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United States Patent [19]

Young et al.

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[45] Date of Patent: May 7, 1996

[54] **LOIN SEPARATION APPARATUS AND METHOD OF OPERATION THEREFOR**

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[73] Assignee: **Hormel Foods Corporation**, Austin, Minn.

[21] Appl. No.: **390,116**

[22] Filed: **Feb. 17, 1995**

[51] **Int. Cl.**[6] **A22C 18/00**

[52] **U.S. Cl.** **452/171**; 452/136

[58] **Field of Search** 452/171, 135, 452/134, 135, 150, 136

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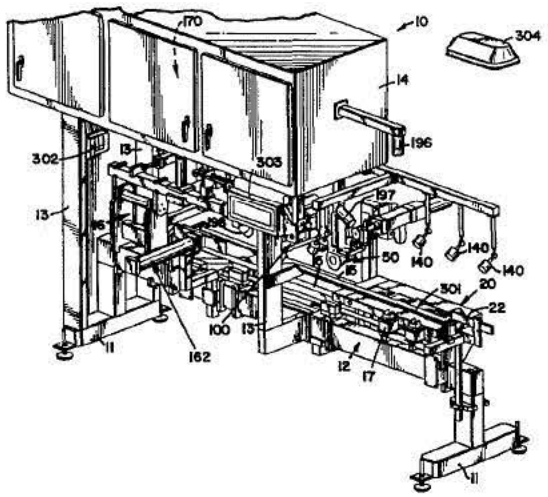
Primary Examiner—Willis Little

Attorney, Agent, or Firm—Merchant, Gould, Smith, Edell, Welter & Schmidt

[57] **ABSTRACT**

A loin separation apparatus and method of operation therefor controls a loin knife assembly in a manner which simulates the anthropomorphic motions of a human operator during a loin pulling operation. The loin knife assembly includes a U-shaped knife blade which is mounted to an arm which is connected to the apparatus through a universal joint to permit lateral and vertical displacement of the knife blade. Moreover, the separation between the sides of the loin knife may be varied. The combination of lateral displacement and varying the separation between the sides of the blade enables the sides of the knife blade to follow separate profiles. The loin separation apparatus generates customized cutting profiles and/or modifies standard cutting profiles for the loin knife assembly, as well as for a scribe saw assembly which may also be included on the apparatus, based upon the particular dimensions, contours, etc. of a specific side of meat.

46 Claims, 15 Drawing Sheets



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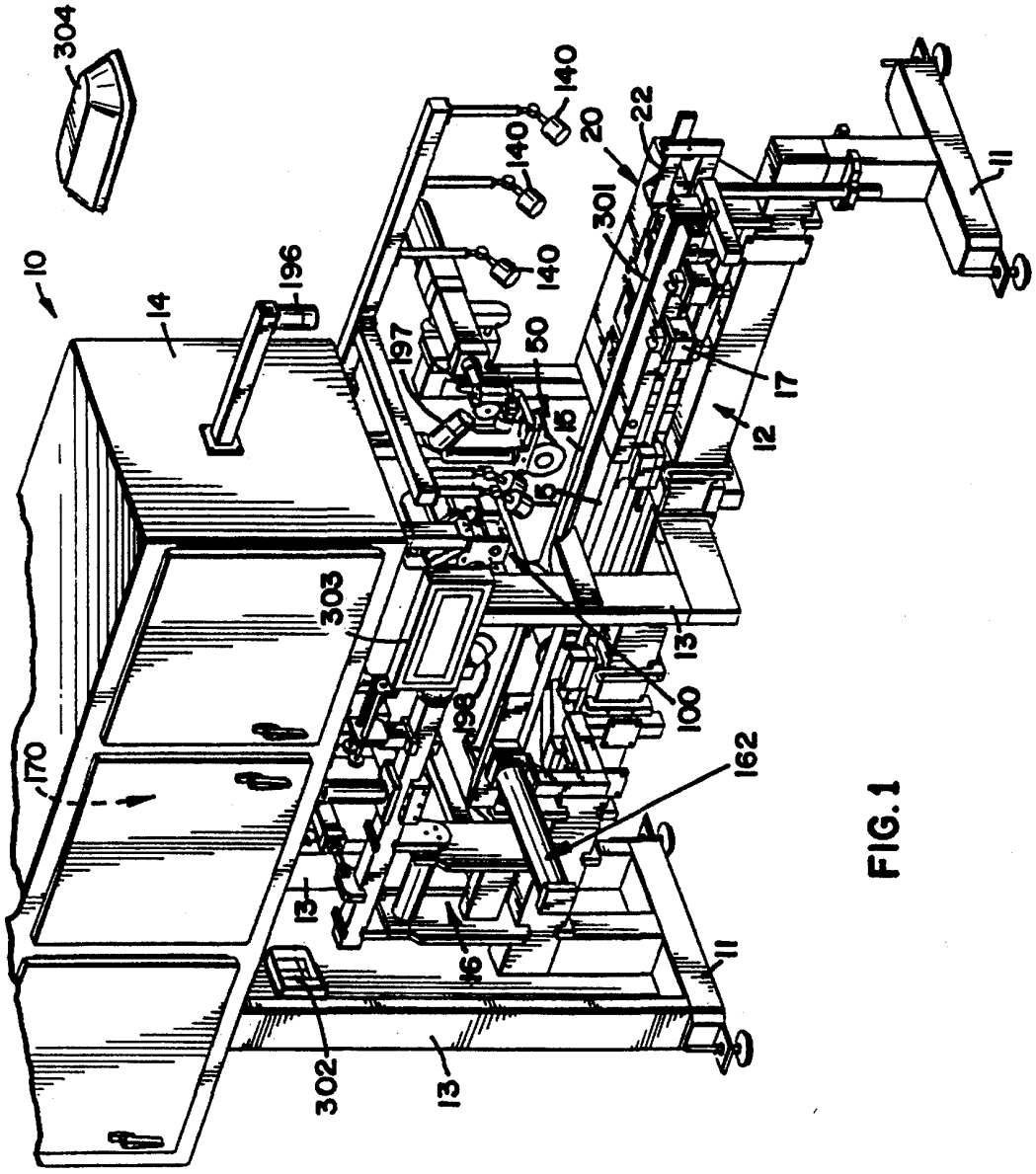
U.S. Patent No. 8,529,321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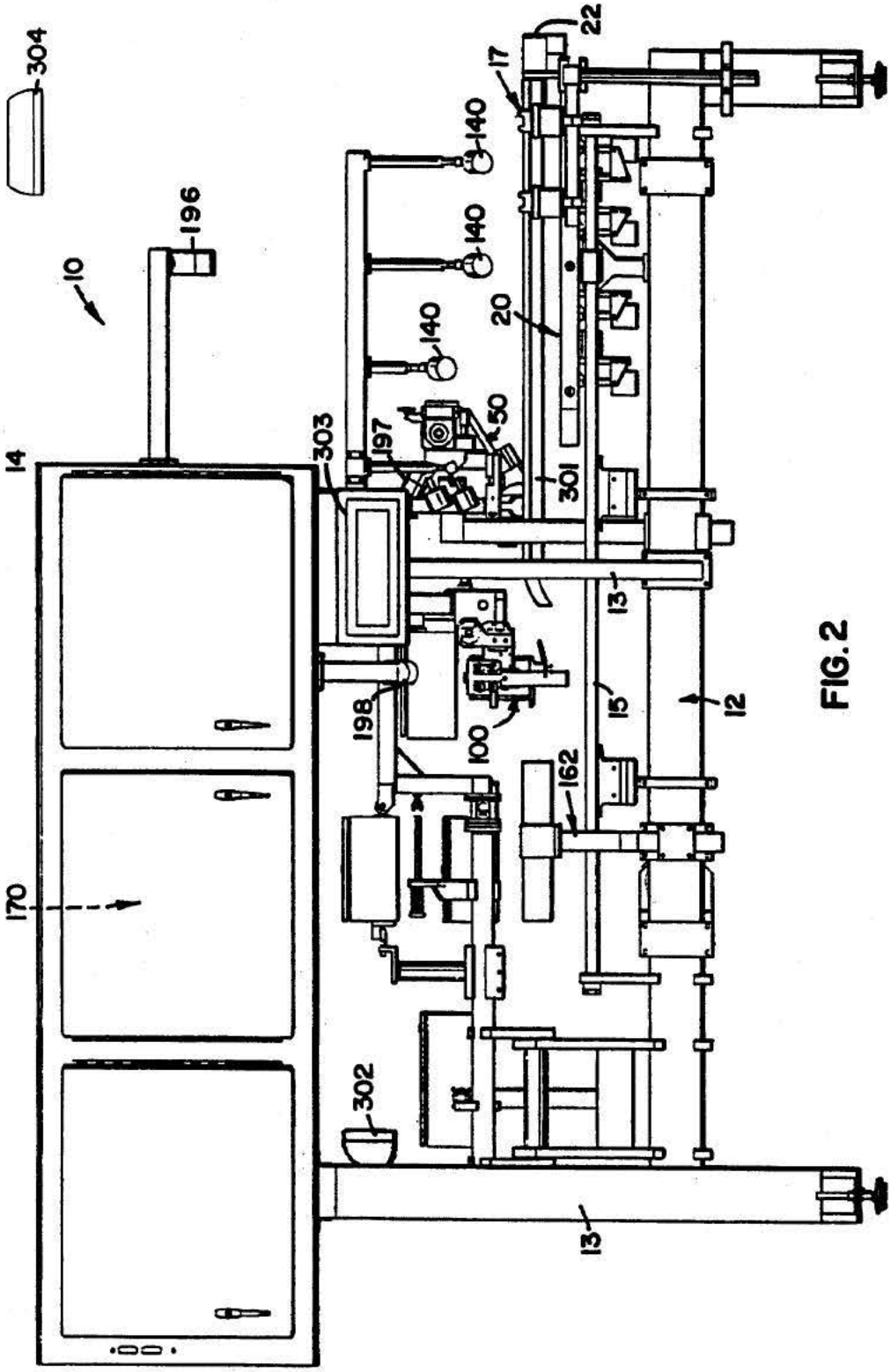
162
170
13
96
11
302
13

FIG.1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170
302
13

FIG. 2

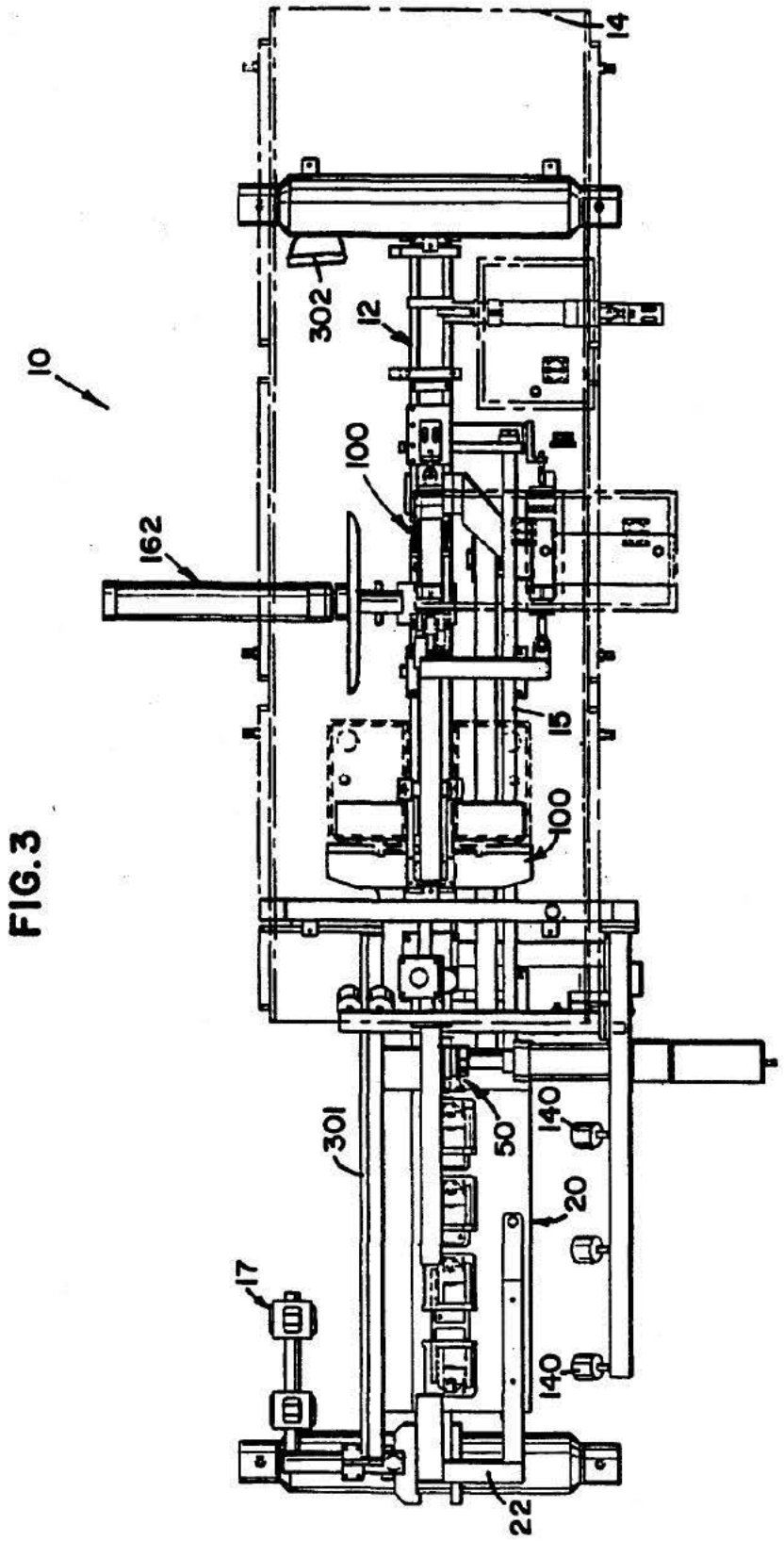


FIG.3

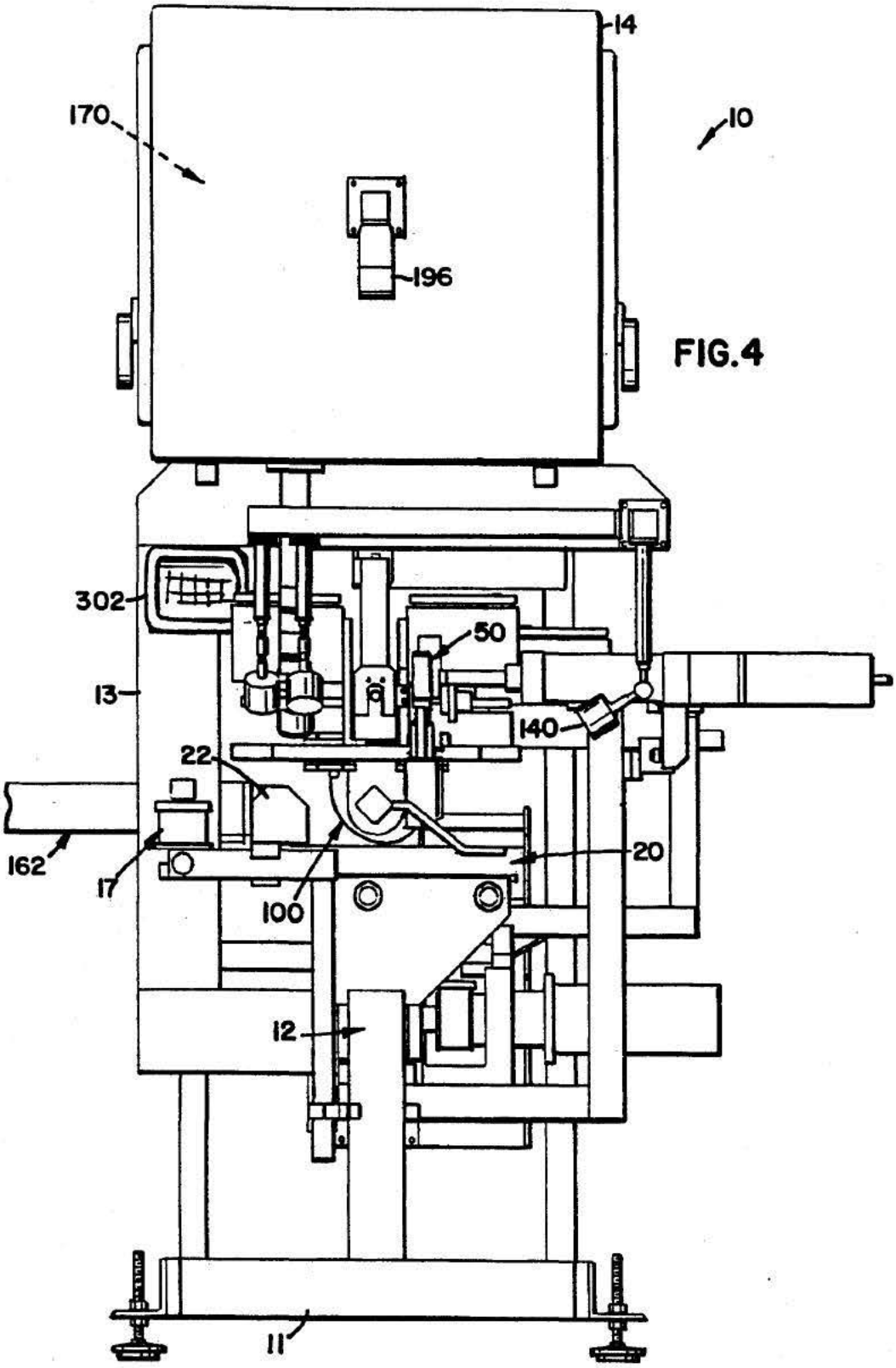
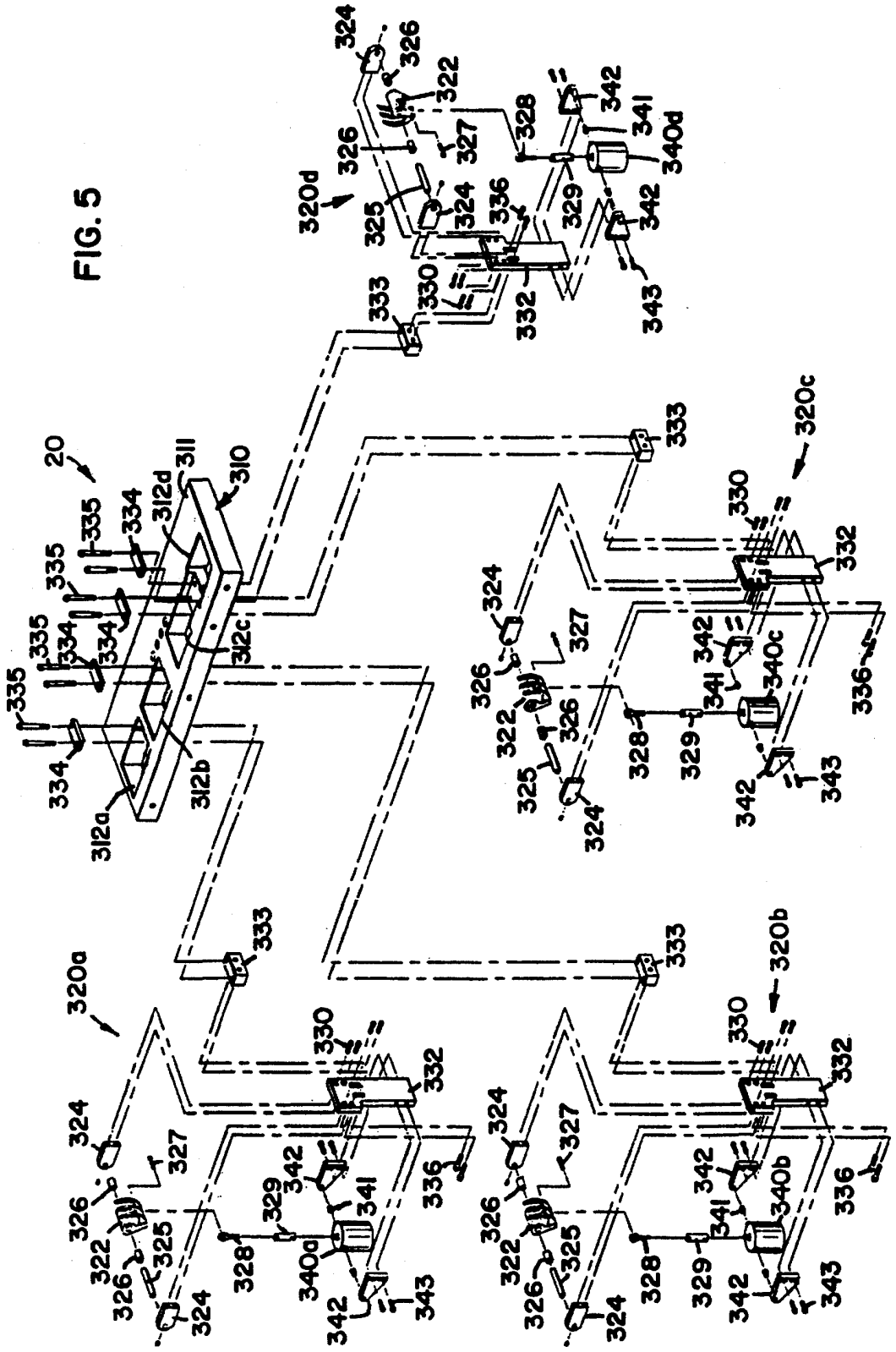


