Agriculture Canada

Engineering Research Service

REPORT NUMBER: 7407

June 1974

Report on the Problems of Improvement in Beef Cattle Marking

W. S. Reid

CONTENTS

Contribution No. 453 from Engineering Research Service, Research Branch, Agriculture Canada, Ottawa, Ontario, K1A 0C6.

1. Introduction

The marking of beef cattle and other livestock is a universal problem and is practiced in virtually every country which has a viable animal husbandry industry. The requirements within a country vary very considerably from that of the individual breeder, farmer, or feedlot owner, to those of the animal health and agriculture departments.

The techniques in current use are usually quite cheap, but can cause significant trauma to the stock, and may also cause damage to the hide.

More sophisticated electronic techniques have recently been used (last 10 - 15 yrs.) to obtain data on the physiological well being and habitat of wild animals.

The work which has already been carried out in the following areas is extensive and is referenced at the end of this report.

1. Identification systems
2. Identification methods
3. Implantation
4. Bone repair
5. Radiotelemetry
6. Radiosondes

Despite all this literature the basic problem still remains which is how to mark individual animals permanently, at very low cost, with difficult identification by thieves and simple identification by authorized personnel.

2. Reasons for marking live and dead stock

2.1 Identification of individual animals for husbandry management.

2.2 Identification for breeding purposes.

2.3 Identification for health requirements - vaccination and disease control.

2.4 Identification for subsidy payments.

2.5 Positive identification in large groups of one colour breeds.

2.6 Identification of ownership in mixed groups.

2.7 Possible identification when stolen.

2.8 Identification after slaughter for quality premiums.

2.9 Identification for tracing through the meat marketing system.

2.10 Identification with physiological monitoring disease control, herd management and stress reduction breeding.

Research has a number of other requirements or reasons, to enumerate a few:-

2.11 Identification of individual animals in feeding experiments.

2.12 Identification of animals for environmental habitat studies.

2.13 Identification in conjunction with physiological monitoring.

2.14 Physiological monitoring.

3. The Problem

3.1 Identification requirements:

3.1.1 Must be cheap < $3 preferably.

3.1.2 Must be reliable < 1 in 10^6 failures in 3 years for beef cattle, longer for dairy cattle (10 years).

3.1.3 Must be inert to biological fluids if implanted.

3.1.4 Must not migrate if an implant.

3.1.5 If an implant, implantation should be feasible in as many locations in the body as possible.

3.1.6 If an implant, implantation should be feasible early in the life of the animal at birth, or at any later date.

3.1.7 Should not be affected by the growth of the animal.

3.1.8 Identify large numbers of animals of any one species say 10^7/Annum minimum.

3.1.9 Detection of identification to be difficult for unsophisticated thieves.

3.1.10 Detection quick and easy with a cheap instrument < $500 by authorized personnel.

3.1.11 Detection range 10-20 m minimum for normal requirements, in habitat work ranges to 4 km required.

3.1.12 Reclamation may be necessary and should be easy, otherwise must be non-poisonous to humans, withstand cooking temperatures and be non-carcinogenic.

3.1.13 If an implant, must be acceptable to regulatory bodies, Government (Animal Health) and S.P.C.A.).

3.1.14 If an implant, should be small - 0.5 cm dia x 2 cm long, or 1.5 cm dia x 2.0 mm thick.

3.1.15 If an implant, should not migrate far from original point of implantation.

3.1.16 If an implant, a passive device would be better than an active device.

3.1.17 Coding capability should be flexible for alternative systems which could include other data such as breed, date of birth, state or province in which born, original owner, and vaccination data, etc.

3.1.18 The ability to add further coded data after implantation could be a further advantage.

3.1.19 In some cases, the possibility of monitoring limited analogue data - temperature, pressure, pulse or heart rate could be valuable.

3.1.20 Infection and rejection if an implant should be at a very low level < 1:1000 or above.

3.1.21 Implantation should probably be sub or intra muscular rather than just sub-dermal. Sub-dermal implantation is probably the easiest to implement but is easy to locate if stock is stolen and slaughtered via the incision scar on the under side of the skin. An intra or sub muscular implant is more difficult to tamper with because a portion of meat or carcass has to be removed to remove the marker, suggesting dishonesty.

