



TECHNICAL MODEL MAKING PART I

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INTRODUCTION

Model making for the jewelry industry continues to become a much more technical and critical issue. As consumers become more educated and demand more from jewelers, manufacturing requirements increase. ISO quality practices and issues related to engineering in the jewelry industry are more the norm now than the exception. We cannot consider our industry as simply an art or a craft, even though you may be a fine artist or craftsman. While higher margin items can afford additional labor in search for excellence, many of us don't have that luxury.

A design is the first expression of an idea and must be considered as part of the engineering process. The model is the first physical form of this new idea and must be esthetically and financially appealing to the customer. Designers, model makers and marketing teams must work together to help each other in a continually more competitive marketplace.

ART & SCIENCE

Of all the manufacturing industries that I know, jewelry manufacturing is probably one of the best examples of an industry that could ideally blend art and science. I say "could" because, regardless of the increasingly available information, a huge part of the jewelry industry still seems to be in the technological dark ages. Manufacturing personnel are very often not included in the initial thought processes of a jewelry line or marketing plan and vice versa. Marketing and merchandising people are typically not included in manufacturing issues and very often choose not to be.

A rivalry tends to exist between design, marketing and engineering in most jewelry companies. Each often sees the other as a hindrance to their goals. These people are on the same team and should be working for the same goals. Their functions are so closely linked that they are, for all intents and purposes, symbiotic. One cannot exist without the other. There are no true separation lines in the jewelry manufacturing system. Without the art and emotion that a jewelry design evokes, there is no consumer desire. Without the right exposure to the market with desirable pricing, there will be no sales. Without the proper process engineering and material properties, there is no profit. An ugly piece of jewelry will not sell no matter how well it is engineered. The most beautiful design that cannot be manufactured at a profit serves only the ego of the designer.

The role of the model technician or engineering team is to provide the manufacturing view that is required by the marketing arm of the design team and to simultaneously provide the highest probability of manufacturing success based

on known scientific principles and geometric configurations. These goals should not be at odds with each other. Both are directly in line with the ultimate goal of the company of maintaining the lifestyles of the owners and employees of the company. Neither is more important and neither can afford to be overlooked nor considered. I am making the huge assumption that, if you are at this symposium; you want to make jewelry that sells for a profit.

MODEL MAKERS

For the record, I would like to state my opinion on the difference between designers, craftsman, CAD operators and what I call a model maker. In my opinion, a designer is someone that can conceptualize a beautiful and hopefully marketable piece or collection of jewelry items. They normally draw sketches on paper. While they may possess good bench skills, they do not necessarily need to have any bench skill with which to physically produce the design that they have created.

A craftsman, or “operator,” takes a sketch or rendering from a designer or artist and interprets that 2D work into a 3D metal, wax or resin representation. When these two discuss flow and modulation, they are almost always discussing esthetic issues. These craftsmen and operators will focus on the appearance of their model and typically are concerned with specific target weights of both metal and stones. Concepts such as directional solidification or subsequent labor steps are rarely considered. A craftsman must have fine bench skills. They may also have design skills. This does not make them a model maker. A CAD operator must know their program, how to manipulate virtual objects and surfaces, and how to get the appearance and physical attributes desired. The CAD people have it a bit easier when it comes to matching target metal weights but seldom use this ability to plan for the best casting properties of a model.

A true model maker is a different and rare beast. Model makers are not typically artists in the ethereal sense. Whether or not they have design skills or not is irrelevant to me. They certainly may have design skills, and often do. They must be able to translate a 2D sketch or concept into a 3D object with a grace and artistry that is intended. My definition of a model maker is more akin to an engineer with an enhanced right brain. To truly attain the title of model maker in my world, you need to have experience in every job on the manufacturing floor. It is also required that you have obtained, and continue to seek, a very intimate and deep understanding of the physics, chemistry and mathematics that govern God’s laws of the materials and methods of our industry. You can call these natural laws if a religious reference makes you uncomfortable.

DIMENSIONAL RIFT

A continuing issue for model makers and CAD operators is how to compensate for dimensional changes that happen during the manufacturing process from the master, the model and through to the final product. Ring size, prong size and practically every other dimension seem to be in constant debate. I’m not really sure that these can be standardized and that is not what I am trying to do in this paper. Customer requirements, price points and proprietary manufacturing processes cause a great deal of variation in these numbers. The numbers that I propose in this paper are my calculated and practiced opinions of these numbers and

how I got them. Hopefully, you will take the formulas or ideas, plug in your own numbers and devise your own model engineering standards for your benefit.

BASICS

There are probably as many opinions on the best shape, size and point of attachment of feed sprues as there are model makers. There are good ways to optimize metal weights to meet customer price point requirements—and there are some very bad ways. The size and spacing of prongs and channels and other stone-setting issues have been a constant source of debate. We have to consider all these things and much more as we design a model. The information in this paper could definitely be used by hand model makers. However, many items are best suited for the precision that can only be obtained by the CAD operator.

WHAT, WHY, WHEN AND HOW?

The first things to consider when starting a project is what exactly are you making, why are you making it, when is it due and what methods can you use in order to accomplish the goal. What you are making depends upon whether you are making a master, a model or going directly to a precious metal casting. This information will determine the amount of dimensional change that you must plan for. Why you're making it relates to the purpose of the final product. Is the final product from your efforts going to be a one-of-a-kind, show sample, a small production run, a large production run or something else? The answer to this "why" question will help you determine the correct master or model material. The answer to the "when" is this project due can help you choose your molding and casting methods.

For example, I have known companies that would build 100 new handmade metal models for styles they are introducing at a trade show. They made test samples to see how the processing would go and if there were any production problems. If problems arose, the metal model was fixed, new molds were made and another round of production samples were run. This process would take months and thousands of dollars per style. The potential sales of these styles were unproven and so much money and time was spent that I wondered why in the world would a company do such a thing? This is a real example of something that actually did happen and continues to happen today. Out-of-control product development costs are a prime reason that many U.S. jewelry manufacturing companies shifted their model and sample work offshore. Because the models were so poorly engineered, these same companies ultimately shifted their production offshore as well because of the high repair and scrap rates for these poorly engineered models.

Domestic factories are often admonished for failing to produce good products from models produced by offshore companies making show samples. When a typical domestic factory suggests a model change for quality sake, no changes in appearance, weight or structure is the rule. The statement often made was, "X factory can do it, why can't you? If you can't produce quality as good as these samples, then I will give the production to X factory." Little consideration is given to the extra efforts that are taken in order to make those five to ten good pieces of show samples.

There has always been a trick that most jewelry companies that outsource their work learn later. If production orders come for new styles, the offshore companies will often rework the models to make it easier for them to produce the parts, rather than do the production with their original, poorly made model. It is not uncommon for the production run of a new style to come in with slight changes to construction, weight and, sometimes, the actual appearance of the piece.

If companies had originally invested the price of one model maker's salary for one year, cost would have been slashed enormously from then on. No metal models would have been required for samples and a great deal of the product testing could have been done at virtually very low cost. I often heard the argument, "What if someone does place an order at the show—then what?" All I could do was look at them and shake my head. From the time a customer places an order until a production model could be made from a CAD file and RP model using one of the new types of mold rubber compounds could be hours and not days. To take it a step further, I have seen so much time and money wasted on product development, that casting analysis software packages could have been purchased to virtually cast the parts to look for trouble spots before the RP model even existed—and at a savings.

The issue of time has a large influence on the method you use to produce the required parts. I like to use the most efficient path to the final goal. A handmade model often takes a couple of days to complete, so I seldom use that option. Making a RP model or milled wax model can take as little as a couple of hours and up to an extreme of 40 hours depending on machine and method. Some of the model materials are better cast directly, some can be cast directly under special conditions and some are better suited to one of the various molding methods to produce injection waxes. I am always looking for ways to make my time, risk and costs lower for the production of anything. If you look at the process breakdown in Table 1, you will see various paths that you can choose to make your products. I would suggest choosing the paths in the scenarios where the quality is highest and the time, the risk and the cost are at their lowest.

Table 1 What are you making and why are you making it?

One-of-a-Kind							Time	Risk	Cost
Hand Fabrication							High	Low	High
RP / Carving Wax	Direct Cast						Low	High	Low
RP / Carving Wax	RTV Mold	PM Castings					Med	Low	Med
RP / Carving Wax	VLT Mold	PM Castings					Low	Low	Low
Samples							Time	Risk	Cost
RP / Carving Wax	Direct Cast						Low	High	Low
RP / Carving Wax	RTV Mold	PM Castings					Med	Low	Med
RP / Carving Wax	VLT Mold	PM Castings					Low	Low	Low
Small Production Run							Time	Risk	Cost
RP / Carving Wax	VLT Mold	Castings					Low	Low	Low
RP / Carving Wax	VLT Mold	Model Casting	Silicone Molds	PM Castings			Med	Low	High
RP / Carving Wax	RTV Mold	Model Casting	Silicone Molds	PM Castings			High	Low	High
Large Production Run							Time	Risk	Cost
Handmade Master	RTV Mold	Model Casting	Silicone Molds	PM Castings			High	Low	High
Handmade Master	LTV Mold	Model Casting	Silicone Molds	PM Castings			High	Low	High
RP / Carving Wax	RTV Mold	Master Casting	RTV Mold	Model Casting	Silicone Molds	PM Castings	Med/High	Low	High
RP / Carving Wax	VLT Mold	Master Casting	VLT Mold	Model Casting	Silicone Molds	PM Castings	Med	Low	High
RP Master	VLT Mold	Model Casting	Silicone Molds	PM Castings			Low	Low	Med

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MASTERS, MODELS, MOLDS AND CASTINGS

For clarity, masters are used to make molds that produce models. Models are used to make molds for production wax and castings. Many people use the terms “master” and “model” interchangeably, but I disagree with that lack of distinction.

BILATERAL SYMMETRY

A good example of the use of a master would be when you need to manually make a ring style that has bilateral symmetry. It is best to make a master of only one side of the style, perfect that side, make a proper mold, shoot two waxes and put them together to make a model with precisely matching sides. If you were making this same model with CAD, you would follow much the same path except that you would do it virtually using the mirror function of your CAD program, instead of the long process of making masters, molds, models, more molds and then production castings.

LARGE ORDERS

You would use the master scenario if you had a production order of 1000 pieces or so and only had a short time to produce them. At best, a production model can only be packed and cut about six times in a standard eight-hour day if you hustle. So you may need multiple models of the same style if your mold requirement is say 20 to 30 molds in a short time.

MULTIPLE SIZES

You may also have the scenario of needing multiple sizes of the same style. It is not a good idea to size and resize the same model to make molds for these orders. In this case, you would also need multiple models of the same style, but in the varying ring sizes.

When you are determining the different size attributes of your master or model, you need to consider what mold material you will be using for each step of the process. It is common industry knowledge that different mold materials shrink at different rates so you must plan your model process accordingly. RTV (room temperature vulcanizing) rubber shrinks the least at about an advertised 0–.25%. The newer LTV (low temperature vulcanizing) rubber shrinks a little more, at about an advertised rate of .65%–1.4%. Natural and silicone HTV (high temperature vulcanizing) rubbers are for metal models only and have the highest shrink at about an advertised 3.5%. You have so many choices in creating your products that it can be dizzying.

NEW WORLD ORDER

The advent of affordable, fast, high quality and rapid prototype machines, mills and materials has made metal masters, silver models and, sometimes, production waxes obsolete. For example, if you are making show samples that have no sales history, why would you go to the trouble of creating a metal master or model just to get four or five sample castings if you didn't have to? In this new world order, your master model is your CAD file and your model is plastic resin or carving

wax. If you are in a pinch, in many cases, you can go directly to casting with many of these new materials if you follow precise burnout and casting procedures.

