QUALITY IN JEWELLERY MANUFACTURE - BEYOND 2000!

Dr Christopher W. Corti
Manager, Technical Information & Development,
World Gold Council, London

ABSTRACT

For some jewellery producers, 'quality' is little more than ensuring the gold content meets minimum legal requirements. For many others, progress has been made with manufacturing and material specifications, and the implementation of quality assurance systems based on ISO 9000 standards so that the product is relatively well-made and defect-free. However, jewellery is still a long way from a high-tech engineered product in quality terms which stems, perhaps, from the craft tradition of the industry where the product is seen essentially as an artistic item.

In this presentation, the concept of quality in jewellery is examined from both manufacturing and consumer viewpoints and the way that these impact on quality assurance systems. Some thoughts on their development beyond the Millennium are explored, with particular emphasis on the trends in consumer and retailer demands and how these will impact on product design and manufacturing. This highlights the need to establish industry 'norms' on material properties and service performance which allow the 'quality' of jewellery to be characterised quantitatively and enable the consumer to differentiate between similar products.

KEYWORDS

Quality, quality assurance, quality control, caratage conformance, colour consistency, service performance, industry standards, performance tests, engineered design, consumer demands, product specifications.

INTRODUCTION

It is a very great honour and privilege to be asked once again to give the Keynote Lecture. Eddie Bell suggested to me that a topic of some interest to the Symposium would centre around 'Quality in gold jewellery'. This is indeed a topic of considerable interest to my organisation, World Gold Council, and much of my activity focuses on assisting the industry worldwide to improve the quality of their jewellery through the better use of technology - to the ultimate benefit of the consumer. Hence I readily accepted the invitation and my lecture today is entitled "Quality in Jewellery Manufacture - Beyond 2000!". This will reflect my personal thinking and not necessarily the views of World Gold Council.

I aim to be a little controversial, to stimulate discussion and to try to initiate a movement here at the Santa Fe Symposium to advance the manufacturing industry's concept of quality in gold jewellery and the implementation of more relevant quality assurance systems that lead to better jewellery products which, in turn, will give consumers more satisfaction. Quality, I believe, should be consumer oriented. At present, I do not believe that it is. What the consumer wants is not necessarily what he or she gets!

THE DEFINITION OF QUALITY

Hold on a minute, I can almost hear some of you say, "What does he mean by better quality?" and " How is quality defined?". The term 'Quality' means different things to different people and I am sure that if I was to ask the members of this audience for their definition of it, we would end up with a plethora of answers, all different from each other, but with some strong threads of commonality.

For many people, Quality means *high quality*, i.e. how well made the jewellery is and how well designed. For the purposes of this presentation, I am not going to discuss quality of design. Good artistic design, vital as it is

to the jewellery business, is a separate issue, although where it does impact on the aspects that I am concerned with, it will be discussed.

To others, the term Quality relates to being made by a high class producer or retailed through a high class retailer - often 'branded' in some way. Cartier and Tiffanys would be examples here in the jewellery field that we would all recognise.

For others, the term Quality means producing or selling jewellery to a consistent, traceable standard where materials, processes and products are defined and attained in practice. This is exemplified by the ISO 9000 standards on Quality Assurance. An important point here is that the jewellery product made under this definition is not necessarily of 'high quality'. As our infamous Mr Gerald Ratner in Britain once observed, with disastrous consequences to his retail jewellery business, "what we sell is crap!" But it is consistent and traceable crap if made under ISO 9000 procedures and so are quality assured products.

If I may return to the first definition of quality, any product that is called high quality - and I am not talking just about jewellery here - has an implication that it is well made and will perform in service better than average in some significant way. It may be purer or smoother, or last longer or wear better, or it goes faster or is safer, etc..... A Mercedes car is perceived to be better engineered than a Ford, for example. This leads me on to two points that we need to consider under a definition of quality:

- 'Fitness for purpose' and...
- Service performance

It is implicit that any product described as high quality is suited for the application for which it is intended - it is 'fit for the purpose for which it is designed and constructed'. This involves design from an engineering standpoint and production integrity. We shall return to this aspect later with regard to jewellery.

On the second point, how does a consumer judge service performance when it comes to jewellery? If he or she is buying a stereo hi-fi system or an automobile, such performance data are often available or easily assessed. But if he or she is buying a gold chain or a bangle, how can he / she differentiate similar products. Will the spring catch function properly or will it bend or fail after a few operations? Will the bangle dent if knocked? Will the polished surface scuff and lose its brilliance quickly? Will the rhodium plating wear off quickly to reveal a not-very-white gold underneath? We will come back to this aspect later, too.

QUALITY IN JEWELLERY - WHAT IS IT?

When you or your spouse (or partner) buy gold jewellery, how do you know what the quality is? Is it what it purports to be? Will it wear well? Will it function properly? Will something fail after a short time? How can you tell whether it is of 'good quality' or 'poor quality'? The price might be a guide as might the reputation of the retailer - but only a guide, I suggest, in most instances.

