

Renishaw Vacuum Casting Techniques User Guide





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Contents

Contents

1 Before you begin1
1.1 Disclaimer
1.2 Trademarks
1.3 Warranty
1.4 Changes to equipment1
2 Introduction
2.1 The mould
2.2 Vacuum casting materials
2.3 Health and safety information
2.4 Suggested personal protective equipment (PPE)
3 Steps to vacuum casting
3.1 Prepare the mould
3.2 Cast the component
4 Prepare a model
4.1 Preparation
4.2 The parting line
5 Make the mould
5.1 Patterns needing no clay support11
5.1.1 Marking
5.1.2 Gating
5.1.3 Preventing air entrapment
5.1.4 Venting
5.1.5 Undercuts
5.1.6 Inserts

5.1.7 Casting frame/moulding box
5.1.8 Suspending the model14
5.1.9 Costing the silicone model14
5.1.10 Primary de-gassing of the rubber15
5.1.11 Casting the rubber mould15
5.1.12 Secondary de-gassing16
5.1.13 Curing the mould
5.1.14 Separating the mould
5.2 Patterns needing support in modelling clay
5.2.1 Embedding the model
5.2.2 Venting
5.2.3 Casting the first half18
5.2.4 Casting the second half
6 Prepare the mould for casting
7 Resin handling and preparation
7.1 Storage
7.2 Prepare the resin
7.3 Remove from the oven
7.4 Calculate the amount of resin
7.5 Weigh the resin
7.6 Resin temperature
7.7 Clean
8 Vacuum casting
8.1 Prepare to cast
8.2 Set the vacuum casting machine
8.3 Cure and de-mould
8.4 Deformity
8.5 Mould storage
9 Technical assistance



1 Before you begin

1.1 Disclaimer

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All other brand names and product names used in this document are trade names, service marks, trademarks, or registered trademarks of their respective owners.

1.3 Warranty

For equipment requiring attention under warranty contact your equipment supplier.

Unless otherwise specifically agreed in writing between you and Renishaw, if you purchased the equipment from a Renishaw company, the warranty provisions contained in Renishaw's CONDITIONS OF SALE apply. You should consult these conditions in order to find out the details of your warranty, but in summary the main exclusions from the warranty are if the equipment has been:

- neglected, mishandled or inappropriately used; or
- modified or altered in any way except with the prior written agreement of Renishaw.

If you purchased the equipment from any other supplier, you should contact them to find out what repairs are covered by their warranty.

1.4 Changes to equipment

Renishaw reserves the right to change equipment specifications without notice.

Vacuum casting techniques user guide

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2 Introduction

2.1 The mould

Moulds used in the vacuum casting system are made of silicone rubber. The grades recommended by Renishaw have been thoroughly tested for suitability and will produce moulds with high accuracy of replication from the original models.

Air or gas inclusions that might occur during mixing are liable to cause distortions that vary in effect at different stages, including distortions of the finished items. For best results it is necessary to de-gas the mixture under vacuum before the mould is formed.

2.2 Vacuum casting materials

The castings are produced from specially formulated polyurethane (PU) resins or nylon.

The resin is usually a two-part mixture. Part A is based on a polyol (such as a polyester or polyether) with catalytic additives, while part B is invariably a methylene diphenyl di-isocyanate, known as MDI. Selection can be made from more than 20 available formulations that provide various combinations of hardness, toughness and flexibility. Some formulations require a third part, C, typically a catalyst, special instructions will be supplied for the order of mixing.

It is possible to add colouring material to part A (polyol) without affecting the quality of the final product; this is recommended for maintaining consistency of colour throughout long production runs. Not all pigments are compatible with polyol, and you are strongly recommended to use pigments from the range offered by Renishaw that have already been tested and shown to be suitable.

2.3 Health and safety information

All materials should be stored safely and used in accordance with the recommendations of the Safety Data Sheets and elsewhere in this user guide. Safety data sheets (SDS) in standard format are supplied where necessary for each component of both Renishaw vacuum casting resins and Renishaw silicone rubber, as well as for ancillary products such as cleaning agents. www.renishaw.com/vaccast-datasheets

Part B of the casting resin is an isocyanate (MDI) with very low vapour pressure (approximately 0.01 Pa (0.00009 mmHg (0.0000035 in.Hg) at 25 °C (77 °F)), which can be safely handled without special precautions against inhalation at working temperatures below 40 °C (104 °F). A risk assessment should be made for those parts of the process in which the unmixed Part B casting resin is maintained at a higher temperature, using the current occupational exposure standard, to reveal any need for special control. For information on the use of isocyanates in general, please contact your Renishaw distributor for specific information on government publications.

