it and the most common alloying elements. Temperature control during melting is a significant but difficult task. Common immersion pyrometers with high-temperature, 'S'-type platinum/rhodium thermocouples cannot withstand the conditions encountered with molten platinum. An optical pyrometer is required. Any fuming from deoxidants, surface slag or poor aiming of the sensing aperture will impair temperature measurement accuracy. Fig. 3 captures the radiant energy of molten platinum during a pouring operation.

The extreme conditions of elevated temperature necessary to melt platinum take a toll on mold materials for controlled solidification. A limited number of materials with high conductivity or high melting temperatures are suitable to be used as platinum molds. Most ceramics are poor candidates since they suffer thermal shock cracking. Poor conductivity also lowers solidification rates, promoting the formation of enlarged grains which compromise the physical properties of the ingot. Steel has poor thermal conductivity, raising the risk of local mold melting even with a protective anti-binding ceramic wash. Both graphite and copper provide good shock resistance and heat dissipating conductivity. Graphite is easy to machine to any size, but suffers from erosion and oxidation deterioration. An assortment of graphite molds are shown in Fig. 4.

Chromium copper molds are difficult to build or purchase. A large mass is required to absorb heat and minimize local melting risk. A typical chromium copper round ingot mold capable of holding 3,500g is illustrated in Fig. 5. The casting of thin sections is greatly hindered by the rapid solidification rates inherent to platinum.

A large quantity of molten platinum promotes the solidification of a high-quality ingot. Temperature measurement by optical pyrometer is more accurate with a large volume of metal. With the inherent rapid solidification of platinum, a prolonged pour assists in controlling shrinkage. It is very difficult to control a pouring event that lasts only a few seconds when less than 1,000g of platinum is melted. Even a 5,000g ingot solidifies only a few seconds after completion of pouring. Last-second controlled additions to the molten pool, a technique common at 1000°C with gold or silver alloys to minimize a shrinkage pipe occurrence, are considerably more difficult to accomplish at 2000°C with platinum alloys. While a large thermal mass is an advantage for control of ingot pouring, this same mass also injures mold materials.

Fig 6 depicts a large ingot and the heat transferred to the mold. The quality of all resulting products is very much influenced by the quality of the static cast platinum ingot. Photo 10 shows a 1,200g wire ingot, a small mass, for induction powered melting. A more typical induction melted sheet ingot weighs about 4,500g.

Continuous Casting of Platinum

The application of continuous casting to precious metal production is well known and widely practiced. The solidified quality of a continuously cast billet or rod is essentially metallurgically perfect from the standpoint of homogeneity, surface finish, lack of gas porosity, absence of shrinkage porosity and elimination of non-metallic inclusions. Controlled conditions that present a large excess of gravity-fed molten metal, covered by a protective atmosphere, to a cooling die where strong direction solidification occurs through controlled withdrawal, contribute to produce the high level of quality. Provided correct processing conditions are employed, excessively large cast grain size can be avoided, furnishing material that will withstand percentage reductions in section that approach 90%. Many materials that do not respond well to static casting practice will fabricate easily with the microstructure produced by continuous casting. Continuously cast billet or rod is the starting

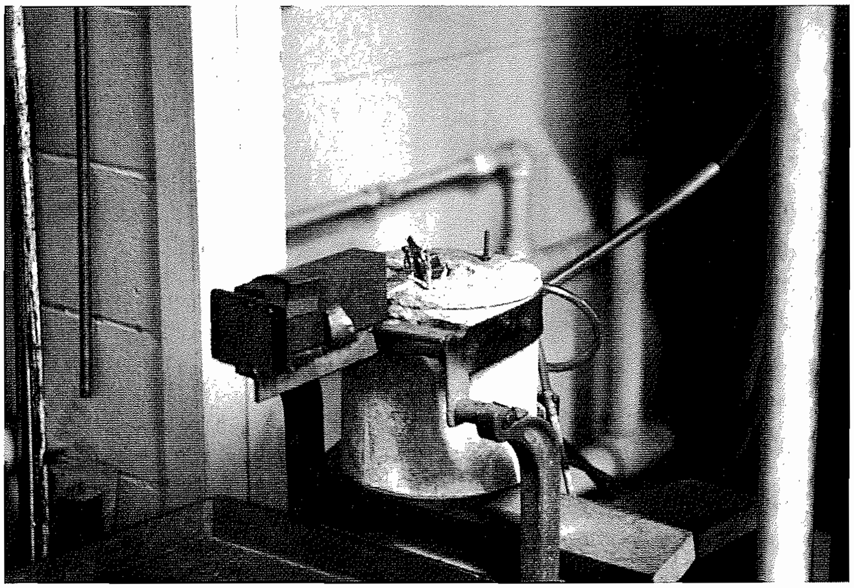

Figure 2: Durville process for melting platinum and pouring into ingot molds. Entire assembly rotates crucible and mold for continuous pour.

stock for high volume production of thin wire and strip that can withstand the rigors of chain making or findings stamping and subsequent mass finishing to the highest standards of quality without fear of scrap generation from internal defects discovered late in the manufacturing process. Incorporating all of these positive features into platinum melting would be highly desirable.

