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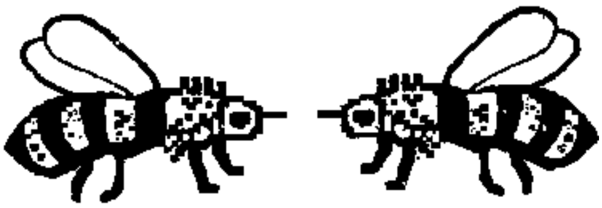
A circuit diagram and technical data can be downloaded from Barry Birkey's website at www.beesource.com/plans/apidictor.htm

Beekeeping in a Nutshell

Listen to the Bees



by Rex Boys

Listen to the Bees

Dedication

Although my name appears as the author of this book, my main purpose in writing it is to set on record the work of the late Eddie Woods, to whose memory it is dedicated.

1999

Rex Boys

The Cottage GL20 7ER

Contents

Introduction

Born in 1901, Edward Farrington Woods graduated from Faraday College, spent some years working for Western Electric and then joined the BBC as a sound broadcasting engineer in 1932. In 1942, when Britain's fortunes were at their lowest ebb, the Government asked everybody to produce as much of their own food as they possibly could; 'Dig for Victory' was the name they gave to the campaign.

Eddie must have had a sweet tooth because he responded by taking up beekeeping. His lively, enquiring mind needed to get to grips with some form of original research, though, so he decided to study the sounds made by the bees. After all, it was his own specialist subject and it was a field in which very little work had already been done. He also had a far-sighted employer who allowed him to borrow specialised equipment that he could never have bought privately.

He really got going after the war when he set up some equipment in his garage at Hinchley Wood with microphone leads going down the garden to his hives. He spent 15 years listening, analysing and recording, not only in his own apiary but up and down the country as well. With access to the extensive apiary of Roland Morris at Penzance, he was able to get through many more experiments in a season than he ever could have done at home. During this time he made some startling discoveries which, after checking and re-checking, he reported in a lecture to the Central Association of Beekeepers in 1950. Over the next 19 years, he wrote extensively about his discoveries, notably in numerous articles in British Bee Journal as well as in Bee World, Nature and New Scientist.

Because his work took him away from home a lot, Eddie's Holy Grail was to design a portable electronic instrument that would predict swarming with more notice and without laborious hive inspections. Although he had a design, it was not until 1964 that industry produced components small enough to make it practicable and in that year he launched the 'Apidictor'. About 300 were sold worldwide; many are still in use but for some reason it never caught on and, along with his other discoveries, is now largely forgotten.

Eddie worked on some notable outside broadcasts including the last Schneider Trophy race and the king's Christmas Day message; it is said that the queen used to ask for "that nice Mr. woods again" and in 1967 he was awarded an MBE. He retired in 1972 and died in 1976.

The following chapters record the work of a truly remarkable beekeeper who could well be described as 'a man for all bee sounds'.

2. What exactly are sound waves?

A definition that is near enough for our purposes is that sound consists of pressure variations that are transmitted through the air and detected by the cars. It is a pity they are called waves because this conjures up visions of the seaside with the water going up and down and they are not really like that at all.

imagine that you are holding a ping pong bat and you 'hit' the air with it, rather like somebody serving at tennis but without a ball. Although it is invisible, air is. a spongy sort of substance and the layer against the bat becomes squeezed or compressed.

It doesn't like this and quite quickly decides to expand again. It cannot go back where it came from so it spreads in the opposite direction and in doing so, compresses the next bit of air. This then expands in turn and you get a little impulse of compression that spreads out away from the bat, getting weaker as it goes. If somebody is standing in its path, it presses very gently on their skin and also goes into the ear to press on the eardrum but no message passes to the brain at this stage.

Now go back to the bat and jerk it backwards. This time a vacuum is created and the air in front of the bat gets stretched. When it shrinks, it sucks air in, stretching the next layer, so this time an impulse of rarefaction travels out and pulls on the eardrum. Vibrate the bat backwards and forwards and the eardrum will follow the vibrations.

Behind the eardrum there is a clever instrument that measures how many times a second it is being vibrated but it does not pass any mgssage to the brain until this frequency is about 15 times a second or more. For an old codger like me, it can measure up to around 8,000 times a second, a young person can detect up to 12,000 and a sheepdog can hear even higher frequencies. Instead of using the three words, 'times a second', from now on I shall use the proper word, 'Hertz', which means the same thing and is abbreviated to Hz.

Because 1 can not vibrate a bat more than twice a second at the most, we need something that can in order to launch our sound waves. That something is a loudspeaker such as is used in radio sets. It consists of a paper diaphragm shaped in a shallow cone and fixed in a metal frame. Do not worry about how it works but there is a coil of wire and a magnet. When an electric current flows through the coil, it pulls on the diaphragm. Make the current flow backwards and forwards umpteen times a second and the diaphragm launches a sound wave of umpteen Hz.

