A System to Singulate and Align Squid for Packaging and Processing

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ABSTRACT—To reduce packaging time of whole California market squid, Loligo opalescens, *and facilitate automatic feeding of a newly developed squid cleaning machine, a system to align and singulate squid has been developed. Squid are circulated in a holding tank by water jets which also singulate and direct the squid through ducts to an alignment slide. The squid slide down the alignment ramp and are oriented mantle first. As the squid slides down the ramp, the tentacles drag, causing the body to rotate clockwise or counterclockwise and orient itself. Data are presented relating system performance to processing rates for the squid cleaning machine and the packing industry.*

Introduction

Squid is an important and inexpensive source of protein in much of the world, particularly the Orient. The current annual world catch is estimated at 450 million kg (500,000 tons) and a sustainable fishery may reach 91 billion kg (100 million tons) (Kato and Hardwick, 1975).

The appearance of whole squid in the local supermarket, where it is sold in small amounts, is considered unpleasant and unappetizing to some consumers despite the low retail price for whole squid, $1.52-2.18/kg ($0.69-0.99/pound). Cleaning squid by hand adds $4.41-6.61/kg ($2.00-3.00/pound) to the price for the restaurateur or retail consumer.

One species, *Loligo opalescens,* commonly referred to as California market squid, abounds off the U.S. west coast. It is currently packed by hand and frozen for foreign and domestic markets in 0.4, 1.3, 2.2, and 4.5 kg boxes (1, 3, 5, and 10 pound boxes). Squid is also hand packed and canned for foreign markets. Automatic weighing machines are used in packing squid to be frozen.

Most hand-packed, boxed, and frozen squid are left randomly oriented. The boxes are then weighed and adjusted to the desired weight by adding or removing individual squid. Random packing of squid which average 13/kg (5.9/pound) in a 0.4 kg (1 pound) box generally takes one worker 5-10 seconds[1].

Certain processors, in an effort to make whole, frozen squid more appealing to the consumer, align the top layer so that the squid are parallel and uniform. A clear plastic window in the box cover allows the consumer to inspect this top layer. This orientation of individual squid is done by hand before or after the boxes are weighed. One processor is currently operating a hand packing line, employing 12-15 workers, at 56.7 kg/minute (125 pounds/minute), using 2.2 kg (5 pound) boxes[2].

[1]DeLucca, A. 1980. State Fish Co., San Pedro, Calif. Pers. commun.
[2]Nobusada, K. 1980. Sea Products Co., Moss Landing, Calif. Pers. commun.

A machine to automatically feed squid, in a uniformly oriented condition, to the workers packaging or canning whole squid would greatly reduce packing time.

A machine to skin and eviscerate *L. opalescens* has been recently developed by Singh and Brown (1980). It automatically mounts an individual squid on a holding device. Using water jets, it skins, eviscerates, and removes the ink sac and backbone in 8 seconds. In an initial staging area the tentacles are severed and saved for consumption. The head is also removed. Squid are uniformly oriented and fed into this machine one by one, mantle first. An orientation device (Brooks and Singh, 1979) was used to feed squid into this machine. Individual squid were deposited by hand on this orientation slide as needed by the cleaning machine. It is estimated that a multihead machine (60-70 cleaning stations), using the principles of this prototype, could process 2,300 kg/hour (2.5 tons/hour). An automatic feeding device, providing oriented, individual squid to each cleaning station, would greatly aid in use of this machine by the seafood processing industry.

Materials and Methods

Our singulation technique (Fig. 1, 2) was developed to provide aligned, individual squid for processing, either packaging or cleaning. It consists of a singulation tank, a circular water tank, 0.91 m (36 inches) in diameter and 25 cm (12 inches) deep with a square, 5 × 5 cm (2 × 2 inch), duct (A, Fig. 1), leaving the tank at a tangent. The operating capacity of the tank is 210 liters (56 gallons).