Unfortunately, continuous casting of platinum is not commercially employed to the knowledge of the author for several significant reasons:

- The ceramics required to withstand temperatures in excess of 1800°C for melting platinum are not inductive susceptors. This means that the crucible will not couple with an induction power source to provide heat and maintain a fluctuating volume of feed metal in the molten state.
- Resistance heating to temperatures in excess of 2000°C cannot be done with a conductive refractory such as silicon carbide because of oxidation or decomposition problems.
- The use of high melting temperature metals such as tungsten or molybdenum for resistance heating requires a vacuum chamber to protect the elements from the atmosphere.
- Even if a vertical feed of molten platinum, assisted by gravity, could be maintained to a cooling die, control of solidification would be a daunting task.
- The poor conductivity and thermal shock resistance of ceramics makes them an unlikely candidate for a cooling section, although their non-wetting and lack of reactivity with molten platinum are desirable. Any thermal spray coating of a conductive metal such as copper would have to withstand severe thermal gradients without lifting or spalling.
- Control of heat removal during solidification with conventional water flow would likely require too severe a cooling gradient. Rapid cooling requires rapid withdrawal of the solidifying metal to avoid freezing back into the crucible. Solidification events must be slowed to be controlled.
- Any withdrawal mechanism would need to have a very rapid response and a wide range of speed adjustment to deal with rapidly changing conditions in cooling.
- The time lag between measuring a given temperature and adjusting a withdrawal rate would have to be very small. It is uncertain if feedback to take action and the initiation of an action could be quick enough to avoid platinum's inherent rapid solidification.
- If platinum is solidified, but is still several hundred degrees hot, all downstream handling and withdrawing parts must be designed to avoid reacting with or contaminating the platinum.
- Even if all these uncertainties and inherent restrictions could be overcome, the grain size of the solidified product must be suitable for cold working.

Considerable engineering work would be required to address all of these uncertainties and make a viable process.

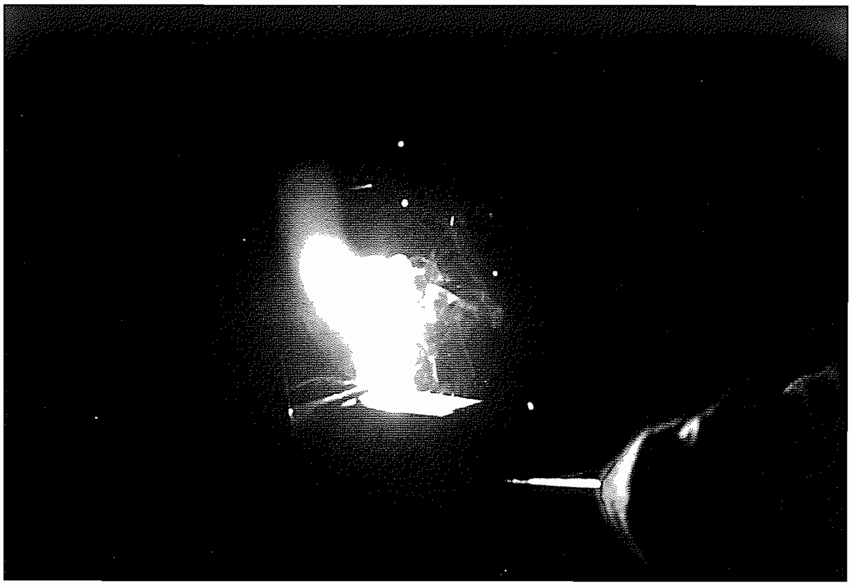

Figure 3: Molten platinum alloys in the Durville process of pouring into ingot mold.