Caratage: So what do we know for sure about the quality of a piece of jewellery? I can guess that you are assured on only one point - the gold content, or caratage/ fineness, of the item. The jewellery piece will, in most cases, be stamped with the fineness or caratage. But can you believe that it is correct? Of course, we do not mind if it contains more than the stated gold content, but what if it contain less? Is it undercarated? Well, I read in a recent AJM report (1) that a survey carried out here in the USA by the Jewelers Vigilance Committee found 90% of 10 carat gold items that did *not* have a manufacturers mark were undercarated, some as low as 7 ct! On the plus side, those that did have a manufacturers mark all assayed correctly. But how many ordinary members of the public would know to look for a manufacturers mark or would recognise the meaning of the fineness mark? How would they know the country of manufacture, even? Even a piece of jewellery sold in Tiffanys may have been made for them in Italy or Thailand, for example.

It is, of course, natural to be concerned with gold content - or caratage conformance- as it is the gold which is the store of value and what you are supposedly paying for. It is why it is marked. Indeed, this concern for consumer protection in jewellery has a long history. As many of you here will know, in Britain we have a system of compulsory marking of all jewellery over 1 gram in weight known as *Hallmarking.* Every piece of jewellery sold must be assayed by an independent, certified assay office and stamped by them with the Hallmark. This Hallmark consists of 4 marks - the fineness mark, the manufacturer (or 'sponsor') 's mark, the Assay office's mark and a date mark, signifying the year of Hallmarking and thus, by implication, the year of manufacture.

The Assay Office guarantees the Hallmark and, if jewellery is subsequently found to be undercarated, the Assay Office is legally liable. Roy Rushforth of the Birmingham Assay Office will, no doubt, expand on this system in his presentation later this week (2). Thus, in Britain and some other countries around the world, there is a consumer guarantee of fineness of the jewellery purchased. It is interesting to note that Hallmarking originated in Britain over 600 years ago in 1300 and is the oldest piece of consumer protection legislation promulgated. But we can ask if we have made much progress since then.

Here in the USA and in other countries around the world such as Italy, India and Indonesia (to name but 3 at random), there is no such legislative requirement for a compulsory Hallmark made by an independent authorised assay laboratory, although here in the USA manufacturers are required to self-mark their jewellery with a fineness mark and conform to a tight negative tolerance. There are heavy penalties for non-compliance but in other countries, there is a more *laissez faire* attitude and relatively light penalties. With the commercial pressures on manufacturers to maintain competitive prices, it is perhaps not surprising that deliberate undercarating is a real problem in some markets.

I frequently meet people in social gatherings who show me a piece of gold jewellery that they purchased on holiday, for example from a stall on the beach in a resort in Turkey or Thailand. " It was really cheap" they tell me "and it is 14 carat!". "How do you know it is 14 ct ?" I usually ask. " Because the vendor told me it was", they usually reply. But where is the proof, even if it is stamped with a fineness mark?

In many parts of the world, the Middle East and the Far East particularly, gold jewellery is sold by weight, irrespective of the time and effort put into its manufacture, and the price calculated on the basis of the gold price and a small mark up for manufacturing and a small profit, say up to 15 - 20%. If you try to beat down the price by haggling, how is the vendor going to make a sufficient profit unless he undercarats? Of course, improved technology should help to add value, but may be considered too costly.

Colour: Apart from caratage or fineness, what else can you expect to know about the quality of your jewellery? Well, the only other thing you know is the colour which you can see for yourself. It is yellow or pink or white or green shade of yellow. If yellow, the colour will tend to be a richer orange colour if it is high carat than the yellow colour of a lower carat item. But a rich orange colour may just be a reflection that the item has been flashed with a pure gold electroplate. A white gold may look very white, but again, it may have been electroplated with a rhodium coating to improve colour. Thin platings will wear off sooner or later. The point I make here is that colour can be a guide but cannot be guaranteed by appearance alone.

A more important point is **colour consistency**. If you buy a gold chain and pendant, will the colour of the chain match that of the pendant? If, at a later date, you buy the matching ear-rings and brooch, will they also be the same colour? Will all the components on the same piece be identical in colour. Is a solder line visible because it is not the same colour shade as the bulk alloy? As you all know, the human eye is very sensitive to small differences in colour shade. Is the consumer reasonable to expect such colour consistency? As a manufacturer, how consistent is your colour from

batch to batch? Do you check it in a quantifiable way? "Is colour anything to do with product quality anyway?", you may ask. I contend that it is. Colour and colour consistency is a significant aspect of gold jewellery quality.

In support of this assertion, we can find parallels in other decorative consumer products. Take tableware - your best bone china or porcelain dinner service, for example? Each item type in the service is made in discrete, separate batches. If you have ever made your own pottery, you know that colour enamels change colour on firing and the final colour shade depends on firing conditions such as temperature and atmosphere. When you buy it, you expect every plate and bowl and cup and saucer not only to have the identical pattern but that each piece has identical colours. If you break a piece some years later, you expect to buy a replacement that matches the original set - and it does! Likewise, with coloured bathroom suites. I replaced my cracked hand basin several years ago, and expected and found that the colour of the replacement - 'putrid pink', I think it was called - matched the other original pieces of sanitaryware - the toilet, the bath and the shower tray.

