THE SANTA FE SYMPOSIUM ON JEWELLERY MANUFACTURING TECHNOLOGY

Mark Grimwade

The Fifth Annual Santa Fe Symposium on Jewellery Manufacturing Technology took place at Santa Fe, New Mexico, U.S.A. on 20-23 May 1991. These symposia were conceived and organised by *E. Bell* of Rio Grande Albuquerque Inc. and *D. Schneller* of Vimar Corporation with the objectives of providing high level technical conferences, attended by the world's leading experts on jewellery manufacture, which would blend theory and technical production knowledge, encourage the use of more systematic and scientific approaches, promote research, and to do this in a non-commercial environment. This year's Symposium was no exception to this philosophy.

This review will concentrate on the theoretical and technical papers relating to jewellery manufacture and only a brief summary of the other papers, which are not strictly within the scope of *Gold Bulletin*, will be given at the end. Nevertheless, it should be said that these other presentations made an equally valuable contribution to the success of the Conference.

The first day was mainly devoted to an introduction to the Symposium and an overview of papers presented at previous symposia. Because an appreciation of metallurgy is beneficial to an understanding of

the technical papers presented later, C.W. Kilgore repeated his 1990 presentation on "Introduction to Metallurgy and Alloys". This dealt with atomic and crystal structure, solidification mechanisms, phase diagrams, the alloying behaviour of the binary systems Au-Ag, Au-Cu, Au-Zn, the ternary system Au-Ag-Cu with liquidus maps and colour triangle, grain size and refinement in casting and the causes of some casting defects – a vast area of knowledge to cover in the time allotted.

"Safety Overview – Silica, Cadmium, Cyanide, Ventilation"

D. Schneller

This should be mandatory reading for all who use these materials in jewellery manufacture. The toxicology of cadmium and cyanides was discussed and recommendations made on safety procedures to be adopted in their use. For instance, solutions for "bombing" operations need not exceed 2 oz/gal (13 g/l) of cyanide and this reduces the risk of causing dangerous levels of cyanide in the body. The inhalation of fine silica dust, which can lead to silicosis, is obviously a problem with investment casting. Surprisingly, tests have shown that the most dangerous period in the whole cycle of the process is wet quenching used to break the casting out of the mould. The various techniques of ventilation, types of protective equipment and their evaluation, were described. Because face masks are used widely throughout the industry and are often the sole means of protection, it is worth noting that these may be inadequate unless great care is exercised in their fitting.

often be attributed to the formation of sulphur dioxide SO₂ due to reaction between calcium sulphate CaSO₄ in the gypsum-bonded investment and residual carbon from incomplete burn-out.

A brief review of previous papers on electroplating and polishing was given. In this context it was announced that an *ad hoc* committee has been set up to look at standardization of colour in various cartages of gold alloys and solders.

The remaining three days of the Symposium were devoted to the presentation of papers on a wide range of topics including metallurgical research and principles, manufacturing processes and problems, ergonomics, statistical control and use of computers, waste minimisation, security, management and industrial engineering techniques. It is a deliberate policy of the organizers to provide such a mix and in this reviewer's opinion it is a policy that succeeded admirably in that it brought together many different aspects of jewellery manufacturing technology.

"Overview of Casting Papers from Previous Symposia"

E. Bell & D. Schneller

The speakers highlighted some of the research findings presented at earlier conferences. These include conditioning the wax by raising it to 200 °F (93 °C) prior to lowering to the injection moulding temperature in order to reduce the amount of warpage in the wax pattern, degassing the wax pot to remove trapped air and the use of ultra-violet light sensitive dyes to follow the progress of steam dewaxing and burn-out. Final flask temperatures could be anywhere in the range 800-1300 °F (425-705 °C) and it would appear that this is not critically important for successful casting. What is becoming increasingly apparent is that control of the temperature gradient in the flask from the time when, after burn-out, the furnace temperature is dropped to the final temperature for casting and when it is withdrawn from the furnace, can have a large effect on the control and direction of solidification and on prevention of shrinkage porosity. Gas porosity can

"Comparative Study of Mass Finishing Techniques on Standard Samples of Gold Castings"

Dr. M. Dreher

Dr. Dreher presented a series of results on the finish achieved on a standard cast gold sample as assessed by surface roughness. This was expressed in terms of a centre-line-average measured using a Talysurf stylus machine. He examined cutting, smoothing and polishing processes with different media and different equipment, namely, tumbling barrels, centrifugal barrels and centrifugal disc machines. The effect of varying cutting, smoothing and polishing time was also investigated.

