



(51) International Patent Classification:

A22B 3/00 (2006.01) A61M 36/00 (2006.01)
A22B 3/06 (2006.01) A61M 36/02 (2006.01)

(21) International Application Number:

PCT/AU2011/000527

(22) International Filing Date:

9 May 2011 (09.05.2011)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2010901954 7 May 2010 (07.05.2010) AU

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: ANIMAL STUNNING

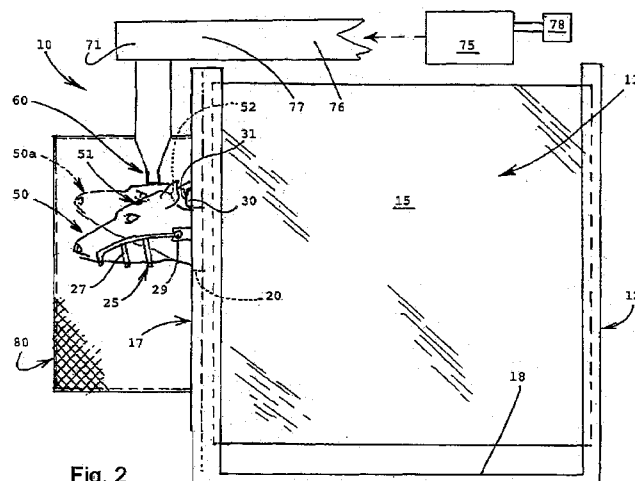


Fig. 2

(57) Abstract: Disclosed are an animal stunning apparatus and method for inducing rapid unconsciousness and insensibility. The apparatus includes a stunning station (10) in which a live subject animal is located in a confined position and an applicator (60) contacts an application point (51) on the live subject animal's head (50) immediately overlying a frontal portion of the animal's brain and couples microwave radiation to the head. A microwave generator (75) generates microwave energy of a suitable power level and frequency, and a waveguide (76) directs the microwave radiation to the applicator (60). Switching means (78) discontinues the application of microwave radiation effecting heating of the frontal portion of the brain after a period of time sufficient to have raised the temperature of the frontal portion of the brain of the subject animal to thereby induce the unconsciousness and insensibility. The period is sufficient only to rapidly induce insensibility, and is insufficient for the insensibility induced to be irreversible, and insufficient to cause significant heating of deeper brain tissues and including the brain stem.

Field of the Invention

This invention relates to methods and apparatus for stunning of animals to induce unconsciousness and insensibility enabling processing or handling of the animal.

Background

5 In slaughtering a live animal in an abattoir for production of meat, hide, and other by-products, the animal is usually restrained and then stunned to induce immediate unconsciousness and insensibility. The slaughter can then be performed without avoidable fear, anxiety, pain, suffering and distress. The stunning can also help avoid difficulties and dangers for persons involved in the processing and handling operations.
10 The "stunning" is commonly carried out either by a mechanical process, such as applying concussion by means of a projectile captive bolt (penetrating or non-penetrating mushroom headed knocker) impacted against the skull of the animal, or by electrical current applied to the animal and passed through the brain, or by inhalation of gases such as carbon dioxide, nitrogen or argon.

15 The terms "stun" or "stunning" are frequently used to refer to irreversible processes, i.e. the "stunning" process causes irreversible damage to the animal, particularly the brain. This may not be a difficult or contentious issue with regard to animal welfare concerns because the slaughter, such as by sticking and exsanguination, immediately follows the stunning and is therefore performed on an irreversibly
20 unconscious and insensible animal.

However, with religious slaughter or ritual slaughter, irreversible stunning is not acceptable. The animal must not be injured or harmed prior to exsanguination. For example, with the Muslim slaughter method or "Halal slaughter", the animal is required to be alive at the time of slaughter. This requirement does not necessarily mean that the
25 animal is not permitted to be first stunned prior to slaughter, as long as there is no injury, e.g. significant damage to the skull, but irreversible stunning may well be unacceptable to comply with the dictated ritual requirements. Likewise with the Jewish or Judaic slaughter method or "Shechita", post-cut stunning of the animal may be permissible, but not irreversible pre-cut stunning that may be deemed unacceptable so that the resulting
30 carcase would not be Kosher.

There have been some references in the published patent literature to use of microwave radiation stunning of animals for slaughter.

US 3,973,290 refers to stunning an animal for slaughter by applying microwave energy to penetrate the animal's skull and heat the brain. A microwave beam is proposed

to be directed at the animal without restraining it, the energy being applied from the side of the skull. Such methods of application would create considerable surrounding tissue damage by largely indiscriminate heating and therefore would be an irreversible process, causing harm to the animal, and is likely to be inhumane.

5 US 4,616,160 describes a microwave heating apparatus for irradiating the entire head of test animals, particularly rodents. The configuration of the apparatus including the manner of coupling the microwave energy to the animal will heat the entire head of the animal. The specification does not explain whether the purpose is to stun the animal but, if so, many organs and tissues of the head are likely to be damaged and the apparatus
10 would therefore be unacceptable from the point of view of animal welfare.

DE 4116670 describes and illustrates an apparatus for irradiating a pig with multiple microwave applicators arranged around the head and in a row along the length of the spine, all being spaced from the animal. Use of such an apparatus design will irreversibly damage tissues by cooking affected tissues, which is likely to be inhumane.

15 JP 3039615 describes apparatus for slaughtering animals using microwaves to heat the brain causing cerebral death.

The above references to and descriptions of prior proposals or products are not intended to be, and are not to be construed as, statements or admissions of common general knowledge in the art in Australia or elsewhere. None are known to have been
20 ever commercially used.

Object of the invention

It is an object of the present invention to provide processes and apparatus for stunning of animals to induce rapid unconsciousness and insensibility. It is a particular preferred object to provide processes and apparatus for stunning of animals to induce
25 rapid unconsciousness and insensibility in a manner that the stun is reversible, meaning that the animal can later regain consciousness and sensibility without significant loss of brain mediated function including motor functions, sensory processing, innate and instinctive functioning, learned behaviour, etc.

With such reversible animal stunning processes and apparatus, animals for
30 slaughter can be stunned in a manner to enable subsequent processing and handling, including slaughter, whilst the system still remains compliant with certain religious slaughter rituals. The achievement of reversible stunning processes and apparatus may also enable such stunning of animals for other kinds of processing or handling, such as for veterinary inspections or purposes, banding, branding, tagging, inspection recording and

re-release, etc. However, the particular processes and apparatus described herein will refer to the primary intended field of application, namely slaughtering of animals for food production, hide recovery and treatment, and other by-product extraction and processing.