MOLD MATERIALS

Required molds can come from zero-shrink RTV compounds or one of the new low-shrink, low-temperature vulcanizing mold rubbers. I never recommend depending on an RTV mold for the production of small numbers of production use waxes. The durometer and tear resistance of these rubber materials is usually not good for production. These rubbers are used for model production or insurance against casting problems only.

The newer low-temperature vulcanizing rubbers like the VLT from Castaldo, Akron's LSLT-160 and the rubber from the Italian company Nicem are some great recent developments. If you are not already aware, you can even make vulcanized molds of carving waxes if you pack your molds properly.

Some of the plastic resins can be polished to a nice quality finish that can produce production quality molds in under an hour. You must always coat the light-cured resin models with Teflon, otherwise the RP material will bond to the low-temperature vulcanized rubber. There is no need for Teflon with RTV compounds. Teflon coating currently comes in a spray, but sprays have problems. Sprays only coat what is not shadowed by the other parts of the model, so inner parts are often uncoated. There is one new product that you can dip your RP resin models into that coats the entire surface evenly without any shadowing. It seems expensive, but considering that 80% or more of your spray never gets on the resin model, it is a bargain since, there is little waste. This liquid dip ensures a good release from the mold rubber and a good mold. These new developments in mold rubbers combined with these new model materials can get you from a CAD file to a tree of production waxes in the same day. So consider investing a little to save a lot. I am personally a big advocate of light-processed models, low-temperature vulcanized rubber molds and the immersion Teflon coating for my low and medium production needs. Only in the case of high production requirements do I even consider a metal model. I no longer consider making metal masters for any reason. I might have to eat my words later, but for now, I have no need.

NEW CAD OPERATORS

The standard CAD operators these days are typically younger and do not have much if any bench or manufacturing experience. They typically do not clean up or make molds of the models that they build on CAD. They often look at shrinkage in the same general terms as most of the jewelry industry and do not consider the specific dimensional changes that occur. A typical CAD scenario is to virtually build the model in the CAD software of choice using the dimensions of the desired final product which is issued by the merchandiser. Once virtually built, the 3D model is selected and scaled up by the mythological shrinkage factor (typically 3.5%–5%) based on ring size or some other selected attribute. You can see in the "production silicone" row of Table 2 where this general shrinkage number comes from. Mainly, it comes from the change in ring sizes from the model to the finished production parts.

Table 2 General (mythological) shrinkage factors

Mythological shrinkage root	Model	Wax	mm wax shrink	Casting	mm metal shrink	Finished	Cast-to-finish growth	Total mm change	Total shrink
RTV	ID	19.95	19.88	0.07	19.63	0.25	19.82	0.190	0.65%
LTV	ID	19.95	19.50	0.45	19.44	0.06	19.60	0.160	1.75%
PS*	ID	19.95	19.22	0.73	18.93	0.29	19.22	0.73	3.66%

*Production silicone

Using general shrinkage factors causes a couple of problems. The first problem is that a 3.5% 3D scale up equals an 8.0 % weight/volume increase. A 5% size increase causes a 16% weight/volume increase. Tables 3 and 4 compare the weight increase in the casting from the same CAD model (Figure 1) that was scaled up in 3D by a factor of 5%. What this means is the casting from a model with a 17.5mm ID would be 7.0 grams of 14K yellow gold. A casting from the same model that was scaled up 5% would weigh 8.11 grams.

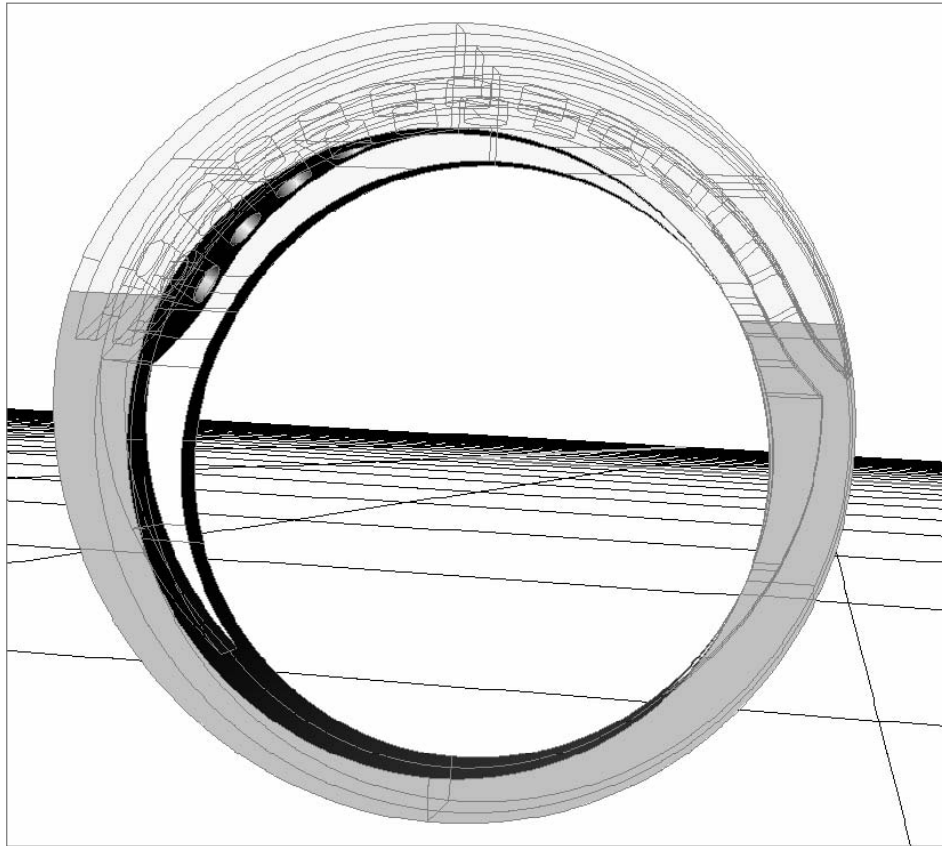


Figure 1 Typical CAD model

Table 4 Comparative weights

Model volume in cubic mm: 582.09			
Enter model volume (cubic millimeters) above or enter the weight of a known metal item in the spaces below. A comparative weight will auto calculate.			
Specific densities		Enter known wt. (grams)	Comparitive weight
Injection wax	0.95		0.589
Carving wax	0.92		0.571
RP resin	1.10		0.682
Sterling	10.36		6.425
9K yellow	11.24		6.969
10K yellow	11.47		7.111
14K yellow	13.07		8.103
18K yellow	14.86		9.215
22K yellow	18.00		11.159
24K yellow	19.32		11.981
9K Ni white	10.75		6.668
10K Ni white	11.05		6.853
14K Ni white	12.56		7.791
18K Ni white	14.42		8.940
9K Pd white	10.75		6.664
10K Pd white	12.47		7.732
14K Pd white	14.25		8.835
18K Pd white	16.61		10.298
900 platinum	21.54		13.354
950 platinum	21.50		13.330
950 palladium	12.11		7.508

A hand model maker typically makes his model the size that he thinks it needs to be that allows for shrinkage. He then trims the inside of the model to meet the target silver weight that he is either given or calculates. The typical CAD model maker builds the virtual model to finished dimensions and the weight if they can. He or she will then scale the model up in 3D to compensate for the "shrinkage." You would think that this would not be a big deal if the size were going to shrink again during molding and casting operations. The problem with this is that during the molding and cleanup operations, the dimensions and weights don't really change in the same way as a CAD model would be scaled. This often results in models that have to be sized, altered and often do not meet the weight and geometry requirements of the project.

You will need to document the change in weight and dimensions that occur

as your masters, models and castings go through your system. To aid you in creating your dimensional change tool, I created a tool called the “Comparative Weights” spreadsheet that can transform the volume of your CAD file or the weight of a known metal into a comparison weight of most common jewelry metals. Many programs can do this for you, but if you don’t have a fancy program or the plug-ins, you can still do it with this free tool. If you do not know the volume in cubic millimeters, but you do know the weight of the item in some known precious metal alloy, wax or RP, then you can enter the weight of this item in the corresponding cell and the other corresponding weights and the volume of that item will be calculated for you. This tool is included on your memory stick if you attended the 2006 Santa Fe Symposium.

MOLD RUBBER

Here are some of my findings on the shrinkage of different rubber materials (Tables 5 and 6). More importantly than the fact that the different rubber shrinks at different rates, is the axis in which the rubber shrinks. I have done this test many times in the X, Y, and Z axes (Figure 2) as well as in a circular ring, ID/OD model (Figure 3). The point was to show myself and my clients how model dimensions change. You can see in Tables 5, 6 and 7 that the shrinkage is not the same in all axes and is pretty predictable for the different mold rubbers. There is one anomaly, and I can explain it in one way. As you can see by the wax and casting numbers in Tables 6 and 7, the casting ID seemed to grow larger when it should have shrunk instead of getting larger. This is easily explained by a heavy-handed person with a caliper measuring soft wax. The numbers went back to normal right after that.



Figure 2



Figure 3

Table 5 Three-axis model RTV shrinkage

RTV	Model	Wax	Casting	Finishing	Total	Total shrink
X	22.92	22.85	22.65	22.39	0.53	2.31%
Y	33.09	32.83	32.65	32.39	0.70	2.12%
Z	9.99	9.62	9.62	9.41	0.58	5.81%
						3.41%

Table 6 Three-axis model LTV shrinkage

LTV	Model	Wax	Casting	Finishing	Total	Total shrink
X	22.92	22.12	21.98	21.77	1.15	5.02%
Y	33.09	31.95	31.94	31.48	1.61	4.87%
Z	9.99	9.48	9.51	9.4	0.59	5.91%
						5.26%

Table 7 Three-axis model silicone shrinkage

Silicone	Model	Wax	Casting	Finishing	Total	Total shrink
X	22.92	21.95	21.79	21.42	1.50	6.54%
Y	33.09	31.75	31.24	31.02	2.07	6.26%
Z	9.99	9.25	9.32	9.08	0.91	9.11%
						7.30%

COMPOUNDED DIMENSIONAL FACTORS

Dimensional changes between masters, models and production castings have competing and compounding factors that require discussion. It is not all about shrinkage. First, you do have the better-known rubber mold shrinkage factor that reduces the size of your parts (as you can see in the previous tables). You can also see in Tables 8, 9 and 10 that the finishing process causes an increase in the ID of ring models and other parts that have a circular geometry. During the processing of all these parts, you do have shrinkage and you also have growth.

Table 8 Band model RTV shrinkage

RTV	Model	Wax	Casting	Finishing	Change from model	% Change
ID	19.95	19.88	19.63	19.82	0.13	0.65%
Width	4.05	4.00	4.12	3.82	0.23	5.68%
Thickness	1.93	1.98	1.91	1.72	0.21	10.88%
Weight/g	5.93		5.877	4.907	1.023	17.25%

Table 9 Band model LTV shrinkage

LTV	Model	Wax	Casting	Finishing	Change from model	% Change
ID	19.95	19.44	19.50	19.60	0.35	1.75%
Width	4.05	3.86	3.95	3.75	0.30	7.41%
Thickness	1.93	1.89	1.82	1.64	0.29	15.03%
Weight/g	5.93		5.315	4.529	1.401	23.63%

Table 10 Band model silicone shrinkage

Silicone	Model	Wax	Casting	Finishing	Change from model	% Change
ID	19.95	19.22	18.93	19.22	0.73	3.66%
Width	4.05	3.85	3.75	3.70	0.35	8.64%
Thickness	1.93	1.84	1.73	1.72	0.21	10.88%
Weight/g	5.93		4.648	4.621	1.309	22.07%

WAX DEPARTMENT EFFECTS

Wax temperature, injection pressure, clamp pressure and dwell time also have a big effect in determining the amount of dimensional change that you experience from either master to model or model to production casting. High wax temperatures, small feed sprues or low injection pressure dwell time can cause mass reduction in the waxes. Excessive wax injection pressure can cause mold expansion and distort your model or production casting dimensions in all axes. High clamp pressures on low durometer rubber molds that have low clearance between the model and the outer mold surface can distort your dimensions wildly as the percentage numbers in Table 5–7 seem to indicate.

