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George Paul Willis for the degree of Master of Science

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Title: SKILL DESIGN, EVALUATION, AND IMPLEMENTATION OF IMPROVED DUNGENESS CRAB MEAT EXTRACTION METHODS

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William Engesser

The Dungeness crab fishery is the largest and oldest known shellfish fishery of the North Pacific coast of North America. The stability and development of this fishery is seriously hampered by increasing meat extraction costs and labor shortages.

Alternative solutions to offset the increasing costs and labor shortages include: 1) development of an automated picking process or machine, or 2) identification or development of techniques to simplify and improve manual meat extraction. Because of the complexity of meat extraction, mechanization does not seem likely for some years. The second alternative can immediately help relieve the fisheries' problem.

This paper has concentrated on the design and evaluation of improved crab meat extraction methods, in terms of skill, time and

cost. The design of the improved method of meat extraction was in terms of the indirect skill factors (the individual, and plan and control), and the direct skill factors (materiel, necessity of motion, rhythm, and speed).

This method's improvement study upgraded the skill level of crab pickers in terms of the six skill factors, and, in turn, reduced meat extraction time and lowered the overall picking cost to the processor. An overall plant meat extraction rate increase of 20 percent was realized by several fisheries, along with increases in meat yield.

A training program, along with a motion picture training film and a pictorial instruction manual, was developed to implement the improved method of meat extraction.

Skill Design, Evaluation, and Implementation of Improved Dungeness Crab Meat Extraction Methods

by

George Paul Willis

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Professor of Industrial and General Engineering
in charge of major

Redacted for Privacy

Head of Department of Industrial and General Engineering

Redacted for Privacy

Dean of Graduate School

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SKILL DESIGN, EVALUATION AND IMPLEMENTATION OF IMPROVED DUNGENESS CRAB MEAT EXTRACTION METHODS

I. INTRODUCTION

Statement of the Problem

One of the most serious constraints in producing fresh, marketable crab meat in the Pacific Northwest, and perhaps throughout the world, is that of economically removing the meat from the shells (shaking, picking, shucking or extracting). This economic problem focuses directly on the labor force, processing techniques, and equipment employed by the seafood processors for crab meat extraction.

Traditionally, crab processed in seafood plants has been hand picked. Moreover, the industry will be characterized by manual picking for some years, as complete mechanization does not seem imminent due to the complexity of meat extraction. This draws attention to the necessity of understanding skill attributes and raising the skill levels of crab meat pickers, if the economic problem of meat extraction is to be alleviated.

The purpose of this paper is to improve manual crab meat extraction skills in today's seafood industry. This improvement can be realized by accomplishing the following objectives:

1. Analyze the present method of manual crab meat extraction in terms of skill, time and cost factors.
2. Design a method of manual crab meat extraction that will improve the present method in terms of skill, time and cost factors.
3. Develop training aids that will be used in implementing an improved manual crab meat extraction method.

Background

The Dungeness crab (*Cancer magister*), also called the Pacific crab, is a hard-shell crab generally measuring up to ten inches across the carapace (Figure 1) (1). Commercial fishing for this crab began in the fishing village of Dungeness on the Strait of Juan de Fuca in Washington, after which the crab is named (1).

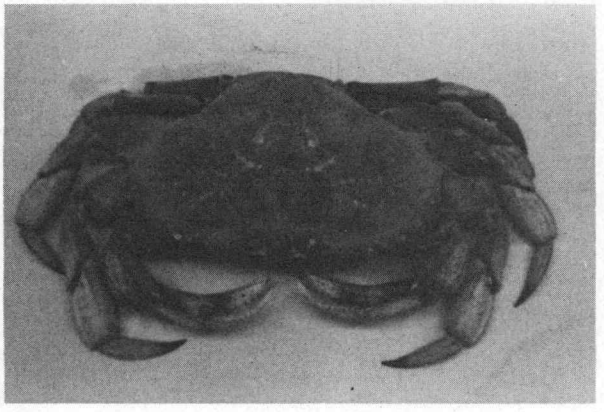

Figure 1. Dungeness crab (*Cancer magister*).

The Dungeness crab inhabits coastal waters from the Aleutian Islands to Mexico (Figure 2), but the most important commercial fisheries are located at San Francisco and Eureka in California; Coos Bay, Newport and Astoria in Oregon; Grays Harbor, Willipa Harbor and Seattle in Washington; and Cordova, Petersburg, Kake, Hoonah, Ketchikan and Kodiak in Alaska (2). In recent years, Dungeness crab fishing has also become an important industry along the coasts of British Columbia, Canada. This crab is usually found in off-shore waters from 2 to 20 fathoms, or in sandy bays (3).

Hipkins[1/] indicates that the Dungeness crab fishery is both the largest and oldest known shellfish fishery of the North Pacific coast of North America (1). This industry represents a small, but essential portion of Oregon's increasing income from the sea. Although the shellfish catch constitutes only about 14 percent of the total value of all fish harvested by Oregon fishermen, it is a substantial part of the total income of many of the state's fishermen, processors and fish wholesalers (2, 4).

Oregon's crab catch during the 1970-71 ocean season was 15.0 million pounds. This amount accounts for 42 percent of the 36.1 million pounds produced by the Pacific Coast Dungeness crab industry.

[1/] Fred W. Hipkins is a marketing specialist employed by the Bureau of Commercial Fisheries, Fishery Products Laboratory, Ketchikan, Alaska.

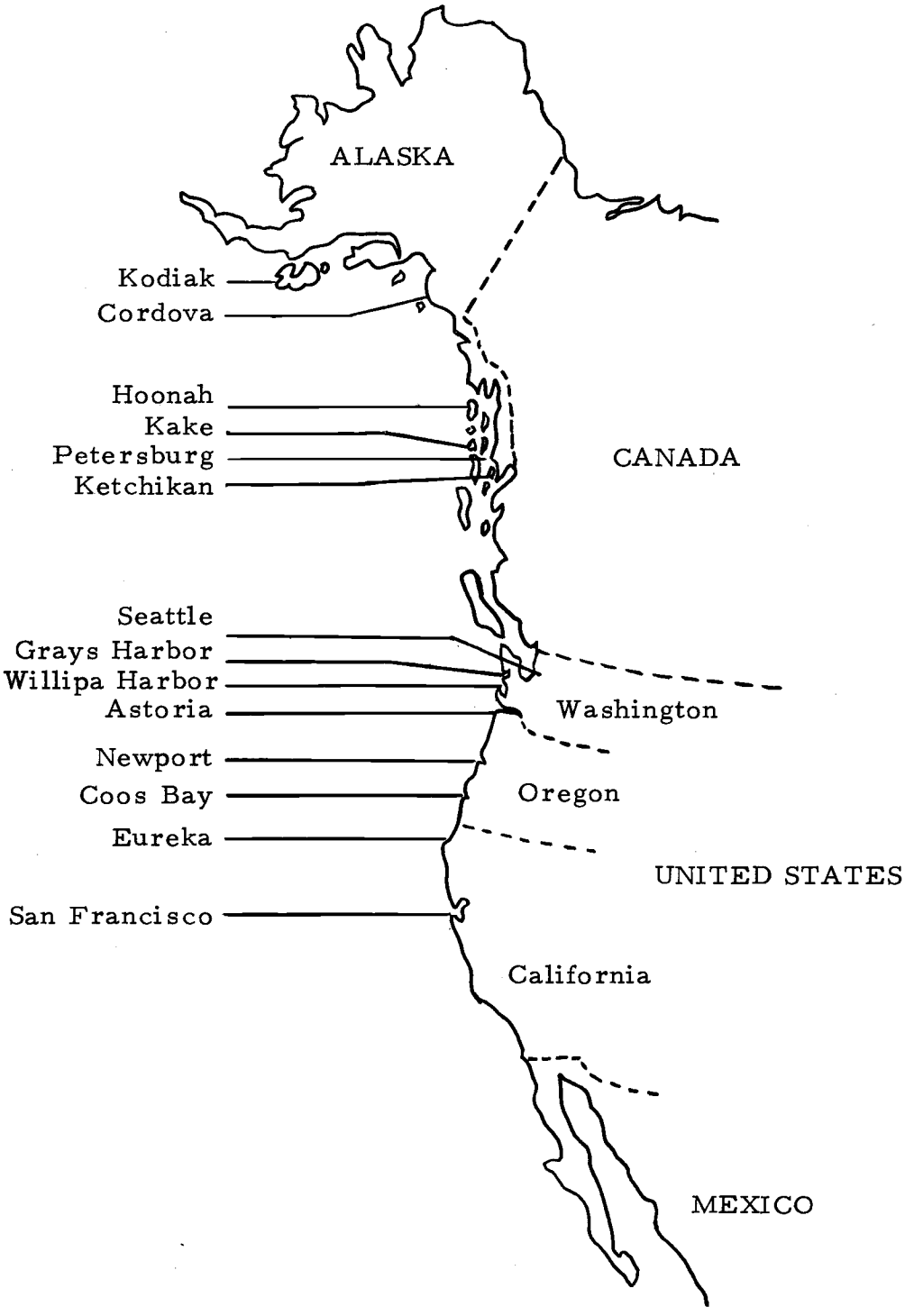

Figure 2. Major Dungeness crab fisheries on the Pacific coast.

The worth of the catch to fishermen was approximately 4.5 million dollars since an average of 30 cents per pound was paid for green crab[2/]. With an average 1971 wholesale price of 3.00 dollars per pound for crab meat and 80 cents per pound for whole or shell crab, Oregon processors added 7 million dollars to the value of the catch. Thus, the total wholesale value of the state's catch in 1971 was about 11.5 million dollars[3/].

Dungeness crabs are also an export commodity. Several million dollars are realized annually from out-of-state shipments (5).

The stability and development of the Dungeness crab fishery is seriously hampered by the quasi-cyclical nature of season to season landings. For example, over the past decade Oregon's landings have varied from a high of 15 million pounds in 1971, to a low of 3.1 million in 1964 (Figure 3).

[2/] Green crab refers to unprocessed crab.

[3/] Data on Oregon catch and fishermen prices were obtained from C. Dale Snow, Director of Shellfish Investigations, Oregon Fish Commission, Newport, Oregon. Wholesale prices for 1971 were taken from interviews with processors.

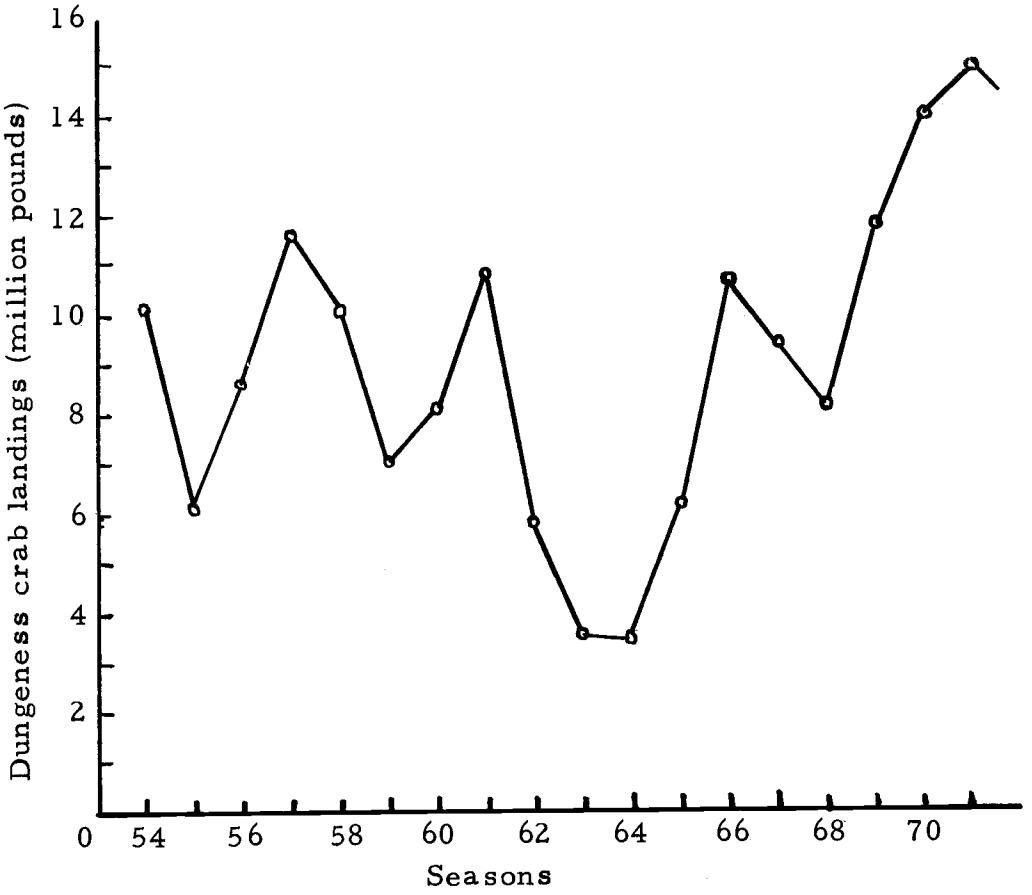

Figure 3. Seasonal landings of Dungeness crab in Oregon.

Harvesting

The Dungeness crab fishing seasons open and close in different months of the year according to the area. Regulations governing the minimum crab size also varies. Oregon's crab season extends from the first of December to the fifteenth of August, and the minimum legal size of a male crab is six and one-quarter inches across the carapace (Figure 4). A Dungeness crab of this size will weigh from one and a quarter pounds to three pounds and will have a meat yield

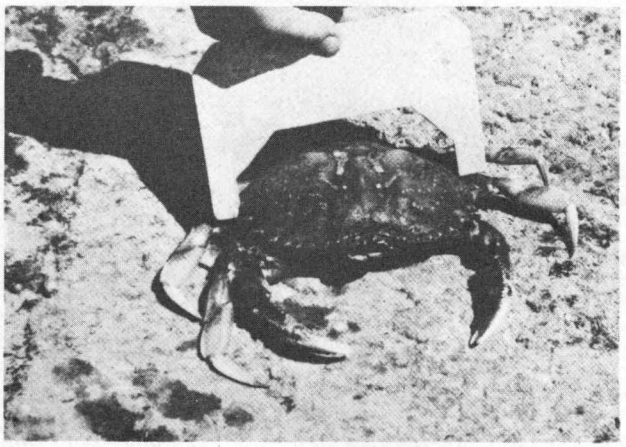

Figure 4. Measuring a crab across the carapace.
(Photograph courtesy of Jay Long)

of from 19 to 25 percent of its harvested weight.

Harvesting is accomplished by the use of pots and ring nets. The baited pots are allowed to "soak" from one to eight days, depending upon weather and rate of catch (5). Upon inspecting the catch, legal size male crabs are placed in holding tanks, while the females, undersized and motling crabs are tossed back (Figure 5).

Processing

The live crabs are then delivered to seafood processing plants, which are generally located on docks near the unloading facilities. At this point, the crabs are sorted into three groups according to size and quality: 1) large prime crabs with undamaged body shells and appendages which are marketed whole; 2) dead and very weak crabs

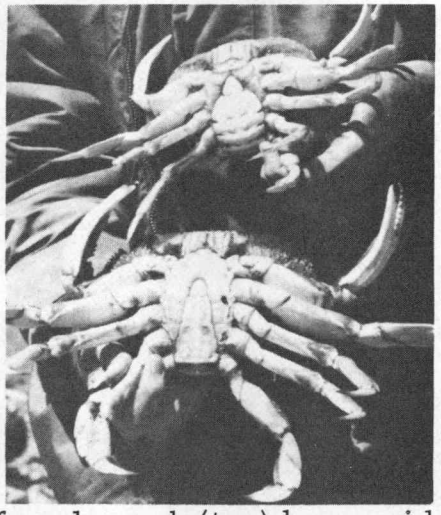

Figure 5. The female crab (top) has a wide sternum or shell flap on the underside. The male (bottom) has a narrow sternum.
(Photograph courtesy of Jay Long)

which are discarded; and 3) the other crabs which are picked for fresh or frozen packaged meat.

The prime crabs are processed and sold on the fresh market as shell or whole crab. These crabs are killed by boiling them in a brine solution from 15 to 20 minutes, depending on their size. After cooking, they are cooled in fresh cold water and the shell is brushed to improve appearance. The shell crabs are packed in ice, or frozen, before shipment to the fresh market. Approximately 30 percent of the crab processed in Oregon is sold as whole or shell crab, with the remainder being marketed as crab meat.

Processing of crab meat involves more operations, equipment and personnel than does the shell crab processing (5, 6). The crabs

are butchered by removing the carapace, the viscera and gills. This is the process that kills the crab. The butchered and cleaned crabs may or may not be broken into two sections before cooking. The sections are cooked in water at 210° F. to 212° F., or steam at 212° F. to 220° F. for 10 to 14 minutes, depending on the crab's physiological condition, and the type of cooker.

Cooked sections are cooled either by submerging in a water bath or by a water spray. Proper cooling is essential for easier meat removal because it loosens the meat from the shell. Once the sections are cooled, they are distributed to the picking tables where the meat is manually removed from the shell. After being weighed, the meat is placed in a salt brine solution (90°-100° salinometer (5, 6)) where the meat floats and the heavier shells and tendons sink to the bottom. The meat is then rinsed in fresh water to remove the salt and drained, before going to the packing tables to be placed in metal cans, weighed and vacuum sealed. The cans are usually packed with a layer of leg meat on top of body meat.

Marketing

The 1920's introduced new forms of marketing Dungeness crabs on the North American Pacific Coast. Prior to 1920, Pacific Coast Dungeness crab was marketed in only one form - freshly cooked shell or whole crab (7). During that time, foreign imports dominated the

domestic canned crab meat market. Now, however, the Dungeness crab is marketed in three different forms: 1) whole crab, fresh or frozen; 2) fresh or frozen meat; and 3) canned meat. Almost 85 percent of the total harvest is marketed fresh and frozen, either as whole crab or as picked meat, in states west of the Rocky Mountains (1).

As a summary, the crab system after harvesting, that has been briefly described above, is illustrated by the use of a schematic diagram (Figure 6).

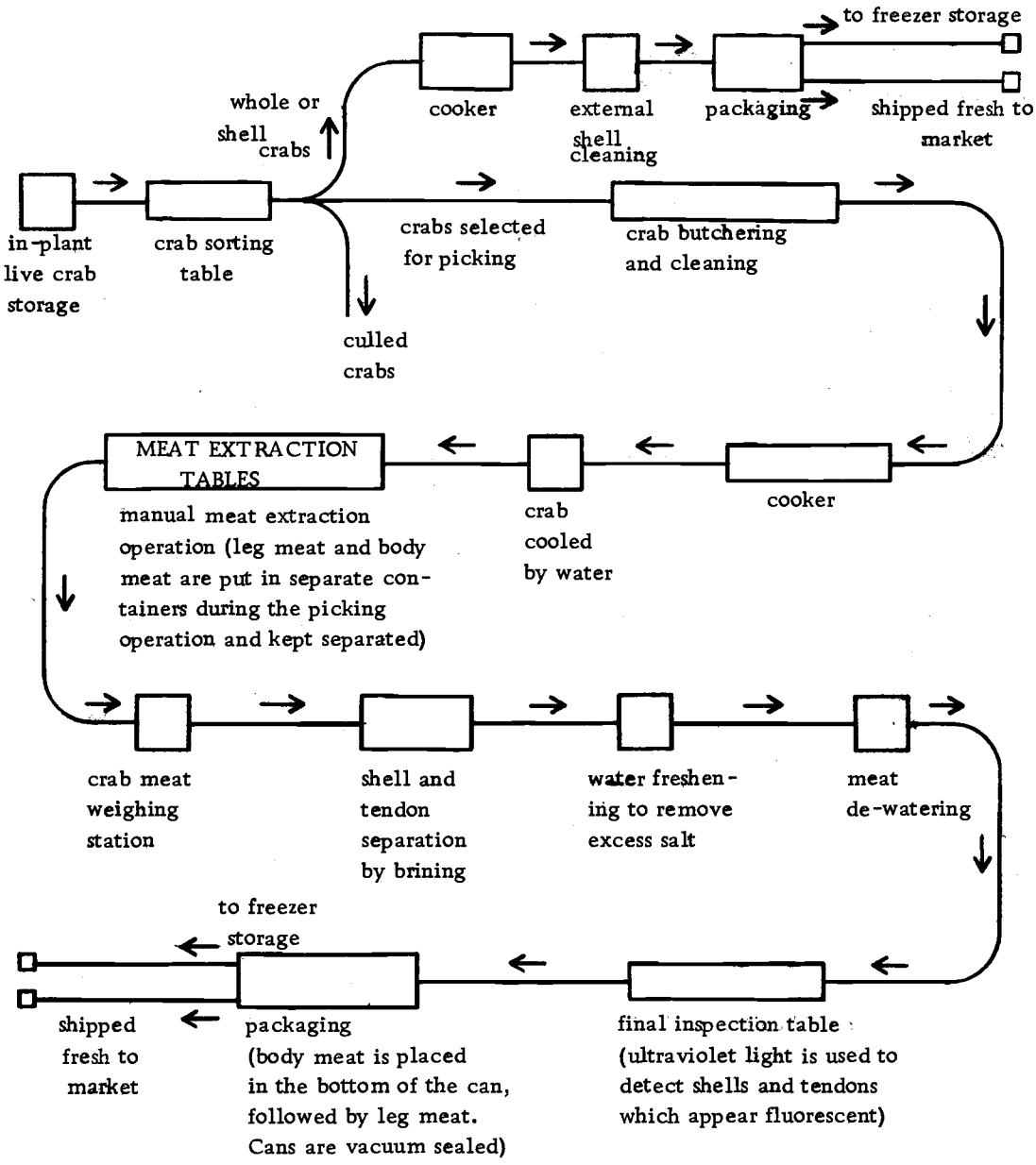

Figure 6. Schematic of a typical in-plant Dungeness crab processing system.

II. DUNGENESS CRAB MEAT EXTRACTION

The cost of meat extraction is the greatest single cost in processing Dungeness crab (Figure 7). Due to the increase in the minimum wage and the limited supply of seasonal labor, meat extraction is one of the major problem areas facing today's seafood processor.

New Federal legislation threatens to enlarge the costs attributed to meat extraction. Unfortunately too, many processors were hit hard economically when the minimum wage went from $1.40 to the current rate of $1.60 per hour. Some unionized plants have a minimum wage of up to $1.75 an hour. Thus, if the new proposed minimum wage of $2.20 an hour is effected, many packers, whose profits now are marginal, would be driven out of business (8). Many processors agree that such an increase would make it difficult, if not impossible, for any but the most skilled to pick enough meat to even pay their own wage[4/].

Picking rates vary considerably among individual pickers. A fast picker working on good crabs may earn as much as $3.50 an hour at the present picking rate, yielding meat in a quality form and leaving minimal amounts of meat in the shells or bones. However, on

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[4/] Although crab meat pickers are paid on a per pound basis, they are guaranteed the Federal minimum wage rate should their overall daily hourly-poundage wage be less than the minimum.

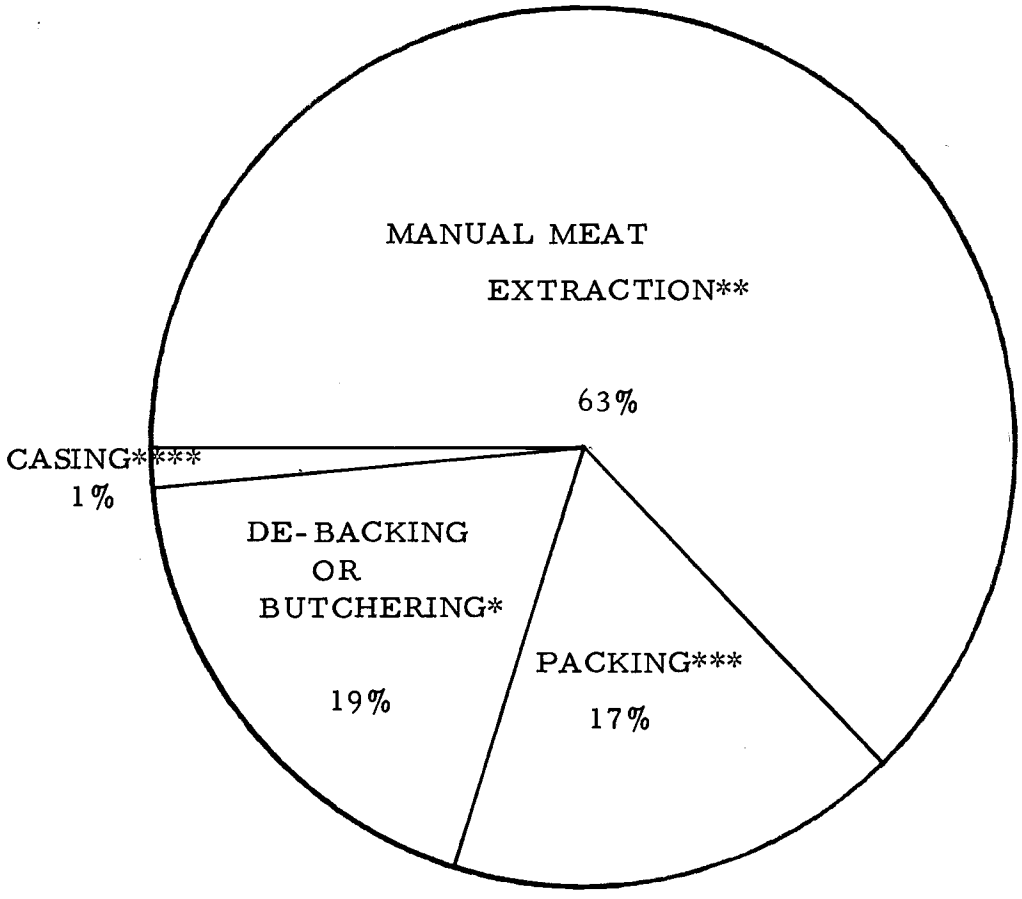

Figure 7. The percentage of total labor cost for processing crab meat is shown for activities comprising the processing system[5/].

[5/] Average values of confidential information obtained from Oregon Seafood Processors, 1971.

* Butchering labor includes the labor of butchers, foreman, lady picking supervisor and miscellaneous labor.

** Manual meat extraction labor includes the labor of pickers.

*** Packing labor includes the labor of inspectors, can packers and associated miscellaneous labor.

**** Casing labor includes the labor of those who put the product into storage.

the same crab, at the same piece rate, a slow picker may earn only $1.00 an hour. The processor must make up the difference between the actual $1.00 earned and the guaranteed minimum wage. Generally, one-third of the pickers can earn their quota regardless of the type of crab they pick. The second third are average, earning just enough to meet the minimum wage most of the time. The last third, not being able to meet the minimum quota, must be paid make-up pay. The above classification would imply that about one-third to one-half of the crab pickers in a typical plant occasionally or never meet the minimum piece rate quota that would equal the minimum wage. Therefore, the packer has two alternatives in dealing with these individuals, either to lay them off or to pay make-up wages.

The labor shortage of seasonal workers, however, quickly eliminates the first alternative from being enacted extensively. According to Youde and Wix's survey of 11 Oregon seafood processors, "most firms indicated that picking labor, not plant capacity, was the limiting factor in their operation" (9, p. 14). The location of the fisheries in small coastal communities seems to limit the supply of seasonal labor available for crab picking. Thus, the second alternative, paying make-up pay, has been the only reasonable course open to many processors.

It is imperative that something be done to counteract the increasing meat extraction costs and labor shortage. Alternative

solutions to offset increasing costs and labor shortages include: 1) development of an automated picking process or machine, or 2) identification or development of techniques to simplify and improve manual meat extraction.

Mechanical Method

Although there is a current trend toward mechanization, the Dungeness crab fishery has seen only a few significant technological changes in equipment over the past 30 to 40 years (5). The quasi-cyclical nature of the catch tends to make packers leery of investing large sums of money in equipment that has a long payback period. The fact that only a small amount of equipment complementary exists between Dungeness crab and the other fish products, tends to further justify the processor's reluctance to invest. The exception is the firm that processes both crab and shrimp, since some of the same processing equipment is used to process both items (10).

Many attempts to develop machines for automated crab meat extraction have been undertaken in the past and efforts in this direction are still underway. Most of the effort has been in developing picking machines for the Atlantic Blue crab (*Callinectes sapidus*), the Queen crab (*Chionoecete opilio*) and the King crab (*Chionoecete bairdii*) industries. With some modification, any successful accomplishments in these areas could be applied to the Dungeness

crab fishery.