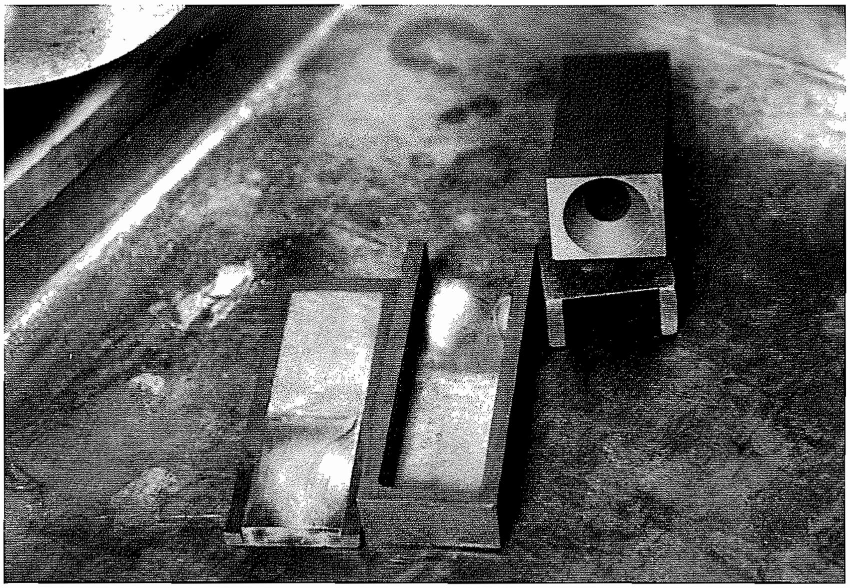

Figure 4: Graphite molds for platinum ingots.

Platinum Assaying

There are subtle yet significant differences in the assaying practice for platinum versus gold. These differences impact on the sampling method, level of accuracy, time for completion of a standard assay and ultimately the service level that can be provided for platinum products. The first problem with platinum involves obtaining a valid sample. Conventional methods such as vacuum tube dip sampling of the molten pool or drilling an ingot encounter some unusual problems. Platinum melting crucibles are usually very narrow in diameter, with small melt weights nested deep down in the base. It is difficult to insert the glass pin sample in the molten pool. Extreme radiant heat can melt the glass tube before the vacuum is broken by the molten pool stopping the required upward draw of molten metal. Additionally, the glass sampling tube can be a source of contamination to the molten platinum.

Drilling the cast ingot to obtain a valid sample introduces the distinct possibility of iron contamination in the chips from a fractured drill edge. Platinum has the unique property of being very tenacious and sticking to any type of tool cutting edge, including very hard carbides, causing high tool wear. Small, broken pieces of drill embedded in the platinum chips will cause erroneously low assay values.

Perhaps the most labor-intensive method of sample preparation, the rolled wrought strip sample, provides a high level of accuracy. With this method, a small piece of the ingot is extracted after initial breakdown procedures, annealed and subsequently rolled down on a mill to a thin foil 0.15mm to 0.006" thick. Additional anneals may be required to ensure the thin foil is provided. Contamination of the sample is still possible from roll oil, any gold and silver on the roll face, or iron picked up on the surface during rolling. The skill and attention to detail required to prepare a strip sample is not usually found in the routine of a mill worker. Assay lab technicians do not normally operate the breakdown mill equipment. Careful training is required to provide quality samples on a regular basis.

Procedures after obtaining a valid sample are far from routine. The standard five to six hour long fire assay technique employed for gold does not apply to platinum. Either the gravimetric method or instrumentation methods such as Atomic Absorption (A.A.) or Inductively Coupled Plasma (I.C.P.) rely on dissolving the weighed platinum sample in strong acids. Depending on the weight and thickness of the sample, it may take a whole day to dissolve and boil off the excess acid. The solution is usually filtered to remove any undissolved platinum group metal elements such as iridium or ruthenium. When the sample is finally diluted and presented to the instrumentation, the issue of interferences between platinum group metals arises. In the hands of a skilled lab, with knowledge of the sample makeup and a good set of standards, either A.A. or I.C.P. can deal with the very similar assay response of iridium and platinum. A blind sample submitted to an inexperienced lab may return results 2% to 3% from the expected values, even with the most modern instrumentation. Accuracy levels approach +/- 0.10%, about 5 times less accurate than the +/- 0.02% commonly quoted for fire assay. The reduced level of accuracy caused by the interferences between the plat-