What I am saying is that the same factors that you need to consider for a production mold must be considered for any mold of any RP, master or model. The feed sprue size, feed sprue placement, mold venting and general cutting quality of a mold to make a model or a production casting must be ideal.

SURFACE QUALITY

There is another factor in the wax injection department that can greatly affect the dimensional change from master, through the model, and down to production casting. But, it has nothing to do with shrinkage. The use of powder inside the mold cavity that actually comes into contact with the wax that is being injected will create very rough surfaces on your waxes that will translate into casting results like those you see in Figure 4. The rougher the model casting surface, the more metal must be removed in order to produce a smooth-surfaced model. Keep in mind that a smooth metal model does not necessarily equal a good model. The more metal that must be removed from the model casting, the further away from the ideal dimensions, weights and casting characteristics you will be. I could do a whole paper just on wax department defects, but I am going to stop here for now. It is an important factor to consider. These mold and wax injection issues determine what I like to call the “cleanup factor.”



Figure 4

CLEANUP FACTOR

The cleanup factor is dependant on the casting quality and the hands of the person finishing your RPs, masters, models or final metal castings. Inside dimensions, especially ring sizes, decrease during molding, wax injection and casting, and then increase during the finishing of the RP, master, model and the production castings. If your casting process is fairly well defined and you get consistent casting results, then this number will typically be a relatively fixed amount of growth due to metal removal from the inside radius of the ring. You can see that the inside dimensions appear to have very little change from the model through to the finished product, while the other parts seem to experience a great deal of change. The thickness of the band model had surface removed from the inside and outside, so it appears to have experienced the most change. The ID shrank during molding, but during the following finishing steps, metal was removed, so the ID expanded due to that metal removal. Since it has both shrink and growth, the ID appears to have had less change. If you look at the change in the weight of the various examples in Tables 8-10, you see a weight change of much more than what is considered a typical shrinkage factor, regardless of mold material from model to finished production casting. Most production jewelry pricing is based on average production casting weight before finishing. Many of the larger jewelry retailers now have very strict rules about finished products being within

a very tight weight tolerance for processing “loss.” So, to be very accurate, you also need to know typical dimensional processing change for certain types of products and the typical volume change for the same in order to create an ideal Master & Model Table. Rings pendants and earrings may experience different dimensional variations.

If you have several people that do cleanup on your models, then this creates a moving target especially for your CAD operators. Because I cannot predict your casting quality, or the skill of you or your model maker, I cannot give you a hard and fast number by which to make your ring sizes. What I can do is show you my research tables and give you some ideas and some comparison rubber shrinkage numbers. With this information you can plug in your test results. I hope that this will help you determine your best master, model and production ring sizes. I have been doing this kind of testing and research for a number of years. I was very happy to see that Apollonius Nooten-Boom II had done similar research for his 2005 Santa Fe Symposium paper, which was a great confirmation of what I have been trying to teach folks for years.

I have included Table 11 as a reference that I developed for making my master and model ring sizes. This table is based on shrink and growth factors for inside dimensions in my world. If I am simply going from RP to low-temperature mold rubber and then to production castings, I would use the center section of the table to locate the millimeter dimension that corresponds to the target finished requirement. For example, if I needed a size 7 finished ring and I was going from a RP to a VLT mold and would generate my samples or small production run from that, then I would see that a size 7 is equivalent to an ID of 17.323mm. I would look in the middle section for the closest thing to 17.323mm which is slightly between a 6^{1/4} and a 6^{1/2}. So, if I look over to the section on the right side to find what size RP in a LTV mold would give me a 17.323 mm finished casting, it would be about a 17.70mm ID RP. If I were using my RP mold as my master to make metal models and then production castings, I would use the table as it appears and start with the final dimension in the left section and move across to the right to get my model and RP dimensions. For example, a 17.323mm finished production casting would require a 17.946mm model that was molded in silicone rubber and an 18.26mm RP master that was molded in LTV.

Table 11 Ring size and millimeter equivalents

CAD model, but omit outside prongs. It is sometimes to your advantage to make holes or grooves with the CAD program and let the hand model maker apply the prongs with the proper sized wire to the metal model casting. Again, it all depends on the situation.

Decent hand model makers can average one model every 1^{1/2} to 2 days as compared to the CAD operators that can make 2 to 3 models per day once they get really familiar with their programs and the targets of the merchandisers. The wave definitely favors the CAD operator, but it would be great if you could pair your CAD operators with experienced hand model makers for reference. Using a blend of experienced input for the CAD operators and a combination of CAM output and hand techniques can produce some superior models. In a perfect world, all your hand model makers would make efforts to also learn CAD and you would then have the best of both worlds.

STONE SIZE VARIANCE AND SETTING DESIGN

A lot of discussion about shrinkage between the model and the actual gold casting seems to center around the ring size. While that is of course an important factor, it is one that can be overcome with a little research and some trials that we will discuss later. Where I see more model makers experiencing failures is in the design of the stone settings. This issue is not entirely the fault of the model maker, although they are probably using some industry stone chart, instead of real diamond measurements. Part of the challenge is in the way most manufacturing companies sort the stones. The other part of the challenge is a problem with the way the stones themselves are cut. Those of you that are setters are probably thinking to yourselves right now, "Tell me something that I don't know." I would dare say that it is common that the model makers and CAD operators hear complaints from setters about models. It is also likely that no one is giving them the information that they need to improve those settings.

The plates that are used to sort the diamonds are called sieve plates (Figure 5). These plates have very precisely drilled holes in progressive sizes that are organized in a container so that stones with a smaller diameter than the hole in the sieve plate will fall through the hole, while larger stones remain on top. A common set of sieve plates in full sizes contains only 21 plates. The plates are numbered by what I consider a strange numbering system that ranges from the #00 plate with a .90mm hole size (about the equivalent of .005ct or less and up) to a #20 plate which has a 4.5mm hole (which equates to about .33ct). There is also a 42-plate set, but the 72-plate set is the best and most accurate for sieving stones for model making and setting.



Figure 5 (courtesy Swiss Axe of Belgium)

FULL PLATES

Table 12 represents a theoretical weight and millimeter variance of what would happen if you were sorting perfectly round, clean diamonds using a brand new set of full plate sizes only. You can see by the highlighted rows that, even in perfect conditions, using full plates to sort stones is a problem for model makers and setters. When you are designing a setting for .02 ct. stones for example, you have the stones that will “just” fall through the #7 plate, but will “just” not fall through the #6 plate. That means stones sieved between a #6 and #7 plate would range from 1.70 and 1.89 millimeters, or about a 20% variance. That is a huge variance, but it would at least be predictable. This is typically what you would expect to get when you order a parcel of .02 ct. diamonds from your friendly neighborhood diamond dealer. You can see by the millimeter equivalents on the table that the millimeter increases in a fixed amount and not proportionally. I have included stone sizes all the way up to .33 ct. in the table so that you can see the declining percentage variance that occurs as the stones get larger. The same fixed variance in millimeter is a lower percentage of a larger millimeter size stone and a larger percentage of a smaller one. It is easier to understand how this reality causes model makers and setters to have problems.

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Table 12 Theoretical full plate sieved variance

Plate size	Appx. weight	Hole diameter	mm variance	% variance
00	0.004	1.05		
0	0.005	1.10	0.10	9.00%
1	0.006	1.15	0.15	12.96%
2	0.008	1.25	0.20	15.92%
3	0.010	1.35	0.20	14.74%
4	0.011	1.45	0.20	13.72%
5	0.013	1.55	0.25	16.06%
6	0.020	1.70	0.35	20.53%
7	0.028	1.90	0.40	21.00%
8	0.033	2.10	0.40	19.00%
9	0.045	2.30	0.40	17.35%
10	0.055	2.50	0.40	15.96%
11	0.063	2.70	0.40	14.78%
12	0.076	2.90	0.40	13.76%
13	0.100	3.10	0.40	12.87%
14	0.125	3.30	0.40	12.09%
15	0.153	3.50	0.40	11.40%
16	0.180	3.70	0.40	10.78%
17	0.210	3.90	0.40	10.23%
18	0.230	4.10	0.40	9.73%
19	0.300	4.30	0.40	9.28%
20	0.330	4.50		

The measurements that you see in Table 13 are typical of the diamond sizes that I have found that serve the American jewelry market. The make of the diamonds is poor and typically leans towards a deep rather than a shallow stone cut. As you can see in this table, the .02 ct. diamonds that we are really getting are usually between 1.6 and 1.78 millimeters. According to (<http://www.khulsey.com/>), a workforce of around 800,000 people cut about 90% of the world's diamonds. Surat, a city by the Gulf of Khambhat (aka the Gulf of Cambay), is considered the hub of the global diamond trade. More and more stones are being cut in China these days, but they are being taught by the Indians. With a few exceptions, Indian companies typically cut for weight and not for "ideal" proportions in order to maximize profit. You can't blame them for that. This is especially true when they are supplying the American market, ergo our diamond variance issue.

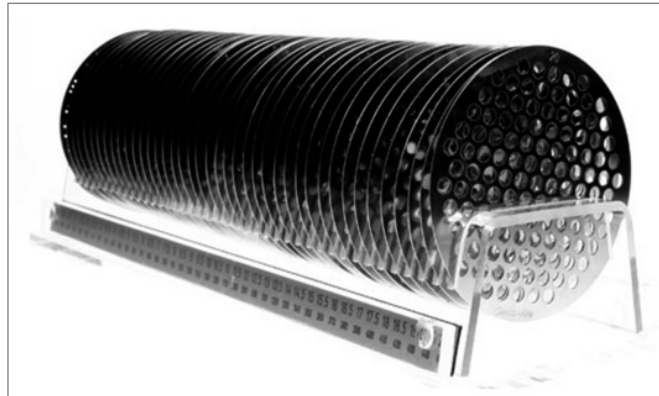


Figure 6

Table 14 Actual half plates sieved variance

Stone weights	Minimum	Maximum	% Range	(Average) millimeter
0.004	0.860	1.010	17.44%	0.960
0.005	0.960	1.060	10.42%	1.026
0.006	1.040	1.100	5.77%	1.070
0.007	1.130	1.210	7.08%	1.160
0.008	1.160	1.280	10.34%	1.215
0.009	1.230	1.300	5.69%	1.263
0.010	1.270	1.350	6.30%	1.310
0.011	1.290	1.350	4.65%	1.326
0.012	1.330	1.420	6.77%	1.366
0.013	1.390	1.470	5.76%	1.438
0.014	1.420	1.490	4.93%	1.454
0.015	1.480	1.540	4.05%	1.505
0.016	1.470	1.580	7.48%	1.531
0.017	1.600	1.660	3.75%	1.615
0.018	1.570	1.670	6.37%	1.626
0.019	1.600	1.670	4.37%	1.630
0.020	1.620	1.720	6.17%	1.671
0.021	1.670	1.780	6.59%	1.720
0.022	1.700	1.790	5.29%	1.743
0.023	1.720	1.800	4.65%	1.755
0.024	1.750	1.900	8.57%	1.823
0.025	1.720	1.870	8.72%	1.800

There is another set of plates that are called “quarter” plates. Unless I misunderstand the label on these sets of plates, they don’t seem necessary for us. Plate sets larger than the 74-plate set do not have plate sizes in between the half plate sizes. What they do have are plate sizes in half increments that are smaller than the #00 plate and larger than 2.9 mm in half plate sizes. That’s great for stone sorters, but the larger size plates don’t mean much to model makers and setters. Where we have the biggest problem is the small stuff, from about .03 ct and smaller. Table 15 shows examples of sets of sieve plates that are available and in use in the industry. You can ask your diamond supplier which set of plates they are using (how many plates), or you can get yourself a set for you own use.