Summary of the Invention

5 According to the first aspect of the present invention there is provided an animal stunning apparatus for inducing substantially immediate unconsciousness and insensibility enabling processing or handling of a subject animal, the apparatus including: a stunning station to which a live subject animal to be processed or handled is introduced, the stunning station being arranged to locate the subject animal in a confined position, an
10 applicator located so as to contact an application point on the live subject animal's head immediately overlying a frontal portion of the animal's brain, the applicator having a coupling conformation to couple microwave radiation therethrough to the head and to the frontal portion of the brain of the subject animal when in the confined position at the
15 stunning station, a microwave generator for generating and radiating microwave energy of a suitable power level and frequency, and a waveguide coupled to the generator so as to receive and direct the microwave radiation to the applicator located at an operative end of the waveguide so as to thereby heat the frontal portion of the brain of the subject
20 animal beneath the application point which the applicator contacts in use, switching means operable so as to discontinue the application of microwave radiation effecting heating of the frontal portion of the brain after a period of time sufficient to have raised the temperature of the frontal portion of the brain of the subject animal to thereby induce the unconsciousness and insensibility.

In the particularly preferred apparatus the switching means is operable to discontinue the application of microwave radiation immediately after a period which is

- 25 • sufficient only to rapidly induce insensibility, and
- insufficient
- (i) for the insensibility induced to be irreversible, and
- (ii) to cause significant heating of deeper brain tissues and including the brain stem.

30 Preferably the application point is medially located on the head of the subject animal above a line extending between the animal's eyes so as to be located at the closest external point to the central and frontal portion of the brain.

The preferred applicator has an opening therein through which the microwave radiation from the waveguide is coupled to the animal's head at the application point, the

peripheral portions of the applicator defining the opening contacting the animal's head to surround the application point when the applicator is in its operative position. The opening of the applicator preferably has an area chosen to provide impedance matching between the impedance of the applicator and the tissues at the application point, the area being bounded by the peripheral portions of the applicator which is composed of shielding material to provide power transfer to the animal tissues without microwave leakage. The peripheral portions of the applicator may be composed of shielding material and are configured to press into the surface tissues of the animal, typically by about 1-2 mm, to promote good coupling and microwave energy transfer without leakage and to resist transverse movement of the applicator if the animal attempts to move its head. By applying the peripheral portions of the applicator defining the opening so that they contact the animal's head surrounding the application point, good coupling of the microwave power from the waveguide through the applicator to the animal's head can be achieved and leakage and loss of microwave energy to the surroundings can be minimal, preventing tissue damage, and therefore more humane stunning may be achieved.

The applicator may have a coupling disk composed of microwave permeable material at the opening, the coupling disk being pressed positively against the animal head at the application point to provide an interface for transferring power at the application point. The coupling disk may be composed of a ceramic material to provide a robust interface for high power transfer. A further ceramic disk may be located in the microwave path of the applicator, the further disk being located upstream of the coupling disk a distance of $\frac{1}{4}$ of the wavelength of the microwave radiation so as to counteract negative affects of the ceramic coupling disk.

In one embodiment the applicator comprises a coaxial applicator passing microwave radiation from the operative end of the waveguide to the application point, the coaxial applicator having a central conductor through the length of the applicator, the central conductor being coaxially located within a surrounding conductive sleeve thereby defining an annular microwave path from the waveguide to the coupling conformation. The coaxial applicator may include a conical section to concentrate the microwave energy from the waveguide upstream, the conical section having a gradual transition to the desired cross sectional area of the coupling conformation while maintaining acceptable power transfer therethrough. The microwave path through the coaxial applicator may be filled with a dielectric material so as to enable higher powered densities than air and to modify or tune the impedance.

The coaxial applicator may be connected to the operative end of the waveguide so as to extend therefrom at an angle to the general line of the waveguide, the connection between the operative end of the waveguide and the coaxial applicator being provided by a transition structure including a tapering cross section area to provide a gradual change in impedance from the waveguide and to provide matching of the impedance between the waveguide and the coaxial applicator and to limit or reduce reflected power losses.

Preferably the applicator is constructed and arranged to apply the microwaves to the animal's head so that the electric field of the microwave energy enters the subject animal's head generally perpendicularly to penetrate the skin and skull at the application point and induce rapid heating of the frontal portion of the animal's brain.

In one embodiment the generator is a TE type wave generator and the apparatus further includes a mode transformer operative to convert the TE type wave to a TM wave. Alternatively for greater power density the generated microwave radiation may comprise a TEM type wave whereby both the electric and magnetic fields enter the subject animal's head generally parallel to the skin surface at the application point.

In one embodiment the apparatus further includes applicator moving means operative to selectively advance the applicator from a retracted position where it is located when the subject animal is being located in the confined position at the stunning station to an operative position when the animal is located and held in its confined position, the applicator in its operative position being engaged against the animal's head at the application point, the direction of the microwave radiation through the waveguide to the applicator being carried out only after the applicator is in its operative position. The applicator moving means may be operative to telescopically move the applicator from its inoperative position to its operative position contacting the animal head. A guiding system may be associated with the movable applicator for guiding movement of the applicator from its inoperative to its operative position, the guiding system including sensor means to sense the presence and location of the animal's head and to which the guiding system is responsive.

In another embodiment the stunning station includes head positioning means to locate and present the subject animal's head in a defined position to the applicator. The head positioning means may include head lift means to locate and lift the subject animal's head to the applicator which is in a predetermined position for the presentation of the animal's head thereto. This may comprise a head tilting mechanism to lift the animal's head by tilting it upwardly to present the application point to the applicator. The

head tilting means may comprise a chin lifting member to lift the chin or lower jaw of the animal upwardly and tilt the head backwardly to present the application to the applicator.

In this embodiment the head positioning means may further include a head tilt limiter towards which and into contact with which the head lift means tilts the animal head, the tilt limiter typically comprising a fixed abutment contacted by the top back
5 portion of a animal's head when the head has been lifted and tilted sufficiently to present the application point to the applicator. Furthermore the head positioning means may include a neck lifting means selectively operable to raise the animal's head (without necessarily tilting of the head) by lifting force applied from beneath to the neck of the
10 animal, thereby raising the head towards the applicator particularly enabling different height animals to be processed.

In one possible apparatus, the head positioning means includes a body lifting means selectively operable to raise the animal's body (without necessarily separately lifting or tilting of the head or lifting the neck) by lifting force applied from beneath to the
15 body of the animal, thereby raising the head towards the applicator particularly enabling different height animals to be processed. In a further possible apparatus, the stunning station includes a body support for the animal support the animal during the application of the microwave energy in case the animal slumps or falls at the onset of insensibility.

Preferably the stunning station includes microwave shielding surrounding at least
20 the position of the animal head when the animal is confined thereby forming a Faraday cage, the shielding having an opening in which the animal's head is located.

