(12) **UK Patent Application** (19) **GB** (11) **2 344 183** (13) **A**

(43) Date of A Publication 31.05.2000

(21) Application No 9900296.6

(22) Date of Filing 07.01.1999

(30) Priority Data
(31) 9824976 (32) 13.11.1998 (33) GB

(71) Applicant(s)
Mars U.K. Limited
(Incorporated in the United Kingdom)
3D Dundee Road, Slough, Berkshire, SL1 4LW,
United Kingdom

(72) Inventor(s)
Richard Fulton Butterwick
Amanda Jane Hawthorne
Richard Bradley

(74) Agent and/or Address for Service
Reddie & Grose
16 Theobalds Road, LONDON, WC1X 8PL,
United Kingdom

(51) INT CL^7
A61B 5/00 , G01B 3/00 5/00 , G01N 37/00

(52) UK CL (Edition R)
G1S SIA
G1M MCDX M11C M12B M13B M13D M13F

(56) Documents Cited
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(58) Field of Search
UK CL (Edition R) **G1M MCCC MCCE MCDX , G1S SIA**
SQA SXX
INT CL^7 **A61B 5/00 , G01N 37/00**
On-line: EPODOC, WPI, JAPIO

(54) Abstract Title
Body fat measurement system

(57) A body fat measurement system for mammals includes means for measuring first and second body dimensions having a high correlation with body fat and low correlation respectively. A lookup table provides an output of the percentage body fat on input of the first and second dimensions.
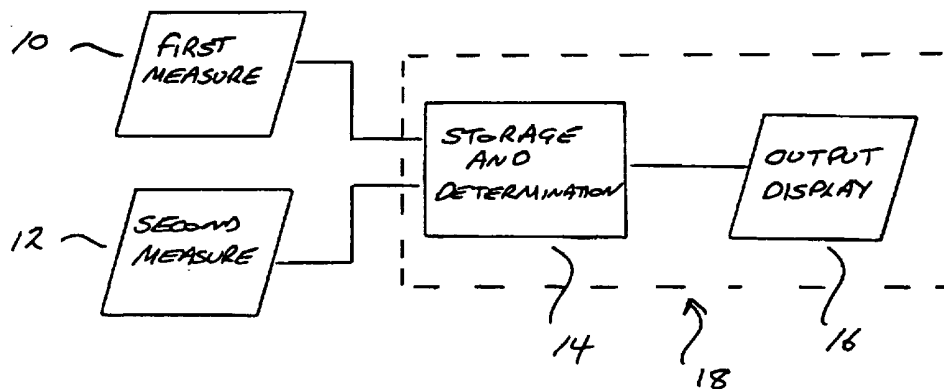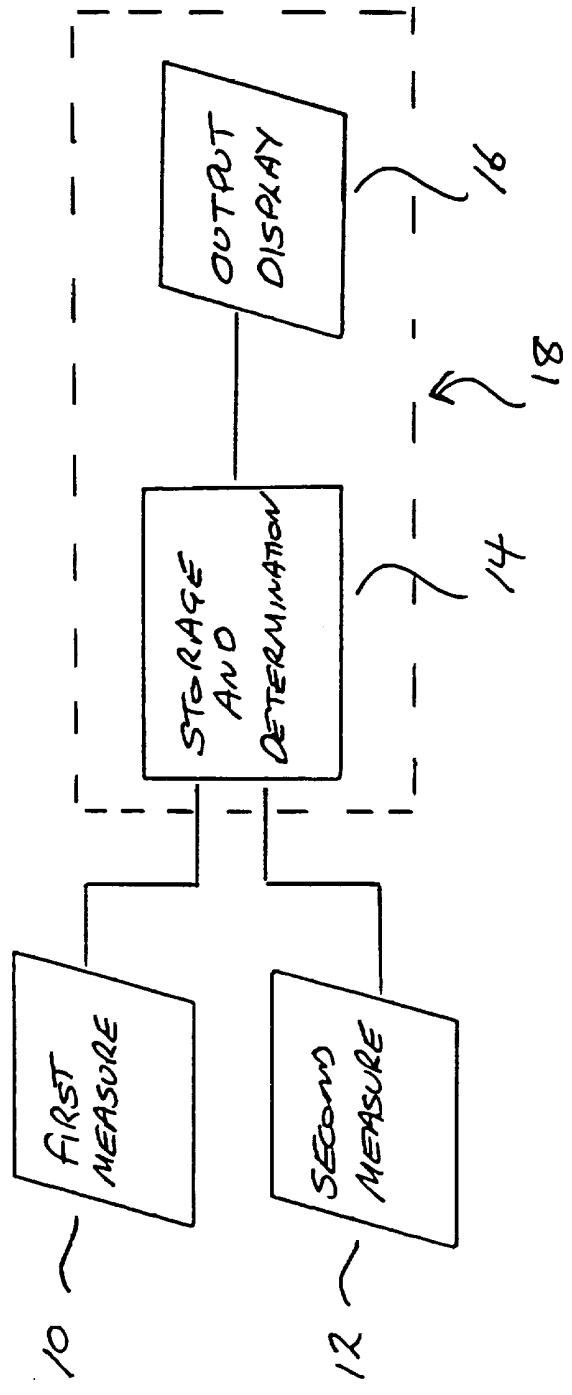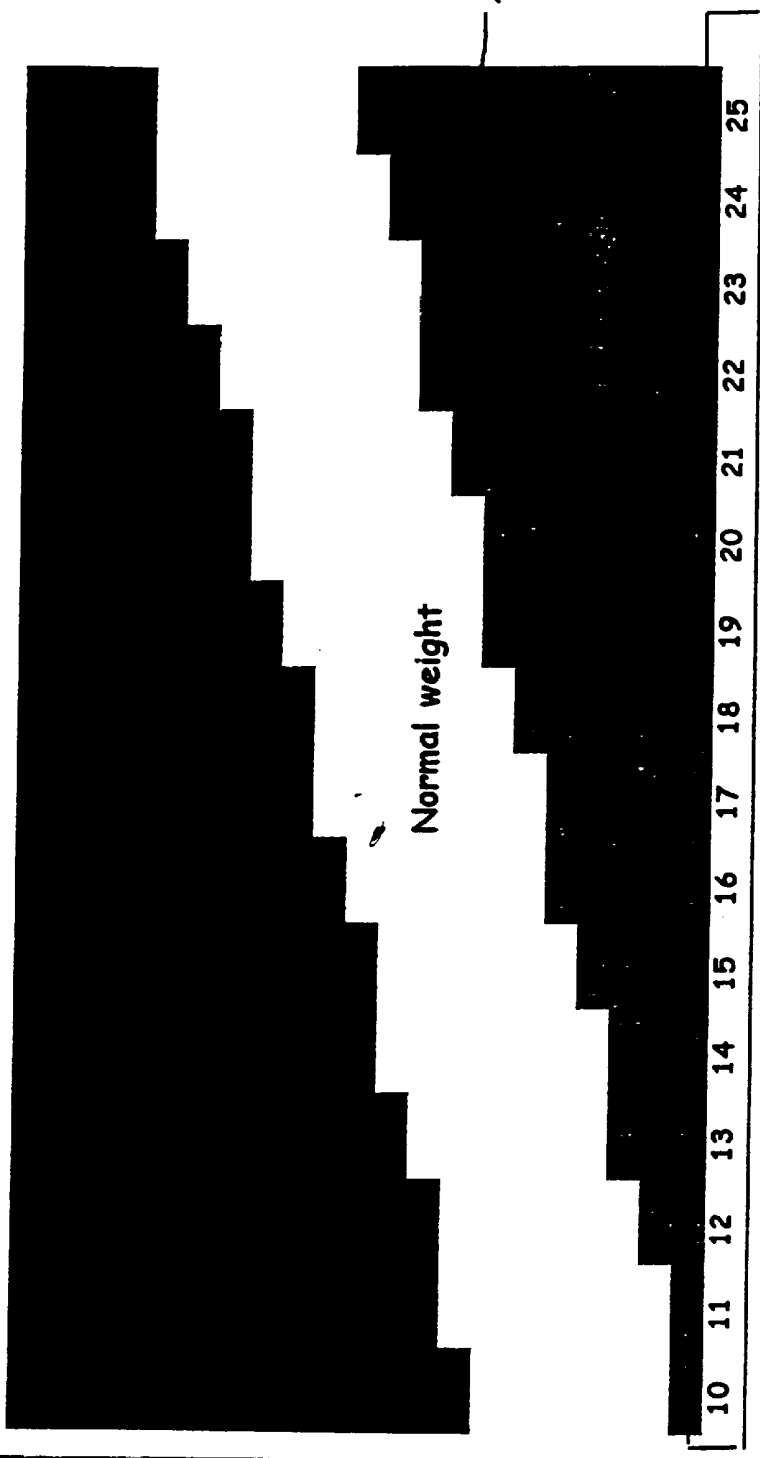
Fig 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