2.4 Suggested personal protective equipment (PPE)

The PPE guidance shown below may be used to consider the risks which may or may not be present. The user should make their own assessment of risks depending upon the exact circumstances of use.

PPE symbol	Hazards	Options
mp2	Abrasion; Temperature extremes; cuts and punctures; impact; chemicals; skin irritation.	Gloves, gauntlets
		Note: Do not wear gloves when operating machines where gloves might get caught. Care in glove selection is needed.
	Chemical or metal splash; dust; projectiles.	Spectacles, goggles, visors.
		Note: Make sure the eye protection chosen has the right combination of protection for the task.
	Wet; slipping; falling objects; heavy loads; metal and chemical slash	Safety boots and shoes.
		Note: Consider conditions of use.
	Heat; chemical or metal splash; spray from pressure leaks; impact; entanglement of own clothing.	Conventional or disposable overalls, aprons.
		Note: Consider choice of materials in relation to the chemicals involved.
B	Dusts; gases and vapours.	Disposable respirators, half masks or full face masks, powered respirators.
		Note: The right type of respiratory equipment must be used for the substance being handled.
	Impact noise; intensities; pitch.	Ear plugs or defenders.
		Note: Refer to any applicable Noise legislation and regulations in the territory where the equipment is used.



5

3 Steps to vacuum casting

3.1 Prepare the mould

1. Prepare the master model.



Figure 1 Master model

2. Make a casting frame and set up the master mould, typically a box made from a smooth surfaced material such as laminted chip board.



Figure 2 Casting frame

3. Measure and mix the silicone rubber.



Figure 3 Mixing silicone rubber

4. De-gas the silicone rubber in the vacuum chamber.



Figure 4 De-gas the silicone

5. Cast the silicone rubber mould.



Figure 5 Cast the silicone rubber mould

6. De-gas further in the vacuum chamber.



Figure 6 De-gassing further

7. After curing, separate the mould by cutting at the predetermined parting line. The cut should be deliberately rough to key or locate the mould halves when re-asembling.



Figure 7 Separate the mould

8. Finished mould.



Figure 8 Separate the mould



3.2 Cast the component

1. Assemble the silicone mould with tape and preheat to the recommended temperature.



Figure 9 Assemble the mould

2. Measure out the polyurethane resin components. Renishaw supply cup and cup liners.



Figure 10 Measure the resin components

3. Place the mould and resins in the vacuum casting machine and select the operating mode. Mix the resin (components A and B). Cast the resin. When mixed, insert a funnel into the mould.



Figure 11 Mixing and casting

4. Cure the resin in the oven at 70 °C (158 °F).



Figure 12 Curing in an oven

5. Separate the mould parts, release the component and trim off the gates and runners.



6. Finished component.



Figure 14 Finished component



4 Prepare a model

4.1 Preparation

- 1. Examine the master model and decide on the parting line and the position of the gate.
- 2. Thoroughly clean the model and if necessary, apply Renishaw barrier film.



Figure 15 Finished component

4.2 The parting line

- 1. Establish the parting line, either by embedding the model in plastic modelling clay, or by using clear adhesive tape. Taping, the most commonly used method, is the quickest way of making the mould.
- 2. Although such cases are very rare, there is no alternative with some objects to embedding the model (left) in plastic modelling clay. This requires a different technique, in which two parts of the mould are made sequentially (see Section 5.2).



Figure 16 Parting line

Vacuum casting techniques user guide

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5 Make the mould

5.1 Patterns needing no clay support

5.1.1 Marking

- 1. Apply clear tape to the parting line and colour the edge of the tape with a marker pen to assist in cutting the mould into two halves.
- To avoid silicone inhibition use only Renishaw recommended tape.
- Models made by stereolithography should be coated with a barrier coat or painted before taping.
- Certain types of paint and filler inhibit the curing of silicone rubber. Use a Renishaw barrier coat on any suspect surfaces, or carry out an appropriate test to determine the material's suitability.



Figure 17 Marking

5.1.2 Gating

- 1. The correct size and number of gates depends on the size, shape and weight of the component. Multiple gates require a longer finishing time, but give better castings. Gates should always be positioned on the rear side of the mould.
- 2. After taping the model, form the gates by gluing ABS or nylon rod to the model in the chosen places. The diameter of the gate should be either 10, 15 or 20 mm (0.39, 0.59 or 0.78 in.), as needed to match the hose connectors. A two-gate system using a 15 or 20 mm (0.59 or 0.78 in.) rod can be used with two-way hose connectors.