According to a second aspect of the invention there is provided a method of stunning an animal for inducing substantially immediate unconsciousness and insensibility enabling processing or handling of the animal, the method including the
25 steps of: introducing a live subject animal to be processed or handled to a stunning station and locating the animal in a generally confined position, locating an applicator in contact with an application point on the animal's head immediately overlying the frontal portion of the subject animal's brain, the applicator having a coupling conformation to couple microwave radiation through the applicator to the head and to the frontal portion of the
30 brain of the subject animal, generating microwave radiation of a suitable power level and frequency and directing that radiation through a waveguide to the applicator at an operative end of the waveguide to thereby heat the frontal portion of the brain of the subject animal, wherein the application of the microwave radiation to effect the heating is continued for a period of time to raise the temperature of the frontal portion of the brain,

coupling conformation 61 to couple microwave radiation therethrough to the head 50 and of the animal. A microwave generator 75 generates and radiates microwave energy of a suitable power level and frequency. Waveguide 76 is coupled to the generator so as to receive and direct the microwave radiation to the applicator 60 located at an operative end 5 77 of the waveguide. Switching means 78 is operable so as to discontinue the application of microwave radiation effecting the heating of the frontal portion of the brain after a period of time sufficient to of raised the temperature of the frontal portion of the brain of the animal to thereby induce unconsciousness and insensibility.

If the animal is to be stunned for ritual slaughter requiring the animal to be live, 10 the switching means 78 is operable to discontinue the application of microwave radiation immediately after a period which is:

- sufficient only to rapidly induce insensibility and
 - insufficient
- (i) for the insensibility induced to be irreversible, and
- 15 (ii) to cause significant heating of the brain tissues and including the brain stem.

Such timing of the application of radiation may also be applicable if the animal is to be held insensible for a time, e.g. for performing veterinary tests or processes, after which the animal is to be returned to its normal sensible and conscious condition by allowing the temperature of the front portion of the brain to return to normal. In this 20 situation, if the animal is to be held insensible for a period of time, the application of microwave radiation may be pulsed or intermittent so as to maintain the insensible state.

Referring particularly to Figure 4, the applicator 60 has an opening 62 through which the microwave radiation from the waveguide 76 is coupled to the animal's head 50 at the application point 51. The peripheral portions 63 of the applicator defining the 25 opening 62 contact the animal's head so as to surround the application point 51 when the applicator 60 is in its operative position. The area of the opening 62 is chosen to provide impedance matching between the impedance of the applicator 60 and the tissues at the application point 51. The area bounded by the peripheral portions 63 are composed of shielding material, typically metal, to provide power transfer to the animal tissues without 30 microwave leakage. As shown in Figure 4, the peripheral portions 63 composed of shielding material are configured so as to project slightly beyond the opening 62 so that they press into the surface tissues of the animal, typically by about 1-2mm, to promote good coupling and microwave energy transfer without leakage and also to resist

transverse movement of the applicator 60 if the animal attempts to move its head particularly generally in the plane of the opening 62.

The applicator 60 shown in Figure 4 comprises a co-axial applicator passing microwave radiation from the operative end 77 of the waveguide 76 to the application point 51. The co-axial applicator has a central conductor 65 through the length of the applicator and which is co-axially located within a surrounding conductive sleeve 66 and thereby defining an annular microwave path 70 from the wave guide 76 to the coupling conformation 61. The co-axial applicator includes a conical section 68 of the sleeve 66 to concentrate the microwave energy from the waveguide upstream, the conical section 68 has a gradual transition to the desired cross-sectional area of the coupling conformation 61 while maintaining acceptable power transfer therethrough. The microwave path 70 through the co-axial applicator is filled with a dielectric material so as to enable higher powered densities and to modify or tune the impedance. A suitable dielectric material may be PTFE or polyethylene that has a small loss tangent, i.e. much less than 1.0, to enable the use of smaller dimensions of the applicator.

The co-axial applicator 60 in Figure 4 is connected to the operative end 77 of the waveguide 76 so as to extend therefrom at an angle (shown as 90°) to the general line of the waveguide 76. The connection between the operative end of the waveguide 77 and the co-axial applicator 60 is provided by a transition structure 71 which includes a tapering cross-section area formed by the taper or ramp 72 to provide a gradual change in impedance from the waveguide 76 and to provide matching of the impedance between the waveguide 76 and the co-axial applicator 60 and limit or reduce reflected power losses. The taper 72 and ridge 73 function as part of the waveguide to co-axial applicator transition and provide a way of matching the waveguide impedance with the co-axial applicator impedance. The dimensions of the taper 72 and of the transition structure 71 are determined based on the required impedance of the co-axial applicator 60.

The centreline of the central conductor 65 and therefore of the co-axial applicator 60 is located for maximum power coupling from the waveguide to the applicator. This is typically where the distance from the short circuit waveguide back wall to the centreline is one quarter or three quarter the wavelength. The dimensions of the central conductor 65 remain constant in cross-section and that dimension is selected with the entire dimensions of the co-axial applicator 60 in mind. The internal and external conductor dimensions are chosen based on the desired impedance of the co-axial applicator 60 and its ability to handle high power without voltage breakdown. The dimensions of the final

section of the co-axial applicator provided by the sleeve portion 69 leading to the opening 62 are designed and dimensioned to match with the impedance of the animal's skin thus ensuring maximum power transfer. Another consideration is to reduce the cross-sectional area of the opening 62 to as small as practical so that high power density can be delivered.

5 The applicator 60 in Figure 4 has the coupling disc 80 composed of microwave permeable material at the opening 62. The coupling disc 80 is pressed positively against the animal head at the application point 51 to provide an interface for transferring power. The coupling disc 80 can be composed of a ceramic material to provide a robust interface for high power transfer. A further ceramic disc 81 is provided in the microwave path of
10 the applicator 60, the further disc 81 being upstream of the coupling disc 80, preferably a distance of one quarter of the wavelength of the microwave radiation, so as to counteract negative effects of the ceramic coupling disc 80.

As shown in Figure 2, the stunning station 10 includes a microwave shielding surrounding at least the position of the animal head 50 when the animal is in its confined
15 position. The shielding 80 forms a Faraday cage for limiting or preventing leakage of microwave radiation. The animal's head 50 in use extends through the opening 20 which constitutes an opening into the Faraday cage. The head end 17, particularly the panels 21, 22 effectively form part of the Faraday cage.

In the alternative possible construction of applicator 60 shown in Figures 5 and 6,
20 there is provided applicator moving means 85 operative to selectively advance the applicator 60 from a retracted position shown in Figure 5 where it is located when the animal is being located in the confined position at the stunning station 10 to an operative position shown in Figure 6 when the animal is located and held in its confined position. The applicator 60 in its operative position in Figure 6 engages against the animal's head
25 50 at the application point 51 and the passing of the microwave radiation through the waveguide 76 to the applicator being carried out only after the applicator 60 is in its operative position. As shown in Figures 5 and 6, the applicator moving means 85 is operative to telescopically move the applicator 60 from its inoperative position to its operative position contacting the animal's head.