3.1.22. Immobilization by external means should be difficult, otherwise substitution with an alternative numbered implant becomes feasible. Another possibility for dishonesty.

3.1.23. Numbers may be preprogrammed, or alternatively programmable on site - much more difficult. It may be possible to incorporate special codings to act as checks for implant substitution.

3.2 Identification coding systems

3.2.1 Strict numerical system from 1 upwards. This means registers are needed stating date of birth, breed, sex, state in which born, owners name, health data, etc. The versatility of the system will determine the selection of the possible coding system. One digit might be allocated to indicate year of birth.

3.2.2 Limited data could be recorded if on site programming is feasible, such as year of birth, 1 digit; continent of birth, 1 digit; country, state or province of birth, 3 digits; owner, 4 or 5 digits; vaccination data, say 1 digit each of 3 diseases (3 digits), overlay might make 2 digits feasible. Remainder would be for enumeration. This would involve 10 digits minimum meaning a minimum of say 15 digits assuming any one owner in any one year would produce not more than 999 to 9999 calves in one year, an unusually high output except for the largest operators who can reach above 20,000 births/annum.

3.2.3 External marking systems such as branding, ear tags, tatoos adopt several identification systems. The more complicated such as ear tagging and tatooing use letters and numbers usually oriented in one plane.

The simpler systems such as branding usually use at most 3 letters and perhaps some other special pattern. With current computer technology the simpler systems do not have enough variants to prevent repetition for the number of animals involved without making patterns that are impossible to describe unless they are drawn. This is not satisfactory for a universal identification system.

Dr. K. Farrell, U.S.D.A., Agricultural Research Service, University of Washington, has developed a system of freeze branding with special brands which are unique and unalterable using a hexadecimal system which can be used to identify 27 billion animals. These are easily read with experience and can be described verbally, and could, therefore, be coded for direct computer terminal entry.

Mr. Harry Link, Regulatory Services, Alberta Dept. of Agriculture has developed a branding system for the province of Alberta which can be described verbally and to a computer, information is being obtained on this system.

There is no doubt many systems which could be used such as the alphabet 26 letters and 10 numbers. If a square pattern is envisaged, of 3 positions on each side of the square and one central position, this would give very many combinations if each letter or number could be rotated through 90^{o} or even 45^{o} in each position of the square. Numbers such as 0, 1, 5, 6 and 9 and letters I, O, M, S and W might be considered to be similar in some respect, reducing the total number of symbols to 24 and 7. 0 has no orientation. I has 2 positions of orientation. S has 2 positions of orientation. Even these letters and numbers could be made to look unique with slight modification. Even a 3 position code would give a large number of possibilities.

Branding is such a well established technique that it is unlikely it will be replaced by any other identification method in the short run, mainly for political, sentimental and trade mark reasons. It is, however, obvious that there is need in this area in the United States at least for a coding system. It is perhaps unfortunate that branding originated in many areas independently without reference to the need for a computer compatible coding. Further consideration is needed in this area after all coding systems have been reviewed.

3.3 Identification methods

3.3.1.1 Passive electronic implant with separate readout, pulse coded signal. This is the most favoured method at present because no other system seems to offer the same potential in terms of cost, versatility, ease of implementation, etc.

3.3.1.2 Passive electronic implant pulse coded signal with physiological monitoring. Costs are likely to be similar to the identification implant, but a double readout device would be needed which would be more expensive. This unit is being considered primarily for implant in the auricle or poll to monitor brain temperature for disease, heat stress and oestrous determination. This is the direction U.S. research is following at present. The location in the poll or auricle does not exactly cover the original specification of Agriculture Canada's Beef Commodity Committee who specified the carcass. No doubt implantation would be possible in the carcass with a special implant tool and with some loss of physiological monitoring sensitivity. There are problems of monitoring physiological data in large numbers when out at pasture or on the range. How do you read each animal? Do you use herdsman with readout, or a salt lick, or water supply decoy with readout? How easy is it to isolate one animal?

