

Silicone

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An abbreviated lexicon for silicone

Annealing: in the case of silicone, annealing refers to its being heat treated during the vulcanization or curing process. Addition-crosslinked silicone can be annealed at temperatures up to 150 °C in order to accelerate the crosslinking process. When annealing, it should be noted that the zero position of the mould, which follows from its expansion as a result of being heated, will only be reached again at the temperature under which it was annealed. If, then, you compare at room temperature the annealed mould with the master pattern it will be much more shrunken than it would be if the crosslinking had taken place at normal temperatures.

In order to establish a reference value for the acceleration of vulcanization, the following rule of thumb applies: the de-moulding time will be shortened by about 10 minutes for every 1 °C temperature rise above 23 °C. In order to keep the above described shrinkage to as small a level as possible, it is recommended that any annealing be done at temperatures lower than the 150 °C maximum. Condensation-crosslinked silicones cannot be annealed!

Block mould: in contrast to flexible moulds, a block mould is one that has thick walls and inherent stability. These moulds, which are more than 3 cm thick, are produced by casting and this can usually be managed without the use of a mother mould. Because single piece block forms must be carefully cut during de-moulding, we recommend the use of transparent or translucent (addition-crosslinked) silicone.

Casting frame: a casting frame is the "box" which is built around the master pattern in order to be able to pour the silicone. If condensation-crosslinked silicone is used, the casting frame must be open to allow the resulting cleavage products to volatilise and the rubber to take on air moisture. When working with addition-crosslinked silicone, however, a closed casting frame with an opening for the pour can be erected because that type silicone does not produce any cleavage products. If the crosslinking reaction is to be speeded up by means of annealing (only possible with addition-crosslinked silicone) it must be kept in mind that the casting frame must be made of correspondingly temperature resistant material.

The size of the casting frame in relation to the master pattern is determined by the desired wall thickness of the mould. The softer the silicone or the larger the master pattern, the thicker the walls should be so that the mould will be able to stand on its own. If necessary, an alternative would be to employ a mother mould (support casing) – see, "Glove process/Flexible mould"

Cleavage products: as a rule, these are undesirable materials which come into being as a result of a reaction between two or more chemicals. In the case of the vulcanization of condensation-crosslinked silicone, cleavage products are produced which must evaporate before the mould can be used for the first time – with the result that a small amount of shrinkage will occur in the silicone rubber.

De-moulding time: the de-moulding time refers to the amount of time that silicone requires in order to cure enough that it can be de-moulded. The times given for each individual product are predicated on a temperature of 23° C – at higher temperatures the times are shorter, at lower temperatures they are longer. In the case of addition-crosslinked silicone, the de-moulding time can be considerably shortened by means of annealing. Total and complete curing, however, will usually not be achieved until after a few days.

Ecology: regardless of the type of crosslinking, non-cured silicone components belong neither in the household trash nor in the plumbing but must instead be disposed of as hazardous waste because they are not bio-degradable. Cured silicone can be disposed of in household trash without any environmental concern.

Elasticity: elasticity is the ability of a material to recover its original form after being deformed through some external force.

Elastomer: elastic plastic (see also, Chapter A "Plastic", introductory information)

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Elongation at Tear (%): elongation at tear describes the amount of stretch in relation to the original length of the material at which the silicone will finally tear. For complicated moulds with significant undercuts, silicone with a high elongation at tear should be used because the material will be exposed to a great deal of tractive force (pulling) during de-moulding.

Fillers: silicone is provided with fillers in order to make it less expensive, to influence its attributes (e.g. to achieve a specific Shore hardness) or to induce the vulcanization process.

Both components of silicones with fillers – e.g. all condensation-crosslinked silicones – must always be thoroughly stirred because the fillers will fall out through sedimentation to the bottom of their containers after a long period of time. In the case of silicone which does not contain fillers, it is component B that must be stirred if it is one of the usual types which are coloured in order to distribute the colour pigments evenly throughout before being added to component A (the colouring makes the mixing process that much more obvious).