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Table 15 Swiss Axe Company plates

1. Small Set (42 plates) from 000 to 20 (full and half numbers) Millimeter: From diameter 0.90mm to diameter 4.50mm										
90	100	110	115	120	125	130	135	140	145	
150	155	160	170	180	190	200	210	220	230	
240	250	260	270	280	290	300	310	320	330	
340	350	360	370	380	390	400	410	420	430	
440	450									42

2. Big Set (74 plates) from < 000 to 20 (full and half numbers) Millimeter: From diameter 0.80mm to diameter 4.50mm										
80	90	95	100	105	110	112.5	115	117.5	120	
122.5	125	127.5	130	132.5	135	137.5	140	142.5	145	
147.5	150	152.5	155	157.5	160	165	170	175	180	
185	190	195	200	205	210	215	220	225	230	
235	240	245	250	255	260	265	270	275	280	
285	290	295	300	305	310	315	320	325	330	
335	340	345	350	360	370	380	390	400	410	
420	430	440	450							74

3. Super Set (79 plates) from < 000 to 20 (full, half and quarter numbers) Millimeter: From diameter 0.80mm to diameter 2.90mm										
80	85	90	95	100	105	110	112.5	115	117.5	
120	122.5	125	127.5	130	132.5	135	137.5	140	142.5	
145	147.5	150	152.5	155	157.5	160	162.5	165	167.5	
170	172.5	175	177.5	180	182.5	185	187.5	190	192.5	
195	197.5	200	202.5	205	207.5	210	212.5	215	217.5	
220	225.5	225	227.5	230	232.5	235	237.5	240	242.5	
245	247.5	250	252.5	255	257.5	260	262.5	265	267.5	
270	272.5	275	277.5	280	282.5	285	287.5	290		79

4. Mega Set (101 plates) from < 000 to 20 (full, half and quarter numbers) Millimeter: from diameter 0.80mm to diameter 4.50mm										
80	85	90	95	100	105	110	112.5	115	117.5	
120	122.5	125	127.5	130	132.5	135	137.5	140	142.5	
145	147.5	150	152.5	155	157.5	160	162.5	165	167.5	
170	172.5	175	177.5	180	182.5	185	187.5	190	192.5	
195	197.5	200	202.5	205	207.5	210	212.5	215	217.5	
220	225.5	225	227.5	230	232.5	235	237.5	240	242.5	
245	247.5	250	252.5	255	257.5	260	262.5	265	267.5	
270	272.5	275	277.5	280	282.5	285	287.5	290	295	
300	305	310	315	320	325	330	335	340	345	
350	360	370	380	390	400	410	420	430	440	
450										101

TOTAL WEIGHT TARGETS

Merchandisers and designers are typically required to design to total weight targets when designing jewelry containing stones of any sort. This, combined with the metal weight (which is a whole other issue), determines the market price. The problem is not the designer using total weights to design a product (because they have no alternative); the problem lies in other places. First, the general rule with the folks cutting diamonds is to cut for maximum yield from the rough, as was stated earlier. The next issue is the way the folks sort the diamonds that fill the bags that go with the mountings for the setters to set. It’s all about the math. The mathematical variance created by the sieve plates is a big enough issue for model makers. Poorly cut stones create a disparity between diameter and weight. The methods in which the plates are used make the problem even more severe.

METHOD VARIANCE ISSUES

The way stones are sorted using these plates begins with the stones being dumped into the sorting cylinder, on top of the largest size plate that the sorter thinks is in the parcel. They then tap (bang) the side of the cylinder with a stick or some other instrument until they are either fairly sure that all the stones that could fall through have fallen through, or until someone pressures the sorter to hurry up and fill an order. There is also a method of using the sieve plates called a “soft” sieve. This simply means that the banging is lighter and done for a shorter time—it is less accurate as a result.

Stone inventory issues create challenges for cutters, diamond merchants and jewelry manufacturers. Diamond merchants and jewelry manufacturers sometimes need to use broader ranges of stones, which usually means up or down one sieve plate size due to excess diamond inventory. The “soft” sieve practice may reduce the inventory, but this practice is a nightmare for model makers and setters. It may even be a bigger deal for the owners of the company, because this practice is very inaccurate and must be to the retail customer’s advantage as far as total

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weight goes. The kind of range that you saw in Table 13 above is difficult and, in some cases, impossible to design for, especially for newer micro-pavé models.

WEAR AND TEAR FACTOR

Another factor with sieving stones is the wear and tear on the sieve plates themselves. Consider that most stone houses or factories that sieve stones on a daily basis cause damage and wear to the ID of the holes in the sieve plates just by using them. The plates are made of steel. Over time, diamonds can enlarge the holes in old or well used sieve plates. Often, used plates must be replaced regularly. Otherwise, this will further increase the millimeter variance of the stones. One last thing that I would like to point out about sieve plate wear is that, when the sorters have tapped all they can on a group of diamonds, some stones actually get stuck in the holes of the plates. Many times I have seen the sorter take the back of their banging stick and force the stones through the holes. Well, I don't suppose I need to tell you what that does to the holes and variance over time. Even with all these sorter issues, there is yet a bigger problem that haunts the technical model maker.

STONE SHAPE “MAKE” VARIANCE ISSUES

You know as well as I do that there is practically no such thing as a perfectly round melee diamond. While most of them look round to the eye, if you pick up a parcel and start measuring stone diameters, you will get different measurements if you measure at 12 and 6 o'clock, as opposed to 3 and 9 o'clock. All of them are some variation of oval even if it is slight. This means that there is a wide side and a narrow side of the girdle. For model makers, this means that we have to design for a true variance that is much different than what the sieve plate standards suggest.

You can see in Figures 7 and 8 that one side of this “.02” ct. diamond is 1.89mm and the other measurement is 1.95mm, which would really make it somewhere between .025-.028 ct. If your diamonds have a reasonable depth proportion, you can see that it is possible for a diamond of this size to pass through the 1.9mm hole of the #7 plate (Figure 7) and land on the #6 plate with a 1.7mm hole. This stone has a measurement of 1.95mm on the stone but would still be classified improperly from a model maker's point of view. The culet will clear the hole if the diamond passes through sideways which they sometimes do. Stones of poor “make” (not ideal proportions) can also be deeper or shallower than ideal proportions and can also throw off weights as compared to millimeter sizes on the average. So, models that are made for the right diameter could have a large weight variance when the stones are of poor “make.”

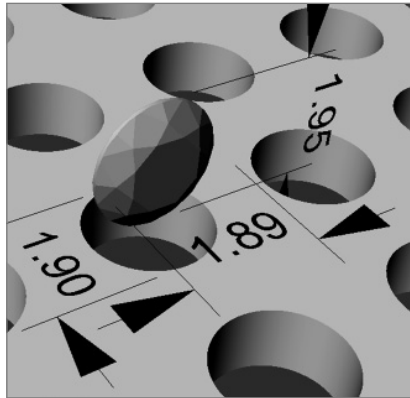


Figure 7

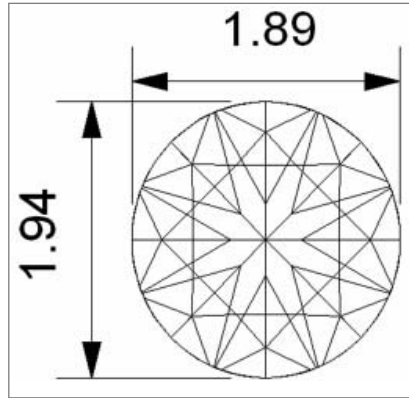


Figure 8

Table 13 shown earlier best demonstrates the reality of stone sizes in the USA. If you are a small user, and maybe you are buying diamonds in small parcels or per job, then your problems are multiplied. The problem with this table is that I measured hundreds of stones and took two measurements on each stone. I measured across 12 and 6 o'clock, as well as 3 and 9 o'clock. Unfortunately, I made the mistake of averaging the two numbers instead of using both measurements to get the minimum and maximum diameter measurements. But, because I had already measured hundreds of stones before I thought of that, I didn't want to start over. Table 14 represents the average measurements of stones that had been sieved and put into parcels using "tight tolerances." Had I used both measurements to calculate the table, the variance would have been much larger.

If you compare the millimeter sizes of the actual stone weights of this real sample (Table 13), you will see that the diameter per weight is much smaller than what the industry sieve plates (Table 12) say it should be. What this means is that if I used industry standard numbers to design my models, my stones below .03 ct. could be swimming in the mountings. This is a serious enough problem for prong mountings, but for channels, pavé, and precision micro-pavé in pre-cut mountings, this can be catastrophic.

So, what is the solution to this diamond size variance issue when making a technically correct model? It is the same for many of the production problems that we have in the jewelry industry. There are no magic bullets. We are not going to talk members of an industry into changing their practice of maximizing their profit any more than they can ask the manufacturers to pay twice the wholesale price for the diamonds. We have to play the hand that is dealt. First, we need to look at the cards. Now that we know more about why the stones never seem to fit in the models and what the real stone sizes are, we can improve our situation a great deal. The main thing that you need to do is build a real table of the stones that your company typically uses. It would be a great idea if you purchased a set of half plates from your jewelry tool supplier. If you are doing nothing more than re-sieving for your own use or checking the incoming parcels for millimeter reality, it can be invaluable for you, your model makers and your setters.

For smaller sized stones, you might consider making some models for small diameter, .02 point stones and to make other models for large diameter, .02 point stones. I'm not saying make two models for the same style number. I am saying that you may want to consider options that involve the maximization of your diamond inventory if you are a big user. If you are like most of us, you just have to design for a bigger range by using ideally sized prongs and ideal spacing between them based on the true range of millimeters for that weight category.

Another option is to use the better-cut stones in models where variance is more of an issue, such as channels and other precision settings where prong size must be kept to a minimum. You can use your parcels that have a larger variance, or poorer make, for prong settings with bigger hand-set prongs where the variance can be better tolerated. I would suggest a combination of these scenarios. In any event, you need to pay more attention to your stones and do a little sieving yourself in order to improve your products.

MATH OF SETTING DESIGN FOR STONE VARIANCE

To help you overcome the stone variance dilemma, this section will explain how to use mathematical ideas to improve your stone settings. We know from the previous section of this paper that we cannot rely on the average stone size in a range of stones or standard industry sieve numbers. These numbers are just not accurate enough for today's quality standards. To make a technically correct model that has a high probability of success and that can handle a range of stone dimensions, we must base our numbers on the minimum and maximum millimeter sizes of stones in a weight category. Only by using minimum and maximum stone sizes, and then considering the difference between them, can you design better settings.

SETTING DIMENSIONS

This part of the paper is really my opinion of how big the parts and the spacing of a setting model should be. Once you know how I calculate and plan a setting, you could change the percentages and use the same format to make your own table. My calculations are loosely based on the classic Tolkowsky cut of diamond (Figure 9), or the ideal cut stone. We both know that most of the diamonds that we set are not "ideal", but it's a place to start. All of the following tables are part of a spreadsheet called The Setting Planner that is on your memory stick in a folder called "Supporting Spreadsheets". These tables all automatically recalculate when you enter the minimum and maximum diameters of the stones that you are using.