3.3.1.3 Passive electronic implant frequency coded signal, multiple frequency code with or without physiological monitoring. Single frequency codes do not have sufficient discrimination for the large number of animals involved.

3.3.2 Genetic cell coding at present, no suitable technology is known.

3.3.3 Multiple pin code - no means is known of satisfactorily implanting these reliably.

Detection is a problem - X-rays could be used, but this would be expensive. Alternatively, it has been suggested the pins could be encapsulated ferrite rods of different frequency response, using a "Q" meter for detection. At present, it is not known what effect embedding in the musculature would have on damping and signal attenuation.

A closely related patent is that of T.F. Thompson, U.S. Pat. No. 3,740,742 of 19 June 1973 entitled "Method and Apparatus for actuating an electric circuit".

There is already such a system in use to prevent theft from clothing stores. Ferrite rods are sewn into the clothing. These actuate an alarm when they pass through the store door unless the clerk has entered the code for that item in the cash register.

3.4 Identification comparative costs

3.4.1 Ear tags are relatively cheap - 20 cents each plus insertion time

- no major damage, slight trauma, limited information, or difficult to read usually means catching animal - larger tags fairly easy to read
- removal and replacement easy
- loss rate at the 1% level or below

3.4.2 Tattoo - Tattoo ink ½ pint $6.40 say 1 cent/animal

- easy to apply, very cheap, fairly easy to read
- animal must be caught and held
- information content limited to 8 combinations of 8 individual letters or numbers - therefore quite good
- cannot be removed, alteration possible

3.4.3 Neck Tags - Delux tags and chain set - $1.75 > 100 units

Standard tags and chain set - $0.95 > 100 units

- fairly easy to read at distance
- information content quite high and can be updated but expensive
- can be removed and/or altered or replaced
- no hide damage - no trauma

3.4.4 Branding hot iron - primitive method - or freeze branding

- information content low for simple branding irons - definition of brand over time more difficult with more complicated brands
- quite traumatic to animal
- freeze branding less traumatic but application more costly
- can be read quite easily at a distance if a simple brand
- hide damage works out to about $2-$3/hide depending whether flank or butt brand
- branding iron cost $6.25 - $52.35

3.4.5 Electronic implant

- target cost < $3/implant plus readout @ < $300
- retail cost of implant tool submuscular estimated @ $25.00
- information content high
- updating difficult at present
- easily read with special readout equipment
- alteration difficult
- application may present some problems of infection, probably little worse than implantation of growth hormone pills
- immobilization detection or removal of submuscular implant not very easy for unauthorized personnel
- reading in free range, easy without catching, but need isolation to prevent interference from other animal implants
- submuscular implant preferred to subdermal for security reasons
- special applicator may be needed

3.4.6 Other

- no other known approach satisfies the over-all requirements as well or as cheaply as the preceeding systems

3.5 Animal health

- all methods except neck tags involve some animal trauma, the level of trauma of a small submuscular implant should not be much greater than existing techniques and may even be less than either hot iron or freeze branding.

The only criteria amenable to evaluation would be the increased occurrence of infection and implant rejection which should be minimal with the development of an effective implant method and encapsulation materials.

3.6 Political. This is perhaps the most difficult problem of all as it involves the interaction of many vested interests some of which are mutually exclusive. The problem areas are as follows:

3.6.1 Many different agencies and personnel are interested in marking for many different reasons - the farmer, the brand inspectors, the state or county, federal governments, the police and the vets.

3.6.2 Branding originated in many areas for many different reasons. This means many brands have emotional and trade mark status.

3.6.3 Legislation on branding is usually a state responsibility and is not favoured in the United States, as only 2 states have legislation regarding use and registration, others are beginning to follow. Federal intervention is not favoured at present.

3.6.4 At present many brands are common to many states leading to confusion in case of disputed ownership or disease origin.

3.6.5 Movement of cattle within the United States and Canada is frequent and often crosses many borders both county, state and national.