“Glove” process/Flexible mould: in the “glove process”, a mould is made that is so thin that after curing it can be rolled off like a glove. These so-called “flexible” or “skin” moulds, which have a thickness of less than 2 cm, are advisable when, for reasons of cost, less silicone is to be used or when you are making a mould for an object with significant undercuts. Because the de-moulding of such master patterns often requires a great deal of strength in order to stretch the silicone over the undercuts, a thinner mould has the advantage that it will be that much easier to remove. For this reason, when making such a thin, flexible mould, the most stretchy and tear resistant silicone with a low Shore hardness should be chosen.

The first step in making a skin thin mould is to apply a thin coat of the silicone with a brush. As soon as that coat has begun to form, a thixotropic (pasty) silicone should be then applied with a spatula for as many coats as is required to attain your desired thickness. In the process, coats of condensation- and addition-crosslinked silicones should NOT, under any circumstances, be applied one on top of the other.

In order to stabilize the (wobbly) flexible mould so that a cast can be made, a mother mould (support casing) must be formed around the outside of the silicone mould while the master pattern is still within it. Because this mother mould must be removed before peeling the mould skin off, care should be taken when applying the last coat of silicone that all undercuts are filled in with more silicone and smoothed over so that when the inflexible, solid mother mould is eventually removed there will be no points of restriction.

After the silicone mould has cured, the mother mould can be made from, logically, a firm, sturdy material. For this purpose, materials such as epoxy resin laminate, fibre glass reinforced acrylic/plaster putties or simple plaster bandages will work great. These materials are to be applied to the silicone mould after the last silicone coat has cured. Before that application, however, a release agent should be applied to the mould skin so as to prevent the silicone mould from sticking to the mother mould. As soon as the mother mould has cured, it can be removed from the silicone mould and reworked as necessary so that it will be able to perform its support function during any future casting work.

At this point, the mould skin should be slowly and carefully removed from the master pattern and positioned in the completed mother mould. The silicone mould should not only be placed in the mother mould for the subsequent reproduction work but also stored there when not in use so as to prevent it from being damaged or losing its shape.

Another method to make thin walled moulds is the casting process. In this process, the master pattern should first be loosely surrounded by a coat of plasticine (sulphur-free, not inhibiting!). Because this coat will eventually serve as a place holder keeping free the area where the silicone mould will form, it should be as thick as you want the mould to be. Here too, care must be taken that the outer side of the plasticine is shaped in such a way that, when later the mother mould is removed, there

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will be no points of restriction. It is not necessary that the plasticine make a snug fit with the master pattern.

Now the mother mould, which can be either single or multiple pieces, should be attached to the outside of the plasticine coat. In doing so, attachment points should be constructed with which the mother mould can eventually be securely attached to the master pattern. In so far as we are dealing with a closed mould, a pouring port should be made through which the silicone can later be poured.

After the mother mould has cured, it should be removed followed by the master pattern then being removed from the plasticine (or vice versa, if you will). The plasticine can be used again but, if that is to be as a place holder again, it can only be for a moulding process that uses silicone with the same type of crosslinking because otherwise there is a definite danger of inhibition taking place. At this point, the mother mould should have a release agent applied to the inside area, plasticine used to seal any leaky areas and finally it should be attached at the prepared attachment points to the master pattern. You are now ready to pour your low viscosity silicone mixture. The silicone will form into a mould in the space that had previously been held by the plasticine.