The title of John Frye's article in the National Fisherman sums up the state of the art of mechanized meat extraction: "The Problem of Automating Crab Picking Continues to Defy Solution" (8, p. 111). A report analyzing six prominent crab meat extraction machines, prepared by FMC Corporation's Central Engineering Laboratories for the Bureau of Commercial Fisheries, is the basis of Frye's statement. The conclusions of the FMC report were that several picking machines could be available in the near future, but "none of the machines observed can extract lump meat that equals the quality of that picked manually" (11, p. 2). The report also emphasized that equipment soon to be available, or presently under development, would not be economical for small processors employing fewer than 20 pickers (11). There are a number of Oregon's crab packers that employ 20 or fewer individuals. These processors would have difficulty funding the initial costs of a machine or family of machines costing from $4,000 to $30,000 (11).

The majority of processors will not purchase any automated crab meat pickers until many important questions are answered. S. L. Simpson, British Columbia Crab Fishery Specialist, suggests the following list of questions for evaluating mechanized crab meat extraction equipment (12, p. 139-142):

1. "Will it assist plant sanitation and bacterial control?

2. "Does it make for a fast steady product flow?

3. "Will it ensure effective, reliable control of that part of the process for which it is designed?

4. "Does the method produce as good quality as hand shucking - that is, as regards retention of pigment, and 'chunkiness' of broken meat?

5. "Does the yield compare favorably with good hand shucking?

6. "Is there a definite, over-all reduction in shucking cost?

7. "Do the advantages justify the capital expense and maintenance costs?"

There is presently no single machine that meets all the requirements listed above. Complete mechanization does not seem imminent, but partial mechanization does show some promise. Rollers, compressed air, vacuum and water pressure are the basis for different methods that have been suggested. Simpson (12, p. 142) captures the gist of the mechanization situation by stating, "Whatever happens it looks as if working out a mechanical method that will fulfill every requirement will not be easy, and hand shucking is liable to be around for a long time yet." Thus, development of a completely automated picking machine, the first alternative to offset increasing costs and labor shortage, must be shelved as a means of alleviating the problem in the near future.

Manual Method

Disregarding the first alternative as an immediate cure-all

for the increasing meat extraction costs, the second alternative, identification or development of techniques to simplify and improve manual meat extraction, was explored as a possible means of relief. An extensive literature search was conducted to obtain information on work that had been done to identify or develop techniques to simplify and improve manual meat extraction. A personal communications survey[6/] of Federal and State (Oregon and Washington) fishery agencies, as well as seafood processors, was also carried on to uncover any investigations that had been done in this area.

The literature search and personal communication survey proved unrewarding, as far as pointing to any written documentation of tests or studies aimed at improving manual meat extraction. There is no documentation of any rigorous systematic approach to the improvement of manual picking. It appears that all existing picking methods have evolved through trial and error.

Manual tasks that evolve through trial and error, readily lend

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6/ Personal communication occurred with the following: Mr. Priddy, Librarian, U. S. Department of Commerce National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Center, Seattle, Washington; C. Dale Snow and Associates, Shellfish Investigations, Oregon Fish Commission, Marine Science Center, Newport, Oregon; Bob Robertson, Fisheries Specialist, Washington State Fisheries Department, Olympia, Washington; Don Giles, Marine Extension Service, Marine Science Center, Newport, Oregon.

themselves to improvement when analyzed from an engineering viewpoint. Thus, the second alternative appears to hold the key to a solution that will possibly counteract the increasing meat extraction costs. The remainder of this paper will concentrate on the design and evaluation of improved manual Dungeness crab meat extraction methods, through the application of methods improvement techniques.

III. METHODOLOGY

"Methods improvement is a systematic technique of studying and improving a work situation so that people are able to do better work with less effort and do it in less time without hurrying and with greater safety and at less cost" (13, p. 176). The following three assumptions are made in methods improvement studies (13):

1. "When a task can be done in several ways, there is usually one of these ways that is more effective than the others.

2. "When the 'best' ways of doing several activities that make up a task are combined, a more effective way of accomplishing a task is created.

3. "Methods are improved through methodical thinking rather than through undisciplined ingenuity."

Methods improvement is not only concerned with process analysis, an over-all study of the crab process, and operation analysis, an intense study of a single operation in the process (crab picking), but also synthesis. In other words, a problem to which this systematic problem-solving technique is applied, is not only analyzed, but it is also solved.

Methods improvement is not a speed-up program, a scheme for getting more work out of an employee, nor a plan to benefit management at the employee's expense. Rather, it is a technique for eliminating unnecessary work, waste motions, and duplication of effort (13). It makes work easier, and enables the employee to turn

out more product and, thereby become more valuable.

Crab meat extraction will be scrutinized in terms of skill[7/], time and cost factors. Such factors influencing skill level include the individual, plan and control, materiel, necessity of motion, rhythm and speed. An explanation of each factor follows (14);

1. Individual aptitude - Inherent characteristics, such as perception, coordination, dexterity and intelligence.

2. Plan and control - The mental work which accompanies the physical work; and the coordination of regulated muscle movements.

3. Materiel - The correct tools and proper use of tools; proper material and proper condition of material (crab sections).

4. Necessity of motion - Length of distances moved; reasonable number of occurrences of a specific basic act; and optimum movement type.

5. Rhythm - Minimum number and length of delays for a specific type of activity; proper timing so that a minimum number of delays exist.

6. Speed - Eye-hand coordination, restricted motions, and relative speed in performing an operation.

[7/] Skill is one's proficiency in performing a specific activity.

Six Step Technique for Methods Improvement

The following summarizes the six steps that will be applied to the methods improvement problem of improving manual crab meat extraction skills to reduce picking cost.

1. Description of the Current Method

    a. Observation
    b. Discussion with others
    c. Motion pictures
    d. Micromotion study

2. Analysis of the Current Method in Terms of the Six Skill Factors

    a. Indirect factors

        1) Individual aptitude
        2) Plan and control

    b. Direct factors

        1) Materiel
        2) Necessity of motion
        3) Rhythm
        4) Speed

3. Development of the Improved Method

    a. Development of a proposed improved method in terms of the six skill factors
    b. Evaluation of the proposed improved method
    c. A summary of the improved method in terms of the six skill factors
    d. Projected savings of improved method over the current method

4. In-plant Experimentation of the Improved Method

    a. In-plant trial application

5. Implementation of the Improved Method

   a. Training aids

6. Evaluation of the Effectiveness of the Improved Method

   a. Design of experiment

IV. DESCRIPTION OF THE CURRENT CRAB MEAT EXTRACTION METHOD

Oregon seafood processors were encouraged to participate in the research effort. Their cooperation was not only essential as far as a source of data, but also necessary if an improved meat extraction method was to be implemented. The rank-and-file worker, as well as the management, feels less resistance to change if he has a hand in making the change. Furthermore, personnel involvement often eliminates the attitudes attributed to those who resist change, e.g., lack of understanding and loss of security (13).

Three seafood processing plants agreed to participate in the crab meat extraction study. The management of each plant acknowledged that any improvement in this area would be beneficial. Thus, they encouraged investigations to start at once. The plants' employees were then informed of the intent of the study and what would be expected of them in the way of cooperation.

Observation

Observation was the first procedure used for gathering information of the current crab meat extraction method. The analyst observed the in-plant crab processing to become better acquainted with the interrelationship of individual operations within the crab system. However, observation alone was not sufficient to give a

complete, informative picture of what was actually occurring during the various stages of crab processing.

Discussion with Others

Discussion with the crab pickers and their supervisors, combined with observation, gave the analyst a complete picture of crab processing (Figure 6). Discussion was also the initial tool used by the analyst to promote personnel involvement in the methods improvement study. A good human relations foundation was developed through discussion, and involvement of those closest to the job, namely the crab picker.

After gaining an overall view of crab processing, attention was focused on the crab meat extraction operation. The picker's work place consisted of a flat table top, which varied considerably in area from plant to plant (Figure 8). On some tables there were partitions

Figure 8. Pickers at work area.

separating work areas. The pickers stand on bare concrete floors, in front of the tables which are of a fixed height.

Cooled crab sections are distributed to pickers in batch lots (Figure 9). The meat from these sections is manually extracted

Figure 9. Crab sections to be distributed to pickers.

from the shell, or bone by women pickers. The equipment used in meat extraction includes a hammer, anvil, and two picking pans, one for leg meat and one for body meat (Figure 10). The meat is shaken out by hitting the section on the edge of the pan (Figure 11). The hammer is used to crack the leg shell prior to shaking out the leg meat (Figure 12). Leg meat and body meat are kept separate from each other because of the industry-wide practice of packing choice whole leg pieces on the top layer of No. 10 cans for appearance

(Figure 13).

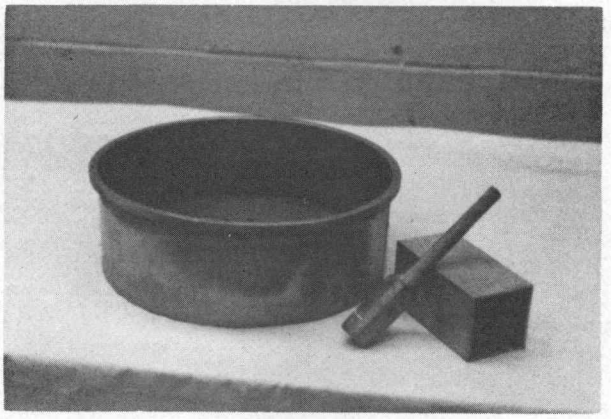

Figure 10. Pan, hammer and anvil used in crab meat extraction.

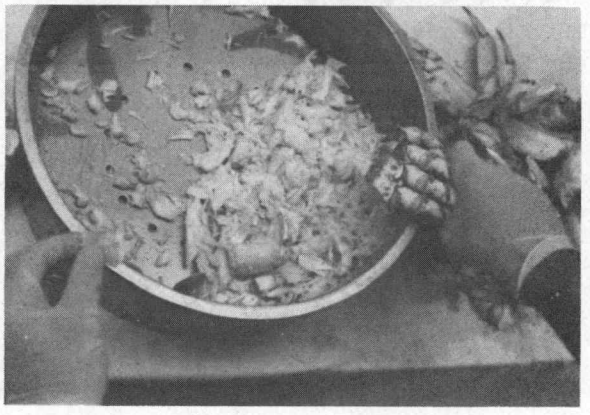

Figure 11. Shaking out body meat.

Figure 12. Cracking leg shell with hammer.

Figure 13. Choice leg pieces placed on top of body meat in No. 10 can.

The meat extraction method used for picking, not only varied from plant to plant, but also from individual to individual within the

same plant. The method subscribed to in each plant has been the result of a long trial and error history and is normally the one the "floor lady," or woman supervisor for the crab pickers, has found acceptable after years of experience as a picker herself.

Motion Pictures

Data Gathering with a Camera

Motion pictures provided a more detailed and accurate procedure for gathering data for analysis of crab meat extraction. This technique was used for recording and timing the short-cycle, highly repetitive manual picking operation.

A Braun-Nizo, Model S-80, Super 8 movie camera was used to film the picking operation. The camera was considered sufficiently accurate to be used also as the timing device. Motion pictures were taken at twenty-four frames per second (FPS) to obtain the proper amount of detail for analysis.

Four skilled crab pickers were selected from the three participating seafood plants. The respective plant supervisors recommended these employees on the basis of picking speed and technique. Thus, the women photographed were above average pickers in terms of their normal daily production output.

Close-up motion pictures were taken of the picking operation.

Permission and cooperation was obtained from the foreman and pickers before the pictures were shot. Involvement brought about willing participation and produced a relaxed working atmosphere.

Since the film contained an exact record of the operation, it was studied in order to construct charts that would illustrate the observed motion patterns.

Micromotion Study

The purpose of the film analysis is to establish a representative description of crab meat extraction as practiced by skilled operators in today's seafood industry. The current method will be a summary of the overall industry methods used and will be applicable to the industry as a whole, with limited application to its parts.

For analysis, the crab meat extraction operation was divided into the three general suboperations of 1) body meat extraction (Figure 14); 2) claw leg meat extraction (Figure 15); and 3) leg meat extraction (Figure 16). These respective body parts make up a crab section (Figure 17).

Simultaneous motion-cycle (simo) charts were developed by counting film frames associated with the respective motions of the left and right hand. Nadler (15, p. 142), defines a simo chart as a "detailed symbolic, systematic, and time presentation of the method of work, as recorded by motion pictures, performed by the body

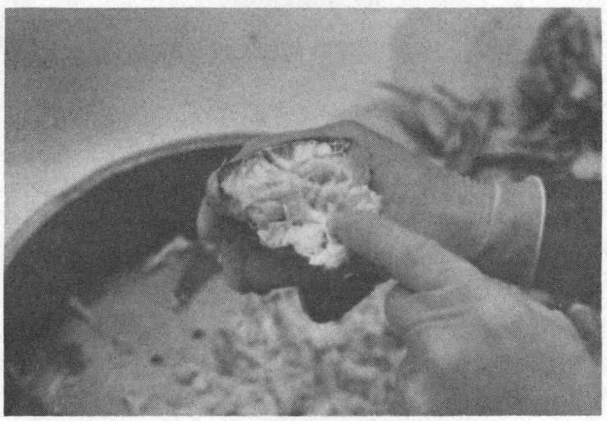

Figure 14. Body cavity from which the body meat is extracted.

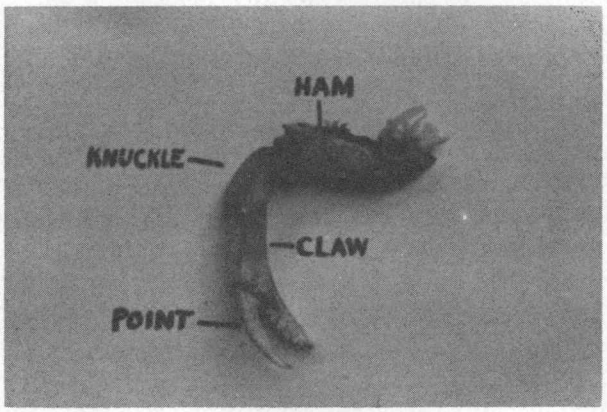

Figure 15. A crab claw leg from which claw leg meat is extracted. The claw leg consists of the ham (merus) section, knuckle (carpus), claw (manus), and point (dactylus).

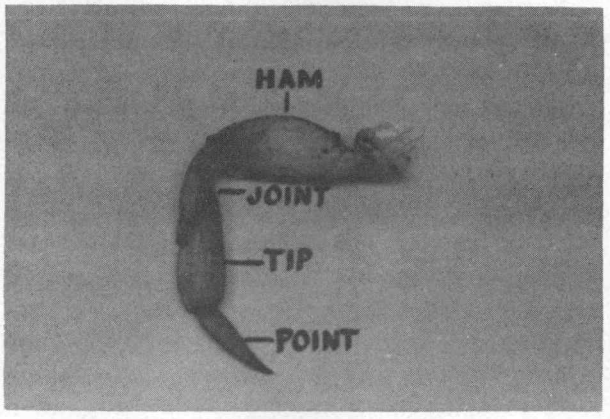

Figure 16. A crab leg from which leg meat is extracted. The crab leg is made up of the ham (merus) section, joint (carpus), tip (manus), and point (dactylus).

Figure 17. A crab section composed of one half of the crab's body, four legs and a claw leg.

members of a man, usually when the work is at one workplace." From the pictures taken of the four women pickers, a total of ninety-four picking cycles were analyzed, using frame-counting and simo charts, by Viravat Cholvanich (16). Of the ninety-four cycles analyzed, thirty-two cycles were of body picking, thirty-two cycles were of claw leg picking, and thirty cycles were of leg picking.

A summary of Cholvanich's analytical findings for each seafood plant and the establishment of an industry average of skilled pickers for crab picking cycle time is shown in the Seafood Processing Plant Comparison Charts, Tables I, II and III. Each table lists the activities that compose the particular suboperation of crab meat extraction being summarized. The minimum, average and highest frame-counts for each activity are posted adjacent to that activity. Average frame-count values are summed to obtain an average cycle frame-count for each plant. An average frame-count for irregular activities[7/]

[7/] Irregular activities are those activities which occur within a cycle at irregular frequencies and are not found among the written list of activities deemed necessary to accomplish the work cycle. Such irregular activities in the meat extraction operation are: removing shells that have fallen into the meat pan; dropping a body part during the meat removal process and having to pick up the part; occasionally transferring a body part to one's other hand to perform an act that is usually performed by the transferring hand; cleaning off the work table; repositioning of the pile of crab parts; and repositioning the meat pan.

TABLE I. SEAFOOD PROCESSING PLANT COMPARISON CHART OF CURRENT CRAB BODY MEAT EXTRACTION ACTIVITY TIMES OF SKILLED OPERATORS

Activity	Plant F_A	Plant F_B	Plant D	Plant J	Industry Average	Best Plant Average
1. Get Crab	9-14-18*	20-24-32	6-12-18	4- 9-26	15	9
2. Tear Off Claw Leg	7-16-30	6-14-20	12-17-21	7-10-12	14	10
3. Hit Out Body Meat From Claw Leg	14-20-30	10-13-23	18-25-27	10-12-17	18	12
4. Compress Body Portion of Section	4-23-30	-- -- --	7-16-25	17-24-30	16	16
5. Remove Key Bone	19-26-32	32-47-68	12-25-32	11-18-22	29	18
6. Hit Out Body Meat	24-76-100	14-21-30	18-38-65	28-39-61	44	21
7. Separate And Discard Legs	13-22-32	10-35-52	4- 6- 8	5- 6- 9	18	6
Average Cycle Frame-count	197	154	139	118	154	92
Average Irregular Activities Frame-count**	65	51	46	39	51	30
Total Normal*** Picking Time Frame-count	262	205	185	157	205	122
Total Normal Picking Time per Body Section in Seconds	10.8	8.6	7.7	6.5	8.6	5.1

* The three figures represent the minimum, average, and maximum frame-count for each activity. (24 frames = 1 second)

** Cholvanich's (16) analysis indicated that the Average Irregular Activity Frame-count was 33% of the Average Cycle Frame-count.

*** Normal time is the total of regular and irregular activity times, without allowance for fatigue, delays, and personal time.

TABLE II. SEAFOOD PROCESSING PLANT COMPARISON CHART OF CURRENT CLAW LEG MEAT EXTRACTION ACTIVITY TIMES OF SKILLED OPERATORS

Activity	Plant F_A	Plant F_B	Plant D	Plant J	Industrial Average	Best Plant Average
1. Get Claw Leg	4- 9-15*	3- 9-15	2- 3- 7	9-15-21	9	3
2. Tear Off Claw And End Of Knuckle Shell	12-17-25	7-16-28	19-29-35	7-11-13	18	11
3. Hit Out Knuckle Meat	16-24-34	7-17-30	10-15-21	10-17-24	18	15
4. Crack Ham Shell And Tear Off End Of Ham Shell	30-33-36	25-33-41	17-22-58	17-23-38	28	22
5. Hit Out Ham Meat	11-28-44	9-14-17	8-15-20	5-23-37	20	14
6. Tear Off Claw Point	9-17-27	12-22-34	6-10-16	11-17-29	17	10
7. Crack And Remove End Of Claw Shell	27-31-41	18-32-42	17-31-74	45-51-68	36	31
8. Hit Out Claw Meat	4-13-25	3-10-16	6-10-13	5-15-33	12	10
9. Discard Claw Shell	5- 7-12	3- 6- 7	3- 4- 5	4- 7- 9	6	4
Average Cycle Frame-count	179	159	138	179	164	120
Average Irregular Activities Frame-count**	41	37	32	41	38	28
Total Normal *** Picking Time Frame-count	220	196	170	220	202	148
Total Normal Picking Time per Claw Leg in Seconds	9.2	8.2	7.1	9.2	8.4	6.2

* The three figures represent the minimum, average, and maximum frame-count for each activity. (24 frames = 1 second)

** Cholvanich's (16) analysis indicated that the Average Irregular Activities Frame-count was 23% of the Average Cycle Frame-count.

*** Normal time is the total of regular and irregular activity times, without allowance for fatigue, delays, and personal time.

TABLE III. SEAFOOD PROCESSING PLANT COMPARISON CHART OF CURRENT CRAB LEG MEAT EXTRACTION ACTIVITY TIMES OF SKILLED OPERATORS

Activity	METHOD 1 - Single Leg (including tip meat)		METHOD 2 - Multiple Leg (excluding tip meat, averaging 2 legs/cycle)		Industry Average - Single Leg Picking	Best Plant Average Single Leg Picking	Industry Average - Multiple Leg Picking	Best Plant Average Multiple Leg Picking
	Plant F_A	Plant F_B	Plant D	Plant J				
1. Get Leg	6- 8-11*	3- 4- 7	4- 7-15	6-15-25	6	4	11	7
2. Tear Off or Pull Point	9-13-17	2- 5- 9	----	----			----	----
3. Crack Tip Shell	----	12-15-19	----	----	16	13	----	----
4. Hit Out Tip Meat	14-15-17	10-12-16	----	----	13	12	----	----
5. Tear Off Tip Shell And Joint End	9-15-16	10-13-17	11-22-39	9-14-20	14	13	18	14
6. Hit Out Joint Meat	8-16-21	2- 4- 5	12-19-34	15-19-34	10	4	19	19
7. Crack Ham Shell	18-21-30	20-22-26	11-20-24	24-28-29	22	21	24	20
8. Tear Off End of Ham Shell	9-12-21	6- 8-12	5- 7- 9	15-16-18	10	8	12	7
9. Hit Out Ham Meat	5-11-17	5-14-35	15-17-23	14-32-42	12	11	24	17
10. Discard Ham Shell	4- 5- 6	4- 6- 9	2- 4- 8	5- 6- 8	5	5	5	4
Average Cycle Frame-count	117	103	96	130	108	91	113	88
Average Irregular Activities Frame-count**	48	42	39	53	44	37	46	36
Total Normal*** Picking Time Frame-count	165	145	135	183	152	128	159	124
Total Normal Picking Time in Seconds	6.9	6.1	5.6	7.6	6.3	5.3	6.6	5.2
Total Normal Picking Time per Leg in Seconds	6.9	6.1	2.8	3.8	6.3	5.3	3.3	2.6

* The three figures represent the minimum average, and maximum frame-count for each activity. (24 frames = 1 second)

** Cholvanich's (16) analysis indicated that the Average Irregular Frame-count was 41% of the Average Cycle Frame-count.

*** Normal time is the total of regular and irregular activity times, without allowance for fatigue, delays, and personal time.

occurring within the cycle and between cycles is added to this value to calculate a total picking time frame-count. The total picking time frame-count is divided by the film speed (24 FPS) to obtain the total picking cycle time in seconds. The figures in the column under "Best Plant Average," represent the lowest average value of all the plants for each given activity. This column will be considered later in the development of the improved method.

The method of work, represented by the column of numbers under "Industry Average" in Tables I, II and III, can be illustrated by the use of simo charts. The charts are a composite of left and right hand motion patterns making up each activity in a particular suboperation. The motion patterns that occurred most frequently in the plants observed, along with the average time to complete the activity, are shown in Figures 18 through 21. Irregular activities are not incorporated into the charts. Thus, the simo charts depict a general overview of the current methods used in crab meat extraction in today's seafood industry.

The movements of the left and right hands are pictured in the simo charts. The number in the lower right hand corner of each activity box is the time, in frames, required for that activity to take place. The classification of the basic hand motions, in terms of therbligs[8/], ,

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8/ Frank B. Gilbreth coined the word therblig to refer to any of a list of seventeen events which he thought common to all kinds of manual work.

OPERATION: Body Meat Extraction — TIME: 1 UNIT = 4 FRAMES — CURRENT METHOD (Skilled Operator)

ACTIVITY	DESCRIPTION LEFT HAND	BASIC ACT	TIME	BASIC ACT	DESCRIPTION RIGHT HAND
1. Get Crab	Reach for crab section	TE	6		
	Grasp	P, G	9 — 9	UD	Wait
15*	Move to R.H.	TL	15 — 15	TE	Move to L.H.
2. Tear Off Claw Leg	Transfer to R.H.	P, RL	18 — 18	P, G	Grasp claw leg and hold
	Regrasp body section -- pull to loosen claw leg	P, R, U	— 20 — 29 — 29	U	Tear off claw leg
3. Hit Out Body Meat From Claw Leg			35	P	Position to hit
18	Wait	UD	— 40 — 47 — 47	U	Hit out body meat from claw leg (3 hits)
4. Compress Body Portion Of Section	Position on table (or hold and wait for R.H.)	P, UD	51	TL, P	Lay claw leg aside
			56 — 56	TE	Move to crab's body
16	Hold crab section	H	— 60 — 63 — 63	U	Hit, squeeze, or press crab's body
5. Remove Key Bone	Move to R.H.	TL	70 — 70	TE	Move to L.H.
	Transfer to R.H.	P, RL	72 — 72	P, G	Grasp section from L.H.
	Move to key bone	TE	76 — 76	H	Hold section
29	Grasp and pull out key bone	P, G, U	— 80 — 92 — 92	H	Hold body section
6. Hit Out Body Meat	Discard key bone	TL, P	99	P	Position to hit
44	Wait	UD	101 — 100 — 120 — 136 — 136	U	Hit out body meat (8 hits)
7. Separate And Discard Legs	Move to R.H.	TE	141 — 140 — 141	TL	Move to L.H.
	Grasp section	P, G	144 — 144	UD	Wait
	hold and wait	UD	152	U, TL, P	Separate legs from section, hit out sticking body meat, discard leg
18	Move to section	TE	154 — 154		

* This figure represents the industry average activity frame-count of skilled operators. (24 frames = 1 second)

Figure 18. Simultaneous motion-cycle chart of the crab body meat extraction suboperation -- current industry average method of skilled operators.

OPERATION: Claw Leg Meat Extraction			TIME 1 UNIT = 4 FRAMES		CURRENT METHOD (Skilled Operator)	
ACTIVITY	DESCRIPTION LEFT HAND	BASIC ACT			BASIC ACT	DESCRIPTION RIGHT HAND
1. Get Claw Leg	Move to R.H.	TE		3	TE	Move to claw leg
				5	P, G	Grasp claw leg
9*			9	9	TL	Move to L.H.
	Grasp claw leg	P, G	11	11	P, RL	Transfer to L.H.
2. Tear Off Claw And End Of Knuckle Shell				14	P, G	Regrasp claw
			20			
				24	U	Tear off claw
18	Hold claw leg	H	27	27	TL, P	Discard claw
3. Hit Out Knuckle Meat	Position to hit	P	32			
			40	40	UD	Wait
	Hit out knuckle meat (3 hits)	U	45		P, G, TL	
				47		Get hammer
4. Crack Ham Shell And Tear Off End Of Ham Shell	Position claw leg on table and hold	P, H	56	56	P, U	Crack ham shell with hammer
				59	TL, P	Discard hammer
			60			
	Move to R.H.	TL	64	64	TE	Move to L.H.
28	Hold claw leg	P, H	73	73	P, G, U	Grasp and tear off end of ham shell
5. Hit Out Ham Meat	Position to hit	P	78			
			80			
				84	AD	Hold end of ham shell
	Hit out ham meat (3 hits)	U	90	88	TL, P	Discard ham shell
20	Discard shell	TL, P	93	94	TE	Move to claw on table
6. Tear Off Claw Point	Wait	UD	98	98	P, G	Grasp claw
	Move to R.H.	TE	102	100 102	TL	Move to L.H.
17	Grasp and hold claw	G, H	110	110	P U	Reposition claw and tear off claw point
				113	TL, P	Discard claw point
7. Crack And Remove End Of Claw Shell	Position claw on table	P	118		P, G, TE	
				120		Get hammer
	Hold claw	H	133	133	P, U	Crack end of claw shell with hammer
				136	TL, P	Discard hammer
	Move to R.H.	TL	140	140	TE	Move to claw
			140			
36	Hold claw	H	146	146	P, G, U	Grasp and remove end of claw shell
8. Hit Out Claw Meat	Position to hit	P	150			
	Hit out claw meat (2 hits)	U	158	156	AD	Hold claw shell and/or meat pan
12				159	TL, P	Discard claw shell
9. Discard Claw Shell 6	Discard claw shell	TL, P	164	164	TE	Move to next claw leg

* This figure represents the industry average activity frame-count of skilled operators. (24 frames = 1 second)

Figure 19. Simultaneous motion-cycle chart of the crab claw leg meat extraction suboperation -- current industry average method of skilled operators.