30 The apparatus may include a guiding system (not shown) associated with the movable applicator 60 for guiding movement of the applicator from its inoperative to its operative position, the guiding system including sensor means such as micro switches, proximity sensors, head image capture means and head shape recognition software, etc to

sense and determine the presence and location of the animal's head and to which the guiding system is responsive to accurately place the opening 62 of the applicator 60.

In the arrangement in Figures 2 to 4, the radiation forms an angle of incidence with the animal head at the application point 51 of about 90°, i.e. generally orthogonal to the flat portion of the animal skull above the line joining the eyes and immediately over the frontal portion of the brain. The generated microwave radiation preferably comprises a TEM (transverse electromagnetic) type wave whereby both the electric and magnetic fields enter the animal head 50 generally parallel to the skin surface. The use of TEM type waves enables higher power transfer through the animal tissues for fast heating.

In an alternative possibility, the microwave radiation generated has its electric field generally perpendicular to the front of the animal's head 50 at the application point 51 whereby the electric field enters the animal's head in a generally perpendicular direction. Known apparatus for microwave heating, such as in industrial processes in which microwaves are used to heat food for cooking purposes, utilise microwave radiation generated in a "transverse electric" or "TE" mode, meaning that the propagating field has the electric field transverse to the direction of propagation along the waveguide. However, the present apparatus may convert a TE type wave to a "transverse magnetic" or "TM" wave in which the electric field is parallel to the propagation direction so as to enter the animal's head at the application point generally perpendicular to the surface of the animal's head at that point. TM waves have a lower wave impedance than TE waves: $Z = E/H$, so that a TM wave will have a lower electric field strength for a particular power setting but it is the electric field strength that can cause arcing and skin heating favouring a TM wave. Also, it is believed that thin material, such as skin, couples energy better when the electric field is parallel to the surface of the material so that, in the present preferred apparatus, our aim is to achieve the opposite, namely weaken the coupling of energy at the surface skin or hide layer. In this possible embodiment, therefore, risk of discomfort or pain to the animal may be reduced by the application of the TM type microwave energy at the application point. Preferably where the generator is a TE type wave generator, the apparatus further includes a mode transformer operative to convert the TE type wave to a TM wave. The mode transformer may be located in series between the waveguide feed from the generator and the applicator.

In this possible embodiment, the applicator has a conformation to apply the TM wave to the animal's head so that the electric field of the microwave energy enters the

subject animal's head generally perpendicularly to penetrate the skin and skull at the application point to induce heating of the frontal portion of the animal's brain.

The apparatus may also include an automatic timer control (not shown) to start and terminate the application of microwave radiation to the animal head depending on programmed criteria. For example, the knocking box may include an animal weight
5 sensor, the output of which is fed to the timer control which determines the necessary period for the application of microwave radiation according to an algorithm or formula.

The microwave generator may be generally conventional in construction and operation. The frequency of the microwave radiation generated and transmitted through
10 the associated waveguide may be any suitable value. Tests involving the application of microwave radiation to cattle and sheep heads have utilised microwave generators operating at frequencies commercially utilised in Australia, namely 922 MHz and 2.45 GHz. These tests demonstrated that with the lower frequency 922 MHz there is better penetration of the energy and less unwanted heating of tissues at the surface and in
15 surrounding tissues, so such a lower frequency is preferred. However, the optimum frequency or frequency range can be determined empirically and is believed to be in the range 500 MHz – 1 GHz.

The power requirements of the microwave generator will be dependent on many factors including, for example,

- 20 • the type of animal to be stunned including species (sheep, cattle, pigs, etc)
- the breed of the particular animal species (Hereford, Brahman, etc)
- the age, body mass, and sex of the animal
- the speed required to achieve effective stunning to induce unconsciousness and insensibility,
- 25 • the temperature rise required within the frontal portion of the animal's brain necessary to induce the unconsciousness and insensibility
- whether TE mode, TM mode or TEM mode microwave radiation is being generated and applied to achieve the frontal brain heating.

Such factors are not necessarily entirely independent of each other.

30 For example, tests on sheep and cattle heads have produced data indicative of the power requirements being:

- for sheep, to induce a 10°C temperature rise of the frontal portion of the brain, in about one second: 40kW power output.

- for cattle (about 300kg body weight), 10°C temperature rise of the frontal portion of the brain, within 1.5 seconds: 100kW power output.

These findings are indicative only because, as explained above, there are many parameters affecting the power requirement to achieve a certain level of heating within a target time period commencing with switching on of the microwave radiation. Therefore, the power requirements for the generator can be empirically determined.

Preferably the temperature rise of the frontal portion of the brain to induce reversible unconsciousness and insensibility is in the range of about 5°C to less than about 10°C. For example, tests with live (anaesthetised) sheep showed frontal brain heating to about 43°C produced electroencephalogram (EEG) traces similar to those observed with electric stunning now widely used in abattoirs, thus indicating that that temperature would achieve unconsciousness and insensibility. However heating to about 50°C or more would start to produce protein denaturation and hence permanent tissue damage.

Upon the application of the microwave energy and achievement of the required degree of heating, the generation of microwave energy is preferably switched off (or otherwise stopped from application to the animal) so as to prevent further heating which would make the stun irreversible. Also the discontinuance of the application of microwave energy limits or prevents heating of deeper tissues, particularly the brain stem, to any significant extent, particularly heating to cause irreversible effects. In particular, heating of the mid and deep brain tissues and particularly the brain stem area (which controls cardiac and respiratory functions) to the same extent as the frontal portion is undesirable, because it may cause immediate effects, such as heart failure which may then lead to the stun and subsequent slaughter being deemed non-compliant with the religious ritual slaughter criteria, the animal carcass being rejected as unacceptable for the intended consumption by the relevant religious group, with consequent devaluation of the carcass and its meat. In the case of sheep, brain stem heating should be limited to maintain the brain stem temperature to less than about 43°C.

The time period required for application of the microwave energy is preferably as short as possible although achieving shorter times entails greater microwave generator power output so there is a necessary balancing of these two parameters. However, preferably stunning to achieve the unconsciousness and insensibility in less than about 2 seconds is preferred to meet reasonable animal welfare considerations (minimising fear, anxiety, pain, suffering, and distress in the animal). Particularly preferred would be

achieving the effective stun in less than about one second and most preferably achieving this in about 0.5 seconds.

