# Technical Application Report

## *Silicone Encapsulants*

The practice of encapsulating and potting electronic components is a well established process designed to protect delicate circuitry. This protection may be required for a number of reasons: - mechanical shock, thermal shock, vibration, chemical attack, humidity, extreme temperatures and wide thermal cycles, to mention a few. In addition to providing protection, the encapsulant may also be used to perform other functions, such as thermal transfer and light emission.

Although the end function may appear simple and straightforward the operating conditions, component design and production methods often place heavy demands on the encapsulant and require very meticulous product selection and testing. There are a variety of materials on offer including polyurethanes, epoxies, silicones and many other polymers, each system will have advantages as well as limitations. It is therefore, important to fully understand the chemical and physical properties of each system and carefully match these to the requirements of the component and manufacturing processes.

## Why use Silicone Encapsulants?

Silicone polymers and elastomers have particular inherent physical properties including:

- Wide operating temperature range -115 to 300ºC
- Excellent electrical properties
- Flexibility
- Hardness range: soft gels to moderately hard rubbers
- UV resistance
- Good chemical resistance
- Resistant to humidity and water
- No or low toxicity
- Easy to use
- Resistant to fungus – silicones do not promote fungus growth

These natural properties can be further enhanced using fillers and chemical additives to provide additional features when needed, including flame retardancy, thermal conductivity, electrical conductivity and adhesion. Through the selection of polymers and fillers it is also possible to adjust viscosity and rheology and the final hardness and modulus of the cured rubber. Control of the curing regime and speed can be achieved using the silicone chemistry to produce both heat and room temperature cure systems. Silicones can be supplied as 1 or 2-part systems. In short, silicone encapsulants are very versatile and provide design engineers with a wide product choice.

## Basic Silicone Chemistry

Systems that cure or change from a liquid to a solid cured rubber at room temperature are also referred to as RTV's (Room Temperature Vulcanising). Silicone encapsulants generally fall into two categories: - condensation cure and addition cure systems. Understanding the differences between the two systems is important for correct product selection.

## Condensation Cure

Condensation cure systems use moisture present in the atmosphere during the curing process and cannot readily be accelerated using heat (applying excessive heat whilst curing can be detrimental). There are usually also small amounts of by-product produced. These two factors dictate that cure will only take place if the material is open to the atmosphere. Curing will be adversely effected if an enclosure is sealed prior to the completion of the cure process. This chemistry is commonly used for 1-Part sealants, coatings and 1 & 2 Part encapsulants.

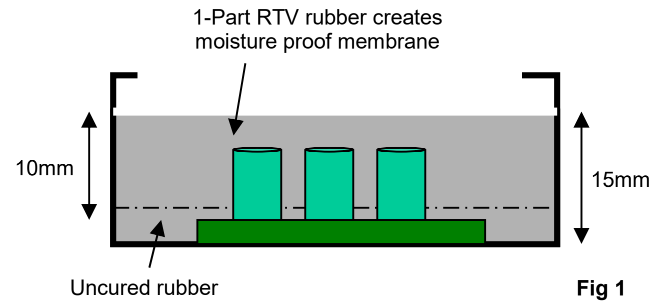

**Fig 1**

1-Part condensation cure (RTV) products should not be used where the depth of encapsulant is more than 10mm, see **Fig 1**, as it will cure to form a moisture proof membrane and prevent the cure in the bottom of the enclosure.

1-Part RTV's use a variety of cross-linkers to form an elastomer; these cross-linkers produce by-products, some of which can be harmful to sensitive electronics. We therefore, only recommend the use of Alkoxy and Acetone cure 1-Part RTV's as encapsulation materials.

| 1-Part RTV Cure mechanisms | By-Product | Effect |
|---|---|---|
| Acetoxy | Acetic Acid | Corrosive |
| Oxime | Ketoxime | Mild Corrosive |
| Alkoxy | Methanol | Non Corrosive |
| Acetone | Acetone | Non Corrosive |

Reversion: - condensation cure systems using organotin catalyst can, under certain circumstances, start to chemically break down and revert to liquid form. This process will begin to take place when the silicone is contained in a closed/hermetically sealed unit that is exposed to continuous elevated temperatures for long periods of time (i.e. 6 months @ 90ºC). If the material is open in some way to the atmosphere reversion will not take place and resistance to high elevated temperatures (up to 300ºC) is possible.