FIG.4

FIG. 5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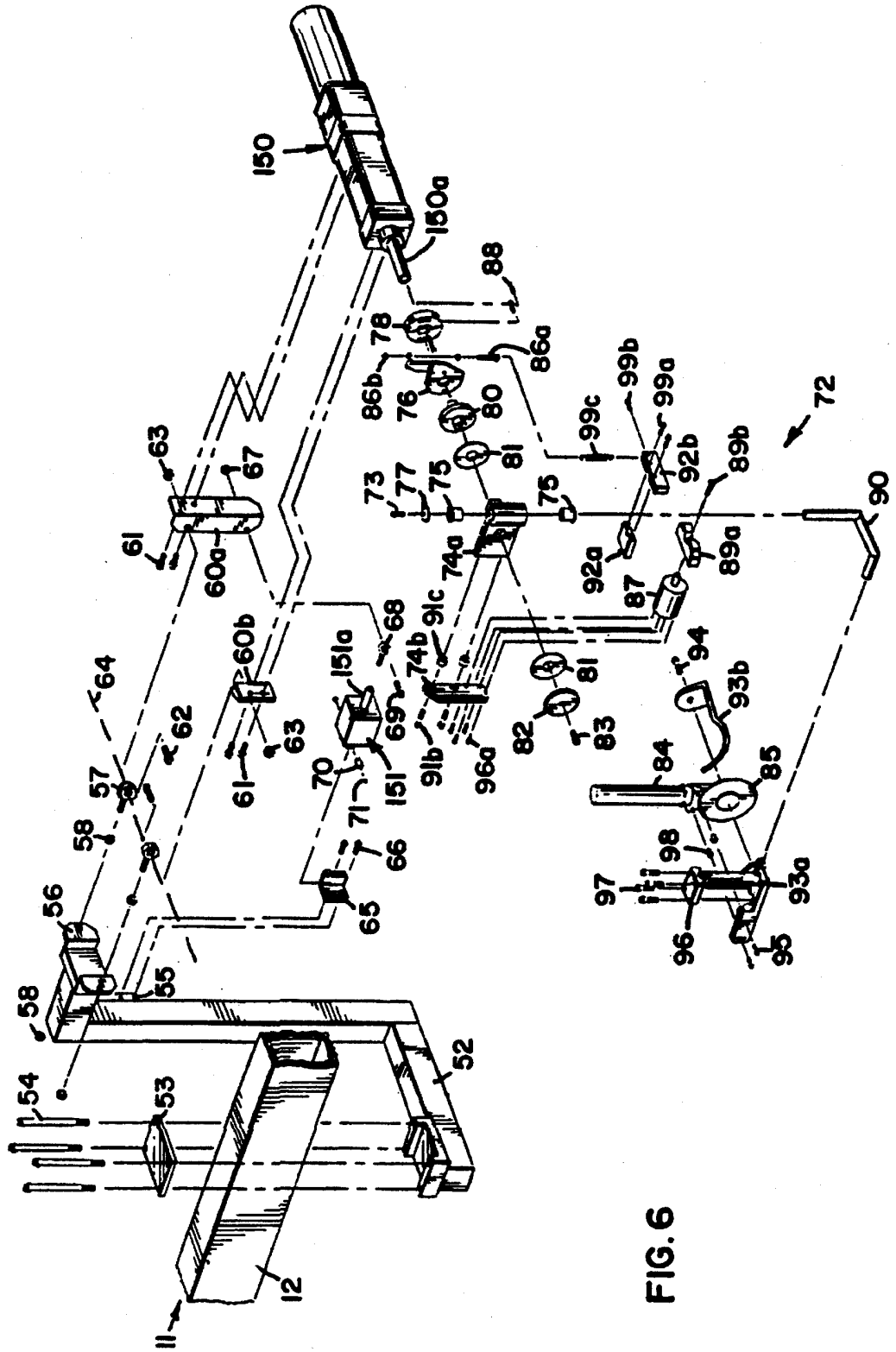
342
343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99a
99c
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81
92b
89b
90
74a
92a
87
89a
60b
68
91c
151a
74b
64
62
69
91b
96a
82
83
94
93b
57
58
70
71
151
66
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84
85
56
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98
97
93a
96
95
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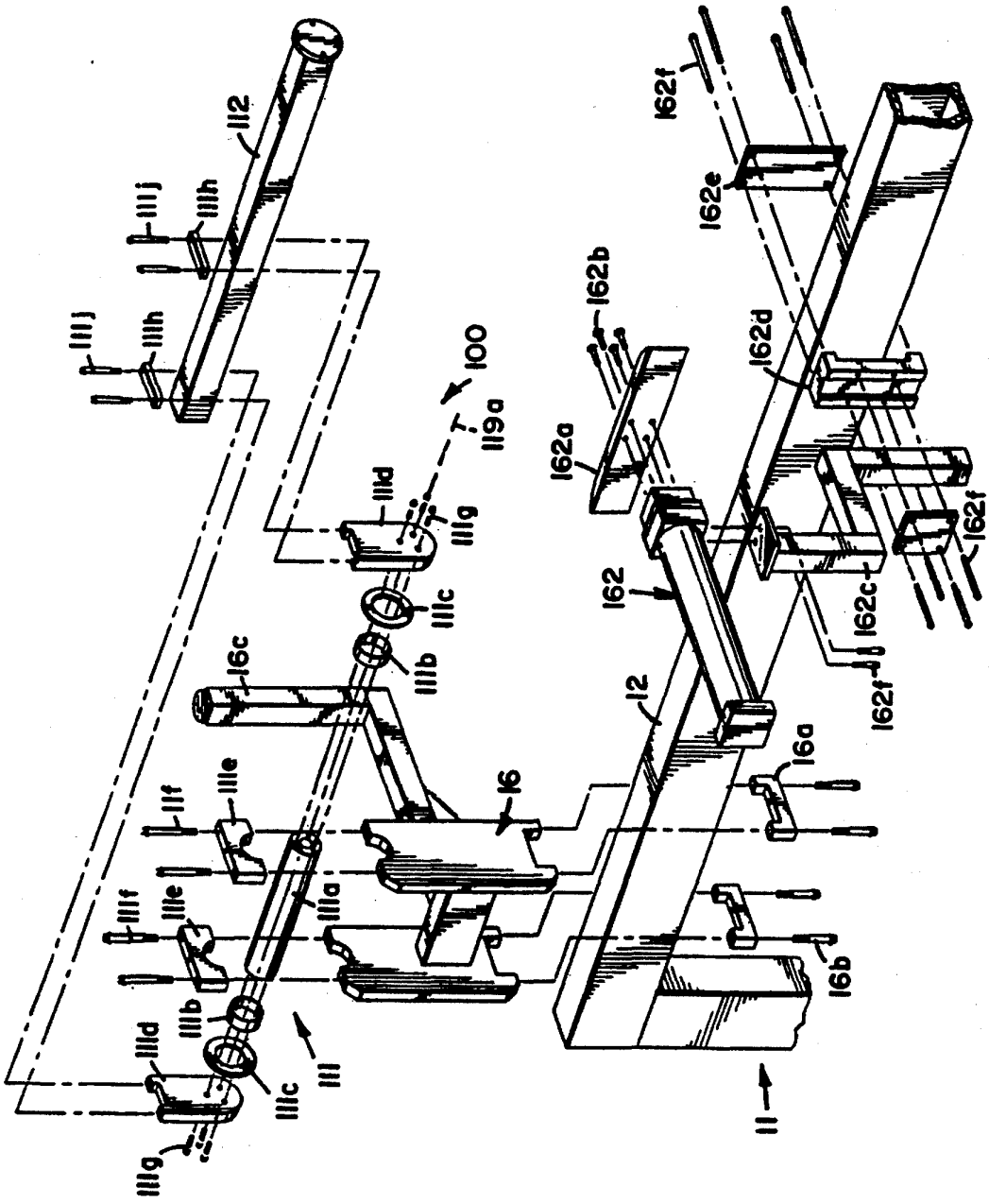
12
11

FIG. 6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111j
111h
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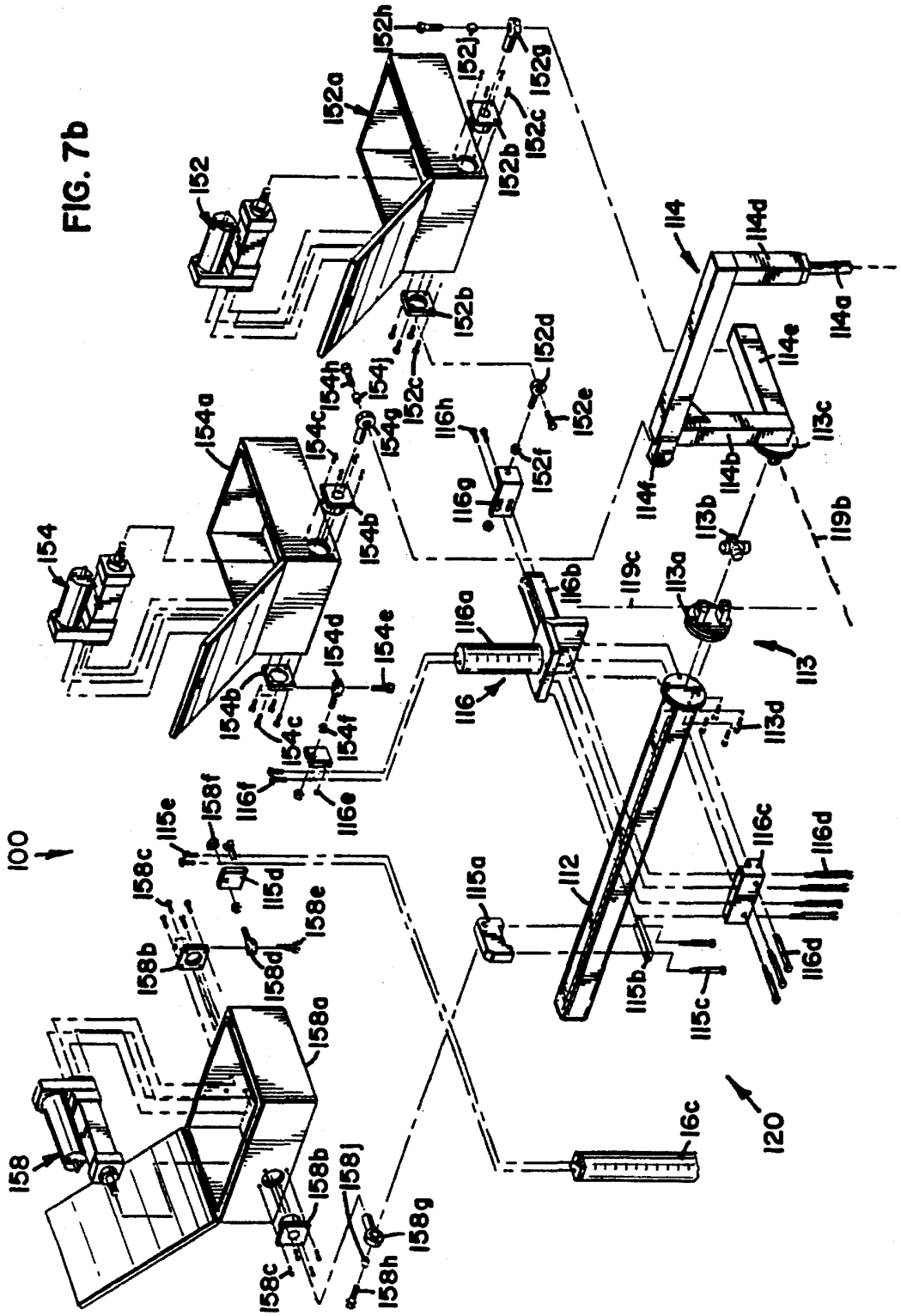
111a
111b
111d
111c
111
111g
162f
162e
162b
162d
162a
162f
162
162c
162f
12
16a
16b
11

FIG. 7a

FIG. 7b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116d
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116g
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119c
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152a
152b
152c
152d
152e
152f
152g
152h
152i
152j
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154a
154b
154c
154d
154e
154f
154g
154h
154i
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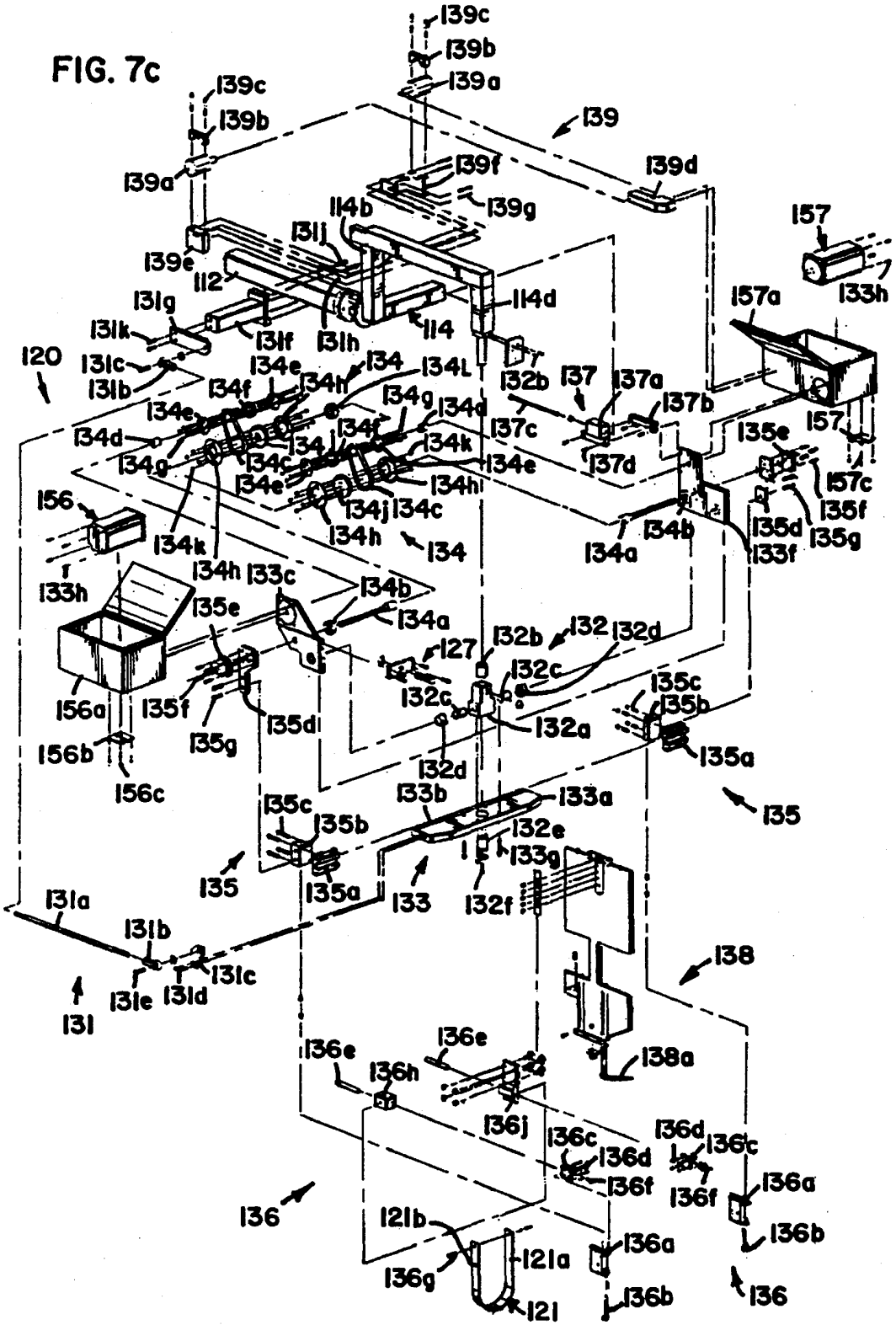
158g
158h
158i
158j
16c

FIG. 7c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131c
131b
134e
134f
134h
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134L
134g
134d
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134j
134c
134i
132b
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137a
137b
137c
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133h
157c
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135a
132d
133b
133a
135
132e
133g
132f
133
131a
131b
131c
131e
131d
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136j
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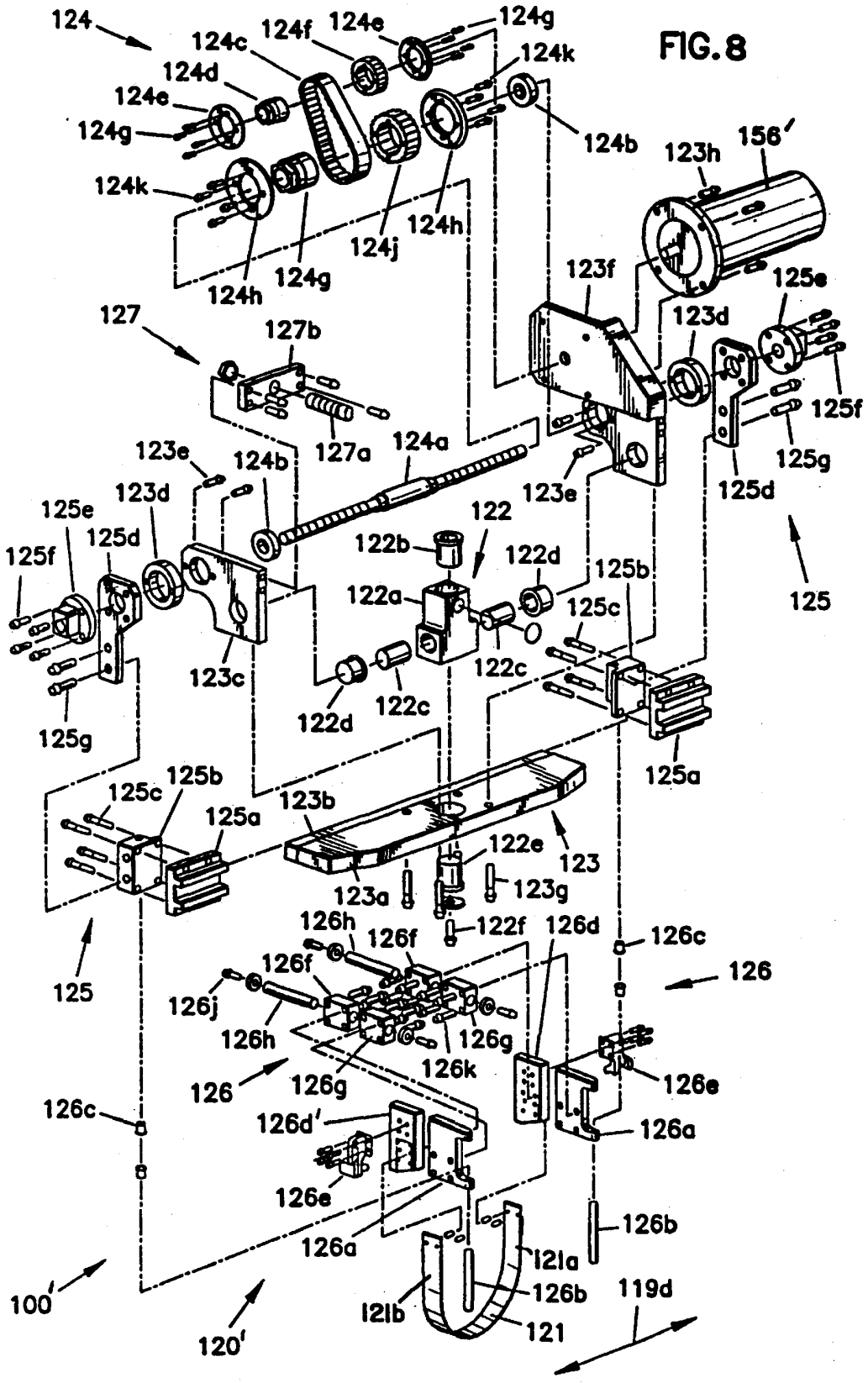
136c
136a
136b
136
121b
121a
121
136g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123h
156'
123f
125e
123d
125f
125g
125d
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127b
127a
124a
123e
124b
123e
123d
125e
125d
125f
122
122b
122d
122a
122c
125b
125c
123c
122d
122c
125g
125
125a
125c
125b
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123a
123g
122f
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126f
126j
126h
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126k
126g
126
126e
126c
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126e
126b
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121a
126b
119d
100'
120'
121b
121