Make the frequency 261 Hz and the ear sends a message to the brain saying, "I am being vibrated 261 times a second". "Thank you", says the brain, "I recognise that as the musical note middle C'. This is a significant moment because we have reached the interface between art and science, between physics and music. The technologist has taken an electric current and converted it into music.

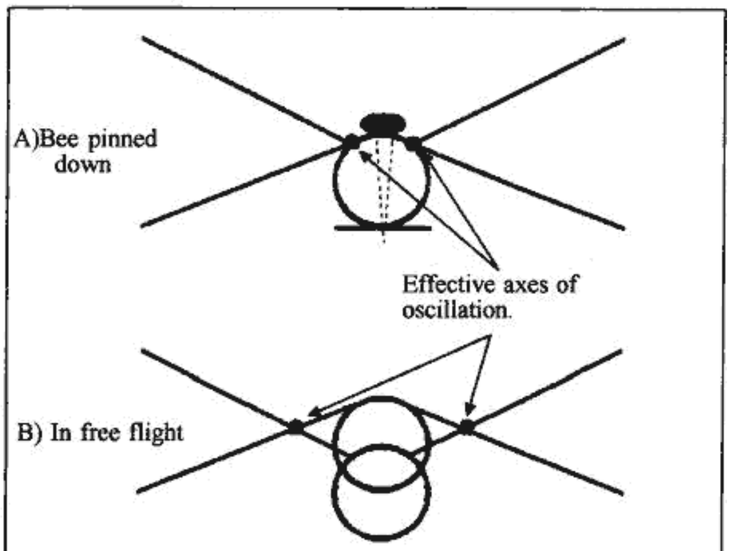
In practice, of course, it is much more complicated. In the first place, we have two ears which report separately to the brain, giving it an indication of the direction of the sound. Secondly, it is very rare to hear just a single frequency because there are usually harmonics mixed in with it. Harmonies are multiples of the basic frequency so that if you play middle A (440 Hz), there may also be some 880Hz, 1760Hz and so on. These are the second and fourth harmonics and translate into musical terms as one octave and two octaves above middle A.

It is the particular mix of harmonics that gives a sound its tone and enables us to distinguish one musical instrument from another. The pure tone of a flute has only a few harmonics but the rasping of a trumpet is rich in them. That's enough of the technical stuff for the moment so let's move on to the bees.

3. Wing Beat Frequency

The generally accepted figure for the number of times a second the bee flaps its wings was 190 for a worker and 140 for a drone, measured by Teale, using a stroboscope. Unfortunately, they are wrong.

In order to use the stroboscope, Teale had to fix the bee down but, not being mechanically minded, he did not realise that this would affect the frequency. In flight, the bee's body moves down and up as the wings go up and down. Hence, the point about which the system oscillates moves a short distance up the wings, shortening the 'pendulum' and causing them to vibrate faster, as this diagram shows.



Illustrating the effect of pinning the bee down

What Eddie did was to get a bee flying around indoors and find the note on the piano that most nearly matched the sound. For a worker, this was b next to middle c, a frequency of 247 Hz, Using a variable oscillator, he later took a more accurate measurement which produced a figure of 250 Hz for a worker and 190 for a drone. When a bee is fanning, it does anchor itself down, though with the feet and not with a pin, of course! Hence, Teales's figures were near enough right for a fanning bee, possibly out by 5Hz since there is a bit of flexibility in the legs that might permit a little body movement.

The general lack of technical understanding on the part of entomologists was something that plagued Eddie throughout all of his investigations. When I was at school, there was no choice; boys did Physics and girls did Biology. Nowadays there is more choice but I suspect that the gap still exists because the sort of people who are interested in living creatures have little time for machines and vice versa.

From the engineering point of view, the bones, ligaments, sinews, muscles, wings etc. can be regarded as a system of rods, levers, cords and cables driven by motors. Like a pendulum, the wing systems have their own natural frequency of vibration and the rule is, the smaller the faster, stretching from the high pitched whine of the tiny mosquito to the slow, laborious beat of a golden eagle.

It is an inescapable scientific fact that if you want a clock to tick once a second, the pendulum has to be close to 39 inches long. Though I know nothing about ornithology, I would hazard a guess that it should be possible to relate the wingspan of a bird to its wingbeats per minute. Perhaps a stopwatch would be useful in identifying large species at a distance!