The flow of water through duct A is accelerated by the action of water jet B (Fig. 1, 3). Water jet B consists

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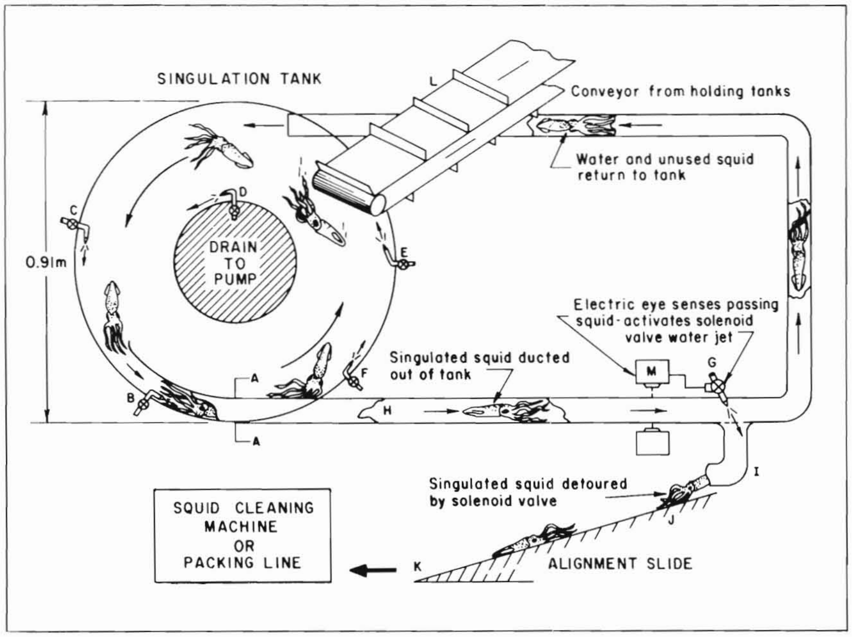

Figure 1.—System to singulate squid.

of a copper tube with an inside diameter of 1.1 cm (0.43 inch). The water flow rate through jet B was maintained at 0.33 kg/second (5.3 gallons/minute) by a centrifugal water pump. This water jet maintains the flow of water through duct A at an average velocity of 0.45 m/second (1.5 feet/second).

The water in the tank is circulated by the action of water jets C, D, E, and F (Fig. 1). These jets were made of 0.25 inch diameter copper tubing and were supplied with a valve to control the flow of water from them.

Water jet G mounted in duct H (Fig. 1) was supplied with a solenoid-controlled valve. The flow rate through it when fully developed was 0.82 kg/second (13.3 gallons/minute). Duct H is 5 cm (2 inches) in diameter. Jet G is aimed at the

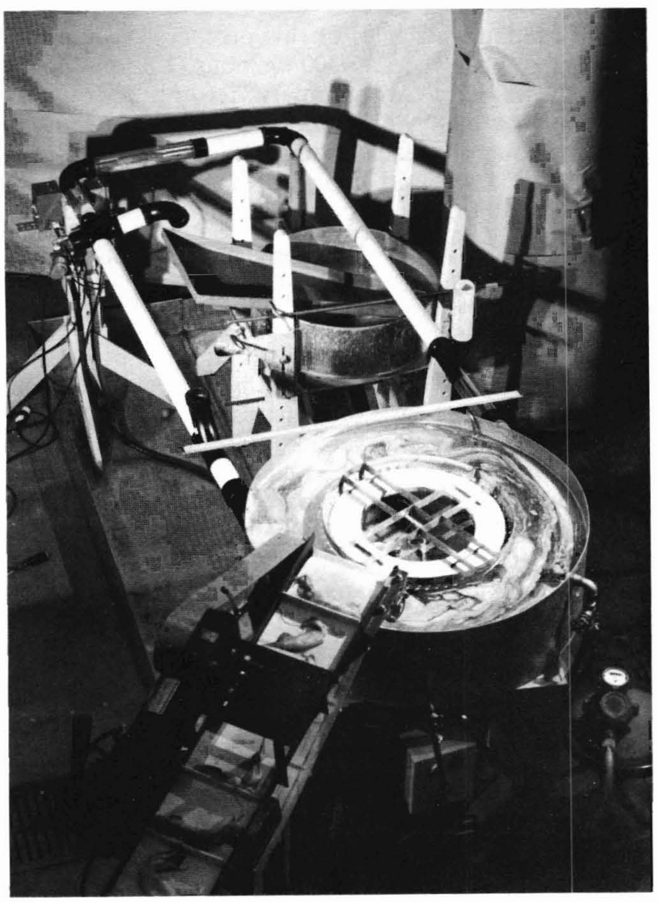

Figure 2.—Tank and duct of system to singulate squid.