FIG. 8

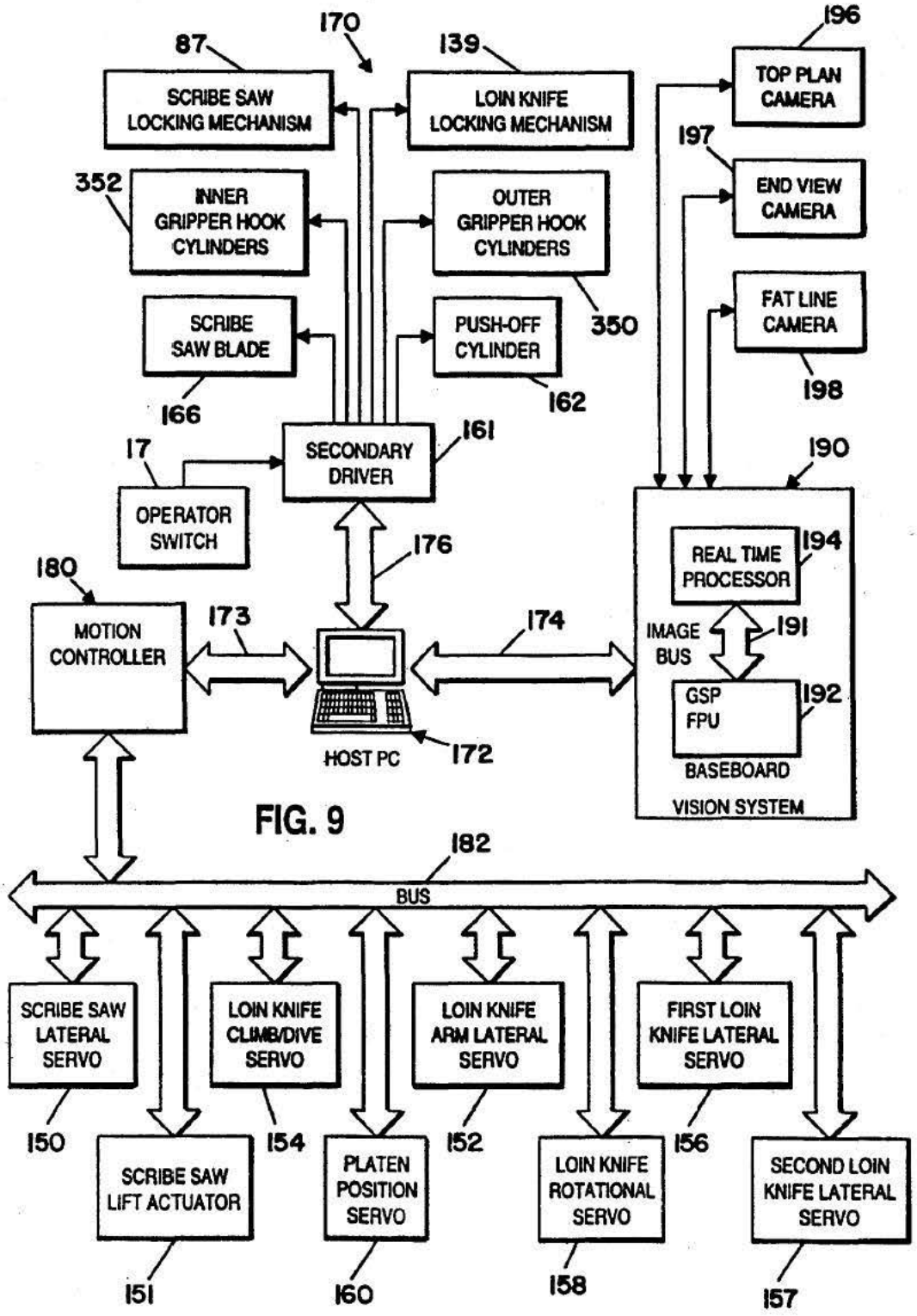

170
87
SCRIBE SAW LOCKING MECHANISM
139
LOIN KNIFE LOCKING MECHANISM
196
TOP PLAN CAMERA
197
END VIEW CAMERA
352
INNER GRIPPER HOOK CYLINDERS
OUTER GRIPPER HOOK CYLINDERS
350
SCRIBE SAW BLADE
166
PUSH-OFF CYLINDER
162
FAT LINE CAMERA
198
17
OPERATOR SWITCH
SECONDARY DRIVER
161
190
180
MOTION CONTROLLER
173
176
174
HOST PC
172
REAL TIME PROCESSOR
194
IMAGE BUS
191
GSP FPU
192
BASEBOARD
VISION SYSTEM
182
BUS
SCRIBE SAW LATERAL SERVO
LOIN KNIFE CLIMB/DIVE SERVO
LOIN KNIFE ARM LATERAL SERVO
FIRST LOIN KNIFE LATERAL SERVO
150
154
152
156
SCRIBE SAW LIFT ACTUATOR
PLATEN POSITION SERVO
LOIN KNIFE ROTATIONAL SERVO
SECOND LOIN KNIFE LATERAL SERVO
151
160
158
157

FIG. 9

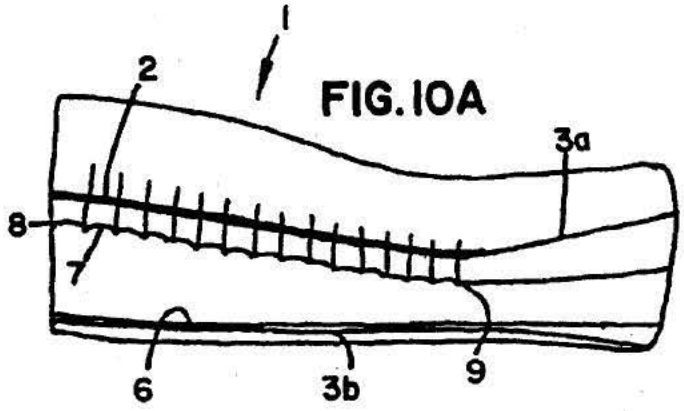


FIG. 10A

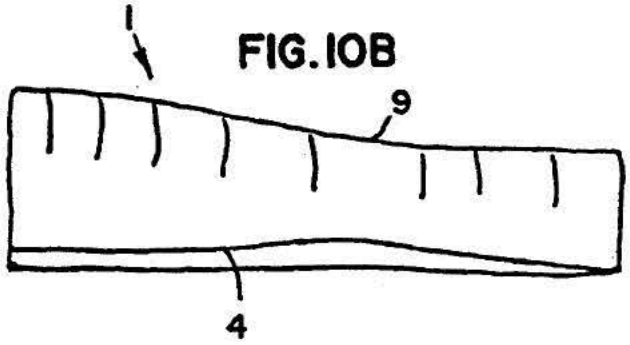


FIG. 10B

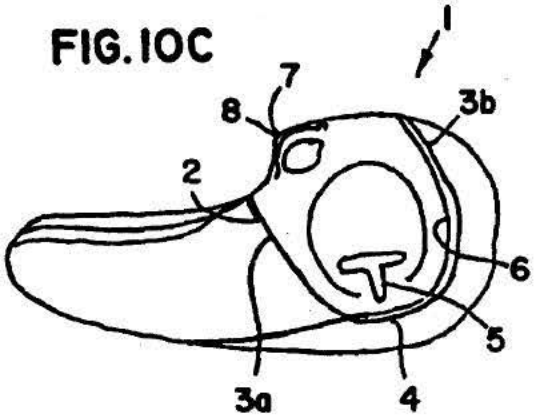


FIG. 10C

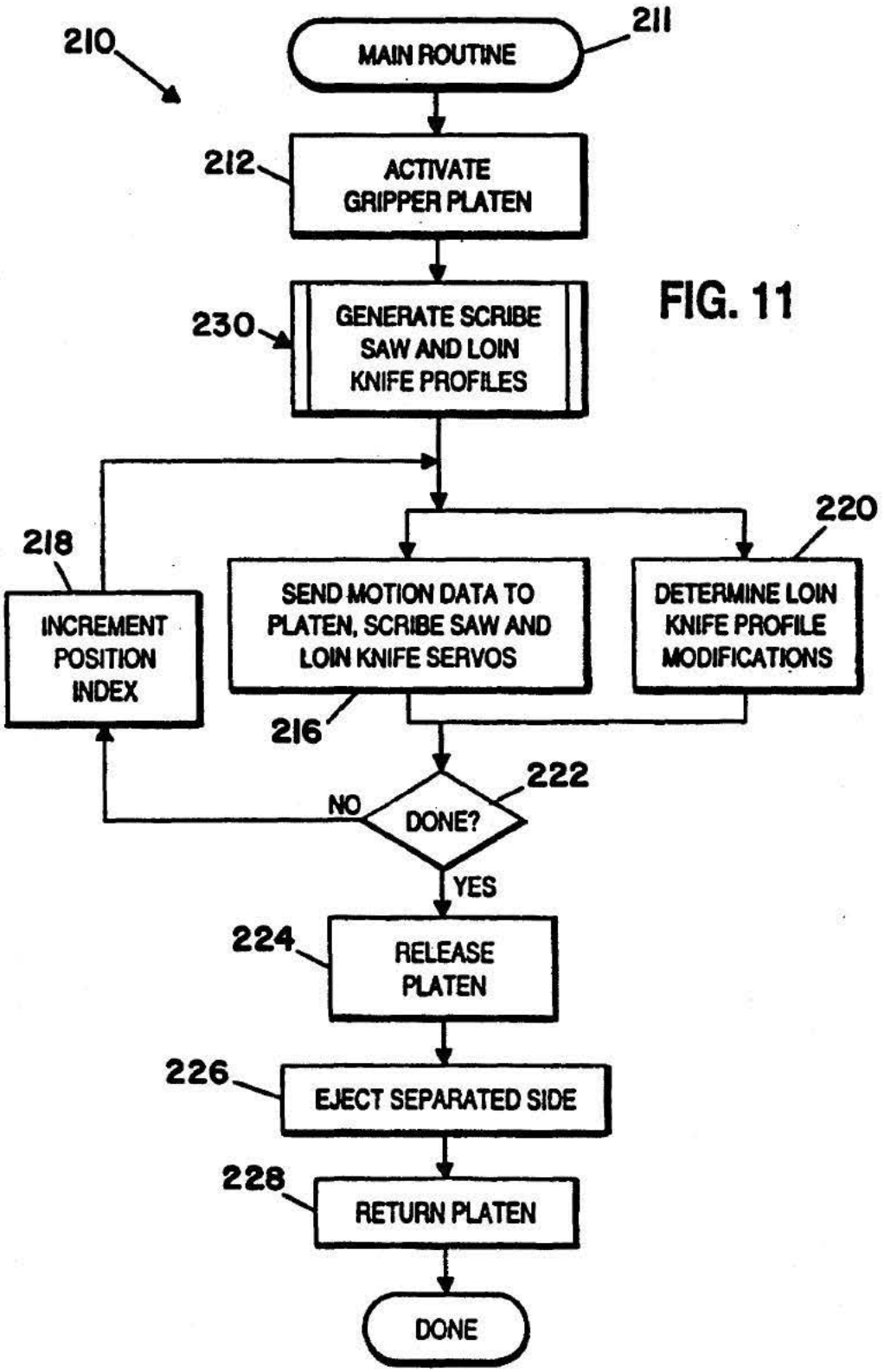
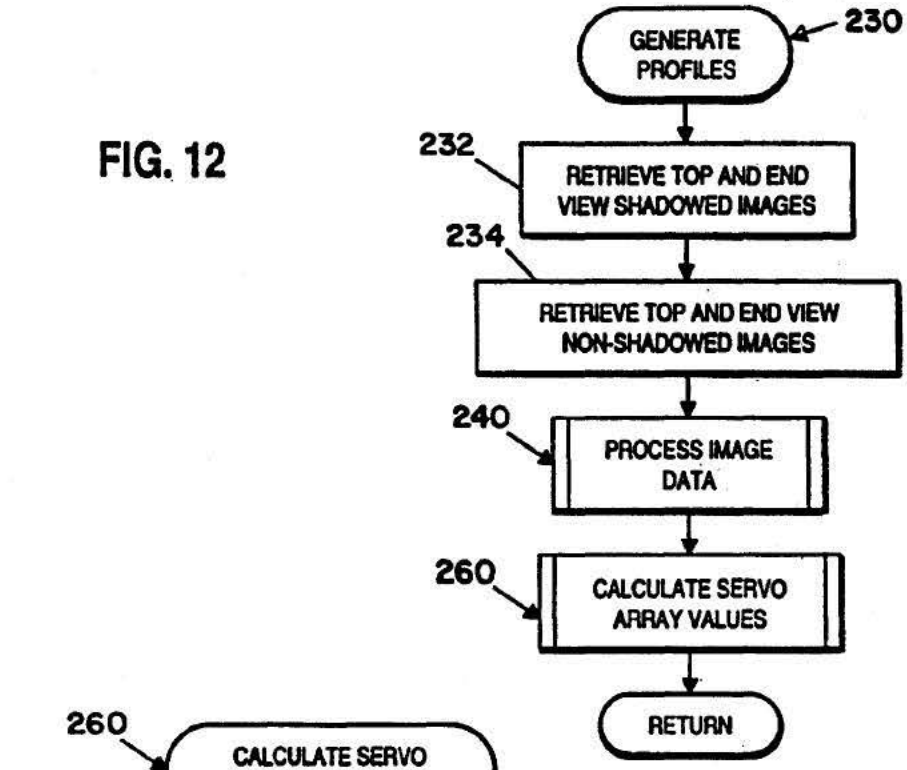

210
MAIN ROUTINE
211
ACTIVATE GRIPPER PLATEN
212
GENERATE SCRIBE SAW AND LOIN KNIFE PROFILES
230
SEND MOTION DATA TO PLATEN, SCRIBE SAW AND LOIN KNIFE SERVOS
216
DETERMINE LOIN KNIFE PROFILE MODIFICATIONS
220
INCREMENT POSITION INDEX
218
DONE?
222
NO
YES
RELEASE PLATEN
224
EJECT SEPARATED SIDE
226
RETURN PLATEN
228
DONE

FIG. 11

FIG. 12


GENERATE PROFILES
230
232
RETRIEVE TOP AND END VIEW SHADOWED IMAGES
234
RETRIEVE TOP AND END VIEW NON-SHADOWED IMAGES
240
PROCESS IMAGE DATA
260
CALCULATE SERVO ARRAY VALUES
RETURN

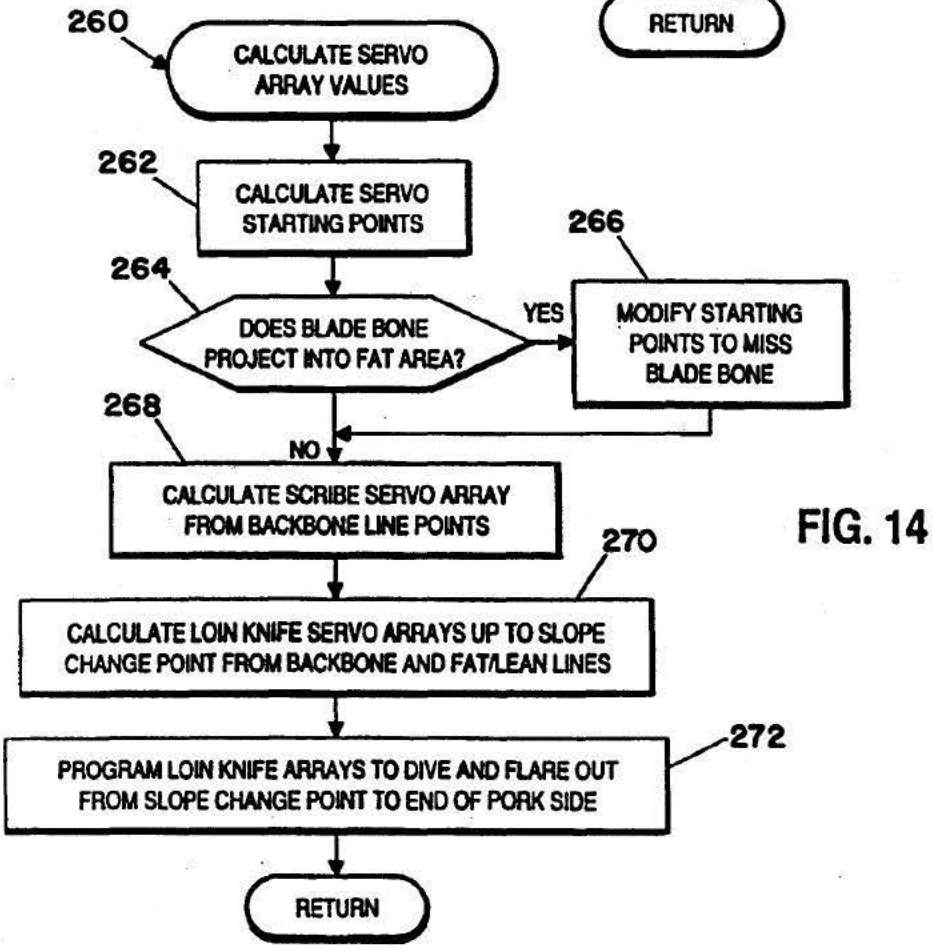
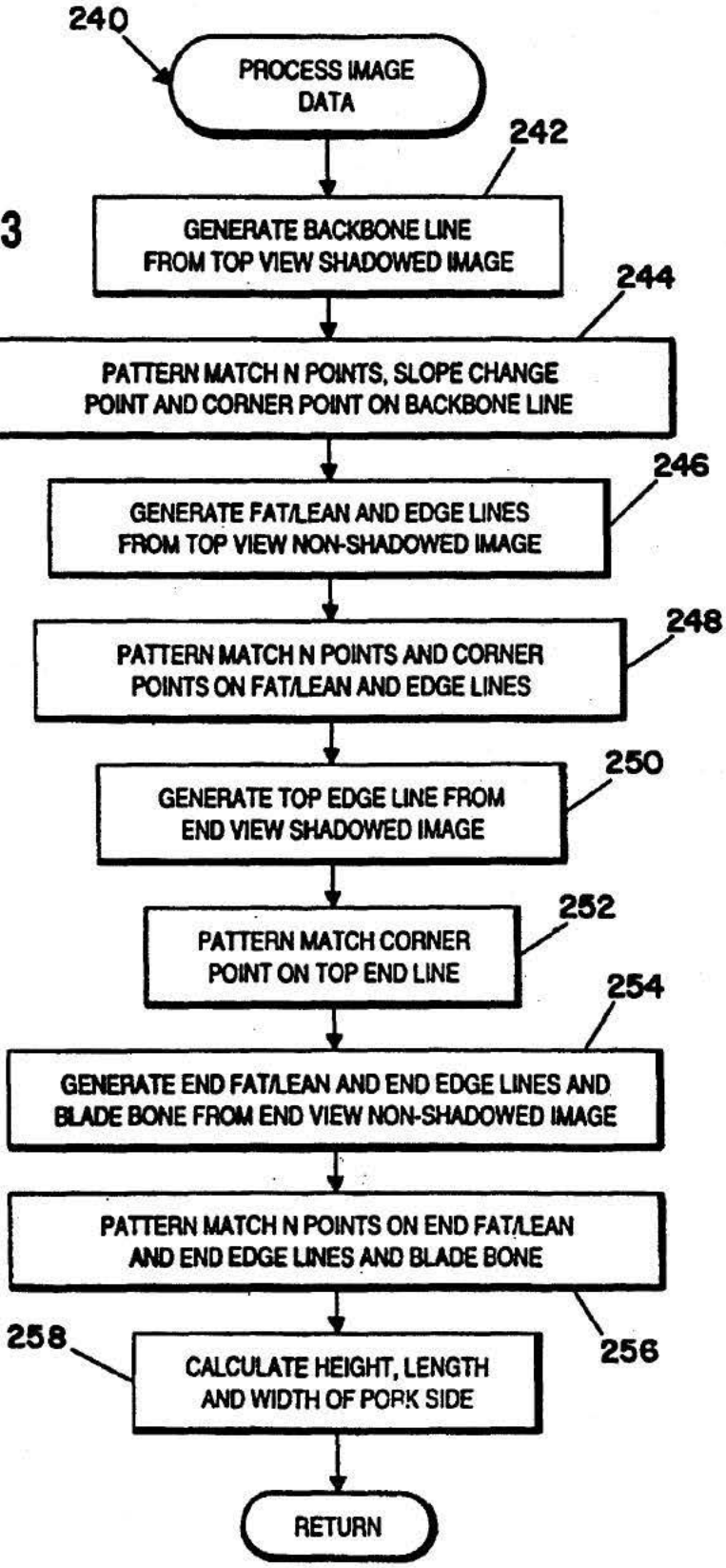