Confinement of the major heating effect to the frontal portion of the animal brain in the process and apparatus of the present invention is required to render the induced insensibility reversible. The frontal portion of the brain is involved in cognitive, perception, sensory, and consciousness brain functioning or processes so that warming of this portion of the brain by the extent indicated leads to unconsciousness and insensibility but without causing irreversible damage to the brain tissues and brain functioning if the elevated temperature does not exceed 50°C.

However although particularly developed and described herein in relation to reversible stunning for ritual slaughter, the apparatus and method may be useful for other processes requiring reversible insensibility. Examples may include veterinary procedures in which temporary insensibility is required or useful. To avoid the animal regaining consciousness the microwave radiation may be applied in pulses or intermittently to maintain unconsciousness without permanent damage or other undesired effects. Analogously the apparatus and method may be useful for other animal processes or treatments or inspections, e.g. docking, tagging, branding, and inspections generally.

Because the stunning using the apparatus and process can produce insensibility or unconsciousness in a manner without excessive stress and pain, the invention can be extended for use as a permanent or irreversible stunning or killing system. By increasing the power or duration of the application of microwaves, the increased heating effect and/or deeper brain heating can enable a useful alternative to current irreversible electrical or percussive stunning of animals for slaughter.

It will be seen that the process and apparatus according to the preferred embodiments described herein, including those described in relation to the drawings, can enable stunning of animals, particularly animals for slaughter, so as to rapidly induce unconsciousness and insensibility enabling further processing or handling, including slaughter in a manner compliant with religious ritual criteria or handling for temporary, such as veterinary, processes because the stun is reversible. The stun also is carried out in a way that complies with good animal welfare handling practices. Indeed, the present inventive method and apparatus are potentially capable of being better than current practices, particularly relating to animal welfare outcomes. For example success rates for rapid and reliable stunning may be better, there may be less risk of operator error, and there may be less stress to animals.

The claims defining the invention are as follows:

1. An animal stunning apparatus for inducing substantially immediate unconsciousness and insensibility enabling processing or handling of a subject animal, the apparatus including:
 - 5 a stunning station to which a live subject animal to be processed or handled is introduced, the stunning station being arranged to locate the subject animal in a confined position,
 - an applicator located so as to contact an application point on the live subject animal's head immediately overlying a frontal portion of the animal's brain, the
 - 10 applicator having a coupling conformation to couple microwave radiation therethrough to the head and to the frontal portion of the brain of the subject animal when in the confined position at the stunning station,
 - a microwave generator for generating and radiating microwave energy of a suitable power level and frequency, and a waveguide coupled to the generator so as to
 - 15 receive and direct the microwave radiation to the applicator located at an operative end of the waveguide so as to thereby heat the frontal portion of the brain of the subject animal beneath the application point which the applicator contacts in use,
 - switching means operable so as to discontinue the application of microwave radiation effecting heating of the frontal portion of the brain after a period of time
 - 20 sufficient to have raised the temperature of the frontal portion of the brain of the subject animal to thereby induce the unconsciousness and insensibility.
 2. Apparatus according to claim 1 wherein the switching means is operable to discontinue the application of microwave radiation immediately after a period which is
 - sufficient only to rapidly induce insensibility, and
 - 25 • insufficient
 - (i) for the insensibility induced to be irreversible, and
 - (ii) to cause significant heating of deeper brain tissues and including the brain stem.
 3. Apparatus according to claim 1 or 2 wherein the application point is medially
 - 30 located on the head of the subject animal above a line extending between the animal's eyes so as to be located at the closest external point to the central and frontal portion of the brain.
 4. Apparatus according to any preceding claim wherein the applicator has an opening therein through which the microwave radiation from the waveguide is coupled to the

animal's head at the application point, the peripheral portions of the applicator defining the opening contacting the animal's head to surround the application point when the applicator is in its operative position.

5 5. Apparatus according to claim 4 wherein the opening of the applicator has an area chosen to provide impedance matching between the impedance of the applicator and the tissues at the application point, the area being bounded by the peripheral portions of the applicator which is composed of shielding material to provide power transfer to the animal tissues without microwave leakage.

10 6. Apparatus according to claim 5 wherein the peripheral portions of the applicator composed of shielding material are configured to press into the surface tissues of the animal, typically by about 1-2 mm, to promote good coupling and microwave energy transfer without leakage and to resist transverse movement of the applicator if the animal attempts to move its head.

15 7. Apparatus according to claim 4, 5 or 6 wherein the applicator has a coupling disk composed of microwave permeable material at the opening, the coupling disk being pressed positively against the animal head at the application point to provide an interface for transferring power at the application point.

8. Apparatus according to claim 7 wherein the coupling disk is composed of a ceramic material to provide a robust interface for high power transfer.

20 9. Apparatus according to claim 8 wherein the applicator includes a further ceramic disk in the microwave path of the applicator, the further disk being located upstream of the coupling disk a distance of $\frac{1}{4}$ of the wavelength of the microwave radiation so as to counteract negative effects of the ceramic coupling disk.

25 10. Apparatus according to any preceding claim wherein the applicator comprises a coaxial applicator passing microwave radiation from the operative end of the waveguide to the application point, the coaxial applicator having a central conductor through the length of the applicator, the central conductor being coaxially located within a surrounding conductive sleeve thereby defining an annular microwave path from the waveguide to the coupling conformation.

30 11. Apparatus according to claim 10 wherein the coaxial applicator includes a conical section to concentrate the microwave energy from the waveguide upstream, the conical section having a gradual transition to the desired cross sectional area of the coupling conformation while maintaining acceptable power transfer therethrough.

12. Apparatus according to claim 10 or 11 wherein the microwave path through the coaxial applicator is filled with a dielectric material so as to enable higher powered densities than air and to modify or tune the impedance.

13. Apparatus according to claim 10, 11 or 12 wherein the coaxial applicator is
5 connected to the operative end of the waveguide so as to extend therefrom at an angle to the general line of the waveguide, the connection between the operative end of the waveguide and the coaxial applicator being provided by a transition structure including a tapering cross section area to provide a gradual change in impedance from the waveguide and to provide matching of the impedance between the waveguide and the coaxial
10 applicator and to limit or reduce reflected power losses.

14. Apparatus according to any preceding claim wherein the applicator is constructed and arranged to apply the microwaves to the animal's head so that the electric field of the microwave energy enters the subject animal's head generally perpendicularly to penetrate the skin and skull at the application point and induce rapid heating of the frontal portion
15 of the animal's brain.

15. Apparatus according to claim 14 wherein the generator is a TE type wave generator and the apparatus further includes a mode transformer operative to convert the TE type wave to a TM wave.

16. Apparatus according to any one of claims 1 to 13 wherein the generated
20 microwave radiation comprises a TEM type wave whereby both the electric and magnetic fields enter the subject animal's head generally parallel to the skin surface at the application point.