Finish and Product Integrity: When you buy a piece of 'quality' jewellery, you also expect it to be properly made - that the components fit together well, are properly soldered, the rough edges are removed. There are no flaws - inclusions, porosity, dents, nicks and cracks, etc - and the complete piece has been finished or polished to a high standard, including the hidden areas not seen when it is worn. On a cheaper, lower quality item, you may expect the finish to be poorer, perhaps the edges not to be so smooth, the diamond cut facets to be not uniform and maybe the gem not to be perfectly set. But how do we assess this quality in meaningful quantitative terms? In engineering, surface finish is certainly quantifiable in terms of average surface roughness. Likewise, soldering is quantified in terms of joint gap, percentage area soldered and smoothness of fillets, etc. I have inspected many a jewellery piece in workshops and factories around the world and seen poorly soldered joints, defective castings, surface porosity, etc. in supposedly finished items.

Coupled with this aspect of quality might be the alloys and solders from which the jewellery is made. For example, are all 14 and 18 carat gold alloys that are a similar yellow or white colour the same in quality terms? We can look at the metallurgical properties from a consumer's perspective as well as the manufacturers. Does a grain-refined alloy yield a better finish or service characteristic such as dent resistance or wear? Is a high zinc-containing alloy worse than a low zinc or zinc-free alloy? How is tarnish and corrosion resistance affected in the lower carat golds? Should the alloy be in a soft or hardened condition?

Well, one aspect that it not obvious to the consumer is the impact of alloying on density. With the density of silver at 10.5 and zinc at 7.14, it is evident that substituting zinc for silver in carat golds reduces alloy density significantly. So what, you may ask. For a jewellery item such as a ring of fixed volume, it means less weight of alloy, i.e. less gold for the same caratage. In the case of white golds, substituting a nickel white for a palladium white (density of nickel is 8.9, that of palladium is 12.02) has a similar effect with the additional saving on palladium cost. But nickel golds are harder and stronger, so wear and scratch resistance should be better, as should dent resistance. The spring properties are superior, too.

As manufacturers, we know that there are optimum alloy compositions and metallurgical conditions for the processes that we use to shape and finish them - stamping, casting, gem setting and chain-making for example. But do we optimise them for service performance - how many manufacturers of red and yellow 14 & 18 ct jewellery bother to age harden the jewellery before sale? Or do a stress relief heat treatment on 8, 9 and 10 ct jewellery to reduce the risk of stress corrosion cracking?

The importance of alloy properties on the service characteristics of jewellery is being increasingly recognised at the high carat gold end of the spectrum. Why else have improved strength micro-alloyed 24 ct golds (of 99.5 and 99.9% fineness) been developed (3-5)? There is concern about the relatively poor hardness and strength of conventional 22 ct golds, too

which is being addressed through R & D projects on alloying improvements. A controlled, fine grain size can be a significant contributor to improving strength through the Hall-Petch relationship in such low alloyed, high carat golds.

Service Performance: This leads us nicely into an aspect of quality that has been much neglected - service performance. Jewellery is sold primarily on its appearance and gold content. How well a piece of jewellery will 'perform' when worn by the consumer is not considered a selling feature as it is not visible. This concept of performance embraces many aspects from how easy it is to put on- does the catch or clasp work smoothly, does it hang or lay flat - to aspects that are time dependent such as wear, scratch resistance, failure of clasp and springs, and aspects that are use dependent such as bending of ear-posts, physical breaking off of part of the piece or loss of gemstones due to poor mounting, chain breaking due to unsoldered links, kinking of herringbone chain, etc. etc.

As Timo Santala reminded us at this Symposium 2 years ago (6), failure in service may be due to inherent design flaws. Lightweight jewellery is perhaps especially prone to poor design. When we talk of design flaws, we are, of course, talking about design from an engineering standpoint, not an artistic one. John Wright (7,8) eloquently took us through the engineering approach to jewellery manufacture last year and this engineering approach is equally applicable to jewellery performance in service, as Timo Santala expertly demonstrated(6).

Failure can equally be due to poor manufacture - production integrity - as we have discussed earlier or to a combination of both factors, design and integrity.

Conclusions: So what is quality as applied to jewellery? As you may have observed, I have concentrated on quality *as the consumer perceives it.* Generally, the consumer is only guaranteed one aspect of quality, namely gold content and, as I have discussed, this is not a cast iron guarantee in many countries without a Hallmarking system. The other aspects of quality

such as colour consistency, engineering design, materials and production integrity and performance in service are generally not considered. The consumer has no effective means of assessing these at the time of purchase, and this is also true in many instances for the retailer. He must rely on the producer to ensure quality.

In some markets, of course, the consumer's expectations in terms of quality are different to those now demanded in the major markets of the West. This is particularly true in the quality of finish and may stem from a different attitude where jewellery is bought primarily as a store of value rather than just for adornment. The pricing approach based on jewellery weight, referred to earlier, is a reflection of this attitude difference.

QUALITY IN MANUFACTURE & QUALITY ASSURANCE SYSTEMS

It is appropriate to turn now to the jewellery producer and look at his concept of quality and how quality is assured. Again, I will look at this aspect in very broad terms. John Wright (9) will discuss Quality Assurance in more depth later this week.