FIRST
MEASURE

SECOND
MEASURE

STORAGE
AND
DETERMINATION

OUTPUT
DISPLAY

Fig 2

Fig 2

Percentage bodyfat content

Rib cage (cm)

| 60 |
| 58 |
| 56 |
| 54 |
| 52 |
| 50 |
| 48 |
| 46 |
| 44 |
| 42 |
| 40 |
| 38 |
| 36 |
| 34 |
| 32 |
| 30 |
| 28 |
| 26 |
| 24 |
| 22 |
| 20 |

Back longbone (cm)	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
		30	30		29		28	29		28	29		28	29	30	
	29	26	27	28	26	27	28	26	27	28	26	27	28	26	27	28
	25	23	24	25	23	24	25	23	24	25	23	24	25	23	24	25
	22	20	21	22	20	21	22	20	21	22	20	21	22	20	21	22
	19	17	18	19	17	18	19	17	18	19	17	18	19	17	18	19
	16	14	15	16	14	15	16	14	15	16	14	15	16	14	15	16
	13	11	12	13	11	12	13	11	12	13	11	12	13	11	12	13
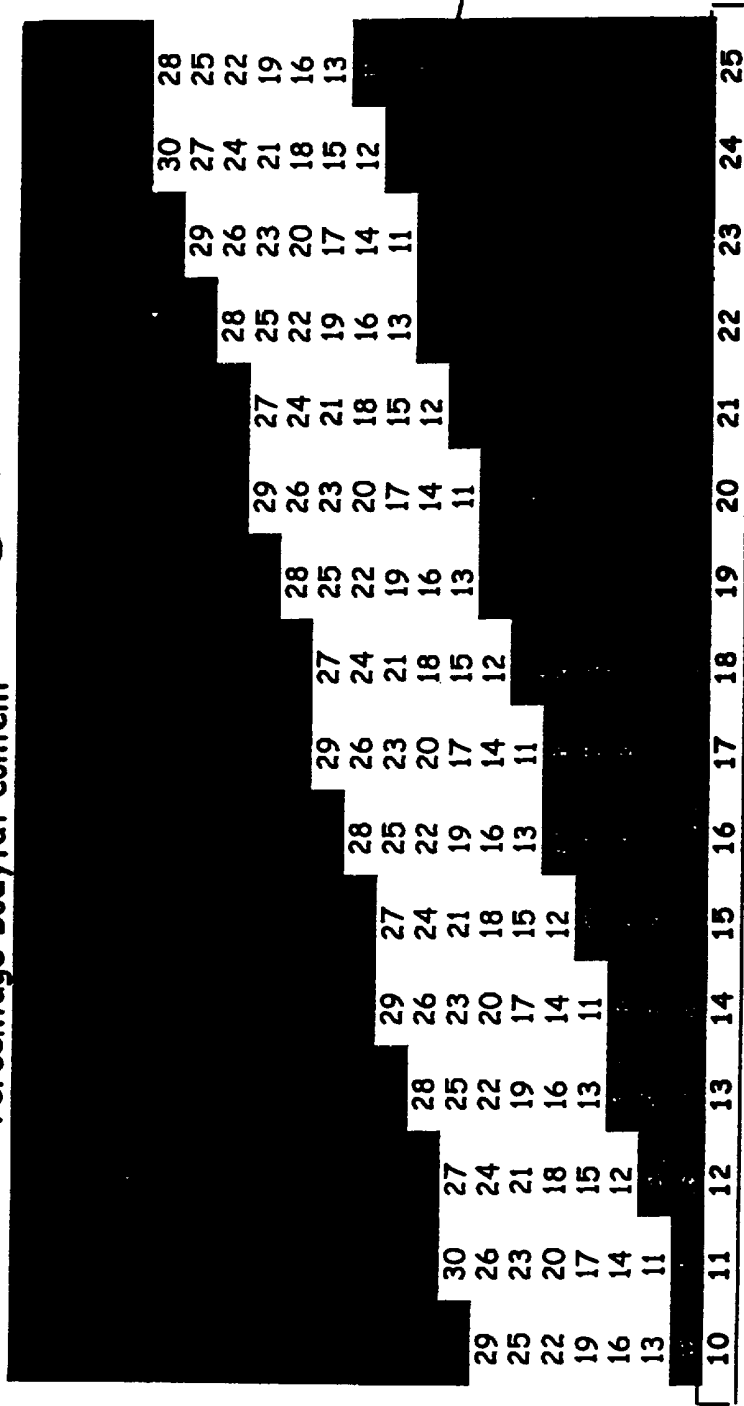
Key