| Condensation Cure Silicones | |
|---|---|
| **Advantages** | **Disadvantages** |
| **1-Part Systems** | **1-Part Systems** |
| Ease of application -No Mixing | Maximum deep section cure 10mm |
| Eliminates user error – incorrect mix ratios | Fixed cure speeds |
| Easy dispensing from cartridge or tube | Limitations in viscosity |
| Ideal for thin section cure <7mm | Reversion to a liquid, if heated in a closed container |
| | |
| **2-Part Systems** | **2-Part Systems** |
| High tolerance to variation in catalyst ratio | Slightly higher shrinkage levels than Addition cure |
| Limited risk of inhibition | Reversion to a liquid, if heated in a closed container |
| Excellent deep section cure | |
| Accelerator available to speed up cure | |

## Addition Cure

Addition cure systems use a platinum catalyst to initiate the cure and do not produce any by-products during the cure process. Once catalysed, they will complete the cure cycle, even in a sealed enclosure and do not need to be open to the atmosphere. 2-Part systems can be designed to cure at room temperature and heat can be used to accelerate the cure if required, without any detrimental effect on the cured elastomer. 1-Part systems will normally require heat before they will cure.

The platinum catalyst is susceptible to attack from certain chemical compounds which in turn, will lead to inhibition of cure resulting in a partially cured product. Bringing the uncured material into contact with the following chemical compounds should be avoided during the mixing or manufacturing process: nitrogen, sulphur, phosphorus, arsenic, organotin catalysts, PVC stabilizers, epoxy resin catalysts, sulphur vulcanised rubbers and condensation cure silicone rubbers (Note that Alkoxy cured RTV's do not cause inhibition).
These systems also require a fine chemical balance to produce the correct physical properties in the cured elastomer. It is therefore, important that the A&B parts are thoroughly mixed prior to weighing out and the correct mix ratio is carefully adhered to. As the A&B parts are normally manufactured as a matched kit, it is unadvisable to mix materials from two different batches.

| Addition Cure Silicones | |
|---|---|
| **Advantages** | **Disadvantages** |
| **1-Part Systems** | **1-Part Systems** |
| Ease of application -No Mixing | Require heat to cure |
| Eliminates user error – incorrect mix ratios | Good adhesion is difficult to achieve |
| Can be used for thin and thick section cure | Prone to inhibition |
| Good physical strength | Short shelf life can be a problem |
| | |
| **2-Part Systems** | **2-Part Systems** |
| Excellent deep section cure | Prone to inhibition |
| Pot life can be extended with use of additive | Require correct mix ratios |
| Will not revert to liquid once cured | Good adhesion is difficult to achieve |
| Low shrinkage | |
| Easily accelerated with heat | |
| Optically clear products available | |

## Choice of Silicone Encapsulant

There are three key considerations when choosing an encapsulant:

1) What are the operating and environmental conditions of the finished product?
2) What physical properties must the encapsulant have to have?
3) How will you process the material?

We will consider factors effecting choice in each of the above in turn.

***Environmental Conditions.***

What are the operating temperatures?
Are there extreme thermal cycles?
  If yes, consider softer or lower modulus materials to prevent stress on components.
Could there be a risk of reversion?
  If yes, select an addition cure
Are you protecting from vibration or shock?
  If yes, consider softer materials or a gel.
Will it be subject to chemical attack?
  If yes which chemicals?

***Physical Properties***

Is hardness important?
Is colour important?
Do you need optical clarity?
  If yes, what refractive index do you need?
Do you require thermal conductivity?
  If yes, to what level?
Flammability, do you require UL Approval?
Do you require adhesion?
  If yes, what substrates are being used?
  Can you use a primer?
What electrical properties are needed?
Will the encapsulant have to resist abrasion or tearing.
Does it have to flow under components?

***Manufacturing Process***

Do you want a 1-Part or 2-part?
If a 2-part how will you mix the material?

How will you dispense the encapsulant?
What viscosity will your equipment handle?
Is it compatible with the pumps and seals?
How flowable do you require the material?

How long can you allow for cure?
Can you cure with heat?
Do you require full cure before completing the next stage?
Will other materials cause inhibition?
If yes, you may need to look at condensation cure or use a primer.

Due to the complexity of product design and the individual manufacturing process, it may not be possible to satisfy exactly all the requirements in every area, so there may well be need for compromise. It is therefore, important to decide which criteria are essential for product performance and longevity. We always recommend fully testing the suitability of the material in each given application and production method employed prior to specification. In some cases it will be possible to provide a bespoke formulation in order to match the design requirements. CHT's technical staff have many years of application based experienced and will be happy to help with the selection process.

## CHT Silicone Encapsulants

For an up to date list of all CHT Silicones Encapsulants please visit
https://acc-silicones.com/products/encapsulants