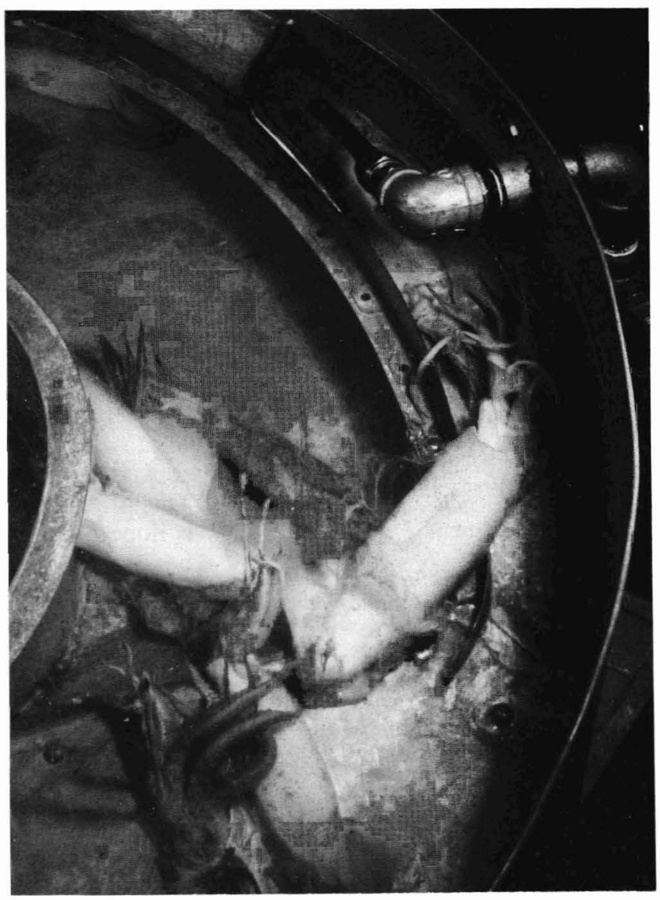

Figure 3.—Exit duct from tank and water jet B.

entrance to duct I (Fig. 1). Duct I is also 5 cm in diameter. A flow of water through duct I is developed by the flow of water from jet G when the solenoid valve is opened. Normally there is little or no flow through duct I because the centerline of the exit of duct I is elevated 5 cm (2 inches) above the centerline of duct H.

An alignment slide, J (Fig. 1), developed for orientation of squid by Brooks and Singh (1979) into a squid cleaning machine developed by Singh and Brown (1980), is located at the exit of duct I. This slide was made of PVC plastic sheet and was fixed at an angle of 20° with the horizon. This angle is close to the minimum angle recommended by Brooks and Singh (1979). A small receiving tank to represent the squid cleaning machine or packing line was positioned at the base of the slide, K (Fig. 1).

Fresh water was continually added to the system at the rate of 0.1 kg/second (1.6 gallons/minute). The overflow was drained off. This was done as a sanitation procedure.

down duct H (Fig. 1). Squid bodies remain parallel with duct H as they flow through it either mantle or tentacles-first. Their average velocity in the duct is 0.45 m/second.

Squid are diverted from duct H to duct I by water jet G (Fig. 1). An electric eye, M (Fig. 1), senses a passing squid and activates a solenoid valve which produces a powerful water jet (G) to divert the squid into duct I at a right angle to the flow in duct H.

The squid travels a short distance in duct I and is then deposited on alignment slide J (Fig. 1, 4). The friction coefficient of the squid tentacles, being higher than that of the body, causes the squid to rotate into the desired mantle-first alignment as it slides down ramp J (Fig. 1). Singh and Brown (1980) used this alignment slide to orient squid for the skinning and evisceration machine. Upon reaching location K (Fig. 1), the squid are properly aligned and ready to enter either a cleaning machine or a weighing and packaging line. The squid that are not removed from duct H by the water jet return to the tank and enter the system again.

As the numerical density of squid in the tank rises, the likelihood of two squid entering the singulation duct A simultaneously, increases. These squids are separated in the duct by the action of water jet B. Water jet B is offset to one side of the duct at A and as two squid enter the duct, they are subjected to a velocity profile difference (Fig. 5) at section A-A. The squid in the region of higher velocity accelerates past the other squid attempting to enter the duct at A with it (Fig. 6). Both squid then proceed single file.