260
CALCULATE SERVO ARRAY VALUES
262
CALCULATE SERVO STARTING POINTS
264
DOES BLADE BONE PROJECT INTO FAT AREA?
YES
266
MODIFY STARTING POINTS TO MISS BLADE BONE
268
NO
CALCULATE SCRIBE SERVO ARRAY FROM BACKBONE LINE POINTS
270
CALCULATE LOIN KNIFE SERVO ARRAYS UP TO SLOPE CHANGE POINT FROM BACKBONE AND FAT/LEAN LINES
272
PROGRAM LOIN KNIFE ARRAYS TO DIVE AND FLARE OUT FROM SLOPE CHANGE POINT TO END OF PORK SIDE
RETURN

FIG. 14

FIG. 13


240
PROCESS IMAGE DATA
242
GENERATE BACKBONE LINE FROM TOP VIEW SHADOWED IMAGE
244
PATTERN MATCH N POINTS, SLOPE CHANGE POINT AND CORNER POINT ON BACKBONE LINE
246
GENERATE FAT/LEAN AND EDGE LINES FROM TOP VIEW NON-SHADOWED IMAGE
248
PATTERN MATCH N POINTS AND CORNER POINTS ON FAT/LEAN AND EDGE LINES
250
GENERATE TOP EDGE LINE FROM END VIEW SHADOWED IMAGE
252
PATTERN MATCH CORNER POINT ON TOP END LINE
254
GENERATE END FAT/LEAN AND END EDGE LINES AND BLADE BONE FROM END VIEW NON-SHADOWED IMAGE
PATTERN MATCH N POINTS ON END FAT/LEAN AND END EDGE LINES AND BLADE BONE
256
258
CALCULATE HEIGHT, LENGTH AND WIDTH OF PORK SIDE
RETURN

LOIN SEPARATION APPARATUS AND METHOD OF OPERATION THEREFOR

FIELD OF THE INVENTION

The invention is directed to an apparatus and method for butchering pork and other meat. More particularly, the invention is directed to apparatus and method for separating loin and belly portions from a side of pork through scribing and loin pulling operations.

BACKGROUND OF THE INVENTION

Various steps are typically required in the processing of meat carcasses such as hog carcasses. One step that typically occurs after a hog is slaughtered, the head, skin and appendages are removed, and the carcass is separated into separate pork sides, is to separate the loin and belly portions of the individual pork sides from one another.

The separation of a pork loin from a pork belly is typically referred to as a loin pulling operation, whereby an arcuate U-shaped knife blade is pulled through a pork side generally along the backbone to separate the loin from the belly. Typically, this involves a preceding step of scribing the ribs to facilitate pulling the knife through the side, as well as a subsequent step of trimming fat from the loin, to obtain a loin with optimum fat covering.

These operations are traditionally performed by human operators using different hand-held tools. An operator at a first station runs a hand held power scribe saw along the backbone of a pork side to cut the ribs from the backbone. The scribe saw has a circular blade which cuts approximately ½ inch deep into the pork side, which is sufficient to sever the ribs. The optimum scribe cut generally follows the contour of the backbone, while starting at about 1¼ inch in from the backbone itself.

The pork side is next transferred to a second station where another operator pulls a U-shaped loin pulling knife through the pork side generally along the backbone to manually separate the loin from the pork belly. In this operation, one side of blade follows the scribe cut through the ribs, while the other side of the blade is maintained as close as possible to the junction between the fat back and the meat of the loin, known as the fat/lean separation line. Several modifications of this general operation are learned by experienced operators to obtain higher yields. For instance, an operator must make sure the bottom of the loin pulling knife clears the "T"-shaped blade bone at the beginning of the cut, as well as the aitch bone at the end of the cut. In addition, the knife may be flared at the end of the cut to maximize the amount of ham kept with the loin. Other subtle movements such as rotating, widening, and tilting the knife blade are learned by more experienced operators to improve the finished product.

A third step of trimming fat from the separated pork loin is also typically required regardless of the experience of the operators, as some excess fat will typically be left on a pulled loin. Some fat is preferred on a loin to keep it from drying out during storage. However, any amount of fat is typically not appealing to consumers, so most of the fat needs to be removed to leave the minimum amount necessary to keep the loin from drying out. It has been found that a fat covering of about 0.1 inch is preferred on a loin, although other thicknesses may also be desired in different circumstances. The fat trimming operation necessary to provide the optimum fat cover is typically manually performed by a separate operator at another station.

Using human operators to perform loin pulling, however, poses several problems. Most notably, loin pulling is one of the most difficult jobs found in a pork processing plant. Turnover is relatively high, since the position is typically reserved for new employees who often transfer to other jobs as soon as they get enough seniority. Therefore, it is difficult to train and keep experienced operators that can efficiently perform the operations and provide high quality product. Also, even experienced operators are not capable of sufficiently high output due to the difficulty of the operations. Further, since the separate steps in separating a loin from a pork belly are performed by different operators at different stations, additional handling and/or transfer steps are often required. In addition, it is difficult for any operator to get the optimum fat levels and loin/ham yield from any side of pork. Consequently, high amounts of unacceptable loins often result from the loin separation process.

To address the problems associated with manual loin separation processes, various automated loin separation systems have been proposed. Examples include U.S. Pat. No. RE 28,508 to Neebel et at., U.S. Pat. No. 3,234,591 to Vogt et al., U.S. Pat. No. 3,685,095 to Metro, U.S. Pat. No. 3,771,196 to Doerfer et al., U.S. Pat. No. 4,189,806 to Van Heyningen, U.S. Pat. Nos. 4,970,755 and 5,090,939 to Leblanc, U.S. Pat. No. 4,979,269 to Norrie, and U.S. Pat. Nos. 5,234,371 and 5,295,898 to Andre et al., among others.

Many of these systems attempt to replace human operators with automated loin knives and scribe saws, often resulting in more efficiency and more repeatable results. However, many prior automated systems are limited in the degree of control they provide over the loin knife and scribe saw. In particular, many systems only allow adjustment of a loin knife and/or a scribe saw in at most one or two axes of motion. It will be appreciated that every pork side is somewhat different in contour, size, weight, etc. Furthermore, it is difficult to reproduce the different subtle motions experienced human operators use to optimize end products with limited control over the loin knife and scribe saw. Thus, conventional automated systems often are not capable of separating loins from bellies at the optimum points of separation, often resulting in unacceptable waste product and lower yields.

Thus, a need has existed in the art for an automated system which offers greater control over loin knife and scribe saw operations to optimize yield and reduce amount of waste product. In particular, there is a need for a loin separation apparatus which may provide customized processing of individual sides of meat to optimize the various operations for each side and thereby result in higher quality and more consistent end products.

SUMMARY OF THE INVENTION

The Invention addresses these and other problems in prior art by providing a loin separation apparatus and method which offers increased control over loin pulling and scribing operations. Preferred apparatus consistent with the invention generate customized cutting profiles and/or modify standard cutting profiles for the loin knife and scribe saw assemblies of the apparatus based upon the particular dimensions, contours, etc. of a specific side of meat, thus optimizing yield and reducing waste product, while providing improved productivity and reduced processing time.

Several advantages may be realized from preferred embodiments of the invention. For example, a preferred loin separation apparatus may include a loin knife assembly

which is controllable to enable the sides of a U-shaped knife blade to follow separate profiles and thereby optimize the cuts formed therefrom. Further, through the use of image processing and motion control, custom profiles may be calculated for the scribe saw and loin knife assemblies to provide optimized operation thereof. Moreover, the movement of the scribe saw and/or the loin knife assemblies through a side of meat may be facilitated through the use of forward steering couplings, which act as casters and assist in steering the respective assemblies through the side of meat.

Therefore, in accordance with one aspect of the invention, there is provided a loin separation apparatus for separating a loin portion from a side of meat. The apparatus includes a frame; conveying means, coupled to the frame, for conveying a side of meat through the apparatus; a loin knife assembly, coupled to the frame, the loin knife assembly including an arm pivotally coupled to the frame to pivot about a lateral axis, a generally U-shaped knife blade coupled to the arm and having first and second sides, vertical moving means for moving the arm vertically about the lateral axis, and first and second lateral moving means for respectively moving the first and second sides of the knife blade in a lateral direction; and a controller, coupled to the conveying means, the vertical moving means and the first and second lateral moving means, for controlling movement of the loin knife assembly to separate the loin portion from the side of meat as the side of meat is conveyed through the apparatus.

According to another aspect of the invention, a loin knife assembly is provided for use in a loin separation apparatus. The assembly includes an arm pivotally coupled to the loin separation apparatus to pivot about lateral and vertical axes; a head assembly, coupled to the arm, the head assembly including a generally U-shaped knife blade having first and second sides; vertical moving means for moving the arm vertically about the lateral axis; lateral adjustment means for moving the arm laterally about the vertical axis; and width adjustment means for varying the separation between the first and second sides of the knife blade.

According to an additional aspect of the invention, a loin knife assembly is provided for use in a loin separation apparatus. The assembly includes a generally U-shaped knife blade having first and second sides; vertical moving means for moving the knife blade in a vertical direction; and first and second lateral moving means for respectively moving the first and second sides of the knife blade in a lateral direction.

According to a further aspect of the invention, a scribe saw assembly is provided for use in a loin separation apparatus. The assembly includes a steering coupling; scribe saw moving means for moving the steering coupling along a lateral axis relative to the loin separation apparatus; a saw blade mounting assembly, pivotally mounted to the steering coupling at a forward point thereon to rotate about a vertical axis, including a saw blade and drive means for rotating the saw blade; and height adjustment means, coupled to the saw blade mounting assembly, for automatically controlling the cutting depth of the saw blade.

In accordance with another aspect of the invention, there is provided a loin separation apparatus for separating a loin portion from a side of meat. The apparatus includes a loin knife assembly, including a generally U-shaped knife blade having first and second sides, first and second lateral moving means for respectively moving the first and second sides of the U-shaped knife blade in a lateral direction, and vertical moving means for moving the U-shaped knife blade in a vertical direction; conveying means for conveying a side of meat past the loin knife assembly; an imaging camera positioned to generate a top plan image of the side of meat; and a controller, coupled to the loin knife assembly, the conveying means, and the imaging camera. The controller includes image processing means for determining backbone and fat/lean separation lines from the top plan image, profile calculating means for generating profiles for the vertical moving means and the first and second lateral moving means to control the first side of the U-shaped knife blade to follow a preset distance from the backbone line, and the second side of the U-shaped knife blade to follow a preset distance from the fat/lean separation line, and activating means for activating the vertical moving means, the first and second lateral moving means and the conveying means to follow the profiles generated by the profile calculating means.

In accordance with a further aspect of the invention, a control system is provided for use in a loin separation apparatus of the type including a loin knife assembly having a generally U-shaped knife blade, first and second lateral moving means for respectively moving first and second sides of the knife blade in a lateral direction, and a vertical moving means for moving the U-shaped knife blade in a vertical direction; and conveying means for conveying a side of meat past the loin knife assembly. The control system includes an imaging system, the imaging system including means for generating a top plan image of the side of meat and means for processing the top plan image to locate a backbone line and a fat/lean separation line on the side of meat; a host controller, coupled to the imaging system and the motion control system, the host controller including profile calculating means for generating profiles for the conveying means, the vertical moving means and the first and second lateral moving means such that the first side of the U-shaped knife blade follows a preset distance from the backbone line and the second side of the U-shaped knife blade follows a preset distance from the fat/lean separation line as the conveying means conveys the side of meat past the loin knife assembly; and a motion control system for controlling the first and second lateral moving means, the vertical moving means and the conveying means to each follow the profiles generated by the host controller.

In accordance with an additional aspect of the invention, a method is provided for separating a loin portion from a side of meat in a loin separation apparatus of the type including a loin knife assembly having a generally U-shaped knife blade, first and second lateral moving means for respectively moving first and second sides of the knife blade in a lateral direction, and a vertical moving means for moving the U-shaped knife blade in a vertical direction. The method includes the steps of generating a top plan image of a side of meat; determining the location of a backbone line and a fat/lean separation line on the side of meat from the top plan image; generating profiles for the vertical moving means and the first and second lateral moving means to control the first side of the U-shaped knife blade to follow a preset distance from the backbone line, and the second side of the U-shaped knife blade to follow a preset distance from the fat/lean separation line; and activating the vertical moving means, the first and second lateral moving means and the conveying means to follow the generated profiles.

These and other advantages and features, which characterize the invention, are set forth in the claims annexed hereto and forming a further part hereof. However, for a better understanding of the invention, and the advantages and objectives attained by its use, reference is made to the drawing which forms a further part hereof, and to the

following descriptive matter, in which there is discussed a preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a perspective view of a preferred loin separation apparatus consistent with the invention.

FIG. **2** is a side elevational view of the apparatus of FIG. **1**.

FIG. **3** is a top plan view of the apparatus of FIG. **1**, with the control system and cabinet therefor shown in phantom for ease of illustration.

FIG. **4** is a front end elevational view of the apparatus of FIG. **1**.

FIG. **5** is an exploded perspective view of the gripper platen for the apparatus of FIG. **1**.

FIG. **6** is an exploded perspective view of the scribe saw assembly for the apparatus of FIG. **1**.

FIGS. **7***a*, **7***b* and **7***c* are exploded perspective views of the loin knife assembly for the apparatus of FIG. **1**. FIG. **7***a* shows the pivotal coupling assembly, FIG. **7***b* shows the arm assembly, and FIG. **7***c* shows the head assembly therefor. FIG. **7***a* also shows the push-off piston for the apparatus of FIG. **1**.

FIG. **8** is an exploded perspective view of an alternate loin knife head assembly consistent with the invention.

FIG. **9** is a functional block diagram of the control system for the apparatus of FIG. **1**.

FIGS. **10***a*, **10***b* and **10***c* are top plan, side elevational and end elevational views, respectively, of a pork side, showing preferred cutting profiles for scribe saw and loin knife assemblies consistent with the invention.

FIG. **11** is a flowchart showing the processing steps for separating a pork loin with the control system of FIG. **9**.

FIG. **12** is a flowchart showing the GENERATE PROFILE routine from FIG. **11**.

FIG. **13** is a flowchart showing the PROCESS IMAGE DATA routine from FIG. **12**.

FIG. **14** is a flowchart showing the CALCULATE SERVO ARRAY VALUES routine from FIG. **12**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Turning to the Drawing, wherein like numbers denote like parts throughout the several views, FIGS. **1–4** show a preferred loin separation apparatus **10** consistent with the principles of the invention. Apparatus **10** generally includes a number of primary electromechanical systems which handle various functions in the loin separation process. A gripper platen **20** is provided which supports a pork side and transports it throughout the different operations in the loin separation process.

A scribe saw assembly **50** is also provided on apparatus **10** for scribing/cutting the ribs along the backbone of a pork side to facilitate the later loin pulling operation. In addition, a loin knife assembly **100** is provided to separate the pork loin from the belly (i.e., to "pull" the loin) after it has been scribed by scribe saw assembly **50**.

An electronic control system **170** is also provided to control the different electromechanical systems of apparatus **10**. Controller **170** includes a motion controller which drives a plurality of servos that activate and control platen **20**, scribe saw assembly **50**, and loin knife assembly **100**. In addition, a separate imaging system is included to determine critical dimensional data for individual pork sides, enabling control system **170** to optimize the loin separation process based upon the dimensions of a particular side of pork.

The above-described systems are preferably disposed on a single frame **11**. The frame also includes a horizontal support beam **12** that supports most of the primary electromechanical components, a plurality of upward supports **13**, a controller cabinet **14** that is supported on supports **13** and houses most of control system **170**, and a loin knife assembly support **16** which provides the primary support of loin knife assembly **100**. The frame is preferably constructed of steel or another suitably strong structural material.

Further, the frame of apparatus **10** includes a pair of stainless steel rails **15** on which platen **20** is supported and allowed to slide upon when transporting a side of pork between the different stations in apparatus **10**.

Several additional components are found on preferred apparatus **10**. A push-off piston **162** is provided to eject the side from apparatus **10** once the loin and belly portions have been separated by loin knife assembly **100**. As shown in FIG. **7***a*, piston **162** includes a push-off member **162***a* mounted through fasteners **162***b*. Piston **162** is mounted to beam **12** of frame **11** by brackets **162***c*, **162***d*, and **162***f* through a plurality of fasteners **162***f*. Piston **162** is preferably a pressure-actuated piston such as the No. NF18A-E02-AMA00 manufactured by C & C Manufacturing, Inc. Other suitable ejection devices are known in the art.

Returning to FIG. **1**, with apparatus **10**, a pork side will be passed through the scribe saw and loin knife assemblies on platen **20**, then will be ejected from the platen at the end of a cycle by push-off piston **162**. Alternatively, platen **20** may be returned to a start position with the loin knife blade lowered to a position to hit the loin portion of the pork side as the platen is returned, such that the loin portion will be dislodged from the platen, and the belly portion will be returned to the starting point to permit and operator to manually remove the belly and place a new pork side on the platen. It may be desirable to include more than two rails **15** such that a dislodged loin will rest on the "table" formed by the plurality of rails.