- ■ Normal weight
- ☐ Over weight
- ■ Under weight

Fig 3

BODY FAT MEASUREMENT SYSTEM

The present invention relates to a system for measurement
of the percentage of body fat by weight of four legged
mammals, in particular domestic cats.

5   Obesity is the most common form of malnutrition in cats,
however, the links between obesity and the risk of
clinical conditions are not well understood. This is
primarily because there is no accepted method for defining
obesity or measuring body fat in cats.

10   The body mass index (BMI), which is based only upon
measurements of body weight and height, allows objective
measurement available for humans. The main techniques
available to veterinary practitioners are subjective ones
such as the Body Condition Score (BCS) system produced by
15   Latflamme.

We have appreciated the requirement for a simple,
objective system for determining the percentage body fat
by weight of four legged mammals, in particular cats. In
particular, we have appreciated that the system should be
20   reliable and capable of implementation in both
technologically simple and complex embodiments. The
system should also be easy for inexperienced operators to
use.

Accordingly, there is provided a system for measuring the
25   percentage body fat of a four legged mammal, comprising:

-       means for measuring a first body dimension having a
        high correlation with percentage body fat;

-       means for measuring a second body dimension having a
        low correlation with percentage body fat; and

- a look-up table comprising a first storage area for storing entries of the first body dimension, a second storage area for storing entries of the second body dimension and an output area for indicating the percentage body fat determined from a relationship between the first and second body measurements.

The system of the invention has the advantages of being simple to operate, reliable and capable of implementation as a low technological manual system, or a more sophisticated computerised implementation.

In a preferred embodiment the first body dimension is the circumference of the ribcage. This measurement has been appreciated, through experimentation, to be highly correlated to a four legged mammal's percentage body fat. In the embodiment, the second body dimension is a leg index measurement, preferably the distance between the Patella (knee) and the calcaneal tuber (hock) with the leg flexed of the hind limb which, we have appreciated, has a low correlation with percentage body fat. The use of the body measurement of high correlation with body fat and one with low correlation increases the accuracy of the determined percentage body fat.

A system embodying the invention will now be described with reference to the accompanying figures in which:-

Figure 1- is a diagrammatic representation of a system embodying the invention;

Figure 2- is a diagrammatic representation of a first look-up table for use in the system of Figure 1; and

Figure 3- is a diagrammatic representation of a second look-up table for use in the system of Figure 1.

The embodiment shown in Figure 1 may be either manually operated, or a computerised system. A first measurement device 10 and a second measurement device 12 are provided to take measurements of, respectively, the ribcage circumference and the leg index measurement [LIM] to provide the results to the look-up table 18. In a computerised embodiment, the measurement devices 10, 12 would provide measurement signals to a computer, storing therein in first, second and output storage areas respectively, ribcage and LIM, and corresponding fat percentage indications. These are shown as storage and determination functions 14 in Figure 1. The results are displayed as an output display 18. The determination algorithm (described later) could be coded in any simple computer language, and is within the common general knowledge of the skilled person, and need not be described here.

A manual representation of the look-up table 18 is shown in Figures 2 and 3. There is shown a first storage area 20, storing first body dimensions (ribcage) measurements, and a second storage area 22, storing second body dimensions (LIM). An output storage area 24 stores an indication of the percentage body fat of a domestic cat as a relationship of the first and second dimensions. The indication is under, normal or overweight in Figure 2. In figure 3, the indication is given as a percentage number.

In appreciating that the system embodying the invention provides a uniquely robust and reliable system for determining the percentage body fat of a cat, a number of experiments were undertaken, as will now be described.

To establish the correlation between body condition score (BCS) and body composition (% body fat) as measured using Dual Energy X-Ray Absorptiometry (DXA), and to compare zoometric measurements with estimates of body condition
5   score and % body fat using DXA, in order to develop a simple objective method of determining body condition, the following method was adopted.