3.6.6 As far as possible the system adopted should be adopted universally on a continent basis.

3.6.7 Canada must integrate with United States systems.

3.7 System development costs

3.7.1 New brand coding systems would mean political negotiation and purchase of new approved branding irons which could be quite expensive, but little system development costs would be involved.

3.7.2 Electronic implant - This is very expensive, so far the U.S. Federal Government has spent $69,000, 1971; $100,000, 1972 and $100,000, 1973 and a great deal more is still needed. The Mechanical Laboratory estimates between $60,000 and $600,00 for equipment only. At this level of expenditure for the expected reward, it is best to investigate 1 avenue at a time and if this proves fruitful, reduce the level of investigation of other systems significantly. If not successful, select the next most promising approach after cost review.

4.0 Research Requirements

- The only new and possibly viable technique of animal identification is that of the electronic implant.

4.1 Electronic Package

4.1.1 The implant - The principal problems in this area are the development of a suitable circuit which is small enough for an implant with adequate encapsulation for protection from biological fluids. Circuit development is in the field of micro electronics and would need to be carried out in association with industrial organizations who specialize in micro-circuitry.

Reliability is not considered to be a major problem.

The technical problems of making a passive device of sufficient power output do not seem impossible at this time.

The principal problem seems to be in the selection of suitable frequencies for energy transmission to the implant and for signal transmission from the implant. Signal attenuation from a sub muscular implant seems to be very important and may be critical especially with micro-circuits.

Schuder and Stephenson discuss some of the problems of coil coupling efficiency in their paper "Energy Transport to a coil which circumscribes a ferrite core and is implanted within the body". Effective systems have been demonstrated with battery power sources and discrete components although most of these have close coupled < 5 cm transmitters and receivers. Detection to 5 m has been reported. The real problem, therefore, is power input to the implant and output from the implant associated with the component miniaturisation of integrated circuitry.

The preferred operating frequency is somewhere in the 80 - 100 M Hz range where body attenuation is at its lowest. At present, this frequency is beyond the range of current micro circuit frequencies. The upper limit of COSMOS, the preferred micro circuit technology, is at present 10 M Hz. At these high frequencies the power dissipation of Cosmos approaches that of TTL at lower frequencies. This implies increasing power requirements. In the literature there is some debate that higher frequencies are the best and one author selected a lower frequency, about 80 - 125 K Hz. The reasons for this are not too clear in the paper.

Another area of doubt is in the selection of a suitable encapsulation material for long term reliability > 10 years. Possible materials would be the silicones, teflon or fused ceramics. Each needs separate consideration with respect to suitability. In no area is the referenced literature sufficiently detailed to predict the final outcome of this approach although it still looks promising.

4.1.2 The readout - This seems to be a development of current technology and does not seem to be problematical. The detection of the signal may need the incorporation of a omni-directional antenna instead of a single dipole as preferred at present. Omni-directional antennas have, however, been developed and do not appear to complicate the associated circuitry unduly.

4.1.3 The implantation tool

The preferred method of implantation would be to shave the area for implant then spray the implant area and end of the implant tool with alcohol for sterilization. Prior to implantation, the incision area and implant guide to be suffused with an inert and sterile gas. Unless this is very simple and suitable for herdsman application, it is likely the system will fail on this count alone.

It is envisaged the implant tool would impell the implant at a specific velocity into the body to be arrested by a bone to lodge the implant submuscularly. The implantation velocity would not need to be excessively high and a pneumatic method should be adequate to give the implant enough velocity for entry.

Alternatively, the implant could be inserted subdermally in which case the incision could be made by the implant tool.

4.2 Current art

The capability to transmit data reliably over long distances external to the animal is common place.

The capability to transmit data from large and small internal radiosondes is used very frequently in research.

The units are usually quite cheap, but seldom is micro circuitry used.

The capability to transmit a 3 digit number from an externally passive device to a receiver 30 - 60 ft away has apparently been demonstrated by a group working at the Los Alamos Scientific Lab., P.O. Box 1663, Los Alamos, California. Project Leader - Dr. Dale Home, Engineer in charge of the development - Mr. Steve Depp.

