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The Design, Construction and Development of a Prototype Machine for Processing Spiny Dogfish Shark

MIT Sea Grant
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ABSTRACT

A project was undertaken to design, construct and develop an advanced prototype machine for processing spiny dogfish shark. The scheme used successfully followed the steps done in the manual processing of dogfish. The machine was constructed primarily of aluminum, stainless steel and plastic to permit easy maintenance and cleanliness.

The processing steps accomplished by independent components were the removal from a whole fish of the tail, dorsal fins, belly-flap and back skin. Actuation of the various devices was done pneumatically. Where cutting was required, four-inch-diameter, peripherally-notched rotary blades, driven by air motors, were used. Control of the machine was accomplished with a solid-state, programmable controller.

The time required to process one fish through the machine was 12 seconds. Some simple developments in future machines could considerably reduce this period. By comparison, an experienced hand laborer takes approximately 30 seconds to perform the same functions.

Acknowledgments

This report describes results of research done as a part of the MIT Sea Grant College Program with support from the Office of Sea Grant in the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, through grant number 04-7-158-44079, the National Marine Fisheries Service, U.S. Department of Commerce, and the Massachusetts Institute of Technology.

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Related Reports

Videotape - REPORT ON THE SPINY DOGFISH SKINNING MACHINE. Documents operation of machine. Approx. 10 minutes. Available through the MIT Sea Grant Program or the MIT Educational Video Resources Office.

Menjivar, Juan A., Rong Chen, and ChoKyun Rha. INVESTIGATION OF MECHANICAL PROPERTIES OF RAW FLESH AND SKIN OF SPINY DOGFISH (SQUALUS ACANTHIAS). MITSG 79-30J. 10 pp. $1.00.

New England Marine Advisory Service, publisher. SEAFOOD SOURCEBOOK: A CONSUMER'S GUIDE TO INFORMATION ON FOOD FROM OUR OCEANS AND LAKES. 48 pp. $1.00.

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Chapter I

Introduction

The Spiny Dogfish Shark (Squalus Acanthias) is a small gray or brownish shark that inhabits most of the temperate oceans of the world. It is distinguished by a large sharp spine or spike lying in front of each of its two dorsal fins. (Ref. 1) The longer back spine is used by the dogfish for defense by curling around in a bow and striking. Adult females are larger than males with the females measuring 2 1/2 - 4 ft. in length, weighing 7 - 10 pounds while the males vary from 2 - 3 feet in length and 5 - 7 pounds in weight. The dogfish has a slender body with a flattened head and snout, and a cross-section along the rest of its length that is essentially circular. Two of the spiny dogfish's most notable characteristics are its abundance and bad personality.

Dogfish feed on virtually anything and everything they can, including cod, haddock and flounder.

> Voracious almost beyond belief, the dogfish entirely deserves its bad reputation. Not only does it harry and drive off mackerel, herring, and even fish as large as cod and haddock, but it destroys vast numbers of them. Again and again fishermen have described packs of dogs dashing among schools of mackerel, and even attacking them within the seines, biting through the net, and releasing such of the catch as escapes them. (Ref. 2)

Damage to gear and loss of fish due to the spiny dogfish costs U.S. fishermen millions of dollars a year; unfortunately this destructive shark is the most prolific one in the sea. Spiny dogfish can sometimes be caught as fast as they can be hauled in: "a long line with 1,500 hooks, has been known to bring in a dogfish on nearly every hook." (Ref. 2) In one season alone, 27,000,000 spiny dogfish were taken off the coast of Massachusetts. (Ref. 2) Furthermore, a campaign launched in 1938 to reduce the spiny dogfish population in Placentia Bay, near St. John's, Newfoundland, succeeded in landing 10,391,000 pounds of dogfish, or two to three million of them. A government report on the campaign claimed that the catching of these millions of dogfish did not result in "any apparent diminution of the supply." (Ref. 3)

Ironically, U.S. fishermen have almost no use for this abundant fish and either throw back those they catch accidentally or maim and mutilate them for vengeance. The small percentage of dogfish kept are brought to shore, processed and exported to Europe where a market currently exists. Almost all of the processing of dogfish in this country is done manually with the only mechanization being the use of conventional filleting machines to skin the belly flaps. Unfortunately, U.S. wage rates make the difficult manual process marginally economic, pointing to a need for increased mechanization.

There have been many efforts to develop automatic or semiautomatic dogfish skinning machinery here and abroad, but none have so far met with success. Some have involved an oscillating or revolving knife which removed a layer of skin as the fish was pressed against a reference surface.

The irregularities of the skin resulted in either the removal of too much flesh or the leaving of "islands" of skin, which had to be removed by hand labor.

Other efforts have involved some form of heat treatment. In one method, the fish was pressed against a metal surface which was maintained at a temperature low enough for the skin to freeze to it. The skin was then torn from the fish by any of a number of different mechanisms. This process left a disfigured carcase requiring further wasteful trimming. In other approaches, the skin was softened by dipping the fish in hot water, hot oil, or by treatment with hot steam. The partial cooking rendered the skin more manageable, so that it could be slit or cut more easily and removed. One proposal was made, but apparently not followed up, for the skin to be inflated with air after being softened by partial cooking; this would, it was claimed, separate the skin from the flesh and facilitate removal by mechanical knives.

Clearly, there existed a need for research, rather than continued trial-and-error development. Through funding from the Massachusetts Institute of Technology Sea Grant Program and the National Marine Fisheries Service, research was done on the mechanical properties of dogfish skin and a laboratory proof-of-concept skinning machine was constructed. This machine, designed and built by M.I.T. graduate student, Michael Atlas, used a horizontal linear conveyor to pull the fish past various operations. The belly-flap cut was made by fixed six-inch long blades that were allowed vertical movement to permit them to "float" up to the fish's backbone as the belly-flap cut was being made. It was found that, rather than rise to the level of the backbone, the belly-flap knives pulled the fish down to them. To grip and pull the skin from the back of the fish, a pointed knife was designed to be driven into the back of the fish's head and then closed against a metal bar. The skin was then held by the pinching action between the knife and the bar, and as the fish was pulled past, the skin should have separated from the back meat. Unfortunately, the pointed knife as well as straight and serrated blades were unable to pierce the shark's tough skin. An attempt was made to overcome this problem by replacing the single fixed knife with a pair of opposed pincer blades. This method also failed to cut the skin. When the cut was made manually, the knife and gripper bar were able to pinch the skin at the cut. Once gripped, the skin separated from the back with some tearing of the flesh. (Ref. 4)

From the encouraging results obtained by Atlas, additional funding was provided by the same sponsors to design, build and test an advanced prototype dogfish processing machine. This report describes the work done on this prototype. The goal was to produce a machine which would take spiny dogfish in the round and remove the tail, dorsal fins, belly flap, and back skin. This would leave a skinned back section attached at the head requiring only a manual head cut and separation of the back meat from the gurry to complete processing. In addition, the feed rate of fish through the machine would be sufficiently high to make a production version economically attractive to U.S. fish processors.

In order to avoid the introduction of a new product into the existing dogfish market and to take advantage of the wealth of experience and knowledge extant in the hand processing of dogfish, it was decided to mechanically duplicate this process wherever possible.

Figure 1 shows the cuts made in the hand process. The numbered steps illustrated in Figure 1 are

1. The tail is cut off.
2. The fish is hooked through the underside of the jaw.
3. The dorsal fins are severed flush with the back.
4. The belly flap is separated from the back section.
5. A small cut or nick is made in the skin behind the head.
6. The skin is gripped at the nick and pulled towards the tail.
7. The head is cut off.

To accomplish steps one through six mechanically, several independent components were developed. Each component, its design and operation, is described in the following pages.

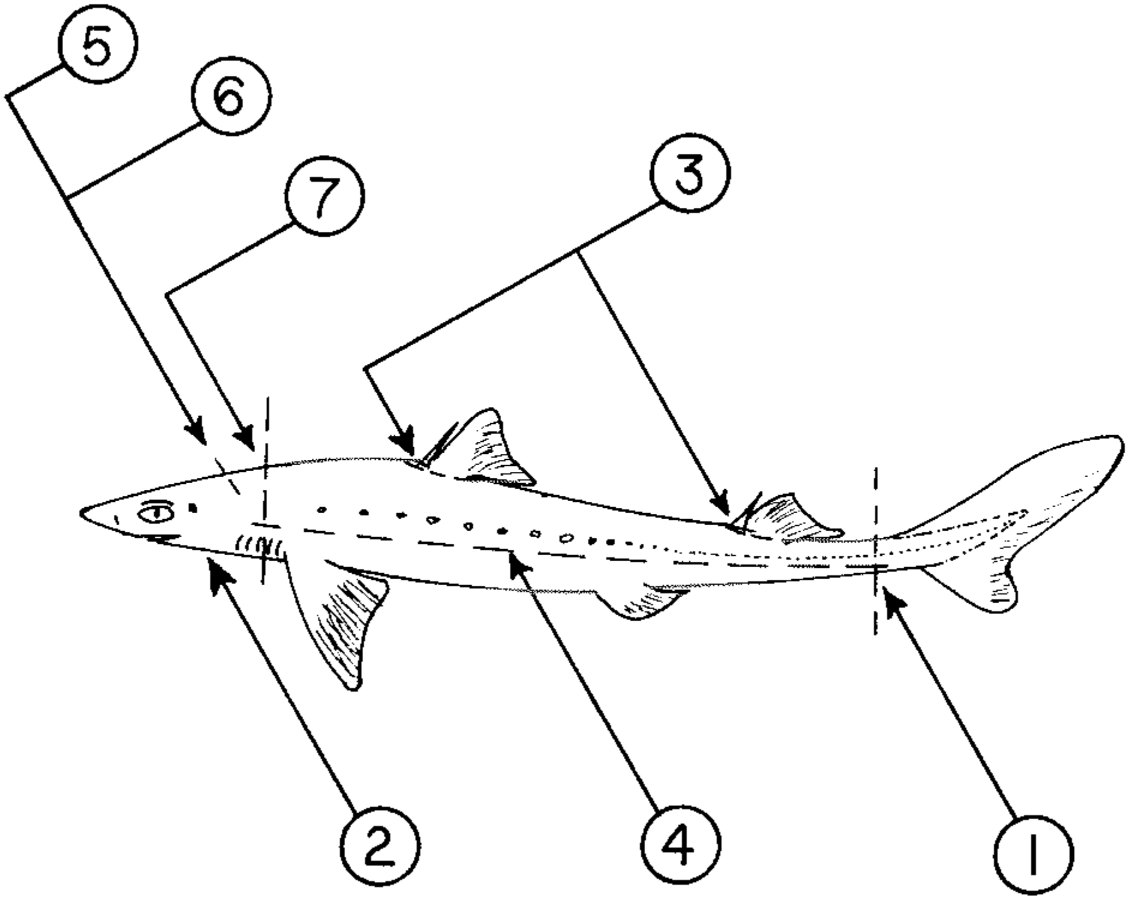

FIGURE 1   HAND PROCESSING STEPS

Chapter II

Frame and Power-Train

In determining the basic configuration of the machine, several factors were considered. To keep the overall size of the machine to a minimum it was felt that a linear conveyor for the fish should be avoided. The estimated length of track required was nine feet, meaning that over eighteen feet of conveyor would have been needed. In addition, because the machine would be used in connection with the food industry, it was mandatory that sanitation be easily maintained. This would have been difficult if some form of chain conveyor had been used due to the multitude of crevices in a chain in which bacteria could multiply and resist removal. Therefore, to achieve a compact, simple and clean method of conveying fish through the machine, a wheel was chosen. A diameter of 32 inches gave a perimeter of 8.5 feet, which provided sufficient space for the anticipated machine functions. By covering the perimeter of the wheel with a one-quarter-inch-thick by six-inch-wide strip of polyethylene, an easily cleaned, durable contact surface was obtained.

Drive to the wheel was done through its shaft by means of a one-h.p., 230-VAC, three-phase electric motor. The motor speed was reduced by pulley before going into a pneumatic clutch/brake provided for starting and stopping the wheel. Coming out of the clutch/brake, the speed was decreased further by a 60:1 right-angle worm-gear reducer to give a wheel speed of approximately 10 rpm. From data on the mechanical properties of dogfish skin obtained by Menjivar, Chen and Rha, the force necessary to separate the skin from the meat was calculated to be sixty pounds for the largest anticipated fish. (Ref. 5) This force, exerted at a moment arm of 21 inches and a maximum anticipated speed of 30 rpm, produced a maximum horsepower requirement for the motor of 0.60 h.p. To facilitate easy disassembly and shipment of the machine, the motor, clutch/brake and speed reducer were mounted on a separate base from the rest of the machine. This base was mounted to the machine through four bolts, and the power was transmitted from the output shaft of the speed reducer to the wheel shaft by a flexible coupling. Figure 2 shows the power-train assembly mounted on its base. The four tubular uprights were used for mounting to the machine.

The frame of the machine was constructed of two-inch by two-inch, one-eighth-inch wall 6063 aluminum tubing. Frame dimensions were five-feet high by five-feet wide by two-feet thick, excluding the infeed table and power-train base. The wheel was mounted inside the frame with its shaft horizontal. A set of mounting rails for the different machine components were formed from the two-inch tubing and mounted in a parallel arc on either side of the wheel.