4. Queen Piping

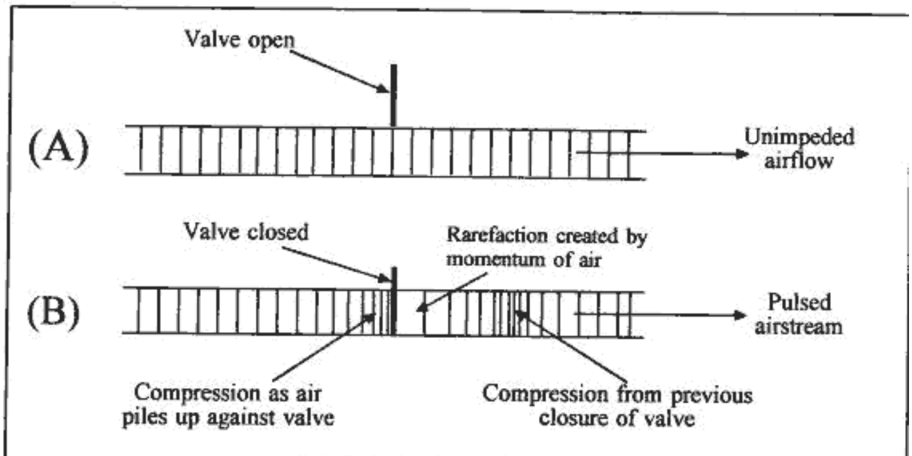
When I talk to an audience, I always ask for a show of hands of who has actually heard queen piping and the result is usually about 50% of the beekeepers present. Then I ask who reckons to hear it at least once every year and further questioning establishes that all these people have more than 20 hives. This is more or less in line with my own experience; with an average of 8 hives over 20 years, I have heard it just 3 times. What this means is that an average beekeeper with 2 hives is likely to hear it once every 25 years! **Clearly it is a pretty** rare phenomenon.

Piping is the sound a queen makes when she detects the proximity of another queen and the words used to describe it are bleating, honking, croaking or mewing. For my money, the nearest sound I can think of is the crying of seagulls when they are competing for your sandwiches. The only time you get two queens in the hive is around swarming and they will usually be virgins that have emerged after the swarm has left. Imagine the difficulty in carrying out research on a sound that in any particular hive, occurs for only a few days in every one or two years! Fortunately, Eddie had access to an apiary with 1,000 hives, albeit right down near Penzance.

Being an expert on loudspeakers, he understood the behaviour of diaphragms and the first time he heard queen piping, his immediate reaction was, "That sound is too loud to be made by a tiny wing smaller than a sixpence". Until that moment, it had generally been assumed that any sound made by bees was generated by the wings vibrating as a pair of free-edged diaphragms, a smaller version of the ping pong bat we started with. Now it was necessary to look closely at the bee's anatomy but first we have to go back to the classroom for another physics lesson on sound.

Looking at the instruments of the orchestra, it is fairly obvious that the drums and cymbals are diaphragms. So also are the piano and the rest of the strings. In a violin the body becomes a diaphragm, driven through the bridge by the strings. Another way of launching a sound wave is by the organ pipe method. Here, air bounces backwards and forwards in a tube, building up to an amplitude at a frequency determined by its length. Instruments working on this principle are the recorder, flute, piccolo penny whistle etc. in which the length and hence the note, is controlled by using the finger tips to open and close holes.

Another method of generating sound is known as the pulsed air stream and here we need a diagram.



Generation of pulsed air stream

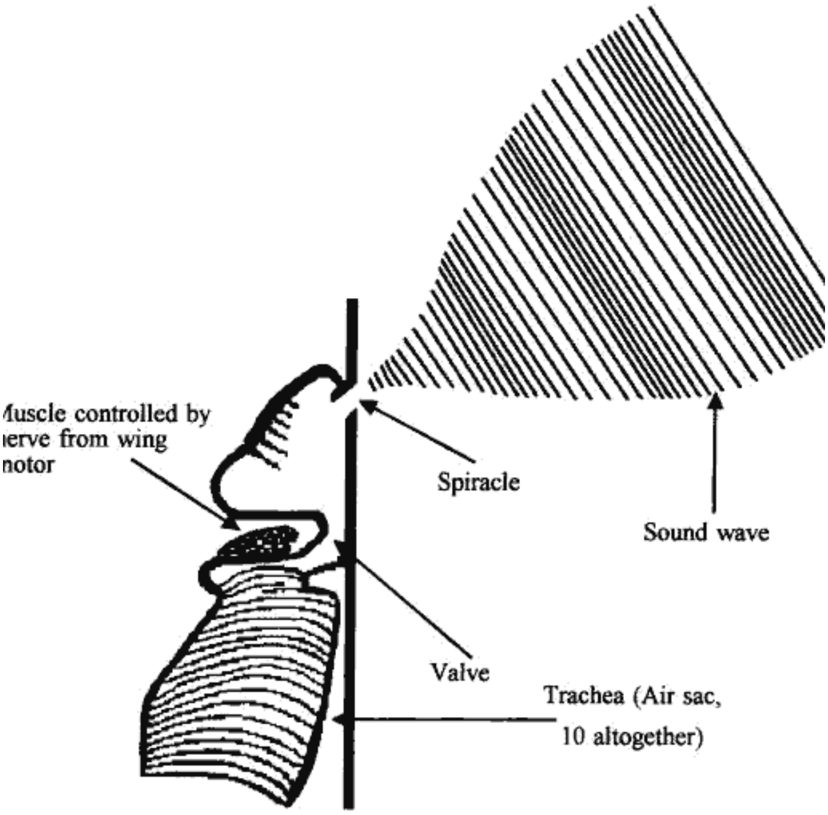
(A) shows a tube with a stream of air passing through it, the air being represented by the parallel vertical lines. The line sticking up above the tube is meant to represent a sliding shutter that can drop down and block the tube. When this happens, as in (B), the momentum of the air causes it to pile up against the shutter and it becomes compressed. On the right hand side of the shutter, the opposite effect happens; the momentum tries to create a vacuum and the air by the shutter becomes rarefied.