At the present time this group is developing a 15 digit implant using micro-circuitry. Their concepts seem to run parallel to those conceived by the Mechanical Laboratory of Engineering Research Service. They were, however, working on this without our prior knowledge and are apparently much further ahead in development.

5.0 Contacts

5.1 Industrial

5.1.1 Integrated circuits

I.B.M. Research Ltd. - Dr. R. Miller,
New York.
914-945-1088

This contact was in connection with sputtering techniques for mass production of micro-circuits. Did not seem to think problem was too difficult.

R.C.A. Canada Ltd. - Mr. J. Dumbroski,
Montreal.
514-457-9000

Would be interested in working in association with Research Branch under development contract for the electronic package. General comment - looks pretty feasible.

Siltek International Ltd.,- Mr. Lesniawski
Airport Industrial Park,
Bromont, Quebec.
514-534-2255

No significant contact

A number of other companies have been suggested for contacts, but in the interests of economy no action was taken since fund availability was apparently going to be the limiting factor in equipment development. Fairchild, Signetics, National Semiconductor, Harris, Texas Instruments and Motorola are the other principal companies in this field. Other companies may be developing technical capability such as Hewlett-Packard, Honeywell and American Micro-Systems Inc. Also Electronic Agricultural Corporation - Mr. A.F. Albert, Suite 408, 1200 Westlake Ave. N., Seattle, Washington.

5.1.2 Animal Factors

Hide losses due to branding

Beardmore, a Division of Canada Packers Ltd. - Mr. Evelyn, 90 Don Park, Toronto - 416-363-4474

Branding and marking equipment

Ketchum Manufacturing Sales Ltd., Ottawa, Canada, K2A 2G6.

Abattoirs - implant location bone structure and development

Thomas C.H. Ltd., 70 Corkstown Rd., Ottawa - Mr. C. Thomas - 828-2502

5.2 Research - This will be limited to those areas likely to be of value in development of an implant, or in the subsequent use of such equipment.

5.2.1 Government

Canada - Federal

Agriculture - Dr. K. Betteridge Health of Animals Branch - 997-2933

- Dr. C. Sayers, Health of Animals Branch - 997-2933 Ext. 47
- Dr. C.K. Hetherington, Health of Animals Branch - 994-5551
- Mr. H. Link, Supervisor, Regulatory Services, Animal Industry Division, Department of Agriculture, 10405 - 100th Avenue, Edmonton, Alberta T5K 2C8 - 403-425-5040

Environment - Mr. F.W. Anderka, Bio-electronics Laboratory, Canadian Wildlife Service - 993-9967

National Research Council

- Mr. J.A. Hopps, Head, Medical Engineering Section, Radio & Electrical Eng. Div.

United States

Co-ordinator livestock identification research U.S.

- Mr. Frank Myers, Programme Specialist, Veterinary Service, Room 871, Federal Center Building, No. 1 Hyattsville, Maryland 28702 - 202-436-8697
- Mr. Hans Van Ness, Chief, Bureau of Livestock Identification, 1220 N. Street, Sacramento, California - 916-445-8108

5.2.2 University

- Dr. Dale Home, Project Leader, Cattle Identification, Los Alamos Scientific Laboratory, P.O. Box 1663, Los Alamos, California - 505-667-5974

- Mr. Steve Depp, Cattle Identification, Los Alamos Scientific Laboratory, P.O. Box 1663, Los Alamos, California - 505-667-5974

- Mr. H.A. Baldwin, Sensory Systems Lab., P.O. Box 208, Los Alamos, New Mexico - 505-662-2985

- Dr. J. Hanton, Montana State University - 406-994-2501

- Dr. K. Farrell, U.S.D.A., Agricultural Research Service, College of Agriculture, Washington State University, Pullman, Washington D.C. 99163 - 509-335-5517

5.2.3 Other-International Livestock Brand Conference Committee

President - Mr. D. Heft

Secretary Treasurer - Mr. H. Van Ness, Chief Bureau of Livestock Identification, 1220 N. Street, Sacramento, California - 916-445-8108

6.0 Conclusions

6.1 The United States is following a continuing programme to develop an electronic identification and physiological monitoring implant. This is similar to one envisaged by Engineering Research Service, Agriculture Canada and appears to be the most versatile and feasible of the electronic systems considered.