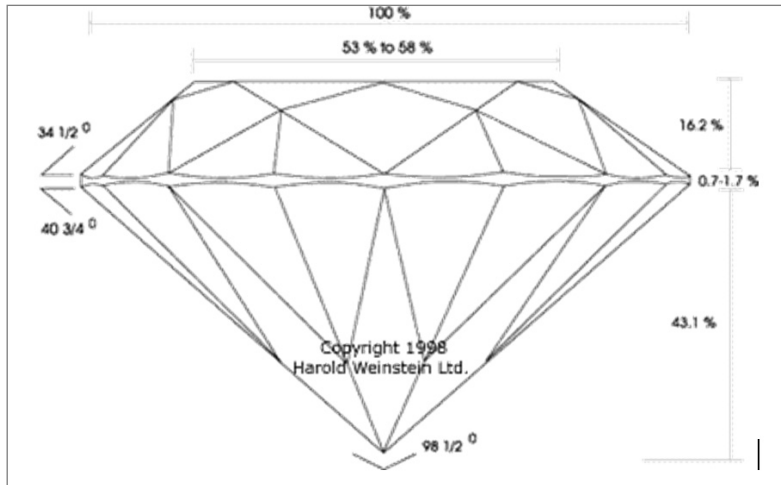


Figure 9 *Ideal diamond proportions (classic Tolkowsky)*

Generally, when I am designing a mounting, I base my prong spacing on the minimum stone diameter and the prong size is based on the difference between the maximum and minimum stone diameter of the range of stones that are typical in a stone weight category. This method assures that the smallest stone in the range will not fall through the prongs and that the larger stones will not cut too deeply into the prongs. If the variance is too large, the prong size will be out of proportion with the stones and will look strange. If you base your model dimensions on logical mathematical concepts, then when merchandisers complain about the “look,” you can better explain why it looks the way it does.

The prong spacing tools that I use are mathematically derived and form a circle that would just touch the inside of all prongs at the same time (Figure 10). I use a circular tool in CAD, as well as by hand, because if you only measure the diagonal distance between prongs, the two distance measurements may be correct, but the alignment could be wrong. Your settings could still not work properly, and you could have problems with setting.

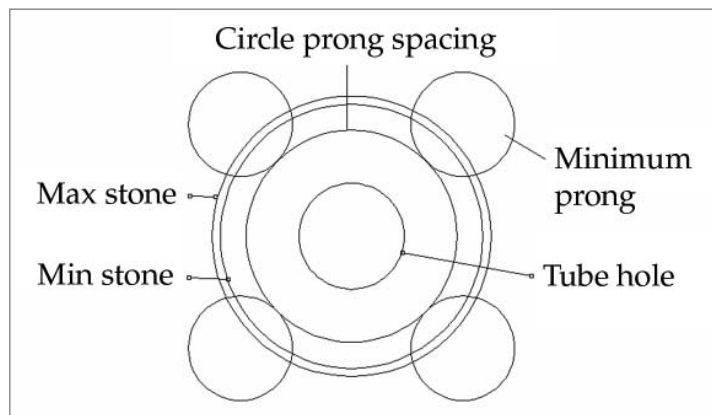


Figure 10

There are varying opinions on the depth of cut into the prongs of various types of settings. The opinions vary in cut depth anywhere from 30% to 50%. For me, if the prongs are not shared, then I am comfortable designing for a 50% cut. This brings the prongs in tighter and reduces the appearance of metal around the stones. If the prongs are shared, then I typically use less. It depends on the situation. The following numbers and formulae are not rules, they are guidelines. Most of the numbers on this spreadsheet are minimums and are sometimes less than I use to make my models. When I am making models for companies that are very price oriented, I use these numbers when trying to meet low target weights and price points. The point of this part of the paper is to show you what I use and how I came up with the formulae for this spreadsheet, so you can develop your own numbers for your use. I have included a tool called The Setting Planner on your memory stick. If you plug in the minimum and maximum stone dimensions that are also supplied in that same workbook for the particular type of setting that you are designing, it will generate numbers that will help you create a setting that will handle that variance.

INDEPENDENT SIMPLE SETTINGS

For independent prong heads, I use the OD of the minimum stone diameter for the stone tube diameter. I don't want to see the metal peeking out from behind the stone. With any shrinkage at all, this number hides the tube from sight regardless of stone diameter. In some cases, you will simply be creating a setting on a surface, so you would only be using the prong spacing and the prong diameter to design your part.

Using 40% of the minimum stone diameter as the size of the "tube hole" (Figures 10 and 11) that goes through the seat is a pretty safe bet. I like to make a small countersink at the top and bottom of the head (Figure 11) if the wall thickness will allow. Designing a setting with a wall thickness less than .60mm is not a good idea for a model. If that is the case, then many times I will simply make a solid setting, indicate where the hole is to be and allow the setter to drill it in the gold or palladium casting.

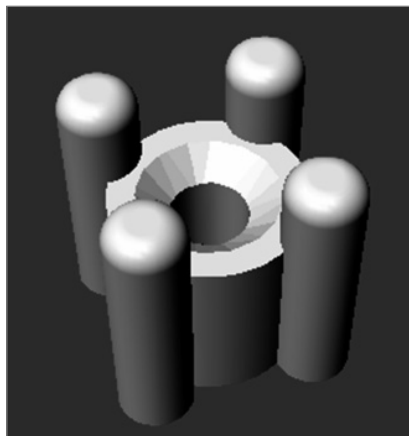


Figure 11

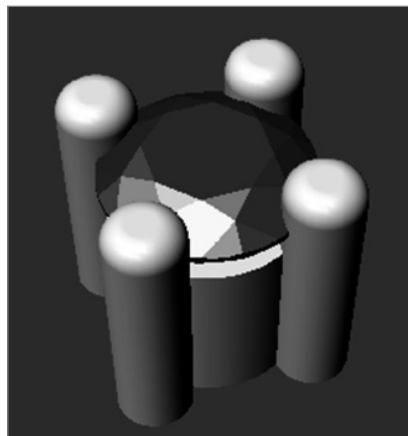



Figure 12

The term “circle prong spacing” (see Figure 10) is something that I made up for my own benefit and for the people that I am teaching. It describes how to properly space the prongs in an array around the stone tube or setting. When I was making most of my models by hand, I would turn down a piece of carbon rod and move my prongs up to touch the rod. I would then tie the prong wire to that rod with binding wire and then assemble. Now I am older and can’t see as well as I once could, so now I do it with CAD using a polar array on a 21-inch flat screen—much easier. In Table 16, you can see what I use to design my settings in CAD, and by hand if I dare still do that.

Table 16

Model dimensions for simple settings	Enter min. mm here	1.62
	Enter max. mm here	1.72
3, 4, 6 prong independent heads	Use these numbers	Description 
Tube or upper gallery ring OD	1.62	= min stone size
Tube or upper gallery hole	0.65	= min stone x .40
Minimum stone tube height	1.25	= max stone size x .6 (minimum 1.25 mm)
Circle prong spacing (circular tool that fits between prongs)	1.30	= min stone size x .80
Minimum prong height (above tube or gallery)	0.70	= if min stone size x .40 < .7 then use .7
Minimum prong diameter (3 and 4 prong settings)	0.64	= (max stone - circle prong spacing) / 2 x 3, with a maximum of 1mm up to 10pts.
Prong diameter on 6 prong settings	0.52	= max stone x .3 with a mamimum of .8 mm up to 10 points

INDEPENDENT BASKET SETTINGS

Table 17 shows the calculations for the basket setting illustrated in Figures 13 and 14.

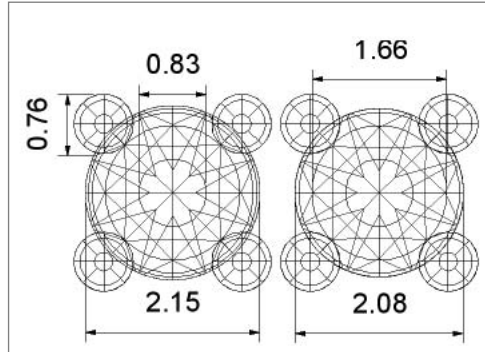


Figure 13

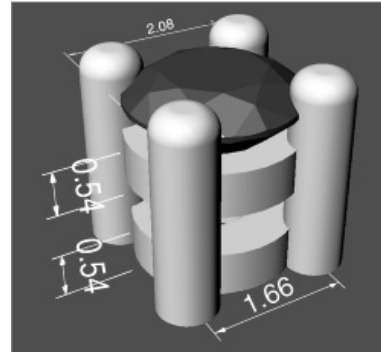



Figure 14

Many of the percentages are the same whether the stone is large enough to have a gallery or not. You can see in a comparison between Tables 16 and 17 that there are a few more lines for basket settings than simple settings. These are my recommendations for the size of the gallery of the basket head.

Table 17

Basket settings	Enter min. mm here	2.08
	Enter max. mm here	2.15
3, 4, 6 prong independent heads	Use these numbers	Description 
Tube or upper gallery ring OD	2.15	= min stone size
Tube or upper gallery hole	0.83	= min stone x .40
Total gallery height	1.61	= max stone size x .75 (minimum 1.50 mm)
Upper gallery height	0.54	= max stone x .25,
Lower gallery OD	2.04	= max stone x .92,
Lower gallery height	0.54	= max stone x .20,
Circle prong spacing (circular tool that fits between prongs)	1.66	= min stone size x .80
Minimum prong height (above tube or gallery)	0.83	= if min stone size x .40 < .7 then use .7
Minimum prong diameter (3 and 4 prong settings)	0.73	= (max stone - circle prong spacing) / 2 x 3, with a maximum of 1 up to 10pts.
Prong diameter on 6 prong settings	0.49	= max stone x .3 with a maximum of .8 mm up to 10 points

I don't recommend making a head with a gallery for stones that are under .05 ct., but there are exceptions. You have to be able to get the rubber out of the head and from in between the gallery parts without breaking the wax. I am including the dimensions for some slightly larger stones to show the relationships that can be used to design gallery settings. All dimensions are based on the minimum and maximum stone ranges in a stone weight category.

SHARED PRONGS

Shared prongs are obviously going to require larger prongs. Since two stone seats will be cut into one prong, you will have to allow for that. The hole through the tube will be the same as an independent setting, but the tube size will either be larger, about 105% (Figures 15 and 16) if you are using round tubes, or another option that I often choose for CAD models, is to make the heads oval (Figures 17 and 18). For shared prongs in a straight line, oval tubes eliminate the space between shared prongs. Round stone tubes can appear too large and you must fill the space between the heads. Table 18 represents the measurements that would be needed to make simple shared prong settings for .02 ct. stones.