OPERATION: Single Leg Meat Extraction			TIME	CURRENT METHOD (Skilled Operator)	
ACTIVITY	DESCRIPTION LEFT HAND	BASIC ACT	1 UNIT = 4 FRAMES	BASIC ACT	DESCRIPTION RIGHT HAND
1. Get Leg 6*	Move to R.H.	TE	6	P, G	Grasp leg
				TL	Move to L.H.
2. Tear Off Or Pull Point 9	Grasp leg	P, G	8	P, RL	Transfer leg to L.H.
			11	TE	Move to tip
	Hold leg	UD	15	P, G, U	Grasp and pull point
3. Crack Tip Shell 7	Position leg on table	P	19	TL, TE, G	Discard point, move to and grasp hammer
			20	U	Crack tip shell with hammer
4. Hit Out Tip Meat 13	Hold and wait	UD	25	TL, P	Discard hammer
	Transfer to RH	TL, P	30	P, G	Grasp leg from L.H.
	Wait	UD	35	U	Hit out tip meat (2 hits)
5. Tear Off Tip Shell And Joint End 14	Move to R.H.	TE	39	TL	Move to L.H.
			40		
	Grasp and tear off tip shell and joint end	P, G, U	49	H	Hold leg
6. Hit Out Joint Meat 10	Discard shell	TL, P	52	P	Position to hit
	Wait	UD	59	U	Hit out joint meat (2 hits)
			60		
7. Crack Ham Shell 22	Grasp leg	P, G	65	TL, P	Transfer leg to L.H.
	Position on table	P	68	TE	
			70	P, G	Move to and grasp hammer
	Hold leg	H	78	U	Crack ham shell with hammer (1-2 hits)
			80	TL, P	Discard hammer
8. Tear Off End Of Ham Shell 10	Move to R.H.	TL	84	TE	Move to L.H.
	Hold leg	H	91	P, G, U	Grasp and tear off end of ham shell
9. Hit Out Ham Meat	Position to hit	P	94		
			96	TL, P	Discard end of ham shell
	Hit out ham meat (2-3 hits)	U	100	AD	Delay
			103		
10. Discard Ham Shell 5	Discard ham shell	TL, P	108	TE	Move to next leg

* This figure represents the industry average activity frame-count of skilled operators. (24 frames = 1 second)

Figure 20. Simultaneous motion-cycle chart of the single leg crab meat extraction suboperation -- current industry average method of skilled operators (tip meat extracted).

OPERATION: Mult. Leg Meat Extraction			TIME	CURRENT METHOD (Skilled Operator)	
ACTIVITY*	DESCRIPTION LEFT HAND	BASIC ACT	1 UNIT = 4 FRAMES	BASIC ACT	DESCRIPTION RIGHT HAND
1. Get Legs			5	P, G	Grasp legs
11**	Move to R.H.	TE	11 11	TL	Move to L.H.
	Grasp legs	P, G	14 14	P, RL	Transfer legs to L.H.
5. Tear Off Tip Shells And Joint Ends			16	TE	Move to tips
			20		
18	Position and hold legs	P, H	29 29	G, U	Grasp and tear off tip shells and joint ends
			32	TL, P	Discard tips
6. Hit Out Joint Meat	Wait	UD	35 35	TE	Move to L.H.
	Transfer legs	P, RL	38 38	P, G	Grasp legs
	to R.H.		40 41	P	Position to hit
19	Wait	UD	48 48	U	Hit out joint meat (3 hits)
7. Crack Ham Shells	Move to R.H.	TE	52 52	TL	Move to L.H.
	Grasp legs	P, G	55 55	P, RL	Transfer legs to L.H.
	Position legs on anvil	P	62 60 62	TE, P, G	Move to and grasp hammer
	Hold legs	H	69 69	U	Crack ham shells with hammer (1-2 hits)
24			72	TL, P	Discard hammer
8. Tear Off Ends Of Ham Shells	Move to R.H.	TL	76 76	TE	Move to L.H.
			80	P, G	Grasp and tear off
12	Hold legs	H	84 84	U	ends of ham shells
9. Hit Out Ham Meat	Position to hit	P	88		
			100 101	AD	Hold ends of ham shells
	Hit out ham		105	TL, P	Discard end of ham shells
24	meat (3-4 hits)	U	108		
10. Discard Ham Shells 5	Discard ham shells	TL, P	113 113	TE	Move to next group of legs

* Activities 2 through 4, dealing with tip meat extraction, were not present in the multiple leg meat extraction cycles analyzed.

** This figure represents the industry average activity frame-count of skilled operators. (24 frames = 1 second)

Figure 21. Simultaneous motion-cycle chart of the multiple leg crab meat extraction suboperation -- current industry average method of skilled operators (tip meat not extracted).

is shown under the "Basic Act" column. Ralph Barnes' (17, p. 136-143) definitions of these hand motions, or therbligs, follows:

1. "Grasp (G): taking hold of an object, closing the fingers around it preparatory to picking it up, holding it or manipulating it.

2. "Transport or move empty (TE): moving the empty hand in reaching for an object.

3. "Transport or move loaded (TL): moving an object from one place to another.

4. "Release load (RL): letting go of the object.

5. "Position (P): turning or locating an object in such a way that it will be properly oriented to fit into the location for which it is intended.

6. "Pre-position (PP): locating an object in a pre-determined place, or locating it in the correct position for some subsequent motion.

7. "Unavoidable delay (UD): a delay beyond the control of the operator.

8. "Avoidable delay (AD): any delay of the operator for which he is responsible and over which he has control."

V. ANALYSIS OF THE CURRENT CRAB MEAT EXTRACTION METHOD IN TERMS OF THE SIX SKILL FACTORS

The current method of crab meat extraction will be analyzed in terms of the direct and indirect skill factors, or direct and indirect factors affecting skill. Engesser (14) points out that every motion is affected by the two sets of factors classified as indirect and direct. The indirect factors are those which have to do with an individual's inherent psychological and physiological traits and which affect an individual's skill potential, namely (14):

1. Individual aptitudes - Inherent characteristics, such as perception, coordination, and intelligence.
2. Plan and control - The mental work which accompanies the physical work; coordination of regulated muscular movements.

The direct factors are those which are directly related to the task being performed by an operator, namely (14):

1. Materiel - The correct tools and proper use of tools; proper material and proper condition of the material (crab sections).
2. Necessity of motion - Length of distances moved; reasonable number of occurrences of a specific basic act; optimum movement type.

3. Rhythm - Minimum number and length of delays for a specific type of activity; proper timing so that a minimum number of delays exist.
4. Speed - Eye-hand coordination; restricted motions; and relative speed in performing an operation.

Check lists and principles of motion economy as posted by Barns (17, p. 191-206, 220) and McCarney (13, p. 225-229), will be applied where applicable, to each skill factor to aid in the interpretation and analysis of the current crab meat extraction method.

Indirect Skill Factors

Individual Aptitudes (First Skill Factor)

The first factor affecting skill, and the first indirect factor, is individual aptitudes.

To perform the crab meat extraction operation satisfactorily, an individual must possess certain inherent characteristics, or aptitudes. An aptitude can be defined as one's capacity to acquire a skill, or one's potential abilities to perform specified physical or mental activities (18). Possession of the necessary aptitudes required for crab picking is essential if an individual is to become a skilled crab picker or shaker.

Determination of the minimum aptitude requirements becomes

paramount, if maximum benefit is to be realized from the development of an improved crab meat extraction method. The task of pinpointing the necessary aptitude requirements was undertaken by the Employment Division of the Oregon State Employment Service, under the direction of Paul E. Kerr, Technical Development and Analysis Section, Salem, Oregon.

The purpose of the Employment Division's efforts was to develop General Aptitude Test Battery (GATB) plant norms for the occupation of crab picker (19). The GATB measures nine aptitudes which have been found to be necessary for satisfactory performance of the activities involved in many different types of manual tasks. Thus, the GATB measures a person's potential for acquiring skill, i.e. learning to do a job quickly and well. The aptitudes measured by the GATB are as follows (18, p. 2):

1. "General learning ability - ability to 'catch on' or understand instruction and underlying principles; the ability to reason and make judgements.

2. "Verbal aptitude - the ability to understand the meaning of words and ideas associated with them and to use them effectively. The ability to comprehend language, to understand relationships between words and to understand meanings of whole sentences and paragraphs. The ability to present information or ideas clearly.

3. "Numerical aptitude - ability to perform arithmetic operations quickly and accurately.

4. "Spatial aptitude - ability to comprehend forms in space and understand relationships of plane and solid

objects. Frequently described as the ability to 'visualize' objects of two or three dimensions, or to think visually of geometric forms.

5. "Form perception - ability to perceive pertinent detail in objects or in pictorial or graphic material. Ability to make visual comparisons and discriminations and see slight differences in shapes and shading of figures and widths and lengths of lines.

6. "Clerical perception - ability to perceive pertinent detail in verbal or tabular material. Ability to observe differences in copy, to proof read words and numbers, and to avoid perceptual errors in arithmetic computation.

7. "Motor coordination - ability to coordinate eyes and hands or fingers accurately so as to make precise movements with speed. Ability to control rapid movements of the hand in accordance with what the eye sees. Ability to make a movement response quickly.

8. "Finger dexterity - ability to move fingers and manipulate small objects with the fingers rapidly and accurately.

9. "Manual dexterity - ability to move the hands easily and skillfully. Ability to work with the hands in placing and turning motions."

An Oregon seafood processing plant provided the Employment Service with a test group for the establishment of GATB plant norms. Hourly piece rate earning was the criterion used to divide the test group consisting of thirty-six female crab pickers into two categories: 1) poor workers and 2) good workers (19). Those individuals whose hourly piece rate earning fell below the current Federal minimum wage rate of $1.60 per hour were considered poor workers; those workers achieving higher hourly piece rate earning were looked upon

as good workers. Thirty-three percent of the 36 pickers were in the poor worker group.

Essential aptitudes for a good crab shaker were determined on the basis of a qualitative analysis of job duties and a statistical analysis of aptitude mean scores, standard deviations, aptitude-criterion correlations and selected efficiences. The following four aptitudes were identified (19, p. 3):

1. "Form perception - important in selecting various sized crab parts for removal of meat according to an established sequence of tasks.

2. "Clerical perception - important in inspection of crab shells as to removal of all meat.

3. "Motor coordination - required in use of eyes and both hands in reaching for and picking up crab parts and knocking out meat.

4. "Manual dexterity - necessary to make a variety of movements with hands and arms in handling crabs and parts, use of hammer to crack shells, and to knock meat out into containers."

Aptitude norms, or minimum requirements, were established for each of the four aptitudes. The effectiveness of the established aptitude norms in the selection of good workers, according to the Employment Division's report (19), is shown in Table IV. This table indicates that in preliminary tests, 77 out of every 100 employees selected by testing will prove to be good workers; whereas, only 67 out of 100 accepted for employment are good workers under the present employee selection criterion.

TABLE IV. EFFECTIVENESS OF NORMS. (19, p. 2)

	Without Test	With Test
Good Workers	67%	77%
Poor Workers	33%	23%

More in-plant tests will be conducted before the Employment Service finalizes an aptitude test for crab pickers. The outcome of the test that was performed should be indicative of future tests, as far as the establishment of necessary crab picker aptitudes. Thus, an individual who has an acceptable amount of the aptitudes of form perception, clerical perception, motor coordination and manual dexterity has the potential for acquiring skill and becoming a proficient crab picker.

Plan and Control (Second Skill Factor)

The next indirect factors affecting skill are described by Lowry, Maynard and Stegemerten (20) as "plan" and "control." Engesser (14, p. 106) summarizes these two factors as follows:

> "Plan is the mental work which precedes the physical work. If an operator is inexperienced, the physical work is likely to be performed more quickly than the mental activities. The hands will move ahead of the mental processes, and there will be delays while the mind decides on the next steps. As the operator gains experience, the mind begins to work ahead of the hands and the time for 'plan' may often be completely

> eliminated especially in highly repetitive short cycle operations.
>
> . . .
>
> "The 'control' factor exerts a similar influence on cycle time. Although the operator knows exactly what to do, he may hesitate many times because he does not have control of his motions. The beginner will use many restricted motions as opposed to the less restricted and more rapid ballistic movements of an experienced operator."

The factors of plan and control usually characterize new employees during their training or learning period (20). However, these factors could overlap in those veteran employees who were not sufficiently trained. Both groups, to varying degrees, hesitate and at times stop their movements completely.

The type and method of on-the-job training appears to influence the time period over which the factors of plan and control effect skill (15). The effectiveness and quality of training varies from plant to plant. Under the present circumstances, the floor lady (woman supervisor of the crab pickers) trains the new employee in the method she has found to be acceptable. Since training is only one of the many responsibilities delegated to the floor lady, she often does not have sufficient time to effectively train a new employee.

Nadler (15) substantiates the fact that an individual reaches his maximum production level faster by consideration of the elements of plan and control in providing an adequate training program. Nadler (15) illustrates the importance of using a training method that is

oriented to increase skill levels of new personnel by learning curves, similar to the one shown in Figure 22. Nadler (15) also points out,

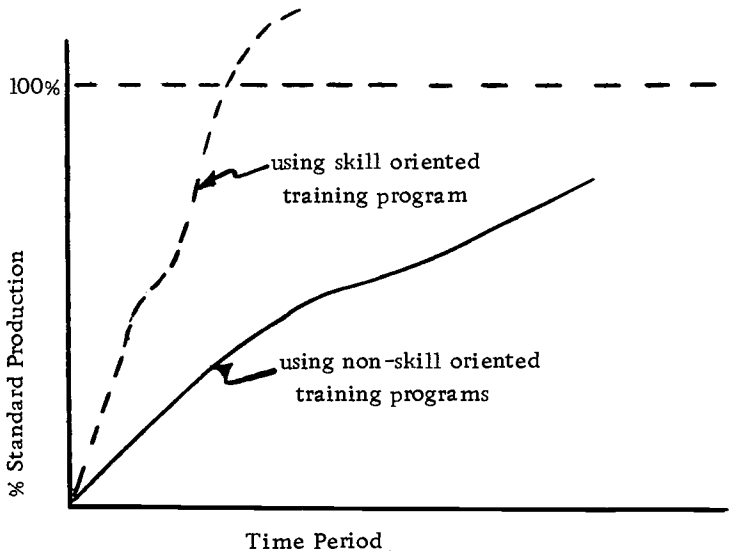

Figure 22. Learning curves illustrate how a skill oriented training program can reduce training time and increase skill levels of new personnel (15, p. 284).

that a training program aimed at raising the skill level of personnel, will usually increase the production of those veteran employees who are not producing at a standard level of production.

Direct Skill Factors

Materiel (Third Skill Factor)

The third factor affecting skill level, and first direct factor, is materiel, which is composed of 1) tools, equipment and the workplace; and 2) materials, or crab sections. The tools used in crab meat extraction consist of a hammer, anvil, and pan. The hammer is used in the suboperations of claw leg and leg meat extraction to crack the appendage's shell. After cracking, the shell can be torn apart to expose the leg meat for meat removal. Two basic hammer configurations exist in the industry. One style has a cylindrical-shaped handle and a rectangular shaped head, all lying in the same plane (Figure 23a). The second type of hammer has a cylindrical-shaped handle and a larger diameter cylindrical-shaped head (Figure 23b). Variations in handle lengths ranged from two inches, which was difficult to grasp, to a length of six inches. The hammer heads were generally of a uniform length of approximately three and one-half inches. The hammers made of aluminum varied in weight due to their dimensional differences. The amount of arm and wrist fatigue produced by a hammer increases with its weight. The weight criterion in hammer design is to have the lightest hammer that will crack the crab shell with minimum effort on the part of the individual user. The weight of the hammer is essentially determined by the

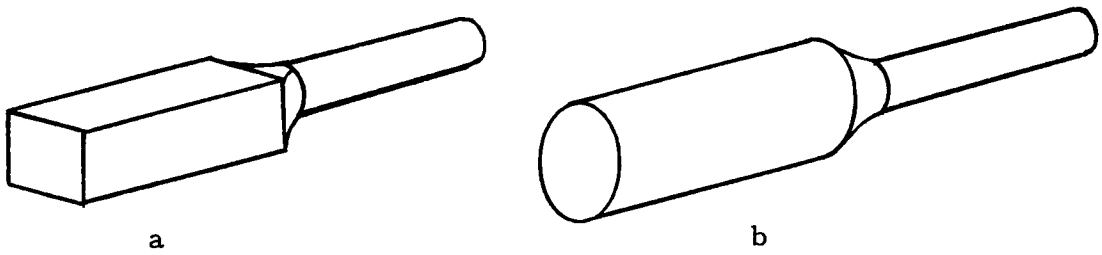

Figure 23. a) Hammer with cylindrical-shaped handle and rectangular-shaped head.
b) Hammer with cylindrical-shaped handle and a larger cylindrical-shaped head.

material used in making it, since the desirable dimensions of the hammer are fixed, as far as general usage is concerned. The aluminum hammers used in processing plants are relatively light, but tend to corrode when brought into contact with salt water used in crab processing.

The hammer with the rectangular-shaped head proved to be the most effective in cracking crab shells[9/]. When a shell is struck with the edge of the hammer head, it will usually separate at that point when torn apart. This makes for more accurate shell separation without disturbing the meat left in the shell. Using a cylindrical-

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[9/] Observations made by author.

shaped hammer head or the flat face of the rectangular-shaped head, tends to flatten out the shell rather than crack it. Extra blows from the hammer will be required if the initial hit doesn't crack the shell. When the shell is cracked, the separating point of the shell is more unpredictable and meat is often torn away with shell removal. Such a flattening blow also tends to mash the meat inside the shell.

The anvil varies in size and shape from plant to plant. The anvil is used as a hitting base when cracking the leg shell. A leg is placed on top of the anvil and the hammer is used to hit the shell at the desired cracking point. An anvil may take the form of a solid piece of cylindrical steel bar stock, or the shape of a railroad track rail in 5 to 6 inch lengths of aluminum, or pieces of aluminum channel, or simply the table top of the work area (Figure 24). The anvil, like the hammer, corrodes in the salt water environment.

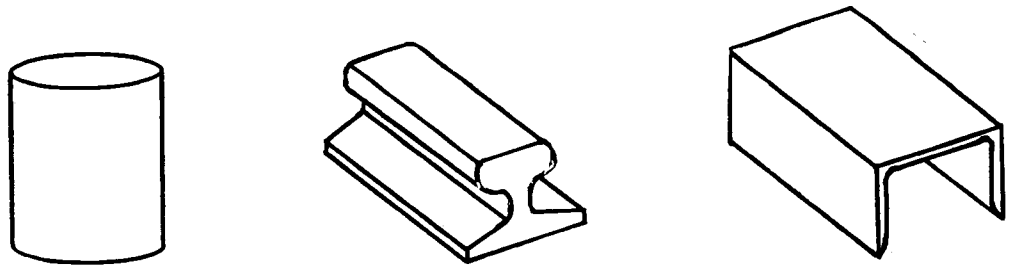


Figure 24. Anvils used in crab meat extraction include;
a) a solid piece of cylindrical steel bar stock;
b) a railroad track rail-shaped piece of aluminum; and
c) a length of aluminum channel.

The design criterion for the anvil is stability, proper distance of the top surface from the table top, adequate flat top surface area for positioning crab parts, and corrosion resistance. All anvils meet the flat top surface area condition, but fail in varying degrees to meet the remaining conditions. The major deficiencies lie in the areas of proper distance of the top surface from the table top and corrosion resistance. The fixed curvatures of the crab's legs and the fact that the hand holding the leg must be along side the anvil for holding and positioning, demands a minimum distance of three inches from the table top to the top of the anvil. Any distance less than this makes positioning of the leg on the anvil very awkward and time consuming.

The picking pan has a major effect on the number of hits required to remove the meat from crab parts. Crab parts are hit against the top edge of the pan, which acts as a hitting bar, to shake the meat loose from the shell (Figure 25). The pans may be round,

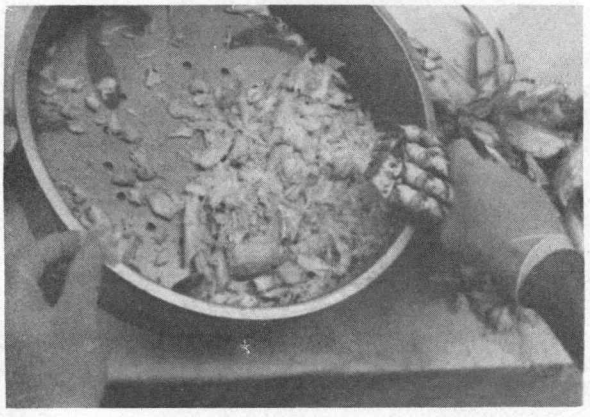


Figure 25. Crab body section being hit against the edge of the picking pan to shake out the body meat.

rectangular, or square, having wide or narrow top rims and drainage holes in the bottom. These pans are made of stainless steel and vary considerably in weight. Stability, in this case closely associated with weight, is essential if the number of hits required for meat removal is to be minimized. Arm and wrist fatigue, as well as overall body fatigue, is directly related to the number of hits made during a work day. Some picking pans had bulges in the bottom, or rounded bottoms, which allowed the pan to wobble and bounce when used as a hitting base. Any movement in the pan lessens the effectiveness of the impact achieved, when striking the shell against the rim of the pan.

The comparison of the number of hits required to hit out the body meat in a plant using unstable pans as opposed to one using heavy stable pans, magnifies the importance of proper pan design. Cholvanich (16) indicated that a maximum of 15 hits for body meat removal, or 65 frames, was required when using wobbly pans, whereas a minimum of two hits for body meat removal, or 16 frames, was required when a stable pan was used. The time difference between these two cases is two seconds per crab section. In this particular instance, a total of four seconds per crab could be saved for useful production if a stable pan were used.

Unstable pans not only require more hits for meat removal, but also eliminates the productive use of overlapping motions[10/].

10/ Overlapping motion is keeping both hands in motion doing different jobs.

An unstable pan requires one hand to hold the pan while the other hand hits out the meat. The hand that hits out and discards the body section must now wait until the hand that held the pan reaches for and grasps the next body section. A stable pan does not require such holding. Thus, in body meat extraction, while the one hand hits out the body meat the other hand is reaching for and grasping the next section. This again is a time saver, approximately ten frames, or 0.41 seconds per section, according to Cholvanich (16).

Although the preceding discussion focused on the suboperation of body meat extraction, the comments are also directly applicable to the suboperations of claw leg and leg meat extraction. The pan is used as a hitting base to remove the claw leg's knuckle, ham and claw meat and the crab leg's tip, joint and ham meat. However, in these suboperations, unlike body meat removal, the palm or edge of the picker's hand strikes the rim of the pan to loosen the meat in the shell (Figure 26). As parts of the leg are picked and discarded, there becomes less and less of the leg to hang on to, this necessitates holding the remaining leg pieces between the fingers. Thus, the impact of hitting the palm, or side of the hand, against the rim must be of such force to be transferred through the hand to the shell held by the fingers in order to dislodge the meat. The rim therefore, must be wide enough, or protected sufficiently to reduce and prevent any damage to the hand. If the pan is to continue to be used as

a hitting base, stability and rim configuration is of utmost importance in pan design.

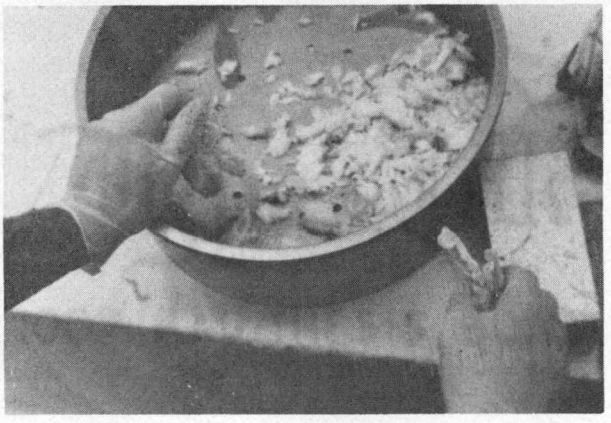


Figure 26. Palm of picker's hand strikes the rim of pan to loosen and shake out leg meat.

Meat recovery and individual picking rates can be increased by providing a meat deflection shield behind the meat pan. During the "hit out meat activities," crab meat was observed going outside the confinement of the pan and landing on the table top or the floor. A deflecting shield would deflect flying meat back into the meat pan.

Equipment

The rubber gloves worn by the pickers are considered to be the most influential equipment in crab meat extraction. The gloves serve to 1) protect the picker's hands from the sharp crab shell and eliminate cuts, and 2) protect the crab meat from contamination due to human contact. However, ill-fitting gloves and gloves that are too thick increase picking effort and time. For example, in body meat extraction, the key bone (Figure 27) must be removed by the fingers to allow the body meat to fall out when shaken. This activity requires that the fingers must slip around the bone, grasp it, twist and pull it out, without removing any of the body meat. Such an operation requires gloves that fit tightly and are thin enough to allow for proper feel. Three things result from improper removal of the key bone: 1) the body meat becomes difficult to hit out, 2) body meat is broken up in pieces, and 3) body meat may be thrown away with the key bone. Awkward and clumsy unproductive effort also results from improperly fitted rubber gloves. All these factors mean time and money to the picker and processor.

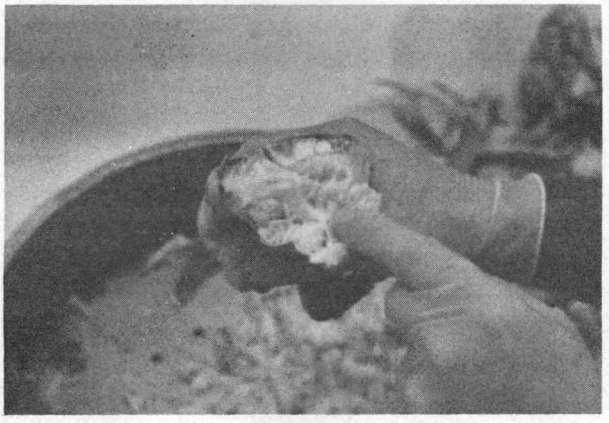


Figure 27. The key bone is located in the midst of the body section and holds in the body meat.

The Workplace

In some cases, the workplace contributes to fatigue and non-productive effort on the part of the crab shaker. Most pickers stand on bare concrete floors, or wooden boards laid on the concrete floor. The employee's legs, as well as their body, feel the fatiguing effect of standing on hard concrete. This in turn produces a restlessness which hampers product output.

Some plants do not provide any means of compensating for individual height differences. The picking tables are a fixed height; thus, some pickers must work bent over, if the table is too low, or

work with arms raised, if the table is too high. Either extreme produces an uncomfortable working situation and reduces an individual's potential of doing satisfactory work. Plants that are aware of this height problem provide wooden boxes or build up layers of boards for shorter pickers. Many times, however, these height raising devices are unstable and distract the picker from her work.

Some table tops are partitioned off and others are not. Partitioning does not seem to be a necessity, but aids in defining each individual's work area. Definite working areas tend to reduce squabbles between pickers which arise 1) when some try to slide small hard-to-pick crab legs to the other pickers (5), and 2) when quarters are so cramped that there is physical interference between pickers. Improper table top construction contributes to uneven or bouncy work surfaces. When not anchored sufficiently, the stainless steel sheeting that is placed over wooden table tops swells up producing a wavy high-low surface. This uneven surface may produce an up and down movement of both the picking pan and anvil, when either is used as a hitting base. The result is an unstable pan and anvil and less efficient picking.

Material (Crab Sections)

Material is the second item composing the first direct factor, materiel. The condition of the material (crab sections), when it

reaches the operators affects their skill level, or proficiency, with which the crab meat extraction operation is performed. The condition of the crab sections also influences the meat yield obtained from the crab. The three most influential operations affecting the condition of the crab sections are; 1) the cooking operation, 2) the cooling operation, and 3) the post-meat extraction handling operations. However, the butchering operation affects yield. A proper butchering operation is essential, if high yields are to be achieved. Adams (5) discusses several adequate butchering procedures.

Ease of meat extraction and maximum yields appear to be a primary function of the time and temperature at which the sections are cooked. It is difficult to arrive at one time and temperature for cooking because of the non-uniformity in the size of the crabs cooked. The problem is somewhat alleviated when shell crab are separated from the crabs to be processed as picked crabs. Such separation reduces the size deviation from the norm of crabs cooked. Ulmer (21, p. 32) indicates, that cooking "... consolidates the meat by coagulating the protein and loosens the meat from the shell so that picking is facilitated." Ulmer (21) further states that either overcooking or undercooking can cause excessive loss of moisture and shrinkage of tissue. This results in difficult picking and decreased yields (21).