6.2 Development costs are so expensive it only seems worthwhile to develop one system at a time until success is attained or costs become prohibitive. Canada could perhaps help in the area of materials testing for implant encapsulation.

6.3 At present for many reasons the implant cannot be considered as a replacement for current techniques of identification and would only be promoted as a supplement in the U.S. at least.

6.4 Unless the implant is very simple to position in the animal, acceptance will not be universal as desired.

6.5 Any electronic identification system should be adopted universally on each continent to economize on readout hardward and to standardize coding method. Canada should be aligned for data processing with U.S. systems.

6.6 Very serious consideration should be given to the kind of coding system to be adopted. What are the real advantages of knowing the state of origin and original owner, etc. on sight. If rapid reference to computer data is available, a simple numeric system might be easier to implement.

6.7 New branding systems should be investigated which can be described to a computer and which would at least identify owners and year of birth if not individual animals. Universal adoption of the selected system would take many years due to the conservatism and emotional attachment of the larger operators to their old brands which in many cases are as good as a trade mark.

Mr. H. Link has adopted a computer compatible system of branding for the province of Alberta.

6.8 Patents - many patents now exist which describe similar concepts of identification, etc. used in different applications. Many of these patents describe techniques which are already well documented in the literature. Attempts will no doubt be made to obtain patent cover for some of these systems of identification which would probably constitute little more than patent proliferation. If, however, patents enable the controlled development of systems and standardization of and adoption of common hardware, a useful function will have been served.

7.0 References

7.1 Books

Bourne, G.H. 1972. The Biochemistry and Physiology of Bone. Vols. 1, 2, 3. Academic Press Inc., New York.

Foster, L.E. 1965. Telemetry Systems. John Wiley & Sons Inc., New York.

Cacenes, C.A. 1965. Biomedical Telemetry. Academic Press, New York.

Mackay, R.S. 1968. Biomedical Telemetry Sensing and Transmitting Biological Information from Animals and Man. John Wiley & Sons Inc., New York.

Poyer, J., Herrick, J. and Weber, T.B. 1967. Biomedical Sciences Instrumentation. Vol. 3. Plenum Press, New York.

Slater, L. 1963. Bio-Telemetry. The Macmillan Co., New York.

72 Papers

7.2.1 Bone strength - musculature - for implant

Ascenzi, A. and Bell, G.H. Bone as a mechanical engineering problem. The Biochemistry & Physiology of Bone Bourne Vols. 1, Chapter 9, pages 311 - 352.

Berg, R.T. and Butterfield, R.M. Growth patterns of bovine muscle, fat and bone. J. Animal Sci. 27: 611 - 619, 1968.

Bernard, C. and Hidiroglou, M. Body measurements of purebred and crossbred shorthorn beef calves from birth to 1 year. Can. J. Animal Sci. 48: 389 - 395, 1968.

Brody, S. and Ragsdale, A.C. The course of skeletal growth in the dairy cow. Miss. Agr. Exp. Stn. Res. Bull. 80: 1 - 35, 1925.

Burt, J.K., Myers, V.S., Hillman, D.J. and Getty, R. The radiographic locations of epiphyseal lines in bovine limbs. J. Am. Vet. Med. Ass. 152: 168 - 174, 1968.

Currey, J.D. Strength of bone. Nature Lond. 195: 513 - 514, 1962.

Currey, J.D. Stress concentrations in bone. Q.J. Micros. Sci. 103: 111 - 133, 1962.

Gardner, E. Structure and function of joints. Am. Vet. M. Assn. J. 141, Pt. 2: 1234 - 1236, 1962.

Ham, A.W. and Harris, W.R. Repair and transplantation of bone. The Biochemistryand Physiology of Bone. Bourne Vols. 1, 2, 3, Chapter 10, 338 - 378.