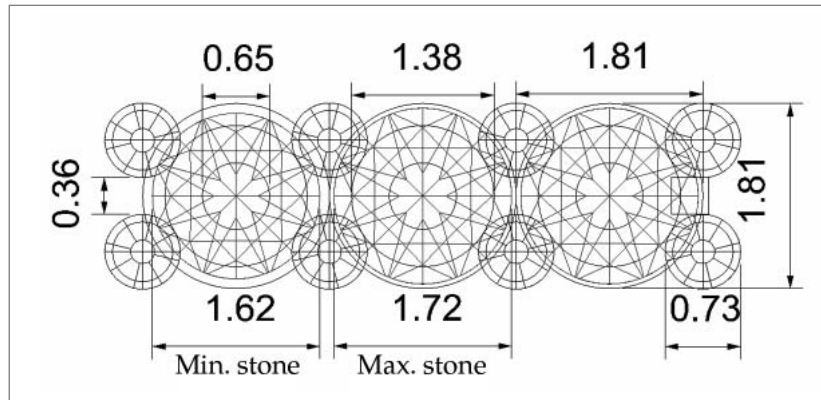


Figure 15

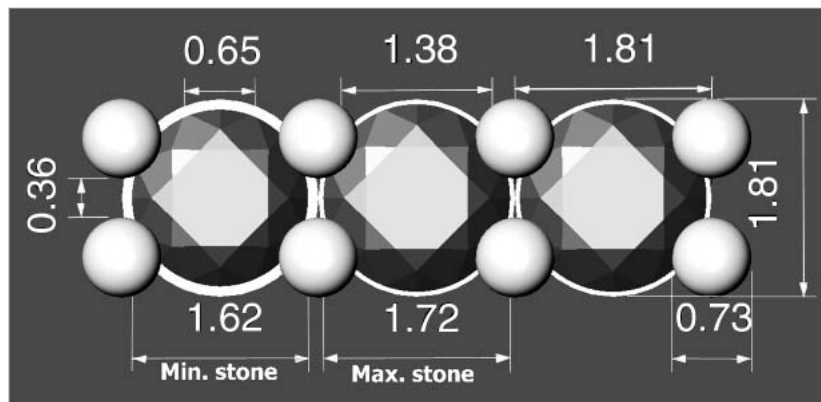


Figure 16

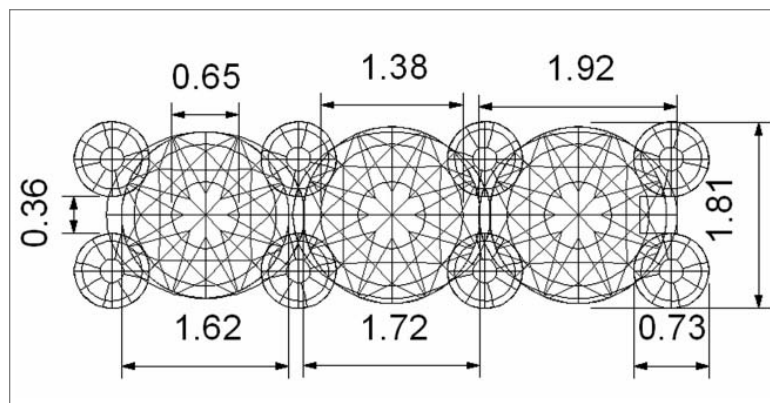


Figure 17

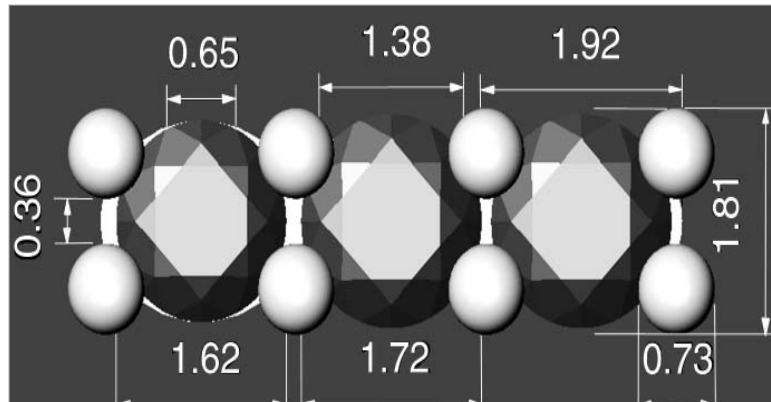



Figure 18

Table 18

Model setting dimensions	Enter min. mm here	1.62
	Enter max. mm here	1.72
Shared prong settings (end to end) simple tubes	Use these numbers	Description 
Tube or upper gallery ring OD	1.81	= max stone size x 1.05
Tube Y axis if making oval heads	1.92	= max stone size x 1.10
Tube or upper gallery hole	0.65	= min stone x .45
Stone tube height	1.50	= max stone size x .6 (minimum 1.25 mm)
Minimum prong height stone tube	0.65	= if min stone size x .54 or a minimum of .65
Circle prong spacing (circular tool that fits between prongs)	1.38	= min stone size x .85
(Very important) Gap between shared prongs	0.36	= max stone size x .21
Low wear prong diameter	0.73	= max stone x .425 (min .65mm with 1mm max)
(Exposed prongs) High wear prong diameter	0.77	= max stone x .45 (.65mm min with 1.10mm max)

SIMPLE SHARED-PRONG SETTINGS

For hand model makers, making oval tubes are difficult, so they typically use larger wire and cut deeper grooves for the prong and fill up the space between the heads with solder. For CAD model makers, you can easily use an oval for a stone tube and array the prongs around the same round prong spacing circle. The


deal is here that you don't want space between the tubes that can trap rubber during the molding process. This intersection of the oval profiles aids the whole process during wax injection and casting as well. Using oval profiles is a good way to solve both issues. I have not included a measurement for the sides of the oval head that intersect each other. The point is that they do intersect, rather than how much. The number that I used for the Y axis of that shared head is about 110% of the maximum stone in that weight category, and I used the diameter of the minimum stone for the X axis.

SHARED-PRONG BASKET SETTINGS

Table 19 below shows the dimensions of a shared prong basket settings for .04 ct. stones. The difference is the gallery dimensions. Since this setting is designed to be round, I use 105% of the maximum stone size for the upper and lower OD of the gallery parts. This ensures that the parts come into contact with each other between the shared prongs to help eliminate spaces that can trap mold rubber and to facilitate wax and casting. You can make simple settings for this size stone and that would probably be best. The purpose here is to point out how I came up with these numbers. Please take notice of the spacing that is the gap between shared prongs of .36mm in Figures 17 and 18 above. The size of the prong and this gap spacing is matched and critical so as not to allow the girdles of the stones to touch or overlap. More stones are broken by stones touching other stones during setting than are damaged by tools during setting. The gap spacing is 21% of the maximum stone size. The prong sizes are between 42.5% and 45% of the maximum stone size.

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Table 19

Model setting dimensions	Enter min. mm here	2.24
	Enter max. mm here	2.38
Shared prong settings (end to end) basket settings	Use these numbers	Description 
Tube or upper gallery ring OD	2.50	= max stone size x 1.05
Tube or upper gallery hole	0.90	= min stone x .45
Total gallery height	1.79	= max stone x .6 (min 1.25mm)
Upper gallery height	0.60	=max stone x .25,
Lower gallery OD	2.50	=max stone x 1.05,
Lower gallery height	0.48	=max stone x .20,
Minimum prong height (above tube or gallery)	0.85	= if min stone size x .54 or a minimum of .65
Circle prong spacing (circular tool that fits between prongs)	1.90	= min stone size x .85
(Very important) Gap between shared prongs	0.50	= max stone size x .21
Low wear prong diameter	1.01	= max stone x .425 (min .65mm with 1mm max)
(Exposed prongs) High wear prong diameter	1.07	= max stone x .45 (.65mm min with 1.10mm max)

The size of the prong and the gap between the shared prongs is critical, whether it is a simple shared prong setting or basket settings with galleries. I can't emphasize this enough. If you follow the percentages that I have included on this worksheet, it is unlikely that you will have any broken stones caused by overlapping stone girdles. Since these numbers are very precise, you will have an easier time doing this on a computer. Also, keep in mind that the illustrations above are model sized and not finished setting size, but the stones are the actual size in comparison, so you are seeing a bit of metal around the edges. I did it this way for illustration purposes.

STRAIGHT SHARED-PRONG RADIUS SETTINGS

The quantity of parts and spacing on any radius is a function of the distance from the center of your array. When creating an outside radius setting in this way, you can use round tubes instead of ovals because they will overlap under the setting anyway (Figure 19). It is important to consider that when creating settings on a radius like an eternity ring you must first calculate the length of all stones plus the spacing in between them. The sum of this calculation is the circumference and must be divided by Pi to calculate the diameter of the circle that crosses the girdles of those stones. $(\text{stone diameter} \times \# \text{ stones}) + (\text{spacing} \times (\# \text{ stones} - 1)) =$

circumference] / Pi (3.14167). You then have to compare that number with the diameter that represents the ring diameter that you want to make.

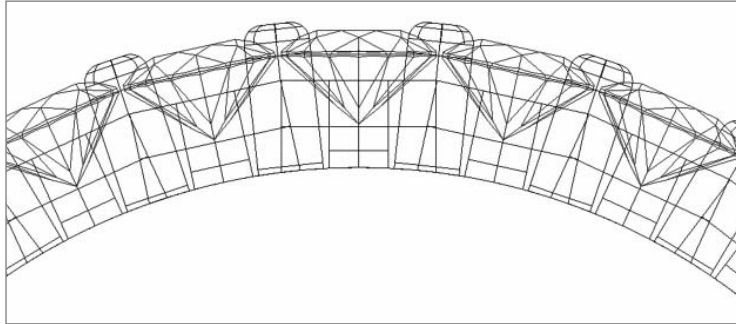



Figure 19

Table 20 Calculations for shared-prong radius settings

Model setting dimensions for settings	Enter min. mm here	2.24
	Enter max. mm here	2.38
Shared prong settings (eternity radius)	Use these numbers	Description 
Enter # of stones required	25	
Tube or upper gallery ring OD	2.38	= max stone size
Spacing between stone girdles	0.21	= max stone size x .90
Diameter at stone girdles	20.33	= (max stone x qty.) + (spacing x qty-1) / Pi
Minimum stone tube height	1.43	= max stone size x .6 (minimum 1.25mm)
Approximate model size diameter	17.47	
Tube or upper gallery hole	0.90	= min stone x .45
Minimum prong height (above tube or gallery)	0.85	= if min stone size x .54 or a minimum of .65
Circle prong spacing (circular tool that fits between prongs)	1.90	= min stone size x .85
Low wear prong diameter	1.01	= max stone x .425 (min .65mm with 1mm max)
(Exposed Prongs) High wear prong diameter	1.07	= max stone x .45 (.65mm min with 1.10mm max)

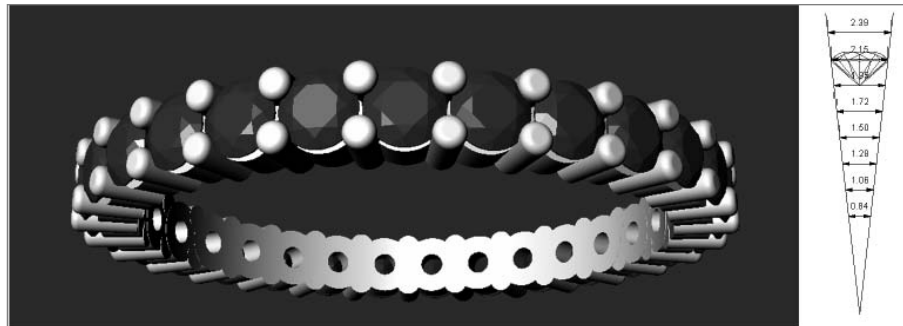


Figure 20

You don't want the ring to be uncomfortable due to the thickness where it passes between their fingers. Knowing the diameter of the stone girdles will tell you if you can actually make the ring in the size and total weight requested.

Using Towkolsky's famous ideal cut proportions, we know that somewhere between 43% and 45% of the maximum stone's diameter will be below the stone diameter circle. You need enough clearance for the culets of the stone so there is no danger of them sticking into your customer's hand or being damaged during processing. I also know that the stone will be slightly above the stone tube for setting and that the prongs will be about 54% of the minimum stone diameter above the stone tube. Adding up these numbers will tell you whether or not this ring will be comfortable to wear. 2mm is about the maximum ring thickness that I want to pass between fingers. You don't need to be as concerned with the spacing between the shared prongs if you have used the circle prong spacing tool at the height of the planned stone seats as your point of reference. Table 20 calculates the dimensions needed for an eternity ring.

INVERTED SHARED-PRONG RADIUS SETTING

If you are doing an inside or inverted radius, then you use the same point of rotation at the stone girdle, but the tube shape will be much different. The spacing between shared prongs would again be important. You can see in Table 21 that the only possible tube shape is oval, and the oval nearest the stone is smaller than the oval at the bottom of the tube. You attain this shape using a loft function and two profiles in CAD, or bar stock if you were doing this by hand. The table helps you choose safe spacing, minimum stone tube length and most of the numbers that you will need to build this type of setting. This type of setting is quite popular for diamond hoop earrings where the front of the earring is set on an outside radius and the back of the hoop is set on the inside radius (Figures 21 and 22). This allows maximum diamond exposure.