Figure 18 Marking

5.1.3 Preventing air entrapment

- 1. During the mould-making operation it is possible for air to become trapped in deep pockets in the mould, even though the rubber is de-gassed.
- 2. Small holes approximately 1 mm (0.039 in.) in diameter should be drilled in the mould to prevent this.



Figure 19 Preventing air entrapment

5.1.4 Venting

 When resin components are mixed together, the chemical reaction that takes place releases a small amount of gas. To prevent imperfections being formed in the components, vents should be placed where gas bubbles are likely to accumulate. The vents are formed by using 1.5 to 2.5 mm (0.059 to 0.098 in.) brass rod, that can be secured to the model with contact adhesive.





5.1.5 Undercuts

1. Although the silicone rubber moulds are flexible, it is advisable, in order to achieve longer mould life, to eliminate any undercuts. This can be done in simple cases by using tape, or by using loose pieces in the mould when the undercut is severe.



Figure 21 Undercuts

5.1.6 Inserts

1. Deep, small diameter holes or rectangular orifices in the component should be made by embedding metal inserts into the mould.



Figure 22 Inserts

5.1.7 Casting frame/moulding box

1. Construct a casting frame from ABS or laminated chip board. Leaving one side of the casting frame loose enables easier access and simplifies the operation. The size is arbitrary, but as an example the dimensions of the frame, assuming a model is 300 wide x 300 long x 30 mm high (11.81 x 11.81 x 1.18 in.), would be approximately 380 x 380 x 110 mm (14.96 x 14.96 x 4.33 in.). The extra height on the frame is needed to contain the silicone rubber during the secondary de-gassing operation. On larger moulds, the dimensions of the frame should be increased proportionately. Mounting props (of 8 to 20 mm (0.31 to 0.78 in.) diameter) in the casting frame makes it possible to set the position very precisely. This filling level mark practice is recommended for patterns that are large and heavy, thin-walled or of more than two sections.





5.1.8 Suspending the model

1. Suspend the model by taping it to the sides of the box with bridges of clear adhesive tape. For heavy patterns, extra props can be fixed inside the bottom of the frame. To avoid flash caused by penetration of the silicone, a single strip of film should be stuck between the frame and the parting line, (Figure 24).





5.1.9 Costing the silicone model

1. Determine the weight of rubber needed. To do this, calculate the cubic capacity of the finished mould and multiply by 1.1, the specific gravity of the rubber, for example:

mould size 2500 cm³ (152.56 cu. in.) x 1.1 = 2.75 kg (6.06 lbs) rubber

- The amount of catalyst needed is typically 10% by weight of the rubber, refer to the mixing instructions for the material being used.
- The mould height should be taken as being approximately 30 mm (1.18 in.) above the highest point of 5 models stacked on top of each other, and not to the top of the casting frame.
- 2. Pour the rubber into a container with capacity approximately five times greater than the amount of rubber (the extra space allows for the temporary increase in volume during de-gassing). Add the catalyst and mix thoroughly.





Figure 25 Casting the silicon rubber

5.1.10 Primary de-gassing of the rubber

1. Place the container inside the vacuum chamber and apply vacuum. As the silicone rubber will expand approximately five times in volume, it is essential to watch the operation carefully until primary de-gassing is complete. Should the level of the rubber reach the top of the container, press the FAST LEAK control once or twice to reduce the level in the container. Primary de-gassing can be considered complete 5 to 10 minutes after the level of the liquid in the container has collapsed.



Figure 26 Primary de-gassing of the rubber

5.1.11 Casting the rubber mould

1. After primary de-gassing, pour the liquid slowly and steadily into the casting frame. To avoid any disturbance, make sure that the rubber initially flows under the bottom of the model. Pour very carefully, avoiding any sudden rush of rubber into the mould or on to the pattern surface.





5.1.12 Secondary de-gassing

1. Place the mould in the vacuum chamber and carry out the same procedure as described above (Section 5.1.10, Primary De-gassing). Secondary de-gassing is normally complete in 10 to 25 minutes, the exact time depending on the volume of rubber.



Figure 28 Secondary de-gassing

5.1.13 Curing the mould

 Although silicone rubber may be left to cure at room temperature overnight, it is recommended that, for high dimensional accuracy in the castings, the rubber is cured in an oven at 40 °C (104 °F) for at least 4 hours. As curing time is mould size dependent, to ensure curing is complete 8 hours at 40 °C (104 °F) is recommended.