Currently sections are cooked either in a continuous cooker

(Figure 28) or in a batch cooker (Figure 29).

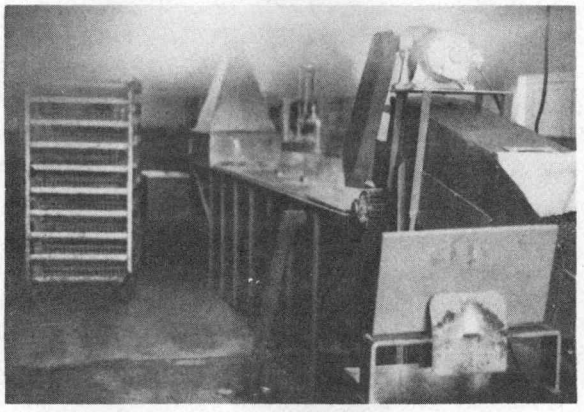


Figure 28. Continuous cooker used in processing crabs.

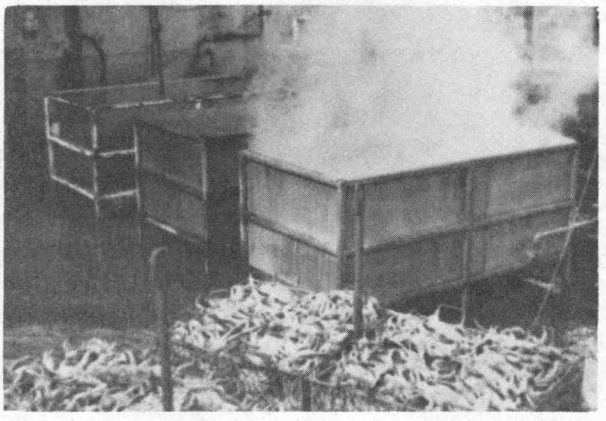


Figure 29. Batch cooker used in cooking crabs.

The continuous cooker provides the following advantages over the batch cooker:

1. Less handling of the product;
2. Fast steady product flow;
3. All crab sections are cooked equally.

An automatic time and temperature control unit could easily be adapted to the continuous cookers used in today's industry. Presently, the time and temperature factors have been arrived at by trial and error and may be increased or decreased depending on the feedback from the crab pickers as to whether the meat shakes out easily or not. Generally, the crab sections are cooked in steam heated water at a temperature of about 212° F. The cook time may vary from 10 to 14 minutes (5).

Proper cooling is also a necessity for easy meat removal and for maximum yields. Dewberry (22, p. 51) states, "The more rapidly the sections are cooled the higher the quality and the greater the percentage of meat recovery." The cooling operation not only stops the cooking, but also shrinks the meat from the shell for ease of meat removal (22). Dewberry (22) further indicates that adequate cooling results in better meat flavor, color, and texture.

Cooked crab sections are cooled either by submerging the sections in a water bath or by passing the sections under a water spray. Tests by Adams (5) point out that either method is adequate,

provided the water temperature is cool enough (less than 50° F). This requires constant circulation of the water in a bath type cooler. Adams (5) observed that cooling in several Oregon processing plants was inadequate and resulted in the following:

1. Increased difficulty of meat extraction.
2. Lower picking yields.
3. Faster bacteria growth.
4. Meat of poor appearance.

The physical condition of the sections as they arrive on the picking table is largely dependent upon the handling of the section in previous operations. Those sections that are damaged or incomplete, that is do not possess four whole legs, one whole claw leg, and a body portion, usually require more time to pick per pound of meat processed than one that is undamaged. The added time is the result of the normal rhythm pattern being disrupted because a certain body member is not present on a particular crab section. Additional time is also needed for the "What do I do now?", or planning phase of the picking operation. Damaged sections tend to reduce the automaticity from the picking cycle and thus increase picking time.

Necessity of Motions (Fourth Skill Factor)

The second direct factor and fourth overall skill factor affecting skill level is the necessity of motion. It has been established

through numerous studies that at least 25 percent of the motions used by the average employee in the average manual type operations are wasted motions (17). The identification and elimination of these wasted, needless motions will reduce operator fatigue and increase production without requiring the expenditure of any more physical effort.

This phase of the analysis will concentrate on determining the necessity of 1) the length of the distances moved, and 2) the number of occurrences of such basic acts of motion as grasp, use, delay, move, hold, and position, and 3) the types of move, grasp, and position that should be employed in the operation of crab meat extraction. The Seafood Processing Plant Comparison Charts (Tables I, II and III), the industry average simo charts (Figures 18-21), and Cholvanich's (16) detailed cycle comparison simo charts of each participating crab picker, will be used along with check lists and principles of motion economy, to identify the necessary movements and motion patterns for each suboperation of crab meat extraction.

Necessity of the Length of the Distances Moved

The distances moved in getting crab body parts and discarding shells or body parts varies from picker to picker. The location of the pile of body sections, claw legs, or crab legs to be picked determines the distance a picker must move to reach the item. The pile

may be to the immediate left or right of the picking pan or at various distances away. Some piles are placed in front of the pan, requiring the picker to reach over the pan. Putting the crab parts into piles, rather than strewing them along the work area, tends to minimize the distance moved in reaching for and grasping a given body part. The distances moved were at a minimum when piles of body parts were placed immediately adjacent to the meat pan and when minimal arm movements were used in discarding shells.

Necessity of the Occurrence of the Basic Acts of Motion

In analyzing the necessity of the occurrence of a particular basic act, each suboperation of the crab meat extraction operation will be scrutinized on an individual basis. The necessity of occurrence of such basic acts as grasp, use, delay, move, hold, and position will be considered. These basic acts are defined on page 42.

The analyses will proceed by inspecting each activity comprising a given suboperation. Major emphasis will be placed on the evaluation of the skilled operator with the best average for each activity. A comparison of the best average motion pattern will be made, where appropriate, with the simulated current industry average simo charts (Figures 18-21). Segments of the respective simo charts will be shown for the activity being discussed.

Crab Body Meat Extraction Suboperation

The suboperation of crab body meat extraction will be investigated first. Both the current cycle times and tentative time savings will be analyzed. Table I and Figure 18 list the activities and basic acts comprising this suboperation. Figure 30 gives a pictorial description of a crab section which is discussed in the following text.

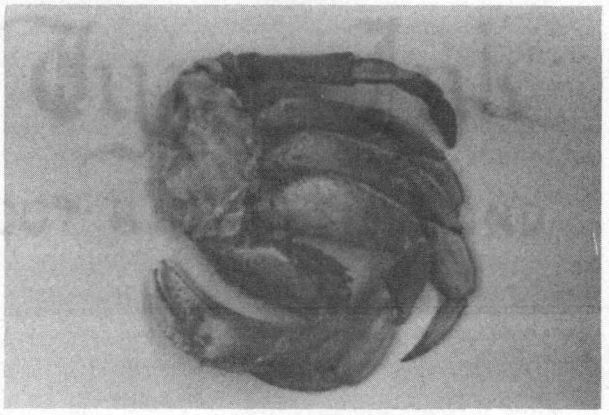


Figure 30. A crab section is composed of one half of the crab's body, four legs, and a claw leg.

"Get Crab" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES	BASIC ACT	DESCRIPTION RIGHT HAND
Reach for crab section	TE	6		
Grasp	P, G	9 — 9	UD	Wait
Move to R. H.	TL	15 — 15	TE	Move to L.H.

The operator from Plant J has the best average for the "Get Crab" activity (Table I). Plant J's operator eliminates the basic act of "delay," by using effective overlapping motion[11/]. This overlapping motion is initiated in the "Hit Out Body Meat" and "Discard" activities. While one hand hits out the body meat and discards the section with the legs attached, the other hand reaches for and grasps the next body section destined for meat extraction. Such overlapping motion can only occur 1) when the "use" basic act (separating the crab legs from the body section before discarding the section) is eliminated, and 2) when the meat pan is stable. An unstable pan requires one hand to hold down the wobbly pan when a body section is hit against the edge of the pan to loosen the body meat.

11/ Overlapping motion is keeping both hands in motion doing different jobs.

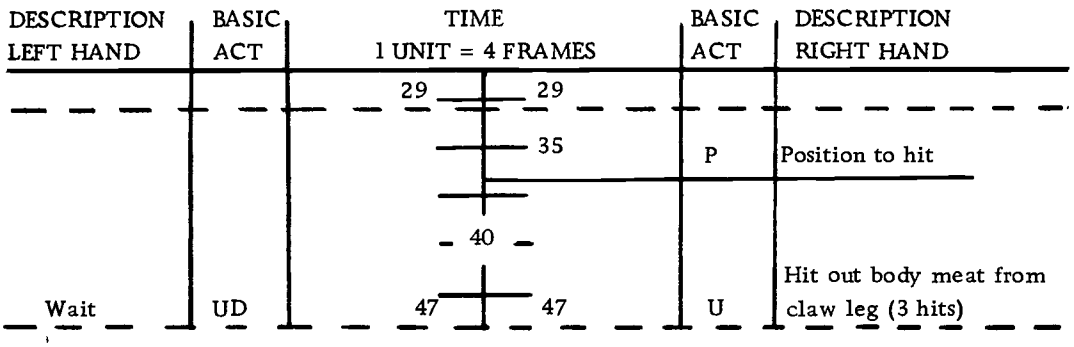
The amount of time spent in reaching for a body section was minimum when the pile of sections was placed immediately adjacent to the meat pan and the hand nearest the pile was used in grasping the section. The savings realized from the use of overlapping motion and moving minimal distances will be an estimated nine frames per section, or .38 seconds per section, since the basic acts of "transport empty" and "grasp" can be performed during the "Discard" activity.

"Tear Off Claw Leg" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES	BASIC ACT	DESCRIPTION RIGHT HAND
		15 15		
Transfer to R.H.	P, RL	18 18	P, G	Grasp claw leg and hold
Regrasp body section -- pull to loosen claw leg	P, R, U	20 29 29	U	Tear off claw leg

The second activity in crab body meat extraction is "Tear Off Claw Leg." In most plants, an unnecessary regrasping of the body section occurs in this activity. The need for regrasping is the result of the left hand indiscriminantly grasping the body section from the pile of sections. The section must then be regrasped by the left hand to provide proper handling when the claw leg is torn off. A minimum time of two frames per body section (.08 seconds per body section) can be saved by eliminating the regrasping of the body section. Regrasping of the section was eliminated when the section was grasped by the body portion of the section when getting a section from the pile. When holding the body portion of the section, the claw leg was easily torn off.

"Hit Out Body Meat From Claw Leg" Activity



The third activity in body meat extraction is "Hit Out Body Meat From Claw Leg." Although most operators shake out the body meat adhering to the claw leg immediately after the claw leg is torn away from the body section, some pickers lay the claw leg aside after tearing off, for future body meat removal. This necessitates additional handling (basic acts of "grasp" and "move") of the claw leg.

The number of hits used to shake out the body meat from the claw leg varies from two to four. An unstable meat pan accounts for part of the variation, while the picker's habit of hitting many times for good measure accounts for the remainder.

Tentative savings will be based on the best plant average (12 frames) for this activity. The hit out activity can easily be accomplished in 12 frames by reducing the number of hits used to a

maximum of two, when using a firm hitting base. The difference between the industry average (18 frames) and the best plant average (12 frames) yields a six frame or .25 second per section savings.

"Compress Body Portion of Section" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
		47	47		
Position on table (or hold and wait for R.H.)	P, UD	56	51	TL, P	Lay claw leg aside
			56	TE	Move to crab's body
Hold crab section	H	63	60 63	U	Hit, squeeze, or press crab's body

The fourth activity composing body meat extraction is "Compress Body Portion of Section." The meat around the key bone must be loosened from the bone and the body's bone network slightly compressed for easy meat and key bone removal. To accomplish the loosening of meat and compression of the bone network, the body portion of the section is 1) laid on the work table or anvil and hit with the palm of the hand (Plant D), or 2) placed between the palm of both hands and squeezed (Plant J), or 3) squeezed by one hand while the other hand holds the section (Operator A, Plant F). If too much pressure is applied to the body section in hitting or squeezing, the body meat will be broken up and come out in an undesirable shreaded

form. Pressing or squeezing the body portion of the section between the hands or in one hand, makes it easier to sense when enough pressure has been applied to the section to loosen the body meat and compress the body bone. This method of loosening the body meat has the potential of yielding a chunky, high quality product. Although the motion pattern is smoother and the quality increased, the time for this activity will be considered to remain the same, until in-plant tests can be made.

Operator B from Plant F does not loosen the meat around the key bone and other body bones before removing the key bone. Although Operator B eliminates this activity, her overall time for activities "Compress Body Portion of Section" and "Remove Key Bone" exceeds that of the other operators. Excessive time results from the meat not being loosened from the body bone and thus sticking in the body cavity.

"Remove Key Bone" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
		63	63		
Move to R.H.	TL	70	70	TE	Move to L.H.
Transfer to R.H.	P, RL	72	72	P, G	Grasp section from L.H.
Move to key bone	TE	76	76	H	Hold section
		80			
Grasp and pull out key bone	P, G, U	92	92	H	Hold body section

The fifth activity in the body meat extraction suboperation is "Remove Key Bone" (Figure 31). The key bone holds the body meat in the body cavity. It was discovered that some operators were

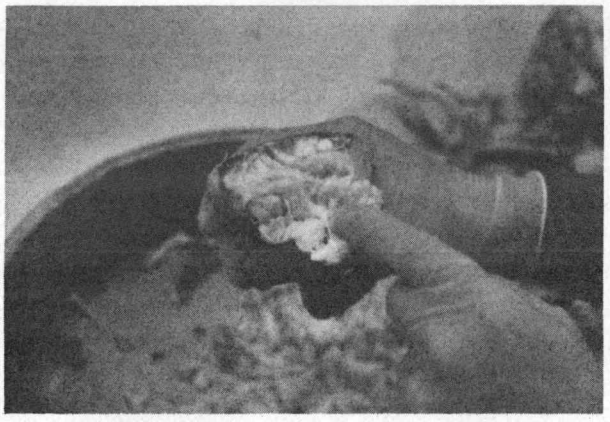
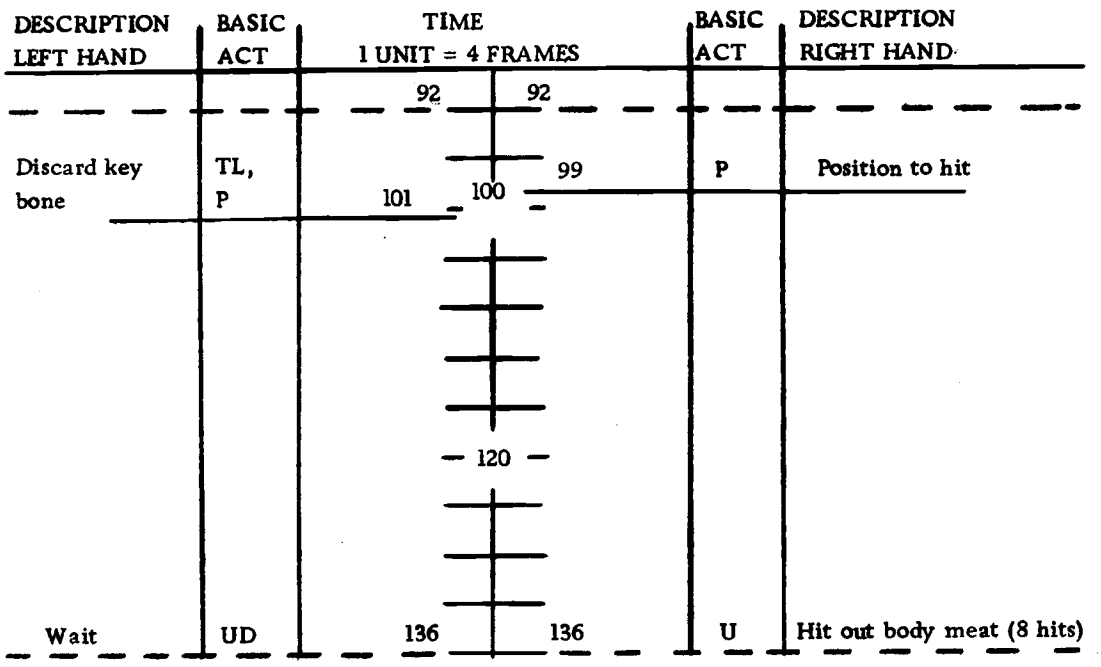


Figure 31. Finger points to the location of the key bone in the body cavity.

uncertain as to the exact location of the key bone. Thus, when removing the bone, these operators put their fingers into what they considered the general location of the key bone and usually pulled out only part of the key bone, along with unwanted body meat. The body meat was discarded with the removed key bone fragments, producing a lower section meat yield.

The proper execution of the basic acts of "grasp" and "use" in key bone removal is essential for effective body meat extraction. Operators knowing the exact location of the key bone and what it looks like, grasp the bone by sliding their fingers around it and remove it with a twisting, pulling action. When the key bone is removed in this manner a minimum amount of meat is disturbed and the meat comes out in high quality chunks when removed from the body cavity. To allow for enough time for clean and proper key bone removal, the industry time average will be used as the representative time to accomplish this activity. Thus, no savings are claimed in this activity.

"Hit Out Body Meat" Activity



The sixth activity making up body meat extraction is "Hit Out Body Meat." The average number of eight hits presently used to shake out the body meat can be reduced significantly. The seven factors which minimize the number of hits required for meat removal are:

1. The proper cooking of the crabs (see previous discussion of this factor under the Materiel section),

2. The proper cooling of the cooked crab sections (see the previous discussion of this factor under the Materiel section),

3. The proper loosening of the body meat in the body cavity,

4. The proper removal of the key bone, that holds in the body meat,

5. The use of a stable meat pan as a hitting base,

6. The use of a combination of rapid arm and wrist movements when hitting the section against the edge of the pan,

7. The awareness, through inspection, that all meat has been removed.

Operator B, from Plant F, combines several of the above mentioned factors and is currently hitting out the body meat in a maximum of three hits. Her plant average of 21 frames will be used as a realistic time for this activity. The time difference between Plant F's operator and the industry average (44 frames), yields a savings of 23 frames per body section, or .96 seconds per body section.

"Separate and Discard Legs" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES	BASIC ACT	DESCRIPTION RIGHT HAND
		136 136		
Move to R.H.	TE	141 — 140 — 141	TL	Move to L.H.
Grasp section	P, G	144 144	UD	Wait
Hold and wait	UD	152	U, TL, P	Separate legs from section, hit out sticking body meat, discard leg
Move to section	TE	154 154		

The seventh and last activity composing the body meat extraction suboperation is "Separate and Discard Legs." Those operators that extract the meat from one crab leg at a time, usually separate the legs from the body section after body meat removal. This activity requires one hand to hold the section while the other hand tears the legs from the section. Any overlapping motion in reaching for and grasping the next section is eliminated since the hand is tied up in holding the section.

The basic acts of "grasp," "hold," and "use" (separate legs) can be omitted by extracting the meat from more than one crab leg at a time as done by operators from Plants D and J. Such multiple leg meat extraction does away with the need for separating each leg from the body section. The hand that held the section during leg separation is now free to reach for and grasp the next body section

while the other hand hits out the body meat and lays aside the body section with the legs attached. A potential savings of 12 frames or .50 second per section can be realized when using overlapping motions and discarding the body section with the legs attached.

Table V summarizes the tentative savings that have been alluded to in the foregoing analysis of the suboperation of body meat extraction.

Crab Claw Leg Meat Extraction Suboperation

In considering crab claw leg meat extraction, both the current cycle times and tentative time savings will be analyzed. Table II and Figure 19 list the activities and basic acts comprising this suboperation. Figure 32 gives a pictorial description of the claw leg.

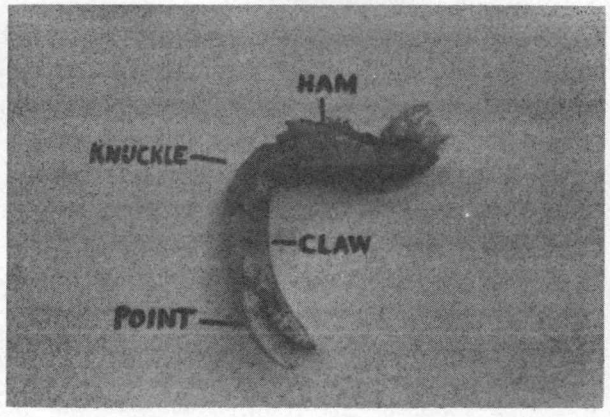


Figure 32. A claw leg consists of the ham (merus) section, knuckle (carpus), claw (manus), and point (dactylus).

TABLE V. SUMMARY OF TENTATIVE SAVINGS FOR BODY MEAT EXTRACTION

Activity	Savings (sec/body section)	Explanation of Savings
1. Get Crab	.38	. Overlapping Motion - one hand should reach for the next body section while the other hand finishes shaking out the meat from the previous section. . Better Work Place Arrangement - the pile of crab sections should be placed immediately adjacent to the meat pan.
2. Tear Off Claw Leg	.08	. Improve Motion Pattern - eliminate transferring and regrasping the body section between hands before tearing off the claw leg, by originally grasping the body portion of the section when getting a section from the pile.
3. Hit Out Body Meat From Claw Leg	.25	. Improve Equipment - provide a firm hitting base to reduce the hits required for meat removal.
4. Compress Body Portion of Section	.00	. Improve Motion Pattern - change the method of loosening the meat around the key bone and body's bone network, by pressing the body portion between the palms of both hands.

TABLE V. Continued:

Activity	Savings (sec/body section)	Explanation of Savings
5. Remove Key Bone	.00	. Improve Motion Pattern - the key bone should be removed by sliding the fingers around the bone, grasping the bone, and removing it with a twisting, pulling action.
6. Hit Out Body Meat	.96	. Improve Equipment - provide a firm hitting base to reduce the hits required for meat removal.
7. Separate and Discard Legs	.50	. Eliminate Activity - eliminate separating the legs from the body portion before discarding the section. . Overlapping Motion - while one hand is discarding the section, the other hand should be in the process of grasping the next section.
TOTAL TENTATIVE SAVINGS FOR BODY MEAT EXTRACTION	2.17	Seconds/Body Section

"Get Claw Leg" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
Move to R.H.	TE		3	TE	Move to claw leg
			5	P, G	Grasp claw leg
		9	9	TL	Move to L.H.

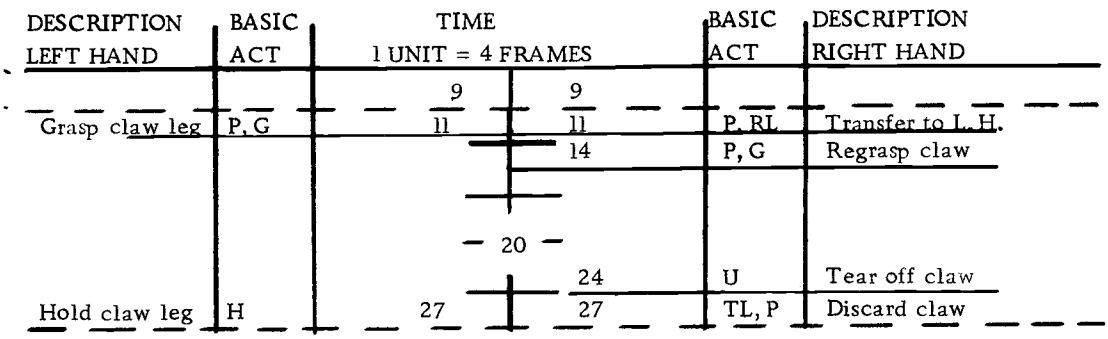
Plant D's operator has the best average for the "Get Claw Leg" activity. Plant D's operator eliminates the basic act of "delay," found in activity eight (Figure 19), "Hit Out Claw Meat," by using effective overlapping motion. This overlapping motion is commenced in the "Hit Out Claw Meat" and "Discard Shell" activities. While one hand hits out the ham meat and discards the empty shell, the other hand reaches for and grasps the next claw leg destined for meat extraction. Such overlapping motion can only occur if the end of the claw shell is discarded immediately after it is torn off, thus eliminating the basic act of "delay"; and if the meat pan is stable. A wobbly pan requires one hand to hold down the unstable pan when a claw leg is hit against the edge to loosen the claw meat.

The amount of time spent in reaching for a claw leg was minimum when the pile of claw legs was placed immediately adjacent to the meat pan and the hand nearest the pile was used in grasping the

leg. The total savings realized from the use of overlapping motion and moving minimal distances will be calculated based on Plant D's average (since overlapping motion is used by this operator) and the industry average. The difference results in a savings of six frames per claw leg or .25 second per claw leg.

High "Get Claw Leg" activity times occur partially because the claw legs and crab legs are intermingled in the pile of body parts. During the body meat extraction suboperation, the claw leg and legs are placed in a common pile. Such mixing of body parts appeared to increase the time for the therbligs of "search" and "select" which compose the basic act of "Grasp." The rhythmic motion pattern is also interrupted when two distinct body parts, each requiring a different motion pattern for picking, are placed in a common pile.

"Tear Off Claw and End of Knuckle Shell" Activity



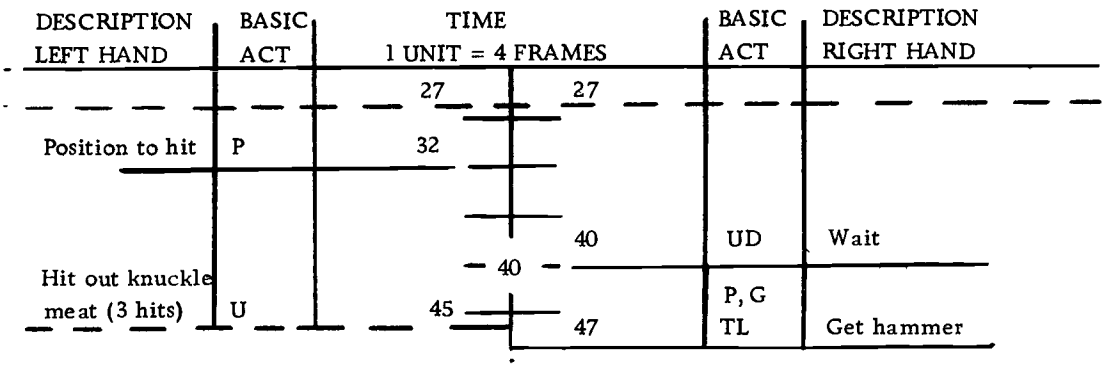
The second activity in claw leg meat extraction is "Tear Off Claw and End of Knuckle Shell." Two of the four operators analyzed tore off the claw and knuckle end and laid it aside to extract the claw meat at a later time in the picking cycle. This action necessitates the double handling of the claw. The other operators avoided the re-handling of the claw by removing the claw meat before tearing off the claw and knuckle end. The omission of the basic acts of "move" (TE) to the claw laying on the table, "grasp" the claw, and "move" (TL) to the other hand in the rehandling activity, will save eight frames per claw leg or .33 second per claw leg. It appears that a change in activity sequence (extracting the claw meat immediately after getting the leg from the pile) and, thus the elimination of the rehandling activity, would be beneficial.

In most plants, an unnecessary regrasping of the claw leg

occurs in this activity. The need for regrasping is the result of the right hand indiscriminately grasping the claw leg from the pile of other legs. The leg must be regrasped by the right hand in order to be in the proper position to tear off the claw. Regrasping the claw can be eliminated if the claw is properly grasped when getting the leg from the pile. An elimination of the regrasping activity carries a potential savings of three frames per claw leg or .12 second per claw leg.

The operator from Plant D uses the hammer to crack the knuckle end of the claw leg before tearing off the claw and end of the knuckle shell. The act of cracking the knuckle end accounts for Plant D's high frame-count of 29 as opposed to the other lower averages of 17 (Plant F_A), 16 (Plant F_B), and 11 (Plant J). Therefore, Plant D can save from 12 to 18 frames per claw leg or .50 to .75 second per claw leg by eliminating the cracking of the knuckle end before tearing off the claw and end of the knuckle shell.