Table 21


Model setting dimensions	Enter min. mm here	2.24
	Enter max. mm here	2.38
Inverted shared prong settings (end to end, radius)	Use these numbers	Description 
Enter # of stones required	20	
Upper tube X axis	2.38	= max stone size
Upper tube Y axis	2.62	= max stone x 1.10
Outside tube Y axis	3.09	= outside circumference / # stones x 1.1
Spacing between stone girdles	0.12	= max stone size x .90
Diameter at stone girdles	15.87	= (max stone x qty.) + (spacing x qty - 1) / Pi
Minimum stone tube height	1.43	= max stone x .6 (min 1.25 mm)
Approximate model outside diameter	18.73	= diameter of the stones x # stones + total stone spacing
Tube or upper gallery hole	0.90	= min stone x .45
Minimum prong height (above tube or gallery)	0.85	= if min stone size x .54 or a minimum of .65
Circle prong spacing (circular tool that fits between prongs)	1.90	= min stone size x .85
(Very important) Gap between shared prongs	0.50	= max stone x 0.21
Low wear prong diameter	1.01	= max stone x .425 (min .65mm with 1mm max)
(Exposed prongs) High wear prong diameter	1.07	= max stone x .45 (.65mm min with 1.10mm max)



Figure 21

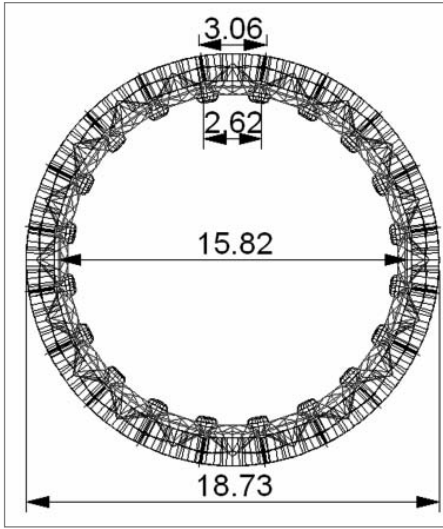


Figure 22

FLAT SHARED-PRONG RADIUS SETTING



Figure 23

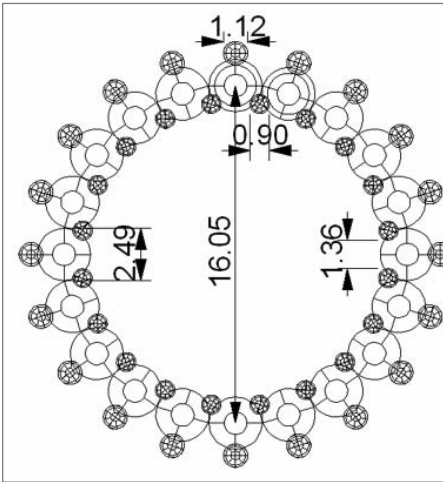



Figure 24

Table 22 and Figures 23 and 24 show calculations needed for a flat, radiused shared-prong setting.

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Table 22

Model setting dimensions	Enter min. mm here	2.24
	Enter max. mm here	2.38
Shared prongs settings (flat radius rotation)	Use these numbers	Description 
Enter # of stones required	20.00	
Tube or upper gallery ring OD	2.38	= 4.5% over max stone size
Spacing between stone girdles	0.18	= max stone x .075
Diameter that passes through center of stone	16.23	= (max stone x qty.) + (spacing x qty - 1) / Pi
Tube or upper gallery hole	0.90	= min stone x .45
Circle prong spacing (circular tool that fits between prongs)	1.95	= min stone size x .87
Total gallery height	1.79	= max stone size x .75
Upper gallery height	0.60	= max stone x .25,
Lower gallery OD	2.38	= max stone x 1.05,
Lower gallery height	0.60	= max stone x .20
Minimum prong height (above tube or gallery)	1.01	= if min stone size x .45 or a minimum of .60mm
Gap between shared prongs	1.46	= min stone size x .65
Low wear prong diameter	1.07	= max stone x .45 or (.65mm minimum, 1.0mm maximum)
High wear prong diameter (exposed prongs)	1.12	= max stone X .47 (.65mm min with 1.2mm maximum)

These types of settings are usually either around some other stone or object. Occasionally, you will see this look as an independent setting, either all diamond or mixed with alternating color stones. In this case, the smaller the radius, the easier it is to space the stones out of danger. As the radius gets bigger, the girdles come closer together and the risk of stone breakage increases slightly. This is especially true if there is a big stone size variance.

CHANNEL SETTINGS

While channel setting is still popular, it is not as popular right now as it has been in recent years. Prong, pavé, and bright-cut seem to be the hot tickets these days. Channels for very small stones will work and these small channels are typically set using a burnishing tool and not by hammering. I prefer not to use stones under .02 ct. for channel setting. Figure 25 illustrates the minimum and maximum stone relationship in this channel. The center stone is maximum and the ones on each side are minimum. I wanted to show the perspective of having to set stones with

big ranges side-by-side in a channel. Do keep in mind again that the numbers from Table 23 are model numbers and the stones are actual, so there will be some dimensional change once it is molded in silicone production molds.

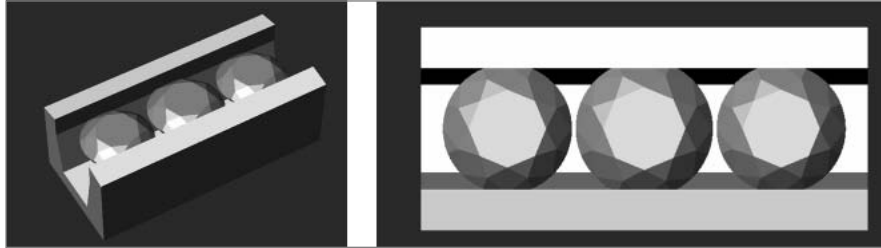
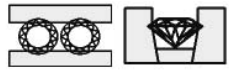


Figure 25

Table 23

Model setting dimensions	Enter min. mm here	2.24
	Enter max. mm here	2.38
Channel settings (Do not channel-set stones less than 2mm)	Use these numbers	Description 
Min channel height (inside channel bottom to top of rail)	2.17	= 70% of max stone size + .5mm or (1.5mm minimum)
Top of rail to center of stone seat	0.69	= max stone size x .35 (.50 min) (.75 max) up to 10 points
Min rail thickness	0.71	= max stone size x .3 (.50 min) (1.00 max) up to 10 points
Min rail spacing	1.90	= min stone size x .85 (rail spacing increases from model to casting)
Max rail spacing	2.02	= min stone size x .9 (rail spacing increases from model to casting)

I have always found that creating channel walls with a slight angle on the top is best for hand setting and wax setting (Figure 26). Most channels are finished with a relatively flat top and that is fine except that most models are also made with flat top channels. Setters either hammer or burnish the channels when they are setting. That action on an already flat channel either angles it down towards the stone, or mushrooms it out. If you had a slight angle on your channel rail, then hammering would simply create the flat channel that you wanted in the end. I have often seen defects created by the use of flat tops on the models for channel rails.

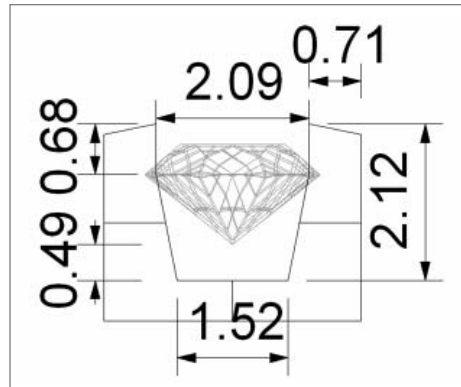


Figure 26

I also like to use a slight angle from what I plan as the stone seat to the bottom of the channel, as you can also see in Figure 26. I don't have a number for that, but the point is to help the setters identify where to put the seats for the stones. This slight angle also helps strengthen the channels and aids fill during wax and casting operations.

NICK SETTING

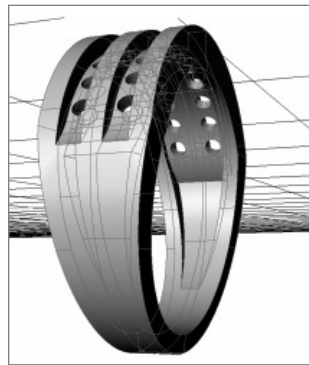



Figure 27

Table 24

Nick setting	Use these numbers	Description 
Min inside rail height	0.52	= max stone x .3 (min .40mm)
Max inside rail height	1.03	= max stone x .7 (min .80mm)
Suggested bottom thickness	0.70	= max stone x .40 (min .60mm)
Min rail thickness	0.65	= min stone x .4 (min .60mm)
Width at bottom of channel	1.54	= min stone size x .95
Hole through the plate	0.97	= min stone x .60

Nick setting isn't for everybody. If you are not familiar with this setting style, it is a pseudo channel-type of setting. You set the stones on a plate in the bottom of a rhodium-plated channel to give the illusion of having a channel full of stones. Unfortunately, because of the continuing demand for cheaper, lighter and still yet cheaper products, this type of setting is popular. Yes, I meant to say cheaper twice. The channel rail height must allow your tool inside the channel without damaging the other channel wall in order to push some metal down on the edge of the stone. That is why the rails on this type of setting may seem low. The rail thickness must be thick enough to allow metal to be taken from the inside of the wall without going through it. Many times, only one of the channel walls has a seat cut into it—you apply light force to the top of the stone to push the stone down onto the base of the channel. The stones for this type of setting are usually of poor quality, so the pressure required must be minimal to none. Normally, only one bead is pushed down onto one side of the stone to set, but a bead on both sides is sometimes required.

PAVÉ SETTING

When you are talking about pavé, it is difficult to define and, because of that, it is hard to calculate spacing dimensions with complete accuracy. Pavé can be on a flat plate or can morph between an outside radius to an inside radius all on the same model. It is best to use the height of the stone girdle off the surface of the mounting as the point of reference and rotation for such settings. I start off drawing a set of circles that represent the maximum stone diameter, the stone offset spacing, the prong spacing and the hole through the plate (Figure 29). I also create an offset border around the area that I want to pavé that later will allow me to add prongs to the outside of the settings without running into the wall. I then orient this set of circles on the surface of my pavé plate.

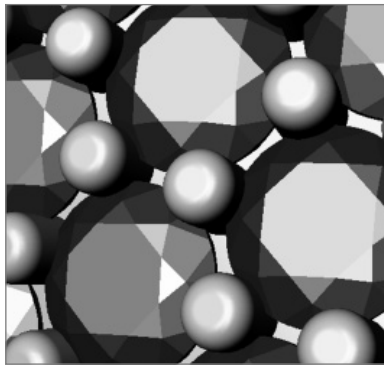


Figure 28

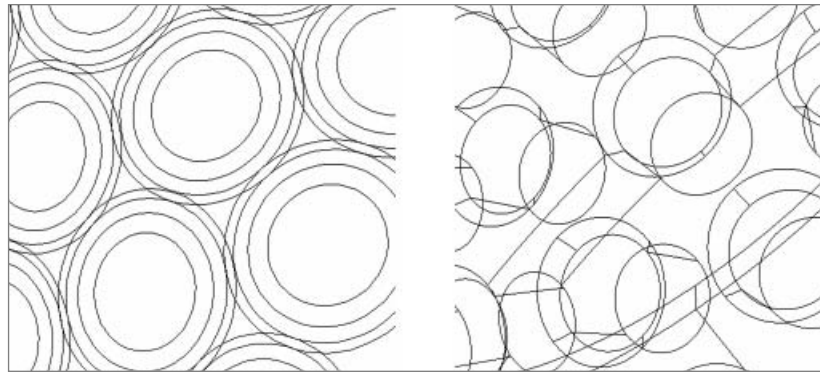


Figure 29

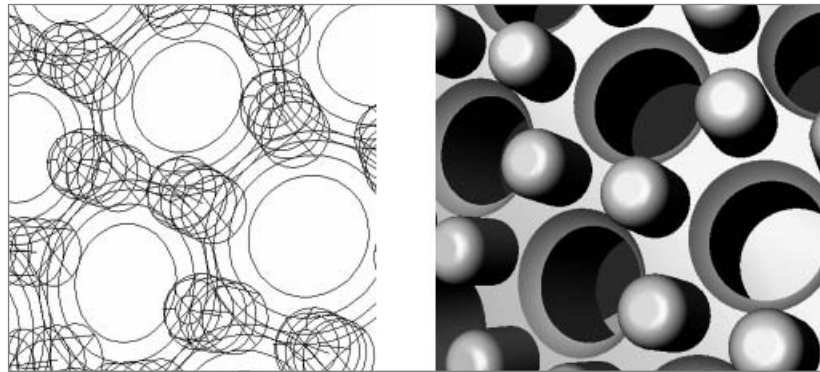



Figure 30

When doing this type of drawing in CAD, I draw a line from the quad of the girdle of the stone to the center of the stone and then draw a line straight down the distance off the surface that I want the stones to be. I group these two items and use the end of that line in the center of the stone for movements. I do the same line trick for prongs. I put a line from the center of the top of the prong and extend it down the height above the surface that I want the prong to extend. I group the line and the prong and then use that end point to orient my prongs on the surface (Figure 30). All prongs will be the right height and in the right orientation. I don't feel that you can group prongs and place them as well as you can do individually. If you follow the formula of using 37% of the maximum stone diameter as in Table 25, the prongs will fit right in between the stones and just touch the prong spacing circle of those stones. By using the circles and the lines inside my objects, I can set my CAD program's "O-Snaps" to their end and center functions to line up all my cutters, stones, prongs and other parts.