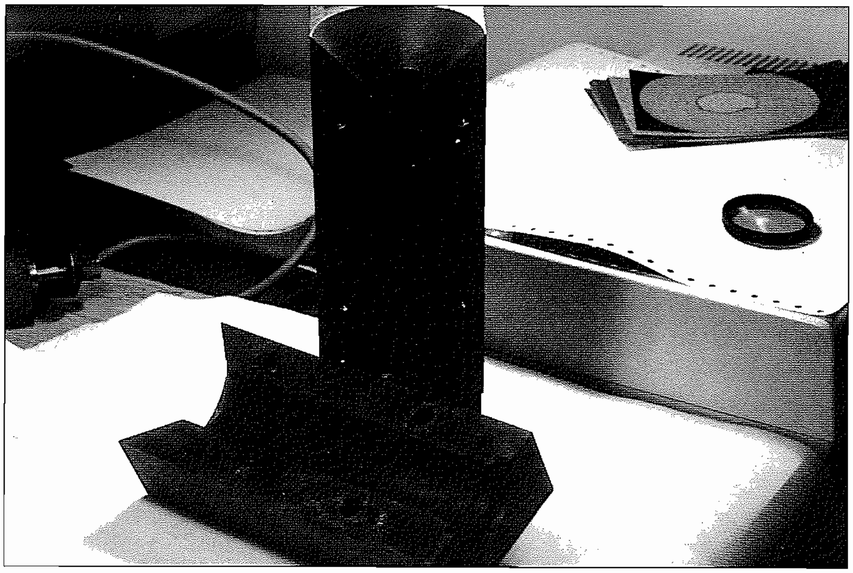

Figure 5: Copper billet mold for platinum alloys.

inum group metals necessitates alloying to 0.20% over the minimum platinum percentage required.

Cold Working Platinum

After preparation of an ingot and submission of a valid sample for confirmation of platinum content, shaping procedures can begin. Platinum responds well to cold work provided the cast ingot grain size is not excessive. Hot working procedures require much more exotic equipment, from pre-heat furnaces to special rolls to unique handling devices with the increased chance of contamination. All this additional effort is hard to justify for a material that can withstand 70% to 90% reductions in thickness from a rod or rolling mill prior to annealing. Common alloys of platinum with 5% ruthenium, 5% cobalt, 10% iridium or 10% palladium are all ductile, solid solutions. No age hardening or phase separations occur. Typical of most metals with a face-centered cubic structure, platinum is very ductile. Alloying additions to harden the material do not greatly impair formability. All of the platinum alloys commonly employed for jewelry fabrication can withstand large reductions in thickness prior to the requirement for annealing. All of the common mill product five alloys can easily withstand an 80% reduction in thickness with hardness increasing to only about 200Hv. This type of ductility and rate of hardening is typical of an 18-karat yellow gold. Because platinum has very high stiffness, routine work hardening during rolling that makes the material appear excessively hard compared to the same amount of deformation applied to material such as sterling silver, which has a much lower stiffness. This behavior, inherent to platinum, should not be mistaken for a lack of ductility.

Excessive grain size resulting in edge tearing or intergranular delamination can easily be mistaken for lack of ductility or embrittlement from a trace impurity. Careful remelting will usually salvage the material. If intergranular separation occurs early in the cold rolling cycle, reducing the percentage reductions with more frequent annealing may actually make the problem worse.

The greatest risk to platinum during cold working comes from pickup of gold, silver or iron from the roll surface. Attention to mill cleanliness prior to rolling is important. The ingot should also be carefully inspected for any ceramic or deoxidant entrapped in the surface. Such inclusions will ruin roll surfaces very quickly. Ingots will normally accept as large a per pass reduction as the particular mill is able to impart. A thin film of clean rolling oil will minimize the pickup of iron from the roll surface.

After completion of initial rolling procedures, the primary shrinkage pipe should be cropped off for recycling. This normally amounts to about 25% of the initial cast weight when a width-to-thickness ratio of less than 3:1 is employed. Careful inspection is required to detect secondary voids in the midsection of the rolled billet.

Platinum is very responsive to shaping operations. It can be formed into bezel tape wire, foil, fully-round wire, half round, square or rectangular. In all cases the amount of definition that can be accomplished through rolling under compression loads should be maximized. Under these conditions the abrasive or reactive bonding tendencies of platinum are not a factor.

When cutting, drawing or shearing under tension are performed on platinum, tool wear can become an issue. Drawing or final shaping operations performed under tension should employ clean, polished tools, preferably of diamond. Tungsten carbide tools will wear more quickly when used with platinum than with other materials. The use of steel draw plates for final shaping under tension is not recommended. A copper layer bonded or electroplated onto the platinum surface will minimize tool wear. This layer can be stripped after the completion of manufacturing with a nitric acid dip. Quality lubricants should also be employed to minimize tool wear and chatter that lower the quality of a finished product's surface. High pressure and high temperatures occur at the interface between the platinum and the tool from the inherent properties of low thermal diffusivity and a high elastic modulus. Molybdenum disulphide is a messy but effective lubricant.