If the shutter is now opened again, airflow restarts with the compression and rarefaction impulses continuing on their way. Making the shutter vibrate in and out generates a train of impulses of the appropriate frequency. If the end of the tube is belied out in a suitable way, it helps to launch the sound wave. In the clarinet, saxophone and oboe, the mouthpiece has a flexible reed that opens and closes to interrupt the airstream at the resonant frequency of the instrument. This, of course, is determined by its working length which in turn, is controlled by the musicians fingers opening and closing holes and valves - and that's how you get the music!

The ~pet, trombone and bugle (and the didgeridoo!) are somewhat different. Instead of a reed, the airflow is started and stopped by the musician vibrating his own lips, blowing a 'raspberry' almost. He has to strike the note and set the length of the instrument to resonate with it. Actually, its a bit more complicated because there are different modes of resonance and for any particular length, he has a choice of notes which he selects by varying the muscular tensions in his lips. The bugle is a fixed length and is capable of producing only four or five notes; very simple and robust but ideal for the few calls required on a battlefield. The hunting horn is just a straightened out bugle.

The important thing about all this is that the pulsed airstream is much more efficient than other methods of generating sound. By efficient, I mean you get the loudest sound for the minimum effort. Just think of the muscular energy it takes to crash a pair of cymbals. Then think how a trumpeter can fill the Albert Hall with just as much sound for a very modest puff of air from the lungs. About 90% of the energy comes out as sound whereas for a bee's wing, the figure would be about 1%. For this reason, Eddie was convinced that it was a pulsed air stream he was looking for - and that is what he found

The bee's anatomy is very different from ours. We use the mouth for eating, breathing and talking; the bee uses its mouth solely for food. Breathing is done through 14 tubes ranged along the thorax and abdomen, two each side of the thorax and five each side of the abdomen. This is where Eddie made his significant discovery which is illustrated in this next diagram.



Production of sound from the spiracles

Air is drawn through the spiracle openings into the tracheae, which is the bee's equivalent of our lungs. On its way it passes through a valve which can be opened and closed by a muscle as indicated. As it exhales, the bee can vibrate this valve to produce its piping in exactly the same way that a trumpeter vibrates his lips. The frequency at which the valve operates is controlled by nerve impulses which originate from the same source that controls the wings. It is important to appreciate what this means.

On the assumption that all sounds were made by the wings, nobody had previously bothered to look any further. Because the spiracle valves are synchronised with the wings, the note they produce is the same, anyway. One might wonder why the Great Designer in the Sky went to the bother of linking the two functions together and further consideration will be given to this in chapter 6.

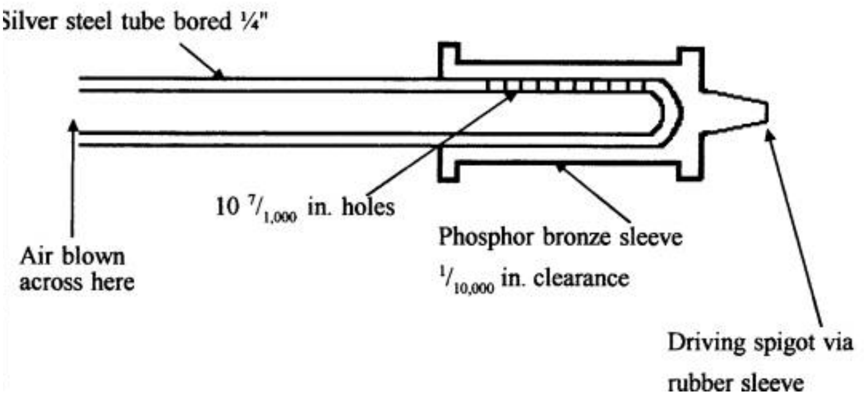
In all Eddie observed three distinct forms of piping. The one that is heard most often is that of a virgin, roaming around the hive after the swarm has gone. Her pipe is at about 340 Hz at first, falling slightly as the wings harden. Eddie described it as a "full round hoot" or a "whoo-whoo". The reason it is higher than the flight or fanning frequency is that when piping, the queen keeps the wings folded and vibrates them in a 'scissors' motion.

From about the fifth day after sealing, the developing queen in a cell can pipe. Having only stumps to vibrate, the frequency is even higher, a feeble bleat at about 450Hz which also falls as she approaches emergence. The fact that she can pipe within the cell should have alerted people to the fact that the sound was not made by the wings.