Hidiroglou, M. Cannon bone and ribeye measurements of shorthorn compared with crossbred beef steers. Can. J. Animal Sci. 43: 327 - 331, 1963.

Ivancsics, J. Examinations of the auricle of cattle with special regard to individual marking. Mosonmagyarovari. Agartud. Foisk. Kozlememenyei 9 (2): 27 - 34, 1966.

Lacroix, P. The internal remodelling of bones. The Biochemistry and Physiology of Bone. Bourne Vols. 1, 2, 3, Chapter 3, 119 - 143.

Lawrence, T.L.J. and Pearce, J. Growth studies of beef calves. J. Ministry Agr. 68: 294 - 299, 1961.

Orme, L.E., Pearson, A.M., Bratzler, L.J., Magee, W.T. and Wheeler, A.C. The muscle-bone relationship in beef. J. Animal Sci. 18: 1271 - 1281, 1959.

Sissons, H.A. The growth of bone. The Biochemistry and Physiology of Bone. Bourne Vols 1, 2, 3, Chapter 4, 145 - 180.

Wolff, E.F. Technics and implants - A review. Vet. Med/Small Anim. Clin. 67 (7): 771 - 774, 1972.

7.2.2 Identification methods and systems

Botha, P.J. Cattle carry identity cards in Ireland. Farming in S. Afr. 45 (1): 12 - 13, 1969.

Crouch, J.L. An international system for cattle identification. Vet. Econ. 12 (9): 46 - 51, 1971.

Dawson, P.L.L. Identification of cattle. Vet. Rec. 80: 607, 1967.

Dull, S. Possible soon: Instant livestock brands (explosive branding technique).

Everett, R.W. and Wadell, L.H. Cow identification - A proposal. Dairy Herd Manage.7 (1): 17, 1970.

Farleigh, E.A. A method of numbering cattle. Inst. Vet. Inspec. New S. Wales Vet. Inspec. Ann. 34: 40 - 42, 1971.

Jones, T.S. Age-marking system for sheep and cattle has many advantages. 117 (3): 78 - 85, 1968.

Kachel, S., Schulze, D. and Martin, J. Kennzeichnung der Milchkühe durch Tätowierung am Euter. Monatshifte fur Veterinarmed 27 (2): 59 - 64, 1972.

Smith, F.F. Identifying cows in herringbone barns. Hoards Dairyman 115: 997, 1970.

Smith, F.F. Cow identification in herringbone milking barns. Calif. Univ. Dept. Animal Sci. 8: 70 - 71, 1969.

Yang, T.T. The investigation on cattle nose pattern in Taiwan. Taiwan J. Vet. Med. & Animal Husb. 18: 19 - 27, 1971.

7.2.3 Telemetry, Radiosondes, selected references only

Allen, K.L. and Sun, H.A. A study of the pressure of the cerebro-spinal fluid in man by remote monitoring through the skull. Paper No. 57. Symposium on biotelemetry, Pretoria, 1971.

Braun, J., Fermvik, L. and Stenbäck, A. Theory and performance of a tritium battery for the microwatt range. J. Phys. E: Sci. Inst. 6: 727 - 731, 1973.

Brox, W.T. and Ackles, K.N. SDL-1 Physiological diver monitoring system progress report No. 1. Def. and Civil Inst. Env. Med. Can. Oper. Rep. No. 73-OR-989.

Cook, H.M. and Riley, J.L. Radio telemetering capsule recording stomach motility in ruminants. Cornell Vet. 60: 317 - 329, 1970.

Decker, J.R. and Gillis, M.F. A completely implantable three channel temperature biotelemetry system. I.S.A. Trans. 12: 97 - 102, 1973.

Gilmour, A. Energy sources for biological telemetering equipment. O.E.M. Marketing and Product Applications, Mallory Batteries Ltd., Crawley, England.

Hindson, J.C. and Turner, C.B. Radio telemetric observation on uterine activity and ring womb in sheep. Vet. Rec. 84: 190 - 195, 1969.