Inhibition: inhibition is the disruption of the vulcanization process by substances that have attributes that interfere with it. Disruptions of vulcanization appear at the contact area between a model or casting frame and the silicone mixture and can normally be traced back to "unclean" work practices. Inhibited silicone either does not cure at all or only at a decelerated rate – it remains gluey or even viscous on the surface. We therefore recommend that a preliminary test always be made. Things that can cause inhibition include:

- Too little or too much moisture
- Interlinkages containing sulphur (chlorine and butyl rubber, certain plasticines, etc.)
- LSR or RTV type silicones catalyzed with metallic salts
- Stabilizers and plasticizers (e.g. in soft PVC)
- Amine hardener in epoxy resin
- Various organic solvents like, for example, ketones, alcohols, ether, etc.

Inhibition risks are primarily associated with the vulcanization of addition-crosslinked silicone. A fundamental requirement for an undisturbed crosslinking is absolute cleanliness and conscientious work habits. In this regard, we would like to make clear that even the tiniest amount of an inhibiting substance is enough to disrupt the vulcanization of this type of silicone. If, for example, the master pattern is hung in the casting frame with bare hands, microscopically small amounts of inhibiting substances can contaminate the handled area of the model to such an extent that inhibition will take place at that spot. When working with addition-crosslinked silicone we therefore recommend that all objects which come into contact with the silicone mixture be thoroughly cleaned with acetone or a benzene cleaner.

Condensation-crosslinked silicone, on the other hand, is much less prone to inhibition as long as it is worked with in temperatures between 20 °C and max. 50 °C. There is a small risk of inhibition if too little moisture is present in the atmosphere because this type of silicone depends upon a certain amount of moisture for vulcanization to take place. For this reason, master patterns made out of absorbent materials like plaster or wood should be moistened with water before being moulded or, even better, sealed and treated with a release agent in order to prevent moisture from being extracted from the silicone. For the same reason, condensation-crosslinked silicone should not be poured into closed moulds because none of the atmospheric moisture will be available to the silicone during vulcanization.

Because condensation-crosslinked silicone has a small amount of water in it's A component, and this is necessary for vulcanization, it can be that after a long storage period it will not cure or will only cure very slowly and will also stick to the master pattern. In such a case it is possible to stir in an additional one to two percent amount of water in order to restore the reaction capability of the mixture. The silicone component must subsequently be stored for at least 24 hours in a tightly closed container.

Interlinking: see "Vulcanization".

Master pattern: in order to maintain clarity in the terminology regarding the various types of models and moulds, the object that is to be the basis for a mould – i.e. the original – is called the master pattern.

Mother mould: a mother mould is a necessary aid for flexible moulds to help in stabilizing the thin walls to such an extent that the reproduction material can be poured into the mould without deforming it. (see, "Glove" process/Flexible mould).

Release Agents: release agents are used in making moulds as well as in the making of reproductions (moulded pieces). They prevent the different materials from sticking to one another.

Despite the self-releasing qualities of silicone, we still recommend that release agents always be used when making moulds in order to avoid inhibition malfunctions and to prevent the eventuality that any potentially sticky substances present on the master pattern will make removal of the silicone mould extremely difficult. Even glass, glassy surfaces and enamel should always be coated with a release agent because silicone rubber will stick to those materials as well.

Master patterns made out of porous materials (wood, plaster, clay, natural stone, cement, etc.) should always be coated with a release agent in order to prevent the moulding material from penetrating the master pattern with the result that the silicone and master pattern will be mechanically interlocked by the silicone in the pores or the silicone will discolour. Suitable pore-sealing release agents include methyl cellulose or soapy water.

When making (large) silicone moulds which require two separate halves, after the first half has been created, it must be treated with a release agent (after it has cured) at the point where the second half will meet the first because the mould casting material of the second stage will otherwise stick to the fresh silicone rubber at that point even though it is in fact cured.

When making reproductions using silicone moulds, a release agent is not actually necessary because of the self-releasing attribute of the silicone rubber itself (with the exception of epoxy resins). Moulds that are not self-releasing (polyurethane, latex, gypsum, etc.) must definitely be treated with a release agent. If you are working with a material that will require subsequent painting, you must take care that the release agent will take to being painted because, at the time of de-moulding, traces of the release agent can remain stuck to the cast piece. There is also the option that you can thoroughly clean the cast object and that way remove any remaining release agent traces before painting it. For this method, benzine cleaner or turpentine can be used.