17. Apparatus according to any preceding claim and further including applicator moving means operative to selectively advance the applicator from a retracted position
25 where it is located when the subject animal is being located in the confined position at the stunning station to an operative position when the animal is located and held in its confined position, the applicator in its operative position being engaged against the animal's head at the application point, the direction of the microwave radiation through the waveguide to the applicator being carried out only after the applicator is in its
30 operative position.

18. Apparatus according to claim 17 wherein the applicator moving means is operative to telescopically move the applicator from its inoperative position to its operative position contacting the animal head.

19. Apparatus according to claim 17 or 18 wherein there is provided a guiding system associated with the movable applicator for guiding movement of the applicator from its inoperative to its operative position, the guiding system including sensor means to sense the presence and location of the animal's head and to which the guiding system is responsive.
20. Apparatus according to any one of claims 1 to 16 wherein the stunning station includes head positioning means to locate and present the subject animal's head in a defined position to the applicator.
21. Apparatus according to claim 20 wherein the head positioning means includes head lift means to locate and lift the subject animal's head to the applicator which is in a predetermined position for the presentation of the animal's head thereto.
22. Apparatus according to claim 21 wherein the head positioning means includes a head tilting mechanism to lift the animal's head by tilting it upwardly to present the application point to the applicator.
23. Apparatus according to claim 22 wherein the head tilting means comprises a chin lifting member to lift the chin or lower jaw of the animal upwardly and tilt the head backwardly to present the application point to the applicator.
24. Apparatus according to claim 22 or 23 wherein the head positioning means further includes a head tilt limiter towards which and into contact with which the head lift means tilts the animal head, the tilt limiter typically comprising a fixed abutment contacted by the top back portion of a animal's head when the head has been lifted and tilted sufficiently to present the application point to the applicator.
25. Apparatus according to any one of claims 21 to 24 wherein the head positioning means includes a neck lifting means selectively operable to raise the animal's head (without necessarily tilting of the head) by lifting force applied from beneath to the neck of the animal, thereby raising the head towards the applicator particularly enabling different height animals to be processed.
26. Apparatus according to any one of claims 21 to 25 wherein the head positioning means includes a body lifting means selectively operable to raise the animal's body (without necessarily separately lifting or tilting of the head or lifting the neck) by lifting force applied from beneath to the body of the animal, thereby raising the head towards the applicator particularly enabling different height animals to be processed.
27. Apparatus according to any preceding claim wherein the stunning station includes a body support for the subject animal operative to support the animal during the

application of the microwave energy in the event that the animal starts to slump or fall at the onset of insensibility.

28. Apparatus according to any preceding claim wherein the stunning station includes microwave shielding surrounding at least the position of the animal head when the animal is in its confined position thereby forming a Faraday cage, the shielding having an opening in which the animal's head is located.

29. A method of stunning an animal for inducing substantially immediate unconsciousness and insensibility enabling processing or handling of the animal, the method including the steps of:

10 introducing a live subject animal to be processed or handled to a stunning station and locating the animal in a generally confined position,

locating an applicator in contact with an application point on the animal's head immediately overlying the frontal portion of the subject animal's brain, the applicator having a coupling conformation to couple microwave radiation through the applicator to the head and to the frontal portion of the brain of the subject animal,

15 generating microwave radiation of a suitable power level and frequency and directing that radiation through a waveguide to the applicator at an operative end of the waveguide to thereby heat the frontal portion of the brain of the subject animal,

wherein the application of the microwave radiation to effect the heating is continued for a period of time to raise the temperature of the frontal portion of the brain, the period being

- sufficient only to rapidly induce insensibility, and
- insufficient

(i) for the insensibility induced to be irreversible, and
25 (ii) to cause significant heating of deeper brain tissues and including the brain stem.

30. A method according to claim 29 wherein the application point is medially located on the head of the subject animal above a line extending between the animal's eyes so as to be located at the closest external point to the central and frontal portion of the brain.

31. A method according to claim 29 or 30 wherein the step of locating the applicator includes selectively advancing the applicator from a retracted position where it is located when the subject animal is being located in the confined position at the stunning station to an operative position when the animal is located and held in its confined position, the applicator in its operative position being engaged against the animal's head at the

application point, the direction of the microwave radiation through the waveguide to the applicator being carried out only after the applicator is in its operative position.

32. A method according to claim 29 or 30 wherein the step of locating the applicator includes selectively moving the animal's head towards the applicator until the applicator
5 contacts the animal head at the application point.

33. A method according to any one of claims 29 or 32 wherein the microwave radiation generated has its electric field generally perpendicular to the front of the animal's head at the application point whereby the electric field enters the animal's head in a generally perpendicular direction.

10 34. A method according to any one of claims 29 to 32 wherein the microwave radiation generated has both its electric field and magnetic field generally parallel to the front of the animal's head at the application point and whereby the microwave radiation enters the animal head in the generally perpendicular direction.

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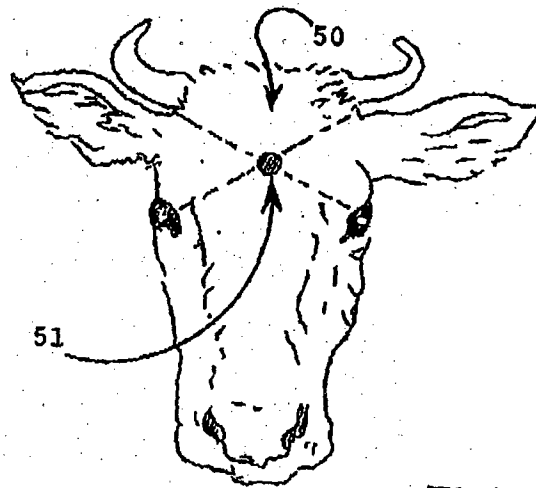