Clearly, piping usually occurs after a swarm has departed; the old queen does not challenge an immature one in her cell. However, there may be occasions when bad weather delays the emergence of the swarm in which case young queens may find themselves near the old lady, whose pipe was described by Eddie as a "quark". (a cross between a quack and a squawk?) It also varies in volume depending on the extent to which her tracheae are distorted by egg-full ovaries. He also used piping as a means of finding the queen. He squashed a queen cell to get the smell on his fingers which he then moved over the face of the combs; when they got near to the queen she picked up the scent and piped.

One thing about Eddie Woods is that he was thorough; not content with a single experiment, he would repeat it several times before reaching a conclusion. Realising that piping was a pulsed air stream from the spiracles, he set about reproducing it mechanically by getting his friend Sydney Pickett to make a tiny whistle. This consisted of a silver steel tube the same diameter as a queen's abdomen in which he drilled a row of 10 holes of 7 thou diameter.

A phosphor bronze sleeve was made to fit over the tube with sufficient clearance for easy rotation. The sleeve had eight longtitudinal slots such that when it was rotated at 45 revolutions a second, the holes were opened and closed 8 x 45 = 340 times a second. Using a fountain pen filler, a gentle puff of air across the end of the tube produced a whistle of about the same volume as a queen piping. Here is a diagram of it; unfortunately the actual whistle can not be found.



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Eddie Woods' model for simulating Queen Piping

This convinced Eddie that the sound did indeed come from the spiracles and that it was the only way a queen could produce such a loud sound. Convincing the beekeeping establishment of the day was a different matter, however. Here was an upstart engineer telling the professional entomologists how a bee functioned; quite naturally, their pride was injured. Furthermore, they did not really understand what he was talking about. Knowing Eddie, 1 suspect that his approach to them may not have been as tactful as it could have been.

In 1963, at the University of California, Adrian Wenner investigated whether the trachea was resonating in the manner of a whistle. He knew that if a whistle was blown with some gas other than air, it produced a different note. When he persuaded a queen to pipe whilst breathing helium, he observed that the note was the same as when she breathed air. From this he concluded, quite correctly, that the trachea was not operating as a whistle.

This was an experiment that Eddie did not need to try. Just as the frequency of a pendulum is determined by its length, so is the resonant frequency of a tube and to produce a note of 340Hz, a closed tube needs to be 10 inches long. He would have been tickled pink at the thought of getting a queen to breathe helium in order to prove that her breathing tubes were less than 10 inches long! The resonant frequency of the trachea, about 35,000Hz, would be way above the audible range but, in any case, the soft tissues would preclude oscillation. You can produce a note by blowing across a milk bottle but you'll not get much sound out of a rubber hot water bottle and even less from a plastic bag.

It was clear from his paper that Wenner had not understood Eddie's findings, being under the impression that the whistle and the trumpet worked on the same principle. The frequency of a whistle is determined by its length. So too is the pulsed air stream of the clarinet. The note of a trumpet, on the other hand, results from the vibration frequency of the lips which is a function of muscular tension, controlled by the musician. In the case of a queen bee, the spiracle valves are synchronised with the wing motors which can go on running, even if the wings are 'stalled! or 'out of gear'. There is no need for a resonant cavity though if one is present, as in a trumpet, it magnifies the sound.

The rate at which the motors vibrate is determined by the pendulum effect of the wings. The highest note of 450 Hz comes from the stunps of a virgin in the cell. As the wings grow and harden, the frequency comes down to the 340 Hz of the emerged queen with the wings in the scissors mode. There will be a further drop when she beats her wings in flight.

From Rothamstead, Dr. Simpson argued against the idea of spiracular sound, suggesting that since the queen adopted a crouching position whilst piping, she was actually vibrating the substrate with her thorax. 1 can imagine this producing sound on a sheet of cold foundation but in midsummer, with a heavy comb full of larvae and honey, it would be about as effective as Fred Astaire trying to do a tap dance on a straw mattress in the middle of a peat bog! The exchange of letters between Eddie and Dr. Simpson reveal a polite but frosty atmosphere!

Wenner also conducted an experiment to determine whether the queen responded to airborne sound or substrate vibration. For the latter, he screwed a transducer to the outside of the hive, assuming that the vibrations would be transmitted via the frame lugs to the comb. Personally 1 think this would have made the brood box itself function as a diaphragm and more **sound would have reached the** queen through the air inside the hive. Later, (1965) he reverted to the idea that the sounds resulted from the wings acting as diaphragms, ignoring the fact that a queen can pipe in her cell before she has any wings.

5. Swarm Prediction

When Eddie first studied queen piping. he hoped it would lead him to a method of swarm prediction but he soon realised that it nearly always indicated that the swarm had already left and was too late to be of any use. so he turned his attention elsewhere.

