PPI

Using an array of punched holes to track cattle hides through the tanning process M.670

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Prepared by:
ISys Intelligent Systems

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Foreword

This feasibility study was conducted by iSys Intelligent Systems under contract M.670 with the Meat Research Corporation during December 1994 and January 1995.

You should read Section 0 if you wish to gain a brief understanding of the scope and results of the study.

You should read the remainder of the report for the details of each stage of the study, including the specification, proposal, tests, results, conclusions and recommendations. There are photographs showing the results of tests, and a bag of leather samples accompanies the report.

Researchers

The research undertaken in this study was carried out by David and Emilie Knight.

Acknowledgements

Our thanks go to Michell Leather Pty. Ltd., who provided access to their tannery in Adelaide and willingly cooperated during the trials.

A special "Thank you" to John Cicchiello, for his help at the sammying stage, and to Geoff Keynes for comments along the way.

A big "Hi" to Joe, Roger, and all the crews whose work we interrupted during our tests.

We also appreciate the assistance of Jon Marlow, technical coordinator of the project, and the discussions we had with him.

Intellectual Property

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0 Overview

0.1 Background

The Meat Research Corporation (MRC), on behalf of the leather industry, is interested in improving the quality of leather derived from cattle. The plan is to be able to trace individual hides from grower to finished product, and thus provide a financial incentive scheme that will reward growers who care for their cattle, and penalise those who do not.

To achieve this goal, all hides must be uniquely tagged at the abattoir.

Through discussion in the industry, the MRC has produced a list of the desirable attributes of a tagging system, ranked in order of importance.

0.2 Principle of operation

This study investigates the feasibility of using a pattern of 40 or more small holes punched through the hide to carry the identification information.

Holes have the advantage that they are cheap, and can be applied to green hides at the abattoir using a suitable automated punch.

Furthermore, holes survive the rigours of the tanning process, and could be read electronically using a machine-vision system.

0.3 Tests

Initial tests were carried out on hides to determine the optimum shape of the hole array (square or hexagonal), and the optimum location on the hide for the pattern (skirt, leg, butt), and the optimum hole size (5, 6, 8mm). These tests were run with a pattern containing nine holes.

Additional tests were then run with a larger array of 24 holes, to further refine the hole size and investigate the butt as preferred location.

Finally, tests were run using an array with 40+ holes, and some "real" patterns, to see what the codes would look like in practice.

Some of the samples were split, and the effect of splitting on the readability of the patterns was investigated.

0.4 Summary

It was immediately evident that the only practical place for the code was at the butt end of the hide, where the tail had been attached. This area is thick enough to survive fleshing, and reliably survives the remainder of the tanning process.

Overall, some 70 hides were tested, and the optimum configuration was found to be an array of holes of diameter 6mm spaced on 12 to 14mm centres.

The holes could be placed on a square or hexagonal grid, and there was little to choose between the two layouts.

Accurate registration of the holes to the nominal grid is a problem, particularly in the presence of fat on the butt, and must be achieved to ensure accurate reading.

There is a good deal of scope for choosing the numeric coding, and some further work is required to determine the optimum coding.

The final size of a complete pattern was approximately 65mm x 120mm.

0.5 Evaluation

Comparing the results with the requirements, we conclude it is feasible to use an array of holes to uniquely identify hides. The scheme has the capacity for at least eight-digit codes, and could be extended, perhaps, to ten digits.

The hole patterns can be applied to green hides, though probably not while the hide is still attached to the animal, survive through the tanning process to the finished leather, and are preserved on the grain and drop split of split hides.

With a suitably-automated punch, (fed by a human operator), and a machine-vision system, an automated identification system is possible. There seems no technical impediment to a fully software-controlled punch.

The reliability of reading cannot yet be determined, because of insufficient data. Our experience however shows that if the pattern is located at the butt of the hide, it reliably survives the tanning process, so we believe there are no fundamental impediments to achieving high-accuracy reading.

An array of holes is human-decodable, albeit inconveniently, but is not human-readable. The optimum coding is likely to further complicate the process of decoding, making human-decodability error-prone.

0.6 Recommendations

Discussions have suggested that a machine which was able to identify and track hides back to each abattoir would be of commercial interest to a tannery. Since the number of abattoirs is far smaller than the number of cattle, a much smaller numeric code is sufficient, thus greatly reducing the number of holes required, and simplifying the punching machine.

We therefore recommend that the next stage of development should be the construction of a production-scale system, with a reduced numbering capacity. The following items will be required:

- A computer-controlled punch capable of applying (say) a 3 x 5 pattern of holes to a green hide. The machine must be rugged enough to operate in a production environment adjacent to the flesher, and apply the code in a few seconds.
- A computer-vision system to read the codes and provide the information in machine-readable form to other equipment on the production floor. The machine must operate in a production environment adjacent to the sammier, and read and decode the pattern in 15 seconds. Note that the TV camera that is used to read the punched code could also be used to compute hide area and search for defects, probably at little extra cost, which is clearly commercially attractive.
- Suitable software to collect statistics about the number of hides processed, which abattoir they came from, the number of mis-reads, and so forth, to allow the accuracy of the system to be assessed.

Evaluation of this reduced-number system in a production environment will provide accurate information about the practicality of using an array of punched holes in full-scale production.

1 Background

The Meat Research Corporation, in conjunction with the Textile Clothing and Footwear Development Association, and the Federated Tanners Association of Australia, has an interest in developing a practical system for identifying animal hides to allow marketing based on the quality of the hides.

A unique identification code will be attached to each hide as it is removed from a carcass at an abattoir, and used to identify the hide at various stages during subsequent processing. The object is to allow payments to growers to be based on the quality of the hides produced, and thus encourage growers to produce a better product.

Two other tagging schemes have already been tried, but have not proved satisfactory for various reasons.

Hides are subjected to gruelling processes during conversion to tanned leather, and the identification system must be able to withstand all stages, including the fleshing machine, concentrated acid and alkali solutions, tumbling, rolling, wringing, and drying and splitting.

The requirements of the system are as follows (5 is important, 1 not very)

5	8 character code
5	Unique code on each hide
5	Human decodable
5	Able to be applied to green hides
5	Hygienic and safe
5	Machine readable
5	Better than 99% recognition
4	Apply while hide still on the animal
4	Readable with hair still on the hide
4	Survival to finished leather
4	Human readable
3	Automatic application
3	Software driven code
2	16 character code
1	Readable on the grain and drop split

The objective of this feasibility study is to demonstrate that an array of punched holes will substantially meet the objectives listed in the table above. Specifically, to:

- Demonstrate the ability to individually code green hides
- Demonstrate the ability for the code to be read at various stages of leather processing
- Investigate the possibility of automatic application
- Propose a basis for the development of prototype machinery

2 Principle of operation

In overview, the plan is to use a pattern of about 40 holes punched into an unimportant area of the hide (say at the end of a leg, or near the edge of the underbelly) immediately after it is separated from the carcass. The code would contain identification data, plus some orientation and checking information. The code would be created by a computer-controlled punch, and read by a computer vision system. The following sections analyse how this system might work in practice, and how well it meets the MRC's requirements.

2.1 8 Character code

We have assumed there is no need to handle the entire Ascii character set, and that digits, or at worst letters and digits will suffice. The holes must be arranged in some sort of pattern, and the size and spacing between holes must be determined. As a first guess, 5mm holes on 10mm centres would probably be feasible.

2.1.1 Minimum number of holes

If we use a pure binary coding, we get the tightest possible coding, and use the least number of holes. The theoretical minimum number of holes required depends on the number of unique codes required according to the formula:

Holes = $\log_2$ (UniqueCodes)= 3.322*$\log_{10}$ (UniqueCodes)

For example, for 10^4 codes, we require $\log_2$ (10^4)= 3.322*4 = 13.288= 14 holes

While a pure binary code is very efficient, it is not easy for humans to decode reliably because of the large amount of arithmetic involved.

2.1.2 Easy-to-read codes

An easier-to-read code could be constructed by using a separate binary code for each digit of the ID number. This coding is reasonably easy to decode, but wasteful of holes.

The theoretical number of holes required for each position in the code is:

- Four, if only numbers are to be encoded,
- Five if only letters are required, and
- Six if both letters and numbers are required.

For example, to encode a four-digit number requires 4*4= 16 holes

To encode a 2-letter/2-digit number requires 2*5+2*4= 18 holes.

2.1.3 Practical codes

Combining the above theoretical information with the requirements for an 8-character code, we find:

- For an all-numeric code, the theoretical minimum number of holes is 27, and an easy-to-read coding would require 32 holes.
- With digits and letters in any combination, the theoretical requirement is 42 holes, and an easy-to-read coding would require 48 holes.
- In a mixed code consisting of 2 letters and 6 digits, the theoretical minimum number of holes is 30, and an easy-to-read code would require 36 holes.

Note that in all cases some additional holes would be required for orientation detection, and for error-checking. Allowing for the size and spacing mentioned earlier, the code might occupy an area of say 40 x 100mm.

Conclusion: The number of holes required is large, but not impractical.

2.2 Human decodable

The best code would be one optimised for machine reading. Such a code would use the pattern of holes most efficiently, and would incorporate error detection (and possibly correction) information to make reading reliable. Such a code, however, is unlikely to be easily decoded by humans.

Any punched code is obviously human-decodable, given sufficient time. If we want decoding to be fast, then the code must incorporate more redundancy, and be more regularly structured than a machine-readable code. Comparing the figures given in section 2.1.3 for an "easy-to-read" code with those for the optimum encoding, gives a measure of the price to be paid for easy human decodability.

Conclusion: Human decodability is achievable, provided the human is prepared to invest some time in doing so (perhaps 30 seconds or more).

2.3 Unique code on each hide

Achieving a unique code on each hide is a problem only during application. Obviously, once the code is on, the reader simply reads it.

Making each hide different implies that the encoding machine must be computer controlled, so that it can generate a different code every time. This clearly raises the cost of the punching machine compared with a fixed code. However, practically speaking a computer controlled machine will be required just to ensure that the generated codes are valid. Manually-generated codes are liable to contain errors caused by the operators, in addition to any errors that may occur during reading.

Conclusion: Achievable with a computer controlled punch.

2.4 Able to be applied to green hides

Green hides come straight off a slaughtered animal. There will be hair and residual flesh and fat on the hide, and it will be very pliable and easily distorted. To reliably generate the hole pattern we need to be able to smooth the hide out in the area where the pattern is to be applied.

If the pattern were to be punched into a leg, this could be done by feeding the hide through the punching machine using rollers, and sequentially punching the code as it went past. Such a scheme has the further advantage of using a far smaller number of punches than are required for the whole code. Other possibilities for creating the holes might be a carbon dioxide laser, or high-pressure water jet - these aspects are not part of this feasibility study.

Conclusion: Codes can be applied to green hides.

2.5 Hygienic and safe

Obviously, a hole is a pretty safe object! There is no hygiene hazard, and the greatest (physical) danger will come from the punching machine.

As the punching machine may be located on the slaughter floor at an abbattoir, the machine itself must be constructed so as to not trap bacteria, and be easily cleanable.

Conclusion: Holes are hygienic and safe.

2.6 Machine readable

The code will be machine readable provided several conditions are met:

- It is put in a location which survives the treatment processes
- The code-location can be placed flat on a surface or conveyor when identification is desired
- The degree of distortion of the code is not too great

The most likely reason for unreadability will be that the code has been destroyed during processing (e.g. ripped off).

Readability depends on being able to see the holes, and will also depend on the hide being flat. If the hide is wrinkled or folded over itself, the holes will be obscured and the code will be unreadable. Hair is also likely to cause a problem, though this could be overcome by illuminating from beneath with a bright light-source.

The reading machine can be made tolerant to quite substantial distortions of the code, such as stretching, trapezium, or parallelogram distortions, but there will of course still be a limit beyond which it will not read reliably.

Conclusion: Code is readable using machine vision techniques.

2.7 99% reading success rate

At this stage it is not possible to estimate the read rate. We understand from discussions with MRC and Michell Leather that there is a small chance that the code will be destroyed, which sets an upper bound on the reading rate. Experimentation is required.

Conclusion: Cannot be determined before experiments are conducted.

2.8 Apply while hide still on animal

Clearly this criterion cannot be met using punch-and-die style hole cutting method! If the hide is already partly peeled off, then it will be possible to apply the code to the peeled area while the remainder of the hide is still attached to the carcass.

Conclusion: Possible depending on interpretation of "on the animal".

2.9 Readable with hair still on

Readability with the hair on will depend on the length of the hair compared with the size of the punched holes. Long hair and small holes both conspire to make reading difficult, suggesting a large open code is desirable. The hairiness of the hide undoubtedly varies from place to place, so it may be possible to put the code where the hair is certain to be short.

Readability may also depend on whether the grain-side or the flesh-side is uppermost, since we would expect the flesh-side to be more easily read. Illumination from below will enhance readability.

Conclusion: Probably achievable by choice of hole size and spacing.

2.10 Survive to finished leather

There seems no reason why the code would not survive to the finished leather. We assume that the chrome tanning process is the most aggressive step, and that later stages are less likely to damage the code. Trimming processes during final tanning may result in the code being cut off.

Conclusion: Should be easily achieved.

2.11 Human readable

We interpret this requirement to mean that the code can be read by any person without special training. This could be achieved if very small holes were used (say 3mm holes on 6mm centres), and the array consisted of 280+ holes laid out to produce visible characters. Such a pattern of holes would be of the order of 90 x 120mm or larger.

Conclusion: Achievable only if the code area is large.

2.12 Automatic application

Since we have already concluded that a computer-controlled punch is required to generate the unique codes, we interpret automatic application to mean that the code can be applied to a hide without operator intervention. A green hide is an irregular and pliable object, so we expect that an operator will be needed to guide the hide into the punching machine so that the holes can be located on the required part of the hide.