Cutting or Shearing Platinum

During operations that shear metal, such as diamond facetting, drilling, filing, lathe turning, punching or sawing, the troublesome tendency of platinum to bond or cold weld to tooling becomes a significant issue. This attribute is unique among precious metals subjected to machining operations. To the uninitiated, it seems improbable that an extremely hard tungsten carbide tool, capable of machining heat treated steel or thousands of gold bands, will be completely destroyed by only three or four platinum machining operations. Visually, the spectacle appears to be caused by platinum that is too soft. It does not shear cleanly, but tends to be gummy or sticky at the tool face. On a microscopic scale the platinum is actually bonded to the tool face in minute particles. Heat and pressure buildup locally at the machined surface is promoted by the low thermal diffusivity of platinum. Additionally, platinum experiences severe local hardening on the surface from high strain rates during machining. Small particles of platinum stick to the tool surface and begin to bond to the shearing metal swarf, tearing away tiny pieces of the actual cutting edge. This phenomenon is self promoting as the damaged tool edge cuts less efficiently, increasing friction heat and the tendency to cold weld. The onset of tool wear can be delayed by maintaining clean, sharp tools while employing liberal lubrication to all operations involving cutting.

With bench operations such as drilling, filing and sawing manipulation of the tool angle is difficult. Good housekeeping practices, including designating tools domesticated for platinum work only, will minimize contamination with gold or silver and can promote tool wear. Operations can be assisted by frequent removal of accumulated platinum on the tool surface, low cutting rates and the use of a lubricant such as oil of wintergreen.

Low-speed stamping and drawing operations can be performed with relative ease provided tooling is polished clean and proper lubrication employed. Figure 7 shows stamped platinum cobalt slugs. High-speed operations can suffer from a buildup of platinum on the cutting surfaces that quickly impairs shearing efficiency. If material is deposited on both the punch and die surface, they may begin to stick or bond to each other, greatly increasing

Figure 6: A hot solidified platinum alloy ingot.

friction and heat during stamping. Cooling sprays of alcohol will reduce the heating effect. Frequent cleaning of tool cutting surfaces to remove platinum buildup is important. The myriad of special thermally sprayed surface coatings available may have application to high speed stamping of platinum. They may reduce pickup on the cutting edge by being non-reactive with platinum. Maintenance of close punch and die tolerance necessary to shear thin strip may be difficult. Zirconium oxide and titanium nitride come to mind as potential candidates. This is an area that warrants further study.

Annealing Platinum

During cold rolling a gradual increase in the dislocation density occurs, causing increased hardness and localized loss of ductility. Annealing commonly employs thermal energy to promote recrystallization that greatly reduces dislocation density, imparting renewed softness and ductility for further forming processes. Recrystallization is essential to provide correct orientation of metal grains when additional cold working greatly alters the direction of definition. Any type of cross rolling operation that re-orients the grain direction by 90° prior to further thickness reduction requires intermediate annealing. As with any metal, excessive time or too high a temperature will promote grain growth causing the so-called "orange peel" effect of massive grain dislocation that impairs physical properties and increases the effort required in finishing operations. This effect will also occur if numerous cycles of low-percentage thickness reductions (<30%) are accompanied with excessively repetitious annealing. Platinum requires a higher annealing temperature than is common for gold and silver jewelry alloys. Pure platinum will anneal at 700°C to 800°C (bright-orange). Common jewelry alloys require 1000°C to 1200°C (mid-yellow) to effect fill softening. This applies to platinum alloys of 5% cobalt, 5% ruthenium, 10% iridium and 10% palladium.

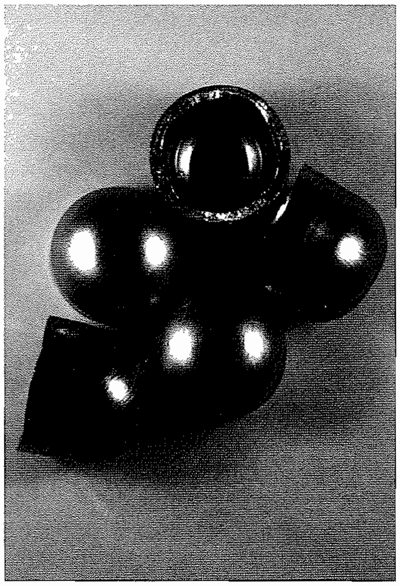

Figure 7: Platinum/ruthenium alloy stamped slugs for the manufacture of seamless wedding bands.

For stamping and drawing operations, temperatures in the range of 1400°C (bright yellow) reduce the "earring" effect. The high stiffness of platinum combined with elongated grains contribute to produce an irregular edge during drawing operations. The elevated annealing range ensures better uniformity in the grain direction to ease stamping operations. Elimination of stamping irregularities should be balanced against the increase in grain size that occurs with the elevated annealing range.