Zoometric measurements and estimates of BCS (body condition score) and body composition (using DXA), were
10   take from 60 domestic, short-haired cats, housed indoors. All measurements were taken between 03/03/97 and 22/05/97, by a single observer. In the study, 28 males (all neutered) and 32 females (of which 8 were entire) were used. The average age of the females was 4.92 years and
15   males 3.94 years. The body weights of entire female cats ranged from 2.34 to 4.1 Kg, the neutered female cats from 2.84 to 6.6 Kg and the males 4.2 to 8.18 Kg. Cats had been fed a variety of diets at the time measurements were taken.

20   The following zoometric measurements were taken from each cat. These were selected because they were considered to represent body condition or had been found from human data to be potentially useful.

Height: The distance between the ground and the
25   Withers (the top of the shoulder blade or scapula) as measured using a measuring stick. This is a wooden metre ruler with a fixed base, perpendicular to the rule and a sliding wooden bar.

30   Chest Dept: The vertical distance from the top of the capula to the bottom of the chest, using a measuring stick.

Girth: The circumference at the point of the 4th lumbar vertebrae, just behind the last rib, using a measuring tape.

Ribcage: The circumference at the point of the 9th rib (5 ribs from the posterior end of the ribcage), using a tape measure.

Length: The horizontal distance from the breast-bone (manubrium) to the thigh (perineum), using a measuring stick.

Elbow: Measured on the left elbow using a calliper. It is the distance between the lateral epicondyle of the humerus and the medial epicondyle of the humerus.

Front Long Bone: The length of the humerus, from the proximal ulnar epiphysis to the distal radial epiphysis, using a measuring stick.

Leg index measurement [LIM]:   The distance between the Patella (knee) and the calcaneal tuber (hock) with the leg flexed.

All measurements were taken from the left hand side of the cat whilst it was standing with its legs perpendicular to the ground and with its head up and looking forward. Cats were weighed prior to taking the measurements, which were taken in a fasted state. Five replicates of each measurement were taken on the same day.

The Purina Body Condition Score (Laflamme, 1998) was used as a subjective assessment of body condition. The cat was given a score on a nine point scale, which ranged from 1

for emaciated to 9 for morbidly/grossly obese, although
experienced assessors are able to grade cats to 0.5 of a
scale. A cat with a BCS score of 5 was considered to be
ideal. This scoring system was based on a variety of
features, which included palpability of the ribs, presence
of a discernible waist and abdominal tuck, and evidence of
bony prominence and fat deposits on the lumbar area and
base of the tail.

The percentage body fat was measured by dual energy X-ray
absorptiometry, using a Hologic QDR 1000/W densitometer.
They were anaesthetised using Domitor (0.1ml/Kg) and
recovery induced with Antisepen.

Eight inexperienced observers each made an estimate of BCS
and took their replicates of each zoometric measurement on
the same seven cats, in order to test for inter-observer
variability in predicting body condition.

Each Zoometric measurement was compared with % body fat
because this represented the most objective estimate of
body composition. The most significant correlation with
% body fat was for ribcage. This factor is more likely to
be affected by an increase in body weight or obesity. It
may therefore be considered to provide an estimate of %
body fat, or 'fatness'. The lowest correlation's with %
body fat were found for the LIM and height measurements
($r^2 < 15.4\%$). This is a low correlation. These may
therefore be considered to be measurements of stature
which are relatively unaffected by changes in % body fat.

We appreciated that a system could be devised using this
data to provide a simple system for measuring the
percentage body fat of cats. The formula that describes

the most variation in percentage body fat and is
biologically meaningful is:

$$Fat=[\frac{(\frac{Ribcage}{0.7067}-LIM)}{0.9156}]-LIM$$

The mean, standard deviation and coefficient of variation
were determined for each of the 60 cats from the five
replicates made for each zoometric measurement by the
experienced observer. The mean and median coefficient of
variation (CV) for each zoometric measurement was less
than 10% suggesting that the intra-observer repeatability
was low and that a single measurement would be needed in
future (see table below).

CV for each zoometric measurement made by a single
experienced assessor.

	Coefficient Of Variation (%)			
	Mean	Median	Min	Max
Weight	2.30	1.19	0	12.78
Girth	1.96	1.57	0.27	6.74
Ribcage	3.03	2.6	0.5	15.57
Height	1.49	0.93	0.18	8.94
Chest Dept	3.54	3.34	1.36	9.62
Length	2.37	2.15	0.22	6.26
Elbow	4.28	4.35	0	9.56
Front Long Bone	2.11	1.77`	0	5.26
LIM	2.5	2.16	0.33	8.19

The cats included in this study encompassed a wide range of body composition and age, but were of a single population of related genetic domestic short-haired stock. They may therefore form a representative sub-sample of the domestic cat population in general.