Several directional terms will be used hereinafter. Therefore, in the context of the preferred embodiments shown in the Drawing, a longitudinal direction will typically represent a direction along the length of the preferred apparatus, e.g., parallel to rails **15**. A vertical direction will typically represent a direction upwards from the floor upon which the preferred apparatus is mounted, e.g., perpendicular to the plane formed by rails **15**. Finally, a lateral direction will typically represent a direction across the width of the preferred apparatus, e.g., orthogonal to the vertical and longitudinal directions.

The preferred loin separation apparatus **10** is preferably for use in separating the loin and belly portions from a side of pork. However, it will be appreciated by one skilled in the art that the principles of the invention will apply to other butchering operations, as well as to other forms of meat including beef, lamb, veal, etc., and therefore the invention should not be limited as such. Each of the primary systems of apparatus **10** will now be described in greater detail below.

A. Gripper Platen

FIG. **5** shows gripper platen **20** in greater detail. As described above, platen **20** is a conveying means which helps in supporting and conveying a pork side throughout

the different loin separation operations performed by apparatus **10**. It has been found that maintaining a pork side in a fixed position on the platen (i.e., with minimum lateral or longitudinal shifting relative to the platen) is significant for ensuring that the image data calculated by the imaging system is valid during the subsequent scribing and loin pulling operations, given that these later operations must assume correct positioning of the pork side to obtain optimum results.

Gripper platen **20** includes a support member **310** having a support surface **311** which supports a pork side thereon. Support member **310** is preferably constructed of UHMWPE, which has been found to be a sturdy and easily cleaned surface. Other materials, including different metals, plastics, and composites, may also be used.

A pork side is preferably positioned on platen **20** by an operator with the side resting on support surface **311**. As shown in FIG. **1**, a fixed side surface **301** mounted to frame **11** of apparatus **10** is used to properly position the pork side on the platen with the fat back downward and with the backbone running longitudinally proximate the side surface. Alternatively, platen **20** may have a second, inclined surface disposed thereon for assisting an operator in properly positioning a pork side on the platen. In addition, as is also shown in FIG. **1**, an end stop member **22** is mounted to the end of platen **20** to abut the trailing end of a pork side placed on the platen and further assist an operator in properly positioning a side on the platen. Stop member **22** moves with support member **310** such that the stop will resist longitudinal movement of a pork side during the loin pulling operations.

Returning to FIG. **5**, gripper platen **20** includes four gripper hook assemblies **320***a*, **320***b*, **320***c* and **320***d* which respectively project through apertures **312***a*, **312***b*, **312***c* and **312***d* in support surface **311** to hook onto the surface of a pork side lying on the platen. Each gripper hook assembly **320***a–d* is substantially the same, varying only in placement and orientation (forward or backward). For example, gripper hook assembly **320***a* includes a hook **322** rotatably mounted on an **325** with spacers **326** between brackets **324**, which are in turn mounted by fasteners **330** to a main bracket **332**. A pressure actuated gripper hook cylinder **340***a*, such as the No. FD-172-2FCMT SF manufactured by Bimba Mfg. Co., is rotatably mounted on brackets **342** with spacers **341** over pins on cylinder **340***a*, which are in turn mounted by fasteners **343** to main bracket **332**. Bracket **332** is mounted through a spacer **333** to member **310** by fasteners **335** through top bracket **334**. Cylinder **340***a* and hook **322** are coupled together by linkage **328**, **329** which is connected at one end to the piston of cylinder **340***a* and at the other end to hook **322** offset from the rotational axis thereof defined by axle **325** through fastener **327**. Gripper hook assemblies **320***b–d* are similarly configured.

Gripper hook assemblies **320***a*, **320***b* and **320***c* preferably orient their respective hooks forward, whereby the hooks will assist in resisting the forces applied to a pork side by the loin knife assembly. Gripper hook assembly **320***d* is preferably oriented opposite to the other assemblies, to assist in stretching out the pork side on platen **20**, and to assist in the penetration of the other gripper hooks into the pork side.

Cylinders **340***a* and **340***d* of the outer gripper hook assemblies are preferably connected to a source of pressure by a manifold and are controlled by a common valve **350** (shown schematically in FIG. **9**), as are cylinders **340***b* and **340***c* of the inner gripper hook assemblies, which are controlled by a common valve **352** (also shown schematically in FIG. **9**). Consequently, the inner and outer gripper hooks may be actuated separately.

The separate actuation of the inner and outer gripper hook assemblies has been found to be beneficial in that the outer gripper hook assemblies may be first actuated to stretch out the pork side and to initially grip the side sufficiently to enable the inner hook assemblies to penetrate the pork side without the side slipping on the platen. However, it will be appreciated that the hooks may be actuated in any order, or at the same time.

As an alternative, one or more vacuum cups may be disposed on platen **20** to provide supplemental attachment to a pork side. The vacuum cups are preferably connected to a source of vacuum to provide a seal against the pork side. The cups may include flexible bellows which conform to the pork side. The cups may also be retractable to permit the cups to pull the pork side taut against the platen.

Returning to FIGS. **1–4**, platen **20** is shown supported on rails **15**, and is moved between stations by sliding along these rails. Positioning of platen **20** is controlled by a platen servo **160**, which is a stepper motor such as the No. S-4050 manufactured by Reliance Electric. Platen servo **160** moves platen **20** through a belt and pulley arrangement, whereby servo **160** rotates a pulley to move a belt to which platen **20** is secured. Other manners of controllably positioning platen **20** at various positions along rails **15** are known in the art.

Various modifications to the preferred conveying mechanism may be made. For example, additional vacuum cups, gripper hooks, support surfaces, etc. may be used. Further, conveyors such as are found in conventional loin separation devices may also be used. However, given the criticality of pork side positioning during imaging, scribing and loin pulling, it has been found that the platen configuration disclosed herein provides a more secure grip on a pork side throughout the different operations. In addition, the platen has been found to be comparatively easy to position, secure and release a pork side. Additional modifications will be appreciated by one skilled in the art.

B. Scribe Saw Assembly

FIG. **6** shows scribe saw assembly **50** in greater detail. Scribe saw assembly **50** is used to scribe, or cut, the ribs along the top surface of the pork side at a fixed or preset distance from the backbone. Scribing the ribs assists in the loin pulling operation because the cutting of the ribs does not have to be performed by the loin knife blade, thereby leaving the knife blade to cut only through meat and fat. The loin knife assembly may alternatively be used to cut through the ribs; however, it would require a much stronger and sturdier loin knife assembly, and would excessively wear the knife blade.

Scribe saw assembly **50** is preferably movable in two directions. A first means of movement for the assembly is provided by a scribe saw lateral servo **150**, which is preferably a linear actuator servo such as the No. S-4050 manufactured by Reliance Electric. Servo **150** supports and moves a scribe saw head **72** along a lateral direction. A second means of movement for the assembly is provided by a scribe saw lift actuator **151**, which is preferably an air cylinder such as the No. S2X25RC2FT2 manufactured by Compact Air Products. Actuator **151** preferably rotates scribe saw head **72** about a lateral axis to raise and lower the head between activated and non-activated positions.

Servo **150** is pivotally supported on a mounting beam **52**, which is mounted to horizontal support beam **12** of frame **11**

with an opposing plate **53** and fasteners **54**. A pair of screw eye bolts **57** are mounted to end **56** of beam **52** using fasteners **58**. A pair of servo mounting brackets **60***a* and **60***b* are mounted to servo **150** using fasteners **61**. Brackets **60***a* and **60***b* are in turn mounted to screw eye bolts **57** using bolts **62** and nuts **63**, such that they are pivotable about axis **64**.

Actuator **151** is mounted to beam **52** through a mounting bracket **65** which is mounted to bracket **55** on beam **52** with fasteners **66**. Actuator **151** is mounted to bracket **65** by pin **70** and clips **71** such that actuator **151** is pivotable about pin **70**. Another screw eye bolt **68** is mounted to the piston **151***a* of actuator **151**. Bracket **60***a* is then mounted to screw eye bolt **68** using bolt **69** and nut **67**. Consequently, linear movement of piston **151***a* of actuator **151** will pivot servo **150** about axis **64**.

Scribe saw head **72** is supported on ball screw actuator **150***a* of servo **150**, and preferably is allowed to rotate about the longitudinal axis of the ball screw to enable the head to automatically adjust to maintain a relatively constant cutting depth as it scribes a pork side. Preferably, the cutting depth of the scribe saw blade is between ⅜ and ¾ inch, more preferably about ½ inch.

A bracket **74***a* is rotatably mounted to ball screw actuator **150***a* through threaded bolt **83**, cover **82**, spacers **81**, bushing **80**, and spring arm **76** mounted to slotted collar **78** with fasteners **88**, and having a threaded stop **86***a* mounted thereto with nuts **86***b*. A bracket **74***b* is secured to bracket **74***a* with fasteners **91***b* and bushings **91***c*. The configuration of bracket **74***a* provides the automatic height adjustment for the saw blade by permitting bracket **74***a* to pivot about the ball screw actuator **150***a*.

A saw blade mounting assembly includes shaft **90**, which is rotatably mounted to bracket **74***a* through a pair of sleeves **75**, a cap **77** and a fastener **73**. A clamping bracket **92***a* and clamp **92***b* are affixed to the shaft by bolts **99***a*. A spring **99***c* is affixed at one end to clamp **92***b* by fastener **99***b*, and at the other end to the threaded stop of spring arm **76**. This configuration allows for automatic adjustment of cutting depth since head assembly **72** will be urged downward by spring **99***c*, and the saw blade will therefore ride along the surface of a pork side during scribing.

Bracket **74***a* also provides a forward steering coupling for shaft **90**, which enables shaft **90** to "caster" and permit the scribe saw blade **85** to be steered through the pork side in response to lateral adjustments by servo **150**. This castering operation may be controllably inhibited by a locking mechanism **87** (preferably an air cylinder) mounted to bracket **74***b* with fasteners **91***a*. A clamping bar **89***a* is mounted to mechanism **87** by fastener **89***b*, such that by activating locking mechanism **87**, clamping bar **89***a* prevents lateral pivoting of head assembly **72** to locate the saw blade at a known fixed orientation. As discussed below, the blade is preferably locked in position when the starting point of the scribe cut is being found, then the blade is unlocked once scribing begins to permit the blade to be steered through the pork side.

The other end of shaft **90** is mounted to a bracket **93***a* by fasteners **97** and plate **96**. The rotational position of bracket **93***a* about shaft **90** may be adjusted through this mounting configuration. Preferably, the bracket is about 0 to 30 degrees, more preferably about 15 degrees, offset from vertical.

A drive member **84**, supporting scribe saw blade **85**, is mounted to bracket **93***a* using fasteners **95** and washers **98**. Drive member **84** has a pressure-driven drive means for driving or rotating the saw blade, which is preferably a Jarvis air motor. A connection to a source of pressurized air (not shown in FIG. **6**) is provided on drive member **84** to actuate blade **85**.

An opposing bracket **93***b* is mounted to drive member **84** with fastener **94**. Bracket **93***b* includes the runner which is designed to ride along a side of pork and automatically maintain the ½ inch cutting depth for scribe saw blade **85**.

Therefore, scribe saw assembly **50** may be controlled to follow a desired profile by activating the scribe saw blade, lowering the blade into an operating position using actuator **151**, and then controlling servo **150** to vary the lateral placement of the scribe saw blade as the pork side is conveyed past the blade. The lateral positioning of the scribe saw blade may be initially locked by mechanism **87** to assist in reliably finding the starting position, then mechanism **87** may be released to permit the blade to be steered through the pork side. The cutting depth of the saw blade is maintained by the runner on bracket **93***a* inducing a rotation of bracket **74** relative to ball screw actuator **150***a*. Then, once the pork side has passed scribe saw assembly **50**, the scribe saw blade may then be de-activated and the assembly raised by actuator **151**. Further, as will be described below, it may be desirable to shut down the blade and raise the assembly at a predetermined point along the pork side after the ribs have been suitably scribed.

Various modifications may be made to the preferred scribe saw assembly consistent with the invention. For example, direct control over the height of the scribe saw head may be provided to generate a custom cutting depth profile for pork sides. Other modifications will also be appreciated.

C. Loin Knife Assembly

FIGS. **7***a*, **7***b* and **7***c* show loin knife assembly **100** in greater detail. Loin knife assembly **100** is used to separate the pork loin from the pork belly once the scribe cut has been made through the ribs. The separation is made by a loin knife which has an arcuate U-shaped blade, similar to the type of hand-held knife used by human operators. Through control of the knife blade along several axes, assembly **100** preferably produces an optimum separation between loin and belly, with a desired fat covering left on the loin.

Loin knife assembly **100** includes an arm assembly **110**, a pivotal coupling assembly **111** and a head assembly **120**. Pivotal coupling assembly **111**, shown in FIG. **7***a*, provides the mounting mechanism for securing the loin knife assembly to frame **11**. Arm assembly **110**, shown in FIG. **7***b*, provides three axes of motion for the loin knife, and includes a cylindrical shaft **112** for supporting an arm **114**. Head assembly **120**, shown in FIG. **7***c*, provides a mounting assembly for the knife blade, and allows for lateral adjustments of each side of the blade.

Turning to FIG. **7***a*, pivotal coupling assembly **111** is rotatably mounted to loin knife support **16**, which is in turn mounted to beam **12** of frame **11** by brackets **16***a* and bolts **16***b*. Assembly **111** includes a shaft **111***a* mounted to support **16** by brackets **111***e* and fasteners **111***f* through bearings **111***b*. A pair of brackets **111***d* are mounted to shaft **111***a* by fasteners **111***g* and using spacers **111***c*. A shaft **112** (part of arm assembly **110**) is mounted to brackets **111***d* by brackets **111***h* and fasteners **111***j*. In this configuration, pivotal coupling assembly **111** permits shaft **112** to pivot along an arcuate path about axis **119***a*.

Turning to FIG. **7***b*, arm assembly **110** includes an arm **114** pivotally connected to shaft **112** at a first end through a universal joint **113**, which includes a lateral pivot mount

113*a* mounted to shaft **112** with fasteners **113***d*, a climb/dive pivot mount **113***c* mounted to arm **114**, and a pivot member **113***b* interconnected therebetween to allow pivoting about two axes, a lateral axis **119***b* (which permits vertical movement of the arm) and a vertical axis **119***c* (which permits lateral movement of the arm). A cover (not shown for illustrative purposes) is preferably included over universal joint **113** for protecting the assembly from dust and debris.

Arm **114** includes a number of members which orient a head assembly receiving shaft **114***a* generally offset a fixed distance from the pivot point formed by universal joint **113** to provide vertical (climb/dive) and lateral movement of head assembly **120**. Several members on arm **114** are offset from the pivot points provided by universal joint **113** to enable the linear actuator servos (discussed below) to induce the lateral and climb/dive displacement of head assembly **120**. In particular, first vertical member **114***b* provides a climb/dive offset from the pivot point of the arm, and lateral member **114***e* provides lateral offset therefrom. Horizontal member **114***c* and second vertical member **114***d* are in turn coupled between vertical member **114***b* and head assembly receiving shaft **114***a* (forming a second end of the arm) to orient the end of shaft **114***a* proximate the longitudinal axis of shaft **112** for balancing the arm.

Other configurations of arm **114** may be used consistent with the invention. However, it has been found that the particular arrangement of members **114***a–e* is preferred because the assembly is substantially balanced during operation. As will be discussed below, head assembly **120** "steers" the knife blade through the pork side (i.e., the blade trails behind the head assembly). Consequently, it is important to orient the shaft **114***a* in front of universal joint **113** and proximate the longitudinal axis of shaft **112** to enable the knife blade to trail the head assembly in a fluid and stable manner.

A number of linear actuator servos, including rotational servo **158**, climb/dive servo **154** and lateral servo **152**, are used to control the positioning of loin knife assembly **100** about different axes. Each servo is controlled in a manner which will be discussed in greater detail below.

Rotational servo **158** is disposed within a compartment **158***a*, and includes a pair of brackets **158***b* secured thereto by fasteners **158***c*. One of brackets **158***b* includes a bushing **158***d* secured by fastener **158***e*. Bushing **158***d* is secured by fasteners **158***f* to a bracket **115***d*, which is in turn fastened to beam **16***c* through fasteners **115***e*. The actuator arm of servo **158** projects through the other bracket **158***b*, and includes a bushing **158***g* mounted at the end thereof. Bushing **158***g* is connected to shaft **112** through a linkage including brackets **115***a* and **115***b* and fasteners **115***c*, using fastener **158***h* and sleeve **158***j*. The linear action of this servo provides rotation around axis **119***a* (shown in FIG. **7***a*), which enables the knife blade to be rotated generally along the longitudinal axis of the pork side.

Climb/dive servo **154** and lateral servo **152** are each mounted on a bracket **116** on shaft **112**. Bracket **116** includes first and second beams **116***a* and **116***b*, and is mounted to shaft **112** by bracket **116***c* and bolts **116***d*.

Climb/dive servo **154** is disposed within a compartment **154***a*, and includes a pair of brackets **154***b* secured thereto by fasteners **154***c*. One of brackets **154***b* includes a bushing **154***d* secured by fastener **154***e*. Bushing **154***d* is secured by fasteners **154***f* to a bracket **116***e*, which is in turn fastened to first beam **116***a* through fasteners **116***f*. The actuator arm of servo **154** projects through the other bracket **154***b*, and includes a bushing **154***g* mounted at the end thereof. Bushing **154***g* is connected to bracket **114***f* on arm **114** by fastener **154***h* and sleeve **154***j*. The linear action of this servo provides rotation around axis **119***b*, which enables the knife blade to be raised and lowered relative to the pork side.

Lateral servo **152** is disposed within a compartment **152***a*, and includes a pair of brackets **152***b* secured thereto by fasteners **152***c*. One of brackets **152***b* includes a bushing **152***d* secured by fastener **152***e*. Bushing **152***d* is secured by fasteners **152***f* to a bracket **116***g*, which is in turn fastened to second beam **116***b* through fasteners **116***h*. The actuator arm of servo **152** projects through the other bracket **152***b*, and includes a bushing **152***g* mounted at the end thereof. Bushing **152***g* is connected to a bracket (not shown) on member **114***e* of arm **114** by fastener **152***h* and sleeve **152***j*. The linear action of this servo provides rotation around axis **119***c*, which enables the knife blade to be displaced laterally relative to the pork side.

Servos **152**, **154** and **158** are preferably type S3007 servos manufactured by Reliance Electric. Other known servos or actuators may be used in the alternative.

Turning to FIG. **7***c*, head assembly **120** provides a fourth axis of motion for loin knife assembly **100**, while providing a leading steering coupling therefor to lead a knife blade **121** through the pork side. As discussed above, knife blade **121** is preferably an arcuate, U-shaped, stainless steel blade sharpened on its forward facing edge, which is similar in design to a hand-held loin pulling knife. Knife blade **121** has a first (right) side **121***a* and a second (left) side **121***b*.

Head assembly **120** is mounted on head assembly receiving shaft **114***a* of arm assembly **110** through a pivot block assembly **132**. Assembly **132** includes a pivot block **132***a* which receives shaft **114***a* through a wear resistant insert **132***b* that allows pivot block **132***a* to pivot around shaft **114***a*. A spring plate **132***g* mounted to vertical member **114***d* of arm **114** with fasteners **132***h* engages pivot block **132***a* to bias the head assembly to a centered position.

A head bracket assembly **133** is mounted to pivot block assembly **132** by a runner, or horizontal plate, **133***a* which is secured to pivot block **132***a* by a fastener **132***f* projecting through a flanged insert **132***e*. Left and right brackets **133***c* and **133***f*, which are secured to plate **133***a* by fasteners **133***g*, are also coupled to pivot block **132***a* by pins **132***c* received in wear-resistant inserts **132***d* fitting into first apertures in the brackets, thereby allowing the head bracket assembly to rotate about a lateral axis defined by pins **132***c*.