First, let us look at Quality. Be it made in a traditional goldsmith's workshop or a modern factory, the quality of a piece of jewellery is defined in terms of both design from an artistic viewpoint and production integrity - how well made it is. The standard of production integrity achieved is dependent on the manual skills of the goldsmith at one extreme to the understanding and control of the technology used at the other. This latter includes equipment and manufacturing procedures and specifications. As I frequently point out in my discussions with manufacturers around the world, good quality can be achieved with poor equipment, although not always consistently, but use of the best modern equipment does not necessarily guarantee that good quality, defect-free jewellery will result unless the underlying materials and production technology is understood and adequately controlled. Unfortunately, this is not always the case.

The level of quality that a manufacturer sets out to achieve will depend upon the demands of his customer, normally the retailer, and the price he can obtain but may be limited by what he can physically achieve with his production facilities and skills and his cost base. If he can only achieve a low margin without a compensating high volume, then cost considerations will limit the quality, for example the finish. A good polished surface is more costly to achieve than an inferior one.

Quality: Cost implications. Another aspect of quality from a manufacturer's standpoint is the adverse impact that poor quality can have on his costs and business success. Any rejects occurring during manufacture and, particularly, reject jewellery at the point of completion is wasted effort and adds to his costs and lead times. Reject jewellery may require more work to rectify it, with associated additional cost, or it may have to be scrapped and the material recycled. As price is a dominant factor in selling product to a retailer, these extra costs will adversely impact on his margins and, together with extended lead times, on his competitiveness. Even worse is returned defective jewellery from the consumer via the retailer (vendor). This can sour the retailer's confidence in you as a manufacturer with long term consequences in terms of lost business.

Quality: Retailer's demands. There is clearly an economic motive for a manufacturer to produce jewellery with no defects in terms of appearance, if he is to sell his product successfully. But does the average retailer/vendor demand more from him in quality terms? With few exceptions, the answer is no, unfortunately! The order of priority is usually: price, design and lead time with caratage conformance expected. Any standard of production integrity, colour and finish is generally defined subjectively, if at all. Certainly not objectively. At best, product integrity, colour and finish may be defined in very general terms, maybe together with the numbers of rejects considered acceptable in each batch. You will note that service performance of the jewellery does not feature in these demands as it is an aspect that is invisible to the consumer when he/she purchases it and it is not a selling point from the retailer's perspective. But remember that not that many years ago, safety or fuel economy were not major selling features for automobiles. Consumer demands do change!

I mentioned that there were a few exceptions in terms of more rigorous demands from retailers (vendors). It is instructive to examine the quality assurance systems that some leading retailers impose on their suppliers as this points the way to the future for the industry. I have to admit that it was an initial discussion with *the* major departmental store chain in Europe on specifications and quality assurance for their newly launched gold jewellery range that set me off to think more deeply about quality in jewellery and the consumer's perspective and this has led to me being here today to talk about quality. I might add that this particular chain of stores is world renowned as a leader and places great emphasis on product quality. Needless to say, they are very demanding of their suppliers in terms of product specifications and quality assurance as well as price. They were a little surprised at the state of the jewellery industry in this area and are intent on implementing high standards of quality with their suppliers.

However, they are not the first to move in this direction. Today, I am going to discuss, briefly, the quality assurance programmes of a major US store, J.C.Penney. Their quality programmes are geared to ensuring their suppliers produce jewellery product which meet three criteria:

- Legal requirements
- Product specification requirements
- Customer expectations for performance and longevity

This is achieved by means of three related programmmes of:

- Testing of product
- Field inspection and auditing
- Factory evaluation

The basis for these are the product specifications agreed with the supplier. These cover the legal requirements on fineness and marking of jewellery and technical requirements in terms of weight and dimensions, gemstone authenticity, sizes and qualities, product integrity and defects, and so on. There are no direct quantitative requirements on service performance characteristics apart from a general statement of functionality and finish, but

some indirect ones such as minimum ring shank width or thickness, earring post minimum diameter, chain strength, impact behaviour and nickel content can be interpreted in terms of service performance. For example, chains should withstand a minimum force of 4 lbs static tension, strong enough to perform their function, but they, or the jump rings, must open at a maximum of 15 lbs force to prevent injury if the chain is pulled while being worn. Colour consistency of components is considered important.

The testing programme comprises both examination and a range of tests to ensure compliance with product specification. This involves metallurgical, mechanical and gemological tests before and after manufacturing and the use of X-ray fluorescence analysis as well as destructive assaying for gold fineness compliance. Atomic absorption spectroscopy is used for nickel analysis.

Field inspection involves J.C.Penney inspectors visiting supplier's factories to visually examine jewellery for workmanship and this includes statistical auditing as well as 100% inspection. On a higher level, the quality of factories are evaluated quantitatively, based on their facilities, the calibre of their quality control systems, consistency and so on.

Needless to say, all this is supported by a comprehensive documentation on standards, test and auditing procedures, classification of defects and gemstones, etc.

Such an approach to quality assurance is not unique, although not in common practice. Another well-known leading retailer/vendor of jewellery is QVC who retail through the medium of TV and are, I believe, the largest purveyor of 14 carat gold jewellery. This TV medium has additional requirements in terms retailing regulations, such as the description of the product, and this impacts on quality assurance requirements in a significant way. You will not be surprised to learn that QVC's approach to product quality parallels that of J.C.Penney. Such a demanding approach to quality does place pressure on manufacturers to implement a good quality assurance system and I shall now turn to this aspect.