BCS was significantly correlated with % body fat, when measured using DXA (r^2 = 73.4%, $p < 0.01$) and gave a reasonable prediction of % fat. However, the correlation was lower than that reported by Laflamme (1998) where r^2 = 83.5%, although 48 cats were used in this study, of which only 4 individuals had a BCS less than 5. Using the BCS system in this study, cats which were of ideal body condition (BCS = 5) had between 15 and 30% body fat. Cats which were considered to be underweight (BCS < 5), were less than 20% fat and those which were overweight (BCS> 6) were more than 30% fat. Whilst these data sets are relatively small (underweight group = 7 cats, ideal = 8 cats) it gives an indication of the cut off points that might be used for these major categories of % body fat for cats. The largest discrepancy between % body fat and BCS occurred for those animals considered to have a BCS between 5 and 6. This may indicate the problems of correctly identifying animals of 'ideal' condition when animals differed greatly in stature. Animal stature, particularly of very large or small cats was considered to be a determining factor in the large variation of BCS assigned to individual cats by different observers, resulting in a relatively high CV of 15.3%. It would appear that the BCS type of assessment is truly subjective.

By comparison zoometric measurements, and ribcage in particular (r^2 = 82.9%) were more highly correlated with % body fat than the BCS system. This is a high correlation.

The high level of repeatability for the ribcage and LIM measurements of cats and the high correlation between the zoometric model and % body fat suggests that this objective measurement is a more appropriate tool for
5   determining body composition of cats than BCS. In addition it is also non-invasive, requires little training to achieve an acceptable level of repeatability and requires only a metric tape measure. This makes this method available for all veterinary practitioners and cat
10   owners.

CLAIMS

1. A system for measuring the percentage body fat of a
    four legged mammal, comprising:

    -   means for measuring a first body dimension
        having a high correlation with percentage body
        fat;
    -   means for measuring a second body dimension
        having a low correlation with percentage body
        fat; and
    -   a look-up table comprising a first storage area
        for storing therein entries of the first body
        dimension, a second storage area storing therein
        entries of the second body dimension and an
        output storage area storing an indication of the
        percentage body fat determined from a
        relationship between the first and second body
        measurements.

2. A system according to Claim 1, wherein the first body
    measurement is the circumference of the ribcage,
    taken at the 9th rib.

3. A system according to Claim 1 or Claim 2, wherein the
    second body measurement is a leg index measurement,
    which is the length of the hind limb measured between
    the patella (knee) and the calcaneal tuber (hock).

4. A system according to any preceding claim, wherein
    the output storage area provides an indication of
    whether the mammal is under, normal or overweight.

5. A system according to any preceding claim, wherein
    the output storage area provides a numerical
    percentage body fat.

6. A system according to any preceding claim, wherein the relationship between the percentage body fat and first and second body dimensions is given by the equation:-

$$PercentageBodyFat = [\frac{(\frac{R}{C_1} - L)}{C_2}] - L$$

where   R =   ribcage circumference

L =   leg index measurement

C1 =   constant

C2 =   constant

7. A lookup table for use in the system of any proceeding claim, comprising:

-    a first storage area storing therein entries of the first body dimension;

-    a second storage area storing therein entries of the second body dimension; and

-    an output storage area storing an indication of percentage body fat determined from a relationship between the first and second body measurements.

8. A system substantially as herein described and with reference to the accompanying figures.

9. A lookup table substantially as herein described and with reference to the accompanying figures.

Application No:	GB 9900296.6	Examiner:	Michael Walker
Claims searched:	ALL	Date of search:	22 March 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): G1M (MCCC, MCCE, MCDX); G1S (SIA, SQA, SXX)

Int Cl (Ed.7): A61B 5/00; G01N 37/00

Other: On-line: EPODOC, WPI, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2220752 A	(CHECKMATE)	
A	GB 2213936 A	(BROSELOW)	
A	GB 2123542 A	(LAFLAMME)	
A	GB 0858738	(HYGRADE)	
A,E	EP 0940120 A1	(SEB SA)	
A	US 4127112	(SHERLOCK SA)	

X Document indicating lack of novelty or inventive step	A Document indicating technological background and/or state of the art.
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