Furthermore, first and second loin knife width servos **156** and **157** are each disposed in a separate compartment **156***a* and **157***a* each having access panels **156***b* and **157***b* secured by fasteners **156***c* and **157***c*, and are mounted respectively to brackets **133***c* and **133***f* by fasteners **133***h*. Servos **156** and **157** are stepper motor servos, such as the S3007 manufactured by Reliance Electric, although other known servos may also be used in the alternative.

As discussed above, pivot block assembly **122** permits lateral and vertical pivoting of the head assembly relative to arm **114**, such that head assembly **120** may be steered through a pork side by the forward steering coupling provided by arm **114**. This "castering" operation may be controllably inhibited by a locking mechanism **139**. As discussed below, the head assembly is preferably locked in position when the starting point of the loin knife cut is being found, then the head assembly is unlocked once cutting begins to permit the blade to be steered through the pork side. Locking mechanism **139** includes a pair of air cylinders **139***a* which are mounted to member **114***b* of arm **114** by brackets **139***b*, **139***e* and **139***f* and fasteners **139***c* and **139***g*.

A clamping arm **139***d* is mounted to compartment **157***a*, and is allowed to slide between the air cylinders **139***a* when they are not activated. However, when the cylinders are activated, they clamp on to arm **139***d* to lock the head assembly in a fixed position.

The relative position of head bracket assembly **133** with respect to pivot block assembly **132** is controlled by a climb/dive angle adjustment assembly **137**, which includes a threaded stop **137***c* threadably received in bracket **137***a*. This bracket is mounted to right bracket **123***f* through another bracket **137***b* using fasteners **137***d*, so that the end of stop **137***c* engages pivot block **132***a*. By threading stop **137***c* in or out of bracket **137***a*, the unloaded climb/dive angle of knife blade **121** may be set to rotate the knife blade angle in relation to the pivot point centerline through pivot block **132***a*.

A pair of servo linkage assemblies **134** transfer the rotational motion of servos **156** and **157** into linear width adjustments for each side **121***a* and **121***b* of knife blade **121**. Each assembly **134** is substantially the same. The primary component of each assembly **134** is a ball screw **134***a* which is rotatably received in the second apertures in the respective bracket **133***c* or **133***f* through bearings **134***b*.

A first timing pulley is mounted on ball screw **134***a*, and it includes a gear **134***j* sandwiched between pulley halves **134***h* and secured thereto by fasteners **134***k*. A second timing pulley is mounted on the rotational shaft of the respective servo **156** or **157** through a member **134***d*. The second timing pulley includes a gear **134***f*, mounted on member **134***d*, and sandwiched between pulley halves **134***e* and secured thereto by fasteners **134***g*. A timing belt **134***c* interconnects the first and second timing pulleys, whereby rotation of the respective servo shaft rotates ball screw **134***a*. A bearing **134***l* is disposed between the ball screws **134***a*.

A pair of sliding assemblies **135** are coupled to ball screws **134***a* and are arranged to slide generally along plate **133***a* in response to a rotation of the respective ball screw by servo **156** or **157**. One assembly **135** is provided for each side of knife blade **121** to allow each side to be adjusted independently. Each includes a slotted member **135***a* adapted to slide along a flange **133***b* of plate **133***a*. A block **135***b* is mounted to slotted member **135***a* through fasteners **135***c*, and a bracket **135***d* is then mounted to block **135***b* through fasteners **135***g*. A threaded member **135***e*, mounted to bracket **135***d* by fasteners **135***f*, then receives one end of the respective ball screw **134***a*, whereby a rotation of a ball screw causes the respective threaded member **135***e* to be threaded along the ball screw, resulting in the respective sliding assembly **135** sliding along flange **133***b* of plate **133***a*. While sliding assemblies **135** are shown sliding along a single horizontal plate, it will be appreciated that different runners, e.g. shafts, may be used as alternatives to a plate, and further, that each sliding assembly may slide on a separate runner.

Knife blade **121** is mounted at each side to one of the sliding assemblies **135** through separate blade bracket assemblies **136**. Each blade bracket assembly **136** includes a recessed member **136***a* which is rotatably mounted on block **135***b* of the respective sliding assembly **135** through a pin **136***b*, thus allowing each side of the knife blade to rotate about a vertical axis defined by pins **136***b*. Knife blade **121** is secured to a pair of blade brackets **136***h* and **136***j* with fasteners **136***g*. Brackets **136***h* and **136***j* are coupled to recessed members **136***a* through pivot blocks **136***c*, fastened to members **136***a* through fasteners **136***d*, and coupled to brackets **136***h* and **136***j* through pins **136***e* fastened by fasteners **136***f*. This configuration permits each side of knife blade **121** to individually rotate about the longitudinal axis of pins **136***e*. Different types of blade fasteners, e.g., quick-connect blade fasteners, may also be used.

Consequently, rotation of either servo **156** or **157** will slide the respective sliding assembly **135** along plate **133***a*, thereby laterally displacing the respective side **121***a* or **121***b* of knife blade **121**. Independent lateral adjustment of the sides of the blade are therefore provided.

A hold down assembly **138** is also optionally provided on head assembly **120**. Assembly **138** includes a runner **138***a* which is disposed forward of the first side **121***a* of blade **121** to spread apart the scribe cut formed by scribe saw assembly **50** during the cutting operation of loin knife assembly **100**. It is believed that by spreading apart the cut, the possibility of hitting the ends of the scribed ribs is minimized, thereby improving the loin cutting and lengthening the life of the knife blade. Alternatively, the cut may be spread by dropping down the backbone side of the meat after scribing, either by mechanical means or by simply not supporting the backbone side of the meat during the loin pulling operation.

In operation, loin knife assembly **100** provides four axes of motion for knife blade **121**. A first or vertical axis of motion is defined by lateral axis **119***b* and controlled by a first moving means (servo **154**) displacing vertical member **114***b* of arm **114**. This axis of motion provides climb/dive or vertical displacement (i.e., to raise or lower the knife blade).

A second axis of motion is defined by axis **119***c* and controlled by a second moving means (servo **152**) displacing lateral member **114***e* of arm **114**. This axis of motion provides lateral displacement (i.e., to move the knife blade side-to-side).

A third axis of motion is defined by axis **119***d* and controlled by a third moving means, which includes first and second lateral moving means (servos **156** and **157**), independently displacing the sliding assemblies **135** that secure each side of knife blade **121**. This motion allows independent adjustment of the lateral placement of each side of the knife blade, thereby enabling the sides to follow separate profiles.

A fourth axis of motion is defined by longitudinal axis **119***a* and controlled by a fourth moving means (servo **158**) displacing shaft **112**. This axis of motion provides rotational adjustment of knife blade **121** along a longitudinal axis of the pork side.

Several important features are provided by the preferred construction of loin knife assembly **100**. For example, the preferred construction allows for independent control of each side of knife blade **121** by the separate action of servos **156** and **157**.

Another important feature of the preferred construction is that the various displacements of the knife blade occur through a steering coupling which "leads" or "steers" the knife blade through the pork side, providing more natural anthropomorphic motions. It will be appreciated that since knife blade **121** is cutting through solid meat, the blade may not simply be moved to any position when desired. In particular, any adjustments to the position of the knife blade must be gradual enough to enable knife blade to work its way to the desired position, otherwise the knife may jam or break, or the pork side may become dislodged from the supporting platen.

In the preferred construction, the knife is located behind the forward point of arm **114**, which is head assembly receiving shaft **114***a*, which provides a forward steering coupling that enables knife blade **121** to operate much the same as a caster. Therefore, any displacement of the head

assembly will merely urge the knife blade in the desired direction until the desired displacement is achieved naturally.

This desired motion is further enhanced by the preferred construction due to the multiple pivot points provided for the knife blade. In particular, pivot block assembly **132** allows the entire head assembly **120** to pivot about a lateral axis (i.e., across the width of a pork side) as well as about a vertical axis (i.e., transverse to the plane of the pork side). Furthermore, recessed members **136***a* enable each side of the knife blade to separately pivot slightly about a vertical axis, and pivot blocks **136***c* enable each side of the knife blade to separately pivot about a longitudinal axis (i.e. along length of pork side). The combination of these pivot points gives the knife blade the freedom to be steered to the desired positions as it cuts through the pork side. In addition, since the knife blade is substantially freer than many conventional designs, it is believed that jamming and breaking of the blade will be reduced since the knife blade will not be as likely to be forced to follow a path beyond its structural capabilities.

The freedom of movement of provided by the multiple pivot points in the preferred loin knife assembly may be adjusted as necessary (e.g., through springs or other counterforce mechanisms) to balance the controllability of the knife blade (which ensures proper positioning thereof) with the flexibility of the knife blade (which ensures more fluid motion and easier passage through a side of meat). Moreover, an alternate embodiment of the loin knife assembly may have the multiple pivot points locked in place, or eliminated altogether, to provide maximum controllability for the knife blade. For example, FIG. **7***c* shows an optional locking mechanism **131** which uses a threaded rod **131***a* having bushing ends **131***b* to lock the pivot points on the head assembly. The rod is connected at one end by a fastener **131***e* to a bracket **131***c* fastened to the head assembly with fasteners **131***d*. The rod is connected at the other end by a fastener **131***e* to a bracket **131***g* fastened to another bracket **131***f* by fasteners **131***k*. Bracket **131***f* is in turn mounted to shaft **112** by bracket **131***h* and fasteners **131***j*.

Several modifications may be made to the preferred construction of the loin knife assembly consistent with the invention. For example, other mechanisms for moving the blade sides on a head assembly (e.g., as an alternative to ball screws and sliding assemblies) may be used, such as pivoting assemblies or alternate mechanical linkages. However, it is believed that the preferred construction would be simpler, less expensive and would remain more balanced regardless of the particular orientation of the knife blade.

In addition, the loin knife assembly may provide fewer axes of motion, e.g. by eliminating rotational control or lateral arm control (i.e., servos **152** and **158**), since the combination of the vertical arm adjustment and the individual lateral adjustments of the knife blade sides provides a significant amount of control over a loin pulling operation. To this extent, universal joint **113** may be eliminated if lateral arm adjustments are not used. However, it is believed that with the preferred configuration, sophisticated, yet natural anthropomorphic knife blade motion may be obtained with less complexity and with greater flexibility.

FIG. **8** shows one alternative head assembly design **120'** which may be used as an alternative to assembly **120** in FIG. **7***c*. Instead of including two separate servos for independently adjusting the sides of blade **121**, assembly **120'** includes a single servo **156'** which varies the separation between the blade sides to control the width of the knife blade. Through the combination of width adjustment of the blade using servo **156'** and lateral adjustment of the arm servo **156'**, first and second lateral moving means may still be defined to respectively control the sides of blade **121** to follow separate profiles which are generally independent from one another.

Head assembly **120'** includes a pivot block assembly **122** which includes a pivot block **122***a* receiving shaft **114***a* of arm **114** through an insert **122***b*. A head bracket assembly **123** is mounted to pivot block assembly **122** by a horizontal plate **123***a* secured to pivot block **122***a* by a fastener **122***f* projecting through insert **122***e*. Left and right brackets **123***c* and **123***f*, which are secured to plate **123***a* by fasteners **123***g* and include spacers **123***d*, are also coupled to pivot block **122***a* by pins **122***c* received in inserts **122***d*. A loin knife width servo **156'** is mounted to right bracket **123***f* by fasteners **123***h*.

The relative position of head bracket assembly **123** with respect to pivot block assembly is controlled by a climb/dive angle adjustment assembly **127**, which includes a threaded stop **127***a* threadably received in bracket **127***b* mounted to the edges of brackets **123***c* and **123***f*, so that the end of stop **127***a* engages pivot block **122***a*.

A servo linkage assembly **124** includes a single double threaded ball screw **124***a* which is rotatably received in brackets **123***c* and **123***f* through bearings **124***b*. A first timing pulley, including a gear **124***j* sandwiched between pulley halves **124***h* and secured thereto by fasteners **124***k*, is mounted on ball screw **124***a* through a member **124***g*. A second timing pulley, including a gear **124***f* sandwiched between pulley halves **124***e* and secured thereto by fasteners **124***g*, is mounted on the rotational shaft of servo **156'** through a member **124***d*. A timing belt **124***c* interconnects the first and second timing pulleys, whereby rotation of the servo shaft rotates ball screw **124***a*.

A pair of sliding assemblies **125** are used, each including a slotted member **125***a* adapted to slide along a flange **123***b* of plate **123***a*. A block **125***b* is mounted to slotted member **125***a* through fasteners **125***c*, and a bracket **125***d* is then mounted to block **125***b* through fasteners **125***g*. A threaded member **125***e*, mounted to bracket **125***d* by fasteners **125***f*, then receives one end of double threaded ball screw **124***a*. Threaded members **125***e* are preferably equidistant from the center of the ball screw to maintain sliding assemblies **125** evenly spaced from center of head assembly **120** to better balance loin knife assembly **100**.

Knife blade **121** is mounted at each side to one of the sliding assemblies **125** through blade bracket assemblies **126**. Each blade bracket assembly **126** includes a recessed member **126***a* rotatably mounted on block **125***b* of sliding assembly **125** through a pin **126***b*. A blade bracket **126***d*, including a blade fastener **126***e* mounted thereon for retaining the side of knife blade **121**, is coupled to recessed member **126***a* through pivot blocks **126***f* and **126***g* fastened to the respective members by fasteners **126***k*. The pivot blocks **126***f* and **126***g* are in turn coupled together by a pin **126***h* fastened at each end by fasteners **126***j*.

Other modifications to the loin knife assembly will be appreciated by one skilled in the art.

D. Electronic Control System

FIG. **9** shows a block diagram of the preferred electronic control system **170**. The primary components of control system **170** are a main controller **172**, a motion controller **180** and an imaging/vision system **190**.

Main controller (host PC) **172** provides the primary control over control system **170**. In particular, controller **172** coordinates the activities of motion controller **180** and imaging system **190** to actuate apparatus **10** to perform the loin separation processes. Cutting profiles for the scribe saw and loin pulling assemblies are preferably generated in controller **172** in response to image data provided by imaging system **190**. Then, after profiles are calculated, controller **172** also communicates with motion controller **180** to coordinate the actions of scribe saw assembly **50** and loin knife assembly **100** as a side is conveyed through the apparatus. Moreover, controller **172** controls a number of secondary components through a secondary driver **161**.

Controller **172** also provides a user interface for operating, programming, modifying, diagnosing, etc. apparatus **10**. Diagnostic information, as well as production data, may also be stored in controller **172**. Other system overseeing functions may also be incorporated into controller **172**.

Controller **172** is preferably an IBM® Compatible personal computer, such as the type based upon an Intel® 486 or Pentium microprocessor. It will be appreciated, however, that other computer systems, either commercially available or custom designed, may be used in the alternative.

Controller **172** communicates with imaging system **190** through a dedicated bus **174**, which is preferably a standard EISA bus on an IBM-compatible PC. The primary function of imaging system **190** is to provide imaging data and digital image processing to controller **172** for determining the necessary modifications to pre-programmed scribe and loin pull profiles based upon the dimensions of the pork side. In the preferred control system **170**, imaging system **190** provides both static and dynamic information about pork sides to assist in optimizing the scribe and loin pulling operations.

Imaging system **190** includes a visioning processor, preferably a Matrox Visioning System Model IM-640, manufactured by Matrox Electronic Systems, Ltd. of Quebec, Canada. Other commercially available imaging systems may be used in the alternative. In the Matrox system, a baseboard **192** includes a pair of processors. The first, a graphics signal processor, handles information exchange with controller **172**, controls the overall visioning processor system, supervises the parallel processing functions for the system, and controls the imaging cameras which provide the images of each side of pork. The second, a floating point unit, performs specialized and processor-intensive numerical operations to support the graphics signal processor.

An internal proprietary image bus **191** in the Matrox system handles information exchange between baseboard **192** and a real time processor **194**. Real time processor **194** provides several standard image processing routines, including routines for neighborhood processing (e.g., edge detection, filters and convolutions), spatial filters, pattern matching convolutions and thresholding, among others.

As discussed above, baseboard **192** of imaging system **190** controls several cameras that provide image data regarding each side of pork processed by apparatus **10**: a top plan camera **196**, an end view camera **197** and a fat line camera **198**. The first, top plan camera **196**, is primarily used to determine the primary physical dimensions and characteristics of a side for generating the profiles for the scribe saw and loin knife assemblies.

As shown in FIG. **1**, top plan camera **196** is positioned directly above platen **20** in the loading position, whereby a top plan image of the pork side may be captured immediately after the platen is activated and the pork side is securely positioned thereon. A plurality of lights **140** are positioned proximate platen **20** and are angled to project a high intensity light against the top surface of the pork side. At the angle shown in FIG. **1**, about 35 degrees from horizontal, it has been found that the light creates a particularly strong shadowline directly along backbone due to the typical contours of a pork side, to the extent that a binarized (or digitized) image of the pork side taken with camera **196** will have a brightly lit (white) area for the ribs, with a dimly lit (black) area for the backbone. As such, the imaging system has little difficulty in determining the positioning and curvature of the backbone therefrom. It will be appreciated, however, that other positioning for lights **140** may also be used in the alternative, given the pattern matching capabilities of the preferred imaging system. Further, as will be discussed below, it may be preferable to take a second image with camera **196** while lights **140** are not on, to gain additional dimensional data regarding the pork side.

The second imaging camera, end view camera **197**, is primarily used to determine the height of the pork side and the positioning of the "T"-shaped blade bone of the pork side on the leading surface thereof, both for aiding in the calculation of starting points for the loin knife and scribe saw profiles. As shown in FIG. **1**, camera **197** is preferably positioned proximate scribe saw assembly **50** and angled forward to view the leading end of the pork side when platen **20** is in a loading position prior to the scribing operation. Light source **140** may be used to project high intensity light on the top surface of the pork side to create a clear delineation along the top edge of the end of the pork side. Again, two images may be taken, one with the lighting and one without, to obtain the preferred image data for generating the assembly profiles.

The third imaging camera, fat/lean separation line camera **198**, is primarily used to provide dynamic (real-time) image data of the fat/lean separation line for the pork side proximate the backbone. Controller **172** uses this information to dynamically modify the cutting profile of loin knife assembly **100** so that the assembly follows a fixed distance from the separation line to provide the optimum fat cover for the loin. As shown in FIG. **1**, camera **198** is preferably positioned proximate loin knife assembly **100** facing inwardly. Preferably, the field of view of camera **198** is adjusted to focus on the positioning of the fat/lean separation line within a relatively small area so that the image data may be coordinated with the small incremental movements of the platen.

Cameras **196**, **197** and **198** are preferably GP-MS112 cameras manufactured by Panasonic, although other cameras suitable for this purpose are available. The magnification, focus and sensitivity of each may be optimized for the different applications of the cameras, e.g., for camera **196**, the field of view is preferably the entire top surface of the pork side, for camera **197**, the field of view is preferably just the end surface of the pork side, and for camera **198**, the field of view is preferably a small area of the fat/lean separation line which is a known distance from the loin knife assembly.

It has been found that certain types of supplemental lighting may also be used to enhance the imaging capabilities of imaging system **190**. For example, as shown in FIG. **1**, a pair of lighting systems **302** and **304** may be used to provide overall illumination of a pork side during imaging. In particular, lighting systems **302** and **304** are preferably mercury vapor lamps, which have been found to possess light wavelengths that accentuate the interface between fat and lean on a pork side. In particular, light wavelengths in the order of 380 to 760 nanometers are preferred (more preferably about 550 to 600 nanometers), which may be

provided by different lighting systems, such as those manufactured by General Electric, Stonco, etc. Lighting systems **302** and **304** may be continuously on during the operation of apparatus **10**, or alternatively, may be turned on and off (or selectively shielded) to operate only during the imaging cycles of apparatus **10**.