Table 25

Model setting dimensions for settings	Enter min. mm here	2.24
	Enter max. mm here	2.38
Pavé	Use these numbers	Description 
Hole through the plate	1.46	= min stone size x .65
Minimum plate thickness	1.79	= max stone size x .75 or a normal plate thickness of about 2mm
Prong height above plate	0.96	= max stone x .40 (minimum .70 mm)
Shared prong diameter	0.83	= max stone size x .35 (min of .65 and max of .9 up to 10 points)
Inner prong spacing (circular tool that fits between prongs)	1.95	= min stone x .87

If I were hand making this, I would make three or four thin circles of metal that were the diameter of the largest stone, plus 5%, and drill a tiny hole in the center of these circular plates. I would then arrange these small plates on my pavé plate surface and mark the center of each by using a sharp tool through the hole that I drilled in the center. Keep moving the plates around the pavé surface until you have covered what you need. I would then drill the holes through the plate for the stone seats if this was to be a hand-cut pavé piece, or I would first drill the holes for the prongs if I was going to solder in prongs instead. It is easier to drill and solder the prongs from the back, before you drill for the stones, because of possible thin metal issues. The steps for hand pavé are numerous and vary by setter, so I will leave that for another person's paper on hand pavé setting.

A MODEL MAKER'S ENGINEERING CHECKLIST

Table 26 below is a checklist that I use for each model maker and the models that they produce. When I am training a company's workers in technical model making, I am not just training the model makers, I am also training the workers to recognize production issues and how they can help to resolve them, ultimately making their own lives easier. I encourage the model makers to use the workers as a resource to help them help the company. No, it is not easy to get model makers to accept constructive criticism from the workers in a factory. And, it is also not easy to get the workers to use statements that are not offensive to the model makers. In a utopian factory, they all realize how essential this type of information exchange is for the health of the company, not to mention their own paychecks.

Table 26 Master/modelmaker engineering checklist

Picture	Model Maker	Inspector	Notes:
	Date Issued:	Date Started:	
	Complete 1	Date Inspected	
	Complete 2	Date Inspected	
	Complete 3	Date Inspected	

Model ID# _____

Production Issues (Have you considered the model impact for the following labor steps?)

Notes:	Checkbox	Mold cutting	Description
		Back cuts	When a mold is being cut, will the proper seam location be obvious and easily accessible?
		Shrinkage	Do the measurements of your model allow for the use of silicone rubber in order to achieve the best wax and cast surfaces?
		Seam Location	Did you plan the sprue location so that the seam will be in the optimum spot to minimize parting line elimination or removal?
		Thin rubber	Will a mold of this model have pieces of rubber that are so thin that they will distort as wax is injected around them or could break with minimal mold use?
		Parts	Should the model be made in 1 or in multiple parts for the best result in mold making, wax, and casting?
Wax Injection			
		Min pressure fill	Does the planning of the model and feed sprue allow for the minimum wax injection pressures to fill the mold?
		Turbulence	As wax is entering the mold cavity, have you minimized turbulent flow that could trap air in the wax or cause defects in the metal?
		part removal	Does the design of the model facilitate easy wax removal the wax from the mold?
		wax flow	Note: Wax injection sprues and casting sprues do not need to be the same sprue.
Tree building			
		Flow	When the molten metal is flowing into the cavity that was left by the wax part, has turbulent flow (backflow), been minimized for this design?
		Markings	Are the sprues marked so that the wax workers will know where to trim the sprue so that they fit into the designated flasks at the correct angle and quantity?
		Part/sprue Angle	Have you configured your part and sprue so that an 80° part to sprue angle can be achieved?
		Flask fit	At the 80° part angle, is there a better way to optimize the sprue configuration for casting that will allow more parts per tree? (ie. 5 parts per mold, bracelet)
Casting			
		Sprue Size and Shape	Does the size, configuration, and point of attachment of the feed sprues on this model match the guidelines for optimal casting practices?
		Min. temperatures	Is this model designed to fill at optimized casting system temperatures that will reduce gas liberation from the investment?
		Directional Solidification	When a casting of this model is cooling, will it cool in such a way (towards the feed sprue), as to minimize or eliminate shrinkage porosity?
		Turbulence	As molten metal is entering the investment mold cavity, have you minimized the possibility of defects related to turbulent metal flow that could cause non-fill?
		Sprue location, geometry defects	As molten metal enters the investment mold cavity, are there thin or weak points or sections that can break off and cause investment inclusions in the castings?
Cutting			
		Sprue Cutting	Will the parts be easy to remove from the tree on the first cut without distorting or damaging the castings?
		Minimal waste	Are the sprues attached so that a good close 2nd cut will minimize waste during later grinding operations?
Grinding			
		Sprue Location	Are feed sprues located in easily accessible areas such as on an outside radius that will reduce cutting time, material waste, and part damage?
		Grinding	Can grinding remove the bulk of remaining sprues easily and without damage to design, detail, or other parts of the casting without hand tool operations?
		Blending	Can all traces of remaining sprue and seams be easily blended using polishing motor operations rather than hand tools or Foredom operations.

Table 26 Master/modelmaker engineering checklist, continued

	Media	Models are not designed specifically so that they can be mass finished but you may need finishing media that will work with your design.
	Precautions	Can certain shapes and sizes of media get permanently lodged inside your parts.

Assembly

	Part precision	Is this model designed so that assembly functions and alignment of parts for assembly are simple and repeatable?
	Alignment	Are the parts for this model precise enough to optimize solder flow during assembly operations?
	Method	Have you designed for and have you designated the best method of assembly for this part, laser, torch, other?

Hand Setting

	Prong size	Are the diameters of the prongs in your model designed to handle the stone variance associated with the millimeter range of stones of their weight category?
	Inside/outside prong spacing	Is the spacing between prongs optimized to handle stone size variance and production needs?
	Prong height	Are your prongs the right height or will they require adjustments after setting to be correct?
	Quantity	Do you have the correct number of prongs for each stone that will ensure durability for this mounting?
	Layout	Does your model reduce or eliminate stone breakage problems associated with overlapping stone girdles?

Wax Setting

	Prong size	Are the sizes of the prongs in your model large enough to allow the metal to pass by the stone without freezing up if 30% - 50% of the prong is cut?
	Prong spacing	Is the spacing or placement of the prongs designed to allow metal flow between stones, especially in shared prongs?
	Prong height	Is the height of the prongs optimized to reduce hand and finishing labor for wax set stones?
	Stone variance	Have you planned the size of the prong and prong spacing to handle the minimum and maximum stone sizes of the designated range of stones?

Polishing

	Access	Does your design allow easy access using conventional finishing tools and equipment to all areas that require hand finishing?
	Pre-polishing (assembly)	If your model requires pre-polishing before assembly, have you considered the cleanup and final polishing after the assembly process?
	Pre-polishing (setting)	Will your model require pre-polishing before setting and have you allowed for the dimensional change that occurs during the polishing process?

Cleaning

	Access	Will it be easy to clean your design after hand setting and polishing so that no polishing compounds are trapped under stones or other areas?
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FUTURE ENGINEERING AND TECHNICAL MODEL MAKING II

Designing the inside of a ring is just as important to the success of a jewelry piece as the design and shape of the outside. Of course, the outside will determine if the piece will ultimately sell and, without sales, there is no point to manufacture. On the other hand, if the piece is not designed well on the inside and production problems occur as a result that cause the profit margin to be at zero or worse, then what was the point of making the piece in the first place?

Taking metal out of the inside of a jewelry design is not only about lowering the weight. It serves many equally important functions, but it must be done with great care and precision as shown in Figure 32. It can allow the customer's skin to breathe and be more comfortable to the wearer by reducing trapped irritants close to the skin. As has been discussed in many Santa Fe Symposium papers before, a properly engineered model is an integral part of the feed sprue system that directs the wax and metal in such a way that it reduces the probability of

manufacturing defects and increases the success rate and profit margins. I more often use the inside of a model to work with the natural laws of the materials than to meet weight requirements of marketing. Fortunately, they can often have the same outcome.

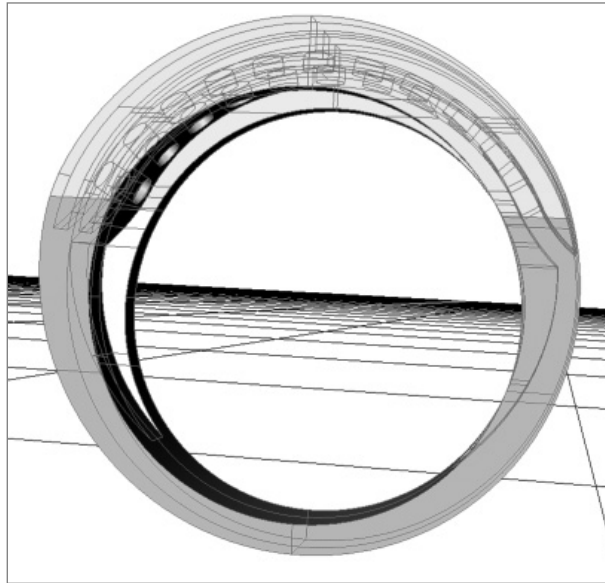


Figure 32

Subjects such as how to structure the inside of a jewelry model, how to shape the prongs, great sprue shapes and locations, really deserve much more specific and intense discussion. I want to see form filling, relationships of wax fill to metal fill, wax setting, stone heat sink relationships, and other subjects covered in greater depth.

No matter how much I write about it, words are no longer enough. Jörg Fischer-Bühner set the bar pretty high with his incredible 2005 Santa Fe Symposium presentation using the Magmasoft program that simulated many common casting questions. We need more computer simulations of directional solidification of actual jewelry model designs for weight reduction, reduced turbulence, etc. We also need a software program that is affordable for us common folks and one that is easy to use. In the meantime, I am saving my pennies and, hopefully, I can be the one to present these things using computer simulation software in my next presentation, *Technical Model Making II*.

The goal of this paper, as always, is to stir some debate and offer some information that might help our industry improve itself. This presentation was obviously not about making artistically beautiful designs—I will leave that paper for someone more qualified than myself to discuss marketable esthetics. It was simply about some mathematical ideas that help me make better engineered models. I hope that this paper is only part of a continually evolving picture here at the Santa Fe Symposium. I hope that others will continue to join in and document this type of information so that we all can benefit.