"Effects of Injection Pressure on Different Moulding Compounds"

L. Sanchez

Using a standard wedding band model, the effect of varying wax injection pressure was studied for a standard mould rubber, a pre-lock rubber and a room temperature vulcanising (RTV) compound. All other variables were kept constant. The effect was assessed by measuring wax band width, thickness and wax weight. In general, the width and thickness increased with increasing injection pressure from below to above the initial model dimensions although with the RTV compound the thicknesses were greater than the model thickness even at low injection pressure. Similar increases were observed for wax weight but for most pressures and mold compounds the wax weight was below that calculated from model weight conversion. The possible effect of barrelling on the thickness with increasing pressure was not investigated.

"Bi-Metal Solder Flush Products for High Productivity Manufacturing"

G. Normandeau

Here the distinction was made between solder-filled wire and strip and solder flush strip sweat bonded to a substrate of carat gold. Examples were shown of each type of product, such as the use of solder-filled strip for box chain manufacture and stampings and pressings from sweat bonded solder flush strip to be subsequently soldered onto a base. The main advantages of these products are that a) they avoid the use of solder pastes and hand soldering, b) there is a considerable saving in both weight and cost, c) high production rates can be achieved in conveyor belt furnaces using a forming gas atmosphere (95 % N₂, 5 % H₂) provided surfaces are clean, and d) strip products can be stamped and deep drawn.

"Casting Defects in Jewellery"

D. Ott

Examples of the effect of changing casting variables and the incidence of defects in cast Cu-6%Sn spheres were shown. This alloy has similar casting properties to those of yellow carat golds. Ott stated that gas porosity in carat golds is almost always due to sulphur dioxide from mould reaction as mentioned earlier. Energy dispersive X-ray analysis was used to identify inclusions in castings. Zinc sulphide needle-shaped inclusions have been found arising from the fact that zinc reacts with the investment particularly in alloys containing a high zinc content, e.g. nickel-white golds. For this reason it is better to cast the nickel-white golds in phosphate-bonded investment despite the higher production cost.

Santa Fe Casting Defects Project

At this point it was announced that a project had been undertaken to produce a catalogue of casting defects. The work will be done by D. Ott at the Precious Metals Institute, Schwäbisch-Gmünd, Germany. He needs examples of castings with defects complete with detailed information on how they arose, i.e. alloy composition, casting conditions, etc. Investigation will be by metallography and other analytical techniques and the purpose will be to produce reports and a catalogue showing the classification of defects by typical characteristics, an indication of their origin, the factors that cause them, and methods that can be employed to avoid their occurrence. It was stressed that company anonymity will be preserved.

"Sprueing of Precious Metal Jewellery"

A. Schaler

Although the jewellery industry is in the habit of referring to sprues as the channels through which molten metal flows into the actual casting, the speaker rightly emphasized that these are in fact the gates, i.e.

the gate is attached to the pattern, and the sprue is the hole through which the metal flows to the gates. The principles of gating in terms of dimensions and geometry were discussed using a large number of illustrations. He also discussed the important features of the sprue, e.g. the central column on which the tree has been assembled. It was considered that for carat golds a 1/2" diameter (12.5 mm) sprue is satisfactory as the extra cost of gold used is more than compensated for by savings on a reduced number of rejects. Another intriguing possibility is to use a hollow tube sprue of 1" (25.4 mm) diameter and a wall thickness of 0.080" (2.03 mm).