There is a phenomenon known to audio engineers as the 'cocktail party effect. This is the ability of the human brain and ears, when in a room full of talking people, to select and concentrate on listening to just one conversation, not necessarily the loudest. Eddie was quite good at it and so, when listening to a hive of bees, he could pick out sounds that others would miss. One he found himself listening to was a sort of warbling sound, a note that varied between 225 and 285 Hz. This corresponded with the fact that the worker bee's wings do not finish hardening till they are about 9 days old and until then have a rather uncertain pendulum frequency. He deduced that the sound came from the 4 1/2-6 day old nurse bees and was due, not to individual bees warbling, but to the combined effect of many individual different frequencies.

An average hive has about 4,000 nurse bees of which half are feeding larvae and the other half the queen, who eats 20 times her own weight in a day. Even if there is a drop in demand, the nurses go on producing food; they cannot help it because they are at that stage in the life cycle. With no outlet for the food, frustration sets in and this, according to **Eddie, leads them** to warble. Hence, the warble indicates that the hive balance has altered because the queen is laying fewer eggs; one possible reason being that she is on a reduced diet to get her weight down ready for flying with a swarm.

Here was a sound that might indicate an intention to swarm. Even if it didnt, it showed that egg laying had declined and that a brood box inspection was desirable. Then another sound came to Eddie's notice, one that might clinch it.

When you give the hive a sharp knock with the flat of the hand, the bees hiss at you and you need to listen to this quite carefully. Under normal conditions, it is a short, sharp noise, lasting about half a second, starting and finishing quite suddenly. The bees are on the alert and defensive. On the other hand, if a swarm is in the offing, they have been at the honey and are in a happy-go-lucky mood, the hiss is not so loud, rises more slowly and tails off more gradually. It's a sort of, "We don't care if you bump the hive, we're leaving soon anyway", reaction. Eddie described it as a loyalty sound.

With the warble and the hiss, he had the ability to predict swarms but the sounds were still mixed up with other hive noises from which they needed separating and amplifying. Designing filters was part of Eddie's regular job at the BBC and it was easy to make one to allow the band of warble frequencies, 225 - 285Hz to pass through, blocking off the rest. Because flight noise falls within this band, it can mask the warble and it is recommended that these tests are done in the evening when flying has ceased.

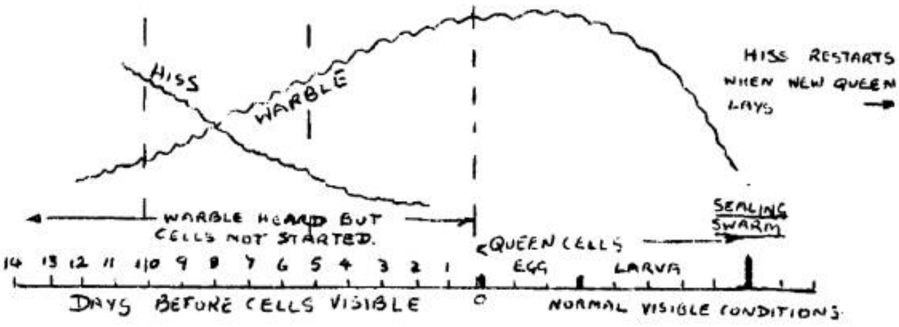
The frequency components of the hiss were above 3,000Hz so a high-pass filter was needed, blocking off sounds below that. The basic design of the instrument was comparitively easy. All that was needed was a microphone, a 3-position switch, two filters, an amplifier and a headphone. However, there were one or two practical difficulties. The components for audio ftequency filters contained a lot of iron and were heavy, too large for a portable instrument. The experimental model took up a lot of room on the bench in Eddie's garage.

Originally the microphone was on a rod pushed into the hive entrance but the bees attacked it rather noisily. The final arrangement was to have a hole in the brood chamber, level with the top of the frames, and the same diameter as a domestic sink plug. The microphone was mounted in a rubber moulding of similar diameter and plugged into this hole when required. Inside, the hole was covered with thin pvc and when not in use it was plugged on the outside with - a sink plug!

Eddie found he was hearing the warble up to three weeks before the swarm left and something like 10 days before the visible signs of queen cells. During that time, the warble gradually increased in volume and he realised that in an instrument for general use he would need some form of measurement so that beekeepers would know at what point to take action. For this he used a small 'magic eye' of the sort that were widely used for tuning some radios from the late 1930's onwards. When there was little or no signal, the eye glowed green. As the signal increased, the eye 'close& to become a thin red line.

Hence, when conditions were normal, it was necessary to turn the volume right up to close the eye but as swanning time approached, it would close with the control at a progressively lower level. The pointer on the volume knob swept over a coloured band, red at the lower levels, yellow in the centre and green at the top.

This next sketch illustrates the timing of the rise and fall of both the warble and the hiss.



As the departure day approaches, the hiss dies away but the warble increases in volume until the queen larva hatches and then declines, vanishing altogether a couple of days before the swarm leaves.