Johansen, H. Studies on telemetric tranmission of ruminal data by means of an Hf-supplied radio controlled endogenous probe. Arch. Tierernährung. 21 (4): 321 - 334, 1971.

Kato, D.S., Roller, W.L. and Teague, H.S. Temperature telemetry from swine. Ag. Eng. 652 - 653, Nov. 1970.

Ko, W.H. and Neuman, M.R. Implant biotelemetry and microelectronics. Sci. 156: 351 - 360, 1967.

Kuck, A., Liebman, F.M. and Kussick, L. A miniature transmitter for telemetering muscle potentials. IEEE Trans. on Biomed. Electronics BME 10: 117 - 119, 1963.

Kurtenbach, A.J. and Dracy, A.E. The design and application of an FM/AM temperature telemetering system for intact, unrestrained ruminants.

Lonsdale, E.M., Steadman, J.W. and Pancoe, W.L. A telemetering system for securing data on the motility of internal organs. IEEE Trans. Biomed. Eng. BME 13: 153 - 159, 1966.

Lonsdale, E.M., Bradach, B. and Thorn, E.T. A telemetering system to determine body temperature in pronghorn antelope. J. Wildlife Mgt. 35: 745 - 751, 1971.

Lutsch, A.G.K. The design of electronic equipment for biotelemetry using microcircuit techniques. IEEE Trans. 10: 363 - 380, 1963.

Mackay, R.S. Implanted transmitters and body fluid permeability. IEEE Trans. Biomed. Eng. 12: 198 - 199, 1965

McGinnis, S.M. Radiotelemetry technique for monitoring temperature from unrestrained ungulates. J. Wildlife Mgt. 34: 921 - 925, 1970.

Morhardt, J.E. Temperature transmission from biopotential radiotelemetry transmitters. J. App. Physiol. 33: 397 - 399, 1972.

Nagumo, J., Uchiyama, A., Kimoto, S., Watanuki, T., Hori, M., Suma, K., Ōuchi, A., Kumano, M. and Watanabe, H. Echo capsule for medical use (a batteryless endoradiosonde).

Riley, J.L. Radio telemetry system for transmitting deep body temperatures. Cornell Vet. 60: 265 - 273, 1970.

Riley, J.L. Frequency to voltage converter for recording animal temperatures by radiotelemetry. J. App. Physiol. 30: 890 - 892, 1971.

Riley, J.L. Radiotelemetry system for transmitting physiologic data from animals. Am. J. Vet. Res. 32: 155 - 161, 1971.

Riley, J.L. An inexpensive indicator for measuring animal temperatures by radio telemetry. Cornell Vet. 63: 106 - 110, 1973.

Sandler, H., Fryer, T.B. and Danton, B. Single channel pressure telemetry unit. J. App. Physiol. 26: 235 - 238, 1969.

Schuder, J.C. and Stephenson, H.E. Energy transport to a coil which circumscribes a ferrite core and is implanted within the body. IEEE Trans. Biomed. Eng. BME 12: 154 - 163, 1965.

7.3 Patents - This is a very restricted list resulting from a very limited search.

U.S. Patent 3,144,017 - Muth Invertor dated August 11, 1964 - Pill-type swallowable transmitter.

U.S. Patent 3,231,834 - Hiroshi Watanabe dated January 25, 1966. Telemetering capsule for physiological measurements.

U.S. Patent 3,508,235 - Joyce, B. Baisden dated April 21, 1970 - Combined diaper fastener and signalling device.

U.S. Patent 3,740,742 - Thomas F. Thompson dated June 19, 1973 - Method and apparatus for actuating an electric circuit.

7.4 Proceedings

Proceedings of the annual conference on Engineering in Medicine & Biology. Boston, Massachusetts. Volume 9, 1967.

Proceedings as above, Houston, Texas. Volume 10, 1968.

Proceedings as above, Minneopolis, Minnesota. Vol. 15, 1973.

Proceedings of the International Federation of Automatic Control Symposium on Automatic Control for Agriculture. Automation in Dairy and Livestock Production, Saskatoon, Saskatchewan, Canada. June 18 - 20, 1974.