The following can be used as release agents: low viscosity or pasty wax dispersion, silicone oil (release agent spray, silicone spray), polyvinyl alcohol, sulphur-free vaseline (pharmacy quality) either "as is" or dissolved in benzine cleaner, and many more.

Service life: silicone moulds only have a limited service life, i.e. they can only be used a limited number of times for reproductions. In this regard, addition-crosslinked silicones are longer-lasting because during the interlinking process, in contrast to condensation-crosslinked silicone, no cleavage products, which in the long term will lead to the mould becoming brittle, are produced. The number of castings that can be made with a silicone mould depends on a number of variables:

- Corrosiveness and temperature of the reproduction material: epoxy resins are very aggressive and produce heat during curing but polyester and PUR resins will also cause cured silicone to become brittle. Molten tin, because of its high temperature, will wear out the mould more quickly.

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- Geometry of the mould: significant undercuts represent a real test for the mechanical resilience of the silicone during de-moulding – the material becomes brittle more quickly as a result of this stress.
- Aeration of the mould: if the mould is given time overnight to aerate between pourings or if it is sprayed with silicone spray or rubbed from time to time with silicone oil, the service life will be considerably lengthened.
- Storage of the mould: silicone moulds are best stored in a dark place (no UV radiation) at temperatures around 20 °C.

Shore hardness: Shore hardness is a measurement of the relative hardness or softness of a material. In the case of soft materials like, for example, silicone, it is given as Shore A (Sh-A). Harder materials use other types of Shore measurements (e.g. Shore D for cured PUR casting materials). When choosing a silicone for a particular task, Shore A, along with the type of vulcanization and tensile strength, is one of the most important criteria. The higher the Shore hardness number, the harder the material. The Shore hardness of a silicone – depending on the batch – is always somewhat different and can, as a result, only be given as a ± 2 value. If you are working without a mother mould, the mould material you use should be correspondingly harder as the model gets larger because otherwise your mould will not be able to hold its shape.

Shrinkage, linear: silicone shrinks somewhat during the curing process. Depending on the planned use, the dimensional stability of the silicone can be extremely important. For uses in, for example, dentistry, but also in precision model making, the demands of exactness on the moulding process are very high.

In these kinds of use, addition-crosslinked silicone should be chosen because this type does not release cleavage products with the result that the vulcanization is practically free of shrinkage. Condensation-crosslinked silicones produce volatile alcohols during the crosslinking reaction which then evaporate during the de-moulding time and thereafter. This process causes the material to shrink slightly (approximately 1% linear).

Tear Propagation Strength: the tear propagation strength measures the amount of force required to completely pull apart silicone that already has an incision in it. It is measured on a piece of silicone that is 1 mm thick and the value is given as N/mm (newtons per millimetre).

Temperature resistance: silicone can be used on a sustained basis at temperatures up to about 180 °C and for short periods of time can be used at temperatures up to about 220 °C. Addition-crosslinked silicones are more temperature resistant than condensation-crosslinked ones. In order to produce a silicone with higher temperature resistance, there are a number of systems on offer which utilize especially temperature resistant (heat dissipating) fillers. It should be noted, however, that the mechanical attributes will always be negatively influenced as a result of this additive. If silicone is exposed to high temperatures, it will definitely begin to become brittle which will then lead to an increase of the Shore hardness, to the diminishing of its mechanical resilience and, long term, to the loss of its self-releasing ability.

Tensile Strength: tensile strength describes the amount of strength that is required to tear a silicone with a defined profile. It is measured in N/mm² (newtons per sq. millimetre).