"Hit Out Knuckle Meat" Activity



The third activity in claw leg meat extraction is "Hit Out Knuckle Meat." The claw leg is hit against the top edge of the meat pan to dislodge the knuckle meat from the shell. An average number of three hits is used to hit out the meat. The factors which minimize the number of hits required for meat removal are:

1. The proper cooking and cooling of the claw leg,

2. The amount the shell is opened to allow meat extraction,

3. The use of a stable meat pan as a hitting base,

4. The manner in which the claw leg is held when hitting out the knuckle meat (the ham shell should be hit against the edge of the pan for maximum impact to dislodge the meat),

5. The awareness, through inspection, that all the meat has been removed.

If the above factors are observed, the number of hits required to shake out the knuckle meat can easily be reduced to an average of two, initiating a savings of three frames per claw leg or 0.12 second per claw leg.

"Crack Ham Shell and Tear Off End of Ham Shell" Activity

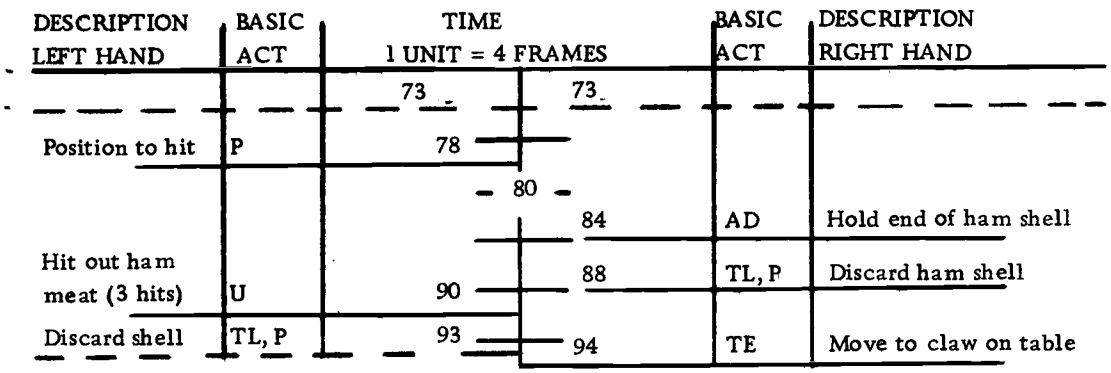
DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
		45	47	P, G T L	Get hammer
Position claw leg on table and hold	P, H	56	56	P, U	Crack ham shell with hammer
			59	TL, P	Discard hammer
Move to R.H.	TL	64	60 64	TE	Move to L.H.
Hold claw leg	P, H	73	73	P, G, U	Grasp and tear off end of ham shell

The fourth activity composing claw leg meat extraction is "Remove End of Ham Shell." All operators use the hammer to crack the ham shell before tearing off the knuckle end of the ham shell to expose the knuckle meat, except the operator from Plant J. Plant J's operator removes the ham shell by tearing off the shell with her fingers. The time required to perform either method of ham shell removal appears to be similar between Plants D and J.

The fact that the use of the hammer can be eliminated, focuses attention on possible improvement of the method of manually tearing off the ham shell. The hammer should be used until further studies can be made on eliminating its use. Savings for this activity can be realized by using overlapping motions (one hand should grasp the hammer while the other finishes hitting out the knuckle meat) and improving the motion pattern (the hammer should be pre-positioned for easier grasping, and the number of hits used to crack the shell should be reduced). The savings attributed to these changes will be the difference between the industry average (28 frames) and the best plant average (22 frames) or six frames per claw leg (.25 second per claw leg).

Ham shell removal must be executed carefully. It is essential that the hams come out in whole pieces, as a premium is paid for unbroken hams. If the hammer is used to crack the ham shell, the blow should not be severe enough to smash and break up the meat. Also, when tearing off the end of the ham shell, care should be exercised to avoid removing meat with the shell when it is torn off and discarded.

"Hit Out Ham Meat" Activity



The fifth activity in the claw meat extraction suboperation is "Hit Out Ham Meat." An average number of three hits is used to shake out the ham meat. The factors which affect the number of hits used in hitting out the ham meat are similar to those mentioned above in the "Hit Out Knuckle Meat" activity. Operator B from Plant F consistently demonstrated that the ham meat can be removed using from one to two hits. Taking the factors mentioned above into consideration, the average number of hits can be reduced to two, or a three frame per claw leg or .12 second per claw leg savings.

The simo chart indicates that during the fifth activity, the right hand holds the end of the ham shell that has been torn off. The shell, however, should be discarded immediately after it is torn off. The right hand should then grasp the claw lying on the table while the

left hand completes ham meat removal and discards the shell (overlapping motion). This overlapping motion would eliminate part, if not all of the wait time found in activity six, "Tear Off Claw Point." Savings will not be attributed to the overlapping motion, since the savings for eliminating the rehandling activity of the claw which commences in the last portion of activity five has already been accounted for in activity two, "Tear Off Claw and End of Knuckle Shell."

"Tear Off Claw Point" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
		93	94	TE	Move to claw on table
Wait	UD	98	98	P, G	Grasp claw
Move to R.H.	TE	102	100 102	TL	Move to L.H.
Grasp and hold claw	G, H	110	110	P U	Reposition claw and tear off claw point

The sixth activity making up claw leg meat extraction is "Tear Off Claw Point." As mentioned earlier, the claw meat should be extracted immediately after the claw leg is removed from the pile of body parts. A minimum savings of eight frames per claw leg or 0.33 second per claw leg was claimed for avoiding the double handling of the claw.

A claw or claw leg that is indiscriminately grasped from the pile usually requires a regrasping process before the claw point can be torn off. Operator A from Plant F avoids regrasping by initially grasping the point of the claw with the fingers that will eventually tear it off. A three frames per claw leg or .12 second per claw leg savings can be realized from properly grasping a leg from the pile.

"Crack and Remove End of Claw Shell" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
		110	110		
			113	TL, P	Discard claw point
Position claw on table	P	118		P, G	
			120	TE	Get hammer
		120			
Hold claw	H	133	133	P, U	Crack end of claw shell with hammer
			136	TL, P	Discard hammer
Move to R.H.	TL	140	140	TE	Move to claw
		140			
Hold claw	H	146	146	P, G, U	Grasp and remove end of claw shell

The seventh activity composing the claw meat extraction sub-operation is "Crack and Remove End of Claw Shell." Usually two to three hits are used to crack the claw shell. However, several operators have demonstrated that a single blow from the hammer is sufficient to crack the shell. Such a reduction in hits can save five frames per claw leg or 0.42 second per claw leg.

Again, care must be exercised not to smash the claw meat when cracking the shell, as premium prices are paid for whole pieces of claw meat. The hammer must strike far enough away from the point end to sufficiently open up the cavity containing the claw meat for easy meat removal.

"Hit Out Claw Meat" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
		146	146		
Position to hit	P	150			
Heat out claw meat (2 hits)	U	158	156	AD	Hold claw shell and/or meat pan
			159	TL, P	Discard claw shell

The eighth activity in claw leg meat extraction is "Hit Out Claw Meat." An average of two hits is used to knock out the claw meat. This average can be set as a maximum number of hits required, as some operators hit out the meat in one to two hits. The factors which determine the ease with which the meat is extracted from the claw shell are:

1. The manner in which the claw is cooked and cooled,
2. The opened cavity area through which the meat must pass,
3. The stability of the meat pan,
4. The manner in which the claw is held during the shaking out process.

Those pickers using unstable picking pans must "hold" the pan while hitting out the claw meat. Such holding retards the use of any overlapping motion, and increases activity time. Since tentatively it appears that a re-arrangement of the activities involving the

removal of the claw meat would be advantageous, only a possible two frames per claw leg or 0.08 second per claw leg savings will be claimed (the difference between the industry average and best plant average from Table II).

"Discard Shell" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES	BASIC ACT	DESCRIPTION RIGHT HAND
		156	AD	Hold claw shell and/or meat pan
		158 159	TL, P	Discard claw shell
Discard claw shell	TL, P	160 164 164	TE	Move to next claw leg

The ninth and last activity composing the claw leg meat extraction suboperation is "Discard Shell." The use of overlapping motion should be employed throughout this activity. While one hand is discarding the shell from which meat was just removed, the other hand should be reaching for the next claw leg. The discarding distance should also be kept at a minimum. The majority of the savings attributable to the use of overlapping motion have been enumerated in the first activity, "Get Claw Leg." The frame-count difference between the industry average and best plant average (Plant D) for this activity from Table II, two frames per claw leg (0.08 second per claw leg), will be considered the possible savings

from the use of overlapping motions and moving short distances in discarding scrap shell.

Table VI summarizes the tentative savings that have been alluded to in the foregoing analysis of the suboperation of claw leg meat extraction.

Crab Leg Meat Extraction Suboperation

The final suboperation to be analyzed is crab leg meat extraction. Both the current cycle times and tentative time savings will be analyzed. Table III and Figures 20 and 21 list the activities and basic acts composing this suboperation. See Figure 33 for a pictorial description of the crab leg.

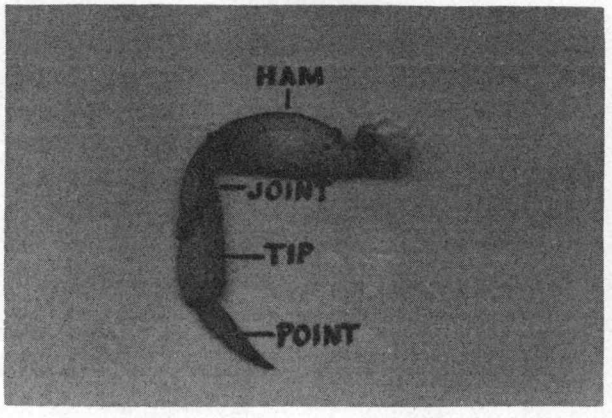


Figure 33. A crab leg is made up of the ham (merus) section, joint (carpus), tip (marus) and point (dactylus).

TABLE VI. SUMMARY OF TENTATIVE SAVINGS FOR CLAW LEG MEAT EXTRACTION

Activity	Savings (sec/claw leg)	Explanation of Savings
1. Get Claw Leg	.25	. Better Work Place Arrangement - position unpicked legs closer to operator. . Overlapping Motion - one hand should reach to next leg while the other hand finishes hitting out meat from previous leg.
2. Tear Off Claw and End of Knuckle Shell	.45	. Change Activity Sequence - pick claw meat immediately after getting leg from pile. . Eliminate Activity - eliminate rehandling of claw by picking claw meat first; eliminate regrasping of claw by initially grasping claw properly.
3. Hit Out Knuckle Meat	.12	. Improved Equipment - provide a firm hitting base to reduce hits required to remove meat.
4. Crack Ham Shell and Tear Off End of Ham Shell	.25	. Overlapping Motion - one hand should grasp the hammer while the other hand finishes hitting out the knuckle meat. . Improve Motion Pattern - hammer should be prepositioned for easier grasping, and the number of hits used to crack the shell should be reduced.

TABLE VI. continued:

Activity	Savings (sec/claw leg)	Explanation of Savings
5. Hit Out Ham Meat	.12	. Improve Equipment - provide a firm hitting base to reduce hits required to remove meat.
6. Tear Off Claw Point	.12	. Eliminate Activity - eliminate regrasping of claw point by grasping claw point when getting leg from pile.
7. Crack and Remove End of Claw Shell	.42	. Reduce Use Frequency - use a single blow from hammer to crack claw end.
8. Hit Out Claw Meat	.08	. Improve Equipment - provide a firm hitting base to reduce hits required to remove meat.
9. Discard Shell	.08	. Better Work Place Arrangement - shorter discarding distances. . Overlapping Motion - reach for next claw leg while discarding shell.
TOTAL TENTATIVE SAVINGS FOR CLAW LEG MEAT EXTRACTION	1.89	Seconds/Claw Leg

It is quite apparent, after looking at the "Total Picking Time Per Leg in Seconds" row of Table III, that the time spent in extracting meat per crab leg is less when using the multiple leg method, as opposed to the single leg picking method. The above is true regardless of whether the tip meat is extracted. Given this premise, the emphasis of the analysis will be placed on multiple leg meat extraction. Multiple meaning two or more legs being handled at any one time. All figures considered for multiple leg meat extraction will be for handling an average of two legs per picking cycle.

The evaluation to follow will consider extraction of meat from all leg parts, including the tip. The activities composing this sub-operation will be studied in the order set forth in Table III.

"Get Leg" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
			5	P, G	Grasp legs
Move to R.H.	TE	11	11	TL	Move to L.H.
			2	P, G	Grasp leg
Move to R.H.	TE	6	6	TL	Move to L.H.

The first activity to be analyzed is "Get Leg." Most operators practice, to some degree, the use of overlapping motion in the last activity ("Discard Shell") of the cycle and the first activity. However, "delays" found in the "Hit Out Ham Meat" activity should be eliminated and overlapping motion begun at this point. Thus, while one hand hits out the ham meat and discards the empty ham shells, the other hand can reach for and grasp the next group of legs from the pile for meat extraction. Such overlapping motion necessitates the use of a stable meat pan as a hitting base to eliminate one hand holding the pan while it is being used as a hitting base.

The amount of time spent in reaching for a group of crab legs was minimum when the pile of legs was placed immediately adjacent to the meat pan and the hand nearest the pile was used in grasping the legs. As mentioned earlier, the claw legs and crab legs are intermingled in the same pile of body parts. Such mixing of body parts tends to increase the time of the therbligs "search" and "select" which compose the basic act of "grasp."

The total savings for multiple leg picking realized from the use of overlapping motion and moving minimal distances will be approximately five frames per two legs or .21 second per two legs. This savings will give a tentative multiple leg activity time of six frames or .25 second per two legs. Similar improvements in the single leg activity will yield a savings of two frames or .08 second per leg and a tentative activity time of six frames or .25 second per leg.

"Tear Off or Pull Point" and "Crack Tip Shell" Activities

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
Grasp leg	P, G	6 8	6 8	P, RL	Transfer to L.H.
			11	TE	Move to tip
Hold leg	UD	15	15	P G, U	Grasp and pull point
Position leg on table	P	19	19	TL, TE G	Discard point, move to and grasp hammer
		20	22	U	Crack tip shell with hammer
Hold and wait	UD	25	25	TL, P	Discard hammer

The second activity in crab leg meat extraction, "Tear Off or Pull Point," will be considered with the third activity of "Crack Tip Shell." Since activities two through four concern the extraction of tip meat, the simo chart for single leg meat extraction will be used exclusively in the analysis of these activities.

Initial savings can be gained by avoiding the transfer ("position," P; "release load," RL) of the leg between the right and left hands. The leg can be picked up by the right hand and the point pulled out by the left hand to realize a gain of five frames per leg or 0.21 second per leg. The "move to tip" (TL) act is no longer needed and is included in the 0.21 second per leg savings.

The tip meat is exposed by using either of two methods. In one method, the point is pulled out, as performed by Operator B from

Plant F, and requires that the hammer be used to crack the tip shell to open up the cavity containing the tip meat. The other method, as performed by Operator A from Plant F, however, eliminates the use of the hammer by tearing off the point and the lower portion of the tip end to expose the tip meat. Although tearing off the point and tip end appears to require less time to perform, finger fatigue and soreness may increase the cycle time. It will nevertheless be assumed that the tearing off method can be used by operators, since it is presently being used by some operators.

Time values for the "Tear Off the Point and Tip End" activity can only be estimated since this activity was not documented for multiple leg meat extraction. On the average, multiple leg picking activities exceed that of single leg picking by a value of 0.4 frames. Thus, Operator A's average of 13 frames for this activity will be multiplied by a factor of 1.4 to get an estimated multiple leg average value of 18 frames for accomplishing the "Tear Off Point and Tip End" Activity.

The savings for single leg picking will be the difference between the current tear off method and the pull and crack method of tip end removal. The difference yields a savings of three frames or .12 second per leg and a tentative activity time of 13 frames (.54 second), when using the tear off method. The tentative multiple leg activity time will be 18 frames (.75 second).

"Hit Out Tip Meat" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
		19	19		
		20	22	U	Crack tip shell with hammer
Hold and wait	UD	25	25	TL, P	Discard hammer
Transfer to R.H.	TL, P	30	30	P, G	Grasp leg from L.H.
Wait	UD	35	35	U	Hit out tip meat (2 hits)

The fourth activity composing leg meat extraction is "Hit Out Tip Meat." Inasmuch as the use of the hammer to open the tip shell was excluded in the preceeding activities analysis, the "discard hammer" (PP) act and the related "hold leg and wait" (H, UD) act can automatically be disregarded. Three frames (.12 second) are added to the savings when the tear off method is used to expose the tip meat.

Additional savings can be claimed by omitting the "transfer" (P, RL) act. If the tip end is torn off by the left hand, as mentioned earlier, the leg will already be in the right hand, and such a transfer would not be needed. A savings of five frames or 0.21 second can be attributed to avoiding this transfer of the leg from hand to hand.

An average of two hits is presently used to knock out the tip meat from a single crab leg. A reasonable maximum number of hits

required for multiple leg tip meat extraction would conceivably be three hits, as some operators hit out the tip meat for a single leg consistantly in one hit. The factors influencing the number of hits required to hit out the meat are:

1. The manner in which the leg is cooked and cooled,
2. The opened cavity through which the meat must pass,
3. The stability of the meat pan,
4. The manner in which the leg is held during the shaking out process.

Time values for this activity must be estimated for multiple leg tip meat extraction inasmuch as actual times were not observed. The two areas of savings, mentioned previously, total eight frames, leaving a new single leg activity time of five frames per leg. The single leg activity time of five frames (assuming two hits are used for meat removal) will be multiplied by the multiple leg equivalency factor of 1.4 to obtain an estimated average value of seven frames. Since the suggested number of hits (three hits) for multiple leg picking is one more than is currently used for single leg picking, an additional three frames will be added to the estimated average value of seven frames. Thus, an estimated ten frames are required to accomplish the "Hit Out Tip Meat" activity for multiple leg meat extraction.

"Tear Off Tip Shell and Joint End" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES	BASIC ACT	DESCRIPTION RIGHT HAND
		11 — 11		
Grasp legs	P, G	14 — 14	P, RL	Transfer legs to L.H.
		16	TE	Move to tips
		20		
Position and hold legs	P, H	29 — 29	G, U	Grasp and tear off tip shells and joint ends
		35 — 35		
Move to R.H.	TE	39 — 39	TL	Move to L.H.
		40		
Grasp and tear off tip shell and joint end	P, G, U	49 — 49	H	Hold leg

The fifth activity in the crab leg meat extraction suboperation is "Tear Off Tip Shell and Joint End." In multiple leg picking, the avoidance of transferring the legs between hands can reduce the frame-count for this activity from 18 to 13, or a reduction of five frames per two legs (0.21 seconds per two legs). This decrease can be achieved by grasping the legs with the right hand, as presently done, and tearing off the tip shells and joint ends with the fingers of the left hand.

The motion pattern presently used in single leg picking is void of needless acts. In the "tear off" (U) act, the tip shell is grasped and often bent back and forth several times before it is torn off. (This method is used in both single and multiple leg picking.) It may be possible to reduce this back and forth motion to a one directional tearing action.

The time for this activity will be that proposed for multiple leg meat extraction of 13 frames, which is the same as the current best plant average for single leg picking. The time value is the same, yet the number of legs picked per given time period has increased two-fold.

"Hit Out Joint Meat" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
		29	29		
			32	TL, P	Discard tips
Wait	UD	35	35	TE	Move to L.H.
Transfer legs	P, RL	38	38	P, G	Grasp legs
to R.H.		40	41	P	Position to hit
Wait	UD	48	48	U	Hit out joint meat (3 hits)
		49	49		
Discard shell	TL, P	52	52	P	Position to hit
Wait	UD	59	59	U	Hit out joint meat (2 hits)

The sixth activity making up crab leg meat extraction is "Hit Out Joint Meat." An average of three hits is presently used in multiple leg picking to shake out the joint meat. It would seem that an upper limit of three hits can be set as the number of hits necessary to remove the joint meat, since the operator from Plant J consistantly hits out the meat in from two to three hits. The factors affecting the number of hits needed to hit out the joint meat and the ease with which it comes out are similar to those previously

mentioned in the "Hit Out Tip Meat" activity.

Traditionally, pickers continue to transfer the legs between their hands in multiple leg picking. Elimination of the transferring act, as portrayed in the single leg simo chart, can save a total of six frames per two legs, or 0.25 seconds per two legs. These savings include the change in the motion pattern of discarding the tip shell held in the left hand while the right hand positions the leg to hit out the joint meat. The above change was set forth in the analysis of the previous activity. The benefit diminishes the multiple leg activity time to 13 frames. The single leg activity time remains at ten frames.

"Crack Ham Shell" Activity

DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
		48	48		
Move to R.H.	TE	52	52	TL	Move to L.H.
Grasp legs	P, G	55	55	P, RL	Transfer legs to L.H.
Position legs on anvil	P	62 — 60 —	62	TE, P, G	Move to and grasp hammer
Hold legs	H	69	69	U	Crack ham shells with hammer (1-2 hits)
Move to R.H.	TL		72	TL, P	Discard hammer

		59	59		
		— 60 —			
Grasp leg	P, G	65	65	TL, P	Transfer leg to L.H.
Position on table	P	68	70	TE P, G	Move to and grasp hammer
Hold leg	H	78	78	U	Crack ham shell with hammer (1-2 hits)
Move to R.H.	TL	— 80 —	81	TL, P	Discard hammer

The seventh activity composing the crab leg meat extraction suboperation is "Crack Ham Shell." The acts making up this activity are identical for multiple and single leg picking. All acts seem to be needed. The transfer of the leg to the left hand is required if overlapping motion (getting the next leg from the pile

while the left hand hits out and discards the ham shell) is to take place in the last two activities. The motion patterns, however, can be smoothed out and shorter distances moved. The tentative time value for this activity will be the best plant average for multiple leg picking, or 20 frames per two legs. A four frames per two legs, or 0.17 seconds per two legs, savings is realized over the current multiple leg industry average (24 frames per two legs). The tentative single leg activity time value will also be the best plant average of 21 frames, which yields a one frame (.04 second) saving over the current industry average.

Ham shell cracking should be performed carefully. Not only should the hammer blow be such that it does not smash the ham meat, but it should strike toward the body end of the ham shell. Cracking and tearing off the body end of the ham shell, as done by the operator from Plant D, provides a bigger opening for ham meat removal. Other operators crack and tear off the joint end of the ham shell.

"Tear Off End of Ham Shell" Activity

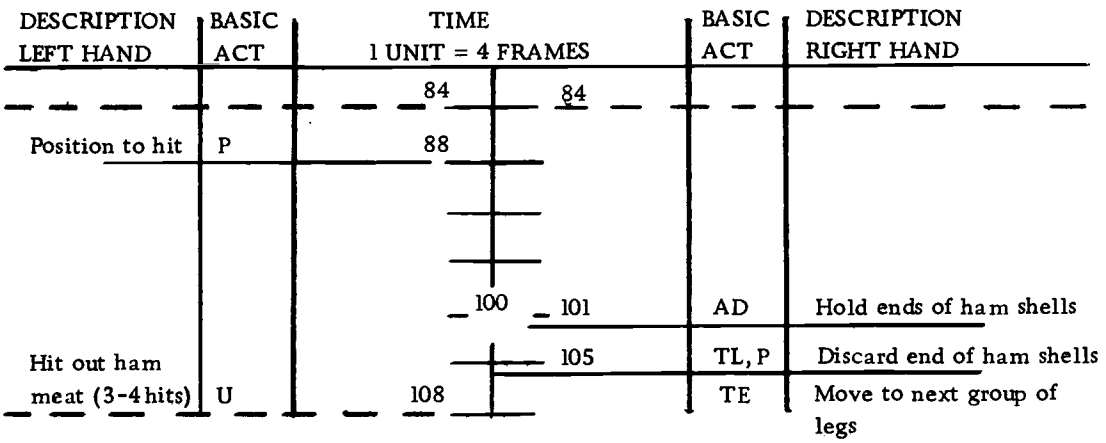
DESCRIPTION LEFT HAND	BASIC ACT	TIME 1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
		69	69		
			72	TL, P	Discard hammer
Move to R.H.	TL	76	76	TE	Move to L.H.
		80		P, G	Grasp and tear off
Hold legs	H	84	84	U	ends of ham shells

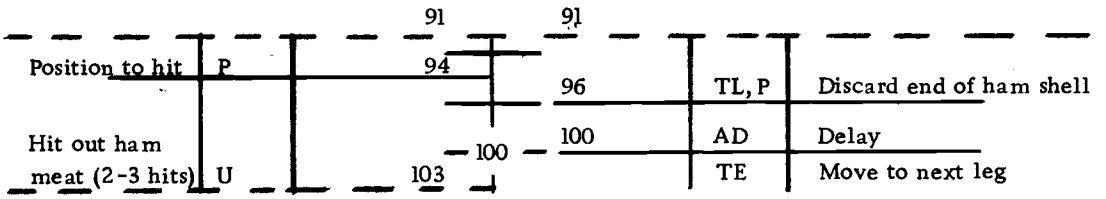
		78	78		
		80	81	TL, P	Discard hammer
Move to R.H.	TL	84	84	TE	Move to L.H.
				P, G	Grasp and tear off
Hold leg	H	91	91	U	end of ham shell

The eighth activity in leg meat extraction is "Tear Off End of Ham Shell." The acts are similar in both multiple and single leg picking. All acts appear to be necessary in accomplishing this activity. Cracking and removing the body end of the ham shell, along with smoother motion patterns can reduce the industry average activity time to that of the best plant average for multiple leg picking, which is seven frames per two legs. The savings for this activity will be the difference between the best plant average and the

industry average for multiple leg picking, or five frames per two legs (0.21 seconds per two legs). Likewise, the single leg activity time will be considered to be the best plant average of eight frames (.25 second), which yields a two frame (.08 second) saving over the current industry average.

"Hit Out Ham Meat" Activity





"Hit Out Ham Meat" is the ninth activity in the suboperation of crab leg meat extraction. From three to four hits are used to remove the meat from the ham shells in multiple leg picking. The factors influencing the number of hits required to shake out the meat are:

1. The manner in which the leg is cooked and cooled,

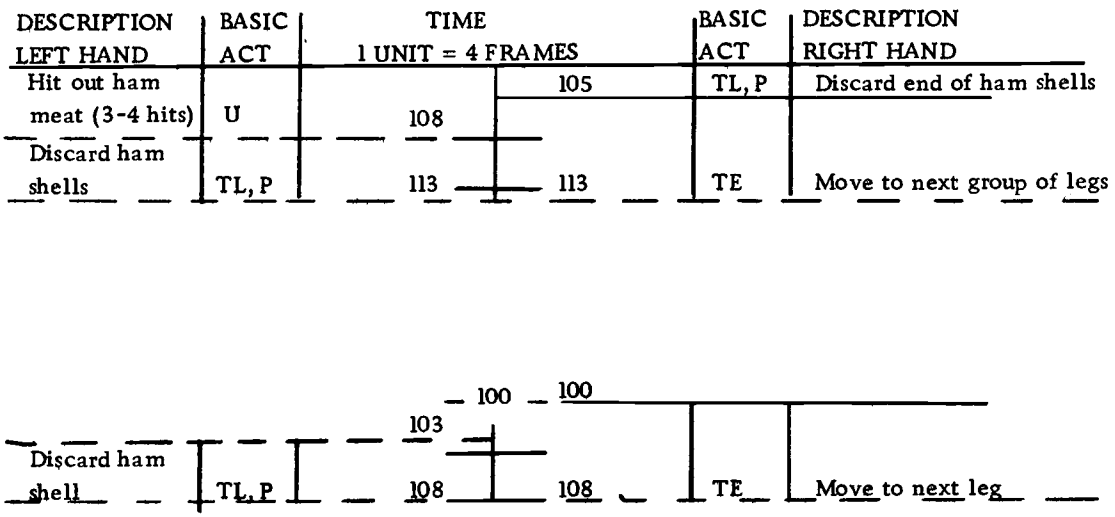
2. The opened cavity area through which the meat must pass,
3. The stability of the meat pan,
4. The manner in which the ham shells are held during the shaking out process.

The operator from Plant D picking multiple legs consistantly demonstrated that the ham meat can be removed in three or less hits. A tentative value of three or less hits will be set for hitting out the ham meat.

The "delay" (AD) of the right hand in commencing the overlapping motion should be eliminated. As soon as the body end of the ham shells are torn off they should be discarded. Upon discarding the shells, the right hand should move to and grasp the next group of legs in the pile while the left hand hits out the ham meat and discards the shells. Since Plant D's operator has a minimal amount of "delay" and uses the suggested amount of hits, her plant average of 17 frames per two legs will be used for the proposed multiple leg activity time for this activity. This is a savings over the current multiple leg industry average (24 frames per two legs, Table III) of seven frames per two legs, or 0.29 seconds per two legs. The current single leg industry average can be reduced three frames (.12 second) by decreasing the number of hits used in hitting out the ham meat from three to two hits. Operator A from Plant F currently uses a maximum of two hits for this activity. Such a reduction in

hits leave a tentative single leg activity time of nine frames.