Conclusion: Human operator required to guide hide, punching carried out automatically.

2.13 Software driven code

We have already concluded that the punch will be computer controlled. This makes software generated codes trivial.

Conclusion: Easily achieved.

2.14 16 Character code

The penalty for a larger code is more holes, requiring a larger area of the hide. If this requirement is combined with the requirement for human-readability, the array of holes becomes immense - up to 90 x 250mm - which seems absurd.

It also seems unlikely that such a large code would be required in practice. Only seven million cattle are slaughtered annually, requiring seven digits for encoding. The proposed 8-digit code would uniquely identify a hide for more than 10 years! To make the code in two parts (abattoir, animal), might require extending the code to 9 digits, which would be reasonable.

Conclusion: 16 Characters not realistically achievable.

2.15 Readable on the drop split

One of the obvious advantages of holes, is they go right through. A split hide, therefore would have the same code in both parts, provided the splitting process did not destroy the code. Clearly the strongest pattern will be one consisting of the least number of small holes, with the largest amount of hide in between. This flies in the face of other criteria, so the choice will eventually be a compromise.

Conclusion: Achievable at no cost provided the splitter does not destroy the code.

3 Tests

We conducted several tests, to investigate how holes might work in practice.

In the first test we wanted to get an idea of the optimum size, spacing and location for the tags. A small pattern was applied to several locations on each hide. Several different hole-sizes and spacings were tried. Results suggested that 5 or 6mm holes on 12 to 14mm centres were optimum, and that the location adjacent to the tail (butt) was the only practical position.

In the second test we increased the pattern size, and concentrated on the 5mm hole size. All tags were applied to the butt. Results confirmed that the butt was reliable, and that 5mm holes were satisfactory.

In the third test, we used a full-size pattern of 41 holes, applied only to the butt. We investigated square and hexagonal array shapes, explored the question of hole-size again, and tried some "real" code patterns. All patterns survived the tanning process.

In the final test we split some samples with a band-knife, to see what might happen during this process.

3.1 Test One - Plan

3.1.1 Objectives

To gather information about suitable tag-locations on hides, and some initial information concerning the size and spacing of the hole-array. All hides will be tagged before fleshing, since the long-term plan is to tag at abattoirs. We expect to learn about :

- difficulties experienced in punching green hides
- hide thickness in the test locations
- damage caused by the fleshing machine
- readability with the hair still on
- survival through the tanning process
- readability at the sammying stage

3.1.2 Method

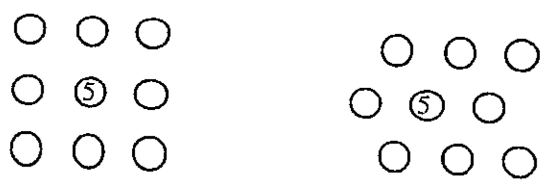
Eighteen hides will be tagged. There will be six groups of three hides each, divided as follows:

Group 1	Each hide will be tagged in three locations (Skirt, Leg, Butt), using a 3x3 square pattern of 5mm holes spaced on 10mm centres.
Group 2	Same as group 1, except 6mm holes on 12mm centres
Group 3	Same as group 1, except 8mm holes on 16mm centres
Group 4	Same as group 1, except holes arranged in a hexagonal pattern, on 10mm centres
Group 5	Same as group 2, except holes arranged in a hexagonal pattern, on 12mm centres
Group 6	Same as group 3, except holes arranged in a hexagonal pattern, on 16mm centres

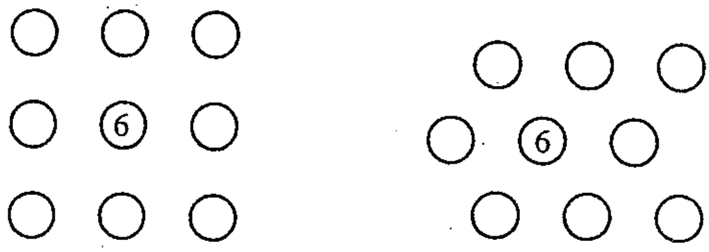
Some hides will be photographed after tagging, but before fleshing, some will be photographed after fleshing. Any flesher damage will be photographed.

After tanning, some hides will be photographed as they travel down the drying conveyor. The object is to capture typical and worst-case results.

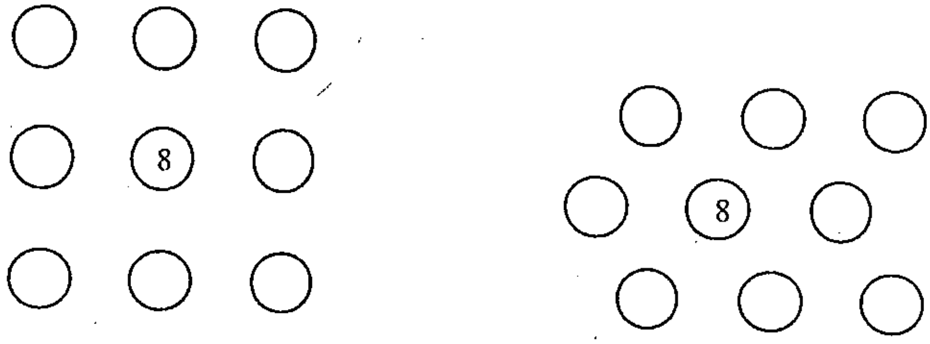
The patterns used were:



5mm holes on 10mm centres, square and hexagon



6mm holes on 12mm centres, square and hexagon



8mm holes on 16mm centres, square and hexagon

3.1.3 Analysis

The roughest step in the tanning process seems to be the flesher, and we expect most damage to tags to occur there. Our goal is for damage to be below 1%, so that 99% readability can be achieved. We expect damage to be greater for larger hole-sizes, but no difference between the square and hexagon arrays. With a sample size of 18, we would hope for no damage.

We expect readability of hides with the hair on to be poor, but better with larger holes.

The tests give us 54 samples of flesher damage, 18 samples of each hole-size, 18 samples of each tag-location, and 27 samples of each array-shape. The total number of holes is approximately 480.

3.2 Test One - Results

3.2.1 Punching

20-Dec-94, 2pm. We used wad-cutting punches to cut the holes, with a red-gum block as an anvil. There was no difficulty cutting the hides, and generally the wads came out cleanly. Some wads were held back by hair, and others by a thin sliver of hide. We left these as they were, to see what would happen later in the process.

Each pattern was printed on a small slip of paper which stuck readily to the fat on the hide. Fat and residual flesh made the hide very slippery, and of variable thickness. There was wide variability from hide to hide, presumably because of the fattiness of the carcass, breed of cattle, and the skill of the flayer.

The presence of fat and hair on the hides makes seeing the punched pattern extremely difficult immediately after punching. The fat slides over the punched holes, obscuring them, and the hairs also tend to lie over the holes. It seems unlikely that it will be possible to read the pattern on fresh hides, before they go through the flesher.

With the 5/10/square pattern, maintaining accurate position-registration was extremely difficult. We did three hides with this pattern, before deciding that the spacing was too small to be reliably reproduced.

We then did three hides with 6/12/square pattern. The larger holes were more easily seen on the hides, but registration remained a problem with the slippery hide surface. Slightly more force was required to punch the 6mm holes than had been needed for the 5mm holes.

Next we did a hide with an 8/16/square pattern. The holes were enormous, and quite easily seen. The wider spacing also helped with registration. Considerably more force was required for these holes, and after about 10 holes, our punch broke. (It was a cheap-and-nasty tool, so we were not surprised!)

Information to this stage suggested that 5mm holes on 12mm centre might work well, so we altered the test plan and did 4 hides with a 5/12/hexagon pattern, and then 3 hides with a 5/12/square pattern. At this point we decided we had done sufficient hides to gather the initial information sought.

3.2.2 Fleshing

We watched the hides as they were put through the flesher. Not surprisingly, the hides were much cleaner after fleshing, with the fatty membrane on the flesh-side removed. Hole patterns were easily visible from the flesh-side after fleshing.

Our feelings about the unsuitability of the 5/10 patterns was confirmed after fleshing. The (ideally) square array of holes was highly irregular on some hides, not because of stretching, but simply as a result of mislocation of the original punched holes on the slippery hides.

Because of the speed and construction of the machine, it was difficult to see whether damage to the patterns had occurred. Patterns on the butt survived well, and were easy to check, while those on the skirt and legs seemed to fare less well. The central location of the butt made it easy for the machine operators to see the tag after fleshing.

Although the array of holes is easily distorted by the weight and flexibility of the hide, it remains clearly visible. Although we do not wish to read the hides at this stage, it seems likely that reading would be possible.

We took several photographs of patterns in various locations on the hide.

3.2.3 Tanning

22-Dec-94, 1pm. We watched the hides as they passed through the sammier, at the end of the tanning process. At Michell Leather, hides come through butt first, to make grading easier. (This may not be the case at all tanneries.)

We did not know what to expect at first, but it turned out to be easy to spot the hides that had tags on the butt.

All the patterns applied to the butt end survived the tanning process, while most of the patterns applied to the skirt and legs were no longer on the hide, or had suffered gross distortion.

Even where leg and skirt patterns had survived the tanning process, the wringing rollers in the sammier significantly stretched and distorted the patterns. These locations would, therefore, be difficult to read.

The tanning process swells the inner layer of the hides, so that the holes are not sharply defined, and the spacing between them is stretched. The overall pattern, however is not significantly distorted. All patterns are clearly visible as dark dots on a pale blue background.

In squeezing the water out of the hides, the sammier ensures that the hide is flat. We believe that the best time to read is immediately as the hide comes out of the sammier, while it is still flat on the drying belt. The butt comes through within ±300mm of the centre line of the sammier, so the machine-vision system's field of view will not need to be very large.

After the sammier, the hide lands on a grading conveyor, and there is a tendency for the butt end to tuck under on some hides at this time. This would make reading much more difficult and less reliable if reading were to occur at this point. In addition, the graders handle the hide, causing it to move on the conveyor, and this too would interfere with the reading process.

Of the 15 hides we marked, we recovered all but one (the faulty 8/16 pattern). The missing hide had not received a pattern on the butt, and was probably damaged by the flesher.

We photographed all the patterns, and kept some samples from the hides.

Unfortunately, as a result of a problem with the camera, which was not detected until the film was processed, all the photographs taken up to this point were lost. Fortunately the samples were available, and these were subsequently photographed again.

The following photographs show samples taken from various hides:

- 5/10 patterns (photo B16)
- 6/12 patterns (photos B13,B22,B15)
- 5/12 patterns (photos B23,B14,B9)
- Flesher damage (photos B7,B17,B19,B10)

All the 5/10 patterns were unsatisfactory, because we found extreme difficulty in maintaining regular spacing between the holes. The 6/12 patterns were only slightly better.

The 5/12 patterns were much better. The increased space between holes helped to maintain the rigidity of the hide, and allowed a greater initial positioning error, thus increading the likelihood that the code would be readable.

Undoubtedly the best location for the patterns was the butt, because the hide is thicker there, and survives the flesher well. In addition, it is the first part of the hide to become visible at the sammier. The other locations suffered extensive damage, either because the hide was thin, or through ripping at the flesher, or by distortion in the sammier.

The sammier operators are able to minimise folding and distortion of the hide at the butt, and centre the holes pattern for reading at the sammier stage.

3.2.4 Photographs

Photo B.7 6/12 Hexagon pattern on a leg, fair punching accuracy, ripped by flesher

3.3.3 Analysis

Our experiments so far have verified that the roughest step in the tanning process is undoubtedly the flesher. The butt seems a good location, since none of the patterns were lost from that location. A larger pattern may be susceptible to flesher damage, and will allow us to better study the variability of hole-spacing that occurs during punching. Our goal is for flesher damage to be below 1%, so we need to collect more samples to verify this.

The tests give us 20 samples of flesher damage, and ten samples of square and hexagon arrays. The total number of holes is approximately 500.

3.4 Test Two - Results

3.4.1 Punching

10-Jan-95 2pm. The hides in this batch were much smaller than those in the first trial. They also seemed a little thinner, but the difference was not great.

There was some problem with fat located near the butt, either side of the spine. The presence of the fat makes accurate (manual) punching difficult, because of its slipperiness. Where the punching was affected, we deliberately omitted odd holes to indicate the affected hides.

3.4.2 Fleshing

We did not observe the Fleshing operation.

3.4.3 Tanning

13-Jan-95 7:30am! All patterns survived the fleshing and tanning processes without damage.

The fatty hides, which had been marked by omitting holes showed the effects of the fat on position accuracy. The holes were obviously out of place, and this would undoubtedly affect reading accuracy.

The tanning process swells the hides, and the result is that the hole tends to close up. This is probably not a problem, since a substantial contrast remains between the hole and the adjacent hide.

To make photographing easier, we asked the sammier operators to call out when a tagged hide was coming through. Because the butt goes through the sammier first, the hole patterns were easily spotted, and they had no difficulty complying with our request.

There seems little to pick between the square and hexagonal patterns. Both are easily visible.