The placement of water jets C, D, E, and F, and others not shown in Figure 1 insure that all squid are kept circulating in the tank and eventually enter duct H. In close observation throughout the development of this system we observed that all squid are removed from the singulation tank. Squid returned to the tank, not diverted to duct I because jet G is closed, are subjected to the action of water jets C through F and reenter ducts A and

Operation

Squid were batch-loaded into the singulation tank from a bucket or bin. Continuous loading was also tried using a metered belt conveyor. The density of squid in fresh tap water is 1.10 g/cc (Brooks and Singh, 1979) and, as expected, the squid sink to the bottom of the tank.

Squid are kept circulating in the tank by the action of water jets C, D, E, and F (Fig. 1). The squid, suspended in the water, are directed by the action of jets C, D, E, and F toward the exit duct A (Fig. 1, 3). The flow of water in this duct is accelerated by the action of water jet B (Fig. 1, 3). The accelerated column of water in the duct draws the squid, suspended in the water, which have been directed to the duct's entrance, out of the tank. The squid then leave the tank and flow single file

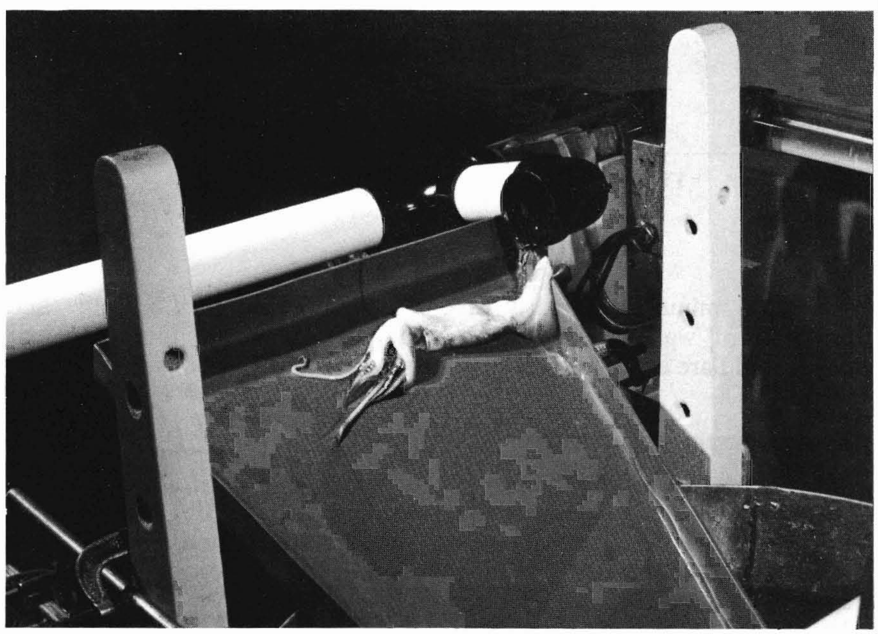

Figure 4.—Squid diverted from ducting and onto alignment slide.

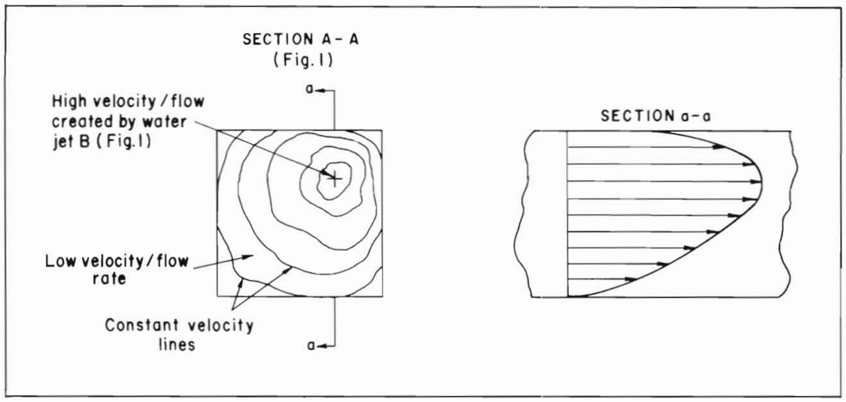

Figure 5.—Velocity profile in singulation duct at entrance.