"Discard Ham Shell" Activity



The tenth and last activity composing the crab leg meat extraction suboperation is "Discard Ham Shell." The use of overlapping motion should be continued throughout this activity. For further improvement, all distances moved in discarding the shells should be kept at a minimum. The frame-count difference between the multiple leg industry average (five frames per two legs) and the best plant average (four frames per two legs, Plant D) for this activity from Table III, one frame per two legs, or 0.04 second

per two legs, will be considered the possible savings from the use of overlapping motion and moving short distances in discarding scrap shell. The tentative activity time for both multiple leg and single leg picking will be four frames or .17 seconds.

Table VII summarizes the tentative savings that have been alluded to in the foregoing analysis of the suboperation of crab leg meat extraction.

TABLE VII. SUMMARY OF TENTATIVE SAVINGS FOR MULTIPLE CRAB LEG MEAT EXTRACTION

Activity	Comparison[1]	Comparison[2]	Comparison[3]	Explanation of Savings
1. Get Leg	.12	.25	.46	. Better Work Place Arrangements - position unpicked legs closer to operator. . Overlapping Motion - one hand should reach to next group of legs while the other hand finishes hitting out meat from previous legs.
2. Tear Off or 3. Pull Point and Crack Tip Shell	.12	.33	--*	. Eliminate Activity - eliminate transferring legs to left hand by tearing off points with left hand. . Improve Method - tear off the point and lower portion of tip ends to expose meat, instead of pulling out points cracking tips with hammer.
4. Hit Out Tip Meat	.33	.00	--*	. Improve Method - hammer is no longer used to crack tip shell. . Eliminate Activity - eliminate transferring legs between hands by originally tearing off tips with left hand

TABLE VII. Continued:

Activity	Comparison[1]	Comparison[2]	Comparison[3]	Explanation of Savings
4. continued				. Improve Equipment - provide a firm hitting base to reduce hits required to remove meat.
5. Tear Off Tip Shell and Joint End	.04	.54	.21	. Eliminate Activity - eliminate transferring legs to left hand by tearing off the tip shells and joint ends with the left hand.
6. Hit Out Joint Meat	.00	.29	.25	. Eliminate Activity - eliminate transferring leg by keeping leg in right hand and tearing off joint with left hand. . Improve Equipment - provide a firm hitting base to reduce hits required to remove meat.
7. Crack Ham Shell	.04	.88	.17	. Improve Motion Pattern - hammer should be prepositioned so it can be easily grasped.

TABLE VII. Continued:

Activity	Comparison[1]	Comparison[2]	Comparison[3]	Explanation of Savings
7. continued				. Improve Motion Pattern - move shorter distances in getting and discarding the hammer.
8. Tear Off End of Ham Shell	.08	.37	.21	. Improve Method - crack the body end of the ham shell, instead of joint end.
9. Hit Out Ham Meat	.12	.04	.29	. Eliminate Activity - eliminate the delay activity by commencing overlapping motion immediately after tearing off ham shells. . Improve Equipment - provide a firm hitting base to reduce hits required to remove meat.
10. Discard Ham Shell	.04	.00	.04	. Better Work Place Arrangement - shorter discarding distances. . Overlapping Motion - reach for next group of legs while discarding ham shells.

TABLE VII. Continued:

Activity	Comparison[1]	Comparison[2]	Comparison[3]	Explanation of Savings
TOTAL TENTATIVE SAVINGS	.89	2.70 (1.35 seconds per leg)	1.63 (.82 second per leg)	

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[1] Comparison of tentative single leg method to current single leg method (seconds/leg)

[2] Comparison of tentative multiple leg method to tentative single leg method (seconds/2 legs)

[3] Comparison of tentative multiple leg method to current multiple leg method (seconds/2 legs)

*Current multiple leg activity times were not observed for activities 2, 3 and 4.

Necessity of the Types of Move, Grasp and Position

The third phase in the analysis of the second direct factor affecting skill level, necessity of motion, is the determination of the move, grasp, and position type used in the operation of crab meat extraction. Each motion requires, for its accomplishment, time and energy on the part of the worker. Time and energy can be reduced and conserved, respectively, by employing the appropriate type of move, grasp, and position, as the case may be. The various motion types will be discussed in the following text.

Types of move. The two basic movement types of restricted or controlled movements, and ballistic movements were observed throughout the industry. A restricted or controlled motion occurs when opposing groups of muscles are contracted, one group against the other (17). On the other hand, ballistic movements are an easy motion caused by a single contraction of a positive muscle group with no other muscle group contracting to oppose it (17). Generally, controlled movements were characteristic of an individual during the learning or training process. Some employees seem to progress to ballistic type movements as the result of practicing a particular motion pattern. Barns (17, p. 246) mentions several reasons why ballistic movement is preferable, whenever possible, to the fixation movement.

> "The ballistic movement... should be used whenever possible. It is less fatiguing, for the muscles contract only at the beginning of the movement and are relaxed during the remainder of the movement. The ballistic movement is more powerful, faster, more accurate, and less likely to cause muscle cramp. It is smoother than the fixation movement, which is caused by the contraction of two sets of muscles, one acting against the other continuously."

Types of grasp. The two main types of grasp are 1) pressure grasp, and 2) hook grasp. A pressure grasp is a pinching action of an object between the thumb and fingers, whereas, a hook grasp occurs when the thumb and fingers grasp an object by reaching around it (hook) instead of grasping by pinching (17). When pressure grasps are used on crab body parts there appears to be less control of the part when tearing activities occur. Often a time consuming regrasping of the part is necessary for proper control. According to Barns (17), the thumb and fingers hook grasp would be the easiest to obtain and provide maximum control for such objects as crab sections, legs and claw legs.

Types of position. The degree to which an object must be properly oriented in order to fit, go into, or be in the location of maximum effectiveness determines the type of position (17). There are several areas where positioning of the crab body part or the operator's hand and/or fingers is critical. These areas are listed below:

1. In grasping a body section from the pile of sections the fingers and thumb should grasp the body portion of the section to facilitate future motion patterns.

2. A high degree of positioning is required for proper and complete key bone removal.

3. The claw leg should be grasped by the point to eliminate transferring and repositioning of the leg in order to tear off the point.

4. The hammer should be prepositioned such that the handle can be easily grasped.

5. Positioning of the crab body parts on the anvil is critical, if a minimum number of hammer blows are to be used and the body part is to be cracked in the proper location.

6. When body parts are torn apart, the location of the fingers that tear off the part is important. Improper positioning may result in loss of meat and quality.

A minimum degree of positioning should be used in discarding scrap shell. The shell discarding time should be a very small value and is least when the degree of positioning is kept at a minimum.

Rhythm (Fifth Skill Factor)

The third direct factor affecting operator skill level in crab meat extraction is rhythm. Rhythm may be defined as the regular, uniform repetition of a certain cycle of motions, which is essential for the smooth and automatic performance of an operation (23). Rhythm can reduce 1) the number and length of hesitations, and 2) coordination delays (14).

Hesitations can be the result of improper synchronization of the mental and physical activities which an operator must perform to complete a work cycle (23). Holmes (23, p. 116) points out that, "The problem of sequence is the operator's largest mental burden." This burden can be reduced by minimizing the number of basic acts composing the work sequence, and by arranging them in such a way that the sequence tends to progress in one direction and to culminate in its completion (23). The relative positioning of tools and equipment, along with crab body parts, will also aid in obtaining a better sequence of movements. The proper sequencing of motions and placement of equipment and material will enable an operator to establish a rhythm which will assist in making the operation practically an automatic performance and reduce greatly the amount of hesitation.

Generally, the current equipment and work place arrangement, along with the sequence of motions used in crab meat extraction, need to be changed if rhythm is to be established. The changes suggested in the analysis of the first and second direct factors affecting skill levels, 1) materiel and 2) necessity of motion, will lead to improved rhythm patterns.

Coordination delays increase the cycle time and are the result of improper timing of movements of particular body members taking part in a given motion sequence (23). Improper timing may result in

pauses, fumbling, variations in sequence, unbalanced simultaneous movements, repetition to accomplish one act, and diverted interest (23). Improvement of the arrangement and use of the work place, along with a correct rhythm pattern can alleviate many of the co-ordination delays (23).

Fatigue is detrimental to rhythm. When an individual becomes fatigued, he may either slow down his work pace and maintain a slower rhythm, or he may introduce delays or interruptions into the cycle, in the form of extra motions (17). E. Farmer and R. S. Brooke conducted a study on the effect of fatigue on rhythm.[12/] The conclusion of this study is summarized by Barnes (17, p. 249), as follows:

> "Fatigue, then, seems to break up the rhythm and disturb the coordination that makes for rapid and easy work. The tired worker is, therefore, not only working slower than when she is fresh, but is also expanding her energy extravagantly."

Consideration of each of the six skill factors can lessen the overall fatigue of an individual.

Holmes (23, p. 114) summarizes the benefits derived from employing rhythm in a work cycle as,

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[12/] E. Farmer and R. S. Brooke, "Motion Study in Metal Polishing," Industrial Fatigue Research Board, Report 15, p. 1-65.

> "... resulting in a lack of tension and a lessening of physical and mental exertion by the operator. It (rhythm) reduces the operator's fatigue, eliminates repeated movements, and lessens the factors of error in method and danger in movement."

Speed (Sixth Skill Factor)

The fourth and last direct factor affecting operator skill level in crab meat extraction is speed. Speed has to do with muscular movements and refers to the rate of physical activity of the worker (17). The action and use of the human senses is directly related to speed. Any one or more of the five senses may be used by the operator during the work cycle. Each one of these senses can usually be affected by training, or practice and mind use (20). Holmes (23) confirms the fact that an operator is limited in the proper use of his senses in an operation by the mental development and training which he acquires. Current training methods in processing plants could be significantly advanced with the development of the proper training aids. Presently, the floor lady is held responsible for training, and often due to her work load cannot spend adequate time with trainees. It appears then, that some type of training aid would reduce the time spent with trainees and make the training more effective.

Any or all of the senses may be used in performing a given task, but the sense of sight is by far the most important (20). In

crab meat extraction, the sense of sight is closely associated with hand movement. The two categories of eye-hand coordination are 1) directional and 2) positional. Directional eye-hand coordination is "the guidance the eyes must give the hands in accomplishing a given task" (15, p. 461). And positional eye-hand coordination is "the guidance the eyes must give the hands when performing terminal activities or therbligs like position, grasp, ..., etc." (15, p. 463).

If the motion pattern is improperly designed, the hands may have to wait for the eyes, depending on the nature of the operation and the distance the eyes and hands have to move. To help alleviate this waiting, Holmes (23) suggests that all eye movements necessary for hand movement should precede and/or commence, as soon as possible, before the physical movement. Further improvements in the eye-hand coordination aspect of crab meat extraction can be achieved by improving the work place, so that the eye fixations are as few and as close together as possible. Crab parts should be placed in the immediate vicinity of the meat pan to minimize the distances moved by the eyes and hands. An adequate work place arrangement can also reduce neck fatigue by limiting the need for head rotation, since eye movement will generally suffice.

As mentioned earlier, adequate training and practice in the proper method can potentially reduce the time and number of eye fixations by 1) eliminating the need for eye fixations, 2) using

overlapping eye fixations and 3) reducing eye fixation time (14). Training and practice usually lead to the work cycle being performed automatically as the result of habit. Barnes (17) conducted a study on the effect of practice on eye fixations during a work cycle. He concluded, "...that the better coordination resulting from practice not only enabled the operator to perform each of the motions in less time ... but also reduced the number of (eye) fixations required" (17, p. 254).

Most important, the speed with which an operation is accomplished automatically increases as a better method of doing that particular operation is developed. In developing a better method all unnecessary work is eliminated, activity sequences are changed, activities are combined and the operation is simplified.

VI. DEVELOPMENT OF THE IMPROVED METHOD OF CRAB MEAT EXTRACTION

Development of a Proposed Improved Method in Terms of the Six Skill Factors

The development of a proposed improved crab meat extraction method will be in terms of the indirect skill factors (the individual, and plan and control), and the direct skill factors (materiel, necessity of motion, rhythm, and speed). The developmental stage will draw heavily from the findings of the preceeding analysis stage. Since the two stages are discussed separately and because of their interdependence, there will be some repetition of information. The goal of this development is to upgrade the skill level of crab pickers in terms of the six skill factors and in turn reduce meat extraction time and lower the overall picking cost to the processor.

Indirect Skill Factors

The Individual (First Skill Factor)

The individual is the key element in the crab meat extraction operation. Proper selection of this person is of paramount importance. Maximum benefits are reaped from methods improvement studies when the personnel using the improved methods are properly suited for the job.

The job of crab meat extraction requires that an individual possess certain inherent aptitudes. Preliminary studies conducted by the Employment Division of the Oregon State Employment Service, indicate that the following aptitudes should be possessed by an individual if they are to be an effective crab picker.

1. "Form perception - Important in selecting various sized crab parts for removal of meat according to an established sequence of tasks.

2. "Clerical perception - Important in inspection of crab shells as to removal of all meat.

3. "Motor coordination - Required in use of eyes and both hands in reaching for and picking up crab parts and knocking out meat.

4. "Manual dexterity - Necessary to make a variety of movements with hands and arms in handling crabs and parts, use of hammer to crack shells, and to knock meat out into containers." (19, p. 3)

To insure, with a reasonable amount of certainty, that new employees possess such aptitudes, each should be required to take the General Aptitude Test Battery for the occupation of crab picker, soon to be made available by the State Employment Division.

The test battery will, eventually, be made available for national use in the operating offices of the State Employment Services. The seafood processors can then send any prospective crab picker to their local State Employment Office for testing to determine if the individual meets the minimum aptitude requirements. The local agency will then inform the processor of the test results on a

pass-fail basis.

Plan and Control (Second Skill Factor)

Regardless of the possession of the required inherent aptitudes, an operator will not be able to perform the crab meat extraction operation without hesitations (plan, p. 48) and delays (control, p. 48) until a certain amount of time has elapsed for becoming familiar with the hand pattern and motions. On-the-job training appears to influence the time period over which the factors of plan and control affect skill (15). A person may know how to do a job but may need to practice to obtain proper control.

A more rigorous training program than those currently being used will reduce the time in which the factors of plan and control affect skill (Figure 22). The training program should be such that it minimizes the necessity for mental planning and accelerates the establishment of habits of muscular automaticity which in turn reduces conscious control. Training methods and programs will be discussed further in section VIII, Implementation of the Improved Method of Crab Meat Extraction.

Direct Skill Factors

Materiel (Third Skill Factor)

Proper tools, equipment, workplace and materiel are essential for effective crab meat extraction. The tools (hammer, anvil and pan) are used continuously, in varying degrees throughout the picking cycle. It appears that a plastic hammer would be more suitable than the aluminum hammers currently being used. The plastic would be lighter than the aluminum and still provide the weight needed to crack the crab shell without added effort on the part of the worker. The plastic hammer also has the advantage of being non-corrosive when brought into contact with salt water.

As alluded to earlier, a hammer with a cylindrical handle and a rectangular-shaped head has proven most satisfactory to employees in cracking crab shells. Figure 34 illustrates this hammer

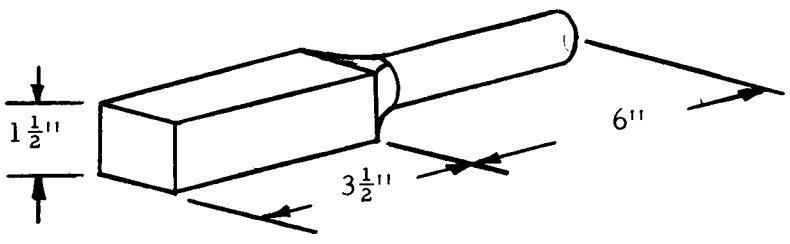

Figure 34. Hammer with cylindrical handle and rectangular-shaped head.

configuration with the appropriate approximate dimensions. The number of edges along the head of the hammer may vary. Using this hammer style, the head rests on the table while the handle is elevated from the surface of the table. An elevated handle is best for grasping, as there is minimal interference with the surface of the table.

In-plant observations were made to determine the most effective anvil shape. Initially a hollow aluminum piece of square three-inch tubing proved most satisfactory. Corrosion was still a problem however. It was concluded that an anvil made of a solid block of plastic three inches by three inches by six inches satisfied the basic design criterion (Figure 35).

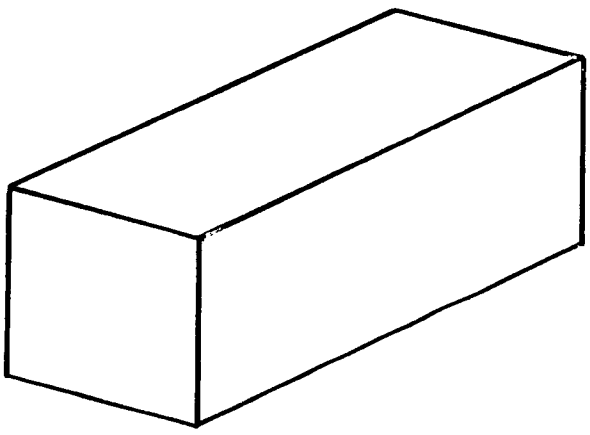

Figure 35. Solid block type anvil made of plastic.

The anvil is stable and has an adequate flat top surface for positioning crab parts. The distance of the top surface from the table top is

sufficient to allow for the curvature of the crab legs hanging over the side and also provides adequate room for the hand that is holding the leg. The corrosion problem with the current aluminum anvil in the salt water environment is also overcome when using plastic material. In addition, a solid block type anvil has no inside surfaces to clean or harbor bacteria (5). Both plastic hammers and anvils are currently used in the Canadian crab processing industry (22).

Observations and tests indicate that the most stable meat pan is one made of a heavy gage stainless steel and having a flat bottom. A light pan, however, can be used if it is placed in a cutout in the work table tap (Figure 36) or held in place by some type of fixture.

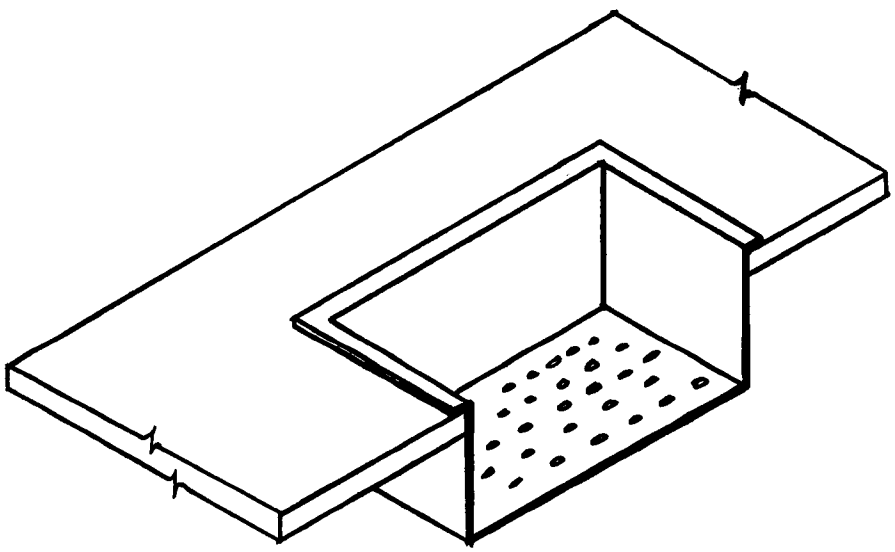

Figure 36. Cross section of a meat pan placed in a cutout provided in the work table.

In either case, the pan will not wobble or bounce when it is used as a hitting base for meat removal. As a result the number of hits

required to shake out the crab meat, along with arm and wrist fatigue, will be minimized. The bottom of the pan contains holes for water drainage. The holes should be large enough to provide for maximum drainage but small enough to restrict the passage of meat.

The rim of the pan should be wide enough, or sufficiently protected to prevent damage to the operator's hand when the hand strikes the rim during meat removal. A pan that is recessed into the table top provides maximum protection. A pan that is set on the table should have a flat rim. A section of the rim can be covered with a piece of plastic hose or other dampening material to further protect the operator's hands.

The flying meat problem may be alleviated by the use of a meat deflection shield placed behind the meat pan to recover meat that flies outside the rim of the pan. The shield should conform to the configuration of the pan and cover the back portion of the pan. For effective deflection, the height of the shield should be twelve inches above the rim of the pan[13/]. The shield should be of a non-corrosive metal or plastic material. It may also be possible to design a meat pan that will accomplish the same purpose as that of the deflection shield.

13/ From in-plant observations made by author.

Equipment

Little improvement was made on the rubber gloves, the basic equipment of the crab pickers. Several types of rubber gloves, both surgical and domestic-household, were tested to find a glove that would fit properly and not be too thick for proper feel in meat extraction[14/]. The surgical gloves tested provided excellent fit and feel but were not durable enough to withstand the sharp edges of the crab shell. These gloves would last from $\frac{1}{2}$ to 2 hours, before becoming perforated with holes. The domestic-household type rubber glove proved to be very durable, but lacked the qualities of proper fit and feel. Several processors feel that until a more durable surgical type glove can be found they will use the domestic-household type. These processors indicated that the money spent in obtaining enough surgical type gloves to be used each day and the time spent in changing gloves, would exceed the value of the meat lost and time lost, due to fumbling, currently existing with the use of domestic-household type gloves.

The Workplace

The crab shuckers work place can be improved. In Oregon,

14/ From in-plant tests conducted by author.

all pickers stand on concrete floors in front of their work area. Body fatigue can be reduced if heavy rubber pads are placed on the floors. Alaskan and several East Coast seafood processors go one step further and provide seating for their crab pickers. To afford maximum comfort, the seating should be designed so that the worker can alternate standing and sitting.

Processors must take individual height variation into consideration, if employees are to work effectively. A height raising device should be provided to compensate for individual height differences. The employee should have some degree of freedom for foot movement to lessen fatigue. And of utmost importance, the device should be perfectly stable. A rubber pad can then be placed on top of the height raising device.

According to Adams (5, p. 37), the "... individual work areas, for interference-free shucking, should be a minimum size of two and one-half feet by four feet." Partitioning of the work area does not seem to be a necessity, but will aid in defining each individual's work area. The table top must be vibration-free, otherwise an undesirable up and down movement is produced in both the picking pan and anvil, when either is used as a hitting base. The tabletop should be covered with plastic or stainless steel to resist corrosion and to avoid harboring bacteria.

Material (Crab Sections)

The crab sections must be in the best possible condition when they reach the pickers, if picking time is to be kept at a minimum and product quality and yield at a maximum. Assuming that healthy, live crabs enter the processing plant, the quality of the crab sections is dependent upon the cooking operation, the cooling operation, and the post-meat extraction handling operations.

Cooking is necessary to facilitate removal of the crab meat from the shells. No documented standards are available as to what the cook time and temperature should be for the Dungeness crab. A survey of Oregon processors revealed that steam-heated water cook temperatures were set at 212° F. and the cook time from 10 to 14 minutes depending on the physiological condition of the crabs and the type of cooker (5).

General principles from Ulmer's (21) study of cooking and cooling operations for the Atlantic Blue crab (*Callinectes sapidus*) can be applied to the Dungeness crab operations. Maximum yields were achieved when the crabs were cooked in 212° F. steam-heated tap water. The use of tap water is more desirable than salt water (21). The cooking method also affects yield. One method, generally used on the West Coast, uses steam to heat the water in which the crabs are cooked. The other method, called pressure steaming,

cooks the crabs in a closed container under a given pressure. Ulmer (21) concluded that the steam heated water method produced higher yields, when appropriate cooking times and temperatures were employed. Dewberry (22) states that cooking in live steam results in difficult shucking, lower yield and poor appearance of the meat due to its sticking to the shells. Dewberry (22) continues that over-cooking makes the meat increasingly difficult to shuck.

Cooking time and temperature must be rigidly controlled. The sections should be cooked in an automatically time and temperature controlled continuous cooker, for an even cook. Previously cited data would suggest that the crabs should be cooked in steam heated water at a temperature of approximately 212° F. Time remains the only unknown variable. A rule of thumb will have to be followed until further studies are conducted to determine the appropriate crab size-cook time relationship for a constant temperature of 212° F. The cook time rule of thumb is as follows:

> The cook time shall range from 10 to 14 minutes. The actual cook time will be determined from feedback from the shuckers as to ease of meat extraction and whether the meat is adequately cooked.

Dewberry (22, p. 51) states "The more rapidly the sections are cooled the higher the quality and the greater the percentage of meat recovery." Preliminary cooling rate tests conducted by

Adams (5) indicates that spray cooling of crab sections is more effective and more sanitary than bath cooling. Spray cooling efficiency can be further increased when a chilling effect is produced by blowing air through the spray cooling unit. Cooling water should have a maximum temperature of 50° F. (5). Adams (5) records the following results achieved from adequate cooling:

1. Easier shucking with a greater yield;
2. Meat with good color and texture;
3. More cohesive meat.

Sections should be cooled as rapidly as possible to improve the condition of the crab.

Post-meat extraction handling of the sections must be clearly supervised. All handling of the crabs must be done with care to avoid damage and loss of body parts. As stated earlier, damaged crab sections usually require more time to pick per pound of meat extracted. Attention should be focused on the butchering operation if maximum yields are to be realized. The incorrect procedure or carelessness can waste a substantial amount of meat.

Necessity of Motion (Fourth Skill Factor)

The second direct factor affecting skill level is the Necessity of Motion. The areas considered in the development will be:

1. The length of the distances moved;

2. The occurrences of such basic acts of motion as grasp, use, delay, move, hold, and position; and
3. The types of move, grasp and position employed in the operation of crab meat extraction.

The objective of this segment of the developmental phase is to eliminate wasted, needless motions, to reduce operator fatigue and increase production without requiring the expenditure of additional physical effort.

Length of the Distances Moved

The distances moved in getting crab body parts and discarding shells, or body parts should be kept at a minimum. The location of the pile of body sections, claw legs, or crab legs should be located as close to the meat pan as possible, without interfering with the use of the hammer and anvil. The length of the move in getting crab parts is reduced when they are originally placed in piles, rather than strewed around the work area. The distances moved will be at a minimum when piles of body parts are placed immediately adjacent to the meat pan and minimal arm-movement distances are used in the reaching and discarding activities.

Necessity of the Occurrence of the Basic Acts of Motion

This portion of the developmental stage will consider the

necessity of the occurrence of the basic acts of motion composing the activities of each suboperation of crab meat extraction. The approaches of eliminate, combine, change and simplify, along with the principles of motion economy, will be used to evaluate the necessity of the occurrence of the basic acts set forth in the simo charts representing the current industry method of meat extraction. The basic acts composing the apparent best industry practices, alluded to in the previous section, Analysis of the Current Crab Meat Extraction Method, will be compared with the basic acts corresponding to the respective activites making up the current industry method of meat extraction. Such a comparison will indicate both the necessity of the presence of a given basic act, and also the necessity of the occurrence or frequency of a given basic act.

The necessity of the occurrence of the basic acts of motion will be discussed under the individual activities composing each suboperation. Only those basic acts making up the current method that can be eliminated, or reduced in frequency of occurrence will be mentioned. The current industry simo chart for each suboperation is shown on pages 38 through 41.

The necessity of the occurrence of the basic acts comprising the suboperation of crab body meat extraction will be considered first.

Activity[15/]	Discussion
2. Tear Off Claw Leg	Currently the fingers of one hand indiscriminately grasp a crab body section from the pile of sections. Such grasping necessitates the transfer (basic acts of "position" and "release load") and regrasping (basic acts of "position" and "grasp") of the body section between hands in order to get the section in position for tearing off the claw leg. These basic acts can be eliminated by originally grasping the body position of the section when getting a section from the pile of body sections. The section is now in a position that the claw leg can be easily torn off.
3. Hit Out Body Meat From Claw Leg	The current average of three hits (basic act of "use") used to hit out the body meat adhering to the claw leg, can be reduced to two hits by using a firm hitting base, instead of an unstable hitting base.
6. Hit Out Body Meat	The current average of eight hits (basic act of "use") used to hit out the body meat, can be reduced to three hits. This reduction is accomplished by using a firm hitting base, by proper key bone removal, by using a combination of rapid arm and wrist movements in hitting base, and by the awareness, through inspection, that all meat has been removed.
7. Separate and Discard Legs	Currently some pickers separate the legs from the body section and then discard the individual legs for future meat extraction. The separation of individual

15/ Activity numbers correspond to the numbers on the current method simo chart, Figure 18.