The lower range of temperatures (800°C to 1100°C) can be obtained with a common electrical resistance heated furnace or a natural gas/air torch. The elevated range from 1200°C to 1400°C can be attained with an oxy-hydrogen torch for small items or induction heating for larger billets. A furnace has the advantage of uniform complete heating for larger sections with control of time and temperature. Because of the inherent oxidation resistance of platinum alloys, it is easy to obtain high annealing temperatures rapidly with a hand-held torch. Care must be taken to avoid contamination with lower melting temperature scraps (silver, for instance) in the annealing area. Excessive annealing temperatures can cause contamination of platinum from alumina-silica ceramics that fuse. Use of high temperature zirconium oxide material for contact with the actual metal will minimize the risk of contamination. An annealing table outfitted with a surface of small beads avoids high temperature contamination while minimizing thermal shock cracking typical of many ceramic sheet products. Oxidizing conditions should be utilized to minimize the risk of trace metal contamination. Good housekeeping is important for low-risk annealing.

Stress Relieving Platinum

When the cold work applied to a piece of metal is uniform across the whole surface or circumference, such as wire drawing or sheet rolling, stress relieving is not usually an issue. Material that has been evenly worked can be subjected to rapid and complete annealing to affect full softening. When hand working produces highly localized or irregular cold work patterns, stress relieving the local heavily worked areas prior to fill annealing is a useful technique to minimize distortion. Normally, stress relieving involves the slow application of mild heating. Platinum has much lower thermal conductivity than gold or silver alloys. This property raises the risk of local overheating during the procedure. A soft flame played slowly over the areas that have received the most cold work first should reduce the chance of warpage (Fig. 8). Raising the temperature of the piece to dull red (650°C) is normally sufficient. When assembly techniques involve the soldering of a cold worked piece to a cast piece, it is important to stress relieve the wrought item to minimize warpage or movement prior to welding or brazing operations. This will reduce the possibility of hot tearing the joint from movement during bonding.

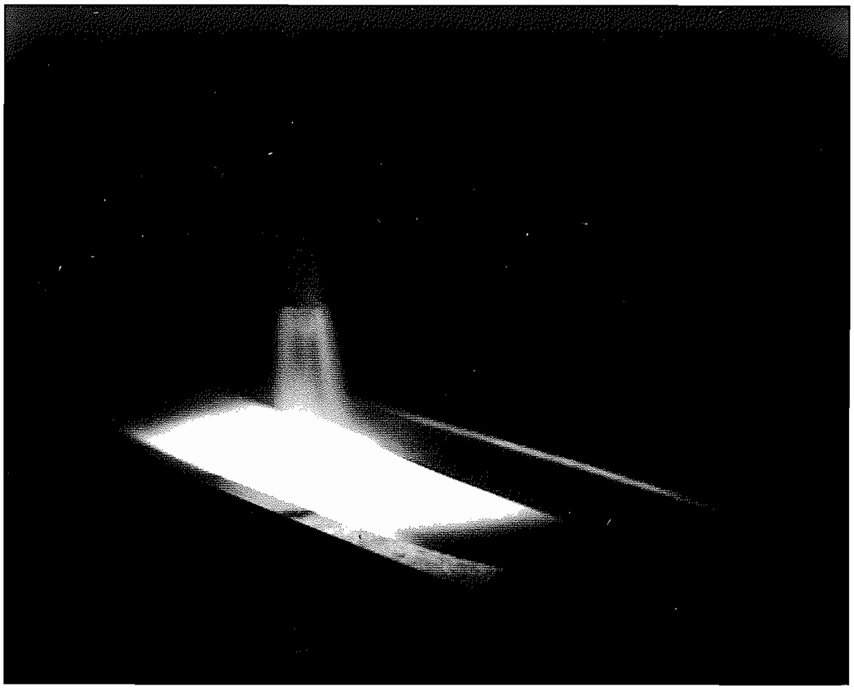

Figure 8: Stress relieving platinum alloy plate.

Seamless Tube Manufacturing

After completion of breakdown rolling, annealing, precision rolling and slitting, platinum strip is ready for processing into seamless tube. A round shape must be formed for presentation to a welding device. This is normally accomplished in a tube welding machine that continuously feeds the formed strip to a Tungsten Inert Gas (T.I.G.) welder. The tendency of platinum to bond to steel guides can be controlled by having all shaping carried out by rolling devices.