For a period of time the machine was oriented so that the wheel shaft was vertical because it was felt that as

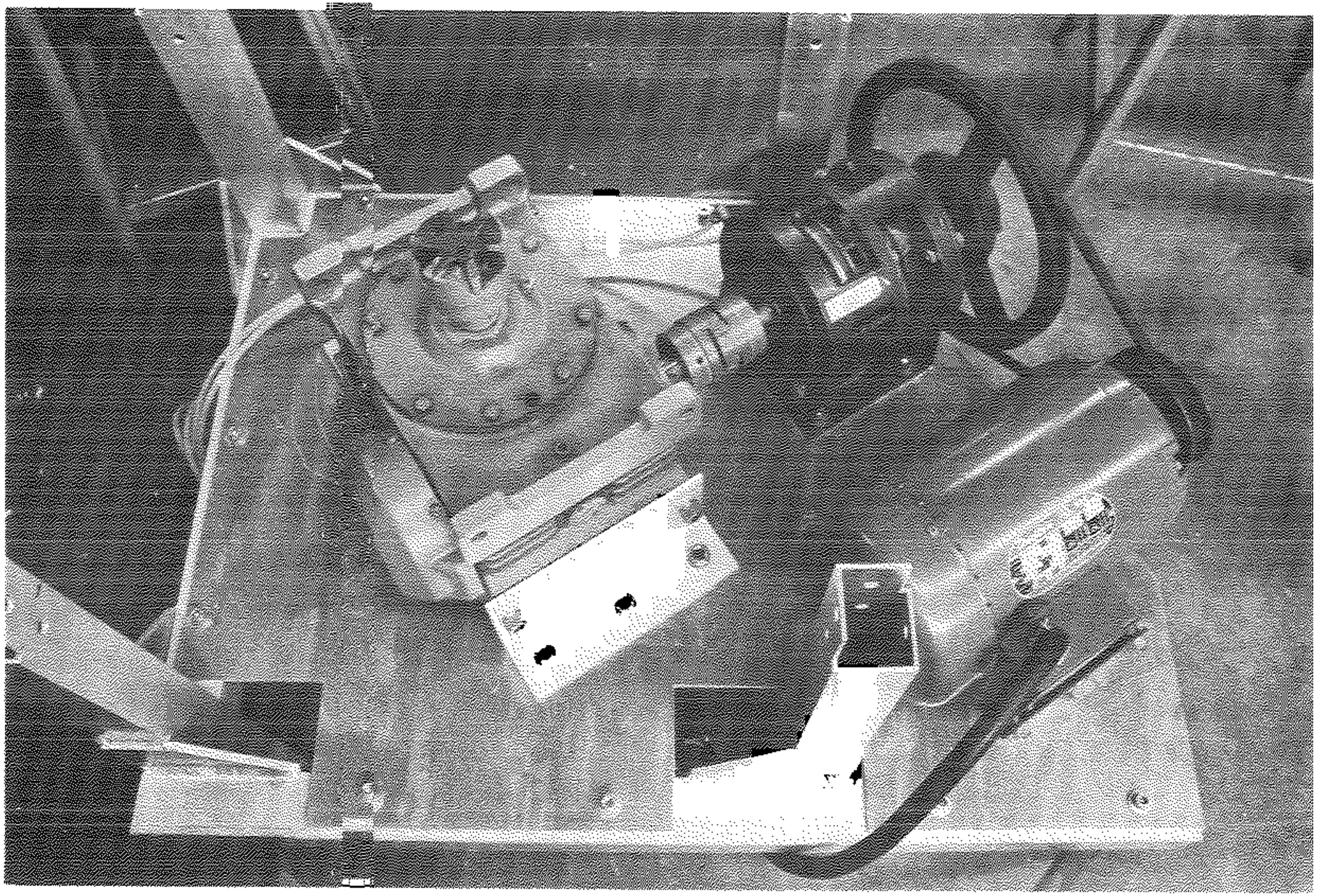

FIGURE 2 POWER-TRAIN AND BASE

parts of the fish were removed they would fall into bins placed under the machine. This belief was based on the assumption that the fish could readily be held up as well as against the wheel, and that once removed, a fin or tail would indeed fall. However, tests of the machine in its almost completed form showed that the problem of holding the fish up as it moved through all the stages of machine operation was much more formidable than originally anticipated. Also, the tail cut was being made at the end of the infeed table, rather than on the wheel, and the fins, cut off while the fish was on the wheel, were being flung into the air rather than immediately falling to the floor. All this pointed to the fact that having the wheel rotate about a vertical axis was not a satisfactory orientation. After consideration, it was decided to try operating the machine with the axis of wheel rotation horizontal. Fortunately, almost all of the components on the machine were insensitive to orientation, making it a relatively minor operation to tip the machine onto one side.

Overall performance of the machine in its new horizontal axis orientation was considerably improved. The problem of the fish not staying positioned with respect to the center of the wheel rim was eliminated along with any of the gravity effects present in some operations. A few small modifications and some "fine tuning" were all that was required to produce fully automatic operation. Figures 3 and 4 show a sketch and picture of the overall machine.

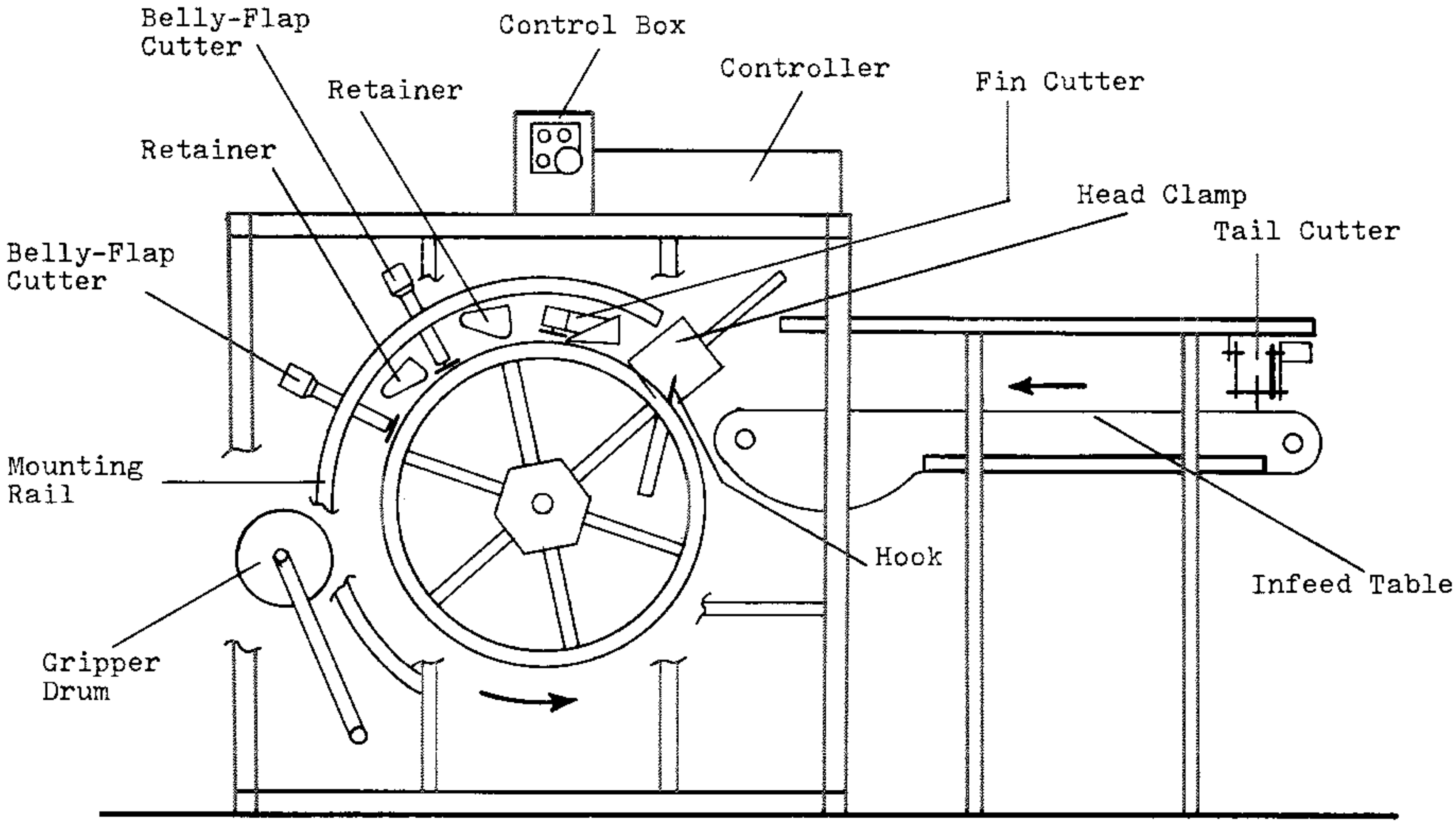

FIGURE 3 OVERALL MACHINE LAYOUT

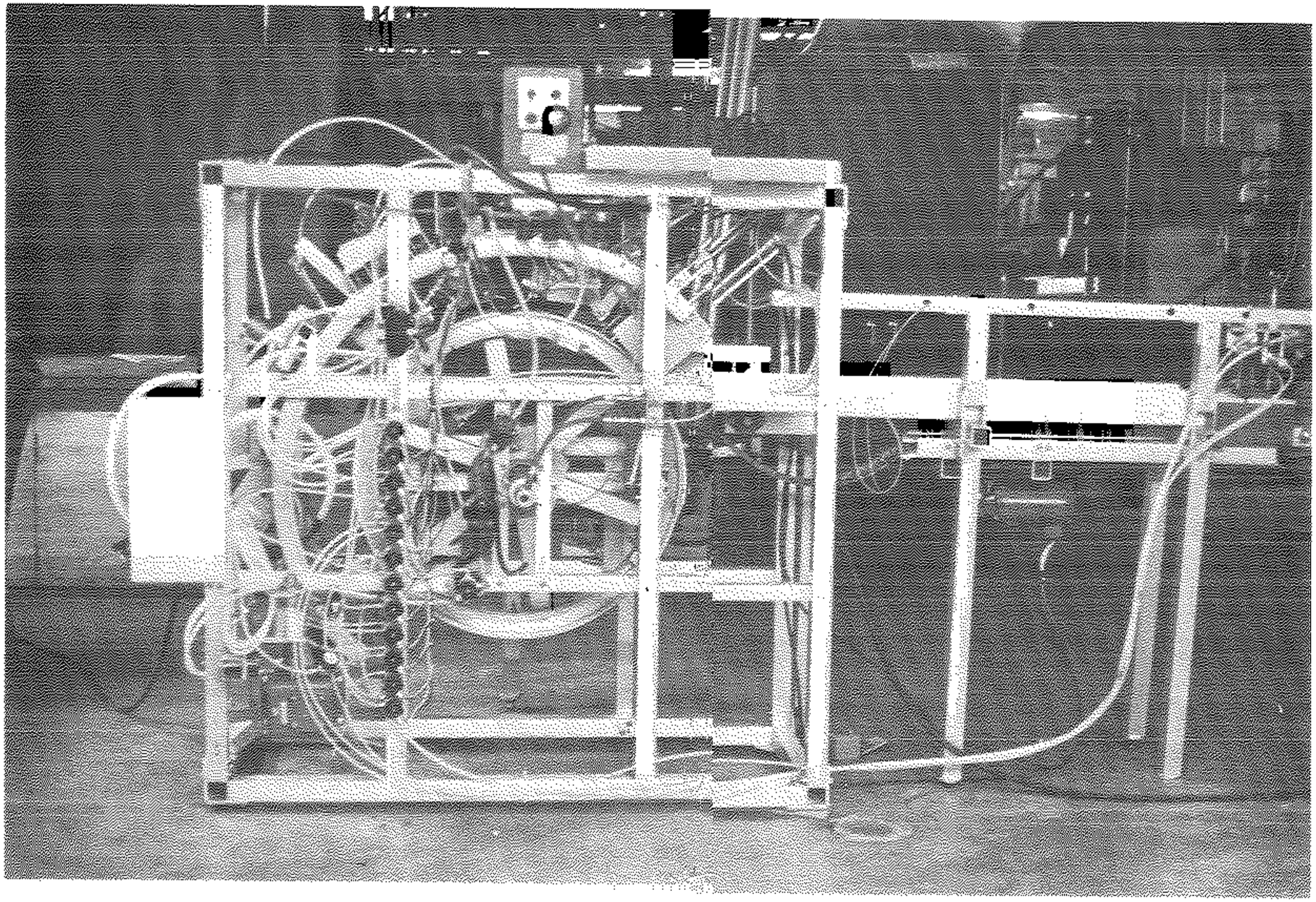

FIGURE 4 COMPLETE MACHINE

It is with respect to this horizontal wheel-shaft orientation that the following description of the machine elements takes place.

Chapter III

Tail Cutter and Infeed Table

In the processing of a spiny dogfish shark, one of the first operations performed is the separation of the tail from the rest of the fish. When done manually, the tail is grasped firmly in one hand while the other is used to cut the tail with a sharp knife. To accomplish this mechanically, the tail cutter was designed to clamp the fish just ahead of the tail and then to use a notched rotary blade to make the cut.

The overall design utilized a four-inch-diameter notched rotary blade on a parallel-shaft arrangement driven through a toothed belt by a 1/2 h.p. air motor. The parallel-shaft assembly pivoted on ball-bearings about the shaft of the air motor, thereby maintaining constant center distance and belt tension between the two shafts. By pivoting the blade, the design of a device to predictably clamp the tail was simplified: All that was required was a slot for the tail to be placed in and an arm to securely clamp the tail. Both the tail clamp and blade pivot were driven by double-acting air cylinders. Figure 5 shows the tail cutter assembly with the notched rotary-blade retracted and the white tail-clamp midway through its range of motion. The entire tail-cutter unit was mounted at the end of the infeed table.