7.	legs can be eliminated by discarding the entire section after body meat removal. Discarding the body section with legs attached eliminates the following basic acts from this activity: "transport loaded and empty," "unavoidable delay," "use," "position," and "grasp."

The necessity of the occurrence of the basic acts comprising the suboperation of claw leg meat extraction will be considered secondly.

Activity[16/]	Discussion
2. Tear Off Claw and End of Knuckle Shell	Currently the claw is torn off and laid aside for future meat removal. Several basic acts can be eliminated by extracting the claw meat immediately after getting the leg from the pile. The transfer (basic acts of "position" and "release load") and regrasping (basic acts of "position" and "grasp") of the claw leg can be eliminated by grasping the point of the claw leg when getting a leg from the pile instead of indiscriminately grasping the leg. The motion of discarding the claw (basic act of "transport loaded" and "position") for future meat removal can be eliminated when the claw meat is extracted immediately after getting the leg from the pile of legs.
3. Hit Out Knuckle Meat	The current average of three hits (basic act of "use") used to hit out the knuckle meat can be reduced to two hits by using a firm hitting base, instead of an unstable hitting base.

16/ Activity numbers correspond to the numbers on the current method simo chart, Figure 19.

5. Hit Out Ham Meat	The current average of three hits (basic act of "use") used to hit out the ham meat can be reduced to two hits by using a firm hitting base, instead of an unstable hitting base. The "avoidable delay" basic act of holding the ham shell that has been torn off, can be eliminated by discarding the ham shell immediately after it is torn off.
6. Tear Off Claw Point	Repositioning of the claw (basic acts of "position" and "grasp") can be eliminated by originally grasping the point of the claw with the fingers.
7. Crack and Remove End of Claw Shell	Reduce the number of hits (basic act of "use") used in cracking the claw shell to one.
8. Hit Out Claw Meat	The current average of two hits (basic act of "use") used to hit out the claw meat, can be reduced to a maximum number of two hits required for meat removal. This reduction is accomplished by using a firm hitting base, by properly opening up of the meat cavity, and by the awareness, through inspection, that all meat has been removed.

The necessity of the occurrence of the basic acts comprising the suboperation of the claw leg meat extraction will be considered thirdly.

Activity[17/]	Discussion
2. Tear Off or Pull Point	Currently the leg is grasped by the right hand and transferred to the left hand, so that the right hand can tear off or pull the point. This transferring (basic acts of "position" and "release load") can be eliminated by tearing off or pulling the point with the left hand.
3. Crack Tip Shell	The use of the hammer to crack the tip shell (basic acts of "position," "grasp," "use," "transport loaded," and "position") can be eliminated by tearing off the tip shell with the fingers (basic acts of "position," "grasp," and "use").
4. Hit Out Tip Meat	The transfer (basic acts of "transport loaded " and "position") of the leg to the right hand for meat removal is no longer necessary if the leg is kept in the right hand as suggested in activity two above. Keep the number of hits used to remove meat (basic act of "use") at a minimum by using a firm hitting base.
5. Tear Off Tip Shell and Joint End	Currently the leg is grasped by the right hand and transferred to the left hand so that the right hand can tear off the tip shell and joint end. This transfer (basic acts of "position" and "release load") can be eliminated by tearing off the tip shell and joint end with the left hand. (The above applies to the current multiple leg method only.)

17/ Activity numbers correspond to the numbers on the current method simo chart, Figures 20 and 21.

6. Hit Out Joint Meat	The current multiple leg method requires the transfer of the leg back to the right for meat removal. This transfer (basic acts of "position" and "release load") can be eliminated by keeping the leg in the right hand from the start of the picking cycle as suggested in activity five above. Keep the number of hits used to remove meat (basic act of "use") at a minimum by using a firm hitting base.
7. Crack Ham Shell	Reduce the number of hits (basic act of "use") used in cracking the ham shell, by using the edge of the hammer to crack the shell. The edge of the hammer cracks the shell, whereas the flat surface of the hammer tends to only smash the shell.
9. Hit Out Ham Meat	The "avoidable delay" basic act can be eliminated by discarding the ham shell immediately after it is torn off and then reaching for the next leg.

Types of Move, Grasp and Position

The next phase in the analysis of the second direct factor affecting skill level, necessity of motion, is the determination of the type of move, grasp, and position. Time and energy can only be reduced and conserved by employing the most appropriate type of move, grasp, and position.

Types of move. Ballistic movements should be used, rather than controlled movements, whenever possible during the crab picking operation. This type of movement should be used when

discarding the claw leg and crab legs into their respective piles during the body meat extraction suboperation and when discarding the scrap shell. Controlled or restricted movements should be used whenever a relatively high degree of positioning is required to enhance future acts as in prepositioning the hammer, or as in moving to grasp and remove the key bone, or as in moving to grasp a particular portion of a crab body part during the tearing off activities.

Types of grasp. Of the two types of grasp, pressure grasp and hook grasp, the hook grasp appears most effective in the crab operation. A hook grasp occurs when the thumb and fingers grasp an object by reaching around it instead of grasping by pinching (17). The hook grasp provides maximum control of the crab body parts during the tearing off and hitting out activities. A hook grasp should also be used when getting claw legs and legs from their respective piles. Barns (17) indicates that the time required to grasp objects in a pile, such as crab legs, is less when the hook grasp is used.

Types of position. The degree to which an object must be properly oriented in order to fit, go into, or be in the location of maximum effectiveness determines the type of position (17). There are several areas where positioning of the crab body part or of the operator's hand and/or fingers is critical. These areas were mentioned earlier on page 123.

Rhythm (Fifth Skill Factor)

Rhythm has a direct effect on the number and length of hesitations and coordination delays (14). Hesitations, which can result from improperly synchronized mental and physical activities, can be reduced by minimizing the number of basic acts composing the work sequence, and by arranging them in such a way that the sequence tends to progress in one direction and to culminate in its completion (23). Coordination delays are the result of improper timing of movements of particular body members taking part in a given motion sequence (23). Training and practice of the proper motion pattern can reduce coordination delays. The number of basic acts has been reduced to a minimum by evaluating the necessity of the occurrence of each basic act composing the current method of meat extraction. This evaluation was presented in the foregoing discussion of the second direct skill factor, necessity of motion.

The most striking sequence change that aids in the progression of the cycle in one direction occurs in the claw leg suboperation. Currently, some of the operators, after getting a leg from the pile, will tear off the claw and lay it aside to be picked at a later time. A smoother more systematic motion pattern is obtained, however, when the meat from the claw is extracted immediately after the leg is grasped from the pile. After picking the claw, the operator can

then naturally proceed to pick the knuckle meat and then the ham meat. The relative positioning of tools, and body parts, as mentioned earlier, will also aid in obtaining a better sequence of movements. The proposed improved method of crab meat extraction, shown in Figures 37 through 40, illustrates how the present number of basic acts used in the current method (Figures 18 through 21) can be reduced to a minimum number and put into a smooth flowing motion pattern that progresses in one direction. Overlapping motion is essential in maintaining a smooth flowing motion pattern.

Fatigue can also be reduced and limited as a detriment to rhythm (17) by following the suggested changes of the current tools, workplace, material arrangement, and the proposed improved arrangement of the basic acts composing the crab meat extraction work cycle.

Speed (Sixth Skill Factor)

The last skill factor to be considered is speed. The action and use of the human sense is directly related to speed. Sight is the most constantly used sense in performing and controlling manual operations (20). The time the hands may have to wait for the eyes before performing an act can be reduced or eliminated by commencing eye movement as soon as possible before the physical movement (23). Crab parts, tools and equipment should be placed in the

immediate vicinity of the meat pan to minimize the distances moved by the eyes and hands. A compact workplace arrangement also will reduce neck fatigue by limiting the need for head rotation, since eye movement will generally suffice.

Adequate training and practice in the proper method can potentially reduce the time and number of eye fixations by 1) eliminating the need for eye fixations, 2) using overlapping eye fixations and 3) reducing eye fixation time (14).

A better method of performing an operation will automatically increase the operator's speed (17). As pointed out earlier in the section containing the analysis of the current method of meat extraction, the simple application of the use of overlapping motions (keeping both hands in motion doing different jobs) can speed up an operation significantly. A comparison of the proposed improved method simo charts, Figures 37 through 40, with the current method simo charts, Figures 18 through 21, will clearly illustrate how a better method can increase an operator's speed.

Summary of the Proposed Changes which Resulted from Consideration of the Direct Skill Factors of Necessity of Motion, Rhythm, and Speed

The proposed change in the current method of meat extraction, which resulted from the consideration of the direct skill factors of necessity of motion, rhythm, and speed, will be summarized in the following text. A recommended list of changes for each activity composing a suboperation will be given. The list will be followed by a simo chart which incorporates the changes into a workable continuous smooth flowing picking sequence. The new picking sequence will be referred to as the proposed improved meat extraction method.

Crab Body Meat Extraction Suboperation

The following list of recommended changes (Table VIII) and the simo chart (Figure 37) set forth the proposed improved method for crab body meat extraction.

TABLE VIII. RECOMMENDED CHANGES[18] FOR THE SUB-OPERATION OF CRAB BODY MEAT EXTRACTION

Activity	Recommended Change[19]
1. Get Crab	. Use Overlapping Motion - one hand should reach for the next body section while the other hand finishes shaking out the meat from the previous section. . Better Work Place Arrangement - pile of crab sections should be placed immediately adjacent to the meat pan. . Improve Motion Pattern - grasp the body portion of the section when getting the section from the pile.
2. Tear Off Claw Leg	. Improve Motion Pattern - eliminate transferring and regrasping body section between hands before tearing off the claw leg, by originally grasping the body portion of the section when getting a section from the pile.
3. Hit Out Body Meat From Claw Leg	. Change Activity Sequence - eliminate rehandling of claw leg by hitting out the body meat adhering to the leg immediately after tearing off the claw leg from the section. . Improve Equipment - provide a firm hitting base to reduce the hits required for meat removal.

18/ Changes are based on comparisons made with the established current industrial average method for body meat extraction (see simo chart, Figure 18).

19/ A more detailed discussion of each change can be found in the preceeding section, Analysis of the Current Crab Meat Extraction Method, by looking under the specific suboperation and activity.

Table VIII. Continued

Activity	Recommended Change
4. Compress Body Portion of Section	. Improve Motion Pattern - change the method of loosening the meat around the key bone and body's bone network, by pressing the body portion between the palms of both hands.
5. Remove Key Bone	. Improve Motion Pattern - complete and proper key bone removal is accomplished by sliding the fingers around the bone, grasping the bone, and removing it with a twisting, pulling action.
6. Hit Out Body Meat	. Improve Equipment - provide a firm hitting base to reduce the hits required for meat removal. . Improve Motion Pattern - complete and proper key bone removal lets the meat shake out easily. . Use Overlapping Motion - one hand should reach for the next body section while the other hand finishes shaking out the meat from the present section.
7. Discard Section	. Eliminate Activity - eliminate separating the legs from the body portion before discarding, or discard the section with the legs attached. . Use Overlapping Motion - while one hand is discarding the section, the other hand should be in the process of grasping the next crab section.

Crab Claw Leg Meat Extraction Suboperation

The following list of recommended changes (Table IX), and the

OPERATION: Body Meat Extraction			TIME	PROPOSED IMPROVED METHOD	
ACTIVITY	DESCRIPTION LEFT HAND	BASIC ACT	1 UNIT = 4 FRAMES	BASIC ACT	DESCRIPTION RIGHT HAND
1. Get Crab 6*	Move to R.H.	TL	6 — 6	TE	Move to L.H.
2. Tear Off Claw Leg	Hold crab section	P, H	9	P, G	Grasp claw leg
12			18 — 18	U	Tear off claw leg
3. Hit Out Body Meat From Claw Leg	Hold crab section	H	20 — 23	P	Position to hit
12			30 — 30	U	Hit out body meat from claw (2 hits)
4. Compress Body Portion Of Section	Position body portion in palm	P	34 — 36	TL, P	Lay claw leg aside
	Press body portion of section with palm of hand	U	38 — 40 — 46 — 46	TE P, U	Move to L.H. Press body portion of section with palm of hand
16					
5. Remove Key Bone	Transfer section to R.H.	P, RL	52 — 52	TE, P, G	Move to and grasp legs
	Move to key bone	TE	56 — 60		
	Grasp, twist, and pull out key bone	P, G, U	75 — 75	P, H	Hold body section by legs
29					
6. Hit Out Body Meat	Discard key bone	TL, P	80 — 80 — 84	P	Position to hit
	Move to next crab section	TE	96 — 98	U	Hit out body meat (3 hits)
21					
7. Discard Section 6	Grasp next section	P, G	100 — 102 — 102	TL, P	Discard section with legs attached

* This figure represents the proposed activity frame-count of a skilled operator. (24 frames = 1 second)

Figure 37. Simultaneous motion-cycle chart of the crab body meat extraction suboperation -- proposed improved method.

simo chart (Figure 38), set forth the proposed improved method for crab claw leg meat extraction.

TABLE IX. RECOMMENDED CHANGES[20] FOR THE SUBOPERATION OF CRAB CLAW LEG MEAT EXTRACTION

Activity	Recommended Change[21]
1. Get Claw Leg	. Use Overlapping Motion - one hand should reach for the next claw leg while the other hand finishes shaking out the meat from the previous claw leg. . Better Work Place Arrangement - the claw legs and legs should be placed in separate piles, and the pile of unpicked claw legs placed immediately adjacent to the meat pan. . Improve Motion Pattern - grasp the claw leg by the point when getting the leg from the pile.
2. Tear Off Claw Point	. Change Activity Sequence - pick the claw meat before extracting the knuckle meat. . Improve Motion Pattern - eliminate transferring and regrasping the claw leg between hands before tearing off the claw point, by originally grasping the claw leg by the claw point when getting a leg from the pile.

20/ Changes are based on comparisons made with the established current industrial average method for claw leg meat extraction (see simo chart, Figure 19).

21/ A more detailed discussion of each change can be found in the preceeding chapter, Analysis of the Current Crab Meat Extraction Method, by looking under the specific suboperation and activity.

Table IX. Continued

Activity	Recommended Change
3. Crack And Remove End of Claw Shell	. Improve Motion Pattern - preposition hammer for easier grasping, and reduce the number of hits required to crack the end of the claw shell.
4. Hit Out Claw Meat	. Change Activity Sequence - hit out claw meat before discarding claw and eliminate rehandling of claw. . Improve Motion Pattern - leave claw attached to claw leg when hitting out claw meat. . Improve Equipment - provide a firm hitting base to reduce the hits required for meat removal.
5. Tear Off Claw and End of Knuckle Shell	. Change Activity Sequence - extract claw meat before tearing off the claw shell and end of kunckle shell.
6. Hit Out Knuckle Meat	. Improve Equipment - provide a firm hitting base to reduce the hits required for meat removal.
7. Crack Ham Shell and Tear Off End of Ham Shell	. Use Overlapping Motion - one hand should grasp the hammer while the other hand finishes hitting out the knuckle meat. . Improve Motion Pattern - hammer should be prepositioned for easier grasping, and the number of hits used to crack the shell should be reduced.
8. Hit Out Ham Meat	. Improve Equipment - provide a firm hitting base to reduce the hits required for meat removal. . Use Overlapping Motion - one hand should reach for the next claw leg while the other hand finishes shaking out the meat from the present leg.

Table IX. Continued

Activity	Recommended Change
9. Discard Ham Shell	. Improve Motion Pattern - discarding distances should be kept at a minimum. . Use Overlapping Motion - while one hand is discarding the shell, the other hand should be in the process of grasping the next claw leg.

Multiple Crab Leg Meat Extraction Suboperation

The following list of recommended changes (Table X), and simo charts (Figures 39 and 40), set forth the proposed improved method for multiple crab leg meat extraction. The list of preliminary recommended changes will consider all phases of leg meat extraction, including tip meat extraction. To coincide with the present industrial practices of individual seafood processing plants, the preliminary simo charts illustrate a motion pattern sequence that includes tip meat extraction and one that does not.

OPERATION: Claw Leg Meat Extraction			TIME		PROPOSED IMPROVED METHOD	
ACTIVITY	DESCRIPTION LEFT HAND	BASIC ACT	1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
1. Get claw leg 3*	Move to L.H.	TE	3	3	TL	Move to R.H.
2. Tear Off Claw Point 10	Grasp and hold claw leg	P, G, H	13	13	U	Tear off claw point
3. Crack And Remove End Of Claw Shell				16	TL, P	Discard claw point
	Position claw on anvil	P	21 – 20 –	23	P, G, TL	Get hammer
	Hold claw leg	H	31	31	P, U	Crack end of claw shell with hammer (1 hit)
				34	TL, P	Discard hammer
	Move to R.H.	TL	38	38	TE	Move to claw
31	Hold claw leg	P, H	– 40 – 44	44	P, G, U	Grasp and remove end of claw shell
4. Hit Out Claw Meat	Position to hit	P	47	47	TL, P	Discard end of claw
10	Hit out claw meat (2 hits)	U	54	54	UD	Wait
5. Tear Off Claw And End Of Knuckle Shell	Move to R.H.	TL, P	59	59	TE, P, G	Move to and grasp claw shell
15	Tear off claw and end of knuckle shell	U	– 60 – 69	69	U	Tear off claw and end of knuckle shell
6. Hit Out Knuckle Meat	Position to hit	P	73	72	TL, P	Discard shell
15	Hit out knuckle meat (2 hits)	U	– 80 – 84	84	P, G, TL	Get hammer
7. Crack Ham Shell And Tear Off End Of Ham Shell	Position claw leg on anvil and hold	P, H	92	92	P, U	Crack ham shell with hammer
				95	TL, P	Discard hammer
	Move to R.H.	TL	99	99	TE	Move to L.H.
22	Hold claw leg	P, H	– 100 – 106	106	P, G, U	Grasp and tear off end of ham shell
8. Hit Out Ham Meat	Position to hit	P	110	110	TL, P	Discard ham shell
14	Hit out ham meat (2 hits)	U	120	120	TE	Move to next claw leg
9. Discard Ham Shell 4	Discard shell	TL, P	– 120 – 124	124	P, G	Grasp point of claw leg

* This figure represents the proposed activity frame-count of a skilled operator. (24 frames = 1 second)

Figure 38. Simultaneous motion-cycle chart of the crab claw leg meat extraction suboperation -- proposed improved method.

TABLE X. PRELIMINARY RECOMMENDED CHANGES[22/] FOR THE SUBOPERATION OF MULTIPLE CRAB LEG MEAT EXTRACTION

Activity	Recommended Change[23/]
1. Get Legs	. Change Method - pick multiple crab legs instead of single legs. . Use Overlapping Motion - one hand should reach for the next group of legs while the other hand finishes shaking out the meat from the previous group of legs. . Better Work Place Arrangement - the claw legs and legs should be placed in separate piles, and the pile of unpicked legs placed immediately adjacent to the meat pan. . Improve Motion Pattern - grasp the legs by the tips when getting the group of legs from the pile.
2. Tear Off Points and Tip Ends	. Change Method - eliminate pulling out the leg points and using the hammer to crack the tip shells, by tearing off the points and tip ends. . Improve Motion Pattern - eliminate transferring and regrasping the legs by tearing off the shells with the opposite hand that grasps the legs from the pile of legs.

22/ Changes are based on comparisons made with the established current industrial average method for claw leg meat extraction (see simo chart, Figures 20 and 21).

23/ A more detailed discussion of each change can be found in the preceeding chapter, Analysis of the Current Crab Meat Extraction Method, by looking under the specific suboperation and activity.

Table X. Continued

Activity	Recommended Change
3. Hit Out Tip Meat	. Improve Motion Pattern - eliminate transferring and regrasping the legs before hitting out the meat, by hitting out the meat with the hand that holds the legs during the previous activity. . Improve Equipment - provide a firm hitting base to reduce the hits required for meat removal.
4. Tear Off Tip Shells and Joint Ends	. Improve Motion Pattern - eliminate transferring and regrasping the legs by tearing off the shells with the opposite hand that held the legs when the tip meat was hit out; use a single back and forth motion in tearing off the tip shells and joint ends.
5. Hit Out Joint Meat	. Improve Equipment - provide a firm hitting base to reduce the hits required for meat removal. . Use Overlapping Motion - the hand that tore off the shells in the previous activity should discard the shells and grasp the hammer for the next activity sequence while the joint meat is being hit out by the other hand.
6. Crack Ham Shells	. Improve Motion Pattern - hammer should be prepositioned for easier grasping, and the number of hits used to crack the shells should be reduced. . Improve Method - crack the body end of the ham shells to provide a bigger opening for meat removal.
7. Tear Off End of Ham Shells	. Improve Motion Pattern - tear off the body end of the ham shells for better meat exposure and removal.

Table X. Continued

Activity	Recommended Change
8. Hit Out Ham Meat	. Improve Equipment - provide a firm hitting base to reduce the hits required for meat removal. . Use Overlapping Motion - one hand should reach for the next group of legs while the other hand finishes shaking out the meat from the present group of legs.
9. Discard Ham Shells	. Improve Motion Pattern - discarding distances should be kept at a minimum. . Use Overlapping Motion - while one hand is discarding the shells, the other hand should be in the process of grasping the next group of legs.

Evaluation of the Proposed Improved Method

In-Plant Evaluation of Proposed Method

After developing the proposed improved method of crab meat extraction, the participation of seafood processing personnel was sought to evaluate and refine the proposed method. The management of what was considered a typical crab processing plant, and a plant that participated earlier in furnishing data for the analysis of picking methods, was approached.[24/]

24/ This seafood processing plant was referred to in earlier chapters as Plant F.

OPERATION: Mult. Leg Meat Extraction			TIME	PROPOSED IMPROVED METHOD	
ACTIVITY	DESCRIPTION LEFT HAND	BASIC ACT	1 UNIT = 4 FRAMES	BASIC ACT	DESCRIPTION RIGHT HAND
1. Get Legs 6*	Move to R.H.	TE	6 — 6	TL	Move to L.H.
2. Tear Off Points And Tip Ends 18	Grasp and tear off points and tip ends	P, G, U	— 20 — 24 — 24	P, H	Hold legs
3. Hit Out Tip Meat 13	Discard shells	TL, P	28 — 26	P	Position to hit
			34	U	Hit out tip meat (3 hits)
	Move to R.H.	TE	37 — 37	TL	Move to L.H.
4. Tear Off Tip Shells And Joint Ends 13	Grasp and tear off tip shells and joint ends	P, G, U	— 40 — 50 — 50	P, H	Hold legs
5. Hit Out Joint Meat 13	Discard shells	TL, P	53 — 53	P	Position to hit
	Wait	UD	— 60 — 63	U	Hit out joint meat (3 hits)
6. Crack Ham Shells 20	Move to R.H.	TE	66 — 66	TL	Move to L.H.
	Grasp legs	P, G	68 — 68	P, RL	Transfer legs to L.H.
	Position legs on anvil	P	74 — 74	P, G, TL	Get hammer
	Hold legs	H	80 — 80 — 80	P, U	Crack body end of ham shells (1-2 hits)
			83	TL, P	Discard hammer
7. Tear Off End Of Ham Shells 7	Move to R.H.	TL	86 — 86	TE	Move to L.H.
	Hold hams	P, H	90 — 90	P, G, U	Grasp and tear off ham shells
8. Hit Out Ham Meat 17	Position to hit	P	94 — 94	TL, P	Discard end of ham shells
	Hit out ham meat (3 hits)	U	— 100 — 107 — 107	TE	Move to next group of legs
9. Discard Ham Shells 4	Discard shells	TL, P	111 — 111	P, G	Grasp group of legs

* This figure represents the proposed activity frame-count of skilled operators. (24 frames = 1 second)

Figure 39. Simultaneous motion-cycle chart of the multiple leg crab meat extraction suboperation -- proposed improved method (tip meat extracted).

OPERATION: Mult. Leg Meat Extraction			TIME	PROPOSED IMPROVED METHOD	
ACTIVITY*	DESCRIPTION LEFT HAND	BASIC ACT	1 UNIT = 4 FRAMES	BASIC ACT	DESCRIPTION RIGHT HAND
1. Get Legs 6**	Move to R.H.	TE	6 — 6	TL	Move to L.H.
4. Tear Off Tip Shells And Joint Ends 13	Grasp and tear off tip shells and joint ends	P, G, U	19 — 19	P, H	Hold legs
5. Hit Out Joint Meat	Discard shells	TL, P	22 — 20 — 22	P	Position to hit
13	Wait	UD,	32	U	Hit out joint meat (3 hits)
6. Crack Ham Shells	Move to R.H.	TE	35 — 35	TL	Move to L.H.
	Grasp legs	P, G,	37 — 37	P, RL	Transfer legs to L.H.
	Position legs on anvil	P	43 — 40 — 43	P, G, TL	Get hammer
	Hold legs	H	49 — 49	P, U	Crack body end of ham shells (1-2 hits)
20	Move to R.H.	TL	52	TL, P	Discard hammer
7. Tear Off End Of Ham Shells 7	Hold hams	P, H	55 — 55 59 — 59	TE P, G, U	Move to L.H. Grasp and tear off ham shells
8. Hit Out Ham Meat	Position to hit	P	63 — 60 — 63	TL, P	Discard end of ham shells
17	Hit out ham meat (3 hits)	U	76 — 76	TE	Move to next group of legs
9. Discard Ham Shells 4	Discard shells	TL, P	80 — 80 — 80	P, G	Grasp group of legs

* Acts 2 and 3 dealing with tip meat extraction have been omitted.

** This figure represents the proposed activity frame-count of a skilled operator. (24 frames = 1 second)

Figure 40. Simultaneous motion-cycle chart of the multiple leg crab meat extraction suboperation -- proposed improved method (tip meat not extracted).

The proposed improved method was presented to the top management of Plant F. The proposed improved method and the resulting potential savings were discussed in depth with the management. Some skepticism was voiced on certain techniques and the methods which were not practiced in the current operations of their plant.

Major questions arose in the area of crab leg meat extraction. The proposed method suggests the use of multiple leg meat extraction. Plant F's management contended that the yield would be lower and the quality of the product would suffer if all pickers in the plant used the multiple leg method. Since there were those in the plant that currently picked multiple legs, a request was made to briefly examine a day's picking records to determine if there was a significant difference in yield between the two methods.

The picking records for August 4, 1970 were submitted for study. The analysis of a single day's picking showed that those who picked multiple legs had an average yield of 52.0%, while those who picked single legs had an average yield of 50.2%, 1.8% less than multiple leg picking.[25/] This survey indicates that yield does not necessarily decrease when using the multiple leg method. The results

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25/ The percentage yield was calculated by dividing the weight of the picked meat by the weight of the crab sections after the section had been debacked, cleaned, and cooked.

definitely lend some doubt to the somewhat common claim that multiple leg meat extraction reduces yield. The management, after viewing the results of the yield study, conceded that this may not be a problem after all. The management was also assured that if the proper techniques were employed, the quality would be of a high level.

The management was then shown motion picture clips of pickers that currently practice a given technique or method that had been incorporated into the proposed improved method. These clips were from the motion pictures taken of numerous crab pickers from various processing plants in Oregon for the purpose of analyzing picking methods. Upon viewing the film clips, the management agreed that the method was worth trying and consented to cooperate in evaluating and further improving or refining the proposed improved method.

The management was requested to select a test group from their present crab picking personnel. To get a typical cross section of individuals with varying skill levels, the group selected was to be composed of two above average skilled operators, two average skilled operators, and two below average skilled operators, with at least two or more years of picking experience.

On Thursday, December 3, 1970, a group meeting was held with the seafood processing plant's manager, superintendent, crab

foreman and the six ladies selected for the test group. The meeting was conducted by the manager of Plant F. He explained to the ladies the evaluation phase of the development of an improved crab picking method and their role in this process. He expressed full endorsement on the part of Plant F's management and requested that the ladies give their cooperation.

An orientation session was then conducted by the author to acquaint the ladies with the methods improvement process and the desired results. Attention was focused on the current in-plant evaluation phase and the significant contribution that the test group could offer by aiding in the removal of any errors, oversights or misjudgements, and the overall betterment of specific techniques and methods appearing in the proposed method.

The evaluation process proceeded with the author explaining the three suboperations of crab meat extraction in terms of the proposed method. After the explanation of each suboperation, questions were solicited from the group. The question-answer period was followed by actual in-plant practice of the suboperation that had been discussed. The test group remained separated from the rest of the pickers throughout the evaluation-training period. The intensive test group evaluation of the proposed method was conducted over a three day period.