3.4.4 Photographs

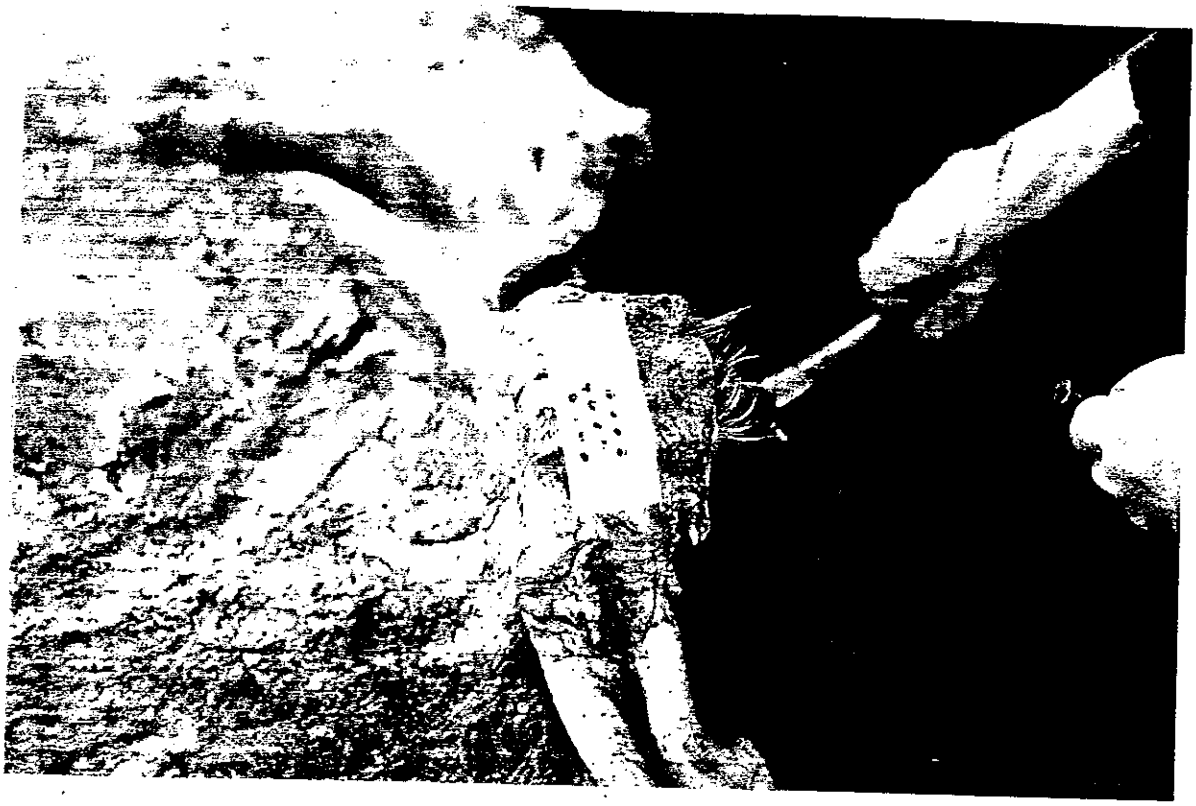


Photo A.0 A hexagon pattern during punching.

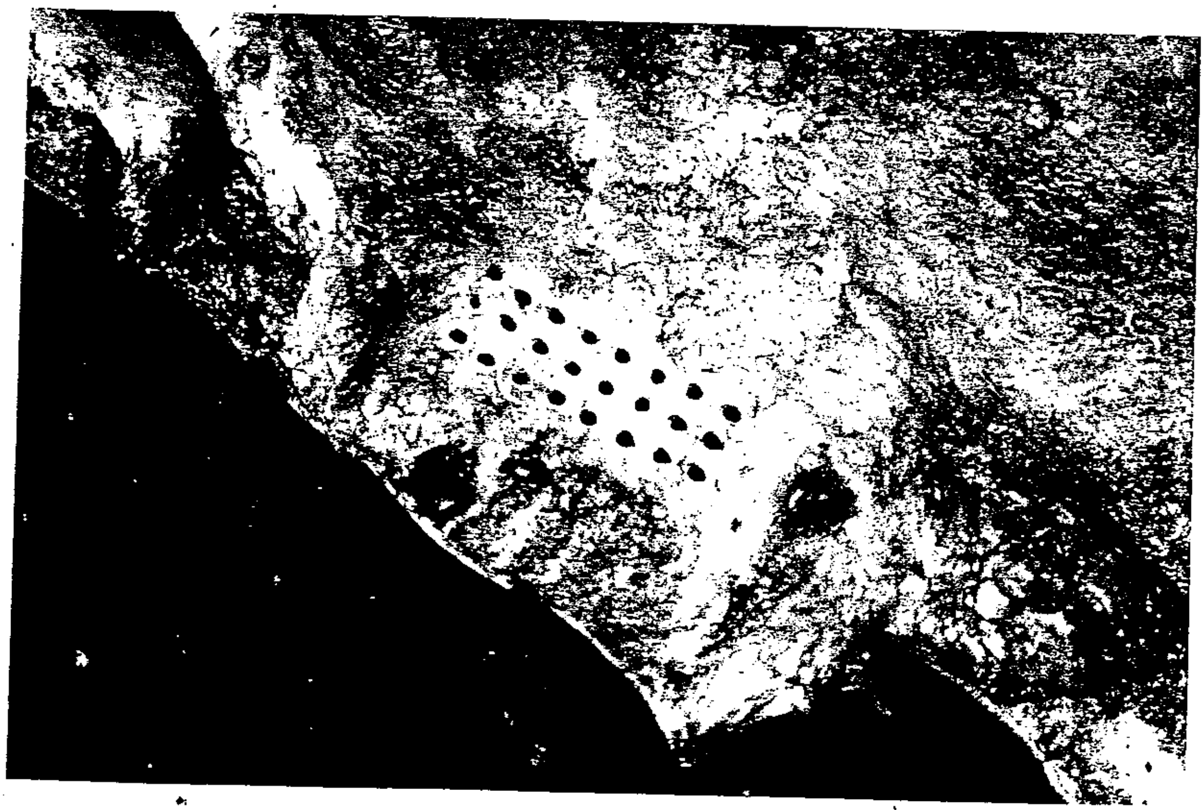


Photo A.4 Completed square pattern lying on the floor, very little fat in the butt area.

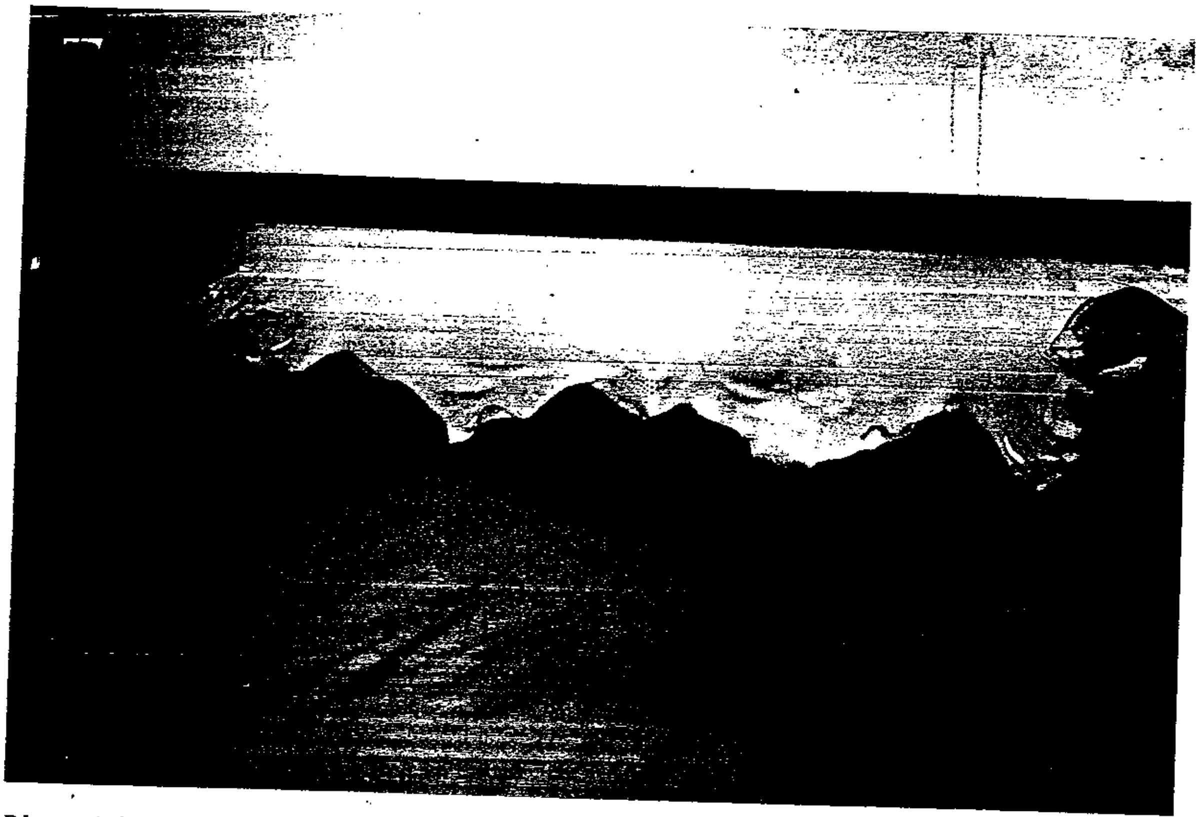


Photo A.9 A hexagon pattern coming through the sammier, note the wrinkle in the hide as it lifts off the roller.

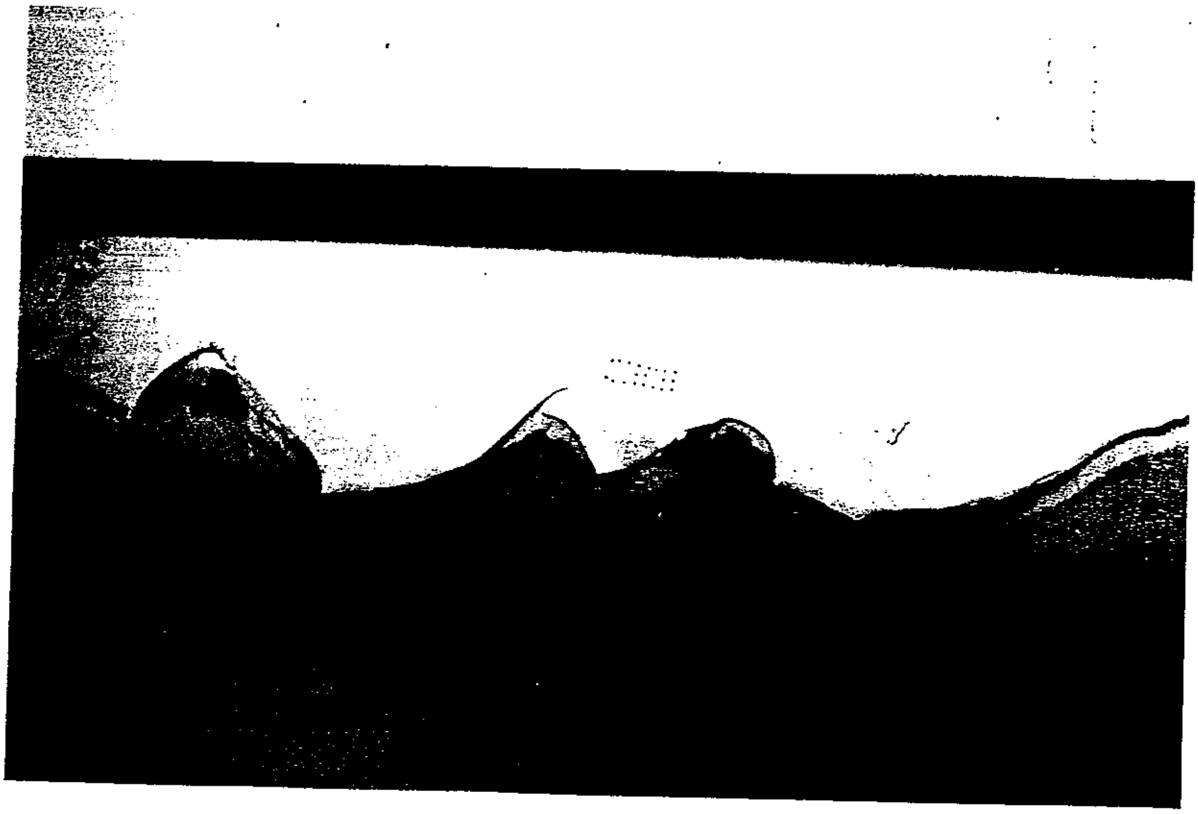


Photo A.13 A square pattern on the sammier, note the displaced holes on the left end, caused by fat