Thixotropic: two-component silicone is referred to as thixotropic when, after being freshly mixed, it has such high viscosity that it will not run off even when placed on a vertical surface. Thixotropic silicones are available as a ready-made product (e.g. Modasil V 55) or can be created by mixing a thixotropic agent into a low viscosity silicone. When doing so, it should be noted that the thixotropic agent must react with the silicone mixture – this reaction will take about 10 to 15 minutes before it is completed. Thixotropic agents can therefore not be used with silicones with extremely short working lives.

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Thixotropic silicones should always be used when a mould cannot or should not be poured. This is, for example, the case, when fixed mounted pieces, very large models or models with significant undercuts are to be moulded. In such cases, the thixotropic silicone rubber is applied to the master pattern in successive steps beginning with a brush and ending with a spatula. Because only a coat of thixotropic silicone up to a certain thickness will not run, a number of coats should be applied to the still sticky previous coat in order to achieve the desired mould thickness (see also, the entry "Glove" process/Flexible mould).

Transparency/Translucence: in the case of single piece solid moulds which must be cut during de-moulding, translucent or transparent silicone should be used in order avoid harming the master pattern because it can be clearly seen during the process. Transparent silicones are also better suited for complicated moulds so that the subsequent pouring process can be monitored and the build up of bubbles be prevented.

Undercuts: an undercut is a recess or an elevation of a model's surface that goes in a reverse direction. An example of this is the neck of a torso which is to be moulded in one piece: the mould material must be pulled up over the much thicker head. Master patterns with significant undercuts must be moulded with the most flexible and tear resistant silicone possible as well as one that has a low Shore hardness because de-moulding will require a great deal of tractive force (pulling).

Vacuum device: a vacuum device is used to rid bubbles from a freshly mixed batch of silicone rubber. In the process, the mixture is placed in a mixing container in a vacuum chamber and de-aerated at 30 to 50 millibars.

During this process, the so-called evacuation, the silicone mixture expands to about 3 to 5 times its original volume – this means that a much larger container must be used to allow for that expansion – and the air bubbles rise to the surface (the mixture looks like it is "boiling"). The de-aeration process can be accelerated if the vacuum is interrupted several times for periods of short duration. After a few minutes, the silicone mixture returns to its original volume and the de-aeration process can be halted.

Whether a silicone must be de-aerated in a vacuum or is allowed during its working life to de-aerate on its own depends on its viscosity and the duration of its working life. A longer working life provides more time for the silicone mixture to de-aerate. Starting at a viscosity of approximately 30,000 mPa-s (see "Viscosity") it is recommended that silicone be de-aerated by means of a vacuum device.

Viscosity: viscosity describes the ability of a material to flow. Among other things, it is dependent on temperature and is measured in millipascal seconds (mPa-s). The higher the value given, the more viscous the silicone; the lower the value, the more the silicone will flow (low viscosity). When the viscosity is about 30,000 mPa-s or more, it is recommended that silicone be de-aerated by means of a vacuum device.

Vulcanization: the chemical interlinking of the two silicone components is called vulcanization – the silicone mixture turns into a rubber elastomer. There are two types of vulcanization: addition-crosslinking and condensation-crosslinking (see above). At lower temperatures (in a refrigerator) the vulcanization takes place more slowly while heating the mixture (warm water bath), on the other hand, will accelerate it.

Vulcanization disruptions: see "Inhibition"

Working life: working life refers to the time, beginning at the mixing stage, that the silicone is still capable of becoming an elastomer rubber. A more exact definition would be the time required for the silicone to double its viscosity. It therefore makes sense to always only mix up the amount of material that can be successfully used during the prescribed time. When working without a vacuum device, silicone with a longer working life allows you to take the necessary time for removal of the bubbles created during mixing and thereby to produce a final mould with less bubbles.

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The working life of a silicone can be adjusted by the manufacturer to within a certain range. The times given at the individual products are predicated on a working temperature of 23 °C; at higher temperatures (warm water bath) the working life is shortened, at lower temperatures (refrigerator) it is increased.

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