"Temperature Gradient Casting – A Practical Approach"

L. Diamond

Early experiments showed that it took 11 minutes to register any drop in temperature in the core of a mould after removal from the furnace. The temperature gradient set up between the surface and the core assists in obtaining castings free from shrinkage porosity. By using thermocouples imbedded in the mould, graphs were produced showing the change in core and near-surface temperature with time and hence the change in gradient. An example of a typical gradient is a core temperature at the sprue of 1150 °F (621 °C) and a temperature at the casting cavity, e.g. a ring on a tree, of 873 °F (467 °C). It was found that attaching the wax pattern to the central column at an angle of 10° to the horizontal gives less shrinkage porosity than when using a steeper angle because 10° gives a wider spread in the flask from the centre sprue and therefore a greater temperature gradient.

"Heat Treatment of Precious Metals and their Alloys"

M. Grimwade

The principles of stress-relief and full annealing, precipitation hardening and the disorder-order transfor-

mation were discussed and illustrated with examples from the Ag-Cu, Au-Ti, Au-Cu binary alloy systems and the ternary Au-Ag-Cu system. Attention was drawn to the problem of "fire-cracking" in nickel-white golds where it was recommended that slow heating to 300 °C should be carried out prior to full annealing at 750 °C to relieve the residual stresses responsible for the cracking. Stress relief annealing is recommended also for low carat golds after working and quenching operations to minimise the risk of stress corrosion cracking. The presentation concluded with a review of the thermodynamic principles underlying the use of protective atmospheres for annealing and hard soldering (brazing) operations in jewellery manufacture.

"Plasma Arc Welding"

C. Cart

The principles of direct current plasma arc welding were explained. The arc electrode is negative and the workpiece to be welded positive. The orifice gas is argon at a pressure of 20 psi (1.4 bar) and a flow rate of 0.5 cuft/h (3.75 cm³/s) and it is ionised in the arc to give the plasma. The shielding gas is argon + 5 % hydrogen also at 20 psi and a flow rate of 10 cuft/h (75 cm³/s). The process was illustrated with reference to welding the joints of a category of bracelet known as a "tennis bracelet". There are problems in soldering this type of joint because of the need to restrict the flow of the solder alloy. Plasma arc welding is ideal for hinge applications. Using an operating current of 1.75 A the operator could make 100 welds per 6 minutes on a "tennis bracelet". The technique can be used also when sizing rings.

"Chain Manufacturing Processes and Problems"

Dr. A. Reti

Dr. Reti began with a review of the types of chain and the alloys used to make them. The importance of supplying wire to the chain-making machine having

constant diameter, fully soft and kink-free was emphasized and continuous strand annealing recommended. The most common method of joining links is furnace brazing using either solder powder rubbed into the joint gaps or solder-filled wire. In addition to carat gold wire and chain production, the manufacture of gold filled wire with a solder core was described. This is a base metal wire, e.g. brass, which is coated with a carat gold, usually 10 ct, containing a core of silver-copper solder and it is analogous to rolled gold strip. Sometimes a nickel underlay is incorporated between the base metal and the carat gold coating but this may give a problem with diffusion of nickel through the coating in wire annealing and soldering.

"Stress Corrosion Cracking Failure in Low Carat Products"

G. Normandeau

After a résumé of the theory of stress corrosion cracking and its occurrence in carat gold alloys in terms of susceptible compositions and corrosive media, the speaker presented the results of long-term tests of up to 60 days on 10, 14 and 18 ct yellow, white and red golds.

Two types of potentially corrosive media were used: 1) 5 and 10 % ferric chloride solutions which are known to accelerate the incidence of stress corrosion cracking, and b) an "artificial perspiration" containing 0.75 % NaCl, 0.12 % KCl, 0.27 % Lactic Acid and 0.1 % Urea. The test samples were cups drawn, redrawn and sized to produce rings of different sizes. The "as sized", "annealed" and "annealed and hallmarked" conditions were examined. The results are too numerous to adequately summarise here but all ring sizes in the hard "as sized" condition cracked within 24 h in 10 % FeCl₃ and after longer times in "artificial perspiration". Fully annealed rings did not crack but 10 ct "annealed and hallmarked" samples cracked in both media. Tests on rings stress relieved at a temperature lower than that for full annealing, say 250-300 °C, were not done and it would be of interest to see if stress corrosion cracking can be overcome while

retaining the strength and hardness resulting from drawing and sizing.