Figure 29 Casting the rubber mould



5.1.14 Separating the mould

- 1. When the mould is fully cured, remove the casting frame and venting gate rods and, using a sharp scalpel and the special mould openers, cut into two halves. To make the two parts fit back together more readily, make the cut along an undulating line.
- 2. To help identify the correct line while cutting, draw it on the outside of the mould with a marker pen, following the contour of the taped split lines. After cutting, the mould is ready for resin casting.



Figure 30 Separating the mould

5.2 Patterns needing support in modelling clay

Note:

Modelling clay – some types of modelling clay inhibit the curing of silicone rubber. It is advisable, before use, to test a product for suitability.

5.2.1 Embedding the model

- 1. Prepare a casting frame, as for a model needing no support. Embed the model, complete with gate up to the split line, in clay that has been packed into the frame.
- 2. Cut into the modelling clay one or two location points that will help ensure perfect matching of the mould halves.



Figure 31 Embedding the model

5.2.2 Venting

1. Fix vents to the model in the way described for 'patterns needing no clay support' (see Section 5.1).

5.2.3 Casting the first half

Note:

1. Prepare and de-gas silicone rubber for casting as if for 'patterns needing no clay support' (see Section 5.1), and cast it over the model and clay, filling the frame to the marked level. Allow the mould to cure at room temperature.



DO NOT carry out a secondary de-gassing in the vacuum chamber. This would disturb the modelling clay, which is also liable to de-gassing.

2. When fully cured, remove the clay without disturbing the model.

5.2.4 Casting the second half

- 1. Clean the surface of the first half-mould with methanol and apply a Renishaw barrier coat. Return it to the casting frame, with the model still embedded and uppermost.
- From this point, the procedure follows that for 'patterns needing no clay support' (see Section 5.1), including secondary de-gassing. Separate the parts with the mould openers.





6 Prepare the mould for casting



Note:

Careful attention to cleanliness is essential. The vacuum casting technique will exactly reproduce every imperfection and blemish of the mould.

- 1. Moulds made in a single step will normally be clean enough for use after the halves have been separated, but the two-stage moulds made by embedding in modelling clay should be scrupulously cleaned with methanol.
- 2. The separate halves of the mould must be preheated in an oven set at 65 to 70 °C (149 to 158 °F) (it is important to set this temperature correctly). After removing them from the oven, apply release agent if required and tape the two parts together. Use an adhesive fabric tape, and make sure that the vent holes are not obstructed.



Figure 33 Preparing the mould for casting

3. Return the assembled mould to the oven while the resin is being prepared.

Vacuum casting techniques user guide

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7 Resin handling and preparation



WARNING:

READ THE APPROPRIATE SAFETY DATA SHEETS FOR THE MATERIALS BEING USED BEFORE HANDLING THE RESINS AND OTHER AGENTS. www.renishaw.com/vaccast-datasheets

7.1 Storage

- 1. The component B is liable to crystallise at low ambient temperatures. Ideally, both resin components (A and B) should be stored at a minimum temperature of 20 °C (68 °F).
- 2. Polyurethane (PU) resin components are hygroscopic, and will absorb water. Never leave cans open to the atmosphere for long periods and replace caps when not in use.





7.2 Prepare the resin

 Open both cans and examine B for signs of crystallisation. Close the cans and place both cans in oven for 2 hours at 70 °C (158 °F) (this will re-dissolve any crystals that may have formed). If excessive crystallisation has occurred in component B the time may need extending to 4 hours.



Figure 35 Preparing the resin

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WARNING: ENSURE CANS REMAIN CLOSED UNTIL COOLED BELOW 40 °C. PRECAUTIONS MUST BE TAKEN TO AVOID THE INHALATION OF VAPOUR WHEN RESIN IS AT ELEVATED TEMPERATURES.

7.3 Remove from the oven

1. Remove the cans from the oven and thoroughly shake or stir both cans. Ensure there is no cross contamination between the two cans by using dedicated mixing tools.

7.4 Calculate the amount of resin

1. In most cases the model will have been fabricated, machined or formed from plastic. To determine the approximate amount of resin required, weigh the model and apply the following simple formula:

Weight of master model x specific gravity (SG) of resin

2. Add an allowance for loss in cups, funnels and vents during casting, examples are:

Master model weight 100 g (0.22 lbs) x SG of resin +100 g (0.22 lbs)

Master model weight 500 g (1.1 lbs) x SG of resin +250 g (0.55 lbs)

Master model weight 1000 g (2.2 lbs) x SG of resin +300 g (0.66 lbs)



Figure 36 Calculating the amount of resin

- When using double gating, allowance must be made for the extra gate and plastic tubing.
- If you attempt to cast less than about 60 g (0.13 lbs) of resin, the difficulty of weighing the components with sufficient precision may cause problems.