Small lengths can be shaped from strip in a die and hand-welded with an oxy-hydrogen torch and the corresponding platinum alloy filler wire. The low thermal conductivity of platinum assists welding procedures by lowering the amperage or amount of heat required to accomplish local fusion. Welded tube must be thoroughly cold worked to destroy the weld microstructure and restore uniformity to the sidewall thickness. This can be accomplished with the use of floating plugs, copper or steel mandrels to maintain the inside diameter, with carbide dies holding the outside diameter. Normally, two cold work sessions imparting a 30% reduction of cross section in a single pass followed by annealing at 1000°C to 1200°C will eliminate the weld microstructure. Because of elevated annealing temperatures, the platinum must be separated from any mandrel material to avoid contamination or possible fusion of the mandrel. Correct lubrication is critical to lower the tendency of platinum to cold weld to steel or carbide tooling. High pressure lithium or molybdenum grease is required. Thin sidewalls and long lengths are difficult to obtain with fixed mandrels because of derailing limitations. More detailed work and research needs to be done in this area as demand for platinum seamless tube grows.

Contamination of Platinum

Platinum can become contaminated from six common sources. Contamination implies an alteration or degradation of desirable properties. It is not limited to material failure or lack of plasticity

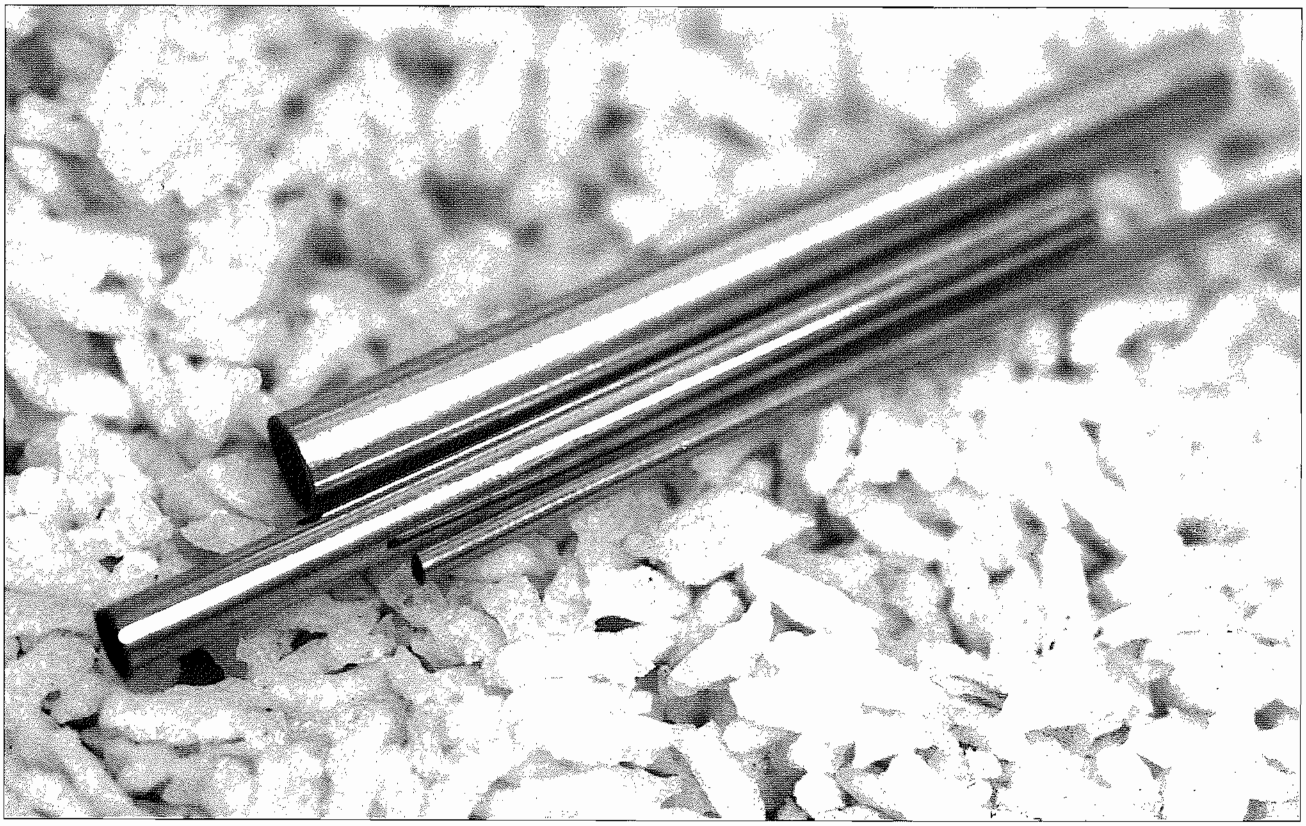

Figure 9: Various diameters of platinum alloy seamless tubes.

exclusively. Each principle contaminant can be discussed separately.