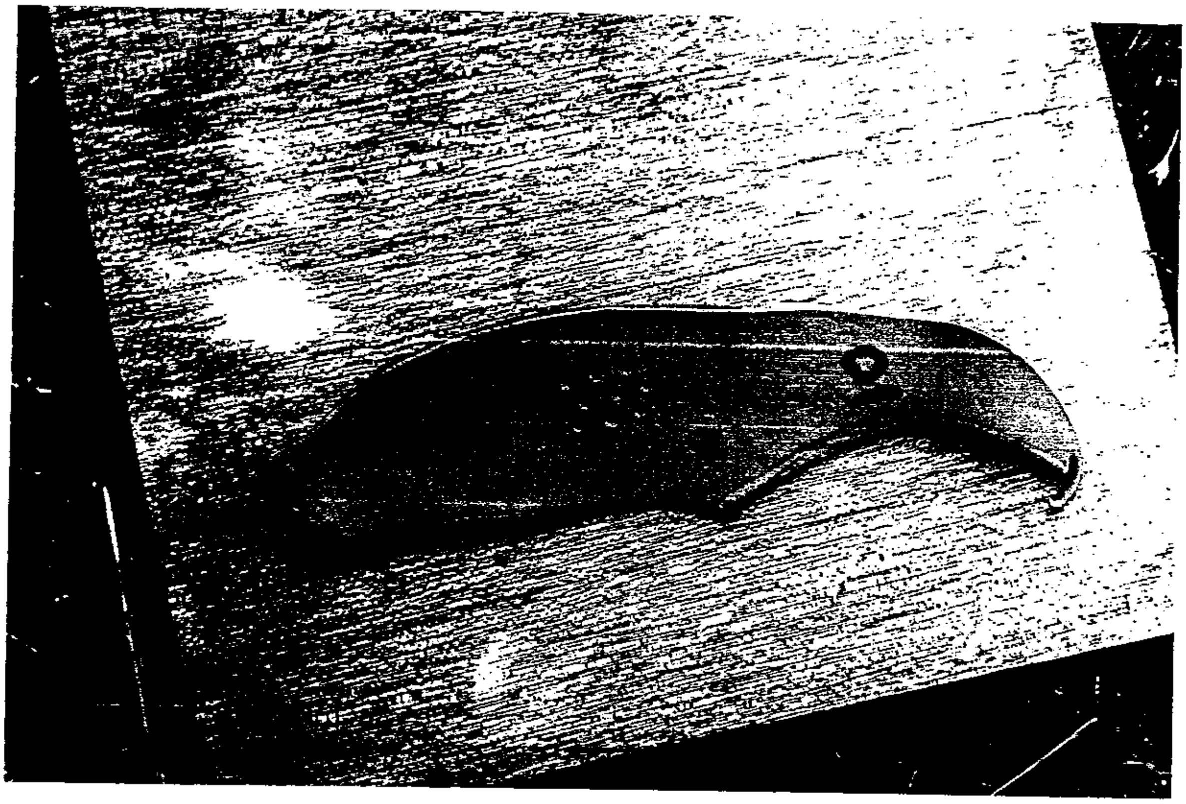


Photo B.9 5/12 Hexagon on the butt, good punching accuracy

Photo B.10 6/12 Square pattern on a leg, Fair punching accuracy, ripped by flesher

Photo B.13 6/12 square pattern, on the skirt, poor punching (wads still attached),stretched, holes too close together

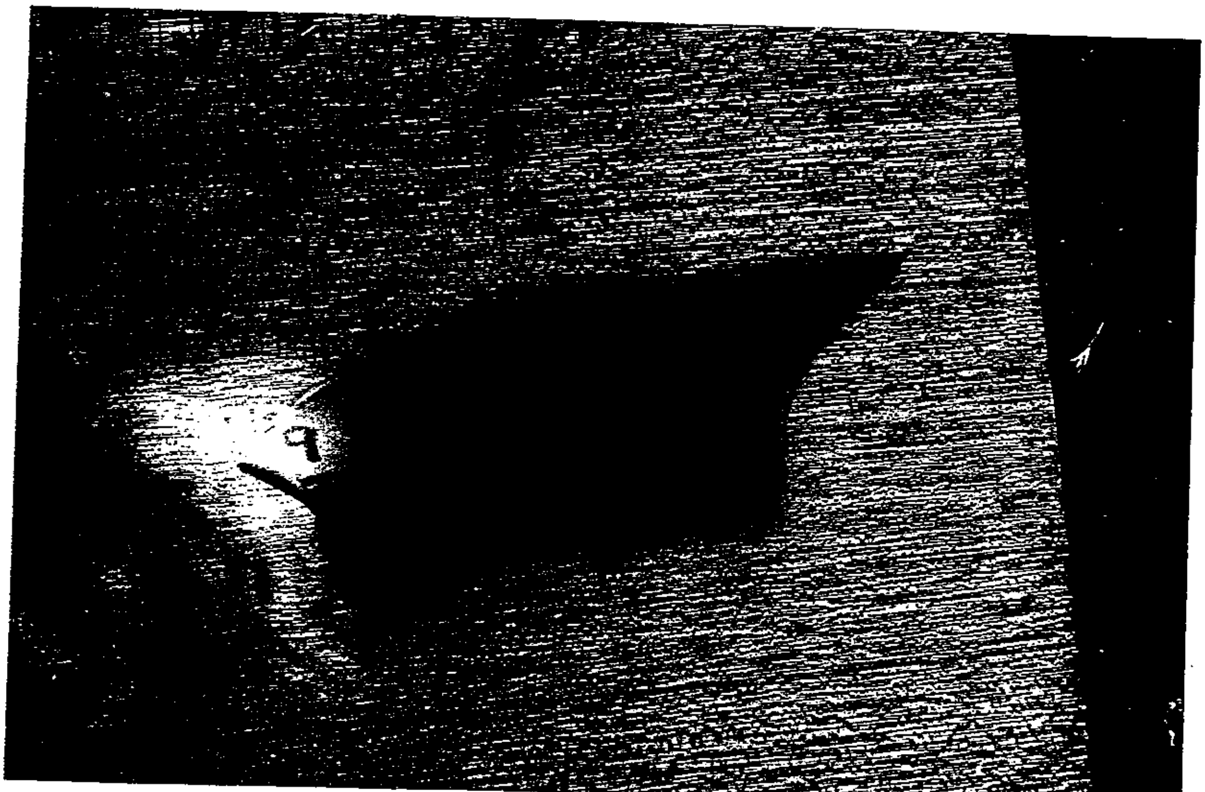


Photo B.14 5/12 Square pattern on the butt, good punching accuracy

Photo B.15 6/12 square paattern, on the skirt , fair punching accuracy, holes too close together

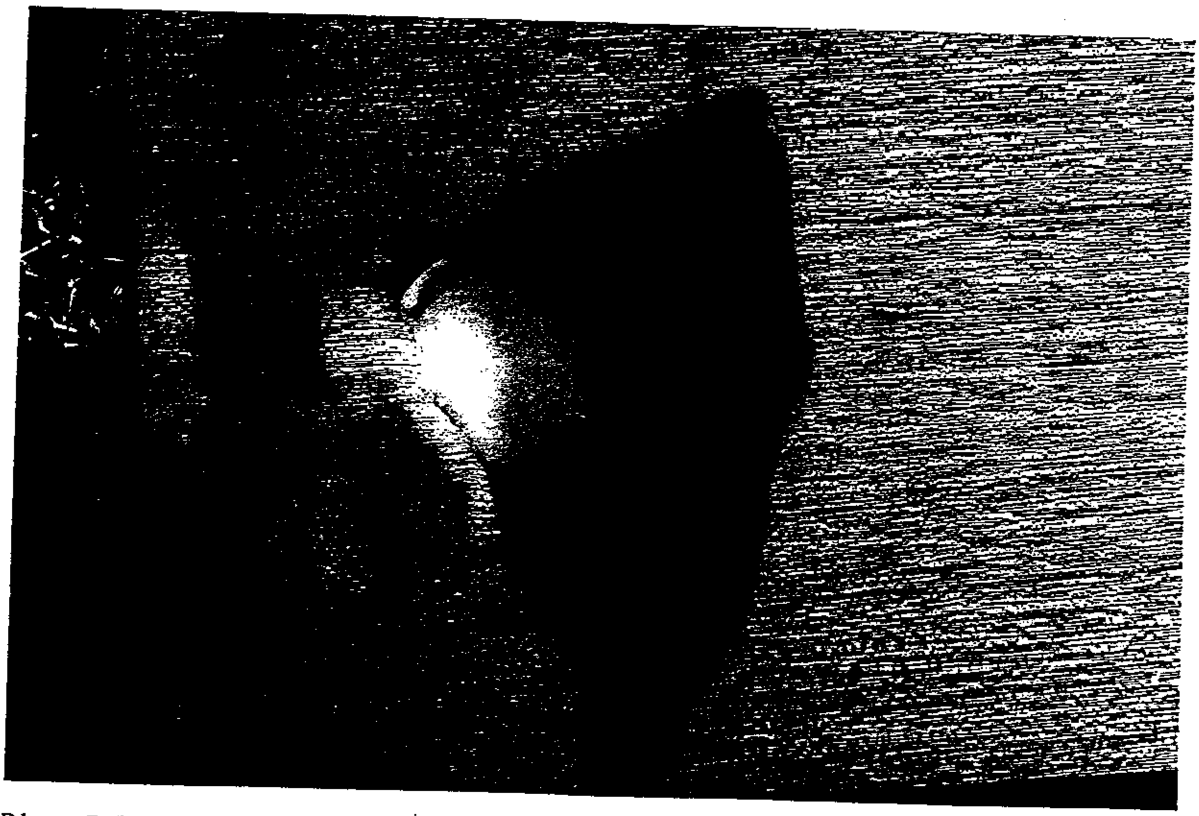


Photo B.16 5/10 hexagon pattern on the butt, poor punching (wads still attached), holes too close together

Photo B.17 6/12 Hexagon pattern on the skirt, ripped by flesher

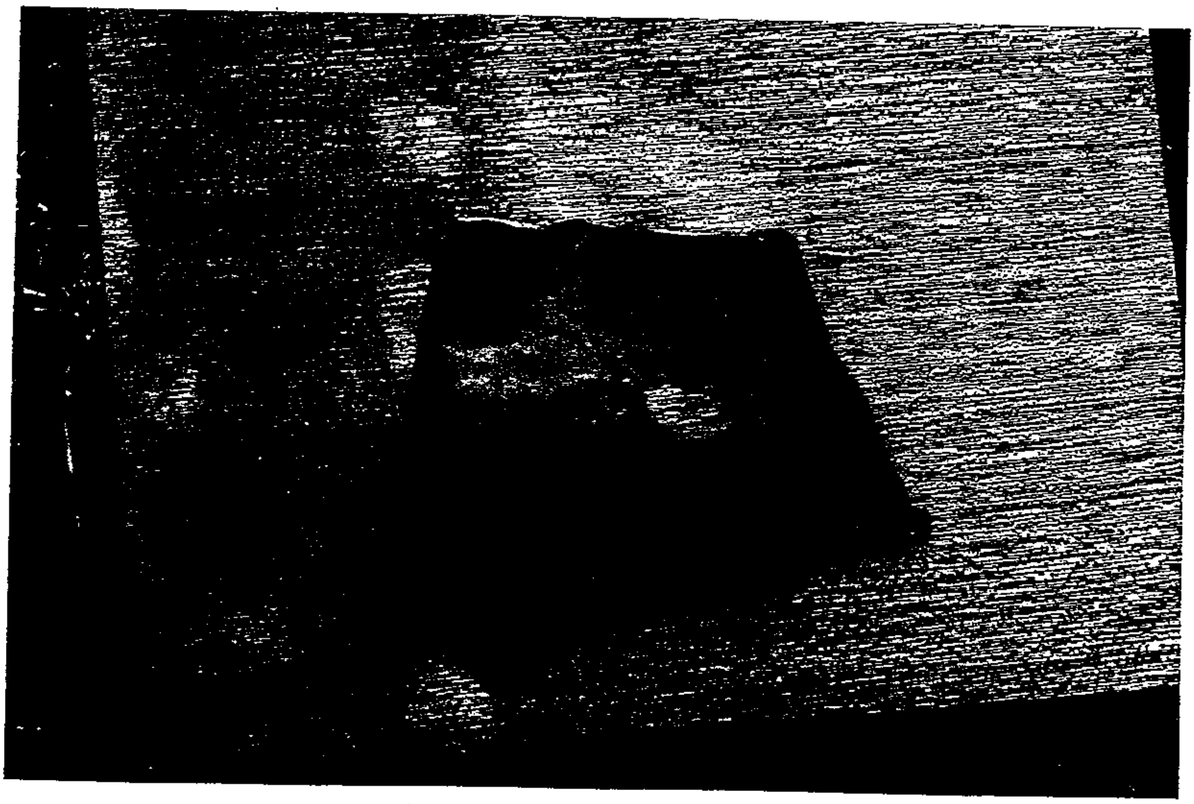


Photo B.19 6/12 Hexagon pattern on a leg. Fair punching accuracy, ripped by flesher, holes too close together

Photo B.22 6/12 square pattern on a leg, good punching accuracy, holes too close together

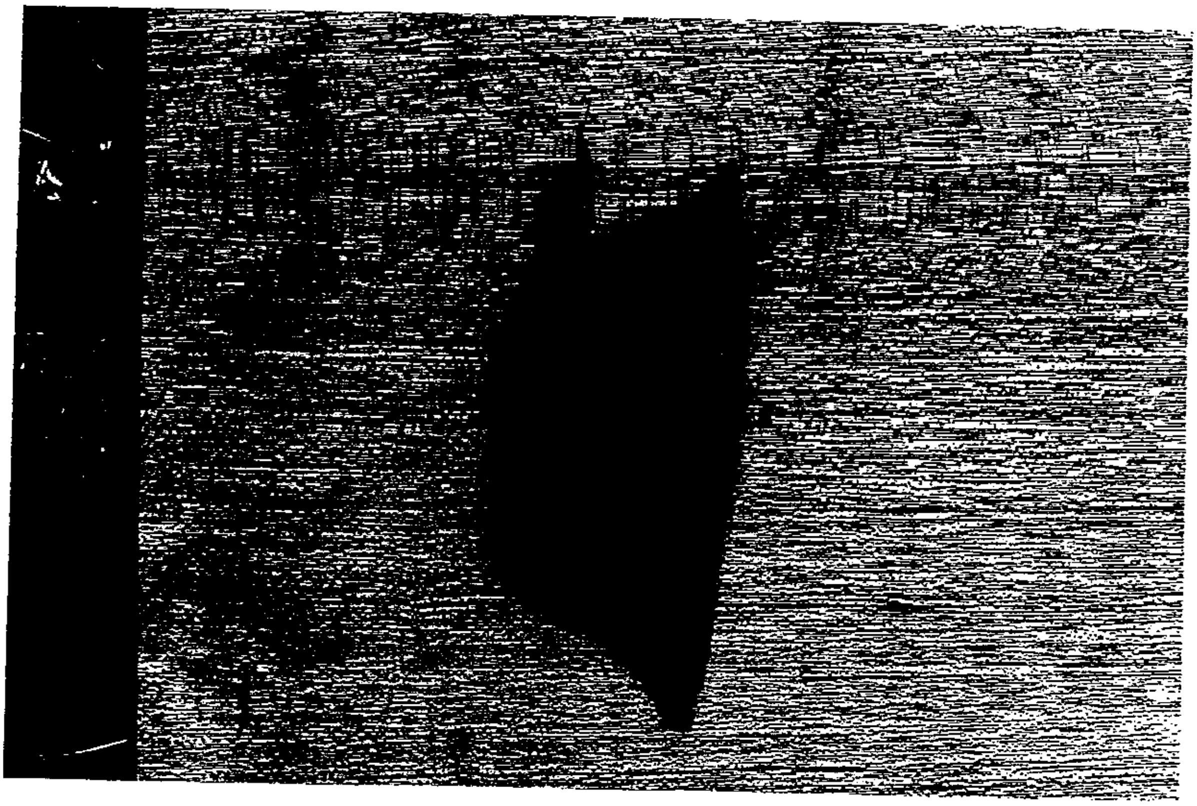


Photo B.23 5/12 square pattern on the butt, good punching accuracy

3.2.5 Conclusions

The only practical location for the patterns is the Butt.