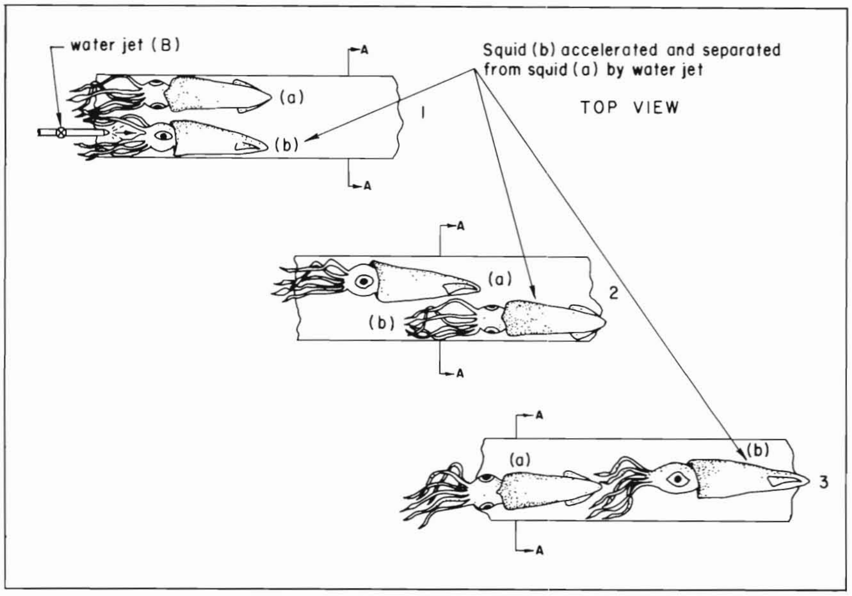

Figure 6.—Squid separated in singulation duct.

H within 3 minutes. Similarly the placement of water jet G insures that all squid are diverted from duct H to duct I.

Performance Investigation

The singulation rate for removing squid from the tank depends on squid density. Three tests were performed to gauge the effect of tank density on removal rate. Frozen, whole squid, *L. opalescens,* were purchased from Meredith Fish Company[3], Sacramento, Calif., and thawed just prior to use. Their overall lengths, from mantle tip to tentacle end, ranged from 23 to 33 cm (9-13 inches). For the first test the number of squid in the tank was maintained at 10 for a 10-minute test period. The number of squid removed and ducted from the tank to water jet removal station G (Fig. 1) were counted. The density of the squid in the tank was then changed to 30 and 60 squid for 10-minute periods.

The 10-minute test period was chosen because the condition of the squid deteriorates if exposed to fresh water and repeated action of the water jets for a greater period. The mucous-like layer covering the squid disintegrates. In actual practice this would not be a problem as the squid would be continuously removed from the system and skinned or packaged. In the above tests the squid were recycled many times.

A second series of tests was performed to test the effectiveness of the water jet removal device and alignment system. Two modes of operation were tested. Continuous operation would simulate the singulation of squid for a packing operation of whole squid. Removal of squid from the ducting system on demand would provide singulated squid for a cleaning machine.

In a continuous operation mode, water jet G (Fig. 1) was fixed in the open position. All squid were to be diverted out of the ducting system onto the alignment slide. The number of squid in the tank was maintained at 60 and the duration of the test was again 10 minutes. The squid arriving at the bottom of the slide in the desired condition for packaging in uniform alignment were counted. All squid were returned to the circulating tank, thus maintaining 60 squid in the tank. The water deposited on the slide with the squid was also recycled by pumping it back into the singulation tank continuously.

In tests simulating the demands for aligned squid of the skinning and gutting machine described earlier, squid were removed from the ducting system every 8 seconds. The electric eye controlling water jet G was equipped with a reset circuit which prevented its operation until a simulated signal from the squid cleaning machine was received. The

[3]Mention of trade names, products, or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

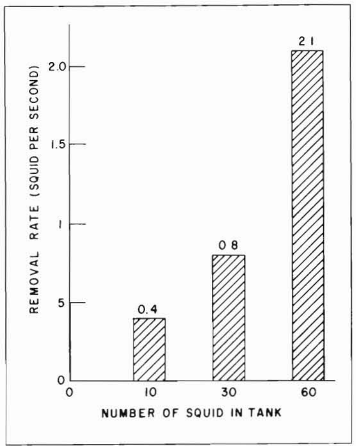

Figure 7.—Average singulation rate of squid ducted out of the holding tank.

