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2 **APPARATUS AND METHOD FOR DISPLAYING NUMERIC**
3 **VALUES CORRESPONDING TO THE VOLUME OF SEGMENTS**
4 **OF AN IRREGULARLY SHAPED ITEM**
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7 Cross Reference to Related Applications

8 This invention claims the benefit of U.S. provisional Serial No. 60/436,078,
9 filed December 23, 2002, U.S. provisional Serial No. 60/440,801, filed January 16, 2003,
10 U.S. provisional Serial No. 60/453,816, filed March 11, 2003, U.S. provisional Serial No.
11 60/498, 639, filed August 29, 2003, and U.S. provisional Serial No. 60/520,812, filed
12 November 17, 2003.

13
14 Background of the Invention

15 This invention concerns the selective segmenting of irregularly shaped items
16 such as fish filets, or meat cuts, particularly at the point of sale. Complex and bulky
17 machinery has heretofore been devised for automatically cutting up food items such as fish
18 fillets into portions of a desired weight in food packing operations which supply food retailers
19 with pre-weighed packages.

20 However, at the retail level, the problem still exists as to how to segment an
21 irregularly shaped food item such as a fish fillet or meat cut to a particular weight requested
22 by a customer (or to a price based on the weight) or to determine the weight and/or cost of a
23 selected portion. When a customer requests a certain weight portion of a food item such as a
24 fish fillet, a segment is cut from the item based on the best estimate made by the server as to
25 the weight of that segment. Too often, upon being weighed, the selected portion does not
26 turn out to weigh (or cost) what the customer requested due to the difficulty in estimating the

1 weight of a particular segment of quite variably shaped food item. This is a particular
2 problem with inexperienced servers. Also, a customer may sometimes wish to see how much
3 a certain portion weighs (or costs) before the portion is cut. The aforementioned automatic
4 machinery cannot do this and is not otherwise suited to retail shop applications, as it is too
5 bulky, complex, and expensive for retail shop use.

6 It is the object of the present invention to provide a relatively simple to use
7 and compact apparatus and method for quickly providing an indication of the weight and/or
8 cost of a particular uncut segment of an irregularly shaped item.

9 It is another object to provide such apparatus and method which is suitable for
10 use in a retail fish or meat market or elsewhere for accurately and quickly providing a
11 computation of the weight (or cost based on weight) of a selected cut or uncut segment of a
12 food or other non-food items.

13 The apparatus and method may also be used for other segmenting applications
14 where a non-food item needs to be portioned or a weight determination made quickly and
15 accurately. While particularly advantageous for retail sale use, it may also be used in
16 industrial applications as providing a lower cost alternative for existing automated processing
17 equipment.

18

19 Summary of the Invention

20 The above recited objects and other objects which will be appreciated upon a
21 reading of the following specification and claims are achieved by a compact device which
22 may be manually operated including a sensor bar supported spaced above a table, conveyor
23 belt, or other support surface at a predetermined height thereabove sufficient to provide

1 vertical clearance for the expected maximum thickness of the range of items to be segmented.
2 The sensor bar support allows the bar to be relatively moved with respect to the support
3 surface to be passed over and along the item while being supported at the predetermined
4 height above the table surface. The sensor bar can be supported on a post at each end, with
5 the posts held vertical and the sensor bar guided in its movement manually by the operator.
6 In this embodiment, the sensor bar can be moved freely on the table surface, and also freely
7 lifted clear for use elsewhere. Alternatively, the sensor bar can be supported elevated above
8 the table surface by uprights and guide bearings, to be constrained in its orientation and
9 position as it is stroked across the width of the table.

10 The sensor bar can thus be manually stroked along the length of an item to be
11 segmented which has previously been placed on the table surface. A selectively controlled
12 powered operation of the sensor bar stroking may also be provided in the constrained sensor
13 bar embodiment.

14 In both forms, the sensor bar carries a sensor arrangement comprising one or
15 more sensors generating signals corresponding to the cross sectional contour of each section
16 of an item passed over during the movement of the sensor bar. In some embodiments, one or
17 more sensors either simultaneously or sequentially measure the height of points on the upper
18 surface of the item above the support surface lying beneath the sensor bar and generate
19 signals corresponding thereto.

20 A displacement measuring detector arrangement is also provided associated
21 with the sensor bar support detecting the extent and direction of displacement of the sensor
22 bar when being passed over the item on the table surface, and also generating corresponding
23 signals. The sensor and detector arrangement signals are transmitted to a suitable

1 microprocessor based signal processor, which processes the signals to continuously calculate
2 the cumulative volume of the uncut segment of the item located behind the section over
3 which the sensor bar is positioned at each of its relative positions over the item on the support
4 surface.

5 Each of these cumulative volume calculations may be converted into
6 corresponding numeric weight values based on a predetermined memory stored density factor
7 for the particular type of item, which factor may be obtained electronically from a look-up
8 table or value loaded into the memory of the signal processor. These numeric weight values
9 (or numerically indicated prices based on weight) are continuously or selectively displayed as
10 the sensor bar passes over the item.

11 The segment can be cut from the item with a knife at any selected point to
12 provide a segment of an accurately predetermined weight (or cost).

13 Various known forms of sensors and displacement detectors may be employed
14 including mechanical, electro-mechanical, optical-mechanical, acoustic, optical devices, or
15 other devices.

16 A knife may be mounted to the sensor bar, and the sensor bar can be
17 selectively lowered by retraction of sensor bar rod supports, allowing cutting of the segment
18 with the knife still attached to the sensor bar. Or, alternatively, the item may merely be
19 marked or scored with, for example, the knife, ink marker devices, heating elements, laser
20 burners, or sharp pointed plungers, for later cutting off of the segment selected. A knife can
21 also be separately stored or detachably mounted to the bar and retrieved to perform the
22 segmenting cut. A separate knife used to cut the segment may be guided by surfaces on the
23 sensor bar support.

1 A powered cutting device such as a rotary blade or laser can also be mounted
2 and driven to traverse along the sensor bar and cut the item into a selected segment.

3

4 Description of the Drawings

5 Figure 1 is a pictorial view of a first embodiment of an apparatus according to
6 the present invention with an item to be segmented shown in phantom lines in position on a
7 supporting table surface shown in fragmentary form, and with an enlarged view of the signal
8 processor case.

9 Figure 1A is an enlarged pictorial view of a control case component of the
10 apparatus shown in Figure 1 partially broken away to show internal components thereof.

11 Figure 1B is a partially exploded view of another embodiment of an apparatus
12 according to the present invention with an item to be segmented shown in phantom lines in
13 position on a supporting table surface shown in fragmentary form.

14 Figure 2A is a pictorial view of another embodiment of an apparatus according
15 to the present invention, with an item to be segmented shown in phantom lines on a support
16 surface.

17 Figure 2B is a pictorial view of another embodiment of an apparatus according
18 to the present invention, with an item to be segmented shown in phantom lines on a support
19 surface.

20 Figure 2C is a pictorial view of another embodiment of an apparatus according
21 to the present invention, with an item to be segmented shown in phantom lines on a support
22 surface.

23 Figure 2D is a pictorial view of another embodiment of an apparatus according

1 to the present invention, with an item to be segmented shown in phantom lines on a support
2 surface.

3 Figure 2E is a pictorial view of another embodiment of an apparatus according
4 to the present invention, with an item to be segmented shown in phantom lines on a support
5 surface.

6 Figure 3A is a partially sectional view taken through one form of a sensor bar
7 included in the apparatus according to the invention together with an item to be segmented on
8 a support surface.

9 Figure 3B is a diagram of the spatial relationship of the elements of the sensor
10 and emitter incorporated in the sensor bar shown in Figure 3A.

11 Figure 3C is an enlarged partially sectional view taken along the sensor bar
12 shown in Figure 3A showing a modification thereof.

13 Figure 4 is a partially sectional view taken through a second form of the sensor
14 bar included in apparatus according to the present invention together with an item on a
15 supporting surface.

16 Figure 5 is a pictorial view of another embodiment of an apparatus according
17 to the present invention with an item to be segmented shown in phantom lines in position on
18 a supporting table shown in fragmentary form.

19 Figure 5B is a pictorial view of another embodiment of apparatus according to
20 the invention utilizing a conveyor as an item support surface.

21 Figure 6A is a partially sectional view taken through a plunger height sensor
22 used in one form of a sensor bar included in an apparatus according to the invention, with the
23 plunger shown in an extended position.

1 Figure 6B is a partially sectional view taken through a plunger height sensor
2 used in one form of a sensor bar included in a device according to the invention, with the
3 plunger shown in the retracted position.

4 Figure 7 is an enlarged transverse sectional view taken through the plunger
5 height sensor shown in Figures 6A and 6B with a diagrammatic indication of one form of a
6 plunger extension detector associated with the plunger.

7 Figure 8A is a fragmentary elevational view of the lower end of a support post
8 with a diagrammatic representation of displacement detector components.

9 Figure 8B is a diagrammatic representations of successive tracking patterns
10 utilized by the displacement detector depicted in Figure 8A.

11 Figure 9A is a fragmentary side elevational view of a sensor bar support post
12 incorporating another form of a displacement detector.

13 Figure 9B is an enlarged representation of the certain components of the
14 displacement detector embodiment shown in Figure 9A.

15 Figure 9C is a perspective view of other components of the displacement
16 detector embodiment shown in Figure 9A with the support post shown in phantom lines.

17 Figure 10A-1 is a fragmentary elevational view of a marking plunger using an
18 ink jet marker, with a fragmentary view of an item to be portioned.

19 Figure 10A-2 is a partially sectional view of the marking plunger and
20 associated mounting shown in Figure 10A-1, with the marking plunger in a retracted position.

21 Figure 10A-3 is a partially sectional view of the marking plunger and
22 mounting shown in Figure 10A-2, with the marking plunger in the extended position.

23 Figure 10A-4 is a partially sectional view of a height sensor plunger and

1 mounting incorporated in the apparatus according to the invention equipped with an ink jet
2 marker device, with the plunger shown in the extended position.

3 Figure 10A-5 is a partially sectional view of the height sensing plunger of
4 Figure 10A-4 but shown with the plunger in the retracted position.

5 Figure 10B-1 is a fragmentary elevational view of a marking plunger using a
6 heater branding device, with a fragmentary view of an item to be portioned.

7 Figure 10B-2 is a partially sectional view of the marking plunger and
8 associated mounting shown in Figure 10B-1, with the marking plunger in a retracted position.

9 Figure 10B-3 is a partially sectional view of the marking plunger and
10 mounting shown in Figure 10B-2, with the marking plunger in the extended position.

11 Figure 10B-4 is a partially sectional view of a height sensor plunger and
12 mounting incorporated in the apparatus according to the invention equipped with a heater
13 branding device, with the plunger shown in the extended position.

14 Figure 10B-5 is a partially sectional view of the height sensing plunger of
15 Figure 10B-4 but shown with the plunger in the retracted position.

16 Figure 10C-1 is a fragmentary elevational view of a marking plunger using a
17 laser marker, with a fragmentary view of an item to be portioned.

18 Figure 10C-2 is a partially sectional view of the marking plunger and
19 associated mounting shown in Figure 10C-1, with the marking plunger in a retracted position.

20 Figure 10C-3 is a partially sectional view of the marking plunger and
21 mounting shown in Figure 10C-2, with the marking plunger in the extended position.

22 Figure 10C-4 is a partially sectional view of a height sensor plunger and
23 mounting incorporated in the apparatus according to the invention equipped with laser marker

1 device, with the plunger shown in the extended position.

2 Figure 10C-5 is a partially sectional view of the height sensing plunger of
3 Figure 10C-4 but shown with the plunger in the retracted position.

4 Figure 10D-1 is a fragmentary elevational view of a marking plunger using a
5 sharp tool marker, with a fragmentary view of an item to be portioned.

6 Figure 10D-2 is a partially sectional view of the marking plunger and
7 associated mounting shown in Figure 10D-1, with the marking plunger in a retracted position.

8 Figure 10D-3 is a partially sectional view of the marking plunger and
9 mounting shown in Figure 10D-2, with the marking plunger in the extended position.

10 Figure 10D-4 is a partially sectional view of a height sensor plunger and
11 mounting incorporated in the apparatus according to the invention equipped with sharp tool
12 marker device, with the plunger shown in the extended position.

13 Figure 10D-5 is a partially sectional view of the height sensing plunger of
14 Figure 10D-4 but shown with the plunger in the retracted position.

15 Figure 11A is a transverse sectional view of a marking plunger, showing a side
16 locking pin in engagement.

17 Figure 11B is a transverse sectional view of the marking plunger shown in
18 Figure 11A but with the locking pin in the retracted position.

19 Figure 12A is a fragmentary elevational view of a piezoelectric ink jet marker
20 mechanism for ink jet marking in its initial state, with a fragmentary portion of an item to be
21 marked.

22 Figure 12B is a fragmentary elevational view of the piezoelectric ink jet
23 dispensing mechanism shown in Figure 12A, in the ink discharging condition depositing on

1 ink droplet on the item to be marked.

2 Figure 12C is a fragmentary elevational view of the piezoelectric ink jet
3 dispensing mechanism shown in Figure 12A in the ink charging condition with an ink mark
4 on an item marked.

5 Figure 13A is a fragmentary elevational view of a thermal bubble ink jet
6 marking mechanism in its initial state adjacent an item to be marked.

7 Figure 13B is a fragmentary elevational view of a thermal bubble ink jet
8 marking mechanism in its ink discharging condition depositing a droplet on an adjacent item
9 to be marked.

10 Figure 13C is a fragmentary elevational view of a thermal bubble ink jet
11 marking mechanism in its ink recharging condition with an ink mark on an adjacent item to
12 be marked.

13 Figure 14 is a diagrammatic representation of Cartesian points set by the
14 height and displacement sensors carried by the sensor bar of a section of an item traversed by
15 the sensor bar, the volume of which is to be determined by the signal processor.

16 Figure 14A is a diagrammatic depiction of various shapes defined by the item
17 segment represented in Figure 14.

18 Figure 14B is a view of the diagram of Figure 14 with certain lines used to
19 calculate the volume of the item segment represented.

20 Figure 14C is a diagram showing additional lines used in a calculation of the
21 item section volume.

22 Figure 15A is a pictorial representation of another embodiment of an
23 apparatus according to the invention incorporating an unconstrained sensor bar with certain

1 lines indicated thereon used to calculate an item section volume.

2 Figure 15B is a diagram of certain sensor bar features illustrating distances
3 used in a calculation of item section volumes.

4 Figure 16 is a pictorial view of a cutting table incorporating an
5 electromagnetic digitizer for detecting support post displacement, with a fragmentary view of
6 the lower end of one support post.

7 Figure 17 is a pictorial view of a cutting table using a pressure sensitive
8 surface for detecting displacement of the support posts, with a fragmentary bottom portion of
9 one support post.

10 Figure 18A is a partially sectional view of a sensor bar incorporating acoustic
11 height sensors, with a diagrammatic representation of acoustic waves emanating from each
12 sensor impinging an item shown resting on a table surface beneath the sensor bar.

13 Figure 18B is a pictorial representation of another embodiment of an apparatus
14 according to the invention utilizing a sensor bar supporting a two dimensional array of
15 acoustic sensors mounted to a transparent plate attached to the sensor bar, with a diagram of
16 certain distances involved in calculating the height of points on the upper surface of the item.

17 Figure 18C is a diagrammatic representation of the distances involved in
18 detecting the height of points on an item by the acoustic detector array incorporated in the
19 sensor bar shown in Figure 18B.

20 Figure 18D is a pictorial representation of apparatus shown in Figure 18B with
21 a diagram of certain distances involved in determining multiplexing values.

22 Figure 18E is a diagram of certain distances used to calculate multiplexing
23 values for the sensor bar shown in Figure 18D.

1 Figure 19A is a partially sectional view of a sensor bar incorporating optical
2 detectors used to determine the height of points on a flat shaped item shown resting on a table
3 surface, with a diagrammatic representation of light waves impinging on the item.

4 Figure 19B is a pictorial representation of another embodiment of an apparatus
5 according to the invention incorporating a two dimensional array of optical height sensors on
6 a sensor bar, with a diagram of distances involved in calculating the height of the points of
7 the curved surface item shown.

8 Figure 20 is a partially sectional view of a sensor bar having a series of
9 sensors mounting thereon utilizing penetrating waves to determine the thickness of a segment
10 of an item resting on a table surface.

11

12 Detailed Description

13 In the following detailed description, certain specific terminology will be
14 employed for the sake of clarity and a particular embodiment described in accordance with
15 the requirements of 35 USC 112, but it is to be understood that the same is not intended to be
16 limiting and should not be so construed inasmuch as the invention is capable of taking many
17 forms and variations within the scope of the appended claims.

18 Referring to the drawings, and particularly Figure 1, the apparatus 10
19 according to the present invention includes a planar table or other support surface 12 on
20 which may be deposited an item 14, such as the fish fillet represented in phantom lines. The
21 table surface 12 may be defined by a cutting board material suitable for cutting the item 14
22 once a desired segment is selected as described below.

23 The item 14 should be substantially flattened on the side resting on the table or

1 other support surface 12 in order for the weight determination to be accurate.

2 An elongated sensor bar 16 is also included in the apparatus 10 which may be
3 conveniently manually manipulated by a person gripping a handle 18 at the near end thereof.

4 The sensor bar 16 is supported spaced above the table surface 12 at a
5 predetermined height by a support arrangement comprised of two support posts 20, 22 fixed
6 to and extending down from the underside of the sensor bar 16.

7 In the embodiment shown, the sensor bar 16 is manually positioned by the
8 user to be upright and extending normally from the front to the rear of the table surface 12, as
9 the sensor bar 16 is freely movable in any way in the plane of the surface 12 and also may be
10 freely lifted from the surface 12 for use elsewhere.

11 In this embodiment, the support posts 20, 22 should be held as close to plumb
12 as possible and a spirit level 24 on a signal processor-controller case 26 may assist in this.

13 An out of plumb alarm or indicator 302 (Figure 1A) in the case 26 may be provided
14 responsive to an excessive tilted orientation of the sensor bar 16 as detected by the level 24.

15 The user initially positions the sensor bar 16 at one end of the item 14 and
16 strokes the same across the width of the table surface 12 thereby passing the sensor bar 16
17 along the length and over the item 14.

18 As will be described below in further detail, the sensor bar 16 in this
19 embodiment mounts a linear array of sensors 38 along its length (depicted only
20 diagrammatically in Figure 1) which each simultaneously or sequentially senses the height of
21 the upper surface of the item 14 above the table surface 12 at a point lying beneath the
22 particular sensor 38 and generates corresponding signals.

23 At the same time, a displacement detector 20A, 22A is associated with each

1 support post 20, 22, producing signals corresponding to the extent and direction of the
2 displacement of the sensor bar 16 in the plane parallel to the surface 12 when being passed
3 over the item 14.

4 The height sensor signals correspond to a close approximation of the cross
5 sectional contour of successive sections of the item 14 at each position of the sensor bar 16 in
6 being passed over the item 14. These signals may be processed by a suitable program of a
7 programmable microprocessor controller 300 contained in a signal processor-controller case
8 26 (which may be powered by a battery 306), with the incremental displacement values as
9 measured by the displacement detectors 22A, 20A, and the contour of each successive section
10 sensed by sensors 38 enabling calculation of an aggregate or running total volume of the
11 segment of the item 14 traversed by the sensor bar 16 along its path of movement. The
12 nature of this calculation is described in further detail below.

13 The calculated cumulative volume of each segment of the item 14 passed over
14 by the sensor bar 16 is multiplied by a density factor for the particular item type, which can
15 be stored in the memory of the signal processor 300, selectively input using keyboard 27 or
16 uploaded via input/output port 58, to arrive at segment weight values for each position of the
17 sensor bar 16, and a corresponding numeric value continuously or selectively displayed on an
18 adjustable tilt display screen 30 mounted to the case 26. A cost for each segment may also be
19 calculated by multiplying the segment weight value by the input cost per unit weight value
20 and selectively displaying either the weight or cost alternatively or at the same time.

21 The display 30 and signal processor 300 may be reset for each new operation
22 by a suitable reset button.

23 A knife blade 15 may be mounted to the sensor bar 16 for cutting a segment

1 from the item 14 as will be described below.

2 In this application, various sensor bar configurations as well as various devices
3 that may be used with these different configurations are described. To demonstrate the
4 operational theory of these designs, a limited number of possible configurations of sensor
5 bars and devices are detailed as examples; however, various combinations of sensor bars and
6 related devices either here described or known elsewhere in the art may be utilized together
7 to meet the requirements of specific applications.

8 Figure 2A shows an alternate support arrangement for supporting a sensor bar
9 16A spaced above a table 32 defining a support surface 34 on which an item 14 is placed, as
10 in the above described embodiment.

11 The sensor bar 16A is connected at either end to a pair of uprights 36A, 36B to
12 form a bridge structure spanning the front to rear dimension of the table 32.

13 The uprights 36 may be supported on suitable guide bearings engaging ways
14 located beneath the table 32 (in a manner not shown but well known in coordinate measuring
15 machines) to allow low friction guided and constrained movement maintaining the
16 orientation of the sensor bar 16A both as to plumb and squareness to the table surface 34 for
17 accurately oriented manual or powered stroking movement of the sensor bar 16A across the
18 width of the table 32.

19 That is, the way bearings support and accurately guide the uprights 36A, 36B
20 to insure squareness of the sensor bar 16A to the table edge as well as to maintain the same in
21 a vertical orientation above the surface 34.

22 A linear array of sensors 38 is mounted along the underside of the sensor bar
23 16A on a forward projecting ledge 17, which generate electronic signals corresponding to the

1 cross sectional contour of the item 14 lying beneath the sensor bar 16A. This done by
2 measuring the height above the surface 34 of points on the upper surface of the section of the
3 item 14 lying below the respective sensor 38. Such sensors 38 may take various forms such
4 as the mechanical, acoustic, or optical devices as described hereinafter.

5 A displacement detector 40 is associated with one of the uprights 36B. A well
6 known form of displacement detector comprises a Moiré fringe device described in U.S.
7 Patent 2,886,717, comprised of an elongated grid 42 fixed along one edge of the table and a
8 slightly tilted optical grating 44 mounted to the upright 36B above the grid 42. When the grid
9 42 is illuminated, relative movement in either direction produces a shifting shadow pattern in
10 either direction, a corresponding number of shadows produced for each incremental
11 displacement of the uprights 36B (and 36A), which can be counted up or down by a light
12 sensor (not shown) to produce a corresponding digital signal in the manner well known in the
13 art. Many other linear displacement detectors are known in the art which could be employed
14 to detect displacement of the sensor bar 16A instead of the Moiré fringe device described.

15 An input keyboard 27 and display 35 allows density settings, etc., to be
16 entered into the signal processor 300 contained within the signal processor controller case 26.

17 In this embodiment, the sensor bar 16A is constrained by the manner of its
18 support, i.e., is held in the vertical orientation and maintained square to the table surface 34 as
19 it is stroked laterally across the width of the table 32. The user need only push or pull the
20 sensor bar 16A along in its constrained path.

21 This simplifies the calculation of segment volumes as skewing or shifting of
22 the sensor bar 16 can occur when it is unconstrained, and each successive section of the item
23 14 might be of a tapered shape requiring more complex calculations.

1 A separate knife (not shown) may be used to cut the selected item segment
2 using the side surface 17 of uprights 36A and 36B as a guide. The sensor bar 16A can also
3 be moved out of the way when carrying out the cutting step.

4 Figure 2B illustrates an alternative embodiment which has a capability of
5 cutting a selected segment from the item 14. A tubular guide rail 206 constrains the bi-
6 directional movement of bracket 208 that is attached to the cutting blade position handle 201.
7 Cutting blade armature 203 protrudes through slot 200 and is affixed at its upper end to
8 cutting blade position handle 201. The base end of cutting blade armature 203 is affixed to
9 the manual or electrically powered rotary cutting blade 204. While securely holding the item
10 14 down against the table surface 34 with one hand, the operator's other hand grips the
11 upward protruding handle 210 and moves the cutting blade position handle 201 in a forwards
12 (and/or backwards) motion producing cuts 214 which segment the item 14 into the desired
13 portion. Pushbutton 202 controls the application of power to the motorized rotary cutting
14 blade 204 implementation.

