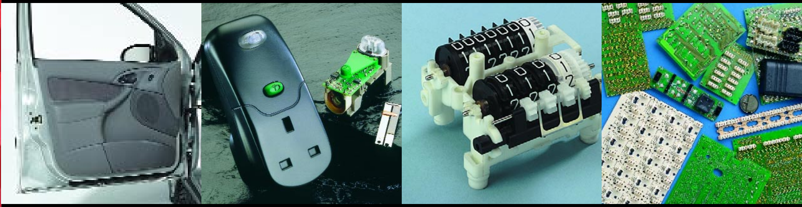


A guide to plastics assembly

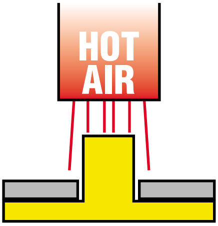
PHASA

● Simply better assembly

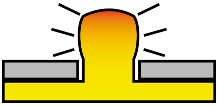
The basic principle of PHASA staking

‘Plastic Hot Air Stake Assembly’ is a simple, cost effective and capable method of permanent assembly. It re-forms extensions on mouldings to simultaneously create multiple fixtures without additional parts and their costs. Thermoplastic assemblies produced by this method are strong, tight and stable.

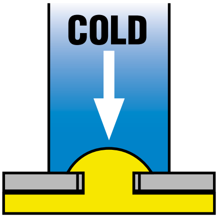
In simple terms, the process involves simultaneously heating each individual retention area and then forming, clamping and chilling them, into the required shape with cold forming tools. This combines the many parts into a strong consolidated assembly, which is undeniably superior to all other commonly used methods.



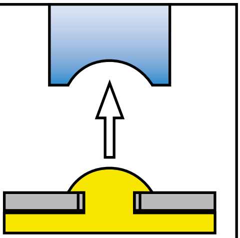
PHASA Processing uses Super-Hot air to heat selected parts of thermoplastic mouldings.



As their is no contact with the parts being heated, the process is CLEAN.



When heated - cold tools are used to FORM, CLAMP and CHILL the specified area into its new shape.

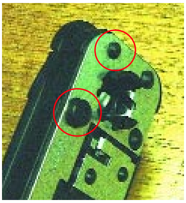


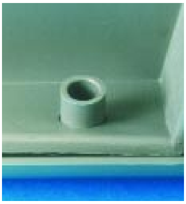
All the plastic has been fully heated and then cooled under pressure.

Types of stakes

ROUND & TUBULAR STAKES

‘Cheese-Head’





Round and tubular stakes are the simplest to tool up, produce and process.

Being round and provided that they are on a flat plain, such stakes require relatively simple machining through all stages of tooling and can be used to produce a variety of different closure designs (ringed on the left are Cheese-head and Rivet or Domed heads).

The long stake, comprising of three or four tapered ribs, is used as a guidance dowel to assist in the location and alignment of the parts during the initial stages of assembly. In this instance it has been formed into a ‘Cheese-Head’ to act as an additional securing point and to minimise the product height in that area.

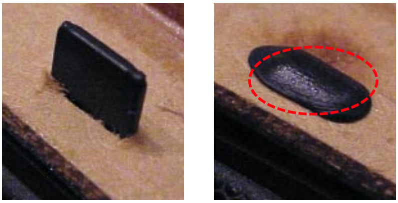
Solid round stakes of more than 3.0mm diameter should be avoided as they can cause ‘Sink’ marks on the ‘A’ face of the moulding and depending upon the materials in use, can extend the processing time.

Therefore, where greater strength is considered necessary, the use of tubular stakes with a wall thickness of between 0.75 and 2.0mm is recommended. Bear in mind that a wall 1.25mm thick is more than adequate for the majority of applications.

The removal of the core to create a tubular stake with a wall of 1.0mm, will produce a coherent stable moulded tube, with considerable advantages in processing capability and ultimate strength over other types of stake.

RIB STAKES

Although ‘Ribs’ are more difficult to tool up, they can be used to considerable advantage to overcome design constraints caused by limitations of space, thickness of the moulding or line of mould draw.



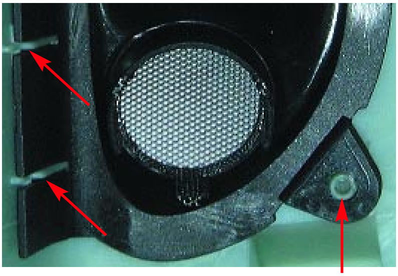
This first ‘Rib’ application secures a speaker fret to a car door finisher. Because of limited space and need for strength, in this instance it was better to use a narrow rib than risk putting a larger round stake either near to the outer edge of the moulding or too close to the cut edge of the fibre (see red indication).

Because of the thin material sections used throughout the product, this ‘Overload Trip Assembly’ uses small ribs to create the retention features required for it’s cover. Note that there is a slight discolouration of the filler on the formed stake. This is on the surface and does not affect the product. It only shows in this magnified image because of the light material colour in use.

COMBINED VERTICAL & HORIZONTAL FIXING

When securing points are required on more than one plain of a moulding, it can be more efficient to use round or tubular stakes where the ‘Line of Draw’ permits and moulded ribs or tabs into slots on the inclined or vertical sides of the assembly.

The illustration on the left is of an ‘Air Bag’ cover moulding. This is staked to an aluminium ‘Anchor Plate’ using 10.0 mm. Tubular stakes with a 1.0 mm. wall thickness on the horizontal line of draw. Additionally 1.2 mm thick rib stakes are used on the inclined plain. Note that the slots in the aluminium plate extend beyond each end of the moulded rib to assist in assembly and allow for expansion.



Tubular stake on Line of Draw

The escutcheon moulding on the left is assembled into the Door Finisher or Top Roll using three tubular stakes on the horizontal L.O.D. and five ribs along the vertical edge. (This illustration is prior to processing in order to show the design detail clearly).

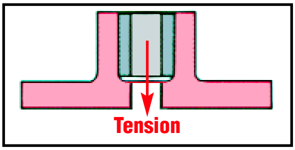
This design is particularly useful for minimising the complexity of mould tooling, which may otherwise necessitate using several auto-cores to achieve stakes around the moulding at different angles to the L.O.D.

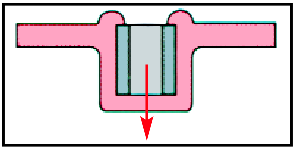
ROLL-OVERS

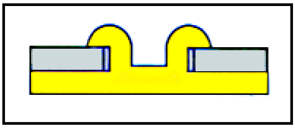
While ‘Ribs’ generally pass through holes and are reshaped into larger heads to prevent them being pulled apart, Roll-Overs are principally ribs set at or around the edge of the assembly, which, when heated, are ‘Rolled-Over’, clamped and chilled to form the retaining feature.

As demonstrated on the left, such devices prove ideal for permanently retaining flat steel (or plastic) parts, which, not being compatible for welding, may prove most difficult to securely attach by other methods

The picture on the left demonstrates the simplicity of securing brass terminations into a plastic end cap. The Roll-Over in this instance is around 80% of the periphery and provides an extremely safe method of assembling this product, which is moulded in G.F. Nylon.







As an alternative to using ‘Threaded Metal Inserts’, which can be expensive to purchase and install, hexagonal cavities can be moulded to receive standard ‘Half’ or ‘Full’ nuts in metal or plastic. These fittings can be retained by Roll-Overs created during the main staking operation. This permits the assembly of the main body to also make provision for later inclusion of parts that may require to be removed for servicing, replacement or which act as access panels.

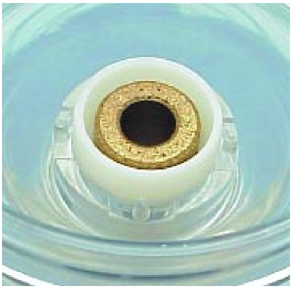
Although the ‘Roll-Over’ is a strong retention feature, wherever possible the tension should be applied to the moulded surface.

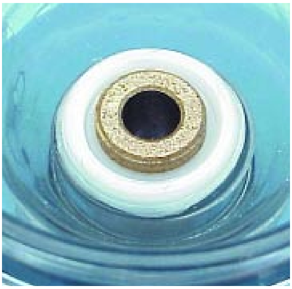
It should be remembered that a ‘Roll-Over’ can be used externally in a similar manner to a tubular stake, but applied to much larger diameters to secure thrust bearings and seals. Sometimes such assemblies will require to be performed in conditions where a pre-load is being applied to a flexible seal within the part during the full assembly cycle.

The example below demonstrates a novel way of captivating the end of an expansion spring, where 65% of the inner edge of the moulding has been rolled outward in what may be termed a semi-annular Roll-Over.

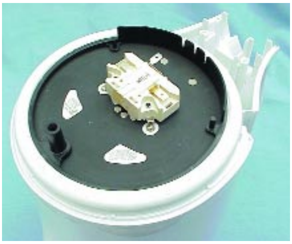
ANNULAR ROLL-OVERS

An Annular Roll-Over is a very useful method of simply, economically and efficiently installing (and possibly sealing) round assemblies of almost any size.





On the left a sintered phosphor bronze bearing has been mounted into a white Acetal housing, which is installed with it's seal into a clear liquidiser jug base using an external Annular Roll-Over. The diameter of the housing is some 25mm.



In contrast, the rim around the base of this 'Jug Kettle' is 125mm diameter before it is heated and then rolled internally over the 'Planar' element assembly. During processing pressure is applied to pre-load the flexible 'C' seal surrounding the edge of the element.

Unless compatible materials can be welded, in order to achieve a hermetic seal it is necessary to use a suitable pliant medium in the joint, or create an adhesive bond. A tight fit will seldom be sufficient to create a seal that will survive all conditions imposed upon it.

It is important that the design of the product and particularly the rib, rim or collar are correct and we would suggest consultation at an early stage with experienced engineers in PHASA staking methods and application.

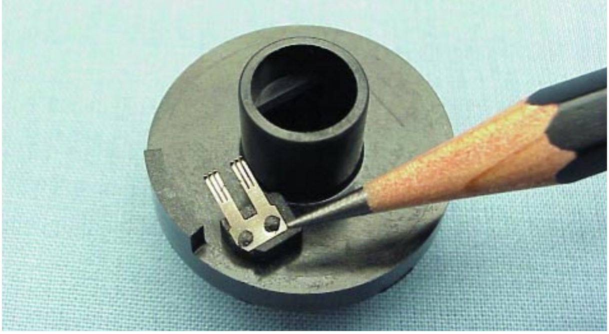
The loudspeaker has been secured to it's plastic 'Front Grille' by means of an internal annular roll-over. We understand, that this total uniform pressure and seal around the rim of the speaker, besides ensuring the durability of the assembly, enhances the acoustic properties of the product.

This final illustration is of a vacuum switch, which is installed into a small pump reservoir by a 25mm diameter internal roll-over. Once again a flexible seal is incorporated and pre-loaded to ensure the integrity of the assembly, which is an essential part of the braking system for and electric powered vehicle.

Designs of special merit

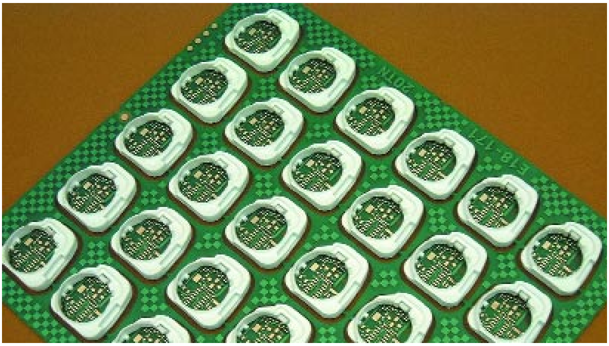
In the authors view, the following applications warrant a special mention.

● ‘Wiper’ contacts are here secured with 0.8mm. G.F. Nylon stakes to prevent any movement, which could lead to distortion of their electronic reading capability. In some instances designers have also included small roll-over ribs at the end indicated by the pencil point.

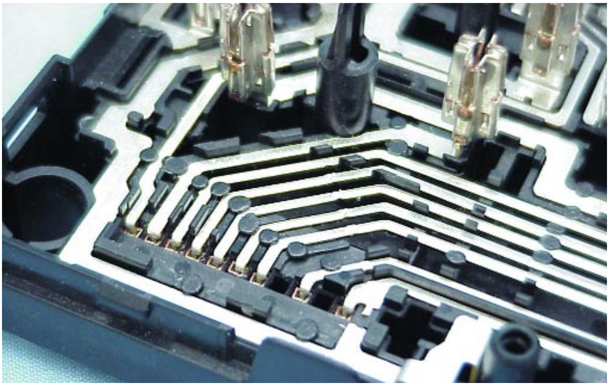


● A steel tape measure is secured to it’s ‘End Piece’ by two mouldings containing the tubular stakes for the assembly operation.

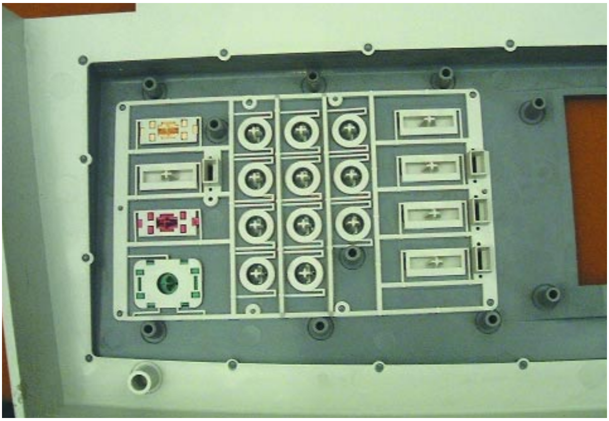
● This is an example of a motherboard being populated by thirty bodies for ‘Remote Door Locking’ devices in one operation. This application has only 90 staking points, whereas some for the Communications Industry have over 200.



● Plastic ribs placed between them keep the feeds in this pressed metal circuit at a safe distance from each other. Some of these ribs are reformed to provide retaining features to prevent the metalwork from lifting and causing short circuits.



- The grey moulding is part of a large assembly and has the white ‘Key Map’, central in the picture, secured to it by half of it’s ten stakes. This permits the replacement of the key map, by using the unprocessed stakes, to be a serviceable event, thus saving the cost of replacing the complete assembly.



- The simple action of staking a plastic guard to each edge of these scissors, immediately turns them into a safe product for use by children.

- In this assembly the designer has made use of staking to join the plastic drive gear, PTFE tensioning washer and die casting. The result is a tight smooth assembly, where the stake has been formed into a countersunk angled recess to ensure a clean and balanced assembly.

PHASA

There is no set formula for determining size, quantity or positions of stakes. However, it follows that the number, size and style of stakes used to join an assembly together will depend upon ;-

1. Total strength required.
2. Support necessary (around edges).
3. Additional parts or vibration damping over large unsupported surfaces.
4. Aesthetics - The balance and general finished appearance.
5. An intelligent safety margin.
6. Common sense.

A NUMBER & POSITION

Identify those places stakes must be positioned at. Corners, long flat sections, weak areas which require more support, as well as those which take more stress. Having decided on the essential fixings, look at the aesthetics. You may feel it necessary to add one or two stakes to enhance the balanced appearance of the completed product, even though they may not be necessary.

B SIZE - DIAMETER

The Designer will now have to assess an acceptable strength for the assembly, given the material specification and number of stakes to be used. A calculation will be required to arrive at the cross section necessary of each stake to enable the assembly to exceed the targeted strength by an acceptable margin. Obviously tubular stakes allow much greater flexibility and where suitable should always be used in preference to solid round stakes.

SIZE - HEIGHT

As a ‘Rule Of Thumb’ the exposed height of a stake (left for forming when assembled) should equal 75% of it’s diameter for an O.D. of 4mm. As the diameter of the stake increases, so the height available for reforming should decrease and visa versa. Thus a 10mm dia. stake could be expected to be 6.5mm high and conversely a 2mm dia. 2.5mm high. The reasoning behind this is that the larger stake will have ample material to provide a strong head and any excessive height will lengthen processing time unnecessarily. Similarly the smaller diameter will need additional height and consequently material to produce a reasonably strong head. The only justification for keeping excessive height on a large stake is when there is too much clearance between it and the hole it fits into, thus making the excess material necessary to in-fill the additional space.

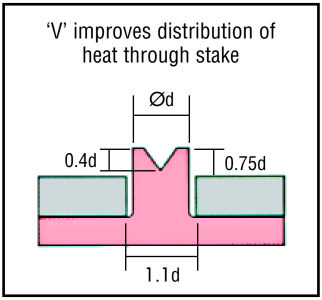
C STYLE

From ‘B’ consider if the size of stakes calculated will look acceptable for the product they are being used on. (Normally limit the size between 0.75 and 10mm dia. or equivalent for different shapes).
If they do not look correct either increase or decrease their diameter to an acceptable size. (In the latter instance additional stakes will need to be added to compensate for the loss of area). Remember that increasing diameter has a marked difference in area and therefore strength, not only for the application but for handling purposes prior to staking.

D TYPE OF STAKE

Although we are using the description ‘Stake’, it is used as a general term for the parts which are to be reformed. These may be round or hollow pillars, ribs, collars or any other shape which may be reprocessed to carry out the designers scheme. Don’t forget that it is quite acceptable to mix sizes and shapes of stakes if required.

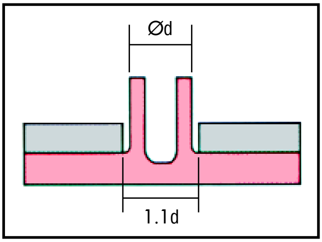
Round stakes



The relationship illustrated on the left is suitable for stake diameters between 2.5 and 4.0mm moulded in unfilled low melt thermoplastic.

- Stakes less than 2.5mm diameter will not benefit from cores or indents unless they are moulded from high temperature or heavily filled materials.
- Stakes over 4.0mm diameter should be cored to minimize the thickness of the plastic to be heated, as well as improving the unformed stakes stability. The tubular stake can also be used to avoid 'Sink's occurring on the 'A' face.
- Remember that there is also the risk of 'Stress Relief' of the substrate if it is relatively thin. Therefore large stakes on thin mouldings should be avoided. Ideally no section of the stake should exceed 70% of the base material thickness. As the diameter of the stake reduces, the amount of material available to produce the 'Head' decreases disproportionately. It is therefore recommended that taking the illustration as the optimum for a 4mm stake the following table can be used as a general guide for other sizes.

Stake Ø	'V' Depth or Core Ø	Stake Exposed Height	Clearance Hole Ø
1mm	N/A	1.75mm	1.10mm
2mm	N/A	2.50mm	2.20mm
3mm	'V' 1.2mm	2.75mm	3.30mm
4mm	'V' 1.6mm	3.00mm	4.40mm
5mm	Core Out 3.5mm	3.75mm	5.50mm
6mm	Core Out 4.5mm	5.50mm	6.60mm
8mm	Core Out 6.0mm	5.75mm	8.80mm
10mm	Core Out 7.5mm	6.50mm	11.00mm
12mm	Core Out 9.0mm	7.50mm	13.20mm

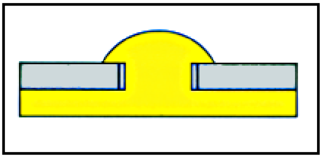


HOLE SIZE OR GENERAL CLEARANCE ;-

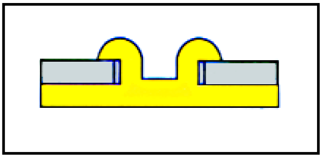
- The clearance around the stake should be the minimum possible, which will still permit rapid assembly. As a rule of thumb we would recommend the aperture to be no more than 10% larger than the stake and a lead-in on the hole and/or stake will assist alignment.
- Splines around the stakes or holes can be used to create friction and loosely hold assemblies 'built off-machine' together prior to processing.
- If excessive clearance is allowed around the root of the stake, it is probable that material designed to produce the head will be lost into the cavity resulting in an inadequate retaining form.
- When circumstances do not permit a close tolerance on the holes, the use of tubular stakes and tooling designed to achieve a greater spread of the head will permit more effective results.
- It is not a normal function of the process to provide lateral location by expanding the stake within the hole. If positive location is required it can be achieved by designed 'Swelling' of the stake base or providing dowels or other forms of location, separate from the processing points.
- Design of long assemblies sometimes includes holes slotted in the direction of the 'Long' edge to allow for differences in length caused by moulding or temperature variations. In such instances tubular stakes with marginally greater height are recommended to allow for the material losses into the elongated slots.

Formed head design

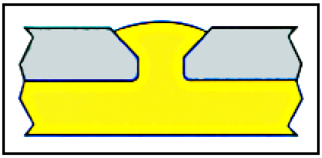
The most simple and effective method of creating a retention feature, is to pass a rod through a hole and then increase it's size so that it cannot be retracted. Thus the head of our plastic stake or tube is heated and re-shaped to make a large head, which cannot be removed from the hole.



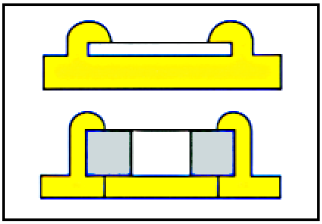
A common shape of such heads is the dome or rivet head, which, if it is a nearly complete hemisphere with reasonable flat land over the edge for retention, is also the best shape to distribute the tension applied to it uniformly. As an alternative, designers sometimes choose a cheese head, which may be marginally weaker, because it is inevitably shallower.



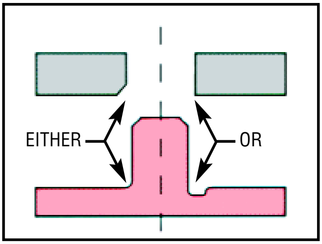
Where greater strength is required of the joint, without creating the risk of sinks on the 'A' face or extending the processing time, Tubular or cored stakes are used and rolled-out to create a raised bead as a retention feature around the hole.



Countersunk stakes with a slight convex radius on the top give a very sound assembly and a smooth tidy finish to the product when aesthetics are important.



Captive, washers, thrust plates, bearings and nuts up to 25mm diameter can be internally staked using conventional equipment, but above this size or if required for more demanding applications annular manifolds would be required

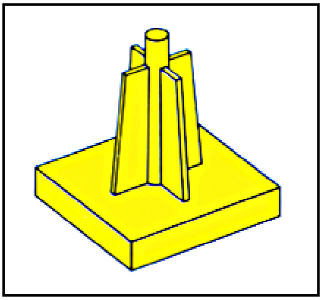


Besides normal moulding draught on the sides, the bottom of the stake should have a radius to improve material flow, stake strength and diffuse the fracture propagation stress point.

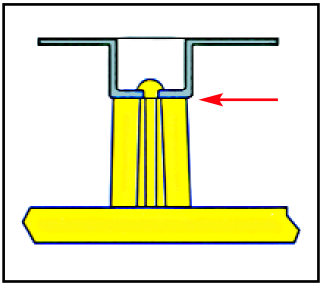
Where ever possible the hole should have an angled or radiused lead-in to assist assembly and accommodate the radius at the bottom of the stake.

If this is not possible then a trough around the base of the stake will be necessary to accommodate the oversize of the base radius.

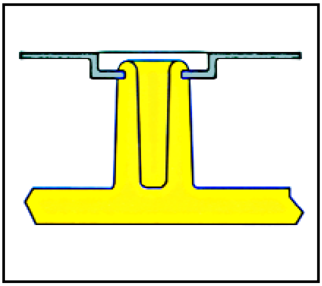
Stand-off pillars



Stand-Off pillars of various designs are used to separate and support parts of the assembly. The four ribs, shown on the left, not only supply support to the part being fitted, but in a situation where a larger or tubular stake cannot be employed, they also considerably strengthen the stake itself. When using this type of support, care should be taken that the clearance holes around the stake are not excessive or there is a risk that air will pass through and melt the supports during the process.

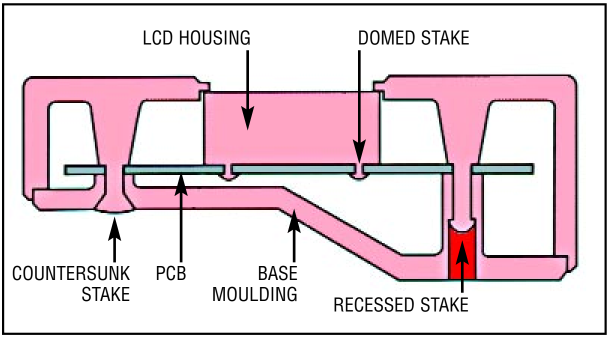


Recessed fixings are often used where parts need to be suspended - such as PCB's, which need an air gap all the way round for cooling and/or for eliminating the risk of damage. Mountings of this type can be used to fit the 'Bottom Tray' to a product and the recesses can be fitted with pushed in plastic feet to conceal the assembly points and 'Finish' the product.

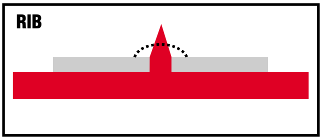


Bifurcated Stand-Offs are based on using a heavier tubular stake for added strength and these can also used where the possibility of the product requiring servicing is present. In such cases the service engineer can simply drill off the top formed section and after servicing replace it with a self tapping screw (with a security head if required).

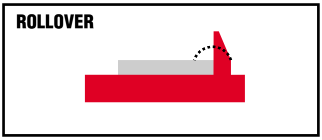
Below is a simple visualization of the use of staking in a simple electrical assembly



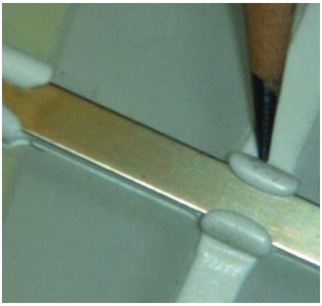
Ribs and rollovers



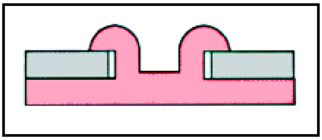
The principle difference between a ‘Rib’ and a ‘Rollover’ is that with the former, the ‘Rib’ passes through a slot or aperture in the material it is to secure and is shaped into a suitable domed bead.



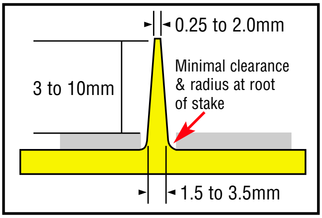
The Rollover, however, is designed to sit on the edge of the part it is to secure and be literally rolled over the edge or edges it has to retain.



In the picture, the 6mm wide flat steel spring has been placed between two up-stands, which have subsequently been heated and formed to retain the part. In all there are three pairs of rollovers, which are shown in greater detail at the top of page ‘4’. These are described as internal rollovers and although an external rollover is possible, in practice they are unlikely to be used.

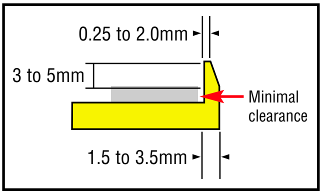


In such cases where a flat panel has to be retained, provided the design will permit, the simplest way is to externally stake tubular rivets, which have been passed through holes pierced or moulded into the part.



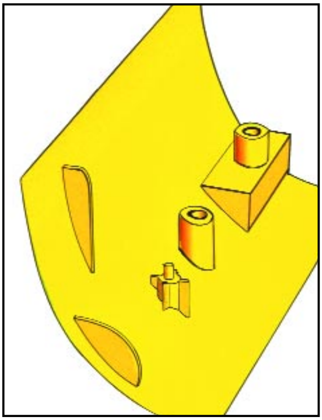
The thickness or weight of a rib assembly should not be more than is necessary and it follows that a rib must always be longer than it’s width or it will become unstable during heating. Again the clearance created by the slot around the rib should be minimal to avoid material being lost into the space instead of forming the head.

If permitted, the rib can be almost parallel where it passes through the slot with the taper starting on the forming side. The thinning created by tapering the rib maintains stability and allows the heat to penetrate more thoroughly into the part requiring to be re-formed. Hence of the exposed rib, the top third should become almost molten, the next third mouldable and the base third should be mouldable on the outside, but with a more rigid core in it’s center.



A Roll-Over should have an angled outer face, which will heat in a similar manner to the rib, but with the majority of the heat being absorbed by the angled face, this will expand more and bias the upstand towards the intended formed position.

Assembly on curved surfaces



In the Automotive Industries, a great number of fixings are made on curved sections and whilst these do not present problems, it is worth bearing in mind the relative merits of different types of stake arrangement.

Generally the automotive parts need to be very strong because of the conditions they work under and life expected of them. Because of this and unless there is very good reason, all stakes should be at least 4mm diameter and be cored (for reasons already mentioned).

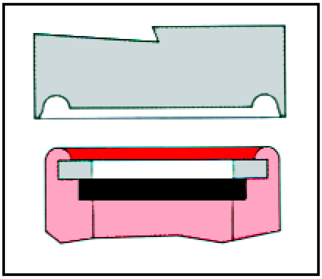
There are no problems with stakes moulded across the flat horizontal pan of the product - In Line of Draw. But those that are on a generous radius, which terminates in an almost vertical wall, as depicted on the left, require special consideration.

The top option, where a short stake has been mounted onto a step, is rarely possible because the step would need coring out and this would affect the aesthetics of the ‘A’ face.

The next method, which shows a tubular stake mounted straight onto a wall, required that orientated cores and forming tools be fitted and presents the risk of the materials being slid down the curve in the product. The tooling set-up also requires special attention in the design of the manifold - as the stake has one long side and the other short and this requires slightly more attention for balancing the system.

The round stake with four spline supports is simple to produce and use, but generally lacks the degree of strength preferred of this type of application.

The two rib stakes, although more expensive to tool up, do answer the need to provide strength without the costs of fitting auto-cores around the mould. They obviously have to pass through slots, which again should not have excessive clearance, and when processed provide an effective answer to meet many difficult situations.

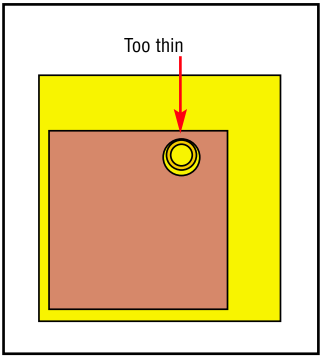


Annular Rollovers can be used for internal applications as shown in the picture on the left, or for external forms as shown earlier on pages ‘4 & 5’. There is no definitive limit to the size of the part that can be processed, but most products in excess of 75mm diameter will benefit from specialised rotary heating systems. Processing is also assisted when the outer edge of the moulding extends vertically down below the formed area, rather than extending horizontally away from the formed edge.

Points to remember

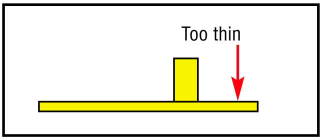
The siting of the stakes we have already discussed in respect of achieving strength, support and a balanced layout. The other points which should be considered are ;-

- Keeping the stakes away from heat sensitive components including thin sections of a moulding (particularly vertical walls which may be nearer to the Hot-Air delivery point that the stake being heated).



- Leave adequate room to enable approach of the system and don't forget that the headed stakes take up more room once they have been processed.

- Remember to ensure there are equal sections around the area being processed. When a hole is placed at the edge of a moulding and there is little or no material on one side, this thinner section will melt away resulting in a total failure of the assembly method.

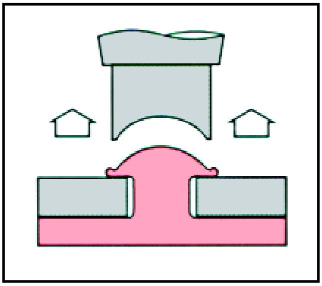


- Do not mould stakes on thin material sections unless there is no other alternative. And where there is no option, keep the thickest section of the stake under 70% of the base moulding thickness.

- Where the material the stake is moulded from is of a much higher melt index than the material being assembled to it, or where a thin thermo-plastic washer is being fitted, extreme caution must be observed. It will be obvious that to reach the high temperature needed for the stake, will create the risk of the hole, it passes through, being melted into an unusable mass. The best option is to use compatible materials where the melt temperature of the stake is equal to or less than that of the material it passes through. If this is not possible then steps can be taken to improve air delivery, mask the problem areas or carry out modifications to the stake to make it more receptive to the Hot-Air.

- Metallised coatings and plating over the stakes will tend to mask and dissipate heat. This should be avoided if at all feasible, alternatively the plating can be masked or kept as thin as possible.

- If plated, extra care is necessary to achieve a very rapid heating of only the part of the stake to be reformed, followed by rapid transition to forming. Unfortunately the plated shell surrounding the stake, will tend to crack-up and spread within the reform, rather like pieces of an eggshell. This, although unsightly, should not have any adverse affect upon the strength and quality of the final assembly.



- If the forming tool is overpacked with material a slight witness around the form may be visible, as shown on the left. Provided this is acceptable to the product, such an indication demonstrates that the assembly has been properly processed and we would suggest it is better left than removed by modifying the tooling.

Heating the plastic

● Thermoplastics are designed to be heated, in order that they soften and become 'Plastic' enough to be moulded. Taken to higher heat they will pass through a stage where they are molten and can be welded until eventually they arrive at the point where they degrade and decompose into a charred mass.

● When Hot-Air staking, the target should be to get the parts designed to be re-formed, heated to the extent that the topmost part is just molten with the plastic below graduated through the length of the stake down to the ambient temperature.

● Since plastic is a good insulator, processing time is proportional to the depth of plastic the heat has to penetrate before forming and how long it takes to remove the heat and 'Freeze' the plastic after forming.

● In practice the aim should be to keep the depth of penetration below 1.5mm. this means that above 3mm diameter a solid round stake needs coring, but in reality a dimple in the top will suffice up to 4.0mm diameter.

● It now becomes more evident why the Tubular stake is more efficient. Given that an 8.0mm tubular stake has a 5.5mm bore - the heat can be applied down the centre and at the same time to the outside of the 1.25mm wall This will substantially speed up heating and produce a more stable and uniform heat pattern.

● An approximate heating time for materials such as P.P., P.E, A.B.S. etc., based on 1.25 depth of penetration will be six seconds and this will be increased by 1.5 to 2.0 seconds if talc or glass fillers are present.

● From this benchmark of six seconds, heating times will increase in relation to the materials melt temperature and the type and amount of filler present to an estimated maximum of twelve seconds. Because of the number of factors affecting the heating it is not possible to specify exact times, but 'Best Guess' estimates from trials on customers material samples are reasonably accurate.

● Cooling of the formed area is far quicker than heating, as the thinned plastic is clamped by cold metal tools into the required shape and 'Freezes' rapidly in times from 1.0 to 5 seconds depending upon the mass and material being processed.

Points to remember

● If they cannot be kept dry, it is preferable to process hygroscopic materials immediately after moulding or the water they absorb can vaporise during processing to cause bubbles in the plastic. This is particularly evident in clear materials such as polycarbonate.

Written by Denis W. Eagles - Development Manager Phasa Developments.

Any expression or opinion contained herein is given in good faith and reflects our general experiences. Requirements and applications may differ and need first to be confirmed directly by Phasa Developments as correct prior to any individual commitment.

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