"Composition Variation Effect on Grain Refiner Performance in Investment Casting of 14 ct Yellow Gold"

T. Santala

Using a standard investment, burn-out, melting and vacuum assisted casting procedure, T. Santala investigated the effects of iridium, cobalt and indium grain refining additions on the grain size of 14 ct yellow gold alloys. Silicon additions acted as a deoxidiser and were found not to give grain refinement. Grain size was measured by the ASTM method. Initially, the copper, silver and zinc contents were varied. The grain refinement effect of an 0.025 % Ir addition depended on the silver and copper content in the alloy whereas an 0.4 % Co addition gave the same amount of refinement irrespective of copper and silver content. Cobalt was found also to give an increase in hardness. In a later series of experiments, the 14 ct gold composition was kept constant and additions of silicon, cobalt + silicon, iridium + silicon and indium + silicon over a range of additive composition were made. Increasing the silicon content alone gave an increase in grain size. The effect of adding iridium, cobalt or indium in the presence of silicon gave grain refinement although it was observed that the degree of refinement was less at higher silicon levels. In polishing tests on rings it was found that polishing was easier with alloys having a small grain size.

"Waste Misinformation on Optimisation in Jewellery Manufacture"

E. Salomon

The statistics of cadmium, lead and cyanide waste products in the jewellery and electroplating industries were given. The opportunities for a reduction in, or

elimination of, the use of CFCs, SO₂, CO, NO, cyanides and hydrocarbons e.g. solvents, were outlined.

"PC-Based Computer Aided Design and Manufacture"

R. Dufault

The application of CAD/CAM to jewellery manufacture using stereo-lithography, AUTOCAD and CADMAX were described. It was said that a suitable PC-CAD/CAM package would cost about 40,000 dollars.

"Computer Programs for the Jewellery Industry"

A. Menon

Two programs were demonstrated. One was concerned with assay procedures, display of results and comparison with a standard. The other used an artificial intelligence language PROLOG for analysis and classification of casting defects.

"Types and Causes of Corrosion in Steel Finishing Media"

Dr. M. Dreher

Dr. Dreher discussed the incidence of corrosion in the use of steel finishing media and steel containers. As expected, stainless steel media has a better corrosion resistance than hardened steel. Additions of complexing chemicals to the media were recommended in order to inhibit attack by chloride ions.

"Statistical Process Control in the Jewellery Industry"

M. Kaehr

The various statistical methods, a key element in "Total Quality", were described. The need to involve employees in data collection and in tracking performance was highlighted.

"World Class Manufacturing"

Dr. T. Billesbach

This was a survey of Demming/Japanese-Type manufacturing techniques such as "Total Quality", "Just-in-Time", "Total Preventative Maintenance", "Employee Involvement" and "Customer Service".

"Ergonomics in the Jewellery Industry"

Dr. G. Donnelly

and

"Carpal-Tunnel Syndrome"

Dr. T. Hales

These two papers complemented each other for they were concerned with occupational safety and health, injuries that can be incurred by workers arising from repetitive actions, and the need to design the work procedure to suit the worker.

"Industrial Engineering
in the Jewellery Industry"

N. Lamontagne

Work evaluation, work measurement, time estimating, work sampling, performance rating and standard setting procedures, were discussed.

"Think like a Thief
– Security in the Jewellery Industry"

L. Weber

This was a comprehensive survey of the types of theft that can occur in the industry, highlighted by actual cases, and the systems and procedures that can be employed to defend against crimes of this nature.

"Employee Suggestion Programs"

J. Louvière

This presentation amply illustrated the advantages to be gained in paying employees for suggestions that are implemented in production.

In conclusion, the Symposium, with its blend of topics coupled with the opportunity to talk to people from different parts of the industry, was both stimulating and enjoyable. The organizers are to be congratulated on their vision and courage in setting up these Symposia. The proceedings of the Fifth Symposium will be published for

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