Quality Assurance in production. In many traditional goldsmith's workshops and jewellery factories, assurance of quality is carried out by a *quality control* approach, i.e. inspection after completion of manufacture and possibly after each major manufacturing step. Items failing are either rectified or scrapped.

In many instances, unless assaying is done on finished jewellery, there is no quality *guarantee* on fineness. If a producer wants to comply with national legislation on fineness regulations and marking of jewellery, it is essential that he has access to some accredited assaying facility, be it an in-house facility or an external assay laboratory.

This quality control approach to achieving quality in the final product can give rise to problems that typically include the costly rejecting and scrapping of complete production batches as underlying problems with materials and equipment go unnoticed until the batch is made and inspected. The possibility of mixing components of different caratages during assembly and wrongly marking finished jewellery with the incorrect fineness mark can also arise where a lax attitude to quality is taken.

On the other hand, the more progressive manufacturers have taken a different approach - the q*uality assurance* approach. This is formalised under the ISO 9000 standards in the form of quality systems, but the principles can be implemented without the need for formal registration as Peter Raw (10) has explained in a recent issue of *Gold Technology*. The basis of this approach is to define and implement rigorously the manufacturing processes and materials, so that compliance will ensure that the resulting product meets the specified quality requirements. These requirements may be as demanding or undemanding as one wishes. As a minimum, they may be just caratage conformance but, more generally, will incorporate some aspects of product integrity. As Raw neatly states, this approach can be summed up in two simple phrases:-

- Say what you do
- Do what you say

The foundation for this approach is written, technical specifications and procedures - for the incoming raw materials and components, the equipment and consumables used, the processes and, of course, the end product. I am not going to go into this aspect in any depth as Raw has covered this well and I would be impinging unfairly on John Wright's presentation later this week. However, I will draw one point to your attention and that is one of tolerances. Whether it be caratage, alloy composition and properties, temperatures, dimensions, processing times or whatever, for each specification, an allowable tolerance must be defined, whereby compliance within the tolerance will ensure that the item of jewellery will meet its final product specification (which in itself will have a tolerance range). It is quality assured.

As inferred by this last statement, written specifications and procedures alone will not guarantee quality. There needs to be a rigorous system of implementing them and auditing their compliance after each processing stage, be it self inspection by the operative or off line inspection by quality assurance personnel. Each item or batch must be identifiable and its processing history traceable. This requires progressive documentation. With modern computing systems, such records can be easily made, maintained and interrogated. Audited regular calibration of measuring systems, maintenance of equipment and training of operatives are an integral part of this approach.

Again, an important point to note is that incoming raw materials need to be defined and specified and checked for compliance. Valerio Faccenda reported an example of major quality problems emanating from use of certain fine gold good delivery bars of 995 fineness containing insoluble platinum group metals at last years Santa Fe Symposium (11). The specification of a 'good delivery' fine gold bar, whether 995 or 9999 fineness, is not sufficient for quality jewellery manufacture. A tighter specification is needed. As some manufacturers have discovered, such gold bars can occasionally assay incorrectly and it is very difficult to persuade refiners to provide a traceable batch number and a full certificate of analysis as opposed to gold fineness. The impurities are equally important.

Likewise, recycled process scrap such as blanked strip and casting feeders must also be defined in quality terms.

A further stage in quality assurance is to aim for continuous improvement - the *Total Quality* approach as exemplified by quality gurus such as Phil Crosby (12). The aim is to seek perfection, with the motto:-

- Do it right first time

In this approach, quality improvements are sought on a continuous basis, through techniques such as Quality Circles, Quality Improvement processes and Error Cause removal systems. Again, I do not intend to discuss this further today.

Voluntary industry quality schemes.

As I stated earlier, in some countries, quality in terms of caratage conformance is guaranteed to the consumer by a compulsory Hallmarking system under national legislation and carried out by an independent assay laboratory. However, there are many countries where such a compulsory system is not in place but where the industry would like to give consumers some recognisable confidence of quality, particularly caratage conformance. World Gold Council has encouraged the setting up of industry-led, self-regulatory voluntary quality systems, initially in Europe where it is known as 'Emagold', the prefix 'Ema' being an abbreviation of the European Manufacturers Association. The setting up of this system anticipated the expected legislation on harmonisation of standards by the European Community, and would be compatible with it. Needless to say, this European Directive of 1992 has still not been agreed by member countries, but is likely to follow the Emagold framework.

More recently, the Emagold concept has been spun off to the Americas where the equivalent 'Amagold' organisation has been set up and is being spearheaded in Mexico, I understand. The prefix 'Ama' is an abbreviation of the American Manufacturers Association.

So what is Emagold and Amagold and how do they work? I shall focus on Emagold.

As I said, it is an association of jewellery manufacturers - currently over 113 - and is composed of 6 national organisations, Italy, France, Portugal, Greece, Spain and the United Kingdom, who operate under the Emagold Europe organisation, based in Belgium. Their mission is (13):-

"To create a quality mark which stands for caratage integrity and quality in the eyes of the consumer and identifies the most progressive part of the European jewellery industry."