The 5/10 patterns are simply too small to allow reliable positioning in the presence of the fatty layer. Both the 5/12 patterns seem acceptable, and there is little to pick between the square and hexagon arrays. Of course, the hexagon pattern is slightly more compact.

3.3 Test Two - Plan

3.3.1 Objectives

To further investigate the suitability of the butt for carrying the patterns, and to investigate the 5/12 pattern in square and hexagon form. We will use a larger pattern, consisting of 24 holes. As before, all hides will be tagged before fleshing, since the long-term plan is to tag at abattoirs.

We expect to learn more about :

- problems with the butt location
- suitability of 5/12 spacing and size
- advantages of square/hexagon patterns
- effect of larger array of holes
- damage caused by the fleshing machine
- survival through the tanning process
- readability at the sammier

3.3.2 Method

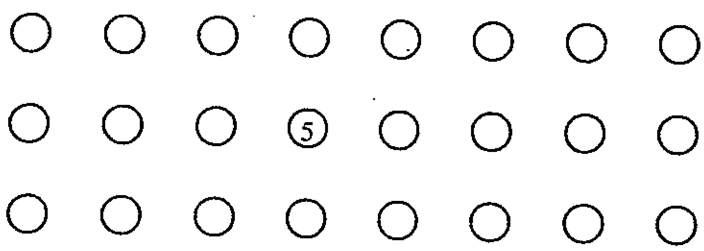
Twenty hides will be tagged. There will be two groups of ten hides each, divided as follows:

Group 1 Each hide will be tagged on the butt, using an 8x3 square pattern of 5mm holes spaced on 12mm centres.

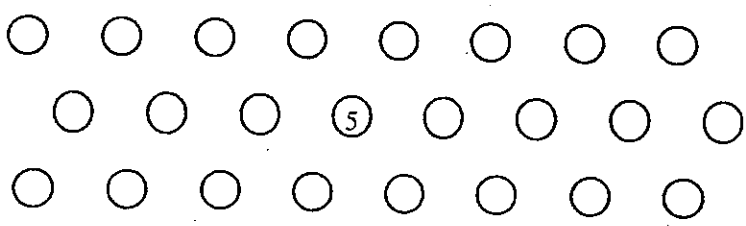
Group 2 Same as group 1, except hexagon pattern

Some hides will be photographed after tagging, but before fleshing. Flesher damage will be observed after tanning. All hides will be photographed as they leave the sammier, and again at close range on the floor. The object is to capture typical and worst-case results.

The patterns used were:



5mm holes on 12mm centres, square



5mm holes on 12mm centres, hexagon

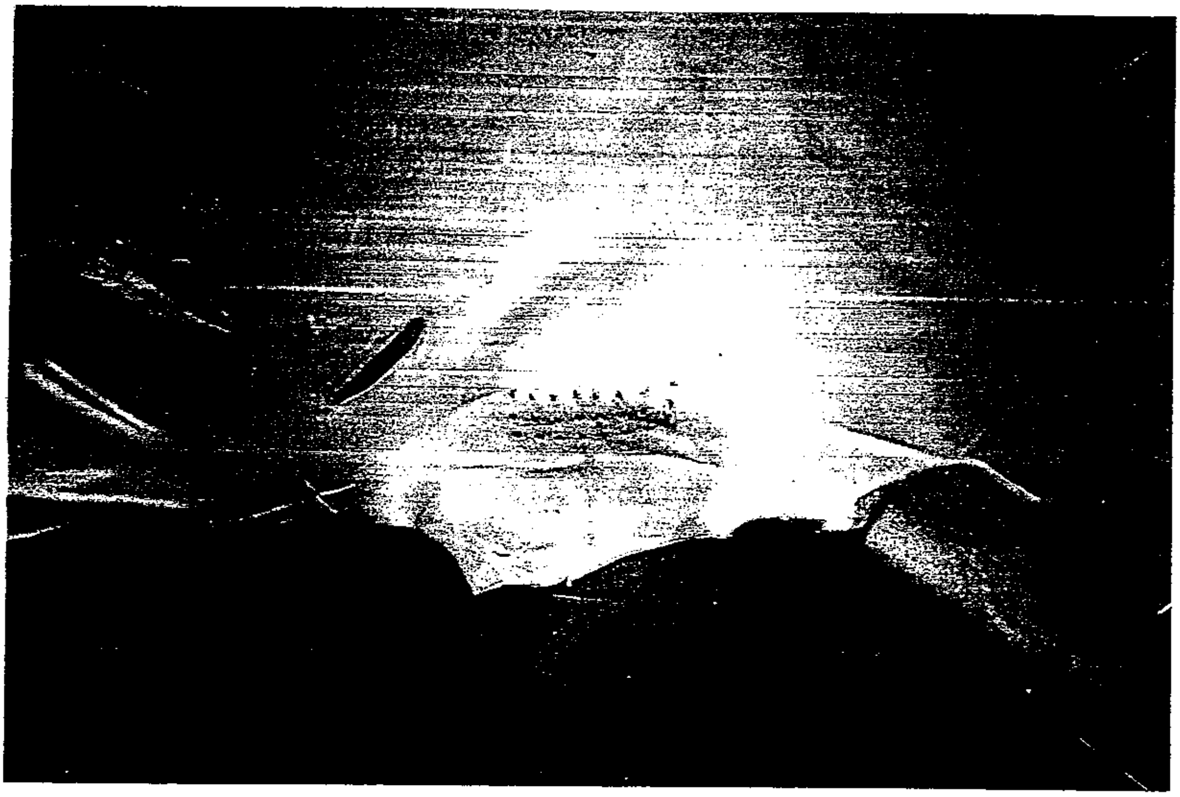


Photo A.19 A Square pattern photographed on the sammier conveyor, the fold in the hide would make reading difficult, more care feeding the sammier would avoid this problem.

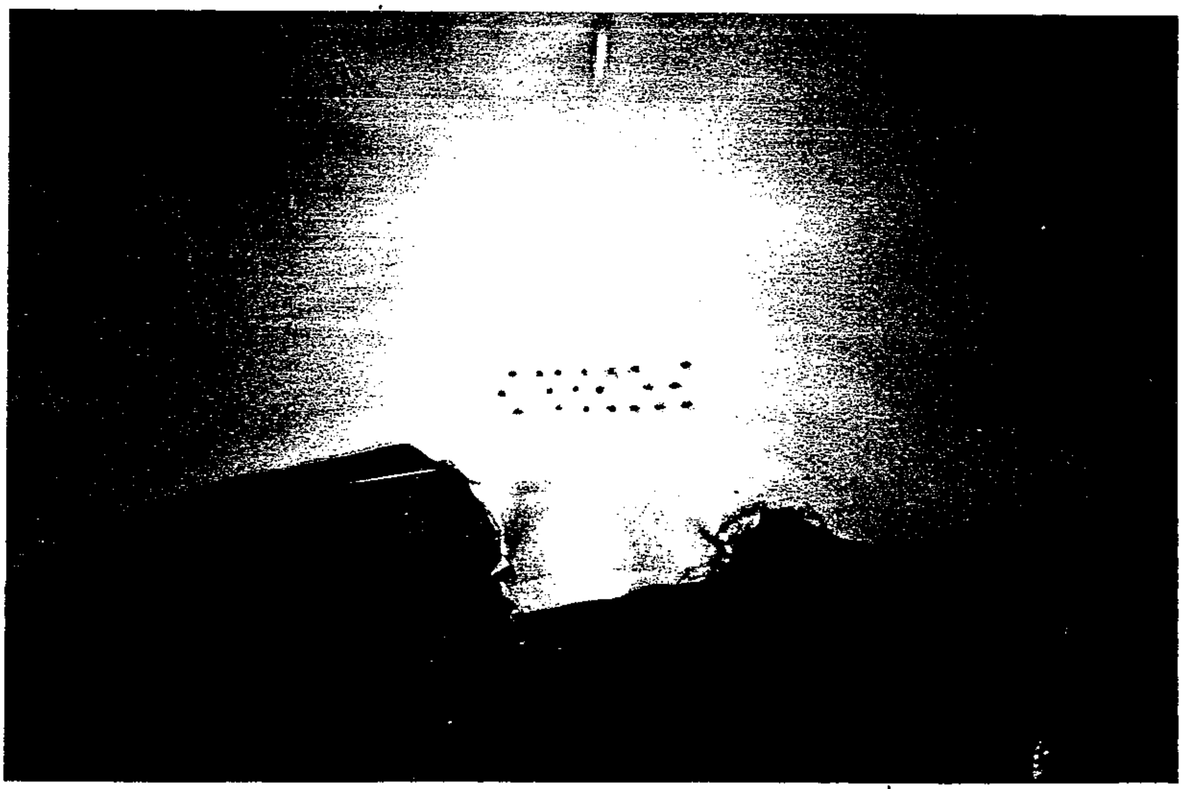


Photo A.21 A typical hexagon code.

Photo A.26 A hexagon pattern on the sammier, the flap of hide folded back could have obscured the code.

Photo A.28 A hexagon pattern folded by the sammier, this pattern would be unreadable

3.3.3 Analysis

Our experiments so far have verified that the roughest step in the tanning process is undoubtedly the flesher. The butt seems a good location, since none of the patterns were lost from that location. A larger pattern may be susceptible to flesher damage, and will allow us to better study the variability of hole-spacing that occurs during punching. Our goal is for flesher damage to be below 1%, so we need to collect more samples to verify this.

The tests give us 20 samples of flesher damage, and ten samples of square and hexagon arrays. The total number of holes is approximately 500.

3.4 Test Two - Results

3.4.1 Punching

10-Jan-95 2pm. The hides in this batch were much smaller than those in the first trial. They also seemed a little thinner, but the difference was not great.

There was some problem with fat located near the butt, either side of the spine. The presence of the fat makes accurate (manual) punching difficult, because of its slipperiness. Where the punching was affected, we deliberately omitted odd holes to indicate the affected hides.

3.4.2 Fleshing

We did not observe the Fleshing operation.

3.4.3 Tanning

13-Jan-95 7:30am! All patterns survived the fleshing and tanning processes without damage.

The fatty hides, which had been marked by omitting holes showed the effects of the fat on position accuracy. The holes were obviously out of place, and this would undoubtedly affect reading accuracy.

The tanning process swells the hides, and the result is that the hole tends to close up. This is probably not a problem, since a substantial contrast remains between the hole and the adjacent hide.

To make photographing easier, we asked the sammier operators to call out when a tagged hide was coming through. Because the butt goes through the sammier first, the hole patterns were easily spotted, and they had no difficulty complying with our request.

There seems little to pick between the square and hexagonal patterns. Both are easily visible.

3.4.4 Photographs

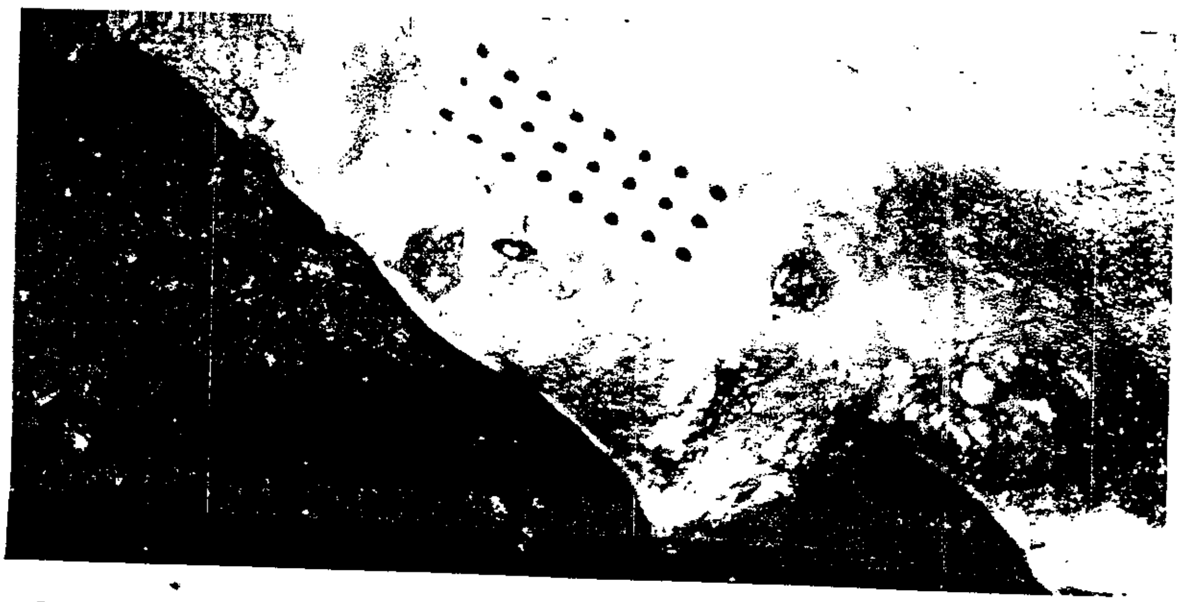


Photo A.4 Completed square pattern lying on the floor, very little fat in the butt area.