The infeed table was used to convey the fish from the

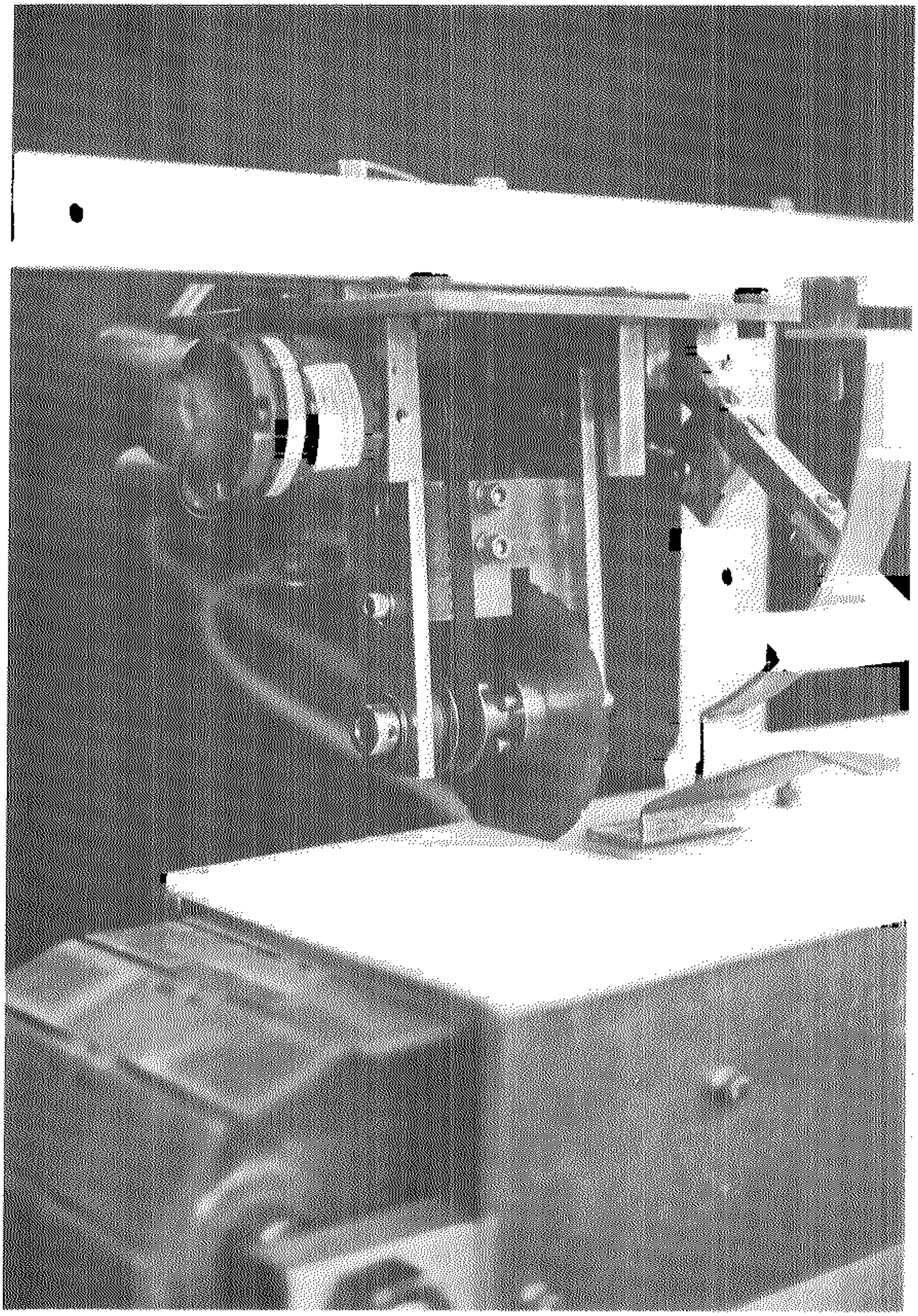

FIGURE 5 TAIL-CUTTER

tail cutter into the machine. This was achieved by using a six-inch-wide PVC table-top chain driven by a 1/6 h.p. electric motor. This motor was geared down to produce a table-top chain linear speed of approximately 110 inch/sec. The surface of the infeed table was approximately 42-inches high and horizontal, permitting the machine operator to place the fish belly down on the table-top chain.

Once the fish was on the infeed table with its tail correctly positioned in the tail cutter, the operator stepped on a foot switch that began the tail-cutter sequence. Immediately, the clamp came down onto the tail and the blade began rotating. After the foot switch had been held for one second the blade pivoted out, cutting the tail. Upon reaching its maximum extended position, sufficient to cut the largest tail, the pivoting blade assembly closed a micro-switch. This switch signal caused the blade to return to its retracted position, the air motor to stop, the clamp to retract, and the infeed-table motor to start. From this point on, the machine operation was fully automatic.

Chapter IV

Hook and Head-Clamp

In the design of an automated machine to process spiny dogfish, it was necessary to develop some means of firmly securing the fish to the wheel at the desired time and releasing it in a reverse fashion. This was done by mounting a double-acting air-cylinder in the rim of the wheel so that the air-cylinder piston-rod formed a 45° angle with a tangent to the wheel. Air supply to the air-cylinder was fed through the wheel shaft via a dual-passage-rotary-union. The end of the piston-rod was sharpened into a point, and served to impale the fish by coming from its retracted position inside the perimeter of the wheel out into the throat region of the fish. Because the air-cylinder was mounted 45° to the tangent, the piston-rod provided a tangential force to the fish necessary to propel it through the machine. The piston-rod is generally referred to as the hook; although in actuality, it was not a curved hook but a straight spike.

When impaling the fish with the hook, the piston-rod exerted a force of almost 200 lbs. against the head of the fish. Therefore, it was essential to exert a reaction force on the head to enable the hook to pierce the tough skin. A clamp to hold the fish's head solidly against the wheel was designed to provide this force. The head-clamp assembly was comprised of the clamp, a nose-stop to accurately position the head, and a nose switch, mounted on the nose-stop, to sense the presence of the fish's nose. The entire assembly moved in and out parallel to the same tangent mentioned above by means of parallel arm linkage driven by a double-acting air-cylinder. The size of this air-cylinder was sufficient to provide the required reaction force against the hook. The nose-stop, also driven by a double-acting air-cylinder, slid in polyethylene slots mounted to the back side of the head clamp. Figure 6 shows the hook extending out of the wheel with the head-clamp retracted. The extended nose-stop is visible directly in front of the hook and on the nose-stop can be seen the hinged plate for the nose switch.

The sequence used to attach the fish to the wheel was as follows: Initially the nose-stop was extended with the head-clamp retracted and the infeed table conveyor running, bringing the fish from the tail cutter to the head clamp. If the wheel was in its correct initial position when the shark's nose closed the nose-stop switch, the head clamp came in, the nose-stop was retracted and the infeed conveyor stopped. If the wheel was not in its correct position, the head clamp waited until the wheel returned to its initial position. After a short time delay to allow the clamp to securely grip the fish, the hook was driven into the underside of the shark's head. Another small time delay (approximately 0.3 seconds) allowed the hook to completely penetrate the fish before the head clamp was retracted and the wheel, with the fish firmly attached, was started.

Chapter V

Fin Cutter

The spiny dogfish shark has two dorsal fins, each of which is directly preceded by a bony spine. From this distinguishing feature, the spiny dogfish derives its name. The spine is approximately one-inch-long and 3/16 of an inch in diameter and has a root of bone-like cartilage that extends to the backbone. The fin itself is soft and flexible and compared to the spine presents little resistance to a blade. When processing a dogfish it is necessary to remove both of the spine-fin pairs in order to have the skin pull off cleanly. For simplicity the spine-fin pair is referred to as the fin.

In the hand process each fin is removed by grasping it with one hand and sawing with a knife held flat against the back surface. To determine a suitable method for mechanically removing the fins several concepts were tried. One method investigated by M.I.T. undergraduate, A. David Boccuti, employed a set of oscillating, serrated knives. The knives were guided by a digital controller so that they initially entered the fish, as it moved past them, in front of the fin and perpendicular to the back. Once into the fish, the knife-set was rotated so that it was parallel to the back. After cutting underneath and past the fin, the knife-set was rotated out of the fish, thus removing the fin. Unfortunately, the controller was susceptible to disturbances from electrical AC noise and a satisfactory test of the system was never completed. (Ref. 6)

Tests using a notched rotary blade and air-motor assembly to cut the fin off flush with the back revealed that the resulting cut was neater than a hand-held knife cut. In addition, the skin separated from the meat around this test cut without difficulty. Using a single rotary blade required the presence of some form of guide to direct the fin against the blade. This guide would also provide the necessary reaction force against the fin to prevent it from deflecting away from the blade rather than be cut off by it.

The fin cutter developed for automatically removing the fins from the fish took advantage of the concept of having one rotary blade positioned just above the level of the back and a guide to direct the fin against the blade. The guide and motor mount were an integral unit in order to accurately control the height of the blade tip from the end of the guide. An end view of the guide shows that it formed a triangular shape with the surface of the wheel. This shape was essentially identical to the cross-section of a fish while on the wheel. The slot in the top of the guide was to position the fin and provide the required reaction force. Because the fish diameter changed with length the entire guide/motor assembly had to pivot. The end of the guide above which the blade was mounted would then follow the fish's back surface as it tapered towards the tail. A double-acting air cylinder was used to provide the pivot force. The supply pressure to the air cylinder was regulated in order to adjust the pivot force because this force was also what caused the fin to protrude up through the guide slot. By forcing the fin into the slot before it encountered the blade, the depth of the ensuing cut would be slightly below the level of the back and the skin would separate cleanly rather than tear due to any remnant of the fin. Figure 7 shows the fin-cutter assembly with the guide slot for the fin directly beneath the blade tip.

In operation, the fin-cutter assembly was initially in its retracted position to allow the fish's head, into which the hook was driven, to pass by. This was done to prevent any possibility of the hook accidentally running into the fin-cutter blade, because occasionally the hook would go through the head. Before the wheel began rotating, the air motor driving the blade was started to allow it sufficient time to come up to full speed. After the hook had passed, the assembly pivoted down onto the fish's back and the fins were directed into the guide slot. As each fin met the rotary blade it was cut off by the sawing action produced at the blade's peripheral notching. The assembly continued to ride along the fish's back, and once the tail had passed, the assembly simply pivoted until the tip of the guide was on the surface of the wheel.

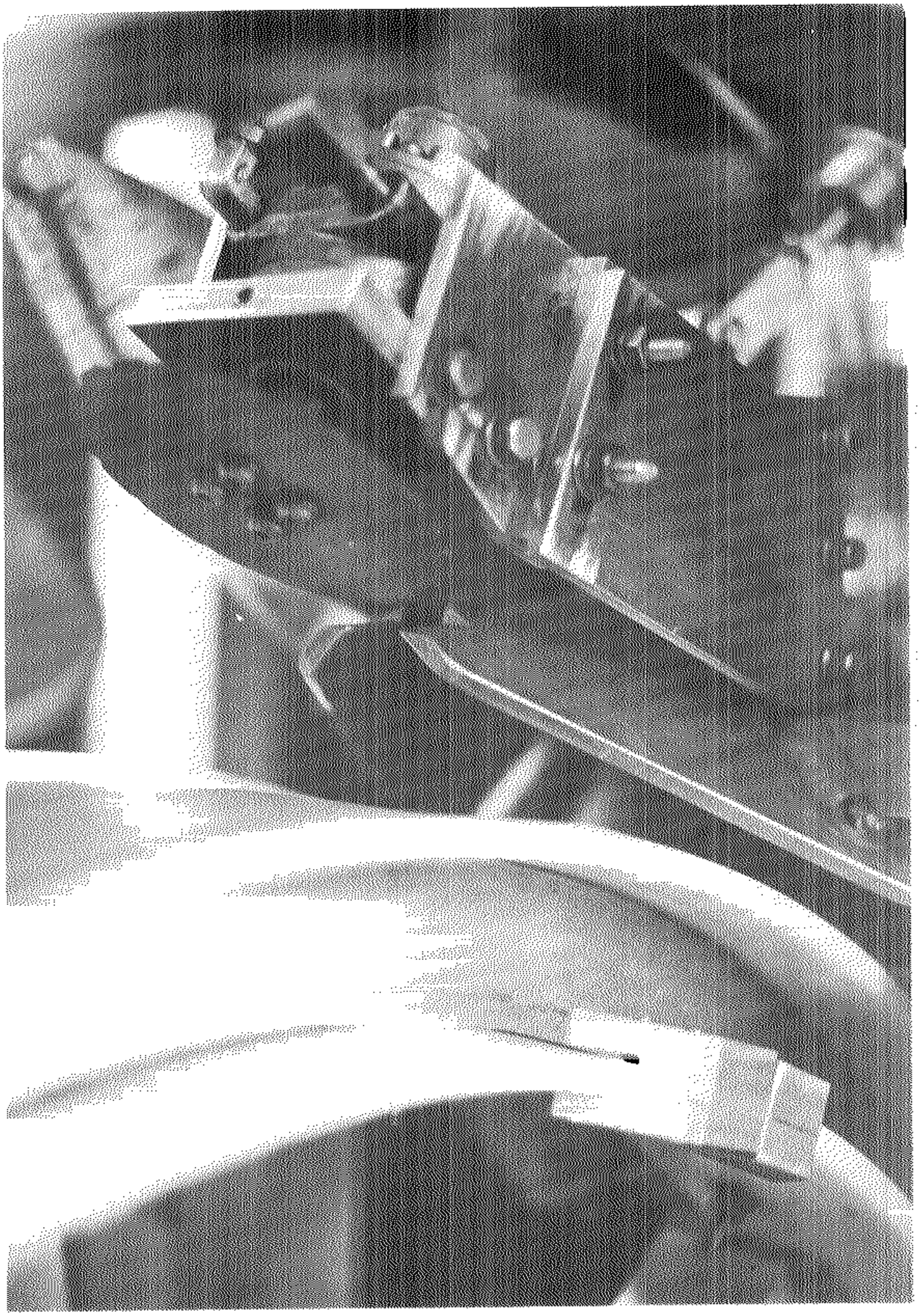

FIGURE 7 FIN-CUTTER

Chapter VI

Belly-Flap Cutters

In hand processing, to make the belly-flap cut, a knife is inserted through the belly cavity behind the gill slits and parallel to the belly. This knife is then drawn towards the tail of the fish under the backbone cartilage, thereby separating the belly-flap portion of the fish and the gurry from the back meat. The belly-flap is subsequently separated from the fish at the head, skinned, cleaned and exported to Europe where it is prized as a delicacy known to Germans as schiller-lacken.

The difficulty with adapting this concept to automated machinery was that the use of a conventional knife blade involved frequent sharpening of the cutting edge. A method common to most fish machinery that enabled less frequent sharpening was the use of motor-driven notched, rotary blades. Employment of 1/8-inch-deep notches along the perimeter of four-inch-diameter rotary blades allowed the cutting action of the blade to be supplemented by a sawing action at the notches.

When using the rotary blades it was necessary to have one on each side of the fish, making cuts just into the belly cavity. It was not feasible to have the knives "float" below the backbone cartilage as is done by the hand-skinners with a conventional blade. In hand-skinning this action separates the gurry from the back meat, terminates the cut at the vent, and makes the cut at the optimum boundary between the belly-flap and the back meat. All these effects are desirable. Using high-speed rotary blades, the third effect, cutting along the optimum path, was accomplished by forcing the belly against the surface of the wheel. The belly-flap cuts were then made along the length of the fish with a rotary-blade-equipped belly-flap cutter assembly pivoting above the fish at a fixed distance from the wheel.

A method was developed to hold the fish against the wheel as it moved through the machine by using shaped pressure plates. The approximate diameter of a fish varies from 6 inches to 1 inch along its length and so a necessary feature of any device to hold the fish against the wheel ("retainers," as they came to be known) was that it be able to account for constantly changing fish diameter. This was accomplished by forming a 90° bend in a 1/4-inch-thick plate of aluminum and then trimming the sides, so that at one end the opening created by the bend and the trimmed sides was big enough to let the maximum cross-section of the largest fish pass through. At the other end the height of the trimmed sides tapered so that only the tail of a fish could pass through. At the large end of the retainer a pivot was provided, while at the small end an air cylinder, connected through a regulator to the main air supply, provided the force to pivot the retainer in towards the wheel and, when a fish was passing through the retainer, press the fish against the wheel. Figure 8 shows a retainer in its unpressurized position. The pivot can be seen directly above the large end.

Immediately after each of the two retainers was a belly-flap cutter assembly. Each assembly consisted of an air motor, extension shaft and tube, pivot mount, blade hub, depth-of-cut cam, and notched rotary blade. The assemblies were mounted so that the tips of the blades came almost to the plane passing through the center of the wheel rim. Figure 9 shows a belly-flap cutter assembly. The depth-of-cut cam can be seen just above the left tip of the rotary blade. As a fish approached the cutters, cams, mounted on the rim of the wheel, shown clearly in Figure 6, pushed the cutters away from the fish until they were past the pectoral fins. The cutters were then allowed to pivot freely towards the fish. Springs pulled each assembly against the side of the fish with the depth-of-cut cams providing the opposing force. As the fish diameter tapered with length, the depth cams continued to follow the side of the fish.

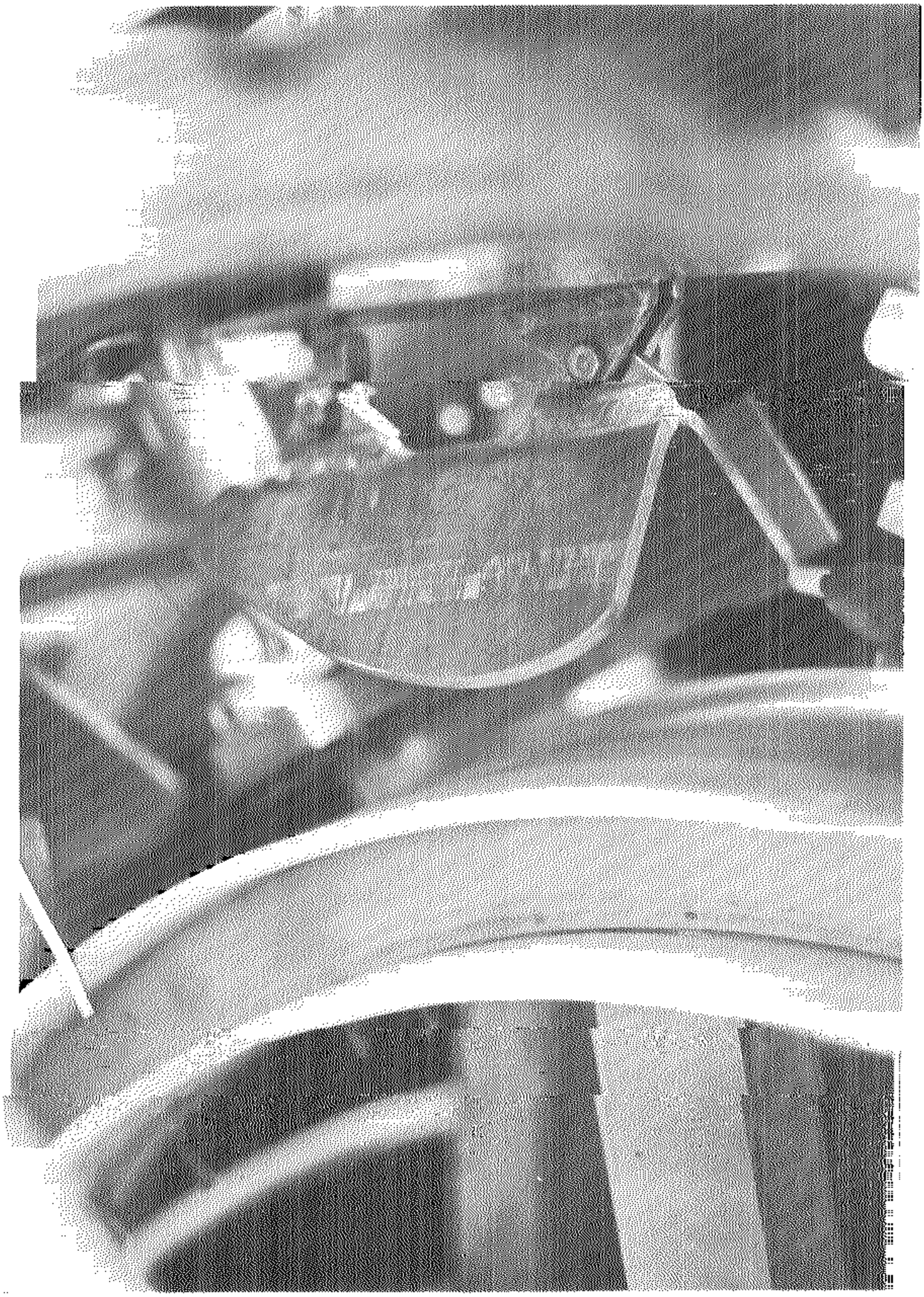

FIGURE 8 RETAINER

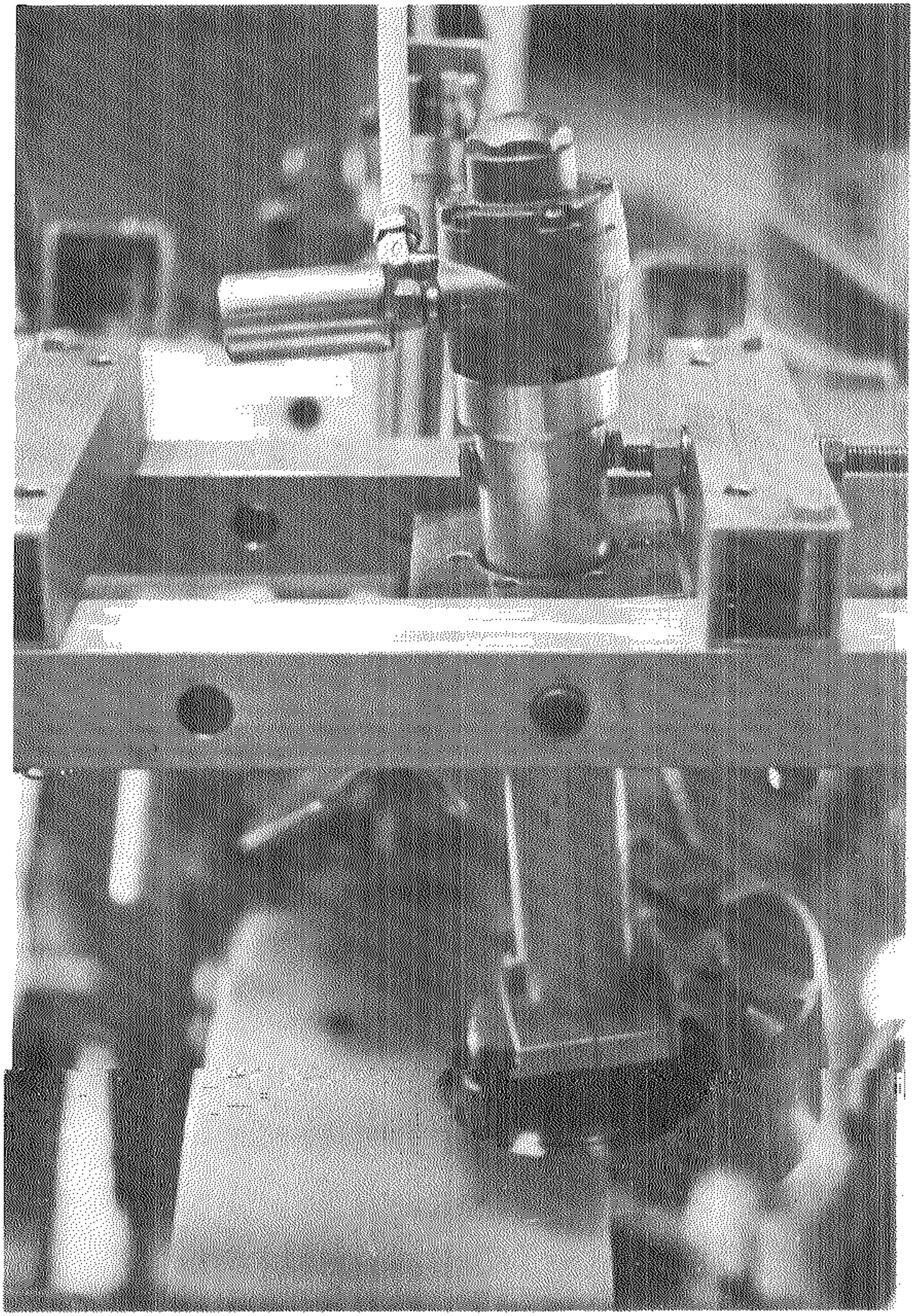

FIGURE 9 BELLY-FLAP CUTTER

Chapter VII

Gripper

After the tail, dorsal-fin, and belly-flap cuts had been made, the principal remaining operation to be performed was the removal of the skin from the back meat. In the hand operation a small cut or nick (approximately 1/4-inch deep and 1-inch long) is made in the back of the fish behind the head. The knife edge is placed in this cut with the blade angled approximately 45° to the back. The thumbs are then used to pinch the skin on the tail side of the cut against the blade and the knife is pulled with a steady motion towards the tail. The skin tears from the nick down to the belly-flap cut on each side and then separates from the meat.

To accomplish this process mechanically, a device, collectively known as "the gripper," was developed to make the nick, grip the skin at the nick and then pull the skin in a direction opposite to the motion of the fish on the wheel. The gripper assembly was a rotatable drum, 10.5 inches in diameter, mounted on a parallel-shaft swing-arm arrangement. These shafts were also parallel to the wheel shaft and were connected to both the shaft, by a series of chains and clutch, and a separate drive motor. Figure 10 shows the gripper drum as viewed from behind the machine. The gripper blade is opposite the wheel and the blade slot is at the top of the drum.

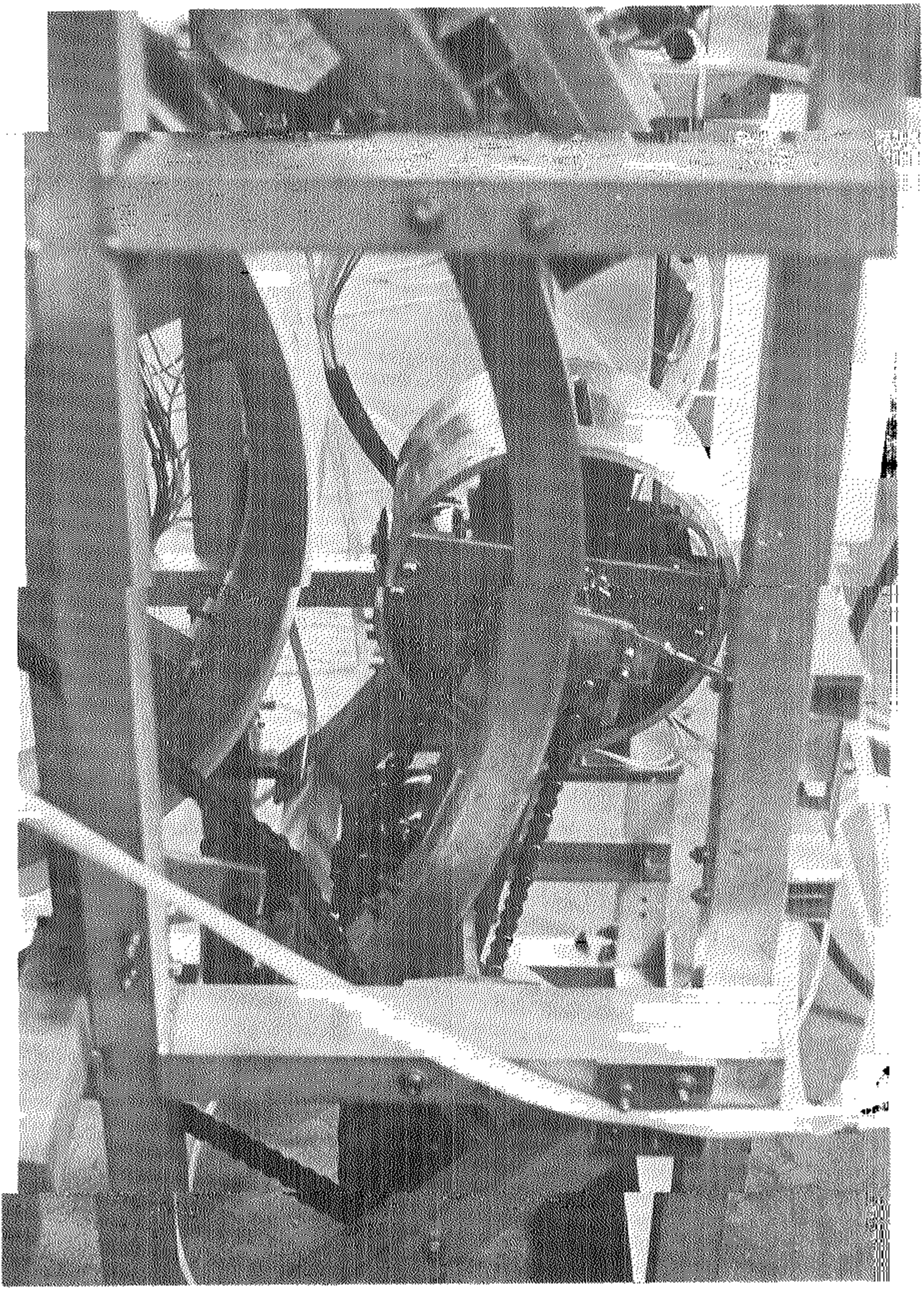

FIGURE 10 GRIPPER DRUM AND DRIVE-TRAIN

When the fish reached the correct position for the gripper sequence, the wheel stopped and the drum then pivoted from its retracted position in against the head of the fish. The ratio of sprocket teeth on the parallel shafts was chosen so that, as the drum moved towards the fish, the same point on the perimeter of the drum remained facing the wheel. This was important because the region of the drum which pressed against the head of the fish contained a slot the length of which was perpendicular to the length of the fish. Once the drum was against the fish an air motor inside the drum began driving a rotary blade mounted on a shaft parallel to the air-motor shaft. After a time delay for the blade to come up to speed, a pneumatic cylinder was engaged to move the rotating blade out of the slot into the neck of the fish, making the nick behind the head. Figure 11 shows the gripper drum rotated so that the blade slot is visible. The rotary blade is extended out of the slot to show its maximum extended position. A limit switch inside the drum sensed that the blade had extended into the fish. The signal from this switch retracted the blade and began the drum rotating in a direction towards the tail of the fish. Based on the signals received from a switch that sensed the position of cams mounted on the drum, a gripper blade was driven into the nick and then pivoted closed, thereby pinching the skin between the blade and a flat spot on the outside of the drum. Figure 12 shows the gripper drum with the gripper blade in its open position. The gap between the

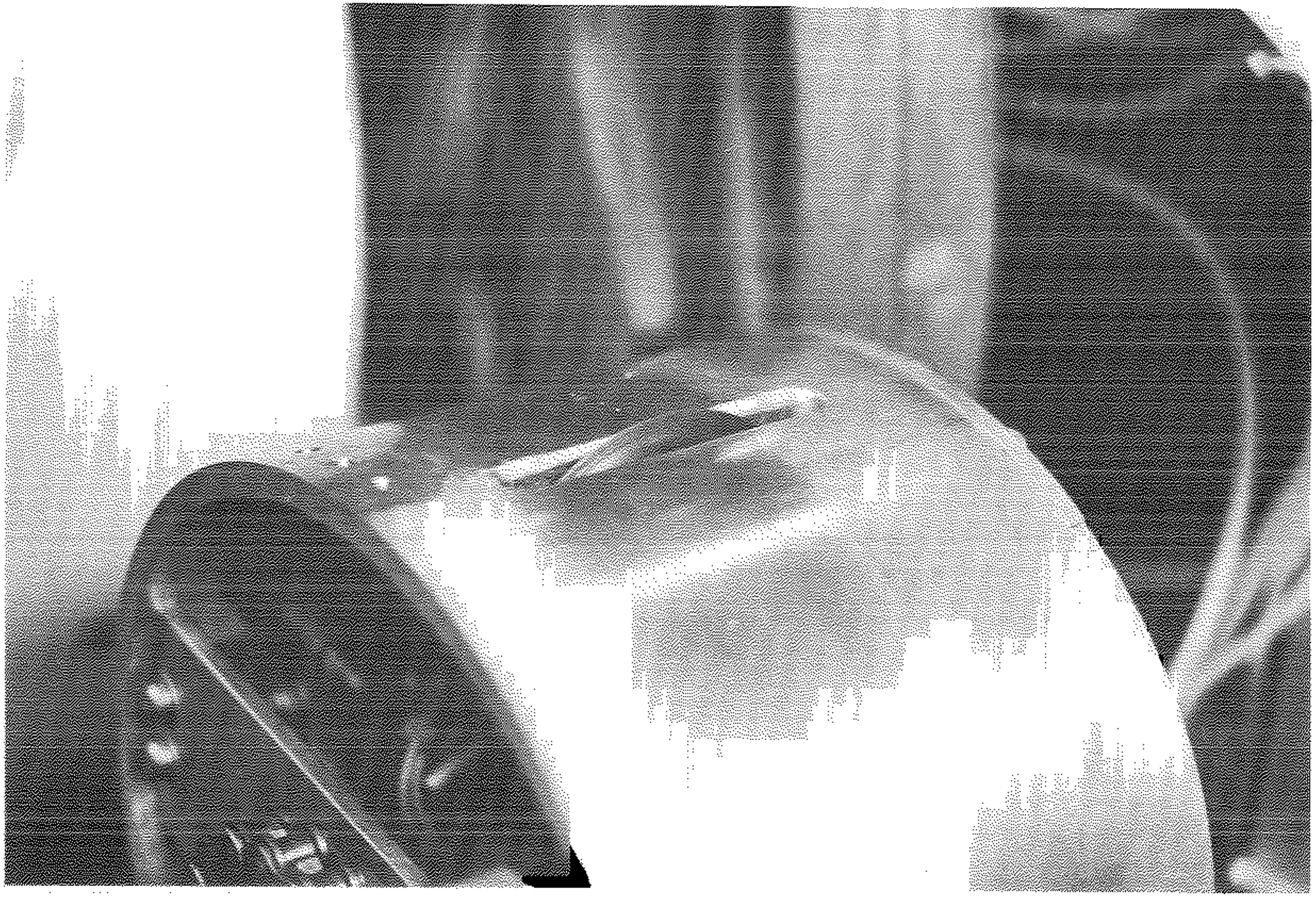

FIGURE 11 GRIPPER DRUM AND SLOT

PPER DRUM AND BLADE

flat surface on the drum and the tip of the blade is approximately 3/8 of an inch. It is in this gap that the skin is gripped. After the gripper blade was driven into the nick and before the blade was closed, gripping the skin, the motor which had been driving the drum through its rotation was shut off. A short time delay was provided for the skin to stretch over the end of the blade and then the gripper was closed. The wheel then began to rotate and 0.3 seconds later the clutch for the chain drive from the wheel shaft to the drum was engaged. The drum rotated in the same direction as when the gripper blade was engaged, i.e. in the direction opposite to the fish movement. The 0.3-second delay was provided to lessen the chance of the skin ripping at the gripper blade due to any shock loadings that might occur from both the wheel and gripper drum starting rotation at the same time. Through the chain drive, the drum and wheel rotated synchronously, with all the power needed to pull the skin off being supplied by the main motor. The duration of this synchronous rotation was chosen so that all the skin from the longest possible fish (approximately 4 feet) would be pulled off before the clutch was disengaged, gripper opened and drum rewind sequence initiated.

Chapter VIII

Results and Conclusions

The objective of this research project was to produce a prototype machine which would take a spiny dogfish shark in the round and remove its tail, dorsal fins, belly-flap and back skin. In addition, the feed rate of fish through the machine was to be high enough to make a production version economically competitive in the U.S. fishing industry. The machine described herein achieved these goals, and a U.S. patent covering the machine was applied for on March 31, 1980.

The design that was developed successfully emulated the hand processing of a spiny dogfish. The average experienced hand laborer can process approximately 120 dogfish per hour or 1 every 30 seconds. By comparison, the machine, programmed according to the control program given in Appendix B, processed a fish once every 12 seconds. A production machine with more powerful fin and belly-flap cutter motors and a higher wheel speed could reduce this time to 8 seconds per fish, or 450 fish per hour.

Other desirable features included were compact size and ease of cleaning. Many fish processing machines of approximately the same size accomplish only one processing function. Therefore, to process a fish completely by machine several hand laborers and machines are necessary. By combining multiple processing functions into the prototype machine, space required in a processing plant or on board a boat was reduced. Due to the almost exclusive use of aluminum, stainless steel and plastic in the construction of the machine, clean-up was easy and efficient.

It is the M.I.T. Sea Grant Program and the National Marine Fisheries Service's desire that with patent protection, the U.S. fish processing machine industry will further develop this machine to meet industry needs. This will allow a valuable source of protein to be utilized rather than wasted.

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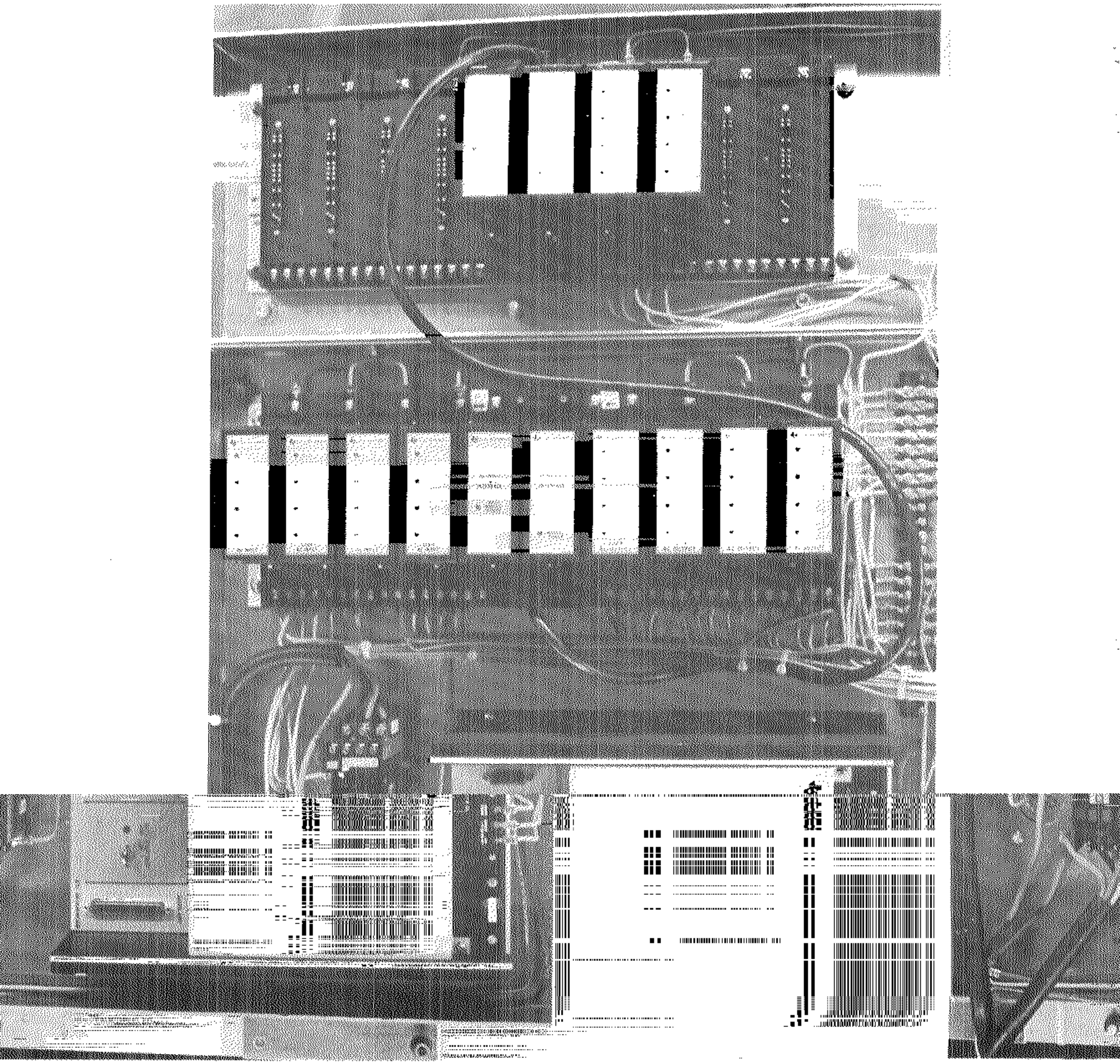
3. McCormick, Harold and Allen, Tom and Young, William. Shadows in the Sea. Philadelphia: Chilton Co., 1963.
4. Atlas, Michael. "Development of Processes for Skinning the Spiny Dogfish Shark." S.M. Thesis, M.I.T., Cambridge: Massachusetts Institute of Technology, 1978.
5. Menjivar, Juan A. and Chen, Rong and Rha, Chokyun. "Mechanical Properties of Fish." Department of Nutrition and Food Science, M.I.T., Cambridge: Massachusetts Institute of Technology, 1977.
6. Boccuti, A. David. "Development of a Mechanism for Removing the Dorsal Fins of Spiny Dogfish Sharks as a Step in Skinning Them." S.B. Thesis, M.I.T., Cambridge: Massachusetts Institute of Technology, 1979.

Appendix A

Description of Controller Inputs and Outputs

The controller used is a Texas Instruments model 5TI-1013 solid-state, programmable controller with a capacity of 256 words. 115 volt AC input and output volt-

[redacted]



MACHINE CONTROLLER

Input	Description
X0	- "AUTO" switch. Located on the control box. Normally open. This switch must be closed and the "START" button pushed for fully automatic operation.
X1	- "MAN" switch. Located on the control box. Normally open. This switch must be closed and the "START" button pushed to energize the machine. Wheel rotation is then controlled by the "JOG" switch (X3).
X2	- This is one set of normally open contacts on the external control relay used to enable operation of the controller and machine.
X3	- "JOG" switch. Located on the control box. Spring-loaded normally open. This switch controls wheel rotation only while in the "MAN" mode.
X4	- Wheel position switch. Located adjacent to the inside rim of the wheel. Normally open roller-switch. Senses the presence of adjustable cams mounted on the inside of the wheel rim.
X5	- Wheel initial position switch. Located next to X4. Normally open cat-whisker switch. Senses the presence of a stud mounted on one of the X4 cams. This cam and stud determine the position of the [illegible] hook in the fish.
X6	- Nose position switch. Located on the nose-stop. Normally open cat-whisker switch. Senses the presence of the fish against the nose-stop.

Input Description

X8 - Tail cutter blade extension switch. Located on the tail cutter. Normally open. Senses that the tail cutter blade has extended far enough to cut the largest tail.

X9 - Tail cutter foot switch. Located on the floor. Spring-loaded, normally open foot switch. Operator actuated, this switch begins the tail cutter sequence. It must be held down for 1 second before the blade is extended.

X10 - Gripper drum position switch. Located on the gripper drum swing-arm. Normally open roller-switch. Senses the presence of cams mounted on the end of the gripper drum.

X11 - Head nick extension switch. Located inside the gripper drum. Normally open. Senses that the head nick blade has extended far enough into the fish to make the nick.

X12 - Nose-stop extension switch. Located on the nose-stop extension air-cylinder. Normally open magnetic reed-switch. Senses that the nose-stop is fully extended, insuring that the fish will be stopped.

X13 - Gripper drum initial position switch. Located on the gripper drum swing-arm. Normally open. Determines the initial position of the gripper drum during rewind.

Output	Description
Y0	Infeed table conveyor motor. 1/6 h.p., 115 VAC electric motor.
Y1	Wheel clutch/brake solenoid-valve.
Y2	Manifold supply solenoid-valve. When energized, this valve connects the air supply to the rest of the machine.
Y3	Hook air-cylinder solenoid-valve.
Y4	Nose-stop air-cylinder solenoid-valve.
Y5	Head-clamp air-cylinder solenoid-valve.
Y6	Gripper drum independent drive clutch solenoid-valve.
Y7	Tail-cutter air motor and clamp solenoid-valve.
Y8	Gripper drum rewind drive air motor solenoid-valve.
Y9	Gripper drum grip-sequence drive air motor solenoid-valve.
Y10	Head nick air motor solenoid-valve.
Y11	Gripper drum motion air-cylinder solenoid-valve.
Y12	Head nick motion air-cylinder solenoid-valve.
Y13	Gripper blade air-cylinder solenoid-valve.
Y14	Gripper drum synchronous drive clutch solenoid-valve.

Output Description

Y15 - Fin cutter motion air-cylinder solenoid-valve.

Y16 - Tail cutter motion air-cylinder solenoid-valve.

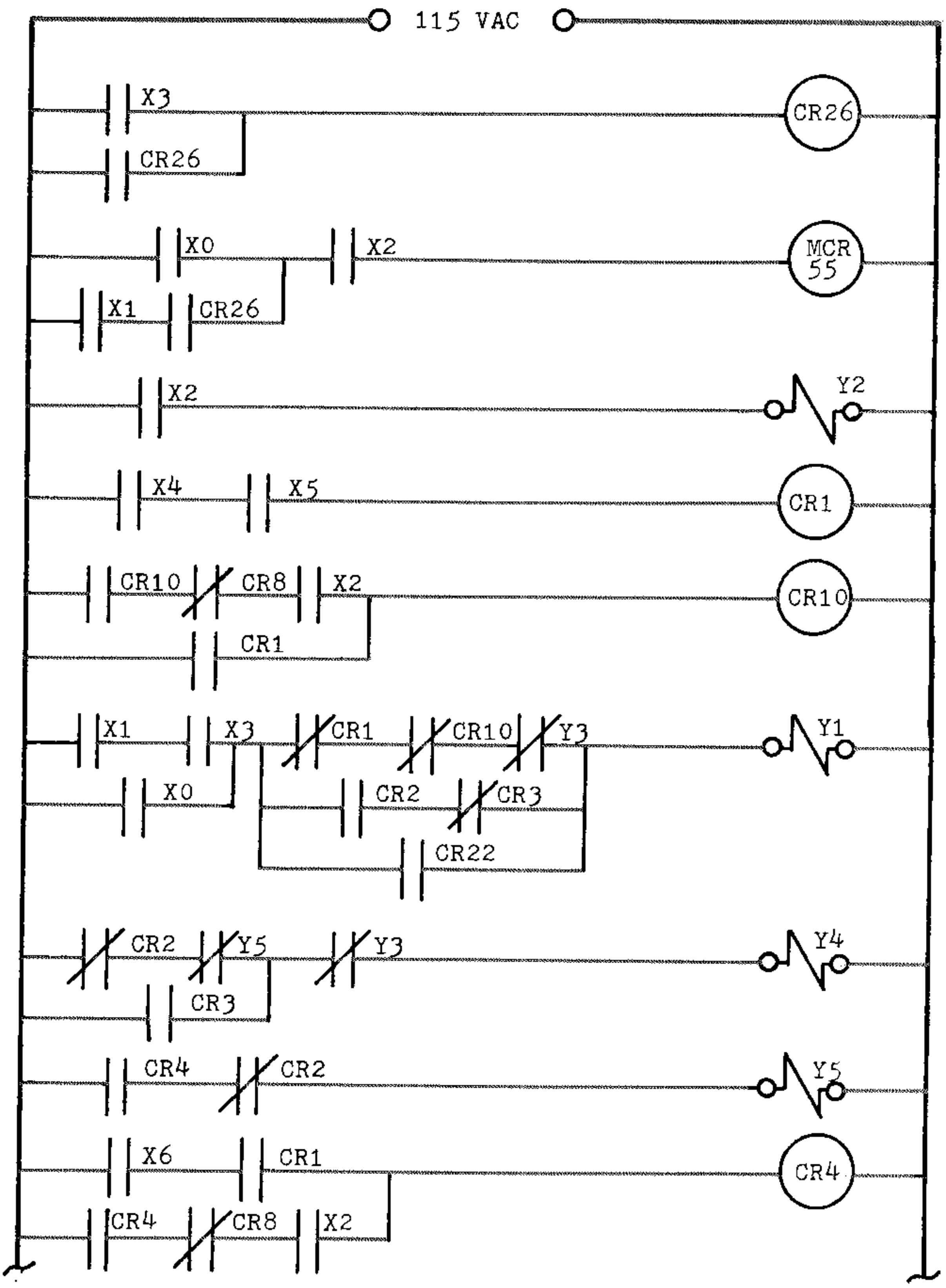
Y17 - Fin cutter air motor solenoid-valve.

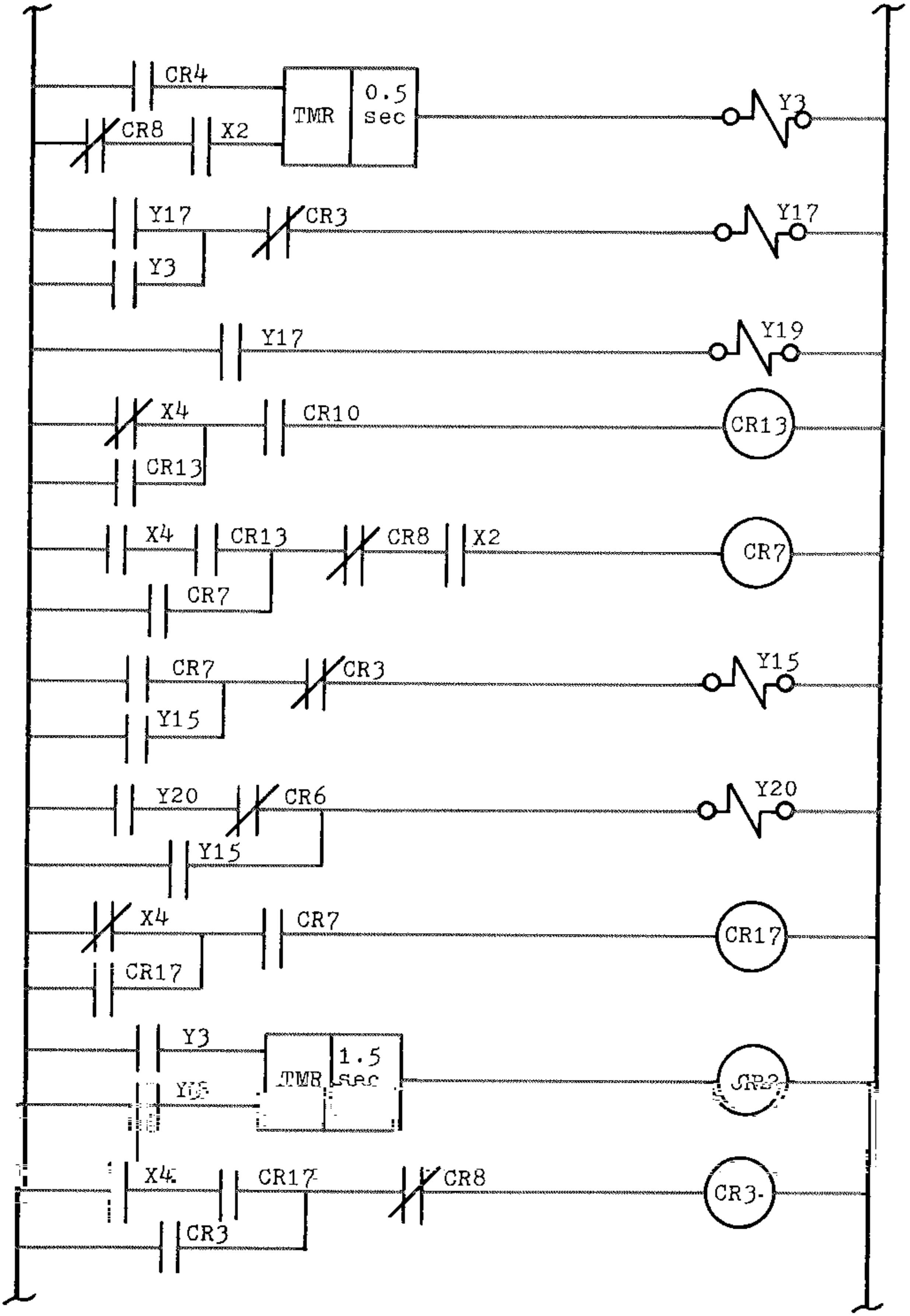
Y19 - Belly-flap cutter air motor #1 solenoid-valve.

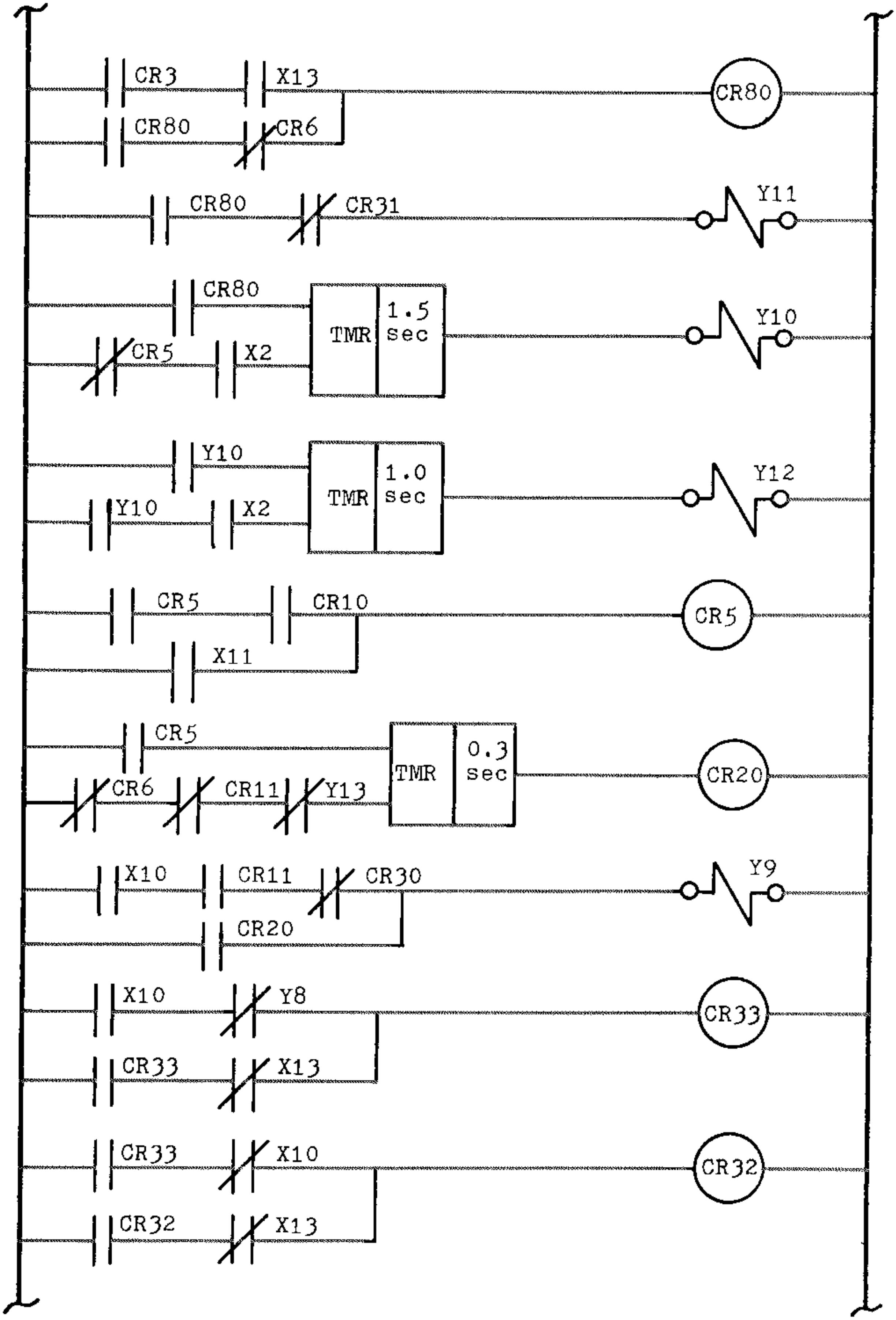
Y20 - Belly-flap cutter air motor #2 solenoid-valve.

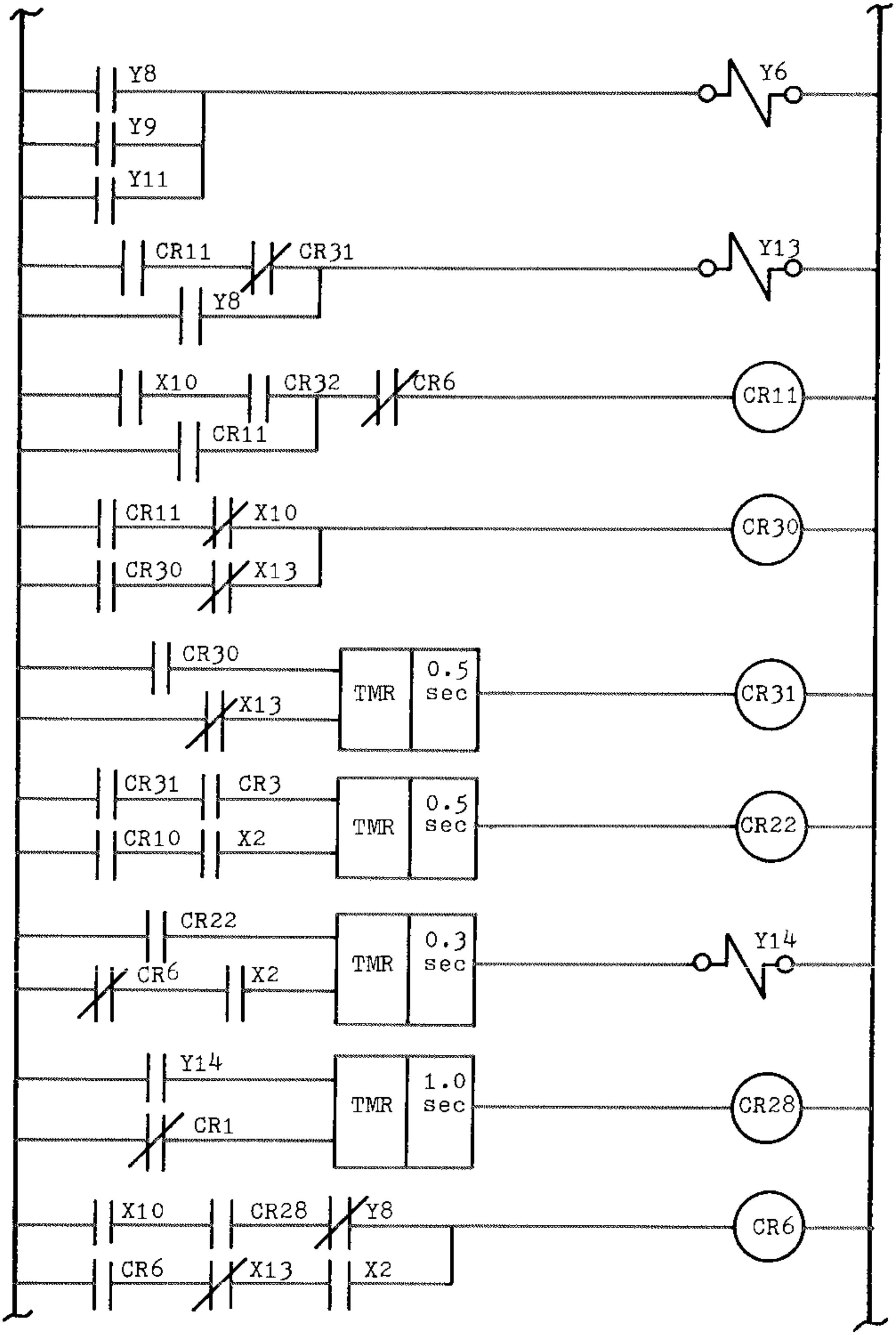
Appendix B

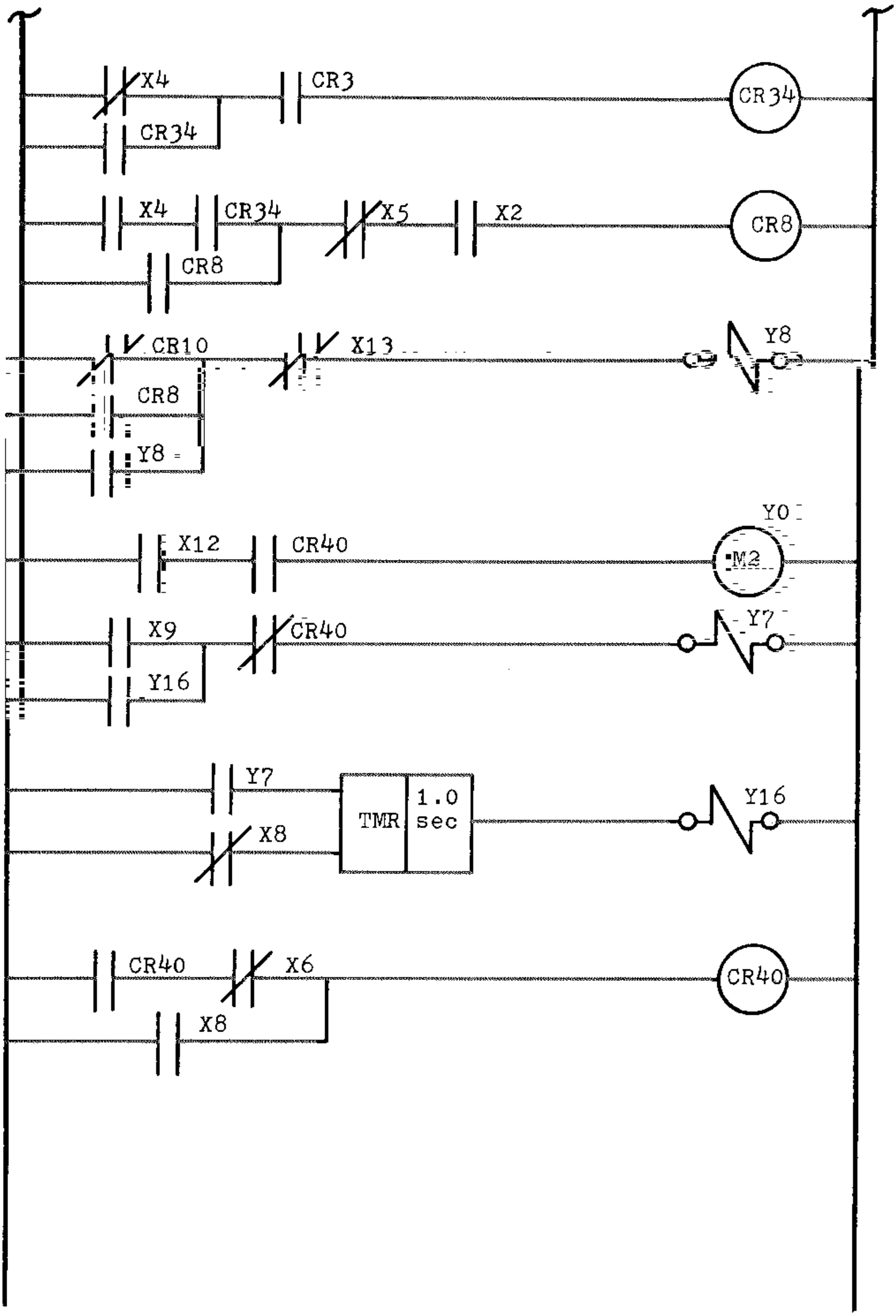
Controller Program




CR4
CR8
X2
TMR
0.5 sec
Y3
Y17
CR3
Y3
Y17
Y17
Y19
X4
CR10
CR13
CR13
X4
CR13
CR8
X2
CR7
CR7
CR7
CR3
Y15
Y15
Y20
CR6
Y20
Y15
X4
CR7
CR17
CR17
Y3
TMR
1.5 sec
CR2
Y15
X4
CR17
CR8
CR3
CR3

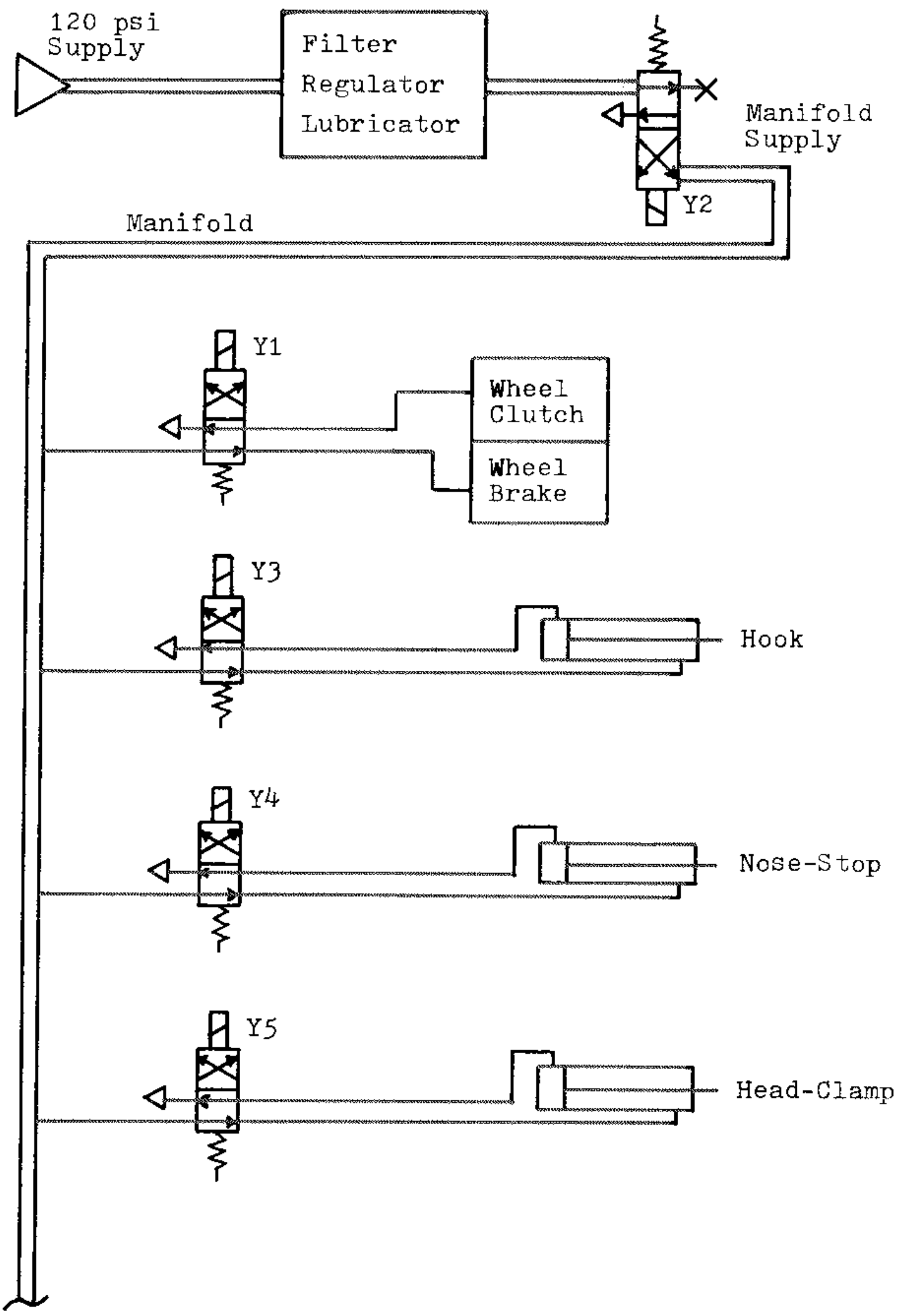

CR3
X13
CR80
CR80
CR6
CR80
CR31
Y11
CR80
TMR
1.5 sec
Y10
CR5
X2
Y10
TMR
1.0 sec
Y12
Y10
X2
CR5
CR10
CR5
X11
CR5
TMR
0.3 sec
CR20
CR6
CR11
Y13
X10
CR11
CR30
Y9
CR20
X10
Y8
CR33
CR33
X13
CR33
X10
CR32
CR32
X13

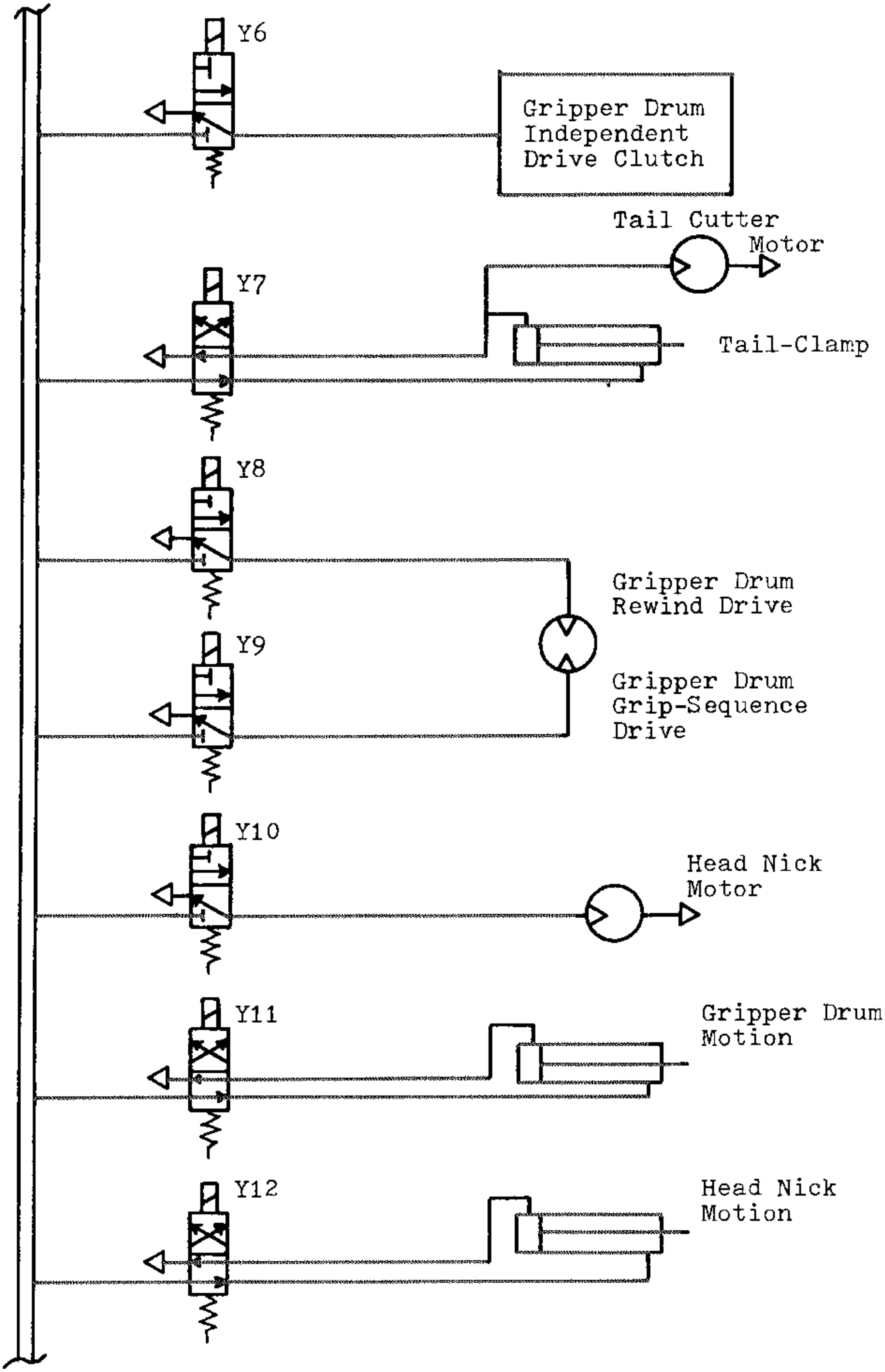

Y8
Y9
Y11
Y6
CR11
CR31
Y8
Y13
X10
CR32
CR6
CR11
CR11
CR11
X10
CR30
X13
CR30
CR30
X13
TMR
0.5 sec
CR31
CR31
CR3
CR10
X2
TMR
0.5 sec
CR22
CR22
CR6
X2
TMR
0.3 sec
Y14
Y14
CR1
TMR
1.0 sec
CR28
X10
CR28
Y8
CR6
X13
X2
CR6

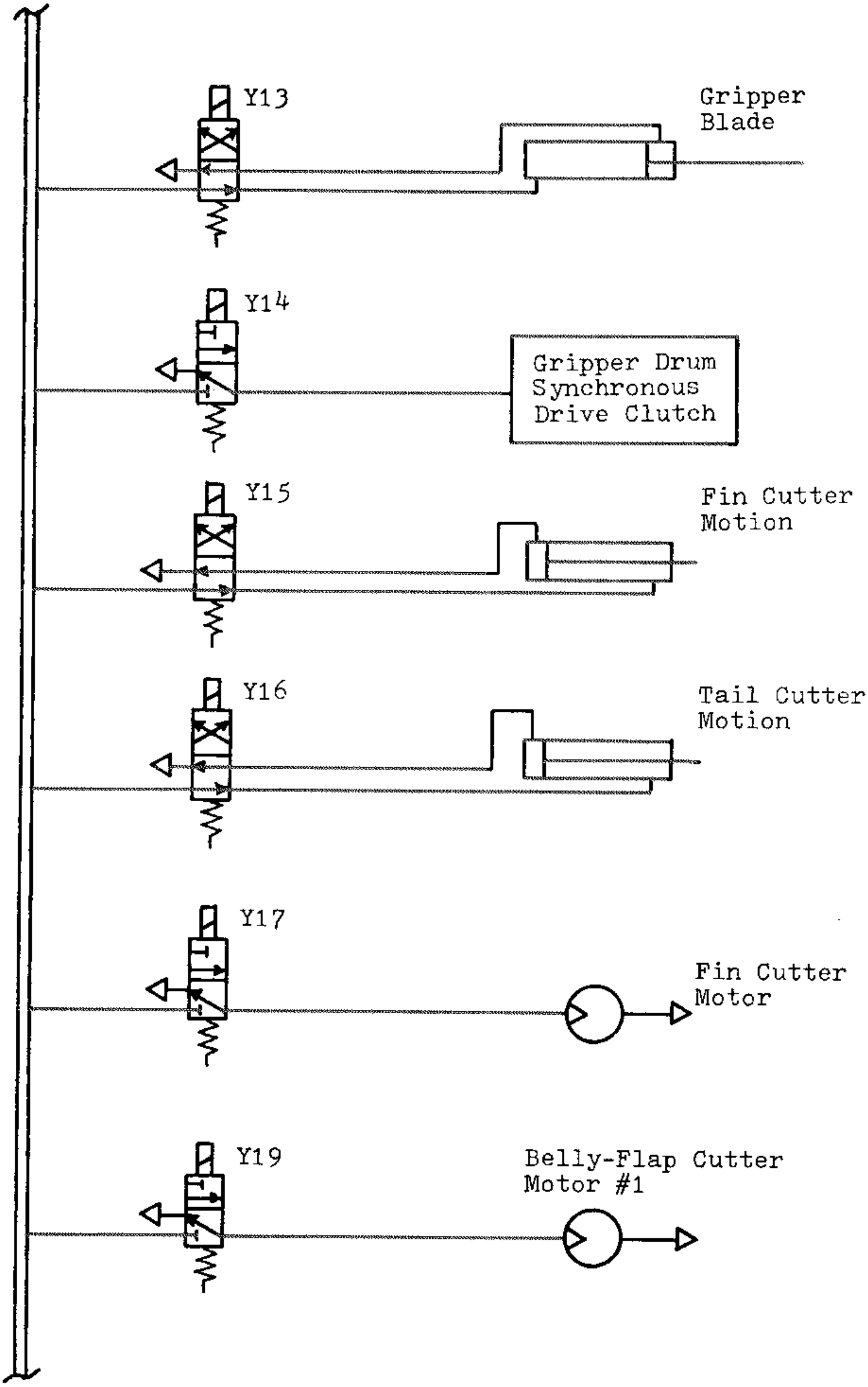

X4
CR3
CR34
CR34
X4
CR34
X5
X2
CR8
CR8
CR10
X13
Y8
CR8
Y8
Y0
X12
CR40
M2
X9
CR40
Y7
Y16
Y7
TMR
1.0 sec
Y16
X8
CR40
X6
CR40
X8

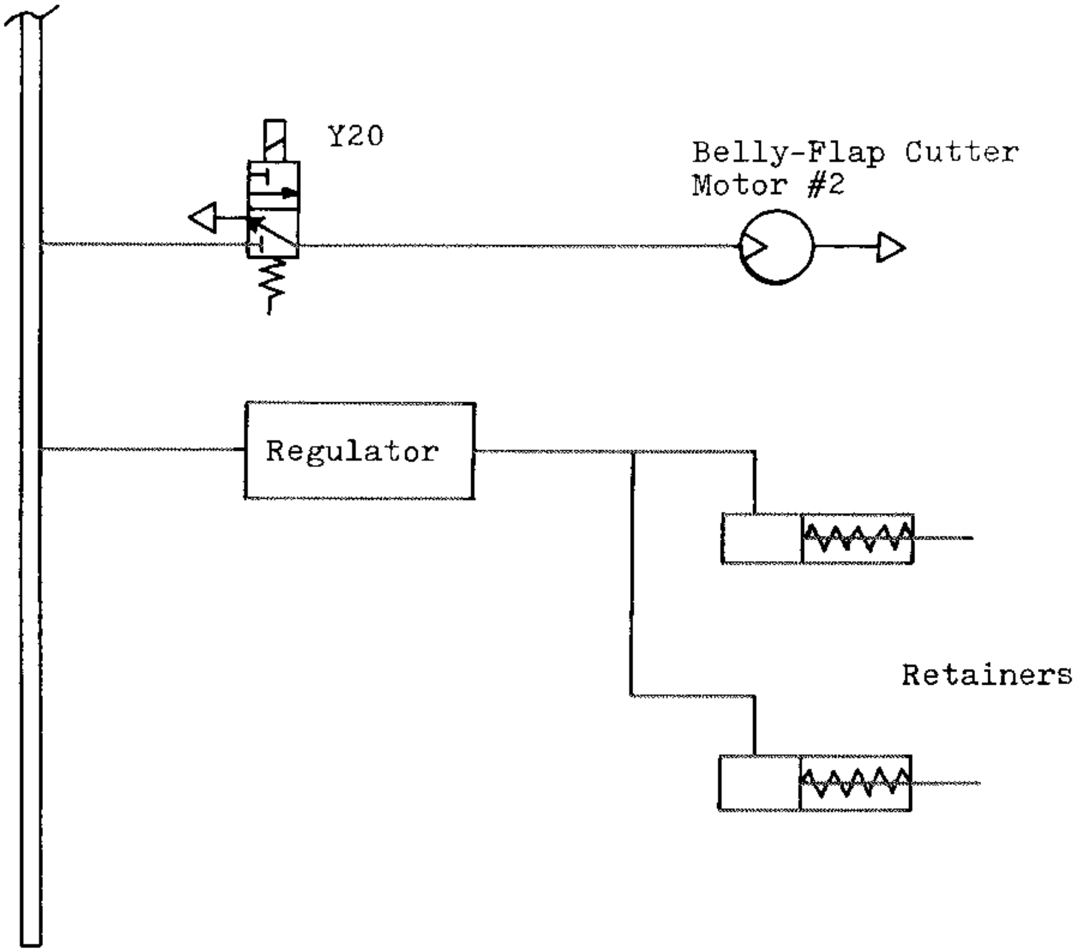
Appendix C

Pneumatic Diagram




Y6
Gripper Drum
Independent
Drive Clutch
Tail Cutter
Motor
Y7
Tail-Clamp
Y8
Gripper Drum
Rewind Drive
Y9
Gripper Drum
Grip-Sequence
Drive
Y10
Head Nick
Motor
Y11
Gripper Drum
Motion
Y12
Head Nick
Motion


Y13
Gripper Blade
Y14
Gripper Drum Synchronous Drive Clutch
Y15
Fin Cutter Motion
Y16
Tail Cutter Motion
Y17
Fin Cutter Motor
Y19
Belly-Flap Cutter Motor #1


Y20
Belly-Flap Cutter Motor #2
Regulator
Retainers