15 In a non-motorized rotary blade implementation of Figure 2B, a spring
16 assembly (not shown) is positioned between the cutting blade position handle 201 and the slot
17 200. This assembly normally pulls the cutting blade armature 203 upwards and enables the
18 cutting blade 204 to successively cut deeper and deeper into the item 14 as the operator
19 applies greater pressure on the cutting blade position handle 201 during the forward and
20 backwards motion of the cutting position handle 201. This enables the operator to easily
21 control the depth of each successive cut as the blade 204 approaches the table surface 34.
22 The aforementioned spring assembly is not required for the electrically motorized rotary
23 cutting blade 204 implementation of Figure 2B, as the item 14 is severed with one complete

1 movement of cutting blade position handle 201.

2 Figure 2C illustrates an additional alternative mechanism used to cut the
3 selected item segment. A guillotine chopping mechanism includes a housing 224 which
4 encloses a cutting blade extender/retractor mechanism 228 that is fastened to chopping blade
5 232 by flush mounting screws 238. While securely holding the item 14 down against the
6 table surface 34 with one hand, the operator's other hand depresses one of the appropriately
7 designated "cut" pushbuttons 56A-56K to control the application of electrical power to the
8 cutting blade extender/retractor mechanism 228 whereby the cutting edge 236 of cutting
9 blade 232 is forced in a downward direction causing the item 14 to be segmented into the
10 desired portion.

11 Figure 2D illustrates another embodiment of the invention incorporating an
12 alternative mechanism to cut the selected item segment. A tubular guide rail 206 constrains
13 the bi-directional movement of bracket 208 that is attached to the cutting position handle 201.
14 Laser mechanism 216 protrudes through slot 200 and is affixed at the upper end to cutting
15 position handle 201. The operator grips the upward protruding handle 210 while moving the
16 cutting position handle 201 in a forwards (and/or backwards) motion producing laser cuts 220
17 from laser light 218 which segment the item 14 into the desired portion. Pushbutton 202
18 controls the application of electrical power to the laser mechanism 216.

19 The described sensing and cutting mechanisms illustrated in Figures 2A, 2B,
20 2C, 2D, 2E can be incorporated into an industrial automated environment whereby the table
21 surface 34 is replaced with a conveyer belt 28 supported by rollers 33 as shown in Figure 5B.
22 Items 14 placed on the conveyer belt 28 are passed under the sensors 38 on sensor bar 16A
23 and cutting 232 as shown in Figure 2C. Computer controlled mechanisms would replace the

1 manual operator controlled functions.

2 Figure 2E illustrates another embodiment of the apparatus incorporating a
3 mechanism used to both measure the volume (and hence the weight based on density, and the
4 cost based on weight) and cut the item 14 into the desired segment size. The illustrated
5 embodiment utilizes a stepper motor assembly 266 which controls the lateral movement of
6 bracket 268 as it traverses laterally across the table surface 34. An additional stepper motor
7 assembly 264 controls the vertical movement of the sensor/cutter assembly 250 which is
8 attached to stepper motor assembly 264 mounted on a bracket 251. Each stepper motor
9 assembly 264, 266 controls the precise linear positional movement of sensor/cutter assembly
10 250 along the lateral and vertical axis of table surface 34 as it traverses the item 14 surface.
11 The combined operation of the dual stepper motor assemblies 264, 266 in controlling the
12 precise position of the sensor /cutter assembly 250 corresponds to the assemblies used to
13 control the position and movement of ink pens used in digital computer plotters. Such
14 plotters have been employed in business and industry for many years.

15 The sensor/cutter assembly 250 consists of a "spot triangulation" height sensor
16 38 hereinafter referred to as height sensor 252 which protrudes through slot 200 and is
17 affixed to the bottom end of sensor/cutter mechanism 250. Height sensor 252 is comprised of
18 an optical emitter unit 254 and optical receiver unit 262. The emitter unit 254 projects
19 perpendicularly downward along the path 256 a light "spot" 258 onto the upper surface of the
20 item 14. The receiver unit 262 images this spot along the path 260 onto an internal CCD
21 (Charge Coupled Device) array or other PSD (Position Sensitive Detector) such as a
22 photodiode array. The distance between sensor 252 (emitter 254) to the perpendicularly
23 projected spot 258 on the upper surface of item 14 directly beneath emitter 254 is calculated

1 by a signal processor integrated into height sensor 252 or by the signal processor 300 in
2 display case 26. A full description of the operation and associated height calculations
3 regarding use of this "spot triangulation" height sensor 252 is described below in the section
4 entitled "Spot Triangulation Based Optical Height Sensor".

5 When the bracket 268 is in a stationary position, the stepper motor assembly
6 264 moves the sensor/cutter assembly 250 from the base side (nearest the operator) of bracket
7 268 to the top side (farthest from the operator) of bracket 268. During this movement, the
8 height sensor 252 is continuously determining the height above the support surface 34 of the
9 underlying item 14 segment directly beneath the sensor 252. As will be described later in
10 complete detail, these height values enable the calculation of the approximate cross sectional
11 area of the item 14 segment traversed by height sensor 252. When the sensor/cutter 250
12 completes its travel at the end of bracket 268, stepper motor assembly 266 incrementally
13 moves laterally to the succeeding position whereby the sensor/cutter assembly 250 then
14 moves in the opposite direction of its current position by action of stepper motor assembly
15 264. The multiplicative product of the incremental distance just traveled by bracket 268 by
16 the just computed cross sectional area of the item 14 results in the volume of the item 14 just
17 traversed by the height sensor 252. As the stepper motor assembly 266 continues to move
18 bracket 268 in a lateral direction across the table surface 34, then stops and waits until
19 sensor/cutter assembly 250 completes its pass from one end of bracket 268 to the other end of
20 bracket 268, the aggregate total volume of item 14 traversed by sensor/cutter assembly 250 is
21 continuously calculated by the signal processor 300 in display case 26 and presented on
22 display 30.

23 Laser cutting mechanism 216 protrudes through slot 200 and is affixed to the

1 bottom end sensor/cutter mechanism 250. Upon reaching the desired item 14 segment weight
2 (or cost based on weight), the stepper motor assembly 264 positions sensor/cutter mechanism
3 250 at either end of bracket 268, whereby stepper motor assembly 264 then moves
4 sensor/cutter assembly 250 from its current position to the opposite oriented position along
5 bracket 268. During this movement, laser cutting mechanism 216 emits light 218 resulting in
6 a continuous cut 220 through item 14, thus severing item 14 as the sensor/cutter mechanism
7 250 progresses across the item 14.

8 Many other types of cutting mechanisms such as (but not limited to) rotating
9 blades 204 as exhibited in Figure 2B, or high pressure water cutters may be employed in
10 place of the aforementioned laser cutting device.

11 This embodiment of sensor arm 16A whereby a movable height sensor device is
12 mechanically moved over an item 14 has many advantages over other non-mechanically
13 driven sensor arm designs presented in this application. By employing only one movable
14 height sensor versus multiple height sensors spaced along the sensor bar 16A length, the
15 number of measured height values along the length of the sensor arm 16A is only limited by
16 the incremental positioning accuracy of the stepper motor assembly 264. This avoids the
17 limit imposed by the number of height sensors that can be physically placed (or fit) along the
18 sensor bar 16A length, whether such height sensors are all placed in a linear order, or
19 multiple rows of height sensors are placed adjacent to each other. Also, by employing only
20 one height sensor, possible interference between multiple height sensors signals is eliminated.
21 Similarly, the overall cost of height sensor mechanisms employed is reduced to the one
22 height sensor versus multiple units.

23 The height sensors 38 themselves may be based on many different

1 technologies such as (but not limited to) optical, mechanical, and acoustical. Some of the
2 various types of height sensors are outlined in the section below titled Additional Height
3 Sensor Technologies. Following is a description of a sensor bar utilizing “spot” triangulation
4 based optical height sensors, succeeded by a description of a sensor bar utilizing “plunger”
5 based mechanical height sensors:

6 “Spot” Triangulation Based Optical Height Sensor

7
8 Referring to Figures 3A, 3B, and 3C, a “spot” triangulation based optical
9 height sensor 38F is shown incorporated in the sensor bar 16F as a linear array arranged
10 along the length of the sensor bar 16F. Each height sensor 38F is comprised of an optical
11 emitter and receiver unit embedded in the sensor bar 16F. Various optical emitter
12 technologies may be employed such as (but not limited to) LED devices and lasers. The
13 emitter unit 38F-1 projects perpendicularly downward along the path 37A a light “spot” 37B
14 onto the upper surface of the item 14. The lens of the offset receiver unit 38F-2 images this
15 spot along the path 37C onto an internal CCD (Charge Coupled Device) array or other PSD
16 (Position Sensitive Detector) such as a photodiode array which then determines the imaged
17 angle (θ) of the spot 37B (Z) relative to the horizontal line formed by the positions of the
18 emitter 38F-1 (X) and receiver 38F-2 (Y). The distance from the sensor 38F (emitter 38F-1)
19 to the perpendicularly projected spot 37B on the upper surface of item 14 directly beneath
20 sensor 38F is calculated by a processor integrated into height sensor 38F or by the signal
21 processor in display case 26.

22 The use of the term “optical” and “light” in this application does not imply
23 only the use of the visible wave portion of the electromagnetic spectrum, but includes all

1 portions (e.g., infrared) of the spectrum that exhibit necessary characteristics of the described
2 technology.

3 The trigonometric method employed to determine the distance from emitter
4 38F-1 to the light spot 37B projected onto the upper surface of item 14 is based on the
5 distance measuring principle of triangulation. Again referring to Figure 3B, the emitter 38F-
6 1 (X) perpendicularly projects a light spot 37B (Z) onto item 14 upper surface. The receiver
7 38F-2 (Y) images this spot onto a Position Sensitive Detector, e.g. a CCD array, which
8 determines the imaged angle (e) of the spot relative to the horizontal line formed by the
9 positions of the emitter X and receiver Y.

10 A right triangle is formed at the vertex X of the three triangular coordinates
11 YXZ, therefore, the following trigonometric relationship applies:

12 (I) $\text{Tan}(e) = c / a$

13

14 Thus, the distance (c), from the emitter 38F-1 (X) to the projected spot 37B (Z) is expressed
15 as:

16 (II) $c = (a) \text{Tan}(e)$

17 The distance, (a), between the emitter (X) and receiver (Y), is a known constant for the
18 specific sensor 38F employed. The angle (e) is determined by the Position Sensitive Detector
19 (e.g., CCD array), thus enabling the calculation of Tan(e). Therefore, the product of (a) and
20 Tan(e) yields the distance, (c), between the emitter 38F-1 (X) and the projected spot 37B (Z).
21 Subtracting the above optically determined distance (c) from the known (constant) sensor bar
22 height (sensor 38F to table surface 12 distance), yields the height of the item 14 upper surface
23 relative to the table surface 12 directly below sensor 38F.

1 If all sensor 38F emitters simultaneously project an optical spot on the upper
2 surface of the item 14, sensor 38F receivers may detect spots that did not originate from the
3 same sensor 38F emitter. This likelihood increases if larger emitted optical beam widths are
4 employed and/or sensor arrays along the length of the sensor bar 16F are comprised of a high
5 density of sensor 38F units. Such interference could result in erroneous item 14 height
6 calculations and can be avoided by multiplexing the operation of the linear array of sensor
7 38F units along the length of the sensor bar 16F.

8 Instead of all sensor 38F units projecting optical spots simultaneously, each
9 sensor 38F is both activated and deactivated sequentially along the length of the sensor bar
10 16F. A successive sensor 38F emitter is not activated until the currently activated sensor 38F
11 calculates the distance parameters for the currently projected spot on the upper surface of the
12 item 14 and is then de-activated. Instead of monitoring the completion of processing for each
13 individual sensor 38F, each successive sensor 38F along the sensor bar 16F may be activated
14 and deactivated at a fixed length time interval that is the maximum time required for a sensor
15 38F to both project a spot and process the distance parameters for that spot. This maximum
16 time is determined by use of the sensor 38F operating specifications whereby the longest
17 (e.g., "worst case") amount of time required to process one height value is utilized.
18 Implementing a multiplexing fixed length time interval longer than this maximum time
19 period ensures that only one sensor 38F is operating at a time and thus eliminates spot
20 recognition errors from multiple sensor 38F units.

21 A sensor 38F may not locate and process an emitted spot image within the
22 allocated multiplexed time interval for reasons such as unfavorable item 14 surface image
23 formation characteristics, or a debris obstructed sensor 38F emitter and/or receiver. In such

1 cases, the item 14 height at this sensor 38F position can be obtained by extrapolating height
2 values determined for surrounding sensor 38F positions.

3 Referring the Figure 3C, increasing the density (the number of sensor 38F
4 units per sensor bar 16F) may be accomplished by incorporating additional sensor 38F units
5 in a row alongside the already described linear array of sensor 38F (R1) units spanning the
6 sensor bar 16F. As illustrated, linear array(s) of sensors 38F (R2) may also be placed
7 adjacent to each other either in a staggered or collinear (not shown) configuration to form a
8 two-dimensional array of sensor 38F units. Calculations requiring the position of each
9 sensor 38F incorporate offset distance factors to account for these offset sensor positions.
10 The increased sensor density enables the collection of more coordinate data points per given
11 surface area of item 14, and hence increases the overall accuracy of the volume and resultant
12 weight and cost (based on weight) calculations.

13 Many "spot" triangulation based optical distance sensors are currently
14 available and are used in diverse applications such as measuring tolerances, determination of
15 positions, gauging existence and extent of material deformation, and quantifying mechanical
16 vibration characteristics.

17
18 "Plunger" Based Mechanical Height Sensor
19

20 Figure 4 shows the sensor bar 16B with a mechanical height sensor
21 arrangement comprised of a linear array of spring urged extendible plungers 46 distributed
22 along the length of the sensor bar 16B. The plungers 46 are each normally biased to a fully
23 extended position by an associated compression spring 48 disposed in a pocket 50 formed in
24 the sensor bar 16B able to receive the length associated with plunger 46 when retracted
25 thereinto. The tip of each plunger 46 is capable of reaching the table surface 12. The

1 presence of any part of the item 14 beneath a particular plunger 46 causes that plunger 46 to
2 be retracted a distance corresponding to the height of the surface of this item 14 above the
3 table surface 12, which in turn corresponds to the thickness of the item 14.

4 The extent of retracting travel of each plunger 46 is sensed by a linear
5 displacement sensor arrangement disclosed hereinafter, which generates corresponding
6 electrical signals.

7 Many different types of displacement sensing technologies may be employed
8 such as (but not limited to) optical, optical-mechanical, mechanical, and electromagnetic.
9 The linear displacement sensor arrangement illustrated below is based on a photoelectric
10 "reflection" sensor array.

11 Linear Displacement Sensor Based On Photoelectric Reflection Sensor Array

12 Figures 6A, 6B, and 7 show details of the arrangement sensing the retraction
13 travel of the plungers 46. Each plunger 46 has a flattened side 60 facing a sensor rod 62 also
14 having a flattened side 64 facing plunger side 60. The flat side 60 of the plunger 46 has a
15 reflective surface imprinted with non-reflective tracking patterns. A linear array of
16 equidistantly spaced angled light emitters (e.g., LED devices) 66 is embedded along the
17 length of the sensor rod 62 directed at the flattened side 60 of the plunger 46, and a similar
18 linear array of equidistantly spaced angled photoelectric receivers 68 is embedded along the
19 length of the sensor rod 62 positioned to receive light from a respective emitter reflected from
20 the side 60.

21 As the plunger 46 moves up and down through the cavity formed by the
22 solenoid coil windings 70 and sensor rod 62, the photoelectric emitter 66 / receiver 68 sensor
23 array determines the displacement distance of the plunger 46 by tracking the changing

1 patterns of received reflected light. To eliminate false readings caused by reflections from
2 the solenoid spring 48 when it occupies the plunger 46 position, the spring 48 has a matte,
3 non-reflective surface (finish).

4 Increasing the density, the number of height sensor plungers 46 per sensor bar
5 16B, may be accomplished by incorporating additional plunger 46 units along the existing
6 linear array of plunger 46 units which span the sensor bar 16B. One or more rows of
7 plungers 46 may also be placed adjacent to each other either with the individual sensors
8 staggered or side by side to form a two-dimensional array of height sensor plunger 46 units.
9 Calculations requiring the position of each plunger 46 incorporate offset distance factors to
10 account for these (adjacent) offset sensor positions. The increased sensor density enables the
11 collection of more coordinate data points per given surface area of item 14, and hence
12 increases the overall accuracy of the volume and resultant weight and cost (based on weight)
13 calculations.

14 Referring to Figures 3A and 4, sensor bar support posts 52 are provided at
15 each end of the sensor bar 16F (and 16B) which may also be retractable for a purpose to be
16 described below. A displacement detector arrangement for generating signals corresponding
17 to the extent and direction of displacement of the sensor bar 16F (or 16B) in a plane parallel
18 to the support surface 12 during stroking thereof. This arrangement includes displacement
19 detectors 54 at the bottom of each support post 52, examples of suitable detectors 54
20 described in detail below. Each detector 54 generates electronic signals corresponding to the
21 position and extent of horizontal travel of the end of each post 52 when the sensor bar 16F (or
22 16B) is stroked across the table surface 12 from a start position beyond one end of the item

1 14. As the sensor bar 16F (or 16B) is stroked across the table surface 12, the bottom end of
2 each support post 52 is kept in constant contact with the table surface 12.

3 Sensor bar support post 52 displacement detectors 54 may be based on many
4 different technologies such as (but not limited to) optical, optical-mechanical,
5 electromagnetic, mechanical, and pressure-sensitive (tactile). Some of the various types of
6 post displacement detectors are outlined in the section titled Additional Support Post
7 Displacement Detector Technologies. Following is a description of an optical based support
8 post displacement detector and an optical-mechanical based support post displacement
9 detector.

10 Theory and Operation of the Optical Support Post Displacement Detector

11 Figure 8A depicts diagrammatically an optical support post displacement
12 detector 54 associated with each support post 52. This embodiment includes a light emitter
13 74 such as a LED which directs a light beam onto the table surface 12 through an opening in
14 the support post 52, a focusing lens 76 which receives light reflected from the table surface
15 12, a light sensitive receiver or sensor 78 which generates electronic signals corresponding to
16 the reflected light images which are transmitted to an image analyzer 80.

17 As each support post 52 traverses the table surface 12 while sensor bar 16F (or
18 16B) is passed over the item 14, successive frame images 82A, 82B, 82C (Figure 8B) of the
19 surface 12 are generated. Fine surface details, (e.g., texture, color, contrasts, etc.,) inherent
20 on the table surface 12 are analyzed to determine the extent and direction of displacement of
21 each support post 52 as it is moved over the table surface 12.

22 The above described optical displacement detector technology is non-
23 mechanical, requires no moving parts, requires no preprinted (embedded, engraved, etc.)

1 tracking patterns on the table surface 12, and is compatible with a wide variety of
2 conventional "off-the-shelf" cutting boards, tables, etc.

3 Such a displacement detector is currently used in many computer mouse
4 devices. As examples of commercially available components of this type, are Agilent
5 Technologies reflective optical sensor HDNS-2000, lens HDNS-2100, LED assembly clip
6 HDNS-2200 and 5mm red LED HLMP-ED80. See also Agilent Technologies Application
7 Note 1179, entitled "Solid-State Optical Mouse Sensor with PS/2 and Quadrature Outputs"
8 for further operational details.

9 Theory and Operation of the Optical-Mechanical Support Post Displacement Detector

10 An optical-mechanical displacement detector 54A is shown in Figures 9A, 9B
11 and 9C, which includes a ball 84, an X axis roller 86, a Y axis roller 88, attached X axis
12 perforated optical encoder disc 90 and Y axis perforated optical encoder disc 92, optical
13 emitters 94, 96 and optical receivers 98, 100. As the ball 84 rolls along the (non slip) table
14 surface 12, the rollers 88 and/or 86 are rotated by frictional contact with the ball 84, causing
15 the discs 90, 92 to also be rotated. The perforations in each optical encoder disc create a
16 number of light and dark patches from light emitted by emitters 94, 96 which are detected by
17 receivers 98, 100 and analyzed. This produces electrical signals corresponding to the
18 displacement of the post 52 along either X and Y axis.

19 The above described mechanical displacement detector technology requires
20 no preprinted (embedded, engraved, etc.) tracking patterns on the table surface 12, and is
21 compatible with a wide variety of conventional "off-the-shelf" cutting boards, tables, etc.
22 Such displacement detectors are well known in the art, are currently used in many computer
23 mouse devices.

1 As the sensor bar 16F (or 16B) is stroked across the item 14 surface, the
2 signals corresponding to the position of each support post 52 as well as the corresponding
3 sensor 38F (or mechanical plunger 46) height positions are continuously captured and
4 transmitted to a signal processor 300 in the case 26. The contoured height positions of the
5 item 14 (data from the height sensors) as well as the corresponding underlying surface area
6 (calculated from positions of the support posts 52) enables the continuous calculation and
7 display of the volume of each segment defined by the sensor bar 16F (or 16B) as it traverses
8 from one end of the item 14 to each successive position in being stroked along the item 14.
9 As the density of each type of item 14 is recorded in the signal processor 300 memory, the
10 real-time calculated volume, weight (volume x density), and associated cost (weight x cost
11 per weight) is continuously displayed on the display 30. Display 30 has an ergonomic swivel
12 and tiltable base 31 to establish a desired viewing angle for ease of operator and customer
13 viewing.

14 Intermittently reversing the direction of movement of the sensor bar 16F (or
15 16B) as it the item 14 is mathematically accounted for by subtracting or adding the traversed
16 volume of the item 14 during the backwards or forwards movements respectively. This
17 enables a continuous readout of the weight and cost (based on weight) of the item 14 as the
18 sensor bar 16F (or 16B) moves forwards or backwards, enabling the operator to accommodate
19 an on-looking consumer's specific requests as per the particular portion desired based on the
20 item 14 physical appearance, weight, and cost BEFORE the item 14 is cut!

21 Figure 1 shows the attachment of knife blade 15 to the sensor bar 16, utilizing
22 protrusions 102 snap fitted into corresponding holes in the knife blade 15, which also has
23 ends snapped into recesses 104 adjacent at each end of the sensor bar 16. The knife blade 15

1 is received into a recess 106 in one side face of 108 of the sensor bar 16 to be located flush
2 therewith. Easy attachment/detachment of the knife blade 15 enables the use of different
3 types of knife blades for the requirements of differently composed items 14.

4 In the case of sensor bar 16F, when the position of sensor bar 16F reaches the
5 desired weight (or cost) of the item 14, the operator manually applies a downward pressure
6 on the sensor bar 16F causing both retractable posts 52 to retract upwards resulting in knife
7 15 moving downwards and making contact with the item 14. Simultaneously applying a
8 continued downward pressure and exerting a back and forth sawing motion across the item 14
9 surface results in the item 14 being completely cut to form the desired segment. Knife blade
10 15 may also be used only to mark (score) the item 14 surface whereupon an independent
11 cutting tool may be used to perform the final cutting of the item 14.

12 After the item 14 is completely cut (or scored) and the sensor bar 16F is again
13 elevated by action of the spring-loaded retractable posts 52 fully extending themselves, the
14 operator depresses the appropriately designated "reset" pushbutton 56A-56K causing the
15 display 30 to clear and the signal processor 300 to ready the sensor bar 16F for new item 14
16 data. The sensor bar 16F is now ready to be stroked over a new item 14.

17 In the case of sensor bar 16B, when the position of the sensor bar 16B reaches
18 the desired weight (or cost) of the item 14, the operator depresses the appropriately
19 designated "cut" pushbutton 56A-56K. Referring to Figures 6A and 6B, a brief pulse of
20 electric power is applied to each solenoid coil windings 70 resulting in the complete
21 retraction of all plungers 46 into the sensor bar 16B, thus compressing spring 48 to bring the
22 stem 47 of plunger 46 against a permanent magnet 72. Each plunger 46 (stem 47) becomes
23 "latched" (held adjacent) to the permanent magnet 72. The plungers 46 remain retracted,

1 aligned next to permanent magnet 72 without further application of electric power solely due
2 to the attractive force of the permanent magnet 72. As described latter, the retracted position
3 of each plunger 46 can be further secured by use of side-mounted solenoid plungers.