3.4.5 Conclusions

The butt remains the preferred location for the hole patterns.

The increased pattern size did not cause any additional flesher damage, and there still seems little to pick between the hexagonal and square patterns.

3.5 Test Three - Plan

3.5.1 Objectives

To further investigate the suitability of the butt for carrying the patterns, and to investigate a slightly larger 6/14 pattern in square and hexagon form. We will use a full-size code pattern, consisting of 40+ holes. All hides will be tagged before fleshing.

We expect to learn more about :

- problems with the butt location
- suitability of 6/14 versus 5/12 spacing and size
- advantages of square/hexagon patterns
- effect of full-sized array of holes
- damage caused by the fleshing machine
- survival through the tanning process
- readability at the drying stage

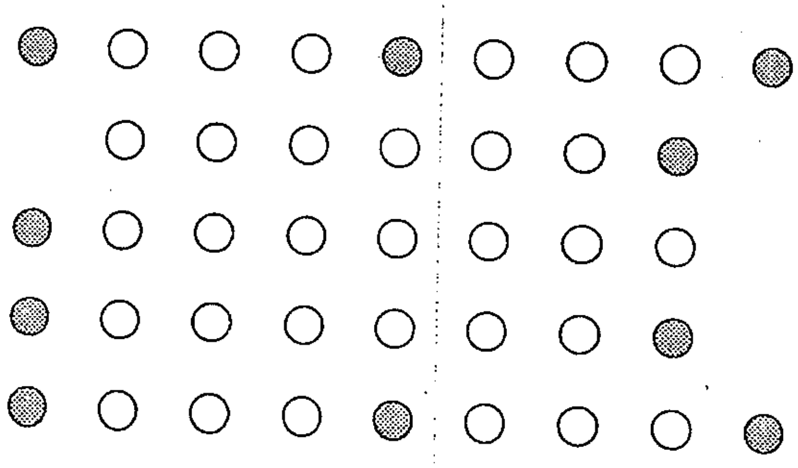
3.5.2 Method

Thirty-two hides will be tagged. There will be eight groups of four hides each, divided as follows:

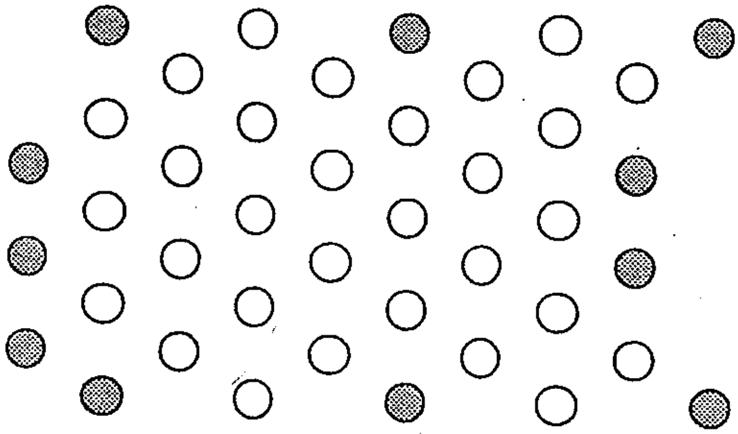
Group 1	Each hide will be tagged on the butt, using a full 9x5 square pattern of 5mm holes spaced on 12mm centres.
Group 2	Same as group 1, but hexagonal pattern.
Group 3	Same as group 1, but with a typical code-pattern of about 10 holes.
Group 4	Same as group 2, but with a typical code-pattern of about 7 holes.
Group 5	Each hide will be tagged on the butt, using a full 10x4 square pattern of 6mm holes spaced on 14mm centres.
Group 6	Same as group 5, but hexagonal pattern.
Group 7	Same as group 5, but with a typical code-pattern of about 10 holes.
Group 8	Same as group 6, but with a typical code-pattern of about 7 holes.

Some hides will be photographed after tagging, but before fleshing. All hides will be photographed as they leave the sammier, and again at close range on the floor. The object is to capture typical and worst-case results.

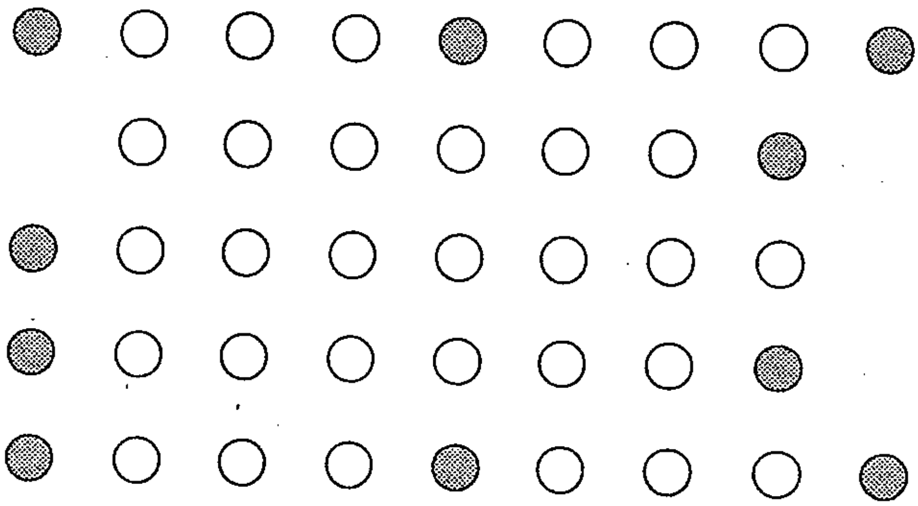
The patterns used were:



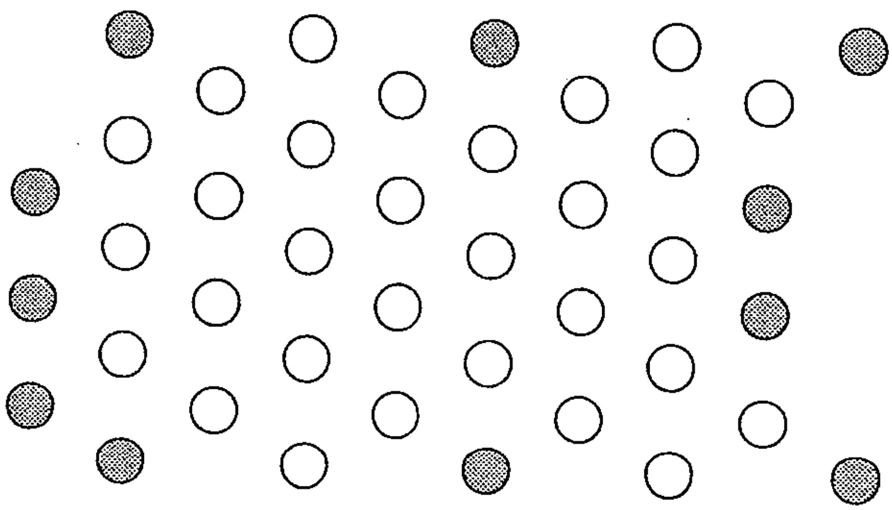
5mm holes on 12mm centres, square



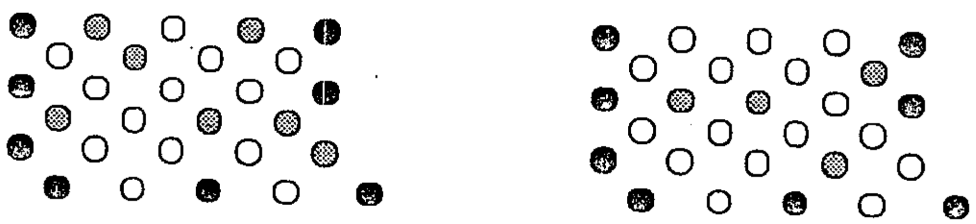
5mm holes on 12mm centres, hexagon



6mm holes on 14mm centres, square



6mm holes on 14mm centres, hexagon



Code patterns, 7 holes, hexagon

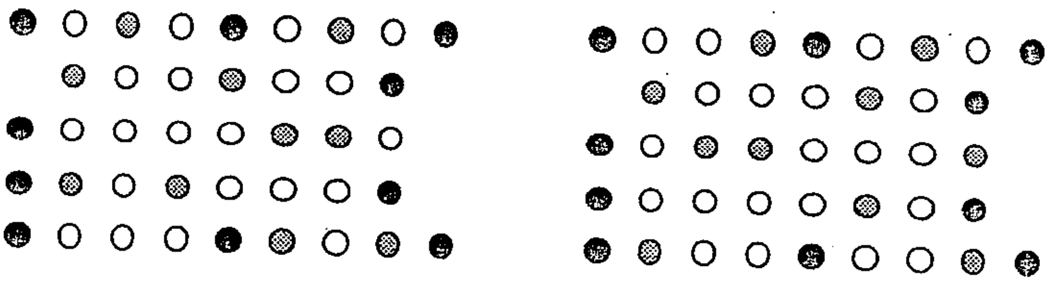
3.5.3 Analysis

Our experiments have verified that the butt is a good tag location, since none of the patterns were lost from that location.

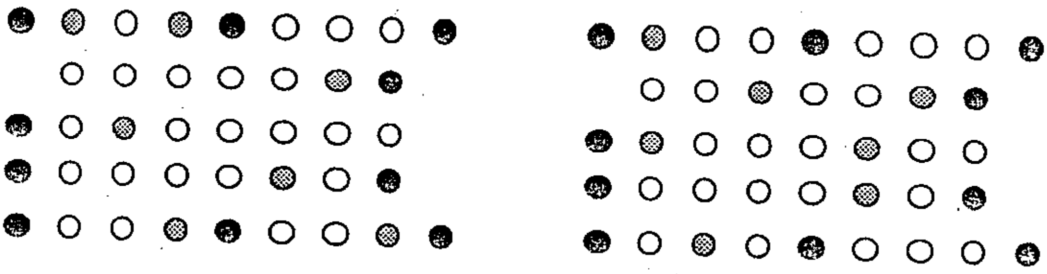
The tests give us 32 samples of possible flesher damage, 16 samples of the 5/12 pattern, and 16 samples of the 6/14 pattern. We also have 16 samples of the square arrangement and 16 samples of the hexagon arrangement. In addition, 16 samples have all holes punched, and 16 have a smattering of holes, such as would occur in real code-numbers.

The total number of holes is about 900.

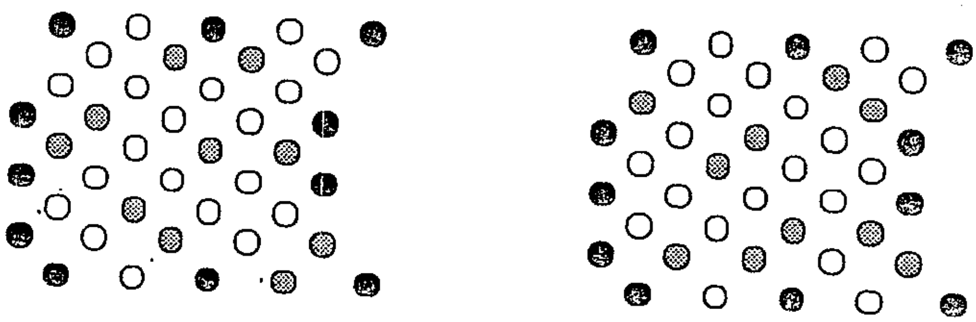
We punched some hides with "real" codes, according to these patterns. The black holes are orientation holes (punched in every hide), and the grey holes carry the code.



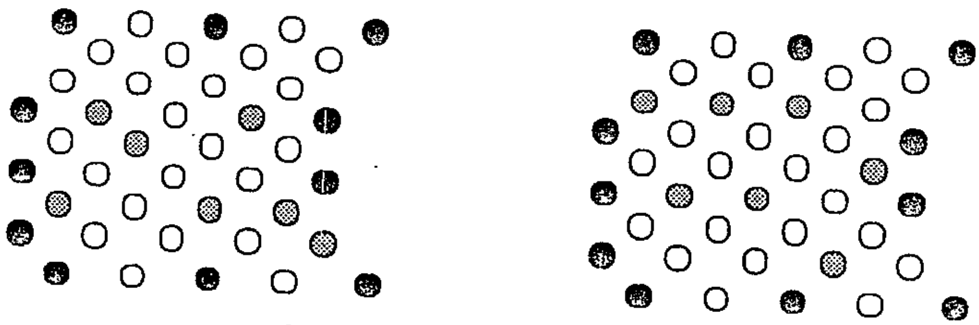
Code patterns, 10 holes, square



Code patterns, 7 holes, square



Code patterns, 10 holes, hexagon



Code patterns, 7 holes, hexagon

3.5.3 Analysis

Our experiments have verified that the butt is a good tag location, since none of the patterns were lost from that location.

The tests give us 32 samples of possible flesher damage, 16 samples of the 5/12 pattern, and 16 samples of the 6/14 pattern. We also have 16 samples of the square arrangement and 16 samples of the hexagon arrangement. In addition, 16 samples have all holes punched, and 16 have a smattering of holes, such as would occur in real code-numbers.