Fig. 1

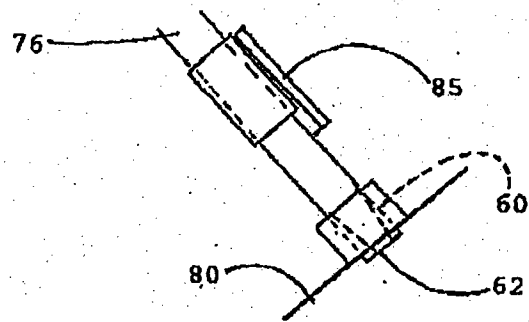


Fig. 5

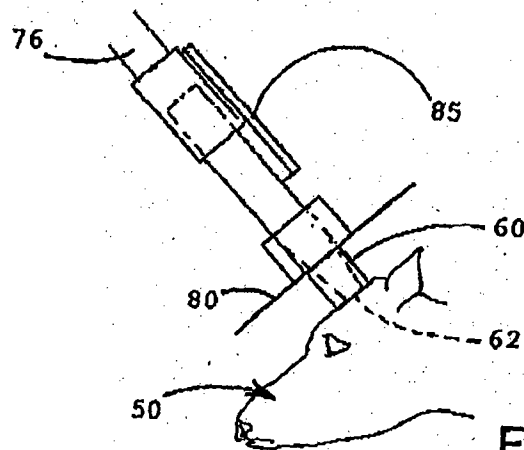


Fig. 6

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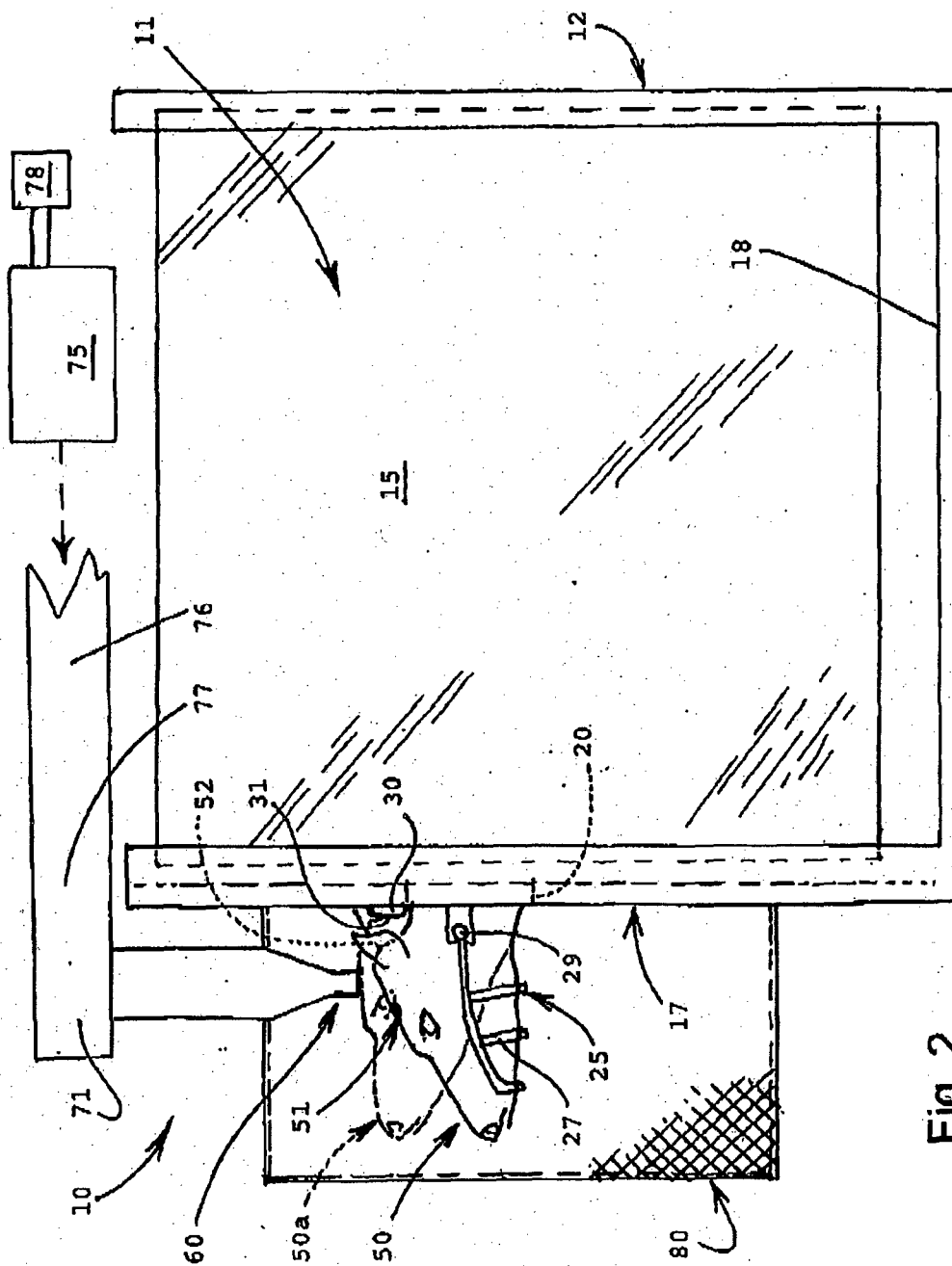


Fig. 2

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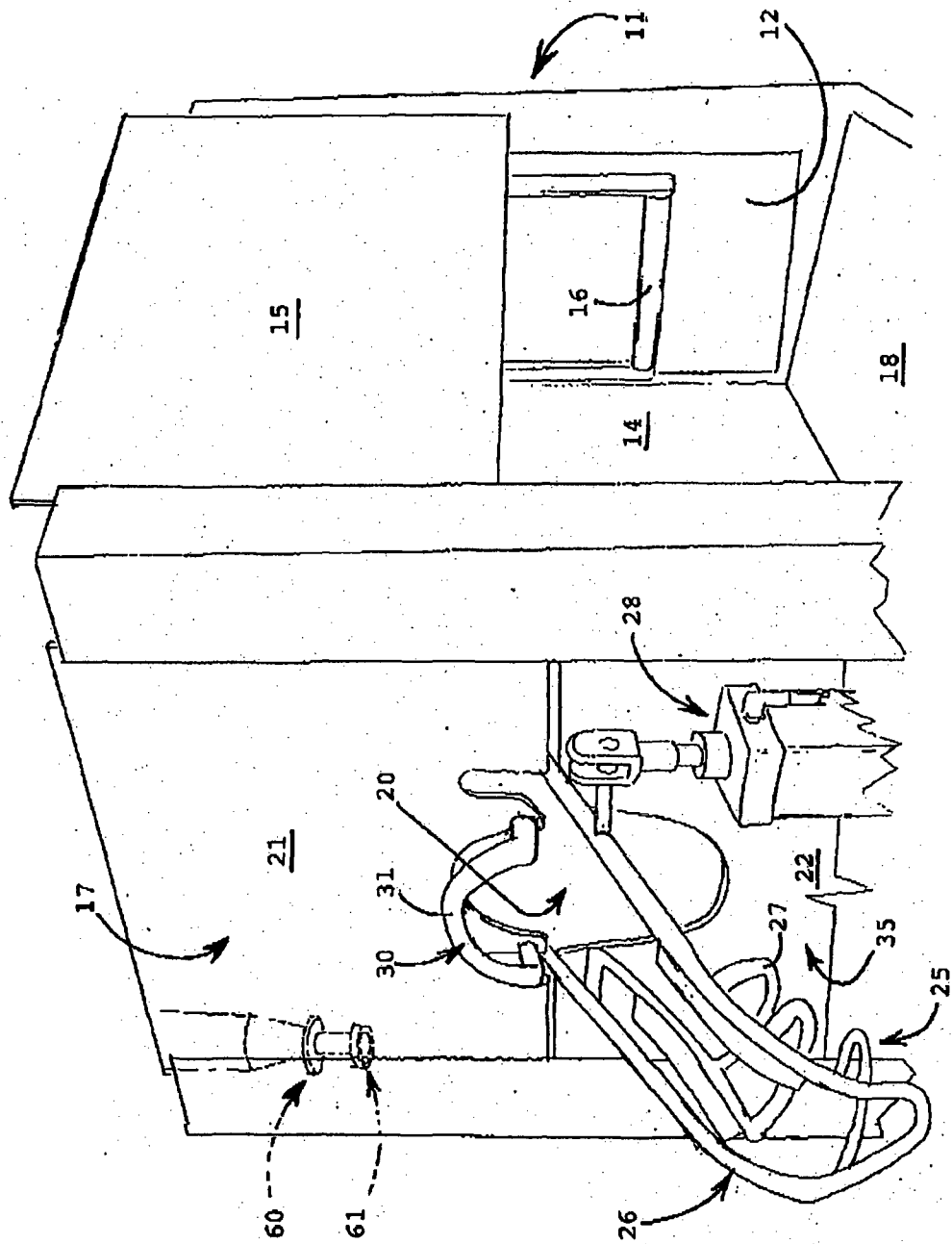