One skilled in the art will appreciate that various connections, peripheral components, etc. may be necessary to drive cameras with visioning system **190**. Furthermore, it will be appreciated that the programming and data exchange necessary for controller **172** to communicate with and control an imaging system in the manner described herein is generally known in art, for example as exemplified by the Matrox IM 640 IMAGE Series Programming Manual, which is incorporated herein by reference.

Returning to FIG. **9**, controller **172** also communicates with a motion controller **180** through a dedicated bus **173**, which is also preferably a standard EISA bus on an IBM-compatible PC. The primary function of motion controller **180** is to control the different servos used in the scribing and loin pulling operations. Controller **172** provides the desired positioning data (profile) for each servo to motion controller **180** on a real-time basis during cycling of apparatus **10**.

Motion controller **180** preferably includes a PMAC Programmable Multi-Axis Controller, manufactured by Delta Tau Data Systems of Northridge, Calif. Other known motion controllers may also be used in the alternative. Motion controller **180** also includes an internal bus **182**, driven by the PMAC Controller, which communicates with a plurality of servo drivers, each of which drives one of the servos, which include scribe saw lateral servo **150**, scribe saw lift actuator **151**, loin knife arm lateral servo **152**, loin knife climb/dive servo **154**, first and second loin knife blade lateral servos **156** and **157**, loin knife rotational servo **158** and platen position servo **160**. The preferred servo drivers are Electro-Craft BRU-200 Servo Drivers manufactured by Reliance Electric. This type of servo driver accepts ±10 VDC Analog signals; consequently, it will be appreciated that the PMAC Controller and internal bus **182** will include all necessary amplifiers, buffers, and other peripheral components for providing suitable control signals to each servo driver. In addition, it will be appreciated that the programming and data exchange between main controller **172** and motion controller **180** is generally known in the art, for example as exemplified by the Delta Tau Version 1.13 PMAC Reference Manual by Data Systems, Inc., which is incorporated herein by reference. It will further be appreciated that different modifications may be made to the preferred design, and that other motion controllers known in the art may also be used.

Main controller **172** also controls several peripheral components through a secondary driver **161** across a bus **176**. Most components are valves for pressure driven devices in apparatus **10**, such as Model 082SA415M LS3BA452B solenoid valves manufactured by Numatics, Inc. For example, controller **172** preferably controls valves **350** and **352** between an air pressure source (not shown) and the outer and inner gripper hook cylinders. Further, another valve **166** supplies a source of pressure to the scribe saw blade driving means to drive the blade during the scribing operation. Also, another air valve is driven by controller **172** to actuate push-off cylinder **162** to eject loins from apparatus **10**. Moreover, a pair of air valves are driven by controller **172** to actuate the scribe saw and loin knife locking mechanisms **87** and **139** for selectively locking the steering couplings of the respective assemblies.

Secondary driver **161** may also be used to receive a signal from an operating switch **17**. As shown in FIG. **1**, switch **17** is used by an operator to activate apparatus **10** to initiate a loin separation cycle. Preferably, switch **17** is of the type which will initiate a cycle on when the operator is clear of machine, primarily for safety reasons. One type of device suitable for use as switch **17** is an OTDVNG switch manufactured by Banner Engineering Corp., which will not initiate a cycle until both of an operator's hands on placed on separate infrared sensors. Other suitable safety actuation switches are known in the art.

Returning to FIG. **9**, other inputs and outputs may be routed through to secondary driver **161** as desired. Further, different buffers, relays, amplifiers, A/D or D/A converters and other peripheral components may be necessary for allowing controller **172** to send and receive signals from the devices interfaced through driver **161**. Other modifications and changes may be made to driver **161** as desired.

Various modifications and changes may be made to control system **170** consistent with the invention. For example, additional imaging and motion functionality may be included to provide more sophisticated profiles using the preferred scribe saw and loin knife assemblies. Also, the design of control system **170** may be modified to incorporate different accessory components on apparatus **10**. Other modifications will be appreciated by one skilled in the art.

E. Operation/Software Configuration

With the preferred design of apparatus **10** as discussed above, a pork side may be separated into the pork loin and pork belly portions with substantially greater accuracy and efficiency. As shown in FIGS. **10***a–c*, a typical pork side **1** includes a backbone **7** which follows a generally curving profile viewed from above. A fat/lean separation line **6** is shown along the outer edge of pork side **1** when viewed from the top and end views, and a "T"-shaped blade bone **5** is shown viewed from the end of pork side **1**.

The desired scribe saw cut is designated by line **2**. It is preferable to cut the ribs as close as feasible to the backbone, preferably along a line which is separated from backbone **7** by about 1¼ inch and which follows the general contour of the backbone. The preferred depth of scribe cut **2** is about ½ inch, which is sufficient to sever the ribs. Moreover, in the preferred embodiment, it is desirable to stop the scribe cut as soon as possible after the last rib is cut to minimize the amount the scribe saw cuts into the tenderloin area following the rib, which could otherwise decrease the quality of the pork side.

The general profile of the loin knife preferably simulates the motions of a human operator. At the entry point into the pork side, the right side of the knife blade **121** enters at the scribe cut, and the left side of the blade preferably enters 0.1 inches from the fat/lean separation line. The bottom of the blade enters below the "T"-shaped blade bone.

The desired loin pull cut is shown by lines **3***a*, **3***b* and **4**, which respectively show the preferred paths for the right side, the left side and bottom of knife blade **121** (when facing the sharpened edge of blade **121**). The right side **121***a* of knife blade **121** preferably follows scribe cut **2** along line **3***a*. The left side **121***b* of knife blade **121** preferably follows line **3***b*, which is a fixed distance (preferably 0.1 inch) from fat/lean separation line **6**, and which generally follows the contour thereof. As discussed above, a 0.1 inch fat covering sufficiently keeps the loin from drying out, but doesn't make the loin look too fat. Other fat thicknesses may be desired in the alternative. The bottom of knife blade **121** also generally follows line **4** (shown in FIG. **10***b*), which generally travels

below blade bone **5** proximate the fat/lean separation area along the bottom of the pork side.

In addition, it may be desired to cause the profiles of the left and right sides and the bottom of blade **121** to dive and flare out, typically a fixed distance after point **9** (FIG. **10***a*), which maximizes the amount of ham pulled with the loin and misses the aitch bone. As the blade dives and flares out; however, it is preferable to control the left side of the blade to follow the fat/lean separation line throughout the entire profile.

FIG. **11** shows a flowchart for the software control of a preferred operating cycle **210** for apparatus **10**. The preferred cycle is initiated in block **211** by an operator activating switch **17** when the operator has properly positioned a pork side on the platen. It will be appreciated that a pork side may alternatively be placed on the platen by automated devices such as conveyors, robotic arms, etc.

The first step in the cycle is to activate gripper platen **20** in block **212**. This step includes sending the appropriate signals to secondary driver **161** as discussed above to first activate valve **350** for the outer gripper hooks and subsequently activate valve **352** for the inner gripper hooks.

Once the pork side has been secured to the platen, control passes to block **230** to determine the preferred profiles for scribe saw assembly **50** and loin knife assembly **100**. The profiles for the assemblies are stored as separate arrays of data points. Each array corresponds to one of the servos, and preferably includes **133** data points indexed by a common position index variable which may correspond to the position of platen **20** (e.g., where there are 133 evenly spaced positions for the platen along the rails). The profile generating routine is discussed in greater detail below with respect to FIGS. **12**, **13** and **14**.

The profiles are transmitted to motion controller **180** by the program loop shown in blocks **216–222**. Upon initiation of routine **210**, the position index will preferably be set to index the beginning data points in the profile arrays. In block **216**, the profile data according to the current position index is transmitted to motion controller **180** to activate each servo according to the programmed profile data. In this block, motion data for scribe saw assembly **50**, loin knife assembly **100** and platen **20** are provided to controller **180**, and further, control signals are provided to secondary driver **161** to operate the secondary components as necessary (e.g., to turn the scribe saw blade on/off, to raise/lower the scribe saw assembly, to unlock the steering couplings once the scribe saw and loin knife have entered the pork side, etc.).

Motion controller **180** preferably takes the data points provided by controller **172** and fits these points to curves for activating the individual servo drivers. This enables motion controller **180** to ensure for proper positioning of the servos at periodic intervals, taking into account the time delays present when moving electromechanical servos. This also enables the scribe saw and loin knife blade to be steered progressively through the pork side by their respective forward steering couplings. Motion controller **180** preferably operates in a known spline mode, whereby the data points are fit to an arcuate curve between points. It will be appreciated that the motion controller may also operate in other modes such as a linear mode.

Concurrent with block **216**, in block **220**, a separate dynamic profile modification routine executes to image the fat/lean separation line of the pork side using camera **198** and make real-time adjustments to the profile of the loin knife assembly, as will be discussed in greater detail below. In general, the data modified in the profile is preferably separated in time from the data being transmitted to the motion controller, so no data conflicts will occur.

In block **222**, the position index variable is queried to determine if the end of the profile has been reached. If not done, control is passed to block **218** to increment the position index and return to execute blocks **216** and **220** for the next position index value.

Routine **210** provides a set of data points on a periodic basis to motion controller **180**, preferably about every 0.5 inches of movement of platen **20**. With the movement of platen **20** separated into 133 datapoints, this preferably enables the platen to be cycled through apparatus 10 in about 7 seconds. Including the time for activating, returning and releasing the platen, initial imaging, and final loin ejection, as well as the operator time for loading a pork side on the platen, it is anticipated that the preferred apparatus **10** should be able to process about 450 pork sides per hour.

Returning to block **222**, if all of the profile data has been transmitted to motion controller **180**, then control is passed to block **224** to release the inner and outer gripper hooks by de-activating valves **350** and **352**. Next, in block **226**, the scribed and separated pork side is ejected from apparatus **10**. In this block, push-off cylinder **162** is activated and withdrawn to eject the pork side from platen **20** into a hopper or bin, or alternatively onto another conveyor (not shown) for further processing. Then, once the pork side is ejected, control passes to block **228** to return the platen to its starting position, preferably by resetting the position of the platen to its beginning point, and sending this information to motion controller **180**, which steps the platen back to its start position.

FIG. **12** shows the overall flow in the preferred profile generating routine **230**. In routine **230**, two separate images are preferably taken for top and end views of the pork side in blocks **232** and **234**. In block **232**, top and end views are taken by cameras **196** and **197** with lights **140** activated to create shadowed top and end images of the pork side. With the high intensity lighting provided by lights **140**, a definitive backbone line will be generated in the top image, and a definitive top edge will be generated in the end image.

In block **234**, similar non-shadowed top and end view images are taken using cameras **196** and **197** without the high intensity lighting of lights **140**. These images provide comparatively more detail of the top and end views of the pork side than their shadowed counterparts, and are used to supplement the image data which may be obtained about the pork side. In the alternative, all of the necessary image data may be obtained from non-shadowed images; however, it is believed that the stark contrasts provided by the shadowed images result in simpler and more reliable detection of some dimensional aspects of the pork sides.

Once the images are taken in blocks **232** and **234**, the images are then processed in a image processing routine **240**, which is shown in greater detail in FIG. **13**. The first step in routine **240** is to generate a backbone line from the top view shadowed image taken by camera **196** in block **242**. Block **242** operates via known image processing techniques, primarily by performing noise reduction, then performing a threshholding operation to binarize the image (i.e., to turn all of the pixels therein to black or white, based upon a comparison with a predetermined median value), and the performing a convolution operation to detect the boundary formed by the backbone. The resulting processed image will include a line which follows the backbone of the pork side.

Next, in block **244**, routine **240** preferably performs pattern matching operations to generate several points from

the processed image. A plurality of points (with corresponding x and y positions) are generated along the backbone line in the processed image. Preferably, **20** points are generated, although more or less may also be generated if desired. Also, a slope change point is calculated, which represents the point along the backbone line in which the slope of the line changes from negative to positive. Further, a "corner" point (point **8** in FIG. **10***a*) is calculated via comparison with a known pattern, to find the general corner of the backbone line and the front end (i.e., the end viewed by camera **197**) of the pork side.

Next, in block **246**, routine **240** generates a fat/lean separation line and an edge line from the non-shadowed top view image. Similar to block **242**, noise reduction, thresholding and convolution are performed on the non-shadowed image to generate both lines. However, it will be appreciated that due to the different lighting, different control variables, e.g., the threshold variable, from the variables used on the shadowed image will be required to generate the fat/lean separation and edge lines from the non-shadowed image. In general, the fat/lean separation line will be distinguished by the interface between the loin meat and the fat covering, which is typically much lighter than meat. Similarly, the edge line (representing the outer surface of the pork side proximate the fat/lean line) will be distinguished by the interface between the fat covering and the platen or other supporting structure proximate the edge of the pork side.

Next, in block **248**, a plurality of points (preferably **20**) are generated for each of the fat/lean separation and edge lines using known pattern matching routines. Further, corner points, representing the ends of the lines at the end surface of the pork side, are also matched and determined for each line.

In block **250**, the shadowed end view image is processed to generate a top edge line similar to the manner discussed above for the backbone line in block **242**. In particular, known noise reduction, threshold and convolution routines are performed to generate a top edge line along the interface of the top and end surfaces of the pork side.

In block **252**, the corner point (point **8** in FIGS. **10***a* and **10***c*) is detected via a pattern matching routine. The corner point corresponds to the same corner point determined in block **244**.

Next, in block **254**, the non-shadowed end view image is processed to generate end views of the fat/lean separation and the side edge of the pork side, to respectively generate end fat/lean and end edge lines. Also, in block **254**, an image of the "T"-shaped blade bone is generated in the processed image. Similar to block **246**, noise reduction, thresholding and convolution are performed on the non-shadowed image to generate the desired image components, using suitable control variables. In general, the end fat/lean separation line will be distinguished by the interface between the loin meat and the fat covering, and the end edge line (representing the outer surface of the pork side proximate the fat/lean line) will be distinguished by the interface between the fat covering and the platen or other supporting structure proximate the edge of the pork side. Moreover, the blade bone interface will be distinguished by the interface between the loin meat and the bone, since bone is typically much lighter than meat.

In block **256**, a plurality of points (preferably 20) are generated for each of the end fat/lean separation and end edge lines using known pattern matching routines. Further, the bottommost point of the blade bone is also calculated by pattern matching, since the blade bone has a distinctive "T" shape.

The aforementioned noise reduction, thresholding, convolution and pattern matching routines are preferably standardized routines provided with imaging system **190**. Further, the particular process control variables, e.g., patterns, threshold values, etc. may vary depending upon several factors, including lighting intensity and type, type of meat, etc. Therefore, the particular process control variables used in the preferred embodiment will not be discussed herein, as they may be determined through routine experimentation.

An additional step is performed in routine **240** before returning to routine **230**. In block **258**, the height, width and length of the pork side is calculated, using the known values calculated in the aforementioned image processing steps, as well as knowing the position of stop **305** on platen **20**, which indicates the position of the opposite end of the pork side. It may also be preferable to compare the calculated widths obtained from the top and end view images for error detection. It will be appreciated that given a known positioning, magnification, and other process characteristics of the image cameras, X and Y coordinates in the top and end view images may be translated to real-world dimensions by a straightforward numerical conversion routine.

The distance from camera **197** to the end of the pork side will typically vary depending upon the length of the pork side. Consequently, the translation between the X and Y coordinates of the image and the real-world dimensions may vary to an extent by the distance from the camera to the pork side. Therefore, it may be preferable to include one or more look-up tables, e.g., indexed by the length or width determined from the corner point in the top view image, to vary the translation of image coordinates to real world dimensions for the end view image. A similar translation may also be used for the top view image.

In block **258**, it may also be preferable to calculate a separate height for the ribs in addition to the height of the backbone. This information may also be obtained by pattern matching the shadowed end view image to find the desired point along the ribs to take the height.

Returning to FIG. **12**, the next step in routine **230** is to execute routine **260** to calculate the array values for each of the scribe saw, loin knife, and platen position servos. As discussed above, loin knife arm lateral servo **152**, climb/dive servo **154** and first and second blade lateral servos **156** and **157** provide three axes of control for each side of the knife blade in loin knife assembly **100**. The positioning of these servos is stored generally as a function of the position of the platen, i.e., the motion data for each servo is stored in a numerical array indexed by the position index (which is also used to index or map a numerical array for the platen position servo).

In the preferred apparatus **10**, a separate profile for rotational servo **158** is not calculated (i.e., servo **158** is not activated during a loin pulling operation). However, it will be appreciated that a separate profile for servo **158** may be calculated in a manner similar to those for servos **152**, **154** and **156** to provide a fourth axis of control for loin knife assembly **100**, and thereby provide greater flexibility and/or simulation of anthropomorphic movement for the assembly. In addition, it will be appreciated that due to the independent lateral adjustments available from servos **156** and **157**, a separate profile for arm lateral servo **152** may not be required.

The data for the positioning of each servo will be dependent upon the dimensions of knife blade, and it will be appreciated that the data for each servo may be calculated using known equations depending upon the dimensions and

desired position of the knife blade, as well as the known physical displacements for each step of each servo. For example, the height of the bottom of the blade **121** may be calculated by a known parabolic geometric equation given the known fixed length of the blade (which forms a perimeter for the parabola) and the controlled and known lateral positions of the sides of the blade. Since lateral adjustments to each side of the blade will vary the width of the blade and necessarily affect the height of the bottom of the blade, the climb/dive adjustment may also be calculated from the known dimensions of the knife blade.

Routine **260** is shown in greater detail in FIG. **14**. In routine **260**, the first step is to calculate the individual servo starting points in block **262**. As discussed above, it is preferable to control servo **150** to start the scribe saw at a preset distance (preferably 1¼ inch) from the corner point on the backbone line generated in routine **240**. Moreover, it is preferable to control servos **152**, **154**, **156** and **157** to locate the right side of the loin knife blade along the scribe cut, locate the left side of the loin knife blade 0.1 inch from the corner point of the fat/lean separation line generated in routine **240**, and locate the bottom of the loin knife blade 0.1 inch from the end fat/lean separation line generated in routine **240**.

Next, in block **264**, the location of the blade bone is checked to determine whether the bottom of the blade bone projects into the fat cover of the pork side. In some pork sides, this may be the case, and could cause the standard starting point generation routine in block **262** to cause the bottom of the knife blade to hit the blade bone. This comparison may be performed by comparing the end fat/lean separation line to the bottom point of the blade bone, both of which were previously calculated in block **256**.

If the blade bone does project into the fat cover of the pork side, control preferably passes to block **266** to modify the starting points of servos **152**, **154**, **156** and **157** to lower the starting point of the bottom of the knife blade to miss the blade bone. For example, the bottom of the knife blade may be controlled to be located a fixed distance from the bottom of the blade bone.

Next, in block **268**, the profile data for servo **150** is generated using the plurality of points generated for the backbone line in routine **240**, as well as the slope change point determined in the same routine. The profile of scribe saw lift actuator **151** is preferably generated to lower the scribe saw near the beginning of the profile array (prior to the saw blade hitting the pork side), so that the height of the scribe saw will be automatically controlled by the runners on the scribe saw head assembly. Also, servo **150** preferably follows at a fixed distance from the contour of the backbone line up to the last rib (which is determined as a fixed distance from the slope change point of the backbone line). After the last rib, scribe saw lift actuator **151** is preferably programmed to raise the scribe saw, and the profile of servo **150** may be generated to center the scribe saw for the remainder of the processing of the pork side. Moreover, a profile for the scribe saw locking mechanism **87** may be generated to lock the steering coupling up to the point at which the scribe saw blade enters the pork side, then to unlock the steering coupling thereafter to allow for the "castering" operation of the steering coupling to take effect.

In block **270**, the profiles of loin knife servos **152**, **154**, **156** and **157** are controlled up to the slope change point on the generated backbone line. The profiles of the right and left sides of the knife blade are selected to follow fixed distances from the backbone line and the fat/lean separation line, respectively, and the profile data for servos **152**, **154**, **156** and **157** are generated accordingly. Moreover, a profile for the loin knife locking mechanism **139** may be generated to lock the steering coupling up to the point at which the loin knife enters the pork side, then to unlock the steering coupling thereafter to allow for the "castering" operation of the steering coupling to occur.