The total number of holes is about 900.

3.6 Test Three- Results

3.6.1 Punching

30-Jan-95 2pm. The batch of hides we processed was quite fatty, particularly either side of the spine near the butt. The thick fat (up to 20mm or more in some cases), made it difficult to accurately locate the punched holes. This was confirmed by examining the hide from the grain-side, when it was obvious that some holes were substantially displaced from their proper position. Clearly the 6/14 pattern is larger than the 5/10 pattern and, not surprisingly, the likelihood of fat getting in the way was greater.

It seems likely that the degree of fattiness here is dependent on the skill of the flayer, and that if he knew holes were to be punched in the butt, he might ensure that fat was not a problem there. We have not verified this thought, however.

We noted that our 5mm cutter was becoming blunt, and the wooden block we used as an anvil was getting rather battered. This was causing the cutter not to completely remove the wad of skin that was being cut. We decided to press on, because we anticipated that in production, cutters would become blunt, and might occasionally be damaged. It seemed useful to know how this would affect readability.

3.6.2 Fleshing

We did not observe the fleshing step.

3.6.3 Tanning

2-Feb-95 8:30am. Because of traffic, we arrived at Michell Leather about 10 minutes after the batch containing our tagged hides had begun passing through the sammier. As a result (we presume), one hide went astray and we only recovered 31 of the 32 tagged hides.

We photographed all hides as they came through the sammier. It was obvious which hides had been fatty, simply because of the irregularity of the pattern of holes, particularly near the edges of the pattern.

The 6/14 patterns had clear holes right through the hide, despite the swelling introduced by tanning. The 5/12 patterns tended not to have clear holes, but were still easily visible. It was clear that the 5mm cutter had not been removing the wads properly, since many holes were partially blocked by the uncut wads. Our impression, however, is that the presence of the wads would probably not have affected reading accuracy.

Inaccurate location of the original punched holes will have a greater impact on reading accuracy.

3.6.4 Photographs

Photo C.18 41 hole square 5/12 pattern, grainside, before fleshing. Note slit and fat on hide

Photo C.21 Same hide as in C.18, coming through the sammier, code easily seen

Photo D.22 Same hide as in C.18, photographed on the floor. Note irregularity of hole spaces caused by fat on hide, slit does not affect readability

Photo G.20 41 hole 5/12 hexagon, from flesh-side. Note fat either side of pattern, slits

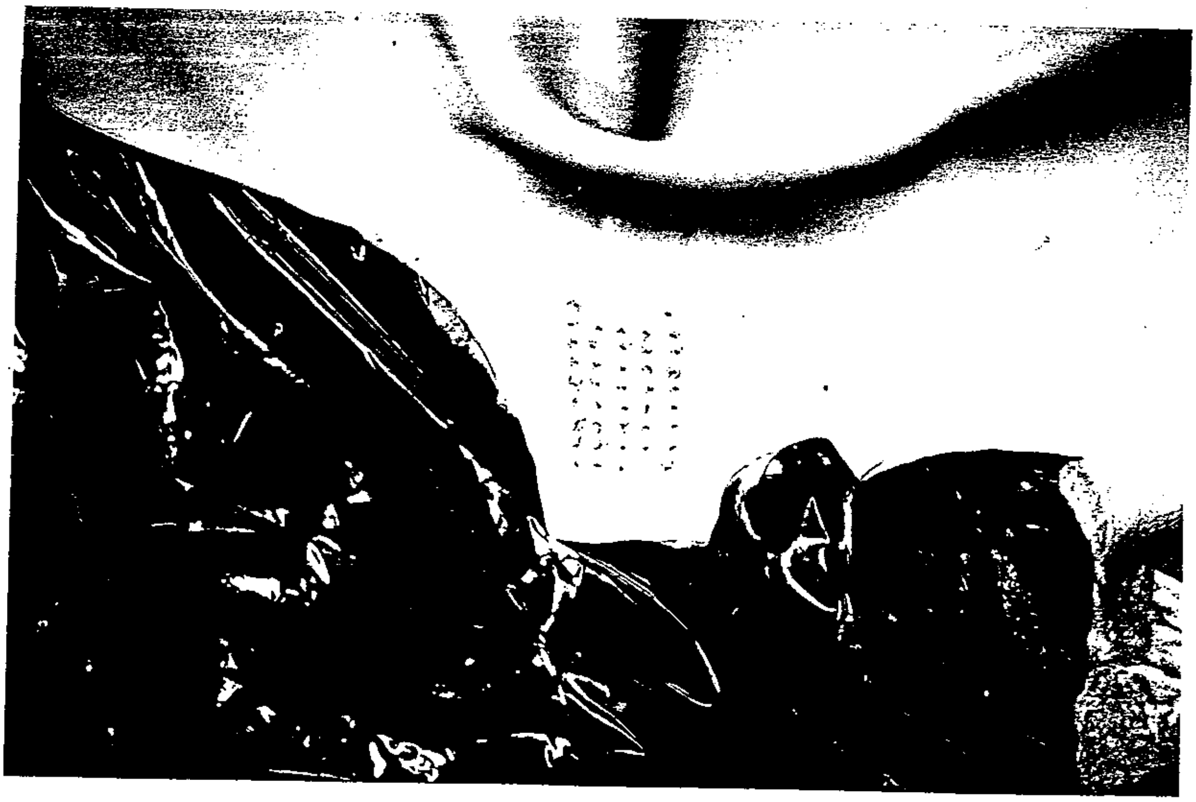
Photo D.24 Same hide as in C.20, on the floor, irregularly shaped holes due to blunt cutter

Photo C.36 Example of wrinkling that occurs as hide leaves sammier

Photo C.31   10-hole 5/12 hexagon "real" pattern on the sammier

Photo D.10   Same hide as C.31, on the floor, holes a bit ragged, but still readable

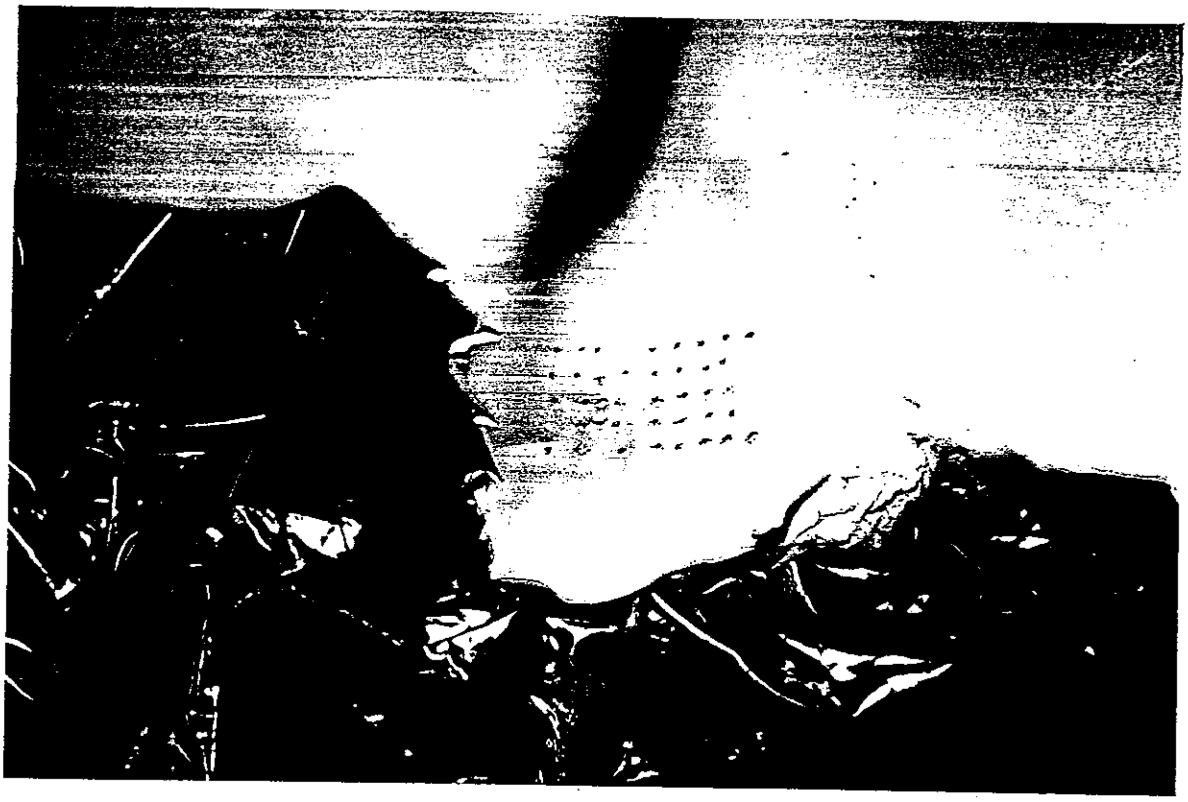
Photo D.18 10-hole 6/14 "Real" code, clearly visible pattern



D.3 A full 5/12 square array, visible, but the cutter is really blunt

D.25 A 7-hole 5/12 hexagon array, irregular hole spacing due to fat on hide, on floor prior to splitting (See sample)

D.26 A full 5/12 hexagon array, cutter blunt, on the floor prior to splitting (See sample)



D.7 A full 5/12 square array, on the floor. Note cutter is blunt, irregular hole spacing is due to very fatty hide (See sample)

3.6.5 Conclusions

The butt remains the preferred location.

Both 5/12 and 6/14 patterns work well. Perhaps a 5/14 would be best, since it would allow more tolerance for position errors. The 6/14 pattern is approximately 140mm x 50mm which is quite large, but still small compared with other damage on hides, such as brands or cuts.

There seems little to pick between the hexagon and square arrays, and the difference in pattern size is very minor. The square array patterns and codes are more easily recognisable to humans than the hexagonal. Distortion from the sammier can be mentally corrected more easily for the square pattern.

3.7 Test Four - Plan

3.7.1 Objective

To determine what effect splitting a hide has on the code pattern area. We expect to learn about:

- Splitter damage to the patterns
- The range of thicknesses that can be achieved

3.7.2 Method

Four of the samples that we have taken from earlier steps will be split. There seems little point in splitting the main body of the hide, since this is a well-known technology.

3.8 Test Four - Results

3.8.1 Splitting

This step turned out to be trivial! We ran the samples through the splitter, with the thickness set from 3mm down to below 1.5mm, and the result was slices of hide, without side effects.

All the grain-split samples came through perfectly.

One of the drop-split samples had slits in it, but this was attributable to cuts on the flesh-side of the hide caused by the flayer, not the splitting machine. We expect that all samples could be read easily.

As observed earlier, the 5mm holes tend to close up in the inner layers of the hides during tanning, and the result was that the readability of the drop-split was poor.

The 6mm holes produced clear holes in the drop split, so that readability remained good.

3.8.2 Photographs and samples

We did not take any photographs. There are some samples with this report.

3.8.3 Conclusions

Splitting will not cause any problems, except where there are cuts on the rear of the hide. As we expect the flayers to take more care here, once they know tags are being applied in this region, we anticipate no long-term problems.

During tanning, the inner layers of the hide swell more than the outer surface. Readability depends on having a clear hole through the hide, and this can be achieved provided the original holes are 6mm in diameter, or larger. The flesh-side of the hide is susceptible to flayer cuts and nicks, and theses nicks show up as slits in some of the drop-split sections.

4 Summary

Our overall impression is that using an array of punched holes is a feasible approach to hide labelling. In this section we review significant observations about the operation of the system.

4.1 Location of the pattern

We explored several locations for applying the pattern of holes. Most locations were unsuitable because either the hide was thin, and the patterns were mutilated during fleshing, or the chosen location was not present in all hides.

Only one location proved to reliably survive the fleshing, tanning, and sammying processes, and that was at butt of the hide. The hide is thicker here, and we experienced no flesher damage in our trials.

4.2 Size of holes

Our tests reveal that holes from 5 to 6mm in diameter are sufficient to reliably pierce the hides and be visible at the wet-blue stage.

During tanning, the inner layer of the hide swells more than the outer layers, so the 5mm holes are no longer clear right through. While this does not affect readability of the complete hide, in the case of split hides it is likely to reduce the accuracy of reading the drop-split or inner-splits.

We suspect that the optimum size is therefore 6mm.

4.3 Spacing of holes

Our tests explored a number of size and spacing combinations. We beleive that because of the slipperiness of the hides, and the presence of fat, the holes need to be a reasonable way apart. Our experiments have suggested that 2 to 3 diameters is optimum. The tradeoff here is obvious: Increasing the spacing makes the reading process more tolerant to punching errors and hide distortion, but at the penalty of increasing the area occupied by the code.

Our feeling is that 12 to 15mm is a good starting point.

4.4 Registration of holes

We punched our patterns using a manual one-at-a-time punch, and printed paper templates. When the hide was flat and free from fatty deposits, we had good results, and the completed patterns were very regular. Where large blobs of residual fat were on the hides, sometimes 20mm or more, we had trouble ensuring that our punch pierced the hide where we wanted it to.

Since the presence of fat is inevitable, any punching machine must be able to hold the hide steady while the complete pattern is punched. Fat is not difficult to punch through, indeed it is much softer than the hide, but it is very mobile, and unless the hide and punch are rigidly aligned, mislocated holes will occur. The price of excessive mislocation is increased reading errors.

Of course, it may be that the flayers can be asked to be careful to trim the fat away from the butt, though it is better not to rely on this being done.

4.5 Orientation of holes

Green hides are quite irregularly shaped, so that the area of hide at the butt is sometimes wide, sometimes narrow. There is really no practical way that a pattern could be aligned (say) along the backbone every time. The conclusion is that to ensure reliable reading, the system must be capable of reading codes independently of their orientation and precise location on the hide.