The test group was very enthusiastic and cooperative throughout

the test period. A summary of the major changes in the proposed method, as a direct result of the test group's suggestions, is shown in Table XI. The major changes are listed according to the suboperation and the activity within that particular suboperation.

TABLE XI. SUMMARY OF THE MAJOR CHANGES IN THE PROPOSED METHOD[26/]

1. Suboperation: Body Meat Extraction

Activity: Compress body portion of section

This activity can be eliminated by compressing the body portion of the section during the Get Crab activity. When getting the section from the pile, the fingers of the left hand should grasp the body portion of the section. While moving the crab section from the table to the right hand, the fingers of the left hand press the body portion against the palm. When the section meets the right hand, the body portion has been compressed.

Activity: Hit out body meat

Generally, there is not much attention given to how the section is held when the body meat is removed. The section, however, should be held such that the hand holding the legs is on top of the legs and the bottom of the crab is facing up. In this position, the curve of the crab's body points down into the pan. If the curve points up, the meat is hard to hit out and will fly in all directions.

26/ The changes are the result of the suggestion made by the test group from Plant F, who were employed to evaluate the proposed method.

Table XI. Continued

2. Suboperation: Claw Leg Meat Extraction

Activity: Crack ham shell and tear off end of ham shell

The method used to open the ham meat cavity, that of cracking the knuckle end of the ham shell with the hammer and then tearing off the end of the ham shell, should be changed. The body end of the ham shell should be removed, as opening this end makes a bigger opening for the meat to come out. The ham shell should be removed by grasping the body end of the shell with the fingers of the right hand and tearing off the shell by using a pinching, twisting, and pulling action. This activity will now be referred to as Tear Off Body End of Ham Shell.

3. Suboperation: Multiple Leg Meat Extraction

Activity: Hit out tip meat, and hit out joint meat

Generally, there is not much attention given to how the legs are held during the hit tip and joint meat activities. The fingers of the hand holding the legs should be holding the ham shells to allow the lower part of the leg to flop freely. This flopping-whipping action aids in shaking out the meat. The fingers of the hand holding the legs just prior to hitting out the meat are usually on the lower part of the legs. A repositioning of the leg is required, so that the fingers will be holding the ham shells during the hit out meat activity. The repositioning is accomplished by pushing the body end of the legs against one's body.

Picking Rate Test of the Modified Proposed Method

The next step of the in-plant test of the proposed method, was to determine if the proposed method would increase the picker's

meat extraction rate. The three day intensive evaluation test at Plant F was followed by a four day picking rate test. The changes listed in Table XI were incorporated into the proposed method to form the modified proposed method. The modified proposed method was used in the picking rate test. Five of the original six ladies in the evaluation test group participated in the rate test.

Most phases of the modified proposed method, in terms of the basic skill factors, were implemented during the test period. The people skill factor remained unchanged. The pickers also continued to use the same type of domestic-household rubber gloves. And, although the hammer and anvil were not made of plastic, they were modified to conform dimensionally to the proposed improved tools. The currently used meat pan was made of a heavy gage stainless steel and met all proposed requirements. The work place did not present any significant influence over picking rate, that would justify the expense of correction. The crab sections were cooked in a continuous cooker according to the suggested rule of thumb and cooled by a water spray. The motion pattern used in the picking tests was the modified version of the proposed method. In addition, the pickers were exposed to the concepts underlying the skill factors of rhythm and speed.

At the end of the first day of crab meat extraction, all pickers were well below their previous picking rate when they had used

Plant F's standard picking method. However, at the end of the fourth day, four of the ladies' picking rates had increased, while one lady's picking rate decreased.[27/] The overall meat yield had also increased approximately 3 percent. Table XII presents the results of the picking rate test.

27/ The lady whose picking rate decreased, had difficulty in following the modified proposed method's motion pattern without reverting to the method she had previously used. Such an intermixing of motion patterns resulted in delays, hesitations, loss of rhythm, and a decrease in her picking rate. Nadler (15) indicates that such reductions in production rate will result when improved methods are introduced to certain individuals due to individual idiosyncrasies, that are either physiologically or psychologically oriented. Nadler (15) further states that such individuals, if producing adequately, should be allowed to use their "own" method if morale is to be maintained. Often it is difficult to determine when an individual is just resisting change or whether they are actually trying to change but cannot, and maintain a satisfactory production rate.

TABLE XII. RESULTS OF PLANT F's PICKING RATE TEST

Employee's Reference Number	Before Test Picking Rate (lbs./hr.)	After Test Picking Rate (lbs./hr.)	Percent (+) increase (-) decrease
11*	9.94	11.25	(+) 13.2
4*	10.11	13.60	(+) 34.5
15**	13.99	17.24	(+) 23.3
7**	14.47	14.73	(+) 1.8
36***	17.30	14.35	(-) 17.1

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* Average skilled operator

** Above average skilled operator

*** Highly skilled operator

Evaluation of the Modified Proposed Method by Numerous Oregon Seafood Processing Plants

Plant F's picking rate test definitely indicated that the modified proposed method had potential merit, but more participation was needed in evaluating the method. Although Plant F's test group had refined the proposed method, more examination of the method by people employed by different seafood plants with varied backgrounds was felt desirable in the developmental stage. The exposure of the method to other seafood plants was to serve a two-fold purpose, that of 1) further evaluation and improvement of the modified proposed method, and 2) the involvement of personnel from numerous Oregon seafood plants in the development of an improved meat extraction method. Final acceptance of an improved method depends on the points of view of as many individuals currently in the industry as possible.

The audio-visual media was selected as the tool to use in reaching the Oregon seafood industry at large for the evaluation of the modified proposed method. A script was written that would introduce, describe in detail, and request the assistance of the industry, and those closely associated with it, in evaluating and refining the modified method. A 16-mm film was produced to correspond with the script, which had been recorded onto a cassette cartridge to be played simultaneously with the showing of the film.

This script and film were the forerunner of the training film produced to implement the improved method (see the chapter entitled, Implementation of the Improved Method).

The motion picture film was ready for viewing by others the first part of March 1971. During the several months that followed, the film was shown in most of Oregon's seafood processing plants. The film was usually shown to the management, floor ladies and several management-selected pickers from each plant on an individual plant basis. The general reception of the method was good. However, the inevitable prejudice of favoring the method currently practiced in the plant was expressed in varying degrees in most plants.

The industry consensus of the method was favorable. Although many opinions were voiced, most concluded that the modified proposed method was basically sound. There were only two major questionable areas in deciding which technique should be used. A summary of these areas follows:

1. Suboperation: Claw Meat Extraction

   Activity: Tear off end of ham shell

   There is a question of whether or not the hammer should continue to be used in cracking the ham shell before it is torn off. In the proposed method, the hammer is eliminated and the ham shell is torn off by a pinching, twisting and pulling action. The analysis shows that both methods are currently practiced and are effective in ham meat removal. Since the proposed method has a shorter activity time, due to the elimination of the hammer

usage, it will continue to be recommended. If for some individual physiological or psychological reason the proposed method cannot be used, the hammer method is suggested as an alternate. The method should also be used if the shell is difficult to tear off.

2. Suboperation: Multiple Leg Meat Extraction

Activity: Tear off points and tip ends

There is a question of whether or not the activity should employ the hammer to crack and open up the tip shell. In this technique, the point is first torn off and discarded. The hammer is then used to crack the tip shell and open up the cavity containing the tip meat. The proposed technique simply grasps and tears off the point and tip end. Analysis shows that both methods are currently practiced and are effective means of opening up the tip cavity. Since the proposed method has a shorter activity time, due to the elimination of the hammer usage, it will continue to be recommended. If for some individual physiological or psychological reason the proposed method cannot be used, the hammer method is suggested as an alternate.

The added evaluation of others did result in important changes in the modified proposed method. Several plants pointed out the potential of shortening and bettering the motion pattern of the claw leg meat extraction suboperation. Table XIII summarizes the suggested changes and lists these changes according to activities.

TABLE XIII. CHANGES TO BE INCORPORATED INTO THE MODIFIED PROPOSED CLAW MEAT EXTRACTION SUBOPERATION

1. Activity: Crack and remove end of claw shell

The modified proposed method does not specifically designate where the hammer should strike the end of the claw shell. It has been suggested that a rule of thumb be established that the hammer should strike the red dot on the end of the claw shell (Figure 41). Analysis has shown that cracking the claw on the red dot assures easy claw meat removal, by adequately opening the meat cavity.

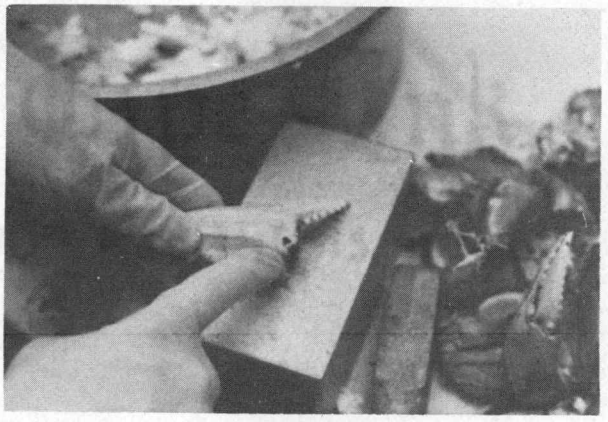


Figure 41. Red dot on the end of the claw shell.

2. Activity: Hit out claw meat, tear off claw and end of knuckle shell, and hit out knuckle meat

It has been suggested that these three activities be combined into two activities, by hitting out the claw and knuckle meat at the same time. The combination of these activities is accomplished by the following motion pattern: instead of hitting out the claw meat after cracking and tearing off the end of the claw shell, tear off the claw shell and knuckle end, by bending the claw's flex joint in the direction opposite to its normal flex. This tearing off of the claw shell and knuckle end is currently done after the claw meat is removed.

Table XIII. Continued

The claw shell is now held in one hand (the right hand in Figure 42) while the knuckle still attached to the ham shell is held in the other (the left hand in Figure 42). The claw and knuckle meat are hit out simultaneously, as illustrated in Figure 42. A stable meat pan is essential, if this technique is to be used. The activity heading used to describe the above mentioned suggested motion pattern will be, "Tear Off Claw and End of Knuckle Shell," and "Hit Out Claw and Knuckle Meat."

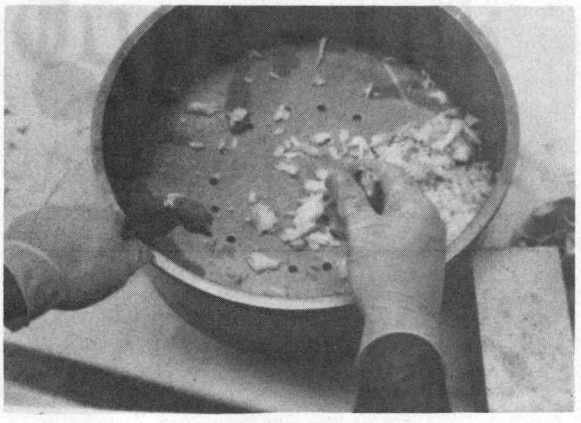


Figure 42. The knuckle meat and claw meat are being hit out simultaneously. The knuckle, attached to the ham shell, is held in the left hand, while the right hand is holding the claw.

A Summary of the Improved Crab Meat Extraction Method in Terms of the Six Skill Factors

This section summarizes the improved crab meat extraction method in terms of the six skill factors. The summary is based on the findings of the previous two sections, Development of a Proposed Improved Method in Terms of the Six Skill Factors, and Evaluation of the Proposed Improved Method. A brief discussion will follow each skill factor.

Indirect Skill Factors

Individual Aptitudes (First Indirect Skill Factor)

The individual is the key element in the crab meat extraction operation. The job requires that an individual possess the following aptitudes, according to preliminary studies conducted by the Employment Division of the Oregon State Employment Service, if they are to be an effective crab picker:

1. "Form Perception - Important in selecting various sized crab parts for removal of meat according to established sequence of tasks.

2. "Clerical Perception - Important in inspection of crab shells for removal of all meat.

3. "Motor Coordination - Required in use of eyes and both hands in reaching for and picking up crab parts and knocking out meat.

4. "Manual Dexterity - Necessary to make a variety

> of movements with hands and arms in handling crabs and parts, use of hammer to crack shells, and to knock meat out into containers." (19, p. 3)

To insure, with a reasonable amount of certainty, that new employees possess such aptitudes, each should be required to take the General Aptitude Test Battery for the occupation of crab picker, soon to be made available by the State Employment Division.

Plan and Control (Second Indirect Skill Factor)

An appropriate training program will reduce the time period over which the factors of plan (the mental work which determines how the physical work should be done) and control (dealing with the control of muscular-regulated movements) affect skill (14). Regardless of the possession of the required inherent aptitudes, an operator will not be able to perform the crab meat extraction operation without hesitations and delays until a certain amount of time has elapsed for becoming familiar with the hand pattern and motions. This familiarization period can be reduced through adequate training. The training program should be such that it minimizes the necessity for mental planning and accelerates the establishment of habits of muscular automaticity which in turn will reduce conscious control.

Direct Skill Factors

Materiel (First Direct Skill Factor)

Proper tools, equipment, workplace, and material are essential for effective crab meat extraction. The hammer and anvil used in cracking crab body parts, should be made of a plastic material. The plastic hammer will be light and yet provide the weight needed to crack the crab shell without added effort on the part of the worker. The plastic hammer also has the advantage of being non-corrosive when brought into contact with salt water. The hammer should have a cylindrical handle and a rectangular shaped head, with a minimum of four edges along the head, Figure 34.

The anvil should be made of a solid block of plastic, three-inches by three-inches by six-inches (Figure 35). This anvil is stable and has an adequate flat top surface for positioning crab parts. The distance of the top surface from the table top is sufficient to allow for the curvature of the crab legs hanging over the side and also provides adequate room for the hand that is holding the legs which must be along side the anvil for holding and positioning. The solid block type anvil has no inside surfaces to clean or harbor bacteria.

The pan should be stable, and constructed of a non-corrosive material, such as stainless steel. Some type of anchoring fixture

should be provided for light weight pans to provide stability. The bottom of the pan should contain holes for water drainage. The holes should be large enough to provide for maximum drainage but small enough to restrict the passage of meat. The rim of the pan should be wide enough, or sufficiently protected to prevent damage to the operator's hand when the hand strikes the rim during meat removal. A section of the rim can be covered with a piece of plastic hose or other dampening material to protect the operator's hands. Pans that are recessed into the table top with the rim essentially level with the table top, provide maximum protection.

A meat deflection shield may be placed behind the meat pan to recover meat that flies outside the rim of the pan during meat extraction. The shield should conform to the configuration of the pan and cover the back portion of the pan. For effective deflection, the height of the shield should be twelve inches above the rim of the pan. The shield should be of a non-corrosive metal or plastic material. A modification of the pan itself could also possibly alleviate this meat flying problem. Further investigation of the pan design is desirable.

Equipment

The gloves used in crab picking should have the qualities of proper fit and feel. A surgical type glove meets these requirements

but is not durable enough for this usage. Until such a glove can be found on the market or manufactured, the domestic-household type of glove is recommended for economic reasons.

The Workplace

Body fatigue can be reduced if heavy rubber pads are placed on the floor in front of the pickers workplace. Some consideration should be given to the East Coast's and Alaska's policy of providing alternate seating and standing facilities for their crab pickers.

A height raising device should be provided to take into account individual height variations. The device should be perfectly stable and provide the employee with some degree of freedom for foot movement to lessen fatigue.

A minimum individual work area of two and one-half feet by four feet is recommended for interference-free meat extraction (5). Partitioning will help define this individual work area. The table top should be vibration-free and made of a plastic or stainless steel material to resist corrosion and to avoid harboring bacteria.

Material (Crab Sections)

After the crab is received by the processor, the in-plant condition of the crab sections is dependent upon the cooking operation, the cooling operation, and the post-meat extraction handling

operation of holding, butchering and handling. Proper cooking will facilitate meat removal and produce maximum yields and a quality product. Ulmer (21) states that maximum yields can only be obtained where crabs are cooked in 212° F steam heated tap water. Until further studies are conducted on cooking times, a rule of thumb must be used in determining the proper cook time, assuming the cooking temperature is kept at 212° F. The cook time rule of thumb is as follows:

> The cook time shall range from 10 to 14 minutes. The actual cook time will be determined from feedback from the shuckers as to ease of meat extraction and whether the meat is adequately cooked.

To ensure an even cook, the sections should be cooked in an automatically controlled time and temperature continuous cooker.

Dewberry (22, p. 51) indicates that "the more rapidly the sections are cooled the higher the quality and the greater the percentage of meat recovery." Spray cooling should be used in cooling sections, rather than bath cooling, as it is more effective and more sanitary (5). Spray cooling efficiency can be further increased when a chilling effect is produced by blowing air through the spray cooling unit (5). Adams' (5) cooling tests indicate that the cooling water should have a maximum temperature of 50° F.

Post-meat extraction handling of the sections should be closely supervised. Damaged crab sections usually require more time to

pick per pound of meat extracted. Attention should be focused on the live crab holding and butchering operations if maximum yields are to be realized.

Necessity of Motion (Second Direct Skill Factor)

There are three parts to the second direct skill factor of necessity of motion, that of 1) length of the distances moved, 2) the occurrence of the basic acts of motion and 3) the types of move, grasp and position in the operation of crab meat extraction.

Length of the Distances Moved. The distances moved in getting crab body parts and discarding shells, or body parts, should be kept at a minimum. The location of the pile of body sections, claw legs, or crab legs should be located as close to the meat pan as possible, without interfering with the use of the hammer and anvil. The distances moved will be at a minimum when piles of body parts are placed immediately adjacent to the meat pan and minimal arm movements are used in discarding shells.

Occurrence of the Basic Acts of Motion. The basic acts of motion deemed necessary in the improved method of crab meat extraction are shown in the simo charts of each suboperation of crab meat extraction, in Figures 43 through 46.

Types of Move, Grasp, and Position. This section sets forth the appropriate types of move, grasp, and position that will tend to make the best use of time and energy expended in the crab meat extraction operation.

Types of move. Ballistic movements should be used rather than controlled movements whenever possible during the crab picking operation. Ballistic movements are the easy motions caused by a single contraction of a positive muscle group with no other muscle group contracting to oppose it, as is the case with a controlled movement (17). Ballistic movements should be used when discarding crab body parts and scrap shell. Controlled or restricted movements should be used whenever a relatively high degree of positioning is required as in pre-positioning the hammer for future use, or as in moving to grasp a particular portion of a crab body part.

Types of grasp. The hook grasp should be used whenever possible in the crab picking operation. A hook grasp occurs when the thumb and fingers grasp an object by reaching around it instead of grasping by pinching (17). The hook grasp assures maximum control of the crab body parts during the tearing off and hitting out activities. An eye-directed hook grasp results in minimum execution time by reducing the search and fine element times, which compose the basic act of grasp.

Types of position. The crab meat extraction operation

requires the employment of varying degrees of positioning. The types of position are in terms of the degree to which an object must be properly oriented in order to fit, go into, or be in the location of maximum effectiveness (17). A minimum degree of positioning should be used whenever possible as in discarding scrap shell. The following areas, however, require a higher degree of positioning.[28/]

1. In grasping a body section from the pile of sections, the fingers and thumb should grasp the body portion of the section to facilitate future motion patterns.

2. A high degree of positioning is required for proper and complete key bone removal.

3. Proper positioning of the crab section in body meat removal is critical. The hand hitting out the meat should be on top of the legs with the bottom of the crab facing up. Such positioning reduces the amount of meat that flies outside the area of the pan during the hitting process.

4. The claw leg should be grasped by the point to eliminate transferring and regrasping of the leg in order to tear off the point.

5. The hammer should be prepositioned such that the handle can be easily grasped.

6. Positioning of the crab body parts on the anvil is critical, if a minimum number of hammer blows are to be used and the body part is to be cracked in the proper location.

28/ A detailed explanation of each area mentioned can be found in the Dungeness crab meat extraction manual in Appendix I.

7. When body parts are torn apart, the location of the fingers that tear off the part is important. Improper positioning may result in loss of meat and quality.

8. The legs should be held by the ham shell when hitting out the tip and joint meat. Holding the ham shell allows the lower part of the leg to flop freely, thus aiding in meat removal.

Rhythm (Third Direct Skill Factor)

Rhythm, which is the regular uniform repetition of a certain cycle of motion, can only be prominent when hesitations and co-ordination delays are reduced or eliminated (14). To reduce hesitations, the number of basic acts composing the work sequence were diminished and rearranged in such a way that the sequence tends to progress in one direction (23). The simo charts of the improved method, Figures 43 through 46, illustrate how the picking operation can be accomplished using a minimum number of basic acts, the sequence of which progress in one direction. Tools and crab body parts should be positioned to aid the betterment of the sequence of movements. Coordination delays, which result from improper timing of movements of particular body members, should be reduced by exposing the pickers to training and practice of the proper motion pattern (23).

Speed (Fourth Direct Skill Factor)

Speed has to do with muscular movements and refers to the rate of physical activity of the worker (17). An individual will reach his maximum potential speed by being exposed to adequate training and practice (20). The proper training program must present the method of operation in such a manner that it can be easily understood. The sooner the basic concepts of crab meat extraction are grasped by the learner and practiced, the sooner the individual will realize their maximum potential speed.

All skill factors have a significant influence on an operator's production rate. However, the mere exposure of an operator to a better method of performing an operation will automatically increase his speed (17). A comparison of the current method simo charts (Figures 18 through 21) with the improved method simo charts (Figures 43 through 46) will plainly illustrate this point. Furthermore, any wasted time attributed to eye-hand coordination can be eliminated by commencing eye movement as soon as possible before the physical movement (23). Crab parts, and tools should be placed in the immediate vicinity of the meat pan to minimize the distances moved by the eyes and hands.

The Improved Motion Pattern for Crab Meat Extraction

The improved motion pattern for the operation of crab meat

extraction will be illustrated by the use of simo charts (Figures 43 through 46). The necessary basic acts have been arranged such that a natural rhythm can be maintained.

A step-by-step explanation of the motion patterns presented in the improved simo charts can be found in the pictorially illustrated manual on crab meat extraction in Appendix I.

Projected Benefits of the Improved Method Over the Current Method

The tables which follow depict the projected time savings when using the improved method of crab meat extraction over the current method. Tables XIV, XV, XVI, and XVII portray the proposed savings to be gained for each activity in a particular suboperation, and the recommended changes in the current method to achieve these savings. Table XVIII compares and summarizes the times required to perform the suboperations of the current and improved methods. When using the improved method, the projected production rate increase is 25%, see Table XVIII. These time production rates can be converted into pounds per hour of crab meat by using Figure 47.

It should be noted that several of the time figures introduced into the overall improved method's times are based on the current method's times. The "Irregular Activities" times for both the current and improved methods are based on the current activity time

OPERATION: Body Meat Extraction			TIME 1 UNIT = 4 FRAMES		IMPROVED METHOD	
ACTIVITY	DESCRIPTION LEFT HAND	BASIC ACT			BASIC ACT	DESCRIPTION RIGHT HAND
1. Get Crab 6*	Move to R.H. while squeezing body portion	TL, U	6	6	TE	Move to L.H.
				9	P, G	Grasp claw leg
2. Tear Off Claw Leg 12	Hold crab section	P, H	18	18	U	Tear off claw leg
			20			
				23	P	Position to hit
3. Hit Out Body Meat From Claw Leg 12	Hold crab section	H	30	30	U	Hit out body meat from claw leg (2 hits)
				34	TL, P	Lay claw leg aside
4. Remove Key Bone	Move to and transfer section to R.H.	TL, P, RL	40	40	TE, P G	Move to and grasp legs
			40			
	Move to key bone	TE	44			
			60			
33	Grasp, twist, and pull out key bone	P, G, U	63	63	P, H	Hold body section by legs
				68	P	Position to hit
5. Hit Out Body Meat	Discard key bone	TL, P	72			
			80			
21	Move to next crab section	TE	86	84	U	Hit out body meat (3 hits)
6. Discard Section 6	Grasp body portion	P, G	90	90	TL, P	Discard section with legs attached

* This figure represents the simulated activity frame-count of a skilled operator. (24 frames = 1 second)

Figure 43. Simultaneous motion-cycle chart of the crab body meat extraction suboperation -- improved method.

OPERATION: Claw Leg Meat Extraction			TIME		IMPROVED METHOD	
ACTIVITY	DESCRIPTION LEFT HAND	BASIC ACT	1 UNIT = 4 FRAMES		BASIC ACT	DESCRIPTION RIGHT HAND
1. Get Claw Leg 3*	Move to L.H.	TE	3	3	TL	Move to R.H.
2. Tear Off Claw Point 10	Grasp and hold claw leg	P, G, H	13	13	U	Tear off claw point
				16	TL, P	Discard claw point
3. Crack And Remove End Of Claw Shell	Position claw on anvil	P	21	23	P, G, TL	Get hammer
	Hold claw leg	H	31	31	P, U	Crack end of claw shell with hammer (1 hit)
				34	TL, P	Discard hammer
	Move to R.H.	TL	38	38	TE	Move to claw
31	Hold claw leg	P, H	44	44	P, G, U	Grasp and remove end of claw shell
				47	TL, P	Discard end of claw
4. Tear Off Claw And End Of Knuckle Shell	Move to R.H.	TL, P	52	52	TE, P, G	Move to and grasp claw shell
18	Tear off claw and end of knuckle shell	U	62	62	U	Tear off claw and end of knuckle shell
5. Hit Out Claw And Knuckle Meat	Position to hit	P	66	66	P	Position to hit
15	Hit out knuckle meat (2 hits)	U	77	77	U	Hit out claw meat (2 hits)
					TL, P	Discard claw shell
6. Tear Off End Of Ham Shell 22	Reposition ham shell and hold knuckle end of ham shell	P, H	99	99	P, G, U	Grasp body end of ham shell and tear off shell
7. Hit Out Ham Meat	Position to hit	P	103	103	TL, P	Discard ham shell
14	Hit out ham meat (2 hits)	U	113	113	TE	Move to next claw leg
8. Discard Ham Shell 4	Discard shell	TL, P	117	117	P, G	Grasp point of claw leg

* This figure represents the simulated activity frame-count of a skilled operator. (24 frames = 1 second)

Figure 44. Simultaneous motion-cycle chart of the crab claw leg meat extraction suboperation -- improved method.

OPERATION: Mult. Leg Meat Extraction			TIME	IMPROVED METHOD	
ACTIVITY	DESCRIPTION LEFT HAND	BASIC ACT	1 UNIT = 4 FRAMES	BASIC ACT	DESCRIPTION RIGHT HAND
1. Get Legs 6*	Move to R.H.	TE	6 — 6	TL	Move to L.H.
2. Tear Off Points And Tip Ends 18	Grasp and tear off points and tip ends	P, G, U	20 — 24 — 24	P, H	Hold legs
			26	P	Position to hit
3. Hit Out Tip Meat	Discard shells	TL, P	28		Hit out tip meat (3 hits)
			34	U	
13	Move to R.H.	TE	37 — 37	TL	Move to L.H.
4. Tear Off Tip Shells And Joint Ends 13	Grasp and tear off tip shells and joint ends	P, G, U	40 — 50 — 50	P, H	Hold legs
	Discard shells	TL, P	53 — 53	P	Position to hit
5. Hit Out Joint Meat 13	Wait	UD	60 — 63	U	Hit out joint meat (3 hits)
	Move to R.H.	TE	66 — 66	TL	Move to L.H.
6. Crack Ham Shells	Grasp legs	P, G,	68 — 68	P, RL	Transfer legs to L.H.
	Position legs on anvil	P	74 — 74	P, G, TL	Get hammer
	Hold legs	H	80 — 80	P, U	Crack body end of ham shells (1-2 hits)
20			80 — 83	TL, P	Discard hammer
7. Tear Off End Of Ham Shells 7	Move to R.H.	TL	86 — 86	TE	Move to L.H.
	Hold hams	P, H	90 — 90	P, G, U	Grasp and tear off ham shells
8. Hit Out Ham Meat	Position to hit	P	94 — 94	TL, P	Discard end of ham shells
17	Hit out ham meat (3 hits)	U	100 — 107 — 107	TE	Move to next group of legs
9. Discard Ham Shells 4	Discard shells	TL, P	111 — 111	P, G	Grasp group of legs

* This figure represents the simulated activity frame-count of a skilled operator. (24 frames = 1 second)

Figure 45. