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# Comb Management





Pictures courtesy of Wally Shaw



# Introduction

Honey bees can successfully live in all sorts of different nest sites - a hole in a tree, a chimney pot or a bee-hive - but in all cases this is just a cavity in which to build their combs. Most of the different functions of the colony occur in or on the combs. The main exceptions being foraging, defence, swarming and queen mating. In fact, over 95% of a typical worker bee's life is spent in the confines of the nest. Unlike most animals, bees do not collect nesting materials made by some other organism, they actually secrete the wax from which the combs are constructed from their bodies (the wax glands). In a sense, the combs are an extension of the bees that made them and it is bees and combs together that constitute the colony. Combs are used for many purposes:-

- a) To raise brood,
- b) To store honey and pollen,
- c) Thermoregulation - as insulation and structure on which to cluster,
- d) To send and receive chemical messages,
- e) As a sounding board - communication through vibrations, and
- f) They are also an essential part of colony hygiene.

# Invention of the Moveable Frame Hive

Up until about 1850, bee colonies, whether wild or under human stewardship (it can hardly be described as management), built themselves a set of combs entirely according to their own design in whatever cavity they could find or was provided by the beekeeper. No restriction was placed on the way the colony used these combs to engage in their main activities of brood production and food storage. With the introduction of the moveable frame hive, followed quickly by the invention of wax foundation and the queen excluder, everything changed. Beekeepers were now able to force the bees to make combs where they (the beekeepers) wanted them, in wooden frames. They could influence the size of cells they built (by the dimensions of the hexagon embossed on the sheet of wax) and could restrict the use of combs for brood (with the queen excluder). Some of the changes that modern beekeeping in a moveable frame hive has imposed on colonies have potential effects on the health and welfare of the bees and others do not.

## Measurements

We are now going to discuss the dimensions of combs and their spacing and this is most easily expressed in metric units (millimetres or mm) rather than Imperial units (inches and fractions of an inch). A difference of one millimetre (1mm) may seem almost insignificantly small to you but it is a lot to a bee - equivalent to about 350mm (14 inches) for us humans! So, if you still tend to think in Imperial measure, here are a few conversions to help you visualise things:-

$\frac{1}{4}$  inch = 6.5mm    $\frac{3}{8}$  inch = 9mm    $\frac{1}{2}$  inch = 12.5mm

1 inch = 25mm    $1\frac{1}{4}$  inch = 31mm    $1\frac{3}{8}$  inch = 35mm

$1\frac{7}{16}$  inch = 36.5mm    $1\frac{1}{2}$  inch = 38mm

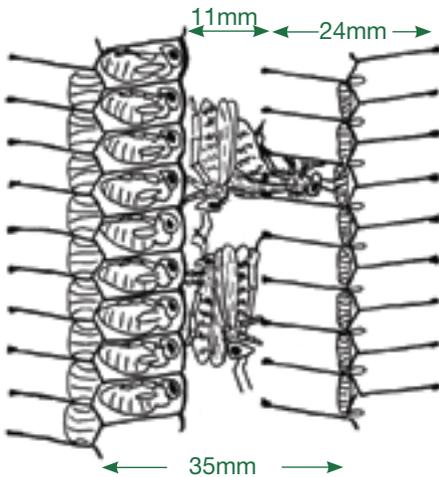
$1\frac{7}{8}$  inch = 47.5mm and 2 inch = 51mm

Bee space is  $\frac{1}{4}$  inch -  $\frac{3}{8}$  inch or 6.5-9mm

# Doing What Comes Naturally

When a swarm of bees takes up occupancy of a nest cavity the first task is to build a set of combs. No matter where they build, the spacing of the combs is always very regular at 30-32mm between centres. Only combs at the outside of the nest may have slightly wider spacing but these are used almost exclusively for honey storage or drone brood. Depending on the shape of the cavity, the combs they build are rarely flat - as we beekeepers force them to do in our hives. They are often curved in graceful arcs and may also be joined in places and braced to the cavity wall. This bracing gives structural integrity so that the combs can bear the weight of a full load of honey - even in hot weather.

Inter-comb space and bee packing with a frame spacing of 35mm



In terms of usage, the combs in a natural nest are multi-purpose and brood is raised almost anywhere with the possible exception of the outside combs. A major influence on which cells are available for the queen to lay in is the preference of the workers to store nectar in cells that have formally held brood. This means that the queen is constantly being moved onto new comb and this is an important part of their hygienic behaviour.

Why is natural comb spacing 30-32mm? Measuring cells that have been prepared for the queen to lay shows that they are all 11-12mm deep. More detailed measurements reveal that it is not uniform depth that the bees are targeting but a width/depth ratio

of about 1:2 - so smaller (diameter) cells are slightly shallower and larger cells are deeper.

Why this particular ratio? The only time the cell is fully occupied is in the later stages of brood development and these are the proportions that exactly fit the occupant - the pupa or pre-emergent bee. Smaller (diameter) cells produce smaller bees; hence it is the width/depth ratio not the absolute depth that is important.

Taking these calculations a stage further, and assuming an average cell depth of 11.5mm, the comb width, where both sides are prepared for brood raising, is  $2 \times 11.5 = 23\text{mm}$ . Subtract this from the comb spacing of 32mm ( $32 - 23 = 9$ ) and this leaves a space of 9mm between opposing comb faces. It just so happens (and it is no coincidence of course) that 9mm is exactly the right space for worker bees to be able to stand on opposing comb faces with their wings just brushing. This means that the nurse bees can move about freely to gain access to the cells for tending the brood. The provision of a 9mm space is also important for thermoregulation which can be most efficiently achieved by just two layers of bees between the combs. In colder conditions more bees are recruited to occupy the between-comb space where they generate heat and slow the convective flow of air. Wider comb spacing requires more bees - and more than two layers - to be packed in under cold conditions to keep the brood warm. Colonies are highly sensitive of the need to keep brood warm and wider spaces between combs means that less brood is produced, particularly during the spring build-up.

When brood combs (or parts of them) are used for honey storage at the end of the summer (in preparation for the winter) the cells are extended to leave a single bee space between them (5-6mm) - just like in the honey supers. But, before these cells can be re-used for brood next spring, they have to be trimmed

to the correct depth. This activity accounts for the drifts of wax fragments that are found under open-mesh floors at this time of year.

## **How is Life in a Movable Frame Hive Different?**

Until the movable frame hive came into widespread use, bees were kept in skeps (or various other containers). In this type of beekeeping, the bees were able to live in almost exactly the same way as they did in the wild. The colony built and used combs in an entirely natural way; the only difference being that a set of combs rarely lasted more than 1-2 years before the beekeeper killed the colony in order to harvest the honey. At harvest the combs were cut out of the skep and, when it was re-occupied by a swarm next year, they had to re-build from scratch. This means that normally no combs were more than 2 years old.

The introduction of the movable frame hive imposed some very big changes in the ways the bees live as compared with their natural way of doing things. The most significant changes can be summarised as follows:-

- a) The bees are forced to build their combs based on sheets of embossed wax foundation (usually with embedded reinforcing wires) firmly fixed in wooden frames.
- b) The use of a queen excluder inhibits natural use of the combs for brood rearing and the queen often has to lay in the same old combs year in year out.
- c) Because the hive is now modular, the beekeeper can increase the space available for both brood and honey by strategically adding new boxes of comb. This delays or prevents swarming and creates much larger colonies than would normally exist in nature.

d) When bees are first installed in a movable frame hive they usually have to build combs from the bottom up instead of from the top down.

## What Differences are Important for the Bees?

All the features of the moveable frame hive are important for honey production - which is why they are so widely used by beekeepers. But what about the poor bee, how does this affect them?

Arguably the single most important difference is the extended life of framed, reinforced combs which are so robust that they can be used and re-used over many years. Beekeepers can (and all too often do) use the same old brood frames year after year and this has serious implications for disease control. **For this reason, regular replacement of brood combs should be standard practice.** In areas where brood disease is not a problem, comb renewal on a 3-year cycle is about right. If disease is a problem locally, then more frequent changes are advisable. Beekeepers hate to spend money, but it is an established fact that the queen lays more brood on new comb. This in turn results in a larger colony with the potential to produce a greater surplus of honey. In practice, the beekeeper will usually recoup the cost of the foundation in the same season.

The use of a queen excluder compounds the problem of old combs by preventing the queen laying in new combs higher up in the hive. The extended life of honey combs - those that have never been used below the queen excluder - is not usually a problem and they only need replacing when very old or damaged. However, an outbreak of disease may sometimes require them to be sterilised.

Apart from longevity, the fact that the comb is constructed within a wooden frame with reinforcing wires has few disadvantages for the bees (and huge advantages for the beekeeper). You only have to try and examine the free-hanging combs in a top-bar hive to realise just how fragile they are. The wooden frame makes inspection of the hive much easier and is absolutely essential for the extraction of honey without destroying the combs. The only disadvantage for the bees is that framed combs do not transmit vibrations as well as free-hanging comb. Although we humans perceive the bee foraging dances visually, for the bees it is quite different. In the dark of the hive, the information contained in the dance is communicated to the onlookers in the form of vibrations transmitted by the comb. To overcome the poor transmission properties of framed combs the bees will often remove a strip of wax along the bottom-bars and part way up the side-bars so that they become better sounding boards. Such 'dance floor' combs are usually found in the middle of bottom brood box, they should be valued by the beekeeper and left in position if possible.

Neither the much larger colony that is produced in a modular hive (as compared with a natural nest), or the fact that the combs are built in a different order, seems to present any significant problems for the bees. Each box of comb is built from the top down and this seems to be acceptable to the bees - except that they will always try to create comb continuity between boxes if the bees-space between them is not right (and sometimes when it is). In nature bees build comb in all sorts of different cavities and have to be very flexible in how they build their nest to accommodate this variability.

# Methods of Frame Spacing

In Britain we are blessed (or blighted) by having no less than three different methods of frame spacing in common use:-

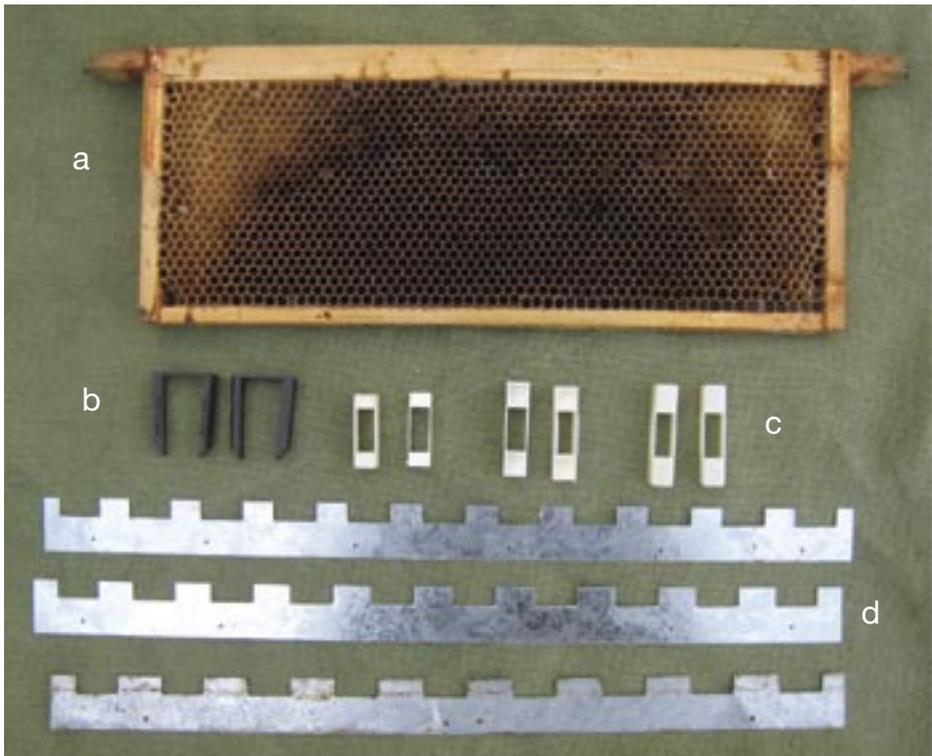
- 1) **Hoffmann self-spacing frames** - giving 12 frames/box (National hive).
- 2) **End spacers** - in no less than 3 sizes; narrow spacers ( $1\frac{7}{16}$  inch or 36.5mm), wide spacers ( $1\frac{7}{8}$  inch or 47.5mm) and extra wide spacers (2 inch or 51mm). These different sizes enable a variety of frame spacing, from 8-11 frames/box, to be attained. Narrow spacers are only used end-to-end but the two wider varieties can be used end-to-end or (staggered) overlapping if required. Also available are Yorkshire spacers that can be used on the frame lug or pinned to the side-bar and give a frame spacing of  $1\frac{7}{16}$  inch or 36.5mm.
- 3) **Castellations** - available in 3 versions of 9, 10 and 11 frames/box. Castellations for WBC hives are available in 8, 9 and 10 frame spacing.

This choice of methods is all very confusing for the beekeeper, so here are a few guidelines:-

- Brood frames are best spaced at 35mm (12 frames/box) as this is the closest approximation to the natural comb spacing of 32mm.
- Brood frames should never be spaced wider than 37mm (11 frames/box) or the inter-comb space becomes too wide and thermoregulation is increasingly difficult.

- Frames containing foundation (for drawing) should also be spaced no wider than 37mm (11 frames/box) - wider spacing usually results in irregular drawing of combs.
- Drawn frames for honey storage can be spaced at anything from 11 frames/box (36.5mm) to 8 frames/box (51mm). The wider the spacing the more likely the bees are to build brace-comb and 8 frames/box is a bit too extreme.

## Spacing Methods



- a. Hoffmann frame
- b. Hoffman converters
- c. End spacers
- d. Castellations

# Hoffmann Frames

These self-spacing frames have a fixed spacing of 35mm (34.5mm for plastic converters) which is ideal for brood rearing. In some countries this is the only method of spacing used throughout the hive. Interestingly, other countries have Hoffmann frames that provide narrower spacing than those available in Britain (33mm). Hoffmann frames are not ideal for honey production because they contain less honey/frame and may have areas of capping that are below the level of the surrounding frame - making them impossible to uncap with a knife alone. Hoffmann frames are also not ideal where a tangential extractor is being used as they do not lie flush on the wire screens. During hive inspection, once the first frame (or dummy board) has been removed from the box, Hoffmann frames can be moved laterally in groups in order to get to particular frames for examination without disturbing the rest. They can also be slid back into place in a similar manner but must be pushed together tightly in the hive to avoid the build-up of propolis on the contact faces. The ideal set-up for a brood box is probably 11 Hoffmann frames and a dummy board. The latter can be used to lever the frames tight after they have been disturbed during inspection.

# End Spacers

This is the most flexible method of frames spacing because a box can be re-configured merely by a change of end spacers. This is useful for beekeepers with only a few hives who may have a limited amount of equipment. A range of frame spacing can be achieved, from 8 frame/box (51mm) to 11 frames/box (36.5-37mm). The wider the frame spacing the more it invites the bees to build brace comb. As it is not possible to get narrower

than 36.5mm spacing using end spacers they are less suitable for brood than Hoffmann frames (by 1.5mm to be precise). End spacers also have the infuriating habit of either falling off at the wrong moment (usually into the hive or long grass) or being stuck solid with propolis when you want to change spacing. Another factor to bear in mind is that, if and when we get small hive beetle in Britain, end spacers will become a liability because they will provide refuges for the beetles - safe from molestation by the bees.

## Castellations

Using castellations means having boxes dedicated to a given frame spacing, so it is not as flexible as end spacers. They are not ideal for brood because, during inspection, frames have to be lifted vertically (10-12mm) before they can be moved laterally. This tends to roll bees between the comb faces - and a rolled bee is not a happy bee! It is also not possible to get spacing of less than 37mm with standard castellations. Castellations are ideal for honey supers because the frames are held very firmly and do not rub together and leak honey whilst in transit. This method of frame spacing minimises the use of propolis.

## Things NOT to do with Frame Spacing

- Do not have a mix of Hoffmann and end spacer frames in the same box - this is the worst of both worlds. The variable spacing tends to produce irregular combs that can not be easily repositioned during hive manipulations and some combs may only fit in one place. Buy yourself some plastic converters to transform ordinary frames into Hoffmann frames and have done with it!

- Do not use Hoffmann frames at 11-frames per box just because this is easier. Popolis will soon build up on the contact faces and the advantages of 35mm spacing will be lost
- Do not leave gaps in boxes of comb or you will get brace comb or combs bulging on one side that will only fit in one place in the box. Get the spacing right or use a dummy board!

## Frames

For the Modified National and WBC hives, frames are sold in a limited range of types which have a standard code name. The first element of the code is the depth of the frame (to fit shallow or deep boxes) and **S** = shallow and **D** = deep. This is followed by the letter **N** which stands for National and this is followed by the numbers 1-5 (except that number 3 seems to have got lost somewhere along the way).

**SN1** and **DN1** frames have  $\frac{7}{8}$  inch top bars and (plain)  $\frac{7}{8}$  inch side-bars.

**SN2** and **DN2** frames have wider  $1\frac{1}{16}$  inch top-bars but the same  $\frac{7}{8}$  inch plain side-bars.

**SN4** and **DN4** frames have  $\frac{7}{8}$  inch top-bars but Hoffmann 35mm self-spacing side-bars.

**SN5** and **DN5** frames have the wider  $1\frac{1}{16}$  inch top-bars and Hoffmann 35mm side-bars.

There is an identical range of British Standard frames for the Smith hive, except that the Smith top-bar has shortened lugs. A wider side-bar, called a Manley, can be fitted to any of these frames. Commercial, 12 x 14 (an extra-deep Modified National box), Langstroth and Modified Dadant hives all have their own specialised frames. A wider ( $1\frac{1}{2}$  inch or 38mm) Hoffmann side-bar is also offered for all these frames but is rarely seen.

What's the difference? For Hoffmann frames the difference is self-evident. Hoffmann frames can also be made by converting non-Hoffmann frames using a nailed-on plastic converter. The idea behind the wider 11/16 inch top-bar is that it provides the correct bee-space between top-bars and thus reduces the amount of brace comb built in this position. It does work and, for brood frames, the extra cost is arguably worthwhile - but probably not for super frames. However, if you already have a large stock of frames with narrow top-bars do not despair, they are still perfectly serviceable - you just get a bit more brace comb.

## **Frame and Spacing Summary**

Much has been said above about the importance of correct frame spacing but, if you are going to have a moveable frame hive in which the frames actually move (freely), the hive boxes have to fit together and leave correct bee-space ( $\frac{1}{4}$  inch -  $\frac{3}{8}$  inch or 6.5-9mm) between them. The space in question is that between the bottom-bars of the frames in the box on top and the top-bars of the frames in the box below. Whether you use a hive with bottom bee-space (standard for the National hive) or top bee-space (Smith, Langstroth and Dadant hives), it is vital to check this space is correct for all boxes and that boxes are compatible.

Standardisation is important in beekeeping and arguably the best choice is Hoffmann frames for brood (below the queen excluder) and castellations for honey (the supers above the queen excluder). A few supers on end spacers can be kept to provide flexibility. At least some of the castellated supers must be of the 11 frame variety in order to get foundation drawn properly. Wider spacing in honey supers gives more weight of honey/box and fewer frames to extract. On the other-hand,

narrow spacing (with more frames) gives more cells for the bees to work on when depositing and drying nectar and also gives more surface area for passive drying prior to capping. Because of drying problems, deep cells have a tendency to contain honey with a slightly higher water content. Closely spaced (thin) combs are more readily capped but more wax has to be produced by the bees - at the expense of some honey. **It is for brood frames that correct spacing really matters.** Spacing of super frames is only critical for comb drawing.

## Comb Drawing

Beekeepers often put frames of foundation in a hive and are disappointed when they do not get drawn. A colony will only draw combs when it actually **needs to** - when there is a shortage of comb for what they want to do at that particular moment. There is no anticipation of future needs and the 'here and now' requirement for comb is the only consideration. Comb building is a heavy drain on colony resources and it is estimated that it takes 8lbs (3.6kg) of honey to produce 1lb (0.45kg) of wax. Additional costs (to the colony) are incurred through the diversion of bees from other duties to become comb builders and the energy needed to produce the local increase in temperature (over 40°C) that is required to for the bees to work the wax properly. Colonies are also more willing to engage in comb building in late spring and early summer, when the queen is laying hard and bee numbers are rapidly increasing, than in the autumn, when the queen is laying less and bee numbers are decreasing. The two main reasons why the colony commences comb building are:-

- 1) It is short of space for the brood nest to expand.
- 2) It short of space to store honey.

In a natural bees nest the distinction between space for brood and honey does not really exist and it is only in a movable frame hive with a queen excluder in place that the two reasons need to be considered separately.

Assuming a colony needs to build comb it also has to have the resources with which to do it. The most important resource is **a current flow of nectar**. Stored food is not normally used for comb building. This is an important survival strategy and conserving existing stores always has priority over comb building. It does not have to be a natural nectar flow and the provision by the beekeeper of sugar syrup is just as effective. The other requirement is plenty of bees to become wax makers. However, if there are not plenty of bees there will be no need for comb building which is why it is no good putting frames of foundation in a weak hive and expecting them to be drawn.

## **Drawing of Brood Combs**

Brood combs are drawn when the brood nest is expanding and more space is required for the queen to lay. When the brood nest encounters a frame of foundation the bees will draw it. However, if there is an unused drawn comb on the other side of the box, the brood nest will expand in that direction first. Many beekeepers put frames of foundation on the outside, next to the hive wall, expecting them to get drawn. In this position they will only be drawn as a last resort and even then it may be only the inner face. Bees much prefer to build a vertical column of combs than to expand laterally. Changing the position of frames; moving drawn combs to the outside and interleaving frames of foundation with drawn combs can be used to force the bees to draw combs when and where the beekeeper wants them.

**Early in the season** - when the brood area is not yet full of bees and the weather is still cool, the correct place for frames of foundation is next to the outermost frame of brood. Even though there are drawn frames outside them, in this position they will have to be drawn to retain brood nest continuity.

**Later in the season** - when the brood area is crammed with bees, frames of foundation can be placed within the brood nest itself. In this position they will be drawn and probably laid in 4-5 days, or less. It is often claimed that interrupting the brood nest with frames of foundation leads to the production of queen cells on the side where the queen is (temporarily) absent. Experience suggests that this does not happen unless the colony is already on the brink of producing queen cells.

## **Drawing of Honey Combs**

The building of combs to store honey is less critical for both the bees and the beekeeper. Badly drawn combs with depressions and bulges will hold just as much honey as a pristine set of combs. The bees will be quite happy with their handywork and it is only the beekeeper who will suffer when extraction time arrives. So to avoid a lot of mess and poorly balanced loads in the extractor, it is better to pay some attention to getting nice evenly drawn honey combs.

The initiation of comb building for food storage is well understood. Incoming foraging bees do not store nectar themselves; they transfer it to receiver/storage bees somewhere near the hive entrance. When the storage bees are fully loaded they move off to find somewhere to store the nectar. If after a reasonable time ('reasonable' does not seem to be specified in

the literature but it is probably a few minutes) a storage bee has not found a vacant cell in which to deposit the nectar - one that is not already full of nectar or is not currently being used by another bee - it ingests the nectar. In this process, the nectar passes from the bee's honey crop into its digestive system and this large intake of sugars converts this bee into a wax-maker. Switching to comb building usually commences when 60-70% of the available storage space is filled with nectar. Having converted to wax-making and comb-building duties, a bee will repeatedly visit the hive entrance to re-fuel from incoming foragers and make more wax. Only when the nectar flow ceases will this behaviour be switched off. The need for new comb will have ceased with the nectar flow and this provides a self-regulating mechanism for the control of comb building - so they do not build more comb than they need.

There is a range of ideas about how best to present combs to a colony to ensure good drawing but it is not clear that this is really important - it is the colony's need to make new comb and a nectar flow to fuel it that really matters. Generally comb building is easiest for the bees in the warmest place in the hive and that is immediately over the queen excluder. But, if the weather is warm and there is a good nectar flow, they will happily draw comb at the top of the hive. Placing a frame containing nectar in the middle of a box of foundation ('seeding') is said to encourage the bees to use the box and draw the foundation earlier than they would otherwise.

# Drawing Combs with a Swarm

This is the ideal method of getting combs drawn quickly and well. A natural swarm is already well prepared - with many of the bees carrying mature wax scales - to build comb. Even though there may be a nectar flow when the swarm is hived, it is still a good idea to supplement this with a generous feed of sugar syrup - 4Lt of syrup in a contact feeder is good. It is good practice to give a swarm about 24 hours to settle in before it is fed.

A swarm should be initially installed in a minimum volume hive and given only those frames that are going to make its brood nest - NO supers. The more bees you can cram into a limited space the quicker and better the combs will be drawn. A good sized prime swarm will be quite happy in a single deep box until it has drawn its first set of combs. Do not forget that this colony will only get smaller for at least 3 weeks, until the first brood laid by the queen emerges. If it is a cast swarm, that has to get its virgin queen mated first, it may be 5-6 weeks before the colony gets any new recruits. If you use shallow boxes for brood rearing, then small swarms and cast swarms can be conveniently hived in one of these. It is not a bad idea to give a newly hived swarm one clean drawn frame in the middle of a box of foundation - this is thought to encourage the swarm to stay (not abscond) and gives comb for the queen to start laying immediately.

When a swarm occupies a box containing foundation they will start to draw as many frames of foundation as they have bees to cover. A really large swarm will simultaneously draw all the

## Well drawn brood comb



frames in a deep box in as little as 48 hours. Smaller swarms will only attempt to draw some of the frames (4, 6 or 8, depending on the number of bees) and will leave the rest untouched. When they have drawn this initial set of combs they will start to use them for brood and food storage and will not attempt to draw any further foundation until they need to - which is when they have fully utilised the initial set of drawn combs. This is not what the beekeeper wants, particularly if syrup is being fed to help with comb drawing. Instead of being used for drawing, this syrup will be stored in the initial set of combs and could later be transferred to the honey supers. To avoid this problem, the frames should be re-arranged, with at least one drawn

frame being moved out on each side of the box and frames of foundation moved in towards the centre of the hive, adjacent to combs on which the queen has started to lay. This way all the frames will be drawn in the shortest possible time and the syrup feed can be withdrawn to prevent its use for other purposes. As soon as the initial box of combs is fully drawn and is being well utilised by the bees, other brood boxes or honey supers can be added - but this is often not until the colony size is starting to increase again.



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