7.5 Weigh the resin

- Inaccurate weighing of the components can adversely affect the resin in its final form. Ideally, the scales used should be accurate to within one gram (0.0022 lbs/0.035 oz).
- 1. Insert cup liners into both A and B cups. Pour the required amounts of components A and B into their respective cups. For the first casting allow an additional 24 g (0.052 lbs/0.85 oz) of component A to allow for loss in the cup (refer to the Product Data Sheet).



2. If the casting is to be coloured, the pigment should be added to the appropriate component A and mixed in before placing A cup in the casting machine.



Figure 37 Weighing the resin

7.6 Resin temperature



Figure 38 Resin temperature

- 1. The preparation procedure for different resins may vary. You should consult the specific product data sheet for the type of resin being used.
- 2. The temperature of the resin when placed in the vacuum casting machine should be 30 to 35 °C (86 to 95 °F). In practice, the preheating carried out during de-gassing and storage often leaves the resin at approximately the correct temperature after weighing. It is however, recommended that both components be checked for correct temperature before placing the cups in the vacuum casting chamber.

7.7 Clean

- 1. Any tools that have become contaminated with resin during the preparation process should be cleaned immediately after use with a cleaning solvent.
- 2. Always use disposable cup and funnel liners. By simply discarding them, you will avoid excessive use of the cleaning solvent.



Figure 39 Cleaning



8 Vacuum casting

8.1 Prepare to cast

- 1. When the resin is ready, place the mould in the vacuum chamber. Attach the funnel and a suitable funnel liner, by means of the flexible hose and hose connectors. Raise or lower the mould to the correct position by means of the lift.
- 2. Ensure that both cups (containing the measured-out components A and B) are in the correct position and that they, and the blending whisk, are securely located.



Figure 40 Preparing to cast

8.2 Set the vacuum casting machine



Before starting, ensure that all machine doors are closed and locked in position.

- 1. All Renishaw Vacuum Casting Machines may be operated manually, but may also be programmed for automatic casting.
- The correct settings for automatic operation, which vary according to the size and shape of component and type of resin used, are preferably established by initially using the manual mode. Once the correct procedure has been established, the automatic mode may be programmed to achieve repeatability.



Figure 41 Setting the vacuum casting machine

8.3 Cure and de-mould

1. After carrying out the casting operation, lower the lift and remove the plastic tube and hose connectors. Any resin in the tube should be drained into a container and discarded. Remove the mixing whisk and clean it immediately.



Figure 42 Curing and de-moulding

- 2. Support the mould on a flat board in the oven and cure the resin for the recommended time and temperature. If the plastic tube is also placed in the oven, any residue of resin will cure and may then be removed from the tube.
- 3. If the next casting is the same resin and colour, only cup B liner needs to be replaced. If either resin type or colour is changed, replace both cup A and B liners, and the funnel liners.
- 4. When the resin has cured, take the mould from the oven and remove the tape. Inject compressed air into the gate and vents to initiate separation of the mould. After the air has loosened the two halves, carefully separate the mould using the special mould openers. Remove the component by using the mould openers again.





Figure 43 Cure and de-mould

8.4 Deformity

- While the component is being removed from the mould, some distortion may occur if the component is still warm. This may be corrected by placing the component back into the oven at the curing temperature of the resin (70 °C (158 °F)) for approximately 10 minutes, when it will return to its original shape.
- 2. Complete the operation by removing the gates and vents from the component.



Figure 44 Deformity

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Note:

The correction of castings can be achieved only on resins with a low thermal distortion temperature, for example below 70 $^{\circ}$ C (158 $^{\circ}$ F). For resins of greater resistance to thermal distortion, the oven temperature will need to be increased.

8.5 Mould storage

1. Silicone moulds may be stored for a period of up to 2 years, if stored at an ambient temperature between 15 and 25 °C (59 to 77 °F).

Vacuum casting techniques user guide

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9 Technical assistance

Together with the Installation and Operating Manual provided with your Vacuum Casting Machine, this Manual should enable you to produce resin castings of outstanding quality.

The Renishaw technical sales team will be pleased to help if you have any difficulty. Do not hesitate to contact them by telephone or email, details of which are shown on the back page.

Renishaw plc

Stone Business Park, Brooms Road Stone, Staffordshire, ST15 0SH United Kingdom T +44 (0)1785 285000 F +44 (0)1785 285001 E uk@renishaw.com www.renishaw.com



For worldwide contact details, please visit our main website at www.renishaw.com/contact