4 With all plungers 46 in their fully retracted position, the cutting edge of the
5 knife 15 becomes completely exposed. By manually applying a downward pressure on the
6 sensor bar 16B, both retractable posts 52 retract upwards causing the knife 15 to move
7 downward and make contact with the item 14. Simultaneously applying a continued
8 downward pressure and exerting a back and forth sawing motion across the item 14 surface
9 results in the item 14 being completely cut to form the desired segment. Knife blade 15 may
10 also be used only to mark (score) the item 14 surface whereupon an independent cutting tool
11 may be used to perform the final cutting of the item 14.

12 After the item 14 is completely cut (or scored) and the sensor bar 16B again
13 elevated by action of the spring-loaded retractable posts 52 fully extending themselves, the
14 operator depresses the appropriately designated "reset" pushbutton 56A-56K causing a brief
15 pulse of electric power of the opposite polarity (of that initially used to retract each plunger
16 46) to be applied to each solenoid coil windings 70 enclosing the plungers 46. Each of the
17 plungers 46 is thus released from the permanent magnet 72 hold and resumes a fully extended
18 position by overcoming the attraction of the permanent magnet 72 and the automatic
19 extension of the compressed springs 48 to their normally extended configuration. The
20 simultaneous action of this "reset" pushbutton is to also cause the display 30 to clear and the
21 signal processor 300 to ready the sensor bar 16B for new item 14 data. The sensor bar 16B is
22 now ready to be stroked over a new item 14.

23 Various industrial applications may utilize different cutting methods in place

1 of the above described knife 15. For example, items 14 may pass via a conveyor belt (Figure
2 5B) under a stationary sensor bar 16A whereupon an automatic chopping blade, laser, rotary
3 blade, or high-pressure water cutter cuts the items 14 into specific portions based on weight
4 or cost. Alternatively, a movable sensor bar 16A may traverse over stationary single or
5 multiple items 14 whereupon the items 14 are cut by the aforementioned cutting tools. In
6 either case, as the plungers 46 never need to be retracted into the sensor bar 16 in order to
7 expose a knife 15, the solenoid latching mechanism is omitted. Similarly, the knife 15 may
8 be omitted from the sensor bar 16 in these configurations.

9 As mentioned above, the sensor bar 16 controller signal processor 300 case 26
10 may have a mercury tilt indicator switch 24 (or similar level indicator) that sounds an alarm
11 302 (Figure 1A) when the sensor bar 16 tilts more than a predefined maximum angle from the
12 vertical (90 degree) position in relation to the table surface 12. As the sensor bar 16 traverses
13 the item 14, an out-of-bounds tilt angle will cause the alarm 302 to sound indicating that the
14 item scan will need to be redone. Alternatively, acceptable out-of-bounds tilt angles can be
15 measured and mathematically compensated for in the volume calculations so that the item
16 scan can proceed without interruption. Along with the signal processor controller 300, tilt
17 switch 24, and sensor bar 16 battery supply 306, the alarm 302 is also contained within the
18 controller-signal processor case 26.

19 Disallowed sensor bar 16 movements are also detected by electrical signals
20 from displacement detectors 20A and 22A corresponding to positions of support posts 20
21 and 22. An example is when the operator holds the sensor bar 16 in too great of a horizontal
22 instead of a more perpendicular position in relation to the operator. Another example is if the
23 operator moves the sensor bar 16 too fast or too slow, or lifts one/both support posts 20, 22

1 off the table surface 12. The detected support post coordinate positions or lack of coordinate
2 positions causes the alarm 302 to sound indicating that the item 14 scan will need to be
3 redone.

4 Intermittently reversing the direction of movement of the sensor bar 16 as it
5 traverses the item 14 is mathematically accounted for by subtracting or adding the traversed
6 volume of the item 14 during the backwards or forwards movements respectively. This
7 enables a continuous readout of the weight and cost (based on weight) of the item 14 as the
8 sensor bar 16 moves forwards or backwards, enabling the operator to accommodate an on-
9 looking consumer's specific requests as per the particular portion desired based on the item
10 14 physical appearance, weight, and cost BEFORE the item 14 is cut!

11 The controller signal processor 300 may be a commercially available
12 programmable microprocessor based computer chip contained within the case 26. The
13 microprocessor signal processor 300 is programmed to perform coordinate, position, volume,
14 weight, cost and other required computations as described herein. The inputting of initial
15 data (e.g., density, cost per weight, product code number, bar code pattern, etc.) into the
16 signal processor 300 memory is accomplished via the control panel keypad 27. Data can also
17 be uploaded from an external source (e.g., desktop, laptop, or palm computers) to the
18 corresponding data I/O (input/output) ports 58 via a wireless data link (e.g., infrared) or other
19 interface connections, e.g., USB (universal serial bus).

20 The data I/O (input/output) ports 58 may also be used to transmit data (e.g.,
21 weight, cost, product code number, bar code pattern, etc.) to external devices such as Point-
22 Of-Sale (POS) terminals, customer readout displays, external computers, receipt and bar code
23 printers, etc. The use of ports 58 is critical when integrating the sensor bar 16 into industrial

1 portioning operations. For example, a production line that simultaneously utilizes many
2 sensor bars 16 may have all collected weight data stored/analyzed by a central computer.
3 Each signal processor 300 can be programmed, via keypad 27 or an external computer
4 communicating via ports 58, to append a unique prefix identifying number to the data stream
5 transmitted to the central computer.

6 As the sensor bar 16 traverses the item 14 and the segment weight (or cost) is
7 displayed, the corresponding perpendicularly (in relation to the base of the sensor bar 16)
8 projected positions of the height sensors 38 onto the item 14 upper surface indicate the exact
9 location where the item 14 should be cut in order to produce the segment of the displayed
10 weight (or cost). In the embodiment of Figures 1, 3A, and 4, the knife 15 is parallel to (and
11 hence does not coincide) with this position. In the embodiment of Figure 2A, a separate knife
12 (not shown) may be used to cut the selected item segment using the side surface 17 of
13 uprights 36A and 36B as a guide. This side surface is parallel to (and hence does not
14 coincide) with the exact cutting position.

15 Similarly, in the embodiment of Figures 2B, 2C, and 2D, the cutting location
16 of the rotary blade, guillotine chopping blade, and laser cutter respectively, are also parallel
17 to (and hence do not coincide) with the exact cutting position. In the aforementioned
18 embodiments, if this small positional difference between the cutting instrument and the exact
19 cutting line is not taken into account, the resultant cut segment weight (or cost) would be
20 slightly different than that indicated on the scan display 30. In many applications this
21 difference may be considered insignificant. In applications such as when quickly estimating
22 a weight or cost, a final weighing (and pricing) using a conventional scale may be performed
23 after the item 14 segment is cut. Nonetheless, this difference can be eliminated for both

1 manual as well as automated industrial applications.

2 In the context of automated industrial applications, since programmed cutting
3 tools (e.g., automatic chopping blade, laser, rotary blade, or high pressure water jet) are used
4 in place of the knife 15, these tools are simply aligned with the height sensor 38 positions
5 whereupon the item 14 is cut on the exact cutting line as the sensor bar 16 reaches the desired
6 portioning position. In partially automated or manual applications, the use of various
7 marking/scoring technologies enables the marking (scoring) of the representative
8 perpendicularly (in relation to the sensor bar 16) projected height sensor 38 positions onto the
9 upper surface of the item 14 whereby blade 15 or a separate cutting tool or knife can then cut
10 the item 14 along the score marks resulting in the weight (or cost) indicated on display 30.

11 Marking (Scoring) Item 14 On The Exact Segmenting Line:

12 Item 14 can be segmented by first marking/scoring the upper surface of the
13 item 14 along the perpendicularly (in relation to the base of the sensor bar 16) projected
14 sensor 38 positions (or linearly located positions between sensor 38 positions), and then
15 cutting the item 14 along these score marks with blade 15 or a separate cutting tool or knife.
16 Many different technologies may be utilized to mark/score the upper surface of item 14 to
17 indicate this cutting line. Examples include (but are not limited to) ink dispensing
18 mechanisms (e.g., piezoelectric based, thermal bubble based, mechanical based,
19 electromechanical based, etc.), thermal/burning electric elements, laser burning emitters, and
20 sharp-ended implements.

21 Following are detailed descriptions of ink dispensing marking mechanisms as
22 well as marking/scoring mechanisms based on thermal/burning electric elements, laser
23 burning emitters, and sharp-ended solenoid plungers. All of these marking mechanisms may

1 be incorporated in either I) normally retracted mechanical solenoid marking plungers 46C
2 (e.g., Figure 4) that are parallel to and positioned in-between the positions of height sensors
3 38, and used exclusively for marking/scoring the item 14 surface, or in II) normally extended
4 mechanical solenoid height sensor plungers 46 that are also used to determine item 14
5 heights. The advantage that the normally retracted marking plungers 46C have over the later
6 described marking/scoring mechanisms located within mechanical height sensor plungers 46
7 is that due to limited physical contact with the item 14 surface, the marking plungers 46C
8 have a reduced possibility of becoming obstructed due to possible surface debris on the upper
9 surface of item 14.

10 I) Marking Plungers 46C – Used Exclusively For Marking/Scoring – Located In-Between
11 Height Sensor 38 Positions

12

13 a) Ink Dispensing Marking Mechanism 127

14 Referring to Figure 10A-1, each normally retracted marking plunger 46C
15 contains an ink dispensing mechanism cavity 126 that contains an electrically controlled ink
16 dispensing mechanism 127 that sprays ink 128 through nozzle 132 onto the upper surface of
17 item 14 forming ink mark 134. The cone shaped collar 145 separates the ink dispensing
18 nozzle 132 from the upper surface of item 14, thus reducing the opportunity of possible item
19 14 surface debris from obstructing the operation of nozzle 132.

20 Ink dispensing mechanisms 127 may be based on many different technologies
21 including (but not limited to) piezoelectric, thermal bubble, mechanical, and electro-
22 mechanical. Following is a description of ink dispensing mechanisms 127 based on
23 piezoelectric and thermal bubble inkjet technologies. These two technologies are widely

1 employed in current inkjet printer devices.

2 Theory and Operation of the Piezoelectric Based Ink Dispensing Mechanism 127:

3 Figure 12A illustrates a piezoelectric based ink dispensing mechanism 127 in
4 its initial state whereby no current is applied to transducer 140 via electrical leads 139. In
5 this state, transducer 140 remains in a flattened configuration. The application of electrical
6 current to transducer 140 causes it to vibrate in an alternating downward and upward
7 direction. Referring to Figure 12B, as transducer 140 flexes downwards, ink 141 is forced
8 out of the nozzle 142 creating ink droplet 144 which forms ink mark 146 on the item 14
9 upper surface. Referring to Figure 12C, as the transducer 140 flexes upwards, ink 141 is
10 drawn out of an ink reservoir (not shown) via conduit 143 thus replacing the ink just released
11 through nozzle 142.

12 The cone shaped collar 145 separates the ink dispensing nozzle 142 from the
13 upper surface of item 14, thus reducing the opportunity of possible item 14 surface debris
14 from obstructing the operation of nozzle 142.

15

16 Theory and Operation of the Thermal Bubble Based Ink Dispensing Mechanism 127:

17 Figure 13A illustrates a thermal bubble based ink dispensing mechanism 127
18 in its initial state whereby no current is applied to heating element 150 via electrical leads
19 138. Referring to Figure 13B, the application of electrical current via electrical leads 138 to
20 heating element 150 heats ink 151. A portion of ink 151 vaporizes resulting in the formation
21 of bubble 156. The increased pressure created by bubble 156 forces ink 151 out of nozzle
22 152 creating ink droplet 154 which forms ink mark 155 on the upper surface of item 14.
23 Referring to Figure 13C, the subsequent collapse of bubble 156 creates a vacuum that results

1 in additional ink 151 being drawn out of an ink reservoir (not shown) via conduit 153 thus
2 replacing the ink just released through nozzle 152.

3 The cone shaped collar 145 separates the ink dispensing nozzle 152 from the
4 upper surface of item 14, thus reducing the opportunity of possible item 14 surface debris
5 from obstructing the operation of nozzle 152.

6 Referring to Figures 10A-1, 10A-2, 10A-3, 11A, and 11B, and briefly
7 summarized here, but subsequently described in detail, the normally retracted position
8 (Figures 10A-2 and 11A) of marking plungers 46C separates the ink dispensing mechanisms
9 127 from the proximity of the upper surface of item 14 as the sensor bar 16 traverses the item
10 14. This reduces the opportunity of possible item 14 surface debris from obstructing ink
11 nozzles 132. When the sensor bar 16 reaches the desired weight (or cost) of item 14, the
12 operator presses the appropriately designated "mark" pushbutton 56A-56K causing each
13 normally retracted marking plunger 46C to extend downwards (Figures 10A-3 and 11B) and
14 make contact with the upper surface of item 14, whereby ink 128 is automatically sprayed
15 through nozzle 132 onto the upper surface of item 14 forming ink mark 134. Two or more
16 ink marks from two or more ink dispensing mechanisms 127 contained within marking
17 plungers 46C indicate the exact cutting line used to segment item 14 into the desired weight
18 (or cost based on weight). Again referring to Figures 10A-2 and 11A, after each marking
19 plunger 46C dispenses an ink mark onto the item 14 surface, plungers 46C are automatically
20 retracted into their respective solenoid coil windings 70C within the sensor bar 16 housing
21 whereby the marking plunger stems 47C at the top of each plunger 46C are held adjacent to
22 permanent magnets 72C by the attractive force of the permanent magnets 72C. Plungers 46C
23 are further secured by the automatic extension of side-mounted solenoid plungers 116C

1 which engage into saw-tooth indentations 110C located on the side of plungers 46C facing
2 side-mounted solenoid plungers 116C.

3 In detail, the normally retracted state of marking plunger 46C is illustrated in
4 Figures 10A-2 and 11A. The stem 47C at the top of each marking plunger 46C is held
5 adjacent to permanent magnet 72C by the attractive force of the permanent magnet 72C. As
6 illustrated, marking plunger 46C is further secured by the normally extended spring 112C
7 which applies force to base 114C of side-mounted plunger 116C which engages plunger 46C
8 indentation 110C. As the sensor bar 16 traverses the item 14 and reaches the desired weight
9 (or cost based on weight), the appropriately designated "mark" pushbutton 56A-56K is
10 depressed causing the simultaneous application of electrical power to solenoid coil windings
11 108C and a brief pulse of electrical power to solenoid coil windings 70C. As shown in
12 Figures 10A-3 and 11B, this causes the retraction of each side-mounted plunger 116C from
13 its engaged holding position in indentation 110C of plunger 46C and simultaneously the
14 holding force of permanent magnet 72C on stem 47C of marking plunger 46C is overcome
15 and compressed spring 48C is thus extended forcing each spring-loaded marking plunger 46C
16 towards the upper surface of item 14.

17 Figures 10A-2, 10A-3, 11A, and 11B show details of the arrangement that
18 senses the extension travel of the plungers 46C. Each plunger 46C has a flattened side 60C
19 facing a sensor rod 62C also having a flattened side 64C facing plunger side 60C. The flat
20 side 60C of the plunger 46C has a reflective surface imprinted with non-reflective tracking
21 patterns. A linear array of equidistantly spaced angled light emitters (e.g., LED devices) 66C
22 is embedded along the length of the sensor rod 62C directed at the flattened side 60C of the
23 plunger 46C, and a similar linear array of equidistantly spaced angled photoelectric receivers

1 68C is embedded along the length of the sensor rod 62C positioned to receive light from a
2 respective emitter reflected from the side 60C.

3 As the plunger 46C moves up and down through the cavity formed by the
4 solenoid coil windings 70C and sensor rod 62C, the photoelectric emitter 66C / receiver 68C
5 sensor array determines the displacement distance of the plunger 46C by tracking the
6 changing patterns of received reflected light. To eliminate false readings caused by
7 reflections from the solenoid spring 48C when it occupies the plunger 46C position, the
8 spring 48C has a matte, non-reflective surface (finish).

9 When the above described optical reflection based displacement sensor detects
10 no movement of the extended plunger 46C for a pre-determined amount of time (e.g., 1
11 second) then plunger 46C is known to have reached its final resting position lying on the
12 upper surface of item 14. The signal processor 300 then automatically applies electrical
13 current to the ink dispensing mechanism 127 causing ink 128 to be ejected out of nozzle 132
14 onto the item 14 upper surface forming ink mark 134. The cone shaped collar 145 separates
15 the ink dispensing nozzle 132 from the upper surface of item 14, thus reducing the
16 opportunity of possible item 14 surface debris from obstructing the operation of nozzle 132.

17 Referring to Figures 10A-2, 10A-3, 11A, and 11B, after ink 128 has been
18 ejected onto the item 14 surface, the signal processor 300 applies a brief electrical current to
19 solenoid coil windings 70C causing marking plungers 46C to be fully retracted into the
20 sensor bar 16 housing. Marking plunger stems 47C located at the top of marking plungers
21 46C are held adjacent to the permanent magnets 72C by the attractive force of permanent
22 magnets 72C without further application of electrical current to solenoid coil windings 70C.
23 When the above described optical reflection based displacement detector measures the

1 ceasing of vertical movement of marking plungers 46C while returning into the sensor bar 16
2 housing, the signal processor 300 automatically stops the application of electrical current to
3 the side-mounted coil windings 108C. This results in the extension of the spring-loaded side-
4 mounted plungers 116C into the corresponding marking plunger 46C saw-tooth indentation
5 110C resulting in further securing the plungers 46C in their retracted position. The signal
6 processor 300 then clears display 30 and sensor bar 16 is readied to perform a new item 14
7 scan.

8 The aforementioned normally retracted marking plunger 46C incorporated an
9 ink dispensing mechanism 127 (Figure 10A-1) as its marking/scoring device. As described
10 below, many other (non-ink dispensing) types of marking/scoring mechanisms may be
11 incorporated into marking plungers 46C such as (but not limited to) thermal/burning heating
12 elements (Figure 10B-1), laser burning emitters (Figure 10C-1), and sharp-ended scoring
13 devices (Figure 10D-1). The implementation of these additional marking/scoring mechanisms
14 is similar to that of the ink dispensing mechanism just described. Thus, the extension,
15 activation, and retraction of the marking plungers 46C and associated marking mechanisms
16 ensures the accurate placement of score marks which indicate the position of the exact cutting
17 line used to precisely portion the item 14.

18 b) Thermal/Burning Marking Mechanism 127A

19 Referring to Figure 10B-1, the normally retracted marking plunger 46C
20 contains a cavity 126 that contains an electrically controlled heating element 127A that upon
21 being energized and contacting the upper surface of item 14 burns a visible mark 161 on the
22 upper surface of item 14.

23 c) Laser/Burning Marking Mechanism 127B

1 Referring to Figure 10C-1, the normally retracted marking plunger 46C
2 contains a cavity 126 that contains an electrically controlled laser mechanism 127B that upon
3 being energized emits laser light 172 through focusing lens 171 that burns a visible mark 173
4 on the upper surface of item 14.

5 d) Sharp Pointed Marking/Scoring Mechanism 127C

6 Referring to Figure 10D-1, the normally retracted marking plunger 46C
7 consists of a marking/scoring mechanism 127C that has at its bottom outside surface a sharp
8 pointed protrusion 175 that upon making contact with and moved bi-directionally (while
9 being progressively lowered) over the item 14 creates a visible score mark 176 on the upper
10 surface of item 14.

11 As in the above detailed description of the operation of ink dispensing
12 marking mechanisms 127, as the sensor bar 16 traverses the item 14 and the desired segment
13 weight (or cost based on weight) is reached, the operator presses the appropriately designated
14 "mark" pushbutton 56A-56K causing each normally retracted marking plunger 46C to extend
15 downwards (Figures 10D-2, 10D-3, 11A, and 11B) and make contact with the upper surface
16 of the item 14.

17 The surface of some items 14 may be difficult to score or mark due to their
18 hard, rough, slippery, or otherwise non-accommodating surface texture. In these cases, the
19 above described sharp protrusions 175 would not sufficiently penetrate the item 14 surface in
20 order to create a visible score mark. A downward pressure exerted on the sensor bar 16
21 would not apply additional pressure from the plungers 46C to the item 14 surface as the
22 plungers 46C would automatically raise into the sensor bar 16. By holding the plungers 46C
23 stationary in their final positions, sharp protrusions 175 can easily score any type of item 14

1 surface with the application of a bi-directional motion and a downward pressure on the sensor
2 bar 16 (causing it to be lowered).

3 When the above described optical reflection based displacement detector
4 measures the ceasing of downward vertical movement as the marking plungers 46C descend
5 upon the upper surface of the item 14, the signal processor 300 automatically removes the
6 application of electrical current to the side-mounted coil windings 108C resulting in the
7 removal of the compression force that plungers 116C exert on springs 112C. The resultant
8 expansion of the normally expanded springs 112C applies a continued force applied to the
9 base 114C of plungers 116C thus moving side-mounted plungers 116C into the adjacent
10 marking plungers 46C saw-tooth indentations 110C. Each marking plunger 46C is now held
11 stationary in its position on the item 14 upper surface. The application of a bi-directional
12 horizontal motion and a downward pressure on the sensor bar 16 (causing it to be lowered)
13 will provide sufficient force for the sharp protrusions 175 to penetrate the item 14 upper
14 surface, thus scoring/markings the exact cutting line contour onto the item 14 surface.

15 To retract the marking plungers 46C back into the sensor bar 16 housing, the
16 operator depresses the appropriately designated "retract" button 56A-56K causing the signal
17 processor 300 to apply a brief electrical current to solenoid coil windings 70C and solenoid
18 coil windings 108C. The application of current to solenoid coil windings 108C causes
19 plungers 116C to retract from the holding indentations 110C and compress the normally
20 expanded springs 112C, while the application of current to solenoid coil windings 70C
21 causes marking plungers 46C to be fully retracted into the sensor bar 16 housing as springs
22 48C compress. Marking plunger stems 47C located at the top portion of marking plungers
23 46C are held adjacent to permanent magnets 72C by the attractive force of permanent

1 magnets 72C and without further application of electrical current to solenoid coil windings
2 70C.

3 When the above described optical reflection based displacement detector
4 measures the ceasing of vertical movement of marking plungers 46C while returning into the
5 sensor bar 16 housing, the signal processor 300 automatically stops the application of
6 electrical current to the side-mounted coil windings 108C resulting in the removal of the
7 compression force that plungers 116C exert on springs 112C. The resultant expansion of the
8 normally expanded springs 112C applies a continued force applied to the base 114C of
9 plungers 116C thus moving side-mounted plungers 116C into the adjacent marking plungers
10 46C saw-tooth indentations 110C, thus further securing the plungers 46C in their retracted
11 position.

12 The above described "retract" pushbutton enables the retraction of marking
13 plungers 46C back into the sensor bar 16 at the operator's preferred time. Alternatively, the
14 marking plungers 46C may automatically retract into the sensor bar 16 housing without
15 operator intervention whereby the signal processor 300 automatically initiates the retraction
16 sequence after a predetermined time interval, e.g., 15 seconds from when the marking
17 plungers 46C rest upon the item 14 upper surface. In either case, the display 30 is cleared
18 and the signal processor 300 is readied to perform a new item 14 scan.

19 After the score marks have been imparted onto the item 14 surface, the
20 operator can cut the item 14 in the most appropriate manner. In the case of sensor bar 16B
21 implementations, the operator first retracts the plungers 46 (Figure10D-2) utilizing the
22 appropriate "retract" pushbutton 56A-56K, then aligns the knife 15 on the score marks and
23 cuts the item 14 by and then applying a downward as well as a back and forth motion on the

1 sensor bar 16B. Alternatively, a separate knife may be employed to cut the item 14 along the
2 score marks.

3 As the use of sharp pointed marking/scoring mechanism 127C requires that
4 the sensor bar 16 move bi-directionally in a sawing motion over the item 14, the
5 implementation of this specific marking/scoring mechanism is suited to sensor bars 16 similar
6 to the configuration illustrated in Figure 1 as compared to those of Figure 2A.

7 For applications that operate only on soft easily penetrated items 14, the use of
8 the knife 15 as a cutting or scoring tool is not necessary and it can simply be detached. In
9 these cases, the sharp-ended protrusions 175 cut (versus only score) the item 14 into the
10 desired portion.