This has the effect of simplifying the design of the punching machine, and the operation of it, in exchange for increased complexity in the reading system. Since machine vision systems can be expected to improve considerably over time, whereas this is unlikely to be true of the mechanical punch, this is clearly the optimum choice.

4.6 Shape of hole-pattern

Our experiments have investigated both square and hexagonal hole arrays, and there appears little to choose between them in terms of readability.

The area of a hexagonal pattern is theoretically 87% of that of a square pattern with the same number of holes which, although not large, is significant.

The choice is best made by the punching machine designers, since there may be mechanical reasons why one arrangement is easier to build than the other.

4.7 Coding

The optimum coding is a difficult question to answer. There is some discussion on this matter in appendix B.

Our feeling is that if the hole patterns are effective and reading is reliable, there will be little reason for humans to want to decode or read them directly.

The benefit of discarding human-readability is that we can optimally exploit the number of holes available, and also utilise modern error-checking and correcting codes to advantage. Error correcting codes are inherently difficult for humans to decode, but can greatly increase the reading accuracy in the presence of random errors.

4.8 Punching machine

Our area of expertise is electronic engineering, not mechanical, so we can only speculate on how best to build a punching machine. However, some restrictions on the design are clear. Any machine designed to operate in an abattoir must be hygienic, since this is a food-processing environment.

The implications of this are that the machine must be simple, and free from corners and crannies where vestiges of flesh can become trapped. It is also desirable that the whole assembly be steam cleanable. This is a stiff requirement, but is achievable with other food equipment, so should be achievable here.

Since the rate of processing may be more than 1000 operations per shift, the punches must remain sharp for a long time. This implies either the use of hard materials on the cutters, or self-sharpening cutters or even on-line sharpening.

It is not clear whether the best style of cutter is hollow wad-cutting punches, as we used in out trials, or solid punches, as are used for punching paper. Easy changeover, in the event of accidental damage is also clearly desirable.

4.9 Machine vision system

Our experience with the sammier shows that the butt end exits the machine in a region about 600mm wide, and that patterns may have been punched with any orientation, implying that the vision system must be able to tolerate this variability. Reading directly on the sammier seems to be best choice, since often a hide buckles slightly as the butt lands on the grading conveyor. The buckled pattern that results would be hard or impossible to read.

The vision system will undoubtedly incorporate a TV camera, and it is clear that with a little extra ingenuity, this same camera, and perhaps even the same processing system, could be made to compute hide area, and perhaps look for flaws.

Of course, these features need not be installed initially, but could be added later once the operation of the system was proven.

5 Evaluation

In this section we examine how well the array of holes has met the MRC's stated requirements, in the light of the information gained from our tests.

5.1 8 Character code

Our final experiments were carried out using a pattern of 41 holes, composed of 31 data-holes and 10 orientation-holes. This pattern provides sufficient holes for 10^8 codes, plus three extra holes that could be used to provide error checking.

There are therefore no barriers to the implementation of a full 8-digit code.

Larger codes could be implemented, and would simply occupy more hide area.

5.2 Human decodable

As noted in section 2.1, a code that is easily decoded by humans would require more holes than a machine-optimal one, but we do not forsee any particular problems with increases in pattern size, except the amount of hide required for the code itself.

Hole patterns will always be inconvenient, though not impossible, for humans to decode.

5.3 Unique code on each hide

Based on our experience with the wad-cutting punches, we are confident that there are no fundamental obstacles to building a machine to punch a computer-selected array of holes.

5.4 Able to be applied to green hides

All our tests were carried out on green hides prior to the fleshing machine.

Except for the problems caused by large fatty deposits, we experienced no difficulty in applying the hole patterns to the hides. Suitable clamping by a punching machine will ensure that registration remains precise. We also presume that during flaying, care could be taken to keep the butt free of fat, and this would substantially overcome the problems we experienced.

5.5 Hygienic and safe

Obviously, a hole is a pretty safe object!

The source of problems is likely to be the punching machine, which is located in the abattoir on the slaughter floor. During operation, the punch will cut wads from the hides, and these will need to be cleared periodically. To ensure hygiene, the machine will need to be constructed of food-grade materials, and be capable of being steam-cleaned (perhaps daily). The design of the machine is outside the scope of this project, and remains a matter for further research.

5.6 Machine readable

We have found a reliable location for the array of holes, at the butt of the hide, and our experiments indicate that the array survives the tanning process.

At the sammier, the array can be easily seen by eye, and we are confident that a machine-vision system could be constructed to read the code.

5.7 99% reading success rate

At this stage it is not possible to quantify the read rate.

Except for one hide we lost, all the patterns located on the butt of the hide came through intact. There are some minor problems through folding of the butt, but these could be overcome by more care from the sammier operators. When not folded, the patterns could easily be read by eye.

We expect the accuracy goal to be achieved.

5.8 Apply while hide still on animal

We cannot apply the hole pattern while the animal is alive, nor while the hide is still on the carcass. However, it is likely that the pattern could be applied while the hide was still partially attached to the carcass. There would be no difficulty applying the pattern immediately after the hide was removed from the carcass.

The precise mechanics of applying the patterns will depend on the way hides are removed. We understand that there are two kinds of hide-pullers, those that pull up and those that pull down. Clearly this will have a big impact on the application of a pattern.

5.9 Readable with hair still on

Our initial impressions about hides proved to be quite wrong. Our experiments reveal that reading the code on a green hide is unlikely to be successful. The hair obscures visibility on the grain-side, and the shifting fat-layer and slippery membranes obscure visibility from the flesh-side.

After fleshing, the hole-pattern shows up as dark holes on a white background, when viewed from the flesh-side of the hide. This could be read provided that the hide could be smoothed out sufficiently.

5.10 Survive to finished leather

There seems no reason why the code would not survive to the finished leather. We assume that the chrome tanning process is the most aggressive step, and that later stages are less likely to damage the code. Trimming processes during final tanning may result in the code being cut off. The main requirement for good reading accuracy is adequate contrast, implying a dark background for wet-blue hides, and a light background for dyed hides.

5.11 Human readable

The hole pattern is not directly human readable.

One possible solution is to punch the hole pattern, for machine readability, and an adjacent digit-pattern using chisel-edged digits for reading by humans. This is the strategy adopted on all bar-coded products. Of course this would take up more hide area, and increase the complexity of the punching machine.

5.12 Automatic application

The irregularity of the shape and thickness of hides precludes a fully automatic application system. However, if a human were to feed the butt of the hide into a punching machine, it seems feasible to punch the code under machine control. This is a matter for further investigation.

5.13 Software driven code

If we have a computer controlled punch, generating unique codes is easy.

5.14 16 Character code

Because of the pattern area already required for 8-digit codes, it seems unlikely that a 16-character code will be feasible. Extending from 8- to 9- or perhaps even 10-digits is feasible, however.

5.15 Readable on the drop split

Provided the hole size is large enough (6mm or more), the drop split will be readable. The splitter does not cause any damage to the patterns, even when the split is very thin. Nicks on the flesh-side of the hide sometimes appear as slits in the split hide, and these may affect accuracy of reading, depending on the severity of the nick.

6 Recommendations

Our tests strongly indicate that an array of holes will be readable under most conditions in a tannery. We therefore recommend that further research proceed as follows:

- Develop a prototype punch
- Develop a small production-scale punch
- Develop a prototype reading system
- Investigate number encoding systems

6.1 Prototype punch

For the array of holes to be practical in production, it must be possible to punch holes easily, reliably, and quickly. While our experiments suggest that the effort required to cut wads out of a green hide is small, the number of wads to be cut in one day is very large - perhaps as many as 2000 holes in each position. It is therefore very important to establish that holes can be punched reliably in a rugged production environment.

The best way to do this is to build a prototype punch, with a small number of cutters, and test it in the factory on a variety of hides. This will also provide the opportunity to see whether it is mechanically easier to build a punch for the square or hexagonal pattern.

Once a prototype punch has been proven, it can be used to generate test-patterns for investigating the prototype machine-vision system. It is not practical to generate test patterns manually because of the time involved, and the imprecision of location which results.

6.2 Small production punch

Our discussions with Michell Leather have indicated that their immediate need is not to tag each hide, but to track each hide back to the abattoir that produced it. The size of the number required to do this is clearly small, two or three digits at most. Naturally, a reduced number would require a far smaller punching machine, and fewer location holes.

To determine the practical limitations of holes, a trial needs to be run where a significant number of hides is tagged, perhaps tens or even hundreds of thousands.

We therefore recommend that a production-scale trial machine be constructed with the capability to uniquely number each abattoir. Such punching machine to be rugged enough to be operated under full production conditions. There are a number of details to resolve:

- Optimum pattern shape (square or hexagon)
- Limitations on inter-cutter spacing
- Cutter design (hollow or solid, self clearing, self sharpening)
- Clamping arrangements
- Actuation arrangements (air, hydraulic or other means)
- Punch sequencing (preferably electronic)

The hides so marked could then be used to test the prototype machine vision system, while at the same time providing useful information about the production process to the tannery. There is no doubt that the cooperation of a tannery is required, and that such cooperation will be more enthusiastic if there is something in it for them.

6.3 Prototype machine-vision system

Once genuine, albeit small, tags can be punched into the hides, it is appropriate to consider the machine vision question. This area of technology has advanced considerably in recent years, and we do not anticipate any major problems achieving a workable system.

We therefore recommend that a prototype machine-vision system be constructed and refined to read the pattern of holes.

Once built, such a machine could produce identification statistics for the tannery, and collect data on readability, reading-accuracy, and tolerance to factory conditions.

Since the machine-vision system will be using a TV camera to acquire the image of the hide, it would be feasible to enhance the software to measure hide area and count defects at the same time as the identification code is being read.

6.4 Number-coding systems

The mapping from the hide number to the pattern of holes on the hide is a matter for further investigation. While a pure binary encoding may be easiest to implement, a code incorporating check-digits, or having certain known statistical properties may be advantageous. Some of the issues involved here are discussed in Appendix B.

We recommend that final decision on the encoding be determined once punching and reading equipment is available. Since both machines will be software controlled, changing the coding will be straightforward and can be done at any time.

A Glossary

Butt	The place on a hide where the tail of the animal was attached.
Flesher	A machine used to remove excess fat and flesh from a green hide. It has a set of knives rotating at high speed against the hide.
Flesh-side	The side of a hide that was inside the animal. Opposite the grain-side.
Green hide	A hide that has been removed from an animal carcass. An untanned hide.
Grain-side	The side of a hide that has (or had) the animal hair on it.
Sammier	A machine used to remove excess liquid from a wet-blue hide.
Wet-blue	A hide which has been stabilised by the chrome tanning process, but has not yet been dyed.

B Coding arrangements

There are numerous ways in which the hide number could be encoded into the pattern of holes, and this does not need to be resolved until the reading and punching machines are available. This is because the punching machine needs to be able to generate *any* pattern, and the reading machine to recognize *any* pattern. The *meaning* of any pattern is a separate issue, determined by the software used in each machine, and is therefore easily changed.

In this appendix, we look at some ways of encoding the hide number to improve the accuracy of reading.

B.1 Encoding

Ignoring, for the moment, the need for human readability, the most efficient encoding of the hide number into the least number of holes will be one based on a pure binary code. An 8-digit code requires 27 holes.

B.2 Parity check

To improve reading accuracy, it is desirable to include some form of error checking. A simple parity bit allows detection of single errors, but provides no ability for correction.

The cost of a parity check is one additional hole.

B.3 Hamming check

A more advanced scheme, based on a Hamming-code would have the ability to detect all single-bit errors, all two-bit errors, and many higher-order errors. It can also correct any single-bit error.

The cost of a Hamming check is an additional 6 holes.

B.4 Statistical properties.

We assume that during processing at an abattoir, code numbers will be assigned sequentially to the hides as they are processed. Since a relatively small number of hides are processed daily, compared with the total counting range of the hide number, we could exploit this statistical knowledge to improve the reliability of reading.

Consider: A large abattoir slaughters fewer than 2000 cattle per day, so that only 11 digits are required to label the animal, plus an additional 8, to uniquely identify the abattoir. These 19 holes can be put anywhere in the pattern of 27 holes, provided that each hole combination is used once only in the complete numbering sequence. The effect is rather like putting all the hide numbers in order, then shuffling them and using them in shuffled order, except that the process is not random, like shuffling, but systematic so we can always repeat it at will.

Natural binary order is a poor choice because half the hides will have even numbers, and the other half, odd numbers. But odd numbered hides differ from their even numbered predecessor by the addition of just one hole!

We therefore seek to generate sequential numbers that produce hole-patterns which are as "different" from one another as possible.

When a batch of hides is received, the decoding system can read the hole-pattern, and decode the number. In those cases where it is unable to determine the actual code (even with error correction information), it can exploit the knowledge that the batch it is reading consists of more-or-less consecutive numbers. From the batch statistics, it can determine where in the sequence this batch is located, and therefore determine the most likely value of a missing or mutilated code.

Note that this method of error resolution involves sophisticated processing and is *not* required for the system to work - it simply allows an improved read rate with mutilated codes. However, in order to be able to exploit this at a later stage, this form of coding must be used right from the beginning.

There is good reason to delay implementing this scheme, because the processing is not quite as simple as suggested here. At a tannery, hides may come from several abattoirs, and within those batches the statistical properties described above will hold true. However, the tannery may choose to process several batches together, resulting in two, three, or more, number sequences appearing at once in the tanning drum. This complicates the business of extracting the sequence information from the hides as they are read at the Sammier.

One final side-effect of coding in this way is that human decoding of the pattern becomes even more difficult. It is almost universally true that ease of processing by computers makes for great inconvenience to humans!