Fig. 3

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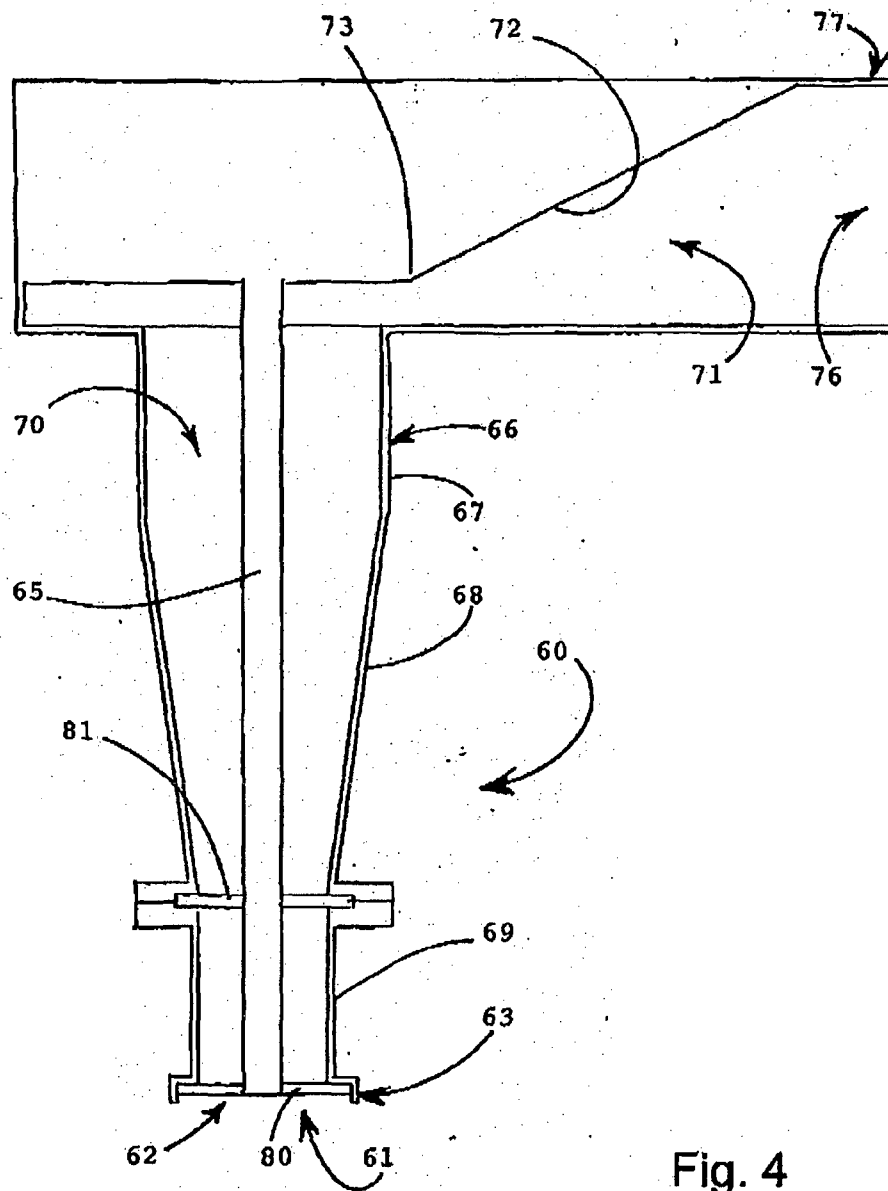


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2011/000527

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

A22B 3/00 (2006.01) A61M 36/00 (2006.01)
A22B 3/06 (2006.01) A61M 36/02 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC; IPC: A22B3/00, A22B3/06, A61M36/00, A61M36/02; and keywords: (microwave, waveguide, heat, animal, head, frontal, brain, electromagnetic) and like terms.

Esp@cenet, Google Patents and same keywords and terms as above.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 09-140324 A (TAKAMURA FUMITOMO ISHIDA KATSUSHI) 03 June 1997 English translation retrieved from PAJ Website: (http://www19.ipdl.inpit.go.jp/PA1/cgi-bin/PA1INDEX) See abstract; paragraphs 13-20, 28, 31-32, 44; claims; Fig 1-5	1, 3-4, 10, 14, 17, 19-20, 27- 28
Y	US 3973290 A (SCHWARTZ) 10 August 1976 See abstract; claims	1, 3-4, 10, 14, 17, 19-20, 27- 28
A	US 4616120 A (MARUYAMA et al.) 07 October 1986 See abstract; Fig 3-5	

☒ Further documents are listed in the continuation of Box C☒ See patent family annex

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
11 July 2011

Date of mailing of the international search report

8 AUG 2011

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2011/000527

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 7244172 B2 (HORST et al.) 17 July 2007 See abstract; Fig 1-2	
A	DE 4116670 A1 (SCHWARTZ, WERNER) 26 November 1992 English translation retrieved from Esp@cenet database See abstract; Fig 1	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2011/000527

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report			Patent Family Member				
US	3973290	NONE					
US	4616120	EP	0171620	JP	61039481		
US	7244172	US	2006135052	US	7241212	US	2006286914
		US	2007254573	US	7588486	WO	2009006314
DE	4116670	NONE					
JP	9140324	NONE					
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.							
END OF ANNEX							