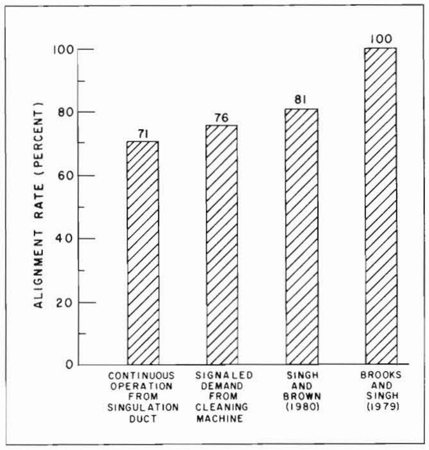

Figure 8.—Alignment rate for squid sliding on inclined ramp.

next squid in the duct then activated the electric eye and the water jet diverted that squid to the alignment slide. The number of squid in the tank was maintained at 60 and duration of the test was 10 minutes. Squid removed from the ducting system and aligned properly were recorded and the squid were returned to the singulation tank.

Results and Discussion

In Figure 7 are shown the results of tests performed to determine the average removal rate over the 10-minute test period for the ducting of squid from the circulation tank. The average removal rates ranged from 0.4 squid/second with a tank density of 10 squid, to 0.8 squid/second for 30 squid, and 2.1 squid/second for 60 squid. For the 60-squid test, the spacing of the squid in the duct dropped to an average of only 25 cm. This is about the minimum spacing required for effective removal of squid from the duct by water jet G (Fig. 1).

The percentage of squid removed from the ducting by water jet G under continuous operating conditions was at the 92 percent level. With a tank density of 60 squid, 1.9 squid/second on the average were successfully diverted to the alignment slide under continuous operation. These squid were aligned at a 71 percent level (Fig. 8). This is lower than the 81 percent level reported by Singh and Brown (1980), and the 100 percent figure reported by Brooks and Singh (1979). The reasons for this low alignment rate will be discussed later.

As noted, 12-15 workers currently pack squid in 2.2 kg boxes, with the top layer aligned, at the rate of 56.7 kg/minute. Using an average of 13.0 squid/kg, 12 workers could pack 740 squid/minute. Each worker packs on the average 1 squid/second. The singulation/alignment technique described in this report could supply a worker with 1.9 squid/second if the 100 percent alignment rate can be achieved.

The second test for removal of squid from the ducting on simulated demand from the squid cleaning machine resulted in an 89 percent removal rate. Every 8 seconds the electric eye was reset with a simulated signal from the skinning/cleaning machine. The first squid passing the electric eye activated the water jet G removal system (Fig. 1). The squid not removed by this system remained in the duct and returned to the circulation tank. Those squid that were deposited on the alignment slide were aligned at a rate of 76 percent (Fig. 8).

Because the skinning machine developed has an operation time of 8 seconds/squid, the singulation machine could provide squid to a large number of skinning machines. Multiple solenoid-controlled water jets diverting squid would be required. With a maximum removal rate from the singulation tank of 2.1 squid/second, this singulation device could automatically feed 15-17 squid skinning machines.

These squid removed from the ducting system and deposited on the alignment slide were aligned at a lower than expected rate. Figure 8 compares these results with previous research. Singh and Brown (1980) reported an alignment rate of 81 percent for squid deposited on the alignment slide of the squid cleaning machine described. In a public demonstration of the squid cleaning machine on 19 April 1980, a near 100 percent alignment rate was observed. The sample size was 150 squid. Brooks and Singh (1979) found a 100 percent alignment rate for squid dropped on an alignment ramp. Operated continuously the alignment slide in this report aligned squid at a 71 percent rate. On simulated demand, a 76 percent rate was achieved (Fig. 8). The two most likely reasons for the difference in performance are: 1) The quantity of water dropped on the slide with the squid; and 2) the material that the slide is made of. Brooks and Singh (1979) observed squid orientation on a galvanized sheet-metal ramp with a constant fine spray of water to facilitate the sliding motion. The squid cleaning machine developed by Singh and Brown (1980) used a Plexiglas slide and fine water spray to orient squid. Large amounts of water are deposited along with the squid by the system described in this report. PVC plastic was used in the construction of the slide.

A mechanical device to separate the squid from excess water and then drop the squid on the slide is needed to improve the alignment rate. An investigation of the slide material and its effect on the friction coefficient of squid tentacles and body would be necessary to select the optimum material for this component of the system. Stainless steel would be preferred by the processing industry.

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