Having formulated the design, Eddie had to wait until 1960 before he could produce an instrument small enough to be carried round an apiary. Valves gave way to transistors and the invention of a component known as a 'pot core' enabled him to miniaturise the filters. His NW was built into an ex-army billy can, strapped to the waist with a webbing belt. For the Mk4 he added the magic eye indicator and this was the model that went into production in 1964. Even smaller than the MK3 it was in a leather case which also carried the microphone and stethophone. The plan was that m the Mk5 the eye would be replaced by a little meter but this never went ahead.

WOODS APIDICTOR MARK IV

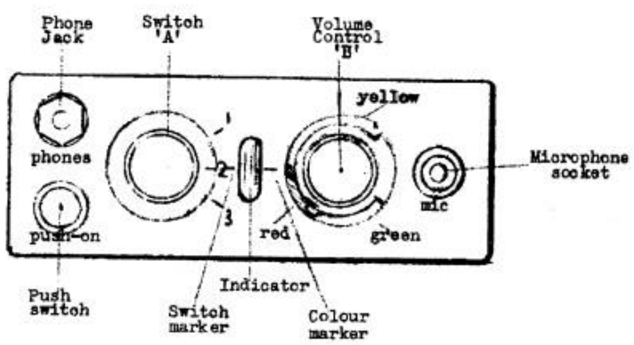


Fig. 1 Front Panel: Woods Apidictor.

The above diagram illustrates the front panel; the instructions for using the Apidictor were as follows:

1. With the instrument in its case, hanging from the neck, the stethophone is hooked into the ears with the flex coming out under the veil and plugged into the socket at the left hand end of the panel.

2. Plug the microphone into the hive and insert its plug into the mic socket at the right hand end of the panel.

3. With Switch'A' at position 1 and the volume turned well up, press and hold down the 'on' button. The complete hive noise will be heard and the indicator will not glow.

4. Switch to position 2 and listen for the warbling or bubbling sound. Turn the volume control B' back until the indicator just lights up green. If the pointer is still in the green area, there are no swarm preparations and the hive can be left for another 9 days. If the pointer is in the yellow area, there may be a swarm in the offing though queen cells may not be visible yet. Test again in 4 days. If the pointer is in the red area, the bees might be preparing to swarm or they might be superceding or there might be some other queen failure.

5. Switch to position 3 and strike the hive with the flat of the hand. If there is a staccato hiss, a swarm is not in prospect but an inspection is needed anyway. If the hiss is quieter **and drawn out, you** can expect to find swarm cells. Note that in position 3, the volume control is inoperative.

In the interest of battery economy, the instrument only functions whilst the 'on' button is held down. Tests should always be carried out in the evening after flying has ceased, otherwise flight noise can obscure the warble. Also, in periods of heavy flow, the warble can vanish altogether, probably because the nurse bees have to go and help in an 'all hands to the pumps' situation.

The Apidictor can also be used for queen introduction. A caged queen placed in a hive can be safely released once a test indicates that the staccato hiss is present again.

Having discovered spiracular sound, Eddie Woods omitted to indicate the source of the hiss which is aperiodic and above 3,000Hz, much too high to originate in the wing motors. My own theory is that it arises from a sudden exhalation of air from the tracheae, without any operation of the valves. This is analogous to the same noise in humans; we do not use the larynx but make the hissing noise at the front of the mouth with the tip of the tongue and the lips. The half second duration of the bees' hiss is about the right length of time for exhaling one trachea full of air.

If the warble indicates a falling off in queen performance, her total absence is indicated by the well-known moaning sound. This again is a fluctuating sound, lower in pitch than the warble. With prolonged queenlessness, it develops into a roar and the colony becomes vicious. Eddie didn't have much to say about this sound but I suspect it arises from the same sense of frustration as the warble, the lower pitch being accounted for by the fact that the adult bees, with their harder wings, have now joined in.

Something like 300 Apidictors were made and sold, many of them overseas. (The design is protected by patent 729067.1958). Although none has been made since 1964, several are known to be still in use and last summer (1998) two beekeepers were supplied with data enabling faults to be cured. They swear by it and still depend on it in their apiaries. It is likely that it never became popular because most beekeepers regarded it as too 'technical'; certainly it needed an understanding of what one was listening for and, to a certain extent, a musical ear.

Eddie always emphasised that the maximum benefit occurred in commercial apiaries where time is money. In the swanning season, all hives had to be inspected every 9 days, each inspection taking 5 -10 minutes and 95% of them proving negative. An apidictor test took 10 seconds and only one in ten indicated the need to do a full brood inspection. Hence the **work load was reduced** to 10% of what it had been. We now live in a more technically minded age, components are really tiny and it is probable that a modem version of the Apidictor would be even smaller, cheaper and more acceptable to the beekeeper. Indeed, I can visualise a future in which each hive has its own miniaturised apidictor which generates an alarm, transmitted back to base by radio when the warble has built up to the **appropriate** level!