The quality mark is the solar mark, shown on this next slide, which is protected by copyright and owned by Emagold. Accredited members can mark their jewellery with the solar mark as well as the fineness/Hallmark and manufacturers mark. An important point to note is that it can only be placed on jewellery of at least 50% gold content, i.e. 12,14, 18 and 22 carats. Also, that caratage conformance is based on zero tolerance in assaying. The use of the solar mark as a common mark of quality, together with the Emagold name, has obvious market promotion advantages and consumer campaigns to 'educate' retailers and consumers and promote Emagold as a brand are carried out. The same solar mark is used by Amagold too.

Basically, Emagold is a voluntary product certification mark, whereby manufacturers are able to self mark their gold jewellery with the fineness, manufacturers mark and the solar mark. The accreditation and subsequent auditing of manufacturers to ensure compliance with the Emagold system and its objectives is carried out by an independent body. In this case it is the internationally renowned Société Générale de Surveillance (SGS), headquartered in Geneva., but with operations worldwide.

Assessment of applicant companies is based on ISO 9002 and 9003 standards and covers the key manufacturing processes that can influence caratage. Moreover, the existing quality control operations are evaluated. An effective internal quality control system based on defined responsibilities and written documentation is sought. The outcome of such an assessment is one of three results:

- *Satisfactory.* - The application goes to the Emagold board for approval.

- *Satisfactory with reservations.* - The applicant has 3 months to take corrective action, which is followed by a re-audit.
- *Unsatisfactory.* - Applicant rejected and has to start again.

It is interesting to note that of the member companies current in 1995, many prestigious names, none were passed first time as completely satisfactory. This can be viewed as a good indication that the European jewellery sector lagged behind other industries in quality assurance.

Once accredited by Emagold, each manufacturer is subjected to:

- One unannounced annual audit of their quality systems, and
- Three unannounced annual audits of products, and
- Visual inspection of the correct positioning and visibility of the 3 marks

The number of items inspected is proportional to the square root of the number of items manufactured in the 4 month period. Assaying by an external laboratory is carried out on a cube root sample of products, components and raw and semifinished materials.

It is not appropriate here for me to go into details of how the system is operated. Suffice to say that since its formation in 1991, Emagold has grown rapidly to over 113 members, producing about 50 million items of gold jewellery, equivalent to approximately 200 tonnes of fine gold and representing about 35% of total European jewellery fabrication. At this point, it only represents a guarantee of caratage integrity, but it is to be anticipated that its quality remit will be extended in future.

I will not say much on the progress of Amagold, launched here in the Americas only last year, except to say that a blueprint quality manual has been developed in Mexico jointly by WGC and SGS for adoption by potential members there.

Well, that concludes the present situation on quality. Let us turn to the future.

THE FUTURE DIRECTION OF QUALITY - BEYOND 2000

The year 2000 is less than 2 years away. Will we see any significant changes to the industry's concept of quality in jewellery over the next 5 years - which takes us *beyond 2000* as highlighted in my lecture title? I think that we will see a shift for a number of reasons:

• The market is becoming increasingly more international and competitive with the centre of gravity of jewellery production moving eastwards to the Pacific rim. Quality will increasingly become a focus of product differentiation in order to attract higher margins and market share.

• The consumer is becoming more conscious of quality issues and more demanding. The precious image of gold jewellery will be expected to be matched by reality. There is a discernible trend to move upmarket and to go for branded designer labels.

• Consumer protection legislation is becoming more severe, placing more emphasis on the accuracy of product description and 'fitness for purpose'. Also, there is an increasing trend for compatibility of national legislation at the international level. For example, we can anticipate that jewellery fineness standards and marking will become more harmonised and the definition of fineness will be on a zero tolerance basis worldwide, with elimination of negative tolerances. This will enable mutual recognition of the standards of fineness and marks between countries.

• In an unbranded goods sector such as jewellery, control of the product tends to lie in the hands of the distribution sector rather than the manufacturing sector which, as a consequence, loses control of product and pricing policies to the large chains and departmental stores. This was another reason for the formation of Emagold (14). Such a loss of control has implications on the setting of quality standards.

Against this background, I believe that the consumer wants and is demanding a higher level of quality in jewellery than just a guarantee of caratage conformance, which even today is not universally available, as discussed

earlier. The more progressive retailers/vendors are already recognising this and taking unilateral action, as I have discussed earlier. I would suggest that manufacturers need to work with the retail sector on this if they are to retain some control and flourish as a business sector. This trend will impact on the structure of the manufacturing industry, too, which is still largely fragmented and unco-ordinated. Small producers will find it more difficult to work with major retailers and meet their demands on quality assurance.

As a first step towards improved quality, the industry needs to define and agree national and international standards of quality in jewellery. These should cover a number of factors, I suggest:-

- Standards of fineness, ie, caratage levels, and tolerances.
- Standards of colour.
- Standards of alloys, embracing composition, conditions and treatments.
- Standards of product manufacture and integrity.
- Standards of service performance.
- Standard test procedures for the aforementioned factors.

I will discuss these points in a little more detail:-

Standards of fineness: In an era of worldwide free trade, the growth of a truly international market in gold jewellery is restrained by a situation where there is a plethora of local fineness standards and fineness tolerances between countries and a lack of mutual recognition of marks (Hallmarks). On just a European scale, the problem is recognised, but agreement through a European Directive on harmonisation of standards is proving to be difficult and protracted. The consumer is confused, too. But I will leave further discussion to Roy Rushforth later this week.