11 As the use of sharp pointed marking/scoring mechanism 127C requires that
12 the sensor bar 16 move bi-directionally in a sawing motion over the item 14, the
13 implementation of this specific marking/scoring mechanism is suited to sensor bars 16
14 resembling the configuration illustrated in Figure 1 as compared to those of Figure 2A.

15 The preceding section described ink dispensing marking mechanisms as well
16 as marking/scoring mechanisms based on thermal/burning electric elements, laser burning
17 emitters, and sharp-ended solenoid plungers. These marking mechanisms were all
18 incorporated inside two or more normally retracted dedicated marking plungers 46C that are
19 located in-between and parallel to the positions of height sensors 38. For sensor bars 16B
20 utilizing mechanical height sensor plungers 46, the above described marking mechanisms can
21 be incorporated inside two or more normally extended height sensor plungers 46 while still
22 enabling the plungers 46 to perform their height determination functions. The base (bottom
23 portion) of the marking mechanism thus becomes the base (bottom portion) of the plunger 46

for height calculation purposes. The following section describes this implementation of various marking mechanisms:

II) Height Sensor Plungers 46 – Incorporating Marking/Scoring Mechanisms

a) Ink Dispensing Marking Mechanism 127

Figure 10A-4 illustrates a normally extended height sensor plunger 46 that contains an ink dispensing marking mechanism 127 whose components and operation were detailed in the above description of Figure 10A-1. As the sensor bar 16B traverses the item 14, all height sensor plungers 46 are in contact with the item 14 surface. When the position of the desired segment weight (or cost based on weight) is reached, the operator presses the appropriate “marking” pushbutton 56A-56K causing electrical power to be applied to each ink dispensing mechanism 127 resulting in ink being expelled through nozzle 132 onto the upper surface of item 14 thus forming an ink mark. The cone shaped collar 145 separates the ink dispensing nozzle 132 from the upper surface of item 14, thus reducing the opportunity of possible item 14 surface debris from obstructing the operation of nozzle 132.

After the score marks have been imparted onto the item 14 surface, the operator can cut the item 14 in the most appropriate manner. In the case of sensor bar 16B implementations, the operator first retracts the plungers 46 by depressing the appropriate “retract” pushbutton 56A-56K.

Referring to Figures 10A-4 and 10A-5, a brief pulse of electric power is applied to each solenoid coil windings 70 resulting in the complete retraction of all plungers 46 into the sensor bar 16B, thus compressing spring 48 to bring the stem 47 of plunger 46 against a permanent magnet 72. Each stem 47 of plunger 46 becomes “latched” (held adjacent) to the permanent magnet 72 solely due to the attractive force of the permanent

1 magnet 72 and without further application of electric power. The operator then aligns the
2 knife 15 on the score marks and cuts the item 14 by applying a downward as well as a back
3 and forth motion on the sensor bar 16B.

4 Alternatively, a separate knife may be employed to cut the item 14 along the
5 score marks. In the case of sensor bar 16A implementations as illustrated in Figures 2A, 2B,
6 2C, and 2D, the cutting tool (separate knife, rotary cutting blade, guillotine chopping blade,
7 laser cutter, etc) is aligned on the score marks whereupon the item 14 is cut.

8 The aforementioned normally extended height sensor plungers 46 incorporated
9 an ink dispensing mechanism 127 (Figure 10A-1) as its marking/scoring device. As
10 described below, many other (non-ink dispensing) types of marking/scoring mechanisms may
11 be incorporated into height sensor plungers 46 such as (but not limited to) thermal/burning
12 heating elements (Figure 10B-1), laser burning emitters (Figure 10C-1), and sharp-ended
13 scoring devices (Figure 10D-1). The implementation of these additional marking/scoring
14 mechanisms is similar to that of the ink dispensing mechanism just described. Thus, the
15 activation and retraction of the height sensor plungers 46 and associated marking mechanisms
16 ensures the accurate placement of score marks which indicate the position of the exact cutting
17 line used to precisely portion the item 14.

18

19 b) Thermal/Burning Marking Mechanism 127A

20 Figure 10B-4 illustrates a normally extended height sensor plunger 46 that
21 contains a thermal/burning marking/scoring mechanism 127A whose components and
22 operation were detailed in the above description of Figure 10B-1. As the sensor bar 16B
23 traverses the item 14, all height sensor plungers 46 are in contact with the item 14 surface.

1 When the position of the desired segment weight (or cost based on weight) is reached, the
2 operator presses the appropriate "marking" pushbutton 56A-56K causing electrical power to
3 be applied to each heating element 127A resulting in a visible burn mark formed on the upper
4 surface of item 14.

5 After the score marks have been imparted onto the item 14 surface, the
6 operator can cut the item 14 in the most appropriate manner. In the case of sensor bar 16B
7 implementations, the operator first retracts the plungers 46 (Figure 10B-5) utilizing the
8 appropriate "retract" pushbutton 56A-56K, then aligns the knife 15 on the score marks and
9 cuts the item 14 by applying a downward as well as a back and forth motion on the sensor bar
10 16B. Alternatively, a separate knife may be employed to cut the item 14 along the score
11 marks. In the case of sensor bar 16A implementations as illustrated in Figures 2A, 2B, 2C,
12 and 2D, the cutting tool (separate knife, rotary cutting blade, guillotine chopping blade, laser
13 cutter, etc) is aligned on the score marks whereupon the item 14 is cut.

14 c) Laser Burning/Scoring Mechanism 127B

15 Figure 10C-4 illustrates a normally extended height sensor plunger 46 that
16 contains a laser burning/scoring 127B whose components and operation were detailed in the
17 above description of Figure 10C-1. As the sensor bar 16B traverses the item 14, all height
18 sensor plungers 46 are in contact with the item 14 surface. When the position of the desired
19 segment weight (or cost based on weight) is reached, the operator presses the appropriate
20 "marking" pushbutton 56A-56K causing electrical power to be applied to each laser
21 burning/scoring mechanism 127B resulting in a visible burn mark formed on the upper
22 surface of item 14. The cone shaped collar 145 separates the focusing lens 171 from the
23 upper surface of item 14, thus reducing the opportunity of possible item 14 surface debris

1 from obstructing the operation of lens 171.

2 After the score marks have been imparted onto the item 14 surface, the
3 operator can cut the item 14 in the most appropriate manner. In the case of sensor bar 16B
4 implementations, the operator first retracts the plungers 46 (Figure 10C-5) utilizing the
5 appropriate "retract" pushbutton 56A-56K, then aligns the knife 15 on the score marks and
6 cuts the item 14 by and then applying a downward as well as a back and forth motion on the
7 sensor bar 16B. Alternatively, a separate knife may be employed to cut the item 14 along the
8 score marks. In the case of sensor bar 16A implementations as illustrated in Figures 2A, 2B,
9 2C, and 2D, the cutting tool (separate knife, rotary cutting blade, guillotine chopping blade,
10 laser cutter, etc) is aligned on the score marks whereupon the item 14 is cut.

11 d) Sharp Pointed Marking/Scoring Mechanism 127C

12 Figure 10D-4 illustrates a normally extended height sensor plunger 46 that
13 consists of a marking/scoring mechanism 127C whose components and operation were
14 detailed in the above description of Figure 10D-1.

15 The surface of some items 14 may be difficult to score or mark due to their
16 hard, rough, slippery, or otherwise non-accommodating surface texture. In these cases, the
17 above described sharp protrusions 175 would not sufficiently penetrate the item 14 surface in
18 order to create a visible score mark. A downward pressure exerted on the sensor bar 16B
19 would not apply additional pressure from the marking plungers 46 to the item 14 surface as
20 the marking plungers 46 would automatically raise into the sensor bar 16B. By holding the
21 marking plungers 46 stationary in their final positions, sharp protrusions 175 can easily score
22 any type of item 14 surface with the application of a bi-directional motion and a downward
23 pressure on the sensor bar 16B (causing it to be lowered).

1 Referring to Figures 10D-4 and 10D-5, as the sensor bar 16B traverses the
2 item 14, all plungers 46 are in contact with the item 14 surface. When the desired segment
3 weight (or cost based on weight) is reached, the operator presses the appropriately
4 designated "mark" pushbutton 56A-56K causing the signal processor 300 to initiate the
5 application of electrical current to the side-mounted coil windings 108 resulting in the
6 engagement of the side-mounted plungers 116 into the adjacent plungers 46 saw-tooth
7 indentations 110 and the corresponding expansion off the normally compressed springs 112
8 resulting in continued force applied to the base 114 of plungers 116 thus further securing
9 plungers 116 in their engaged position in indentations 110 of marking plungers 46. This
10 causes each marking plunger 46 to be held stationary in its position on the item 14 upper
11 surface. The application of a bi-directional horizontal motion and a downward pressure on
12 the sensor bar 16B (causing it to be lowered) will provide sufficient force for the sharp
13 protrusions 175 to penetrate the item 14 upper surface, thus scoring/markings the exact
14 cutting line contour onto the item 14 surface.

15 To disengage the plungers 46 from their vertically fixed position, the operator
16 depresses the appropriately designated "release" button 56A-56K causing the signal
17 processor 300 to terminate the application of electrical current to side-mounted plunger
18 solenoid coil windings 108 thus removing the pulling force causing the expansion of springs
19 112. This results in the automatic compression of the normally compressed springs 112
20 which causes the disengagement of plungers 116 from indentations 110 of marking plungers
21 46. Plungers 46 are thus no longer held in their fixed vertical position by plungers 116.

22 The above described "release" pushbutton releases marking plungers 46 from
23 their fixed vertical position at the operator's preferred time. Alternatively, the marking

1 plungers 46 may automatically release from their static position without operator intervention
2 by having the signal processor 300 automatically initiate the retraction sequence after a pre-
3 determined time interval, e.g., 15 seconds after the plungers 46 were secured in their vertical
4 positions. In either case, the signal processor 300 clears display 30 and is readied to
5 perform a new item 14 scan.

6 After the score marks have been imparted onto the item 14 surface, the
7 operator can cut the item 14 in the most appropriate manner. In the case of sensor bar 16B
8 implementations, the operator first retracts the plungers 46 (Figure 10D-5) utilizing the
9 appropriate "retract" pushbutton 56A-56K, then aligns the knife 15 on the score marks and
10 cuts the item 14 by and then applying a downward as well as a back and forth motion on the
11 sensor bar 16B. Alternatively, a separate knife may be employed to cut the item 14 along the
12 score marks.

13 As the use of sharp pointed marking/scoring mechanism 127C requires that
14 the sensor bar 16B move bi-directionally in a sawing motion over the item 14, the
15 implementation of this specific marking/scoring mechanism is suited to sensor bars similar to
16 the configuration illustrated in Figure 1 as compared to those of Figure 2A.

17 For applications that operate only on soft easily penetrated items 14, the use of
18 the knife 15 as a cutting or scoring tool is not necessary and it can simply be detached. In
19 these cases, the sharp-ended protrusions 175 cut (versus only score) the item 14 into the
20 desired portion.

21 Dedicated Marking/Scoring Sensor Bar

22 Figure 5 illustrates a stabilized four support post sensor bar 16 configuration
23 used for marking/scoring an item 14 on the precise cutting line used to cut the item 14 at a

1 desired weight(or cost based on weight). The sensor bar 16 depicted in Figure 5 is
2 constructed of a clear see-through material enabling the operator to view the item 14 through
3 the sensor bar 16 as the sensor bar 16 traverses the item 14. Once marked/scored, a separate
4 knife (not shown) may be used to cut the selected item segment. As each of the four support
5 posts has the same height, the sensor bar 16 is constrained in a level horizontal position. This
6 configuration helps eliminate inexperienced operators from introducing unwanted sensor bar
7 orientations as the item 14 is traversed.

8 Again referring to Figure 5, displacement detectors 20A, 22A associated with
9 each support post 20, 22, produce signals corresponding to the displacement of the sensor bar
10 16 while being stroked over the item 14. Support posts 52Y do not contain displacement
11 detectors and are employed solely to provide a horizontally stable sensor bar 16
12 configuration. A linear array of height sensors 38 generates electronic signals corresponding
13 to the height of points on the upper surface of the item 14 lying below the respective sensor
14 38. A knife blade is not incorporated into this sensor bar configuration, therefore none of the
15 four support posts are retractable.

16 As the sensor bar 16 traverses the item 14, the weight (or cost based on
17 weight) of the item 14 is continuously displayed on screen 30. When the position of the
18 desired weight (or cost) is reached, the operator depresses one of the appropriately designated
19 "mark" pushbuttons 56A-56K to control the application of electrical power to the
20 marking/scoring devices. The activated scoring/marking devices place physical marks on the
21 item 14 upper surface indicating the exact location where the item 14 should be cut in order
22 to produce a portion of the desired weight (or cost). Many different marking/scoring
23 technologies may be employed such as (but not limited to) ink deposition, heating/burning

1 element marking, laser scoring, and sharp pointed implements used to penetrate and mark the
2 item 14 surface. After the item 14 has been marked/scored, the operator uses a separate knife
3 or cutting tool to cut along the score marks to produce an item 14 portion of the desired
4 weight (or cost).

5 Wireless Communication Between Sensor Bars and External Devices

6 As illustrated in Figure 1B, the operator may interact with sensor bar 16 via
7 pushbuttons 56A-56K, as well as controller 178. This figure shows that by utilizing an
8 infrared, radio frequency, or other wireless interface, controller 178 (original position) may
9 be detached from sensor bar 16 and moved to a new position (denoted by label 179) whereby
10 the controller may interact with the sensor bar 16 from a distance. Furthermore, wireless
11 peripheral devices such as customer Point-Of-Sale (POS) displays 187, receipt printers 188,
12 cash registers 189, and computer controlled inventory systems (not shown) may similarly
13 communicate with each other. Such configurations enable a modular approach to designing
14 measurement based systems that can be customized to varied applications. Detaching
15 controller 178 from the sensor bar 16 housing also confers a lighter weight sensor bar 16 and
16 provides for less chance of sensor bar 16 damage due to rough handling or cleaning regimens.

17 Again, referring to Figure 1B, sensor bar 16 has at its distal end (in relation to
18 the operator) a vertically mounted rod-like structure 180. For an infrared based wireless
19 interface, structure 180 is a hollow tube containing electrical wires that originate from the
20 sensor bar 16 embedded wireless communications module 308 (Figure 1A). At the top of
21 structure 180, such wires are attached to an omni-directional infrared emitter/receiver array
22 181 comprised of, e.g., LED infrared emitters and photosensitive receivers. Infrared array
23 181 bi-directionally communicates via infrared signals 182 with controller 179 (and

1 optionally other devices). Similarly, controller 179 communicates via vertically mounted
2 hollow rod-like structure 184 which is attached to an omni-directional infrared
3 emitter/receiver array 185 comprised of, e.g., LED infrared emitters and photosensitive
4 receiving elements. Structure 184 is connected via connector 183 to a wireless
5 communications module 308 contained within case 26.

6 For a radio frequency based wireless interface, structures 180 and 181
7 comprise an antenna connected at its base to electrical wires that originate from the sensor
8 bar 16 embedded wireless communications module 308. The antenna bi-directionally
9 communicates via electromagnetic signals 182 to controller 179 (and optionally other
10 devices). Similarly, controller 179 communicates via structures 184 and 185 which comprise
11 an antenna attached via connector 183 to a wireless communications module 308 contained
12 within case 26.

13 The above referenced sensor bar 16 transmitter/receiver interface (e.g.,
14 infrared or radio frequency) may be embedded into various locations within the sensor bar 16
15 such as in a hollowed-out handle 18, within the vertical protrusion at the distal end (in
16 relation to the operator) of the sensor bar 16, adjacent to the height sensors 38, and/or under
17 pushbuttons 56A-56K.

18 Although the above described implementation of wireless devices was
19 presented in relation to sensor bar 16, the same operational and technical principles are
20 applicable to all other sensor arms described in this application.

21 As previously described, the controller 178 (or 179) interface 58 also contains
22 I/O (input/output) ports such as USB and infrared. The interface 58 infrared ports enable bi-
23 directional communication between the controller 178 (or 179) and other devices that are

1 positioned within a "line-of-sight" of the interface 58 as compared to the more flexible omni-
2 directional array 181 (or 185) that contains multiple infrared emitters and receivers positioned
3 in numerous orientations enabling the transmission and receiving of infrared signals from a
4 variety of differently orientated (positioned) devices.

5

6 ADDITIONAL FEATURES OF INK DISPENSING MECHANISMS 127 (Figure 10A-1)

7 Segmenting applications (whether food or non-food) often involve different
8 types of items 14 whose surface colors vary considerably, e.g., red fish filets, white fish filets,
9 or dark blue fish filets. Currently available ink dispensing technologies based on the already
10 described piezoelectric and thermal bubble mechanisms enable the controlled simultaneous
11 discharge of multiple colors of ink that when combined together form virtually any color. A
12 pre-programmed look-up table containing specific item 14 types, colors, and corresponding
13 high contrast (and hence highly visible) marking colors is stored in the signal processor 300
14 memory. As the operator indicates via the keypad 27 the specific type of item 14 to be
15 processed, the sensor bar 16 signal processor 300 automatically selects an appropriate ink
16 from the look-up table that ensures high visibility score marks against the item 14 surface
17 colors and sends appropriate electrical signals to the ink dispensing mechanism 127. Thus,
18 when segmenting a light colored fish filet, dark colored ink would be employed. The
19 operator has the ability to override pre-selected colors and use alternative colors by entering
20 preferences via keypad 27.

21 The above described selection of the optimally visible ink color for the
22 specific item 14 being marked can be entirely automated thus eliminating both operator
23 intervention and the use of item specific pre-stored color look-up tables. Along the

underside of the sensor bar 16B that contains the height sensors 38, a photosensitive CCD sensor 75 (Figure 4) is installed facing downward towards the upper surface of the item 14. When an operator depresses the appropriately designated “mark” pushbutton 56A-56K, this sensor analyzes an image of the item 14 upper surface to determine its color characteristics, whereupon the sensor bar 16B signal processor 300 utilizes a non item specific color look-up table to select the most contrasting/visible marking color. The signal processor 300 then sends electrical signals to ink mechanism 127s specifying the color to be applied to the item 14 surface.

For food segmenting applications, non-toxic inks are employed. For non-food applications, various inks such as (but not limited to) indelible, removable, fluorescent, or magnetic may be employed. The use of “interactive” marking inks such as (but not limited to) fluorescent or magnetic may be used so that after the item is marked, sensors can detect the marks positions and instruct automated cutting tools where to perform the final cutting. Various automated cutting tools such as (but not limited to) automatic chopping blades, lasers, rotary blades, and high-pressure water cutters may be employed to perform the final segmenting cuts.

17 . ACCURACY CONSIDERATIONS

18 The sensor bar 16 determined volume of each item 14 segment traversed is
19 multiplied by a density factor for the particular item type to arrive at segment weight values
20 for each position of the sensor bar 16 in its stroke. The accuracy of sensor bar 16 determined
21 weights can easily be verified by weighing a sample item 14 with a traditional calibration
22 scale and comparing the result to the weight determined by the sensor bar 16.

23 Additionally, the sensor bar 16 can scan pre-made “calibration molds” of

1 various contours and pre-determined weights and volumes to verify the overall accuracy of
2 the sensor bar 16 as well as to interact with built-in diagnostic software to test and calibrate
3 individual sensor components to certify that they are functioning properly and are operating
4 within specified tolerances.

5 Calibration of the sensor bar 16 for a specific item 14 material is accomplished
6 by adjusting the density value for the specific item 14 material stored in the memory of the
7 signal processor 300. The operator interacts via the control panel keyboard 27 and associated
8 control panel display with a built-in calibration software program by entering the item 14
9 weight as determined by a traditional calibration scale. The program divides this weight by
10 the item 14 volume as determined by the sensor bar 16. The resultant density value
11 (weight/volume) replaces the existing density value stored for the specific item 14 material.

12 Density values for different item 14 materials can be acquired by using pre-
13 calculated values or by basic experimental measurement, e.g., displacing a volume of water
14 by a weighed item 14, whereby the density is expressed as the weight divided by the
15 measured displaced volume of water.

16 Prominent factors that enable increased accuracy of the sensor bar 16
17 determined volumes (and hence, weights and costs) include increasing the number and
18 resolution of the height sensors per sensor bar 16 and increasing the resolution of the
19 displacement detectors.

20 When a marking device (e.g., Figure 10A-1) rests on a flat portion of the item
21 14 surface, the marking element is located directly over the desired position and marks it
22 accordingly. When the marking element rests on a steep slanted portion of the item 14
23 surface, the steep angle may cause the resultant mark to the item 14 surface to be angled in

1 appearance. As the relative width (diameter) of each marking device is relatively small, this
2 effect should not cause the operator to misinterpret the position indicated by any marks. The
3 method to creating perfectly formed marks on an item 14 that consists of steep surfaces is to
4 place the marking device at the tip end of each plunger 46C (or 46) whereupon it can freely
5 rotate (pivot) so that the marking device rests perpendicularly against the steep portion of the
6 item 14 surface.

7 DIMENSIONS OF SENSOR BAR

8 Sensor bars may have various dimensions, e.g., height and length etc., as well
9 as the number of height sensors 38 employed, to accommodate various applications as well as
10 gross differences in item 14 dimensions.

11

12 Calculations - Introduction

13 Following is a description of specific case calculations utilized to compute the
14 volume of an item 14 whose data was obtained by use of sensor bars 16A mechanically
15 constrained in their lateral movements as illustrated by Figures 2A, 2B, 2C, and 2D. While
16 traversing the item 14, these sensor bars 16A are also not able to move away from or towards
17 the operator. The calculation presented is based on the determination of the cross sectional
18 areas of sections of the item 14 lying beneath successive sets of height sensors 38. These
19 areas are determined by obtaining the contour of adjacent sections of the item 14 as
20 determined by adjacent sensors 38, as well as the adjacent coordinate positions of these
21 perpendicularly projected sensor 38 positions onto the table surface 34. Such areas are then
22 multiplied by the incremental distances moved by the sensor bar 16A as determined by
23 displacement detectors 40, thus providing the volume of each section traversed by the sensor

1 bar 16A. The cumulative total displacement produced by successive sensor bar 16A
2 movements in traversing the item 14 segment yields the total volume of the item 14 traversed.
3 Multiplying the total volume by the predetermined density of the item 14 yields the weight of
4 the segment of the item 14 up to the current position of the sensor bar 16A. The weight is
5 then multiplied by the cost per unit weight to obtain the cost of the thus far traversed item 14
6 segment. Either or both are displayed.

7 After the calculations regarding sensor bars 16A that are constrained in their
8 movements (e.g., Figures 2A, 2B, 2C, and 2D) are presented, generalized calculations will be
9 described which enable the computation of the volume of an item 14 from data obtained from
10 any of the various sensor bars 16 appearing in this application, whether such sensor bars are
11 constrained in their movements or not.

12 These calculations accommodate irregular sensor bar 16 movements across the
13 table surface 12 as the sensor bar 16 passes over the item 14. For example, the operator may
14 skew or shift the sensor bar 16 while passing the sensor bar over the item 14. That is, during
15 this motion, the sensor bar 16 may be moved towards the operator or away from the operator.
16 Or, the near support post 20 may alternately be ahead of the far support post 22 (e.g., the near
17 support post would have an x-axis coordinate value larger than the x-axis coordinate value of
18 the far support post) or behind the far support post 22 (e.g., the near support post would have
19 an x-axis coordinate value smaller than the x-axis coordinate value of the far support post).

20 Thus, even though the support posts may be displaced unequally, the volume
21 of the item section traversed is correctly computed. Of course, at all times the base of both
22 support posts must make contact with the table surface 12 and the sensor bar 16 maintaining a
23 near vertical position in relation to the supporting table surface 12. The use of such an

1 adaptable device to measure item segment weights (based on volume) and costs (based on
2 weight) eliminates the need for bulky traditional weight scales that waste valuable counter
3 space.

4 Furthermore, its ease of use enables the device to be operated by relatively
5 inexperienced personnel and to be carried to different work areas where the cost of a
6 traditional weight scale might not be justified.

7 These calculations are based on a different approach to calculating volumes as
8 that described above. Specifically, successive section contours defined by successive sets
9 (from successive sensor bar 16 positions) of item 14 heights and the associated
10 perpendicularly projected height sensor positions (onto the table surface 12) define
11 geometrical solids whose volumes may be calculated. As the calculations used to determine
12 the volumes of the geometric solids do not require specific pre-determined height sensor (or
13 associated perpendicularly projected height sensor 38 positions onto the table surface 12)
14 positions, the sensor bar 16 is not limited to moving in a regular constrained motion in
15 passing over across the item 14.

16

17 Calculation of item 14 volumes for mechanically constrained sensor bars 16A (e.g., Figures
18 2A, 2B, 2C, and 2D):

19 Referring to Figure 14, for the initial sensor bar 16A position, the first height
20 sensor 38 (closest to the operator) measures an item 14 height value represented by Z1. The
21 position of this height sensor projected perpendicularly onto the table surface 34 is
22 represented by N1. Similarly, the next adjacent height sensor 38 (in the direction away from
23 the operator) measures an item 14 height value represented by Z2. The position of this height

1 sensor projected perpendicularly onto the table surface 34 is represented by N2. Thus, for the
2 initial sensor bar 16A position, the cross sectional area below the first two height sensors is
3 represented by the area bound by the four vertices N1, Z1, N2, and Z2. For the successive
4 sensor bar 16A position, these same two adjacent height sensors 38 measure item 14 height
5 values of Z3 and Z4 corresponding respectively to height sensor positions N3 and N4
6 projected perpendicularly onto the table surface 34. These calculations are repeated with
7 adjacent sensor 38 height sensors along the length of the sensor bar 16A as the sensor bar
8 16A traverses the item 14 surface.

9 To approximate the volume of the item 14 lying under the path traversed by
10 these two height sensors 38, the cross sectional area defined by vertices N1, Z1, Z2, and N2
11 is multiplied by the incremental distance that the sensor bar 16A moves as determined by the
12 displacement detector 40. Various calculations may be employed to determine the item 14
13 volume underlying the sensor bar 16A positions. The calculations presented herewith utilize
14 basic geometry and algebra.

15 Figure 14A illustrates basic shapes corresponding to the areas bound by (N1,
16 Z1, Z2, N2). The constant/fixed distance between two adjacent height sensors 38 is denoted
17 as K_N .

18 - Shape (I) is defined by both item 14 heights, Z1 and Z2 being zero. Thus, the cross
19 sectional area of the item 14 lying beneath the two height sensor 38 positions corresponding
20 to this shape is zero, indicating that the item 14 is not present beneath the two height sensors.

21 - Shape (II) is defined by both item 14 heights, Z1 and Z2, being equivalent (and not zero).

22 Thus, the cross sectional area of the item 14 lying beneath the two height sensor 38 positions
23 is defined by a rectangular (or square) shape and is calculated as the product of the fixed

1 distance between the two height sensors, K_N and the item 14 height $Z1$ (or $Z2$).

2 -Shape (III) is defined by item 14 height of $Z1$ being greater than zero and the adjacent item
3 14 height of $Z2$ having a height of zero. Thus, the cross sectional area of the item 14 lying
4 beneath the two height sensor 38 positions is defined by a right triangular shape and is
5 calculated as one half of the product of the fixed distance between the two height sensors, K_N
6 and the height $Z1$.

7 -Shape (IV) is defined by item 14 height of $Z2$ being greater than zero and the adjacent item
8 14 height of $Z1$ having a height of zero. Thus, the cross sectional area of the item 14 lying
9 beneath the two height sensor 38 positions is defined by a right triangular shape and is
10 calculated as one half of the product of the fixed distance between the two height sensors, K_N
11 and the height $Z2$.

12 -Shape (V) is defined by item 14 height of $Z1$ being greater than the height of the adjacent
13 item 14 height of $Z2$, where the height of $Z2$ is greater than zero. Referring to Figure 14A-
14 (V), an imaginary line with endpoints RR and $Z2$ perpendicularly intersects the line with
15 endpoints $N1$ and $Z1$ at point RR , and is parallel to the line with endpoints $N1$ and $N2$. Thus,
16 this imaginary line divides the shape ($Z1, N1, N2, Z2$) into a right triangular shape ($Z1, RR, Z2$)
17 lying above a rectangular (or square) shape ($RR, N1, N2, Z2$). The area defined by the right
18 triangular shape is calculated as one half of the product of the fixed distance between the two
19 height sensors, K_N , and the height of the right triangle represented as the difference between
20 $Z1$ and $Z2$, e.g., $Z1 - Z2$. The area defined by the rectangular (or square) shape is calculated
21 as the product of the fixed distance between the two height sensors, K_N , and the item 14
22 height $Z2$. Therefore, the cross sectional area of the item 14 lying beneath the two height
23 sensor 38 positions is defined as the sum of the areas of the triangular shape and the

1 rectangular (square) shape.

2 -Shape (VI) is defined by item 14 height of Z2 being greater than the height of the adjacent

3 item 14 height of Z1, where the height of Z1 is greater than zero. Referring to Figure 14A-

4 (VI), an imaginary line with endpoints RR and Z1 perpendicularly intersects the line with

5 endpoints N2 and Z2 at point RR, and is parallel to the line with endpoints N1 and N2. Thus,

6 this imaginary line divides the shape (Z1,N1,N2,Z2) into a right triangular shape (Z1,RR,Z2)

7 lying above a rectangular (or square) shape (RR,N2,N1,Z1). The area defined by the right

8 triangular shape is calculated as one half of the product of the fixed distance between the two

9 height sensors, K_N , and the height of the right triangle represented as the difference between

10 Z2 and Z1, e.g., $Z2 - Z1$. The area defined by the rectangular (or square) shape is calculated

11 as the product of the fixed distance between the two height sensors, K_N , and the item 14

12 height Z1. Therefore, the cross sectional area of the item 14 lying beneath the two height

13 sensor 38 positions is defined as the sum of the areas of the triangular shape and the

14 rectangular (square) shape.

15 Upon calculating the cross sectional areas lying beneath each set of adjacent

16 height sensors 38 along the length of the sensor bar 16A, each cross sectional area is

17 multiplied by the incremental displacement value of the sensor bar 16A as measured by

18 displacement detector 40 to arrive at a total volume of the item 14 along the length of the

19 current sensor bar 16A position. As the sensor bar 16A traverses the item 14, an aggregate or

20 running total volume of the segment of the item 14 to the rear of each position of the sensor

21 bar 16A is calculated.

22 This cumulative volume of each segment traversed is multiplied by a density

23 factor for the particular item 14 type, which can be stored in the signal processor 300 and

1 may be input on keyboard 27, to arrive at segment weight values for each position of the
2 sensor bar 16A in its stroke, and a corresponding numeric display of weight continuously
3 updated and displayed on an adjustable display 30. A cost on unit weight basis may also be
4 calculated and displayed either alternatively or at the same time.

5 As the item 14 weight and cost (based on weight) is continuously calculated
6 and displayed on display 30 during the sensor bar 16A movement, the operator may
7 intermittently move the sensor bar 16A in the left direction (e.g., "back-up") or right direction
8 in order to decrease or increase the portion size, weight, or cost, to satisfy the requirements
9 of an observing customer. The signal processor 300 in controller case 26 automatically
10 computes the decreasing or increasing volumes (hence weights and cost) in real time and
11 provides the updated current information to the operator and consumer via display 30 thus
12 enabling the operator to accommodate an on-looking consumer's specific requests as per the
13 particular portion desired based on the item 14 physical appearance and associated weight or
14 cost (based on weight) BEFORE the item 14 is cut.

15

16 Generalized calculation of item 14 volumes for all sensor bars:

17 Referring to Figures 1 and 14, as the sensor bar 16 traverses the item 14,
18 displacement sensors 20A and 22A continuously capture each sensor bar 16 support post 20
19 and 22, respectively, coordinate positions. This data enables the calculation of the positional
20 coordinates of each height sensor 38 that is perpendicularly projected onto the table surface
21 12 (N1, N2, N3, N4). Item 14 surface heights (Z1, Z2, Z3, Z4) corresponding to the
22 projected position of each height sensor 38 (N1, N2, N3, N4) respectively, are obtained from
23 corresponding height sensor 38 measurements. Adjacent sets of coordinate data,

1 (N1,Z1,Z2,N2) and (N3,Z3,Z4,N4), from successive sensor bar 16 positions define three-
2 dimensional geometric solid portions of the item 14 that span the length of the sensor bar 16.

3 The planar four-sided base of each geometric portion is defined by four (4)
4 vertices lying in the plane of the table surface 12: two vertices (N1, N2) from an initial
5 sensor bar 16 position and two vertices (N3, N4) from a successive adjacent sensor bar 16
6 position. The corresponding item 14 height values (Z1, Z2) from the initial sensor bar 16
7 position and the height values (Z3, Z4) from the succeeding adjacent sensor bar 16 position
8 define the upper four (4) vertices of the geometric portion.

9 The determination of the eight coordinate positions (N1, N2, N3, N4, and Z1,
10 Z2, Z3, Z4) enables the calculation of the volume of the geometric solid portions defined by
11 the eight coordinate positions. The summation of the portioned volumes along the length of
12 the sensor bar 16 and along the path of the sensor bar 16 as it traverses the item 14, yields the
13 total volume of the item 14 segment up to the current position of the sensor bar 16.
14 Multiplying the total volume by the predetermined density of the item 14 yields the weight of
15 the segment of the item 14 up to the current position of the sensor bar 16. The weight is then
16 multiplied by the cost per unit weight to obtain the cost of the thus far traversed item 14
17 segment.

18 Although the following calculations refer to the sensor bar 16 configuration
19 exemplified by Figure 1, similar calculations are performed for all sensor bar configurations
20 described in this application.

21 Referring to Figures 1, 14, 15A, and 15B, as the sensor bar 16 traverses the
22 item 14, the support post displacements detectors 20A and 22A continuously capture the near
23 (nearest to the operator) support post 20 coordinate positions $CB_I (X_I, Y_I)$ and the far (farthest

1 from the operator) support post 22 coordinate positions $CT_I(X'_I, Y'_I)$ respectively.
 2 Simultaneously, the item 14 surface heights (Z_1, Z_2, Z_3, Z_4) corresponding to each height
 3 sensor 38 (N_1, N_2, N_3, N_4) respectively are captured.

4 The following illustrates the method whereby the coordinate position of each
 5 height sensor 38 is calculated for any arbitrary position of the sensor bar 16 as the sensor bar
 6 16 traverses the item 14. This information is required in order to specify the coordinates that
 7 define the geometric solid portions that comprise the item 14.

8 Referring to Figures 15A and 15B, a right triangle is defined by line AB (the
 9 distance between the near support post 20, $CB_I(X_I, Y_I)$, and the far support post 22, $CT_I(X'_I,$
 10 $Y'_I)$), line BC (the vertical distance between near support post 20 and the far support post
 11 22), and line AC (the horizontal distance between the near support post 20 and the far support
 12 post 22). The length of line AB (denoted as K_T) is a known constant for the specific sensor
 13 bar 16 used. The length of K_T includes the distance, K_N , which is the distance from the
 14 geometric center of the first height sensor 38 (N_1) to the geometric center of the adjacent near
 15 support post 20 (coordinate position $CB_I(X_I, Y_I)$). The length of K_T also includes the same
 16 distance, K_N , measured from the geometric center of the last height sensor 38 (N_{LAST}) to the
 17 geometric center of the adjacent far support post 22 (coordinate position $CT_I(X'_I, Y'_I)$).
 18 And finally, the length of K_T also includes the sum of the distances between the geometric
 19 center of each successive height sensor 38 (beginning with N_1 and ending with N_{LAST}). In
 20 Figure 15B and the calculations presented, the distance K_N is the same as the distance
 21 between each adjacent height sensor 38 (N) (e.g., the distance between N_1 and N_2 , N_2 and
 22 N_3 , N_{LAST-1} and N_{LAST}). The length of vertical line BC is calculated as the difference
 23 between the y coordinate positions ($Y'_I - Y_I$) of the far support post 22 and the near support

1 post 20. Similarly, the length of horizontal line AC is calculated as the difference between
 2 the x coordinate positions ($X'_I - X_I$) of the far support post 22 and the near support post 20.

3 The calculation of the coordinate position of each height sensor N that is
 4 projected perpendicularly onto the table surface 12 is achieved by applying the Law of
 5 Similar Triangles which states: "If two triangles are similar, then the length of their sides are
 6 proportional."

7 As triangle ABC is similar to the smaller triangle A'B'C', AC/K_T is
 8 proportional to $A'C'/K_N$. Thus, $A'C' = (AC/K_T) \times K_N$, whereby the values of K_T and K_N are
 9 known constants and the value of AC is calculated by performing coordinate subtraction as
 10 described above. The derived value of A'C' is the horizontal coordinate of the first height
 11 sensor N1 whose position is projected perpendicularly onto the table surface 12.

12 Similarly, as BC/K_T is proportional to $B'C'/K_N$, the value of B'C' is calculated
 13 by evaluating the expression $B'C' = (BC/K_T) \times K_N$, whereby the values of K_T and K_N are
 14 known constants and the value of BC is calculated by performing coordinate subtraction as
 15 described above. The derived value of B'C' is the vertical coordinate of the first height
 16 sensor N1 whose position is projected perpendicularly onto the table surface 12.

17 The above calculations yield the projected 2-dimensional coordinate position
 18 (onto the table surface 12) of the first height sensor N1 as $((AC/K_T) \times K_N, (BC/K_T) \times K_N)$.

19 The 3-dimensional (X,Y,Z) coordinate position of the item 14 upper surface
 20 that corresponds to the first height sensor N1 is represented as $((AC/K_T) \times K_N, (BC/K_T) \times K_N,$
 21 $Z)$, where Z is the item 14 height coordinate obtained from measurements made by the first
 22 height sensor N1. Applying the same procedures yields the 2-dimensional projected and 3-
 23 dimensional coordinate positions of all of the height sensors N1 through N_{LAST} .

1 As just described, the complete (X,Y,Z) coordinates of the eight vertices that
2 define each item 14 geometric solid portion (Figure 14) are calculated by using known
3 constants and sensor bar 16 obtained measurements. This coordinate data enables the
4 approximate volume calculation of each item 14 geometric solid portion that spans the length
5 of the sensor bar 16. The successive sum of these sensor bar 16 portions yields the total
6 volume of the item 14 segment up to the current sensor bar 16 position. Utilizing this volume
7 value enables the calculation of the weight (volume x density) and cost (weight x cost per
8 weight) of the thus far traversed segment of the item 14.

9 As described above, four item 14 height values (e.g., Z1, Z2, Z3, Z4) define
10 the top surface vertices of each item 14 geometric solid portion. The top surface defined by
11 these four vertices may be flat or irregularly shaped, e.g., convex, concave, or a combination
12 of various contours. Various algorithms may be employed to optimize the accuracy of the
13 volume calculation by taking into account specific topical surface characteristics of each type
14 of item 14 medium.

15 When an operator specifies (via the keypad 27) the type of item 14 to be
16 scanned, the sensor bar 16 signal processor 300 automatically selects the appropriate pre-
17 programmed volume calculation algorithm. The selected algorithm (program) optimizes the
18 volume calculations based on the top surface contour characteristics of the specific item 14
19 medium. Alternatively, a generalized volume approximation calculation may be performed
20 based on the average of the four geometric solid upper surface height values (e.g., Z_{AVERAGE}
21 = $(Z1+Z2+Z3+Z4) / 4$). The use of Z_{AVERAGE} provides an appropriate height approximation
22 as the top surface contours of most common items, e.g., fish filets, have smoothly changing
23 slopes versus erratic and jagged shifting contours. This average height, Z_{AVERAGE} , defines

1 the height of a planar quadrilateral surface that is parallel and identical to the bottom planar
 2 quadrilateral surface of the geometric solid portion. Various computational methods may be
 3 employed to perform this volume calculation. The following calculations exhibit one
 4 method using only basic geometry and algebraic techniques.

5 As noted in Figure 14B, adjacent sets of coordinate data (N1, Z1, Z2, N2) and
 6 (N3, Z3, Z4, N4) from successive sensor bar 16 positions define three-dimensional geometric
 7 solid portions of the item 14 that span the length of the sensor bar 16.

8 The four height values (e.g., Z1, Z2, Z4, Z3) define the top surface vertices of
 9 each geometric solid portion, whereas, the four perpendicularly projected (onto the table
 10 surface 12) height sensor 38 positions (N1, N2, N4, N3) define the bottom surface vertices of
 11 the solid. As described above, the average of the four upper surface height values, e.g.,
 12 Z_{AVERAGE} (where $Z_{\text{AVERAGE}} = (Z1+Z2+Z3+Z4) / 4$), defines the height of the planar
 13 quadrilateral surface (Z1, Z2, Z4, Z3) that is parallel and identical to the bottom planar
 14 quadrilateral surface (N1, N2, N4, N3).

15 Determination of the area of the quadrilateral (N1, N2, N4, N3) and
 16 multiplying this value by the average height of the geometric solid, Z_{AVERAGE} , results in the
 17 approximate volume of the geometric solid portion traversed by two adjacent height sensors.

18 As illustrated in Figure 14B, the quadrilateral defined by (N1, N2, N4, N3) has
 19 four sides labeled a, b, c, d. Various methods may be employed to calculate the area of this
 20 quadrilateral such as the use of Varignon's Theorem which states that a parallelogram is
 21 formed when the midpoints of the sides of a convex quadrilateral are joined in order. The
 22 area of the parallelogram is half of the area of the original quadrilateral. The area of the
 23 parallelogram is determined by the product of its base and height, whereby, this value is

1 doubled to obtain the value of the original quadrilateral.

2 A simpler method of determining the area of the quadrilateral involves use of
3 Bretschneider's Formula which states that for a given general quadrilateral with side lengths
4 a, b, c, d, and diagonal lengths p and q, the area, A, is given by:

$$5 \quad A = (1/4)\sqrt{4p^2q^2 - (b^2 + d^2 - a^2 - c^2)^2}$$

6

7 Referring to Figures 14B and 14C, as the coordinate values of each vertex N1,
8 N2, N3, and N4 are calculated as described above, the side lengths a, b, c, d, and diagonal
9 lengths p, q, are determined by application of Pythagoras Theorem, whereby each side
10 length or diagonal length represents the hypotenuse of a right triangle. Thus, if the
11 coordinate for vertex N1 is expressed as (x1,y1), the coordinate for vertex N2 is expressed as
12 (x2,y2), the coordinate for vertex N3 is expressed as (x3,y3) and the coordinate for vertex N4
13 is expressed as (x4,y4), then the side lengths a, b, c and d are expressed as:

$$14 \quad a = \sqrt{(x3 - x1)^2 + (y3 - y1)^2}$$

$$15 \quad b = \sqrt{(x4 - x3)^2 + (y4 - y3)^2}$$

$$16 \quad c = \sqrt{(x4 - x2)^2 + (y4 - y2)^2}$$

$$17 \quad d = \sqrt{(x2 - x1)^2 + (y2 - y1)^2}$$

18 Similarly, the diagonal lengths p and q are expressed as:

$$19 \quad p = \sqrt{(x4 - x1)^2 + (y4 - y1)^2}$$

$$20 \quad q = \sqrt{(x3 - x2)^2 + (y3 - y2)^2}$$

21

22 Figure 14C illustrates the values utilized in the calculation of side length a.

23 Substituting the above determined values of a, b, c, d, p, and q into

1 Bretschneider's Formula yields the area, A , of the quadrilateral defined by (N1, N2, N4, N3).

2 Determination of the area of the quadrilateral (N1, N2, N4, N3) and
3 multiplying this value by the average height of the geometric solid, Z_{AVERAGE} , results in the
4 approximate volume of the geometric solid portion traversed by two adjacent height sensors.

5 The sum of the volumes traversed by each set of adjacent height sensors 38
6 along the length of the sensor bar 16 as the sensor bar 16 traverses the item 14 is the total
7 volume of the segment of the item 14 to the rear of the current sensor bar 16 position. This
8 cumulative volume of each segment traversed is multiplied by a density factor for the
9 particular item 14 type, which can be stored in the signal processor 300 and may be input on
10 keyboard 27, to arrive at segment weight values for each position of the sensor bar 16 in its
11 stroke, whereby such values are continuously displayed on an adjustable display 30. A cost
12 on unit weight basis may also be calculated and displayed either alternatively or at the same
13 time.

14 As the item 14 weight and cost (based on weight) is continuously calculated
15 and either selectively or continuously displayed on display 30 during the sensor bar 16
16 movement, the operator may intermittently move the sensor bar 16 in the left direction (e.g.,
17 "back-up") or right direction in order to decrease or increase the uncut segment size, weight,
18 or cost, to satisfy the requirements of an observing customer. The signal processor 300 in
19 display case 26 automatically computes the decreasing or increasing volumes (hence weights
20 and cost) in real time and provides the updated current information to the operator and
21 consumer via display 30 thus enabling the operator to accommodate an on-looking
22 consumer's specific requests as per the particular portion desired based on the item 14
23 physical appearance and associated weight or cost (based on weight) BEFORE the item 14 is

1 cut.

2

3 ADDITIONAL SUPPORT POST DISPLACEMENT DETECTOR TECHNOLOGIES

4

5 Electromagnetic Based Support Post Displacement Detectors That Interact With

6 Electromagnetic Based Table Surfaces

7 Referring to Figure 16, an electromagnetic flatbed digitizer tablet 118 is used
8 as a cutting board. The tablet 118 defines a suitable hard surface 12A.

9 The bottom end of each support post 52A contains an electromagnetic cursor
10 coil 122. As the sensor bar 16 traverses the item 14, the bottom tip of each support post 52A
11 is kept in constant contact with the table surface 12A. The digitizer tablet 118 continuously
12 captures the absolute coordinate positions of each support post 52A during the movements of
13 the sensor bar 16. These coordinates are transferred via an invisible data link (e.g., infrared)
14 or e.g., USB (universal serial bus) connection to the sensor bar 16 signal processor 300 via
15 input/output ports 58 or wireless communications module 308.

16 The sensor bar 16 signal processor 300 continuously processes support post
17 52A coordinate positional data signals along with the height sensor 38 data signals.

18 The energized cursor coil 122 generates a magnetic field. The underlying
19 digitizer tablet 118 has an embedded electromagnetic sensor grid 124 that locates the absolute
20 coordinate position of the cursor coil 122 by determining the location of the cursor generated
21 magnetic field as the support post 52A traverses the surface 12A.

22 Electromagnetic based cursor/digitizer technology has been in use for many
23 years and is used in diverse applications ranging from transferring drawing data (coordinate
24 positions) into architectural software programs to entering menu selections at a restaurant.

1 Firm-Pointed Stylus Based Support Post Displacement Detectors That Interact With
2 Pressure-Sensitive (Tactile) Based Tables Surfaces

3 Referring to Figure 17, a pressure sensitive (tactile based) flatbed digitizer
4 tablet 126 is used as a cutting board. The tablet 126 defines a suitable hard surface 12B.

5 The bottom end of each support post 52B contains a firm-pointed stylus 130.
6 As the sensor bar 16 traverses the item 14, the bottom tip of each support post 52B is kept in
7 constant contact with the table surface 12B. The digitizer tablet 126 continuously captures
8 the absolute coordinate positions of each support post 52B during the movements of sensor
9 bar 16. These coordinates are transferred via an invisible data link (e.g., infrared) or e.g.,
10 USB (universal serial bus) connection to the sensor bar 16 signal processor 300 via
11 input/output ports 58 or wireless communications module 308.

12 The sensor bar 16 signal processor 300 continuously processes the support
13 post 52B coordinate positional data signals along with the height sensor 38 data signals.

14 The digitizer tablet 126 contains a pressure sensitive sensor grid 132 that
15 resolves the absolute coordinate position of each stylus 130 by tracking the depression weight
16 of the stylus 130 as it traverses the surface 12B.

17 Pressure-sensitive (tactile) based digitizer technology has been in use for many
18 years and is used in many applications such as those described above for electromagnetic
19 based cursor/digitizer systems.

20 ADDITIONAL HEIGHT SENSOR TECHNOLOGIES

21 Reflecting Acoustic Height Sensor Used On Relatively Flat Item 14 Surfaces
22 Reflecting Acoustic Height Sensor Used On Relatively Flat Item 14 Surfaces

23 Referring to Figure 18A, an acoustic height sensor 38C is shown incorporated
24 in the sensor bar 16C as a linear array arranged along the length of the sensor bar 16C. Each
25 in the sensor bar 16C as a linear array arranged along the length of the sensor bar 16C. Each

1 acoustic height sensor 38C is comprised of an acoustic emitter/receiver unit embedded in the
2 sensor bar 16C. Various acoustic emitter/receiver technologies may comprise the height
3 sensor 38C. A common technology utilizes piezoelectric ceramic as the active sensor
4 element. Piezoelectric ceramic enables the conversion of electrical to acoustic energy as well
5 as the conversion of acoustic to electrical energy. This property enables the same
6 piezoelectric ceramic to act as both the emitter as well as the receiver in the sensor 38C.

7 Alternatively, a separate acoustic emitter and receiver may comprise the height sensor 38C.

8 As the sensor bar 16C traverses the item 14, the acoustic emitters 38C pulse
9 the upper surface of the item 14 lying beneath the sensor bar 16C. The determination of the
10 height of the item 14 top surface above the table surface 12 directly below each sensor 38C
11 corresponds to the round-trip time required for the emitted acoustic waves to reach, reflect off
12 of the item 14 top surface, and return to the respective originating overhead acoustic receiver
13 in the sensor 38C. This round-trip time is commonly called the Time-Of-Flight and its
14 determination is integral for computing distances in many products such as camera auto focus
15 range finders, burglar alarm motion detectors, and robotic collision avoidance devices.

16 Figure 18A illustrates a sensor 38C emitted acoustic waves reflecting off of a
17 relatively flat item 14 surface and returning to the originating sensors 38C. Subtracting the
18 acoustically determined sensor bar 16C to item 14 distance from the known (constant) sensor
19 bar 16C height (base of sensors 38C to table surface 12 distance) yields the height of the item
20 14 upper surface relative to the table surface 12.

21 For example, assuming that the sensor bar 16C height is 100mm, the speed of
22 an acoustic wave is 340mm/ms, and the round-trip time for an emitted acoustic wave to
23 reach, reflect off of the item 14 surface, and return to the originating sensor 38C is 0.45ms,

1 the following calculation determines the height of the item 14 upper surface relative to table
2 surface 12 located directly below the sensor 38C is 23.5mm:

$$\begin{aligned}
 & \text{Height Of Item 14 (relative table surface 12)} \\
 & = (\text{sensor bar 16C height}) - ((\text{speed of acoustic wave}) \times (\text{round-trip travel time})) / \\
 & 2) \\
 & = 100\text{mm} - ((340\text{mm/ms}) \times (0.45\text{ms})) / 2) \\
 & = 100\text{mm} - 76.5\text{mm} \\
 & = 23.5\text{mm}
 \end{aligned}$$

9
10 If all sensor 38C emitters simultaneously discharge their acoustic waves, then
11 interaction among different emitted waves would cause unpredictable wave patterns and
12 sensor 38C receivers may detect reflected acoustic pulses that did not originate from the same
13 sensor 38C emitter unit. This likelihood increases when larger emitted acoustic beam widths
14 are employed and/or sensor arrays along the length of the sensor bar 16C are comprised of a
15 high density of sensor 38C units. Such interference could result in erroneous item 14 height
16 calculations and can be avoided by multiplexing the operation of the linear array of sensor
17 38C units along the length of the sensor bar 16C.

18 To multiplex the sensors 38C, instead of all sensor 38C units emitting acoustic
19 waves simultaneously, each sensor 38C is both activated and deactivated sequentially along
20 the length of the sensor bar 16C. A successive sensor 38C emitter is not activated until the
21 currently activated sensor 38C receives back the reflected acoustic wave that it emitted and is
22 then deactivated. Instead of monitoring the transmit and corresponding receive progress of
23 each wave cycle, each successive sensor 38C along the sensor bar 16 may be activated and

1 deactivated at a fixed length time interval that is the maximum time required for a sensor 38C
2 to emit and receive a reflected acoustic wave from any item 14. This maximum time is
3 determined by calculating the time required for a sensor 38C emitted acoustic wave to reach
4 the table surface 12, reflect off the table surface 12, and return to the originating sensor 38C.

5 Implementing a multiplexing fixed length time interval longer than this
6 maximum time period ensures that only one sensor 38C is operating at a time and thus
7 reduces the possibility of unwanted acoustic wave interactions from multiple sensor 38C
8 units.

9 Implementing a multiplexing time interval that is longer than this determined
10 value also reduces the likelihood of possible residual acoustic wave bounce-backs between
11 the sensor bar 16C and item 14 will affect upcoming sensor readings. Such bounce-backs are
12 diminished or eliminated by employing a tapered base and non-reflective (reduced-reflective)
13 surface on the sensor containing underside of the sensor bar 16C, as unwanted waves will be
14 reflected upwards and outwards instead of being reflected back in the direction of the item
15 14.

16 An example of the calculation used to determine the fixed length multiplexing
17 time interval follows. By assuming that the sensor bar 16C height (base of sensors 38C to
18 table surface 12 distance) is 100mm, the speed of an acoustic wave is 340mm/ms, and the
19 item 14 height is 0.0mm, the following calculation determines the maximum possible round-
20 trip time required for an emitted acoustic wave to reach any item 14 upper surface, reflect off
21 of the item 14 surface, and return to the originating sensor 38C:

$$\begin{aligned} \text{Maximum Round-Trip Time} &= (2 \times (\text{sensor bar height})) / (\text{speed of acoustic wave}) \\ &= (2 \times (100\text{mm})) / (340\text{mm/ms}) \end{aligned}$$

1 item 14, and hence increases the overall accuracy of the volume and resultant weight and cost
2 (based on weight) calculations.

3 As the speed of acoustic waves traveling in air varies for different air
4 temperatures, the controller-signal processor case 26 contains a miniature temperature sensor
5 304 (Figure 1A) that continuously measures the operating environment air temperature. The
6 signal processor 300 continuously cross references the measured air temperature against a
7 stored temperature versus wave-speed look-up table to mathematically compensate the
8 temperature dependent item 14 height calculations to ensure their accuracy. In lieu of using
9 the above described look-up table, the signal processor 300 may use the measured air
10 temperature value in a wave speed approximation formula to calculate the temperature
11 adjusted acoustic wave speeds. Other parameters affecting air speed such as humidity and
12 air pressure can similarly be adjusted for, whereby the operator enters such information into
13 the signal processor 300 via keypad 27.

14 Again referring to Figure 18A, as sensor bar 16C traverses the item 14 and the
15 position of the sensor bar 16C reaches the desired weight (or cost) of the item 14 as shown on
16 the display 30, the operator manually applies a downward pressure on the sensor bar 16C
17 causing both retractable support posts 52C to retract upwards resulting in knife 15 moving
18 downwards and making contact with the item 14. Simultaneously applying a continued
19 downward pressure and exerting a back and forth sawing motion across the item 14 surface
20 results in the item 14 being completely cut to form the desired segment. Knife blade 15 may
21 also be used to only mark (score) the item 14 surface whereupon a separate cutting tool may
22 be used to perform the final cutting of the item 14. Alternatively, previously described
23 marking plungers 46C may be employed to indicate the exact cutting line whereupon the item

1 14 is subsequently cut by a knife or other cutting instrument.

2 After the item 14 is completely cut (or scored) and the sensor bar 16C is again
3 elevated by action of the spring-loaded retractable posts 52 fully extending themselves, the
4 operator depresses the appropriately designated "reset" pushbutton 56A-56K causing the
5 display 30 to clear and the signal processor 300 to ready the sensor bar 16C for new item 14
6 data. The sensor bar 16C is now ready to be stroked over a new item 14.

7 For sensor bar implementations 2A, 2B, 2C, or 2D that utilize acoustic sensors
8 38C, the item 14 can be scored and or cut using a separate knife, rotary cutting blade, laser
9 cutter, guillotine, or other slicing or chopping mechanism.

10

11 Reflecting Acoustic Height Sensor Used On Irregular (or Flat) Item 14 Surfaces

12 The above section entitled "Reflecting Acoustic Height Sensor Used On
13 Relatively Flat Item 14 Surfaces" describes the interaction of acoustic waves on a relatively
14 flat item 14 surface. Specifically, an emitted acoustic wave from a sensor 38C reflects off of
15 the item 14 at a near (allowing for small surface deviations) 90 degree angle relative to the
16 item 14 surface and returns to the same originating sensor 38C. If, however, a sensor 38C
17 emits an acoustic wave that interacts with an appreciably irregular (angled) surface portion of
18 item 14, the reflected acoustic wave will not return to the sensor 38C where the wave initially
19 originated, but instead will propagate in the direction dictated by the angle of reflection at the
20 item 14 surface according to the Law Of Reflection which states "A wave incident upon a
21 reflective surface will be reflected at an angle equal to the incident angle".

22 Referring to Figure 18B, the detection of acoustic waves reflected from
23 irregular (angled) item 14 surface areas is achieved by implementing a two-dimensional array

1 of acoustic receivers 39C embedded into a clear sensor panel 200C that is orthogonally
2 affixed to the top of the sensor bar 16C. Each acoustic receiver 39C detects the presence and
3 magnitude (amplitude) of acoustic waves impinging upon its surface. Various acoustic
4 receiver technologies may comprise the acoustic receiver 39C. A common technology
5 utilizes piezoelectric ceramic as the active sensor element. As piezoelectric ceramic enables
6 the conversion of acoustic to electrical energy, sensors 39C constructed of this material are
7 able to detect both the presence and magnitude of incident acoustic waves.

8 In the previous section entitled, "Reflecting Acoustic Height Sensor Used On
9 Relatively Flat Item 14 Surfaces" each sensor 38C positioned along the sensor bar 16C is
10 both sequentially activated and deactivated before a successive sensor 38C is activated. This
11 multiplexing procedure prevents an acoustic wave emitted from one sensor 38C from being
12 detected by a different sensor 38C, and helps eliminate unwanted wave interactions. In the
13 case of waves reflecting off an irregular item 14 surface and the use of sensor panel 200C, the
14 position of the specific (to be impinged) sensor receiver is not known in advance, and hence
15 all sensor receivers are simultaneously active and awaiting possible impingement from a
16 reflected wave.

17 As the acoustic wave reflecting off of the item 14 surface may impinge upon a
18 number of nearby acoustic receivers 39C (or 38C), the acoustic receiver 39C (or 38C) that
19 detects the strongest magnitude (amplitude) acoustic signal is considered to be the receiver
20 most inline with the reflected wave. Other methods used to determine the receiver most
21 inline with the reflected wave include (but are not limited to) calculating the mathematical
22 central point of all impinged receivers and selecting the receiver 39C (or 38C) closet to this
23 point.

1 Increasing the density (number) of acoustic receivers 39C (and 38C)
2 embedded in sensor panel 200C (and along the length of the sensor bar 16C) increases the
3 accuracy of detection of acoustic waves reflected off of the item 14, and hence increases the
4 resultant accuracy of the item 14 height calculations. Similarly, decreasing the beam width of
5 sensor 38C emitted waves reduces the number of acoustic receivers impinged upon, and
6 hence increases the accuracy of detecting the most in-line reflected wave thereby increasing
7 the accuracy of the item 14 height calculations.

8 The shape of sensor panel 200C may be varied, e.g., elliptical, circular,
9 rectangular, etc. The larger the surface area of sensor panel 200C that overlays the item 14,
10 the more acoustic waves that are reflected off the item 14 surface will be detected. This
11 assumes, of course, that the density of embedded acoustic receivers 39C in panel 200C is
12 sufficiently large to capture the acoustic waves reflected from the item 14. High degrees of
13 irregularity (e.g., steep surface angles) on the item 14 surface result in high angles of acoustic
14 wave deflection relative to the acoustic wave path defined by the originating acoustic sensor
15 38C position to the interception point on the item 14 surface. Thus, high degrees of surface
16 irregularity result in more reflected acoustic waves being detected towards the outward
17 boundaries of sensor panel 200C. As the sensor panel 200C is easily detached by means of
18 two screws 204C and a recessed data cable 205C near one of the screw mountings, sensor
19 panels of various shapes and embedded receiver 39C densities can easily be
20 installed/exchanged to match the degree of surface irregularity (and hence the degree of
21 acoustic wave reflection) of the item 14.

22 Sensor panel 200C is composed of a clear material whereupon the sensors 39C
23 are embedded, thus enabling the operator to view the underlying item 14 during operation of

1 the sensor bar 16C. The underside of the sensor panel is non-reflective (low-reflectance) to
2 inhibit waves that impinge upon the sensor panel from reflecting back downward and then
3 again reflecting upward towards sensors 38C or 39C.

4 The thin median region of the sensor panel 200C along the length of the sensor
5 bar 16C is devoid of active acoustic receivers 39C as the physical presence of the underlying
6 sensor bar 16C prevents acoustic waves from reaching this central area. Acoustic waves that
7 otherwise would have reached this area along the median region of sensor panel 200C are
8 detected by the acoustic sensors 38C positioned along the base of the sensor bar 16C. Item
9 14 height calculations are simply adjusted to account for the difference in physical height
10 between the 38C sensor array embedded along the base of the sensor bar 16C and the 39C
11 sensor array embedded in the panel 200C.

12 As the sensor bar 16C (Figure 18B) traverses the item 14, the acoustic emitters
13 38C pulse the upper surface of the item 14 lying beneath the sensor bar 16C. The
14 determination of the height of the item 14 upper surface relative to the table surface 12
15 directly below each sensor 38C corresponds to the time required for an emitted acoustic wave
16 to reach and reflect off of the item 14 upper surface, and either impinge upon the same
17 acoustic sensor 38C (if the underlying item 14 surface portion is relatively flat), or impinge
18 upon a different acoustic sensor 38C along the length of the sensor bar 16C, or impinge upon
19 an acoustic receiver 39C embedded in sensor panel 200C.

20 A sharply angled reflected acoustic wave may avoid detection by bypassing
21 both the linear sensor 38C array and the sensors 39C embedded in sensor panel 200C. In this
22 case, the reflected wave travels beyond the boundaries of the sensor panel 200C by entering
23 an "open air region" that is in-between the table surface 12 and the sensor panel 200C.

1 Similarly, an acoustic wave emitted from a sensor 38C is not detected if it impinges upon a
2 non-reflective surface region of the item 14. The method of handling these non-detection
3 exception cases is discussed in a following section.

4 Subtracting the acoustically determined sensor 38C to item 14 upper surface
5 distance from the known (constant) sensor bar 16C height (base of sensor 38C to table
6 surface 12 distance) yields the height of the item 14 upper surface relative to the underlying
7 table surface 12 at the position located directly below sensor 38C.

8 Referring to Figures 18B and 18C, following is an example of a hypothetical
9 sensor bar 16C calculation to determine the height, h , of the item 14 upper surface (E)
10 relative to table surface 12 (W) at the position located directly below sensor 38C (T). The
11 sensor 38C (T) emitted acoustic wave reflects off of the upper surface of the item 14 (E)
12 whereby it impinges upon a receiver 39C (P) embedded in sensor panel 200C.

13 The sensor bar 16C height, s , defined as the distance from the base of sensor
14 bar 16C (T) (position of sensor 38C) to table surface 12 (W), is 100mm. The distance, a ,
15 between the sensor 38C (T) and the sensor panel 200C (U) is 20mm, and the speed, v , of the
16 acoustic wave is 340mm/ms. Furthermore, the sensor bar 16C determined travel time, t , for a
17 sensor 38C (T) emitted acoustic wave to reach and reflect off of the upper surface (E) of the
18 item 14 and then impinge upon receiver 39C (P) embedded in sensor panel 200C is .90ms.

19 The emitting sensor 38C (T) and receiving sensor 39C (P) each lie within
20 different horizontal planes (P1 and P2 respectively), each parallel to the other, as well as to
21 plane P3 which contains table surface 12. The sensor 38C (T) lies in the horizontal plane
22 (P1) defined by the linear array of sensor 38C units at the base of the sensor bar 16C, while
23 sensor 39C (P) lies in the horizontal plane (P2) defined by the sensor panel 200C. Thus, the

1 horizontal distance between these two sensors is the shortest distance between an imaginary
 2 line drawn orthogonally through the emitting sensor 38C (T) positioned within plane P1, and
 3 an imaginary line drawn orthogonally through the acoustic receiver 39C (P) positioned within
 4 plane P2. Since the exact position of each sensor 38C (T) and 39C (P) is a known constant
 5 for the specific sensor bar 16C and sensor panel 200C utilized, the signal processor 300
 6 calculates this horizontal distance, x, between these positions once the specific receiver 39C
 7 that detects the emitted signal from the specific sensor 38C is known. In this example, the
 8 signal processor 300 determines the horizontal distance, x, between the emitting sensor 38C
 9 (T) and the receiving sensor 39C (P) as 200mm.

10 Again referring to Figures 18B and 18C, the vertices E, U, and P form a right
 11 triangle where the 90 degree angle is at the vertex U. Applying Pythagoras Theorem, the
 12 square of the reflected wave distance (E to P), d, equals the square of the sensor 38C (T) to
 13 receiver 39C (P) horizontal distance, x, plus the square of the sensor panel 200C (U) to item
 14 14 (E) distance, (a + c). This relationship is expressed as:

$$15 \quad (I) \quad d^2 = x^2 + (a + c)^2$$

16 Replacing known values into the above equation yields:

$$17 \quad (II) \quad d^2 = (200\text{mm})^2 + (20\text{mm} + c)^2$$

18 Multiplying the speed of the acoustic wave, v, by the total wave travel time, t, yields the total
 19 two segment (c + d) distance traveled by the wave (e.g., the distance traveled from sensor
 20 38C (T) to the item 14 surface (E) to the receiver 39C (P)). This relationship is expressed as:

$$21 \quad (III) \quad vt = c + d$$

22 Replacing known values into the above equation yields:

$$23 \quad (IV) \quad (340\text{mm/ms}) (.90\text{ms}) = c + d$$

1 or

2 (V) $306\text{mm} = c + d$

3

4 The two equations, (II) and (V), of two variables are solved to yield the distance, c , that the
5 acoustic wave travels from the sensor 38C (T) to the upper surface of item 14 (E). The value
6 of c is 81.65mm. Subtracting this distance from the known sensor bar 16C height, s , yields
7 the height, h , of the item 14 upper surface (E) relative to table surface 12 (W) at the position
8 located directly below sensor 38C (T). Thus,

9 (VI) $s = c + h$

10 (VII) $h = s - c$

11 Replacing known values into the above equation yields:

12 (VIII) $h = 100\text{mm} - 81.65\text{mm}$

13 (IX) $h = 18.35\text{mm}$

14 Thus, the height of the item 14 upper surface (E) relative to the underlying table surface 12
15 (W) is 18.35mm.

16 Similar item 14 height calculations are performed for the cases where the
17 reflected acoustic wave impinges upon the same originating sensor 38C (e.g., when the
18 acoustic wave impinges upon a relatively flat item 14 upper surface) or a different sensor 38C
19 located along the length of the sensor bar 16C. In these cases, the transmitting and receiving
20 sensor(s) 38C units lie in the same horizontal plane (or are the identical unit) at the base of
21 the sensor bar 16C and thus the horizontal distance between the two sensors is simply the
22 linear distance of separation.

23 If all sensor 38C emitters simultaneously discharge their acoustic waves, then

1 interaction among different emitted waves would cause unpredictable wave patterns and
2 sensor receivers 38C or 39C may not properly associate a detected wave with the proper
3 originating sensor 38C. Multiplexing the operation of each sensor 38C along the length of the
4 sensor bar 16C eliminates this problem by sequentially activating and de-activating each
5 sensor 38C emitter at a fixed length time interval that exceeds the maximum amount of time
6 an emitted acoustic wave from any sensor 38C emitter would require to reach an item 14
7 upper surface, reflect off of the item 14 surface, and reach any sensor 38C or 39C. This
8 maximum time interval is determined by calculating the time required for an acoustic wave
9 emitted from the sensor 38C located at either end of the sensor bar 16C to reach and reflect
10 off of the table surface 12 directly below the sensor 38C, and then to impinge upon the most
11 distant receiver at the opposite side of the sensor bar 16C.

12 Implementing a multiplexed fixed length time interval longer than this
13 maximum time ensures that only one sensor 38C emitter is operating at a time and thus
14 reduces the possibility of unwanted acoustic wave interactions from multiple sensor 38C
15 emitters. Similarly, longer time intervals further reduce the possibility that residual acoustic
16 wave bounce-backs between the sensor bar 16C (as well as the sensor panel 200C) and item
17 14 (or table 12 surface) will cause erroneous detection readings. Such bounce-backs are
18 diminished or eliminated by employing a tapered base and non-reflective (reduced-reflective)
19 surface on the sensor containing underside of the sensor bar 16C as well as on the underside
20 (facing the table surface 12) of the sensor panel 200C.

21 Following is an example of a hypothetical sensor bar 16C calculation used to
22 determine the fixed length multiplexing time interval. As previously described, this time
23 interval directly corresponds to the longest possible path for an acoustic wave to travel from

1 any emitting sensor to any receiving sensor. Referring to Figures 18D and 18E, the path
2 begins at sensor 38C (A) located at the rightmost sensor 38C position whereby an acoustic
3 wave emitted perpendicularly downwards from this position reaches and reflects off of the
4 table surface 12 (B), and then impinges upon the most distant sensor receiver 39C (G).

5 The position of the most distant sensor receiver 39C (G) relative to the
6 intercepted table 12 position lies along the median of sensor panel 200C at the opposite end
7 of the sensor bar 16C that contains the emitting sensor 38C (A). As outlined previously,
8 though, the median region of the sensor panel 200C along the length of the sensor bar 16C is
9 devoid of acoustic receivers 39C as the physical presence of the underlying sensor bar 16C
10 prevents acoustic waves from reaching this central area. Although an acoustic wave
11 reflected from the item 14 would actually be blocked from reaching this position by the
12 underside of the sensor bar 16C, this position is used for this calculation as it defines the
13 farthest outer boundary of a reflected acoustic wave position.

14 Again referring to Figures 18D and 18E, the sensor bar 16C height, n , defined
15 as the distance from the base of the sensor bar 16C (A) (position of the sensor 38C) to the
16 table surface 12 (B), is 100mm. The distance, m , between the sensor 38C (A) and the sensor
17 panel 200C (D) is 20mm, and the speed, v , of the acoustic wave is 340mm/ms. The exact
18 position of each sensor 38C (A) and 39C (G) is a known constant for the specific sensor bar
19 16C and sensor panel 200C utilized. In this example, the horizontal distance, k , between the
20 outermost emitting sensor 38C (A) and the furthest receiving sensor 39C (G) is 300mm.

21 The vertices G, D, and B form a right triangle whose 90 degree angle is at
22 vertex D. Applying Pythagoras Theorem, the square of the distance (B) to (G), p , equals the
23 square of the sensor 38C (A) to receiver 39C (G) horizontal distance, k , plus the square of the

1 sensor panel 200C (D) to table surface 12 (B) distance, $(m + n)$. This relationship is
2 expressed as:

3 (I) $p^2 = k^2 + (m + n)^2$

4 Replacing known values into the above equation yields:

5 (II) $p^2 = (300\text{mm})^2 + (20\text{mm} + 100\text{mm})^2$

6 The above reduces to:

7 (III) $p = 323.11\text{mm}$

8

9 The total wave travel length, f , is the sum of the two segments n and p . Thus:

10 (IV) $f = n + p$

11 Replacing known values into the above equation yields:

12 (V) $f = 100\text{mm} + 323.11\text{mm}$

13 or

14 (VI) $f = 423.11\text{mm}$

15 Since the acoustic wave speed, v , is 340mm/ms , the total travel time is expressed as:

16 (VII) $t = f / v$

17 Replacing known values into the above equation yields:

18 (VIII) $t = 423.11\text{mm} / (340\text{mm/ms})$

19 or

20 (IX) $t = 1.24\text{ms}$

21 Thus, as the time interval corresponding to the longest possible path for any acoustic wave to
22 travel from an emitting sensor to a receiving sensor is 1.24ms , a fixed multiplexing time
23 interval longer than 1.24ms is employed.

1 As previously indicated, an acoustic wave reflected from a sharply angled item
2 14 surface may avoid detection by bypassing both the linear sensor 38C array along the base
3 of the sensor bar 16C as well as the two-dimensional sensor 39C array embedded in sensor
4 panel 200C. In this case, the reflected wave travels beyond the sensor panel 200C by
5 entering an "open air region" that is in-between the table surface 12 and the sensor panel
6 200C. Similarly, an acoustic wave emitted from a sensor 38C would not be detected if it
7 impinges upon a non-reflective surface region of the item 14. This latter occurrence can be
8 avoided by applying (spraying, painting, dipping, etc) an appropriate coating onto the item 14
9 surface.

10 If during the allotted multiplexed fixed time interval an expected reflected
11 acoustic wave is not received by a sensor 38C or 39C, the item 14 height at the originating
12 sensor 38C position can be obtained by extrapolating calculated height values determined for
13 surrounding sensor 38C or 39C positions.

14 As the speed of acoustic waves traveling in air varies for different air
15 temperatures, the controller-signal processor case 26 contains a miniature temperature sensor
16 304 (shown in Figure 1A) that continuously measures the operating environment air
17 temperature. Air vent 310 allows free circulation of ambient air to the temperature sensor
18 304. The signal processor 300 continuously cross references the measured air temperature
19 against a stored temperature versus wave-speed look-up table in memory to mathematically
20 compensate the temperature dependent item 14 height calculations to ensure their accuracy.
21 In lieu of using the above described look-up table, the signal processor 300 may use the
22 measured air temperature value in a wave speed approximation formula to calculate the
23 temperature adjusted acoustic wave speeds. Other parameters affecting air speed such as

1 humidity and air pressure can similarly be adjusted for, whereby the operator enters such
2 information into the signal processor 300 via keypad 27.

3 Again referring to Figure 18B, as sensor bar 16C traverses the item 14 and the
4 position of the sensor bar 16C reaches the desired weight (or cost) of the item 14, the operator
5 manually applies a downward pressure on the sensor bar 16C causing both retractable support
6 posts 20 and 22 to retract upwards resulting in knife 15 moving downwards and making
7 contact with the item 14. Simultaneously applying a continued downward pressure and
8 exerting a back and forth sawing motion across the item 14 surface results in the item 14
9 being completely cut to form the desired segment. Knife blade 15 may also be used only to
10 mark (score) the item 14 surface whereupon an independent cutting tool may be used to
11 perform the final cutting of the item 14. Alternatively, previously described marking plungers
12 46C may be employed to indicate the exact cutting line whereupon the item 14 is
13 subsequently cut by a knife or other cutting instrument.

14 After the item 14 is completely cut (or scored) and the sensor bar 16C is again
15 elevated by action of the spring-loaded retractable posts 20 and 22 fully extending
16 themselves, the operator depresses the appropriately designated "reset" pushbutton 56A-56K
17 causing the display 30 to clear and the signal processor 300 to ready the sensor bar 16C for
18 new item 14 data. The sensor bar 16C is now ready to traverse over a new item 14.

19 Reflecting Optical Height Sensor Used On Relatively Flat Item 14 Surfaces

20 Referring to Figure 19A, an optical height sensor 38E is shown incorporated
21 in the sensor bar 16E as a linear array arranged along the length of the sensor bar 16E. Each
22 optical height sensor 38E is comprised of an optical emitter/receiver unit embedded in the
23 sensor bar 16E. Various optical emitter/receiver technologies may comprise the height

1 sensor 38E. Examples of optical emitters include (but are not limited to) LED and laser units,
2 while examples of optical receivers include (but are not limited to) CCD (Charged Coupled
3 Devices) and other PSD (Position Sensitive Detectors) such as photodiodes or photodiode
4 arrays. Thus, a separate optical emitter and receiver comprise each height sensor 38E.

5 As the sensor bar 16E traverses the item 14, the optical emitters 38E pulse the
6 upper surface of the item 14 lying beneath the sensor bar 16E. The determination of the
7 height of the item 14 top surface above the table surface 12 directly below each sensor 38E
8 corresponds to the round-trip time required for an emitted optical wave to reach, reflect off of
9 the item 14 top surface, and return to the respective overhead optical sensor 38E. Subtracting
10 the optically determined sensor bar 16E to item 14 distance from the known (constant) sensor
11 bar 16E height (base of sensors 38E to table surface 12 distance) yields the height of the item
12 14 upper surface relative to the table surface 12 directly below the respective originating
13 overhead sensor 38E.

14 Calculations regarding the optically determined height of an item 14 are
15 similar to those previously presented regarding the acoustically determined height of an item
16 14 in the section entitled "Reflecting Acoustic Height Sensor Used On Relatively Flat Item
17 14 Surfaces". The primary operational and computational difference is that the speed of light
18 is used in place of the speed of the acoustic waves.

19 Many methods may be employed to determine the aforementioned Time-Of-
20 Flight, or round-trip travel time required for an optical wave to reach and reflect off of the
21 item 14 upper surface and then return to the originating optical sensor 38E. Some methods
22 involve determining the optical wave round-trip travel time for a single wave pulse, while
23 others average round-trip times produced by multiple waves of light. Additional methods

1 include (but are not limited to) transmission/receiver systems that use phase shifting which
2 compares the phase shift between emitted modulated waves and the returned waves. Such
3 methods have the advantage of reducing background noise and false readings. Optical Time-
4 Of-Flight determination is commonplace for computing distances in many devices such as
5 surveying distance measurement equipment, range finders, as well as various displacement
6 detection mechanisms.

7 Multiplexing the operation of sensor 38E units along the sensor bar 16E in
8 order to avoid unwanted optical wave interactions from multiple sensor 38E units is similar
9 to that previously presented regarding multiplexing acoustic sensor 38C units in the section
10 entitled "Reflecting Acoustic Height Sensor Used On Relatively Flat Item 14 Surfaces".
11 Determination of the multiplexing time interval and subsequent calculation of the item 14
12 height is similar to that described for the acoustic wave sensor bar 16C, with the notable
13 operational and computational difference that the speed of light is used in place of the speed
14 of the acoustic waves employed.

15 A sensor 38E may not receive back an emitted optical wave within the
16 allocated multiplexed fixed time interval due to the item 14 surface containing an area(s) that
17 are non-reflective. The application (spraying, painting, dipping, etc.) of an appropriate
18 coating onto the item 14 surface eliminates this phenomenon. A sensor 38E also may not
19 receive back an emitted optical wave within the multiplexed time interval due to the item 14
20 having an irregular (angled) or relatively non-flat surface. Such surfaces cause the incident
21 optical wave to reflect in directions other than directly back to the originating sensor 38E
22 position. The implementation of an enlarged optical receiver panel enables the successful
23 detection of the scattered reflected waves. This sensor panel enables both the detection and

1 interpretation of the errant waves and is fully described in the section entitled "Reflecting
2 Optical Height Sensor Used On Irregular (or Flat) Item 14 Surfaces". Malfunctioning or
3 debris covered 38E sensors as well as other conditions may also prevent the detection of an
4 emitted wave. Regardless of the cause, the item 14 height at the originating sensor 38E
5 position is obtained by extrapolating height values determined from surrounding sensor 38E
6 positions.

7 Increasing the density (the number of sensor 38E units) positioned along the
8 sensor bar 16E enables the collection of more coordinate data points per given surface area of
9 item 14, and hence increases the overall accuracy of the volume and resultant weight and cost
10 (based on weight) calculations.

11 Again referring to Figure 19A, as sensor bar 16E traverses the item 14 and the
12 position of the sensor bar 16E reaches the desired weight (or cost) of the item 14, the operator
13 manually applies a downward pressure on the sensor bar 16E causing both retractable support
14 posts 52E to retract upwards resulting in knife 15 moving downwards and making contact
15 with the item 14.

16 Simultaneously applying a continued downward pressure and exerting a back
17 and forth sawing motion across the item 14 surface results in the item 14 being completely
18 cut to form the desired segment. Knife blade 15 may also be used only to mark (score) the
19 item 14 surface whereupon an independent cutting tool may be used to perform the final
20 cutting of the item 14. Alternatively, previously described marking plungers 46C may be
21 employed to indicate the exact cutting line whereupon the item 14 is subsequently cut by a
22 knife or other cutting instrument.

23 After the item 14 is completely cut (or scored) and the sensor bar 16E is again

1 elevated by action of the spring-loaded retractable posts 52E fully extending themselves, the
2 operator depresses the appropriately designated "reset" pushbutton 56A-56K causing the
3 display 30 to clear and the signal processor 300 to ready the sensor bar 16E for new item 14
4 data. The sensor bar 16E is now ready to traverse over a new item 14.

5 For sensor bar implementations 2A, 2B, 2C, or 2D that utilize acoustic sensors
6 38C, the item 14 can be scored and or cut using a separate knife, rotary cutting blade, laser
7 cutter, guillotine, or other slicing or chopping mechanism.

8 The use of the term "optical" and "light" in this application does not imply
9 only the use of the visible wave portion of the electromagnetic spectrum, but includes all
10 portions (e.g., infrared) of the spectrum that exhibit necessary characteristics of the described
11 technology.

12

13 Reflecting Optical Height Sensor Used On Irregular (or Flat) Item 14 Surfaces

14 The above section entitled "Reflecting Optical Height Sensor Used On
15 Relatively Flat Item 14 Surfaces" describes the interaction of optical waves on a relatively
16 flat item 14 surface. Specifically, an emitted optical wave from a sensor 38E reflects off of
17 the item 14 at a near (allowing for small surface deviations) 90 degree angle relative to the
18 item 14 surface and returns to the same originating sensor 38E. If, however, a sensor 38E
19 emits an optical wave that interacts with an appreciably irregular (angled) surface portion of
20 the item 14, the reflected optical wave will not return to the sensor 38E where the wave
21 initially originated, but instead will propagate in the direction dictated by the angle of
22 reflection at the item 14 surface according to the Law Of Reflection which states "An wave
23 incident upon a reflective surface will be reflected at an angle equal to the incident angle".

1 Referring to Figure 19B, the detection of optical waves reflected from
2 irregular (angled) item 14 surface areas is achieved by implementing a two-dimensional array
3 of optical receivers 39E embedded into a clear sensor panel 200E that is orthogonally affixed
4 to the top of the sensor bar 16E. Each optical receiver 39E detects the presence and
5 magnitude (amplitude) of optical waves impinging upon its surface. Various optical receiver
6 technologies may comprise the optical receiver 39E. An active sensor element such as a
7 CCD (Charged Coupled Device) enables the detection of both the presence and magnitude of
8 incident optical waves.

9 In the previous section entitled, "Reflecting Optical Height Sensor Used On
10 Relatively Flat Item 14 Surfaces" each sensor 38E positioned along the sensor bar 16E is
11 both sequentially activated and deactivated before a successive sensor 38E is activated. This
12 multiplexing procedure prevents an optical wave emitted from one sensor 38E from being
13 detected by a different sensor 38E, and helps eliminate unwanted wave interactions. In the
14 case of waves reflecting off an irregular item 14 surface and the use of sensor panel 200E, the
15 position of the specific (to be impinged) sensor receiver is not known in advance, and hence
16 all sensor receivers are simultaneously active and awaiting for possible impingement from a
17 reflected wave.

18 As the optical wave reflecting off of the item 14 surface may impinge upon a
19 number of nearby optical receivers 39E (or 38E), the optical receiver 39E (or 38E) that
20 detects the strongest magnitude (amplitude) optical signal is considered to be the receiver
21 most inline with the reflected wave. Other methods used to determine the receiver most
22 inline with the reflected wave include (but are not limited to) calculating the mathematical
23 central point of all impinged receivers and selecting the receiver 39E (or 38E) closest to this

1 point.

2 Increasing the density (number) of optical receivers 39E (and 38E) embedded
3 in sensor panel 200E (and along the length of the sensor bar 16E) increases the accuracy of
4 detection of optical waves reflected off of the item 14, and hence increases the resultant
5 accuracy of the item 14 height calculations. Similarly, decreasing the beam width of sensor
6 38E emitted waves reduces the number of optical receivers impinged upon, and hence
7 increases the accuracy of detecting the most in-line reflected wave thereby increasing the
8 accuracy of the item 14 height calculations.

9 The shape of sensor panel 200E may be varied, e.g., elliptical, circular,
10 rectangular, etc. The larger the surface area of sensor panel 200E that overlays the item 14,
11 the more optical waves that are reflected off the item 14 surface will be detected. This
12 assumes, of course, that the density of embedded optical receivers 39E in panel 200E is
13 sufficiently large to capture the optical waves reflected from the item 14.

14 High degrees of irregularity (e.g., steep surface angles) on the item 14 surface
15 result in high angles of optical wave deflection relative to the optical wave path defined by
16 the originating optical sensor 38E position to the interception point on the item 14 surface.
17 Thus, high degrees of surface irregularity result in more reflected optical waves being
18 detected towards the outward boundaries of sensor panel 200E.

19 As the sensor panel 200E is easily detached by means of two screws 204C and
20 a recessed data cable 205C near one of the screw mountings, sensor panels of various shapes
21 and embedded receiver 39E densities can easily be installed/exchanged to match the degree
22 of surface irregularity (and hence the degree of optical wave reflection) of the item 14.

23 Sensor panel 200E is composed of a clear material whereupon the sensors 39E are embedded,

1 thus enabling the operator to view the underlying item 14 during operation of the sensor bar
2 16E. The underside of the sensor panel is non-reflective (low-reflectance) to inhibit waves
3 that impinge upon the sensor panel from reflecting back downward and then again reflecting
4 upward towards sensors 38E or 39E.

5 The thin median region of the sensor panel 200E along the length of the sensor
6 bar 16E is devoid of active optical receivers 39E as the physical presence of the underlying
7 sensor bar 16E prevents optical waves from reaching this central area. Optical waves that
8 otherwise would of reached this area along the median region of sensor panel 200E are
9 detected by the optical sensors 38E positioned along the base of the sensor bar 16E. Item 14
10 height calculations are simply adjusted to account for the difference in physical height
11 between the 38E sensor array embedded along the base of the sensor bar 16E and the 39E
12 sensor array embedded in the panel 200E.

13 As the sensor bar 16E (Figure 19B) traverses the item 14, the optical emitters
14 38E pulse the upper surface of the item 14 lying beneath the sensor bar 16E. The
15 determination of the height of the item 14 upper surface relative to the table surface 12
16 directly below each sensor 38E corresponds to the time required for an emitted optical wave
17 to reach and reflect off of the item 14 upper surface, and either impinge upon the same optical
18 sensor 38E (if the underlying item 14 surface portion is relatively flat), or impinge upon a
19 different optical sensor 38E along the length of the sensor bar 16E, or impinge upon an
20 optical receiver 39E embedded in sensor panel 200E. A sharply angled reflected optical
21 wave may avoid detection by bypassing both the linear sensor 38E array and the sensors 39E
22 embedded in sensor panel 200E. In this case, the reflected wave travels beyond the
23 boundaries of the sensor panel 200E by entering an "open air region" that is in-between the

1 table surface 12 and the sensor panel 200E. Similarly, an optical wave emitted from a sensor
2 38E is not detected if it impinges upon a non-reflective surface region of the item 14. The
3 method of handling these non-detection exception cases is discussed in a following section.

4 Subtracting the optically determined sensor 38E to item 14 upper surface
5 distance from the known (constant) sensor bar 16E height (base of sensor 38E to table surface
6 12 distance) yields the height of the item 14 upper surface relative to the underlying table
7 surface 12 at the position located directly below sensor 38E.

8 Calculations regarding the optically determined height of an item 14 are
9 similar to those previously presented regarding the acoustically determined height of an item
10 14 in the section entitled "Reflecting Acoustic Height Sensor Used On Irregular (or Flat) Item
11 14 Surfaces". The primary operational and computational difference is that the speed of light
12 is used in place of the speed of acoustic waves.

13 If all sensor 38E emitters simultaneously discharge their optical waves, then
14 interaction among different emitted waves would cause unpredictable wave patterns and
15 sensor receivers 38E or 39E may not properly associate a detected wave with the proper
16 originating sensor 38E. Multiplexing the operation of each sensor 38E along the length of the
17 sensor bar 16E eliminates this problem by sequentially activating and de-activating each
18 sensor 38E emitter at a fixed length time interval that exceeds the maximum amount of time
19 an emitted optical wave from any sensor 38E emitter would require to reach an item 14 upper
20 surface, reflect off of the item 14 surface, and reach any sensor 38E or 39E. This maximum
21 time interval is determined by calculating the time required for an optical wave emitted from
22 the sensor 38E located at either end of the sensor bar 16E to reach and reflect off of the table
23 surface 12 directly below the sensor 38E, and then to impinge upon the most distant receiver

1 at the opposite side of the sensor bar 16E.

2 Implementing a multiplexed fixed length time interval longer than this
3 maximum time ensures that only one sensor 38E emitter is operating at a time and thus
4 reduces the possibility of unwanted optical wave interactions from multiple sensor 38E
5 emitters. Similarly, longer time intervals further reduce the possibility that residual optical
6 wave bounce-backs between the sensor bar 16E (as well as the sensor panel 200E) and item
7 14 (or table 12 surface) will cause erroneous detection readings. Such bounce-backs are
8 diminished or eliminated by employing a tapered base and non-reflective (reduced-reflective)
9 surface on the sensor containing underside of the sensor bar 16E as well as on the underside
10 (facing the table surface 12) of the sensor panel 200E.

11 As previously indicated, an optical wave reflected from a sharply angled item
12 14 surface may avoid detection by bypassing both the linear sensor 38E array along the base
13 of the sensor bar as well as the two-dimensional sensor 39E array embedded in sensor panel
14 200E. In this case, the reflected wave travels beyond the sensor panel 200E by entering an
15 "open air region" that is in-between the table surface 12 and the sensor panel 200E.
16 Similarly, an optical wave emitted from a sensor 38E would not be detected if it impinges
17 upon a non-reflective surface region of the item 14. This latter occurrence can be avoided by
18 applying (spraying, painting, dipping, etc) an appropriate coating onto the item 14 surface.

19 If during the allotted multiplexed fixed time interval an expected reflected
20 optical wave is not received by a sensor 38E or 39E, the item 14 height at the originating
21 sensor 38E position can be obtained by extrapolating calculated height values determined for
22 surrounding sensor 38E or 39E positions.

23 Again referring to Figure 19B, as sensor bar 16E traverses the item 14 and the

1 position of the sensor bar 16E reaches the desired weight (or cost) of the item 14, the operator
2 manually applies a downward pressure on the sensor bar 16E causing both retractable support
3 posts 20 and 22 to retract upwards resulting in knife 15 moving downwards and making
4 contact with the item 14. Simultaneously applying a continued downward pressure and
5 exerting a back and forth sawing motion across the item 14 surface results in the item 14
6 being completely cut to form the desired segment. Knife blade 15 may also be used only to
7 mark (score) the item 14 surface whereupon an independent cutting tool may be used to
8 perform the final cutting of the item 14. Alternatively, previously described marking plungers
9 46C may be employed to indicate the exact cutting line whereupon the item 14 is
10 subsequently cut by a knife or other cutting instrument.

11 After the item 14 is completely cut (or scored) and the sensor bar 16E is again
12 elevated by action of the spring-loaded retractable posts 20 and 22 fully extending
13 themselves, the operator depresses the appropriately designated "reset" pushbutton 56A-56K
14 causing the display 30 to clear and the signal processor 300 to ready the sensor bar 16E for
15 new item 14 data. The sensor bar 16E is now ready to traverse over a new item 14.

16 The use of the term "optical" and "light" in this application does not imply
17 only the use of the visible wave portion of the electromagnetic spectrum, but includes all
18 portions (e.g., infrared) of the spectrum that exhibit necessary characteristics of the described
19 technology.

20

21 "Penetrating" Wave Height Sensor

22 Referring to Figure 20, a penetrating acoustic or electromagnetic based height
23 sensor 38D is shown incorporated in the sensor bar 16D as a linear array arranged along the

1 length of the sensor bar 16D. Each penetrating height sensor 38D is comprised of an
2 emitter/receiver unit embedded in the sensor bar 16D. As the sensor bar 16D traverses the
3 item 14, the emitters 38D pulse the item 14 lying beneath the sensor bar 16D. Unlike the
4 previously described sensor bars 16 whose item 14 height determination is based upon wave
5 emissions that are reflected from the item 14 upper surface, the height of the item 14 upper
6 surface relative to the table 12 surface directly below a sensor 38D corresponds to the round-
7 trip time required for a wave pulse to leave the sensor 38D emitter, penetrate the item 14,
8 reflect off of the table surface 12, re-penetrate the item 14, and then return to the respective
9 sensor 38D receiver. Penetrating wave sensors thus eliminate the need for a sensor panel
10 200C type of configuration as waves do not reflect off of the item 14 surface, but instead
11 return to their originating sensor 38D.

12 For a given set of conditions (e.g., temperature, humidity, etc), experimentally
13 determined correspondences between round-trip wave propagation times and item 14
14 thickness is produced. For example, it may be experimentally determined that a 1 second
15 round-trip time is required for a wave pulse to leave an emitter 38D, penetrate a 1cm thick
16 item 14, reflect off of the table surface 12, re-penetrate the item 14, and then return to the
17 respective sensor 38D receiver. Creating a time versus distance equivalence lookup table that
18 is stored electronically in the memory of signal processor 300 in case 26 enables the
19 determination of item 14 thickness by equating sensor bar 16D determined round-trip wave
20 travel times to pre-determined item 14 thickness values. Sensor bars 16D employ different
21 types of sensors 38D with correspondingly different types of waves in order to accommodate
22 items 14 of various compositions.

23 INDUSTRIAL APPLICATIONS

1 Various industrial applications may utilize different configurations of the
2 sensor arm designs presented. Adaptations to the described devices are easily accommodated
3 to meet the requirements of automated assembly lines as specific sensor bar features may
4 easily be added or omitted from a configuration. For example, items 14 may pass via a
5 conveyor belt under a stationary sensor bar 16 whereupon an automatic chopping blade, laser,
6 rotary blade, or high-pressure water cutter cuts the items 14 into specific portions based on
7 volume, weight or cost. Alternately, a movable sensor bar 16 may traverse over stationary
8 single or multiple items 14 whereupon the items 14 are either marked for cutting or cut by
9 implements such as the aforementioned cutting tools. In either arrangement, the knife 15
10 and retractable sensor bar 16 support posts 20 and 22 are omitted from the configuration.

11 As each sensor arm contains a signal processor 300, flexible bi-directional
12 communication and control by a centralized computer enables the simultaneous monitoring
13 and operation of many sensor arms.

14 ADDITIONAL APPLICATIONS FOR ABOVE DESCRIBED SENSOR BARS

15 The above described sensor bars may also be used as a low cost, compact,
16 hand-held (or table unit) device used to determine 3-dimensional coordinate positions,
17 volumes, and associated weights of various objects (items 14). Such data may be transferred
18 into graphics or other data-manipulation software programs, e.g., architectural, drafting, and
19 CAD (Computer Assisted Drawing), via input/output ports 58 or wireless communications
20 module 308. As this use of the above described sensor bars does not involve cutting or
21 marking the above referenced objects, knife 15 and the aforementioned marking/scoring
22 facilities may be omitted for this implementation.

23

1 Claims

2 1. An apparatus for displaying a numeric value corresponding to the
3 volume of segments of an item having an irregular shape comprising:
4 a support surface for supporting said item;
5 an elongated sensor bar;
6 a support for positioning said sensor bar on said support surface spaced above
7 said item and allowing relative movement therebetween in either direction in a manner
8 allowing said sensor bar to be passed over said item;
9 a displacement detector arrangement which generates signals corresponding to
10 displacement of said sensor bar along said support surface in being passed over and along
11 said item;
12 a sensor arrangement generating signals corresponding to the cross sectional
13 contour of successive sections of said item passing beneath said sensor bar;
14 a signal processor receiving said signals generated by said displacement
15 detector arrangement and said sensor arrangement and computing therefrom a cumulative
16 volume of the segment of said item traversed by said sensor bar in passing over said item;
17 and
18 a display displaying numeric values corresponding to said computed
19 cumulative volume of the segment of the item that said sensor bar has passed over when said
20 sensor bar is positioned over a section of said item defining said segment.

21

22 2. The apparatus according to claim 1 wherein said support for said
23 sensor bar includes a pair of support posts extending downwardly from said sensor bar at a

1 respective end thereof, said support posts each having a lower end contacting said support
2 surface to provide said support of said sensor bar at a predetermined height above and allow
3 said sensor bar to be stroked over said item on said support surface.

4

5 3. The apparatus according to claim 1 wherein said support surface
6 comprises a movable conveyor carrying said item positioned thereon past said sensor bar to
7 thereby be passed over said item.

8

9 4. The apparatus according to claim 2 wherein each of said support posts
10 has an associated respective displacement detector which generates signals corresponding to
11 the displacement of the lower end of a respective support post, said respective displacement
12 detectors together comprising said displacement detector arrangement.

13

14 5. The apparatus according to claim 4 wherein each of said displacement
15 detectors comprises an optical tracking assembly including a light emitter directing a light
16 beam at said support surface and a light receiver receiving a light reflection from said table
17 surface, and an image analyzer analyzing successive images produced by said receiver to
18 determine the extent and direction of displacement of said respective support post.

19

20 6. The apparatus according to claim 4 wherein each of said displacement
21 detectors includes a ball mounted on the end of said associated support post engaging said
22 support surface to be rolled by movement of said associated support post, X-Y axis rollers
23 engaged with said ball to be rolled by rolling movement of said ball along either axis, and an

1 optical encoder arrangement sensing the rotation of each roller to thereby generate signals
2 corresponding to the extent and direction of each support post.

3

4 7. The apparatus according to claim 2 wherein said displacement detector
5 arrangement comprises an electromagnetic coil on each support post, and a grid in said
6 support surface generating electrical signals corresponding to the extent and direction of
7 movement of each support post across said support surface.

8

9 8. The apparatus according to claim 2 wherein said displacement detector
10 arrangement comprises said support surface having a pressure sensitive covering and each
11 support post having a sharpened end generating pressure on said pressure sensitive surface to
12 create corresponding signals as said associated support post is displaced thereon.

13

14 9. The apparatus according to claim 8 wherein said signals correspond to
15 the extent and direction of said displacement of each of said support posts.

16

17 10. The apparatus according to claim 1 wherein said support for said
18 sensor bar comprises a pair of uprights each having an upper end connected to a respective
19 end of said sensor bar, and a lower end supported with respect to said support surface for
20 guided movement of said sensor bar across said support surface, so as to constrain movement
21 of said sensor bar over said support surface to be along a fixed normal direction and
22 orientation.

23

1 11. The apparatus according to claim 1 wherein said sensor bar support
2 allows free and unconstrained movement of said vertically oriented sensor bar parallel to the
3 plane of and above said support surface.

4

5 12. The apparatus according to claim 11 wherein said sensor bar support
6 allows said sensor bar to be freely lifted off and away from said support surface.

7

8 13. The apparatus according to claim 1 wherein said sensor arrangement
9 comprises a single sensor movably mounted on said sensor bar and a sensor drive carrying
10 said sensor to scan said item to generate signals corresponding to the cross sectional contour
11 of a section of said item extending along and beneath said sensor bar.

12

13 14. The apparatus according to claim 13 further including a cutter device
14 selectively driven along said sensor bar to cut said item in a direction extending along said
15 sensor bar.

16

17 15. The apparatus according to claim 2 wherein said displacement detector
18 arrangement comprises a respective displacement detector associated with each of said two
19 support posts.

20

21 16. The apparatus according to claim 15 wherein each displacement
22 detector generates signals corresponding to the extent and direction of displacement of each
23 support post on said support surface.

1

2 17. The apparatus according to claim 10 wherein said displacement
3 detector arrangement includes an elongated optical grid extending along said support surface,
4 a skewed reader grid mounted to said one upright and over said elongated grid to create a two
5 directional shifting and readable Moiré fringe pattern upon displacement of said one upright.

6

7 18. The apparatus according to claim 1 wherein said sensor arrangement
8 comprises a series of spaced apart vertically extendable plungers arranged along said sensor
9 bars biased to be urged towards said support surface to bring a tip thereof into contact with an
10 upper surface of said item lying below said plungers, and a sensor for each plunger
11 generating signals corresponding to the distance an associated plunger is extended, said
12 signal processor receiving said signals and determining therefrom the height above said table
13 surface of a point on said upper surface of said item lying beneath a respective plunger to
14 thereby determine the contour of each successive section of said item extending in a direction
15 along said series of plungers.

16

17 19. The apparatus according to claim 18 further including a respective
18 solenoid associated with each plunger selectively operable to overcome the urging of said
19 biasing and retract said associated plunger out of contact with said support surface and said
20 item.

21

22 20. The apparatus according to claim 19 further including a magnet located
23 above each plunger holding a retracted plunger in position until said associated solenoid is

1 operated to overcome the force of said magnet.

2

3 21. The apparatus according to claim 19 further including a knife blade
4 attached to said sensor bar extending along said series of plungers, said knife blade having a
5 cutting edge exposed when said plungers are retracted.

6

7 22. The apparatus according to claim 18 wherein at least two of said
8 plungers has a sharp tip enabling scoring of said item by movement of said sensor bar.

9

10 23. The apparatus according to claim 18 wherein at least two plungers
11 have a selectively operable marker device for marking said upper surface of said item lying
12 beneath said plunger to enable cutting of said item along markings applied thereby across
13 said item.

14

15 24. The apparatus according to claim 1 further including a marking
16 arrangement on said sensor bar selectively operable to mark the upper surface of said item
17 along a line lying below and along said sensor bar to provide cutting guide marks on said
18 item.

19

20 25. The apparatus according to claim 1 wherein said sensor arrangement
21 comprises at least one sensor emitting a penetrating beam at points on said item to determine
22 the thickness of said item thereat.

23

1 26. The apparatus according to claim 2 wherein said support posts are
2 selectively retractable, and further including a knife blade attached to extend alongside said
3 sensor bar, said knife blade having a cutting edge exposed when said support posts are
4 retracted.

5
6 27. The apparatus according to claim 26 wherein said knife blade is readily
7 detachable from said sensor bar for easy replacement.

8
9 28. The apparatus according to claim 1 further including a cutting device
10 mounted on said sensor bar for traversing movement therealong and selectively engageable
11 with said item to cut a segment therefrom along a direction extending along and beneath said
12 sensor bar.

13
14 29. The apparatus according to claim 1 wherein said sensor arrangement
15 includes a sensor able to scan across said item at each location of said sensor bar reached in
16 being passed across said support surface.

17
18 30. The apparatus according to claim 1 wherein said sensor arrangement
19 includes at least one sensor including an optical emitter-receiver projecting a beam so as to
20 impinge on an upper surface of said item at points extending across said item and sensing
21 impingements of said beam across the upper surface of said item and generating signals
22 therefrom corresponding to the distance to said points on said upper surface; and, a signal
23 processor determining the height of said upper surface points above said support surface from

1 an analysis of said signals and also thereby determining the cross sectional contour of a
2 section of said item extending through said points.

3

4 31. The apparatus according to claim 1 wherein said sensor arrangement
5 includes one or more sensors having an acoustic emitter-receiver emitting sound waves and
6 detecting a reflection thereof from a series of points extending across an upper surface of said
7 item and generating signals therefrom corresponding to the distance to said points on said
8 upper surface of said item; said signal processor computing the height of said upper surface
9 above said support surface from said distance signals, and the cross sectional contour of at
10 section of said item at said points on said item.

11

12 32. The apparatus according to claim 31 further including a temperature
13 sensor sensing ambient temperatures and producing signals corresponding thereto, said signal
14 processor receiving said signals to compensate said computing for the effects of changes in
15 temperature.

16

17 33. The apparatus according to claim 18 wherein each of said plungers has
18 an optical emitter-receiver array adjacent to one side of each of said plungers, each emitter
19 emitting a beam towards said side of said associated plunger, each receiver positioned to
20 receive a reflected beam from said one side of a respective plunger, and a signal processor for
21 determining the distance said associated plunger is retracted from signals received from said
22 emitter-receiver to thereby enable determination of the height of the point on said upper
23 surface of said item contacted by said associated plunger.

1

2 34. The apparatus according to claim 1 wherein said sensor arrangement
3 includes a series of sensors mounted in a row extending along said sensor bar.

4

5 35. The apparatus according to claim 34 wherein said sensor arrangement
6 includes two or more adjacent rows of sensors.

7

8 36. The apparatus according to claim 1 further including stored density and
9 cost per unit weight values for a particular type of item utilized by said signal processor to
10 determine a total cost of said item segment, and said display displaying the total cost of each
11 segment defined at each position of said sensor bar item in being passed over and along said
12 item, as determined by said signal processor.

13

14 37. The apparatus according to claim 1 further including stored density
15 values for a particular item utilized by said signal processor to determine the total weight of
16 each item segment, and said display displaying said total weight of each segment defined at
17 each position of said sensor bar item in being passed over and along said item, as determined
18 by said signal processor.

19

20 38. The apparatus according to claim 36 further including data
21 input/output ports for selectively receiving and storing density or cost per unit weight values
22 for use by said signal processor and exporting data therefrom.

23

1 39. The apparatus according to claim 36 further including data
2 input/output ports for receiving and sending data signals.

3

4 40. The apparatus according to claim 1 further including a vertically
5 movable cutting blade device mounted to said sensor bar selectively operable to enable
6 cutting of a segment from said item along the direction of said sensor bar.

7

8 41. The apparatus according to claim 1 further including a rotary blade
9 cutter mounted to said sensor bar so as to enable cutting a segment from said item.

10

11 42. The apparatus according to claim 1 further including a cutter device
12 comprising a laser beam mounted to said sensor bar.

13

14 43. The apparatus according to claim 24 wherein said marker arrangement
15 includes at least two ink jet printer devices able to print marks on said item upper surface.

16

17 44. The apparatus according to claim 43 wherein said ink jet printer device
18 is capable of marking said items with one of a plurality of ink colors.

19

20 45. The apparatus according to claim 43 further including a color sensor
21 on said sensor bar detecting the color of said item, said ink jet printer device capable of
22 switching ink colors to mark said item in an ink color contrasting to said sensed color of said
23 item.

1

2 46. The apparatus according to claim 24 wherein said marker arrangement
3 includes a plurality of marker devices mounted along said sensor bar, and wherein each
4 marker device comprises a thermal marker mounted to a retractable plunger selectively
5 operable to burn a mark on said item upper surface beneath said sensor bar.

6

7 47. The apparatus according to claim 24 wherein said marker device
8 comprises a laser scoring marker.

9

10 48. The apparatus according to claim 24 wherein said marker device
11 comprises a sharp instrument for scoring said items mounted on a retractable plunger.

12

13 49. The apparatus according to claim 18 wherein at least two of said
14 plungers each have a marker device mounted thereto and which is selectively operable to
15 mark an upper surface of said item.

16

17 50. The apparatus according to claim 46 wherein each marker device
18 includes a sharp tool at the tip of said associated plunger, and further including a locking
19 mechanism for locking said plunger in any of a plurality of extended positions to enable
20 pressure to be exerted by said marker device sharp tool.

21

22 51. The apparatus according to claim 18 further including a marker device
23 mounted between adjacent plungers, each marker device mounted on a marker plunger

1 extendibly mounted to said sensor bar and selectively operable to mark an upper surface of
2 said item.

3

4 52. The apparatus according to claim 1 further including at least two
5 marker devices mounted along said sensor bar selectively operable to mark said item upper
6 surface to together provide at least two markings as an aid in cutting said item.

7

8 53. The apparatus according to claim 52 wherein each marker device
9 comprises an ink jet printer mounted to a plunger retractable into said sensor bar.

10

11 54. The apparatus according to claim 53 wherein each ink jet printer
12 includes a nozzle and a spacer collar mounted thereto preventing contact with said item to
13 thereby avoid blocking said nozzle with debris from said item.

14

15 55. The apparatus according to claim 51 wherein said marker plunger is
16 selectively locked when retracted to keep said marker devices out of the way when not in use.

17

18 56. The apparatus according to claim 53 wherein each of said ink jet
19 printer devices comprises a piezo electric ink jet printer device mounted to a plunger
20 retractable into said sensor bar.

21

22 57. The apparatus according to claim 53 wherein each of said ink jet
23 printers comprises a thermal bubble ink printer device.

1

2 58. The apparatus according to claim 52 wherein each marker device is
3 mounted to be extendible and retractable on said sensor bar.

4

5 59. The apparatus according to claim 58 further including a sensor
6 associated with each marker device detecting an extended position in contact with said item
7 and a retracted position thereof.

8

9 60. The apparatus according to claim 58 further including a selectively
10 operable locking device preventing retraction or extension of said marking device from each
11 position thereof.

12

13 61. The apparatus according to claim 2 further including a second pair of
14 support posts spaced laterally from said first mentioned pair of support posts and extending
15 downwardly from said sensor bar to contact said support surface, providing a four cornered
16 stable support for said sensor bar.

17

18 62. The apparatus according to claim 1 further including a controller-
19 signal processor case mounted on said sensor bar and having tactile controls connected to
20 said signal processor selectively controlling operation of said sensor bar.

21

22 63. The apparatus according to claim 62 wherein said controller-signal
23 processor case includes a keyboard for inputting values with respect to item characteristics

1 for use by said signal processor in determining item segment cost numeric values.

2

3 64. The apparatus according to claim 63 wherein item density values may
4 be selectively input to a memory of said signal processor by said keyboard.

5

6 65. The apparatus according to claim 63 wherein item cost per unit weight
7 values are selectively input to the memory of said signal processor by said keyboard.

8

9 66. The apparatus according to claim 62 wherein said controller-signal
10 processor case is detachably mounted on said sensor bar and further includes a wireless link
11 transmitting signals between said sensor bar and controller signal processor.

12

13 67. The apparatus according to claim 66 wherein said wireless link
14 includes radio frequency transmitter-receiver.

15

16 68. The apparatus according to claim 66 wherein said wireless link
17 includes a omnidirectional infrared communication device.

18

19 69. The apparatus according to claim 66 further including transmitting
20 signals via a wireless link between said detachable controller signal processor case and
21 external devices such as point of sale displays, receipt printer, or cash register.

22

23 70. The apparatus according to claim 34 wherein each of said sensors

1 includes an emitter emitting a beam of waves at said item and an associated receiver
2 responsive to impingements of said beam on an upper surface of said item.

3

4 71. The apparatus according to claim 34 wherein each of said sensors
5 includes an emitter emitting a beam of waves at said item, and further including a two
6 dimensional array of receivers positioned to detect waves reflected from said item.

7

8 72. The apparatus according to claim 71 wherein the receiver in said two
9 dimensional array with the strongest signal is utilized by said signal processor to determine
10 height of a point on said item.

11

12 73. The apparatus according to claim 70 wherein at least some of said
13 sensor emitters are operated at different times to minimize response by each sensor receiver
14 of impingements of beams from other emitters.

15

16 74. The apparatus according to claim 73 wherein a time interval is
17 provided between operation of successive emitters in said row of sensors sufficient to prevent
18 response to impingements of beams resulting from operation of more than one emitter at a
19 time.

20

21 75. The apparatus according to claim 71 wherein the signals produced by
22 all of said receivers are processed to determine the receiver most in line with the
23 impingement of a beam from an associated emitter, the signal from which is used by said

1 signal processor in calculating the height of a point on the upper surface of said item.

2

3 76. The apparatus according to claim 34 wherein at least two rows of
4 sensors are mounted along said sensor bar.

5

6 77. The apparatus according to claim 71 wherein said two dimensional
7 array of receivers is mounted to a transparent piece mounted on said sensor bar.

8

9 78. The apparatus according to claim 1 wherein a manually graspable
10 handle is affixed to one end of said sensor bar.

11

12 79. The apparatus according to claim 62 wherein said control signal
13 processor case includes a display screen attached to project above said sensor bar.

14

15 80. The apparatus according to claim 2 further including an alarm
16 indicating an unallowable operation such as a tilt of said sensor bar and support posts being
17 out of plumb to a predetermined unallowable degree.

18

19 81. The apparatus according to claim 2 further including a level indicator
20 fixed with respect to said sensor bar indicating a tilt condition of said attached support posts.

21

22 82. The apparatus according to claim 1 further including a cutting device
23 mounted to said sensor bar and a powered drive for driving said cutting device along said

1 sensor bar.

2

3 83. The apparatus according to claim 70 wherein each receiver is offset
4 from the associated emitter and includes a position sensitive detector laterally locating an
5 image of said beam impingement on said item seen by said position sensitive detector,
6 thereby enabling determination by triangulation of the distance from the emitter to said point
7 of impingement on an upper surface of said item whereat said emitting beam is directed.

8

9 84. The apparatus according to claim 30 wherein said receiver of each
10 sensor is offset from its associated emitter and includes a position sensitive detector
11 determining the position of images seen by said position sensitive detector of said beam
12 impingements, thereby enabling determination of the distance to points of impingement on an
13 upper surface of said item whereat said emitting beam is projected.

14

15 85. The apparatus according to claim 1 wherein said display is
16 continuously updated by said signal processor as said sensor bar is passed over and along said
17 item.

18

19 86. The apparatus according to claim 34 wherein each of said sensors
20 simultaneously generate signals.

21

22 87. A method of displaying a numeric value corresponding to the volume
23 of segments of an irregularly shaped item comprising the steps of:

1 disposing said item on a support surface;
2 supporting an elongated sensor bar at a preset height above said surface
3 sufficient to clear said item;
4 relatively moving said sensor bar and said support surface to cause said sensor
5 bar to pass over and along said item from one side thereof;
6 generating signals corresponding to the contour of successive sections of said
7 item passing beneath said sensor bar as said sensor bar is passed thereover;
8 detecting displacement of said sensor bar relative to said surface as said sensor
9 bar is passed over and along said item and generating corresponding signals;
10 processing said generated sensor and detector signals to calculate therefrom
11 the cumulative volume of the segment of said item which has been passed over by said sensor
12 bar;
13 deriving a numeric value corresponding to a calculated volume of each
14 segment defined by successive positions of said sensor bar; and
15 displaying said numeric value thereby derived.

16

17 88. The method according to claim 87 wherein said step of generating
18 signals corresponding to the contour of each successive section of said item comprises the
19 step of sensing the height of an upper surface of said item above said support surface at a
20 plurality of points lying on each section of said item as said sensing bar passes thereover.

21

22 89. The method according to claim 87 wherein said step of sensing the
23 contour of each successive section of said item includes the step of engaging an upper surface

1 of said item simultaneously with a bottom end of each of a series of vertically moveable
2 plungers carried by said sensor bar as said sensor bar passes over said item and generating
3 signals corresponding to the vertical position of each of said plungers during said relative
4 movement of said sensor bar.

5

6 90. The method according to claim 88 wherein said step of sensing the
7 height of points along each successive section of said item comprises the step of directing a
8 beam at said points on said upper surface of said item from each of a series of emitters on
9 said sensor bar as said sensor bar is passed thereover.

10

11 91. The method according to claim 90 wherein said step of directing a
12 beam at points on the upper surface of said item along successive sections of said item further
13 includes the step of mounting a series of image readers along said sensor bar positioned to
14 detect images of beam impingements on said item.

15

16 92. The method according to claim 88 wherein said step of generating
17 signals corresponding to the contours of successive sections of said item includes the step of
18 scanning a beam across said item at each of successive sections of said item as said sensor
19 bar passes thereover and detecting images of impingements of said beam to determine said
20 contour of successive sections of said item at each position of said sensor bar.

21

22 93. The method according to claim 87, further including the step of
23 marking an upper surface of said item across along a section thereof as a guide to cutting said

1 item into a segment after a selected segment is reached by said sensor bar.

2

3 94. The method according to claim 93 wherein said step of marking said
4 item includes the step of mounting a series of ink jet printer devices to said sensor bar.

5

6 95. The method according to claim 93 wherein said step of marking said
7 item includes the step of mounting a series of heating element branding to devices to said
8 sensor bar.

9

10 96. The method according to claim 93 wherein said step of marking said
11 item includes the step of mounting a series of laser beam marking devices to said sensor bar.

12

13 97. The method according to claim 93 wherein said step of marking said
14 item includes the step of mounting a series of sharp pointed marking devices to said sensor
15 bar.

16

17 98. The method according to claim 88 wherein said step of processing said
18 generated sensor and detector signals includes the step of defining a solid in part by said
19 signals corresponding to said contours of said item sections at successive sensor bar positions
20 and calculating the volume of said defined solid.

21

22 99. The method according to claim 87 wherein said step of determining
23 said numeric value includes the step of multiplying said calculated volume by a stored

1 density factor so that said displayed numeric value corresponds to the weight of an item
2 segment.

3

4 100. The method according to claim 99 wherein said step of determining
5 said numeric value further includes the step of multiplying said weight by a cost factor so that
6 said numeric value comprises the cost of an item segment.

7

8 101. The method according to claim 89 wherein said step of engaging said
9 item upper surface with plungers carried by said sensor bar, comprises the step of mounting a
10 series of vertically movable plungers spaced apart along the underside of said sensor bar and
11 biasing said plungers to move down to engage a tip of each plunger with an upper surface of
12 successive sections of said item or with said table surface in the absence of said item
13 therebeneath, and further including the step of simultaneously generating signals
14 corresponding to the position of each plunger tip while said sensor bar is moved relative to
15 said support surface to pass over said upper surface of said item, with said plunger tips in
16 engagement with said support surface or said upper surface of successive sections of said
17 item.

18

19 102. The method according to claim 101 further including the step of
20 mounting a knife to said sensor bar and selectively retracting all of said plungers to expose a
21 blade edge of said knife to allow slicing said item therewith.

22

23 103. The method according to claim 87 further including the step of

1 mounting a knife blade to said sensor bar so as to enable slicing of said item therewith.

2

3 104. The method according to claim 87 wherein said step of supporting said
4 sensor bar comprises the step of mounting a support post at either end of said sensor bar
5 projecting downwardly to engage said support surface to support said sensor bar thereon.

6

7 105. The method according to claim 87 wherein said step of supporting said
8 sensor bar includes the step of supporting said sensor bar on a table defining said support
9 surface so as to constrain the motion thereof over said table to move through successive
10 parallel and aligned positions.

11

12 106. The method according to claim 87 wherein said step of supporting said
13 sensor bar on said support surface comprises the step of mounting pairs of support posts to
14 each of two opposite ends of said sensor bar to stably support said sensor bar on said support
15 surface.

16

17 107. The method according to claim 87 wherein said step of supporting said
18 sensor bar allows said sensor bar to be moved freely in a plane parallel to said support
19 surface.

20

21 108. The method according to claim 107 wherein said step of supporting
22 said sensor bar also allows said sensor bar to be freely lifted and taken away from said
23 support surface.

1

2 109. The method according to claim 87 wherein said step of relatively
3 moving said sensor bar and a support surface includes the step of conveying said item on a
4 conveyor belt comprising said support surface beneath said sensor bar.

5

6 110. A method of generating coordinate data corresponding to the
7 configuration of an irregularly shaped item comprising the steps of:

8 disposing said item on a support surface;

9 supporting an elongated sensor bar at a preset height above said surface
10 sufficient to clear said item;

11 relatively moving said sensor bar and said support surface to cause said sensor
12 bar to pass over and along said item from one side thereof;

13 generating signals corresponding to the contour of successive sections of said
14 item passing beneath said sensor bar as said sensor bar is passed thereover;

15 detecting displacement of said sensor bar relative said surface as said sensor
16 bar is passed over and along said item and generating corresponding signals; and

17 processing said generated sensor and detector signals to derive therefrom
18 coordinate data defining the configuration of a segment of said item which has been passed
19 over by said sensor bar.

20

21 111. The method according to claim 110 wherein said sensor bar is
22 manually held when being passed over said item.

23

1 112. The method of cutting a segment from an item to a purchaser of a
2 desired weight or cost comprising the steps of:
3 passing a sensor bar over said item capable of generating signals from which
4 the volume of each uncut segment passed over may be calculated;
5 calculating the volume of each segment and substantially contemporaneously
6 displaying a related numeric value at each position of the sensor bar so as to allow viewing of
7 the same; and,
8 upon reaching a sensor bar position corresponding to a desired segment,
9 thereafter cutting said item to create a corresponding selected item segment, whereby an
10 accurately predetermined segment of a desired weight or cost is defined prior to cutting.

11

12 113. The method according to claim 112 further including the step of
13 marking said item at said sensor bar position as an aid in cutting said item to create said
14 segment of a desired weight or cost.

15