Eddie Woods checking a hive with the Mk4 Apidictor

6. The Paradox Resolved!

All the sounds that have been discussed so far originate inside the hive and only queen piping is loud enough to be heard outside. Clearly, at the time he measured wing beat frequency, Eddie still believed that the sound came from the wings and it was only when he started investigating piping that he discovered spiracular sound.

It would then have been obvious to him that normal flight noise also came from the spiracles but he never mentioned it specifically, only in passing when talking about something else. Knowing how the flight noise is generated, I began asking myself, Why?' Why did the Great Designer in the Sky decree that bees should buzz when other insects of similar size and construction fly around in silence - those hoverflies, for example, that pretend they are bees? More particularly, why go to all the trouble of linking the spiracle valves to the wings?

Imagine an alien from outer space emerging from his flying saucer at Heathrow. He would almost certainly ask, "What is the purpose of the loud sound made by your aircraft?" The answer is, of course, "It has no purpose but is an unavoidable consequence of the method we use for propelling them. If we could invent silent engines we would do so." 1 believe the same answer applies to the bee and the fact that you can hear the buzzing is quite incidental

This next paragraph is the most significant in the whole book. read it carefully.'

Sound consists of alternate pulses of compressed and rarefied air. On the bee, these emerge from 14 little holes ranged along the thorax and abdomen underneath the wings; they are also locked in frequency to the wings. It would be a simple matter to phase them so that the compression pulse coincides with the downbeat of the wing. Fourteen little lumps of compressed air arriving under the wings as they descend would undoubtedly generate extra lift and improve its flight characteristics That, I believe, is the reason for it. Whether or not the bee or anyone else can hear the buzzing is of no consequence, the sound is simply a byproduct of the aerodynamics. (The rarefied half of the cycle would have no effect because the wing is feathered on the upbeat). The effect is illustrated on the next page.

Proving this theory is a different matter, way beyond my capabilities and I can only propose it in the hope that somebody else will be inspired to have a go. Almost certainly it applies to the other buzzing insects, bumblebees, June bugs, mosquitoes etc. What do they have in common? Do they all have spiracle valves driven by their wing motors? Do they all have two pairs of wings? Certainly they all have small wings in relation their body size and could probably do with extra lift.

There is just one little thing that makes me think 1 am right about this. It is said that mathematicians once calculated that in theory a bee should not be able to fly. Presumably they worked on the basis of bodyweight, wing area and frequency but my theory resolves this paradox because they were, of course, unaware of the extra lift provided by the compressed air from the spiracles!

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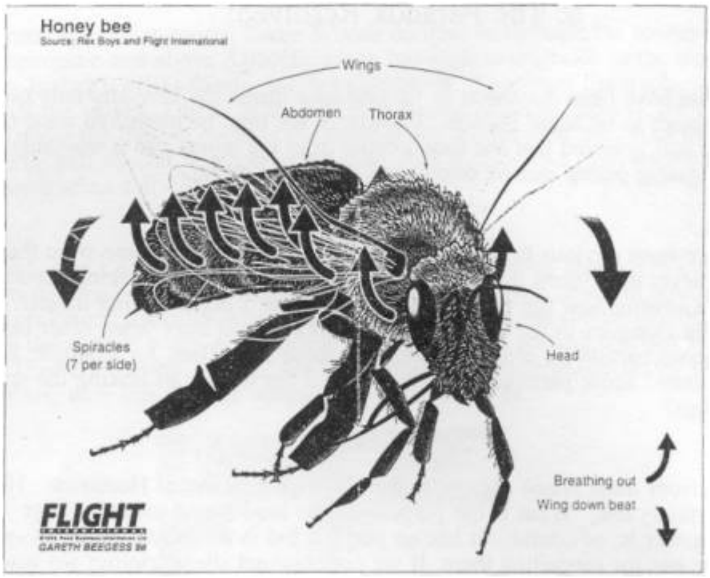

ABOUT THE AUTHOR

Born in 1923, Rex grew up in Northamptonshire and, at the age of 16, took his first swarm from the hedge surrounding the BBC 5XX transmitter building at Daventry where he worked as office boy. However, it was not until he took early retirement in 1978 and moved to Bredon in Worcestershire that he actually became a beekeeper.

He spent some years as Secretary to the Worcester Branch and in 1980 was commissioned by the BMA to design and set up a permanent exhibition in the Dixon Pavilion at Stoneleigh, serving on the Stoneleigh Committee until it was disbanded.

His interest in bee sounds stems from the fact that in the 1960's Eddie Woods was his regular lunchtime companion in the canteen at Broadcasting House and, through his job, he was able to help Eddie in obtaining components for his Apidictor development.

Rex has written many articles on the subject, mostly in British Bee Journal, and has added a few ideas of his own to Eddie's findings. In 1995 he gave the opening lecture at the National Honey Show in London, calling it 'Listen to the Bees' and is using the title again for this book.