Next, in block **272**, the profiles of the loin knife servos **152**, **154**, **156** and **157** are controlled to dive and flare out the sides of the knife blade at a substantially constant rate so that the width of the blade is proximate a maximum width and the bottom of the blade is at a low point once the end of the pork side is reached. During this period, however, the left side of the knife blade is still controlled to follow the fixed distance from the fat/lean separation line throughout the remainder of the loin pulling process.

Various modifications to the aforementioned profile generation routine **230** may be made consistent with the invention. For example, standard profiles for the scribe saw and loin knife assemblies, which may be determined empirically, may be used and modified (for example, by determining lateral or height offsets from the standard profiles) based upon the images obtained from the imaging system. In this configuration, the motion controller would preferably include a learning setup, whereby the loin knife and scribe saw assemblies would be stepped through a representative cycle using a typical pork side. The position of each servo would be individually controlled and recorded for each position of the platen. Then, once the entire range of datapoints were stored, the resulting profile could be "smoothed out" by a known curve-fitting algorithm. Moreover, empirical data may alternatively be obtained for different sizes and shapes of pork sides to generate additional profiles for building a database of profiles for selection by a best fit algorithm.

Returning to block **216** in FIG. **11**, the profile data for servos **152**, **154**, **156** and **157** are preferably dynamically modified to control the left side of the knife blade to better follow a fixed separation from the fat/lean separation line of the pork side.

The dynamic profile modification routine in block **220** preferably periodically checks the position of the fat/lean separation line at a fixed position in front of knife blade **121** (i.e., a position on the pork side prior to its being cut by loin knife assembly **100**). Since this position occurs prior to the loin pulling operation, the routine in block **220** may not be active for the loin separation operations.

Controller **172** utilizes imaging system **190** to provide offset data dynamically for correcting the loin knife assembly profile. First, controller **172** commands imaging system **190** to capture an image of the fat/lean separation line with fat line camera **198**. Then, the captured image is image processed, typically through noise reduction, thresholding and convolution, to generate the fat/lean separation line. The lateral position of the fat/lean separation line at a particular platen position index value may be calculated, for example, by determining the X coordinate of the fat/lean separation line in the processed image at the appropriate Y coordinate corresponding a known fixed position from the loin knife blade.

An appropriate position for the left side of the knife blade may be calculated for the particular platen position being processed using the lateral position data generated from the processed image described above. This value is compared to the actual profile data for the left side of the knife blade from the profile data stored for servos **152**, **154**, **156** and **157**, and

if the actual value is outside of an acceptable range (i.e., greater than about a one percent deviation), the profile data points for servos **152, 154, 156** and **157** for the remainder of the profile data points are preferably modified to shift the left side of the knife blade over a distance equal to the difference between the prior profile and that calculated dynamically as described above.

It will be appreciated that other modifications may be made to the preferred dynamic routine **220** consistent with the invention. For example, using suitable pattern matching, the preferred routine may be used to detect protrusions of the backbone into the fat cover, which could otherwise obstruct the knife blade as it passes along a normally calculated profile. As above, the profiles of the servos **152, 154, 156** and **157** may be modified to shift the left side of the knife blade to clear a detected protrusion. This may be accomplished by modifying the profile data points immediately proximate the protrusion, or alternatively, by shifting all of the profile data points remaining after the protrusion, and allowing the profile data points to be shifted back in later iterations when the protrusion is no longer detected by the routine.

The invention therefore provides a loin separation apparatus which offers precise and efficient control over scribing and loin pulling operations utilizing highly controllable scribe saw and loin knife assemblies. The multiple axes of control for the assemblies, and the use of controllable motion and imaging systems, further offers significant sophistication, flexibility and expandability in controlling these operations. As one skilled in the art will appreciate that various modifications may be made to the preferred embodiments without departing from the spirit and scope of the invention, the invention thus resides in the claims hereafter appended.

What is claimed is:

1. A loin separation apparatus for separating a loin portion from a side of meat, the apparatus comprising:

(a) a frame;

(b) conveying means, coupled to the frame, for conveying a side of meat through the apparatus;

(c) a loin knife assembly, coupled to the frame, the loin knife assembly including:

(1) an arm pivotally coupled to the frame to pivot about a lateral axis;

(2) a generally U-shaped knife blade coupled to the arm and having first and second sides;

(3) vertical moving means for moving the arm vertically about the lateral axis; and

(4) first and second lateral moving means for respectively moving the first and second sides of the knife blade in a lateral direction; and

(d) a controller, coupled to the conveying means, the vertical moving means and the first and second lateral moving means, for controlling movement of the loin knife assembly to separate the loin portion from the side of meat as the side of meat is conveyed through the apparatus.

2. The apparatus of claim **1**, wherein the arm is coupled to the frame through a universal joint, wherein the head assembly includes a width adjustment means for varying the separation between the sides of the knife blade, wherein the loin knife assembly includes lateral adjustment means, coupled to the arm, for moving the head assembly in a lateral direction, and wherein the first and second lateral moving means each actuate the width adjustment and the lateral adjustment means in combination to position the first and second sides of the knife blade, respectively.

3. The apparatus of claim **1**, wherein the arm is mounted to the frame through a shaft which is rotatably mounted to the frame to rotate about a longitudinal axis, and wherein the loin knife assembly further includes rotating means for rotating the shaft about the longitudinal axis.

4. The apparatus of claim **1**, wherein the knife blade is coupled to the arm through a head assembly, and wherein the first and second lateral moving means each comprise:

(a) a horizontal runner coupled to the head assembly;

(b) a sliding assembly slidably mounted on the runner and coupled to a side of the knife blade;

(c) a screw received in a threaded aperture in the sliding assembly; and

(d) a stepper motor servo coupled to rotate the screw to slide the sliding assembly along the runner.

5. The apparatus of claim **4**, wherein the arm includes a first vertical member having first and second ends, the first end disposed proximate a pivot point for the arm, a second vertical member having first and second ends, the head assembly pivotally coupled to the first end to pivot about a vertical axis disposed forward of the knife blade and thereby permit the knife blade to be steered through the side of meat, and a horizontal member joining the second ends of the first and second vertical members, and wherein the vertical moving means is mounted to the first vertical member; whereby the head assembly is disposed a fixed distance from the pivot point.

6. The apparatus of claim **1**, further comprising a scribe saw assembly mounted to the frame, the scribe saw assembly including:

(a) a scribe saw head having a saw blade and being pivotally mounted at a forward point to rotate about a generally vertical axis such that the saw blade is steered through the side of meat;

(b) moving means for moving the scribe saw head in a lateral direction;

(c) means for raising and lowering the scribe saw head; and

(d) means for rotating the saw blade.

7. The apparatus of claim **1**, wherein the conveying means includes:

(a) a platen slidably mounted on at least one rail;

(b) means for moving the platen along the rail;

(c) at least one gripper hook rotatably mounted to the platen to project through an aperture in a supporting surface of the platen; and

(d) means for rotating the gripper hook to engage the side of meat when the side of meat is supported on the platen.

8. The apparatus of claim **7**, wherein the means for moving the platen includes a belt coupled to the platen and a stepper motor for rotating the belt and thereby sliding the platen along the rail, and wherein the means for rotating the gripper hook includes a cylinder activated by pressurized gas.

9. The apparatus of claim **7**, wherein the conveying means includes four gripper hooks disposed along a longitudinal axis, three of the gripper hooks facing forward and one facing backward, and a fixed stop member fixedly mounted proximate a rear edge of the platen.

10. The apparatus of claim **1**, wherein the controller includes:

(a) imaging means for generating a top plan image of the side of meat;

(b) image processing means for determining backbone and fat/lean separation lines from the top plan image;

(c) profile calculating means for generating profiles for the vertical moving means and the first and second lateral moving means to control the first side of the U-shaped knife blade to follow a preset distance from the backbone line, and the second side of the U-shaped knife blade to follow a preset distance from the fat/lean separation line; and

(d) means for actuating the vertical moving means and the first and second lateral moving means to follow their respective profiles.

11. The apparatus of claim **10**, wherein the imaging means includes means for generating images of the fat/lean separation on the side of meat at a plurality of time intervals, and wherein the controller further includes means for dynamically modifying the profile of the second lateral moving means in response to the images of the fat/lean separation on the side of meat.

12. In a loin separation apparatus, a loin knife assembly comprising:

(a) an arm pivotally coupled to the loin separation apparatus to pivot about lateral and vertical axes;

(b) a head assembly, coupled to the arm, the head assembly including a generally U-shaped knife blade having first and second sides;

(c) vertical moving means for moving the arm vertically about the lateral axis;

(d) lateral adjustment means for moving the arm laterally about the vertical axis; and

(e) width adjustment means for varying the separation between the first and second sides of the knife blade.

13. In a loin separation apparatus, a loin knife assembly comprising:

(a) a generally U-shaped knife blade having first and second sides;

(b) vertical moving means for moving the knife blade in a vertical direction; and

(c) first and second lateral moving means for respectively and independently moving the first and second sides of the knife blade in a lateral direction.

14. The assembly of claim **13**, wherein the knife blade is mounted to a head assembly including a horizontal plate, and wherein the first and second lateral moving means each comprise:

(a) a sliding assembly slidably mounted on the plate and coupled to a side of the knife blade;

(b) a screw received in a threaded aperture in the sliding assembly; and

(c) a stepper motor servo coupled to rotate the screw to slide the sliding assembly along the plate.

15. The assembly of claim **14**, further comprising an arm pivotally coupled to the loin separation apparatus to pivot about a lateral axis, wherein the head assembly is pivotally mounted to the arm at a point forward of the knife blade.

16. The assembly of claim **15**, further comprising locking means for locking the head assembly in a fixed position with respect to the arm.

17. The assembly of claim **13**, further comprising a controller, coupled to the vertical moving means and the first and second lateral moving means, for controlling movement of the loin knife assembly to separate a loin portion from a side of meat as the side of meat is conveyed through the loin separation apparatus, the controller including:

(a) imaging means for generating a top plan image of the side of meat;

(b) image processing means for determining backbone and fat/lean separation lines from the top plan image;

(c) profile calculating means for generating profiles for the vertical moving means and the first and second lateral moving means to control the first side of the U-shaped knife blade to follow a preset distance from the backbone line, and the second side of the U-shaped knife blade to follow a preset distance from the fat/lean separation line; and

(d) means for actuating the vertical moving means and the first and second lateral moving means to follow their respective profiles.

18. A loin separation apparatus for separating a loin portion from a side of meat, the apparatus comprising:

(a) a loin knife assembly, including:

(1) a generally U-shaped knife blade having first and second sides;

(2) first and second lateral moving means for respectively moving the first and second sides of the U-shaped knife blade in a lateral direction; and

(3) vertical moving means for moving the U-shaped knife blade in a vertical direction;

(b) conveying means for conveying a side of meat past the loin knife assembly;

(c) an imaging camera positioned to generate a top plan image of the side of meat; and

(d) a controller, coupled to the loin knife assembly, the conveying means, and the imaging camera, the controller including:

(1) image processing means for determining backbone and fat/lean separation lines from the top plan image;

(2) profile calculating means for generating profiles for the vertical moving means and the first and second lateral moving means to control the first side of the U-shaped knife blade to follow a preset distance from the backbone line, and the second side of the U-shaped knife blade to follow a preset distance from the fat/lean separation line; and

(3) activating means for activating the vertical moving means, the first and second lateral moving means and the conveying means to follow the profiles generated by the profile calculating means.

19. The apparatus of claim **18**, wherein the loin knife assembly further includes a head assembly for supporting both sides of the knife blade, and wherein the first and second lateral moving means each comprise:

(a) a horizontal runner coupled to the head assembly;

(b) a sliding assembly slidably mounted on the runner and coupled to a side of the knife blade;

(c) a screw received in a threaded aperture in the sliding assembly; and

(d) a stepper motor servo coupled to rotate the screw to slide the sliding assembly along the runner.

20. The apparatus of claim **18**, wherein the loin knife assembly further includes:

(a) a head assembly for supporting both sides of the knife blade, the head assembly including a width adjustment means for varying the separation between the sides of the knife blade;

(b) an arm supporting the head assembly and pivotally mounted within the apparatus through a universal joint; and

(c) lateral adjustment means, coupled to the arm, for moving the head assembly in a lateral direction, wherein the first and second lateral moving means each actuate the width adjustment and the lateral adjustment means to position the first and second sides of the knife blade, respectively.

21. The apparatus of claim 18, wherein the image processing means further includes means for matching patterns in the top plan image, means for determining a plurality of points on each of the backbone and fat/lean separation lines, and means for determining a corner point representative of a leading end of the backbone line.

22. The apparatus of claim 21, further comprising a second imaging camera positioned to generate an end view image of the side of meat, and wherein the image processing means further includes means for determining an edge line from the top plan image, and means for determining an end fat/lean line and an end edge line from the end view image.

23. The apparatus of claim 22, wherein the profile calculating means includes means for determining starting data points for the profiles for the vertical moving means and the first and second lateral moving means.

24. The apparatus of claim 23, wherein the image processing means further includes means for locating a blade bone from the end view image, and wherein the means for determining starting data points includes means for modifying the starting data points responsive to the location of the blade bone.

25. The apparatus of claim 22, further comprising lighting means for projecting high intensity light onto the top surface of the side of meat at an angle which creates a shadow along the backbone thereof, and wherein the controller further includes activation means for, in a first time period, activating the first and second imaging cameras to respectively generate first top plan and end view images with the lighting means activated, and, in a second time period, activating the first and second imaging cameras to respectively generate second top plan and end view images with the lighting means deactivated.

26. The apparatus of claim 25, further comprising supplemental lighting means for illuminating the top and end surfaces of the side of meat, wherein the supplemental lighting means includes at least one mercury vapor lamp.

27. The apparatus of claim 22, wherein the image processing means further includes means for determining a slope change point representative of the point at which the slope of the backbone line changes, and wherein the profile calculating means generates the profiles of the vertical moving means and the first lateral moving means to respectively control the knife blade to dive and the first side of the knife blade to flare after the slope change point on the backbone line.

28. The apparatus of claim 22, further comprising a third imaging camera positioned to generate a fat/lean image of the fat/lean separation on the side of meat, wherein the image processing means includes means for periodically determining the fat/lean separation on the side of meat at a fixed distance from the loin knife assembly, and wherein the controller further includes means for periodically modifying the profile of the second lateral moving means when the profile departs from a desired profile calculated from the fat/lean image.

29. The apparatus of claim 18, further comprising a scribe saw assembly for scribing ribs on the side of meat, the scribe saw assembly including a rotating scribe saw blade, first scribe saw moving means for moving the scribe saw blade in a lateral direction, and second scribe saw moving means for moving the scribe saw blade in a vertical direction, and wherein the profile calculating means includes means for calculating a profile for the first scribe saw moving means to control the scribe saw blade to scribe the ribs a preset distance from the backbone line determined by the image processing means.

30. The apparatus of claim 29, wherein the image processing means further includes means for determining a slope change point representative of the point at which the slope of the backbone line changes, and wherein the profile calculating means includes means for calculating a profile for the second scribe saw moving means to raise the scribe saw blade at a fixed distance from the slope change point.

31. The apparatus of claim 18, wherein the profile calculating means generates profiles by modifying standard profiles in response to dimensional aspects of the side of meat determined by the image processing means.

32. The apparatus of claim 31, wherein the profile calculating means includes means for selecting standard profiles from a plurality of separate profiles based upon dimensional aspects of the side of meat determined by the image processing means.

33. In a loin separation apparatus of the type including (1) a loin knife assembly having a generally U-shaped knife blade, first and second lateral moving means for respectively moving first and second sides of the knife blade in a lateral direction, and a vertical moving means for moving the U-shaped knife blade in a vertical direction, and (2) conveying means for conveying a side of meat past the loin knife assembly, a control system comprising:

(a) an imaging system, the imaging system including means for generating a top plan image of the side of meat and means for processing the top plan image to locate a backbone line and a fat/lean separation line on the side of meat;

(b) a host controller, coupled to the imaging system and the motion control system, the host controller including profile calculating means for generating profiles for the conveying means, the vertical moving means and the first and second lateral moving means such that the first side of the U-shaped knife blade follows a preset distance from the backbone line and the second side of the U-shaped knife blade follows a preset distance from the fat/lean separation line as the conveying means conveys the side of meat past the loin knife assembly; and

(c) a motion control system for controlling the first and second lateral moving means, the vertical moving means and the conveying means to each follow the profiles generated by the host controller.

34. A method of separating a loin portion from a side of meat in a loin separation apparatus of the type including a loin knife assembly having a generally U-shaped knife blade, first and second lateral moving means for respectively moving first and second sides of the knife blade in a lateral direction, and a vertical moving means for moving the U-shaped knife blade in a vertical direction, the method comprising the steps of:

(a) generating a top plan image of a side of meat;

(b) determining the location of a backbone line and a fat/lean separation line on the side of meat from the top plan image;

(c) generating profiles for the vertical moving means and the first and second lateral moving means to control the first side of the U-shaped knife blade to follow a preset distance from the backbone line, and the second side of the U-shaped knife blade to follow a preset distance from the fat/lean separation line; and

(d) activating the vertical moving means, the first and second lateral moving means and the conveying means to follow the generated profiles.

35. The method of claim 34, wherein the determining step includes the steps of matching patterns in the top plan image,

and determining a plurality of points on each of the backbone and fat/lean separation lines.

36. The method of claim **35**, wherein the image generating step further includes the step of generating an end view image of the side of meat.

37. The method of claim **36**, wherein the profile generating step includes the step of determining starting data points for the profiles for the vertical moving means and the first and second lateral moving means from the top and end view images.

38. The method of claim **37**, wherein the determining step further includes the steps of locating a blade bone from the end view image, and modifying the starting data points responsive to the location of the blade bone.

39. The method of claim **36**, wherein the image generating means further includes the step of generating shadowed top plan and end view images while projecting high intensity light onto the top surface of the side of meat at an angle which creates a shadow along the backbone thereof.

40. The method of claim **39**, wherein the image generating step further includes the step of illuminating the top and end surfaces of the side of meat with at least one mercury vapor lamp.

41. The method of claim **36**, wherein the determining step further includes the step of determining a slope change point representative of the point at which the slope of the backbone line changes, and wherein the profile generating step generates the profiles of the vertical moving means and the first lateral moving means to respectively control the knife blade to dive and the first side of the knife blade to flare after the slope change point on the backbone line.

42. The method of claim **36**, wherein the activating step includes the step of periodically updating the generated profiles during the loin separation operation, which includes the steps of generating a fat/lean image of the fat/lean separation line on the side of meat, determining the location of the fat/lean separation line from the fat/lean image, determining a desired profile datapoint from the fat/lean image, and modifying the profile of the second lateral moving means when a current datapoint in the profile departs from the desired profile datapoint.

43. The method of claim **34**, wherein the loin separation apparatus includes a scribe saw assembly which includes a scribe saw blade, first scribe saw moving means for moving the scribe saw blade in a lateral direction, and second scribe saw moving means for moving the scribe saw blade in a vertical direction, and wherein the profile generating step includes the step of calculating a profile for the first scribe saw moving means to control the scribe saw blade to scribe the ribs a preset distance from the backbone line.

44. The method of claim **43**, wherein the determining step further includes the step of determining a slope change point representative of the point at which the slope of the backbone line changes, and wherein the profile generating step includes the step of calculating a profile for the second scribe saw moving means to raise the scribe saw blade at a fixed distance from the slope change point.

45. The method of claim **34**, wherein the first and second lateral moving means move the sides of the knife blade independently.

46. The method of claim **34**, wherein the first and second lateral moving means each activate lateral adjustment means for moving the knife blade in a lateral direction and width adjustment means for varying the separation between the sides of the knife blade.

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