Standards of colour: Colour is a measurable, quantifiable property, and gold jewellery is unique compared to platinum and silver in that it is available in a range of colours from red to pink/rose to deep yellow to pale yellow, green shade and through to white. However, there are no national or international standards of gold jewellery colours over the range of caratages. I believe that there is a strong case for defining a basic range of standard colours at all accepted caratage levels.

This is not to say that jewellery may only be made in these standard colours, but much jewellery would be made close to such basic shades. As Greg Raykhtsaum and D.P.Argarwal state in their introduction to their paper on the colour of gold (15), "What is the colour of Hamilton gold?". It is not a defined colour. Neither are the shades standard yellow, dark yellow, pale yellow or green. What about red, pink (or rose) or white? A standard definition, with tolerance band, in CIELAB colour co-ordinates is needed at all appropriate, recognised caratages. Its use in defining colour of jewellery would save a lot of problems between manufacturers, alloy and findings suppliers and retailers.

Defining colour by alloy composition alone is not sufficient. As Dieter Ott (16) and Grig Raykhtsaum (17) have shown, surface treatments can affect colour shade. Some, such as 'bombing', are designed to chemically remove the base metals and leave a gold-enriched surface, the colour of which is not typical of the bulk alloy underneath.

Of course, I must make mention of the European colour standards - or Norms - for the colours of 18 and some 14 carat golds, originally developed by the French and Swiss and now covered by the European standard EN 28654 and the International standard ISO 8654. These cover 6 colours and alloy compositions at 14 and 18 carat, designated 0N to 5N, and the Germans have added 1 more at 14 carat, designated 8N, under DIN 8238 standard, as shown in Table 1. We need to build on this base.

From a practical standpoint, it is essential that such standard colours are available as reference materials against which the jeweller can compare his own jewellery or alloys, as it is not realistic for every producer and retailer to have his own colour spectrophotometer. The MJSA Color Reference Kit (15),

has been produced to cover such a need, and I do not need to mention the role played by the Santa Fe Symposium, with World Gold Council support, in bringing this Kit to commercial fruition. This kit covers 18, 14 and 10 carat alloys and will need to be extended in future to cover other caratages such as 21 and 22 carat, if it is to be of universal utility.

Standards of alloys: At each caratage level, manufacturers use a variety of alloy compositions to achieve similar colours but having a range of properties. There are a number of reasons for this, including:-

• Modification of mechanical, physical and/ or chemical properties to suit particular production process. For example, to improve deformability in stamping, or fluidity in casting, or prevention of 'orange peel' by grain refinement.

• To obtain surface cleanliness, e.g. in casting.

• Reduction in cost through cheaper alloying metals and reduced density, eg. by use of high zinc contents.

• Uncontrolled losses of base metal constituents in casting, through evaporation or oxidation, and/ or use of variable scrap composition which leads to uncontrolled, variable alloy composition.

• Need to avoid health and safety problems, particularly avoidance of nickel or cadmium.

Again, the end result may be an alloy with inferior service performance, such as lower tarnish resistance, poorer spring properties or ductility and lower strength, as well as a greater propensity to defect formation in manufacture.

Whilst a number of gold alloy data sheets have been published, for example by World Gold Council in its *Gold Technology* journal, these are essentially basic compositions of gold-copper-silver alloys without the major or minor alloying additions typically found in commercial alloys. I believe that there needs to be agreed standard alloy compositions with full alloy property data available, related to the colour standards and manufacturing process needs,

for all agreed international caratage levels. I include gold solders in this, for which there is very little compositional and property data published.

Thus, a retailer or consumer can buy jewellery in the knowledge that it conforms to an alloy and colour standard and meets certain minimum property levels that relate to service performance, including health and safety aspects. This he cannot do at present. For example, he cannot assume that a palladium white gold is necessarily nickel-free. Alloy compositions tend to be treated as commercial secrets by manufacturers and alloy suppliers. How short sighted! There are no secrets in our industry.

Standards of product manufacture and integrity: For a product with a quality image, I believe that there needs to be an agreed set of minimum manufacturing standards that include the engineering aspects of design and construction, the execution of manufacture and finish. This, we summarise as product integrity. It is an integral part of a product specification, along with artistic design, caratage and colour and product performance.

This is a large topic which has to be reflected in quality assurance systems and inspection techniques and time does not permit me to expand my thoughts today. I know that John Wright will cover some aspects in his presentation. I would suggest it as a major topic for a future Santa Fe Symposium.

Standards of service performance: As I have mentioned earlier, this is an area that the industry has generally neglected. It must take it seriously. It is an aspect that can allow product differentiation in both quality and price terms.

For each product category, there needs to be minimum standards of the principal performance characteristics. I am not going to spell out what exactly these characteristics should be here today, although I have given some indications earlier. You, the manufacturing industry, together with the retailers, need to decide these. Clearly, for each characteristic, be it wear, scratch or dent resistance, spring and catch durability, chain strength and kink resistance, the performance level will be influenced by factors such alloy composition and caratage, product size, alloy heat treatment and other aspects of engineering design, as Timo Santala has already pointed out (6). One

would not expect a 24 carat ear-ring post to perform as well as an identical one in a hardenable 18 carat yellow alloy that has been heat treated to maximum hardness, nor a wire hook on a 24 carat chain to be as resilient as a lobster claw on a 14 carat one.