Silicon

Ceramics used for melting crucibles or annealing blocks may contain silicon dioxide as a trace addition or binder. Reducing conditions during melting or annealing may convert the oxide to an element. PtSi or Pt2Si are brittle compounds that may form. These compounds embrittle the grain boundaries, greatly diminishing physical properties.

Phosphorous

Ceramics used for investment casting contain phosphates. Reducing conditions during melting or annealing may convert the PO4 radical to brittle PtP2. Such compounds can accumulate at the grain boundaries severely impairing formability.

Iron

Contaminated annealing work areas, filings, forming roll surfaces, grindings or tooling can contribute iron to platinum. Melting and annealing operations can melt iron into platinum surface. Small quantities do not embrittle. Iron oxidizes during annealing to yield dark surface blotches. Pickling may remove them; otherwise an oxidizing remelt or refining are required. Typical iron content on refined platinum is approximately 50 parts per million (ppm). This can increase to 80ppm during a single normal rolling and handling. Material subject to multiple recycling operations can accumulate iron up to 200ppm. This level does not cause detrimental effects.

Gold

Shavings or film on roll surfaces, small embedded pieces, or contamination of the annealing area may contribute small quantities of gold. Gold dissolves into platinum when molten during annealing or melting. Gold does not embrittle platinum. Formation of an ordered PtAu3 phase promotes hardening through phase separation. Refined platinum can have from 10ppm to 150ppm of gold. Recycled mill product accumulates gold from 15ppm to 125ppm with recycling. Lathe scraps can accumulate significantly more gold, up to 1000ppm.

Silver

Shavings or film on roll surfaces, small embedded pieces, or contamination of the annealing area may contribute small quantities of silver. It dissolves into platinum when molten during annealing or alloying. Low melting temperature PtAg3 or Pt3Ag phases accumulate at the grain boundaries causing hot shortness during annealing or welding.

Assorted Abrasives

Silicon carbide, aluminum oxide or other abrasives employed during rough dressing or surface sanding of platinum can become embedded in the surface from the application of excessive pressure. Careful re-sanding with clean abrasives and minimal pressure should loosen particles trapped in platinum's surface.

The key to avoiding most of these sources of contamination rests with good housekeeping practices during any high temperature process such as annealing, melting or welding. Oxidizing conditions should always be maintained to capitalize on the inertness of platinum while ensuring potential embrittling elements remain as oxides. Careful cleaning will ensure that potential sources of reducing carbon, such as lubricating oils from forming, do not convert silicon or phosphorous into a form that is harmful to platinum. Periodic cleaning of rolling equipment, including the roll surfaces, will ensure that uptake of gold and silver is minimal. Avoiding excessive pressure or the use of poorly bonded abrasives will minimize embedding of particles in the surface of platinum.

Summary

Platinum processing has numerous inherent differences when compared to conventional gold and silver alloy handling procedures. In general, high temperatures dominate the processing of platinum. Significant points can he separated:

- Melting operations require special crucibles, heat sources, molds and temperature measurement equipment. Contamination risks during melting require special attention. Solidification shrinkage losses from pouring even a large ingot can be significant.
- The process of assay sample preparation requires attention to detail and methods slightly different from conventional gold and silver materials. Determination of platinum is slower than the conventional fire assay, with consideration required of the interference between the platinum group metal elements.
- Cold working of platinum by most rolling and shaping procedures can progress rapidly, taking advantage of the considerable ductility inherent in most commercial alloys. Assuming that the grain size of an ingot is not too large, overall reductions from 70% to 90% of cross section are possible. Wire shaping by drawing tension will produce significant wear to steel tooling. Rolling to shape or utilizing diamond tooling will reduce problems, especially with quality lubricants. Likewise for stamping operations, clean, polished tooling with correct lubrication and frequent sharpening will control excessive wear caused by platinum.
- Annealing operations require attention to cleanliness with different equipment and ceramics required to attain the 1200°C to 1400°C range and prevent contamination.
- Seamless tube (Fig. 9) manufacturing can be difficult when platinum bonds to tooling. Mandrel drawing on steel or copper can minimize some of the problems that quality lubrication cannot. More study is required in this area.
- Contamination of platinum can be avoided with good housekeeping, with special attention to details during high temperature processes such as melting, annealing and welding.

Overall, platinum has properties of color, high density, resistance to corrosion and stiffness that are unique among precious metals. Obstacles encountered in processing platinum can be surmounted with care and attention to detail. Numerous areas of platinum manufacturing require more study to overcome or minimize the inherent properties that conflict with high productivity processing methods. ◆