I do not see just one performance standard, but a number of performance levels for each characteristic, so that the product can be rated as Grade 1 or 2 or 3 in overall performance terms. For those of you who go camping, you know that sleeping bags are rated on a similar performance basis, some suitable only for lightweight use in hot summer climes and others suitable for warmth retention in cold winter conditions and some even for use on the exposed summit of Mount Everest.

The question as to how one measures such performance levels and sets a range of standards leads to the need for a standard set of laboratory test methods. This leads me into the final point...

Standard test procedures: If one is going to go down the road of standards of performance in service for jewellery, one needs a set of test methods for assessing these in the laboratory on finished jewellery. For example, there are a number of test methods for measuring wear and scratch properties in use in the engineering industries, and the measurement of tensile properties and hardness are also well established. But how do you measure dent resistance of bangles or electroformed ear-rings, or the kink resistance of herringbone chain? We need to establish some standard test methods that reflect actual practical conditions met in jewellery use.

A number of manufacturers have developed their own in-house test methods for some aspects of performance characteristics over the years but these have tended to remain commercially confidential. An exception to this is Leach and Garner who have done some excellent work in this field, reported at this Symposium in 1995 and 1997 (18,19). We need to build on this base. I am aware that some major retailers are also moving independently in this direction. We do not want a plethora of test methods that are not comparable, but a common one acceptable to all.

Once the industry has agreed the test method, it can then set performance standards, based on them. For example, in the elasticity cycle test for bangle snaps (18, 20), a number of performance levels can be set, for instance:-

Grade 1	up to 15,000 cycles
Grade 2	15,000 - 25,000 cycles
Grade 3	25,000 - 35,000 cycles
Grade 4	above 35,000 cycles

Thus, we have the framework for product differentiation in quality terms which can feature in the product specification.

Impact on Quality systems: If the industry is to move to higher, more demanding levels of quality in gold jewellery, along the lines I have outlined, then this will clearly impact on the quality systems used in production. It becomes essential for manufacturers to move from a simple quality control approach to a quality assurance approach based on ISO 9000 procedures. Such a move, for example, would necessitate more detailed product and manufacturing specifications as well as manufacturing and auditing procedures. Item and batch traceability is implicit in this approach.

Jewellery design also needs to become more sophisticated with the CAD approach embracing engineering aspects, as John Wright has indicated (7,8), and in many situations there will be a need to upgrade manufacturing facilities and equipment to enable tighter control to meet the standards demanded.

Such upgrading of quality systems is a major task for many companies, particularly for the smaller enterprises and there is a lot to be gained from an industry collaborative approach.

CONCLUSIONS

In conclusion, I hope my presentation has given you a strong indication of how quality is defined and, importantly, in which direction I believe Quality in gold jewellery manufacture is headed in the years beyond the Millennium. Jewellery product is going to be more tightly specified in terms of

- Caratage conformance
- Colour consistency
- Product integrity in terms of 'fitness for purpose' as well as artistic design.
- Service performance

I remind you all that the leading retailers/vendors are already moving down this track. It will not be an option. The consumers are becoming more aware and more demanding too.

I also remind you that the retailers are dictating the pace of change at the present time. The manufacturing industry must respond in a pro-active way if it wants retain the initiative and set the agenda on quality. It must take a more professional, engineering approach to its products.

A major aspect of implementing these higher quality standards is the setting of industry standards at both national and international levels. I remind you that we are referring to standards of caratage, colour, alloys and solders, product integrity and service performance. The latter requires the establishment of suitable laboratory test procedures. Good work has already been done by the industry which serves as a basis but much work still needs to be done. There is a need for action now, not to wait until after the year 2000.

The opportunity is there. I believe this Santa Fe Symposium can take a lead, in co-operation with organisations like the MJSA, World Gold Council, Emagold and Amagold.

I wish you all a very successful and enjoyable Symposium.

Thank you

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Figure 1 Solar mark of the Emagold system

Table 1 Standard European Gold Colours (ISO 8654 1987[E])

Designation	Colour	Alloy Composition, %wt					Colour Co-Ordinates Chromacity			CIELAB[1]		
		Au	Ag	Cu	Zn	Ni	*x*	*y*	ρ	L*	a*	b*
0N	Green-yellow	58.5	34.0	7.5			0.3383	0.3362	0.90	93.5	-4.7	21.8
1N	Pale-yellow	58.5	26.0	15.5			0.3526	0.3700	0.82	92.5	-1.5	22.3
2N	Pale yellow	75.0	16.0	9.0			0.3590	0.3766	0.82	90.7	-0.5	26.8
3N	Yellow	75.0	12.5	12.5			0.3601	0.3729	0.79	89.3	2.5	24.5
4N	Pink/Rose	75.0	9.0	16.0			0.3612	0.3659	0.76	88.2	4.9	22.2
5N	Red	75.0	4.5	20.5			0.3591	0.3604	0.74	86.0	7.4	19.4
8N[2]	White	59.0		24.0	7.0	10.0	-	-	-	85.5	-0.6	8.7

(1) Taken from reference 17

(2) After DIN8238. Taken from Edelmetall Taschenbuch, by Degussa, pub. Hültig GmbH, 1995, page 503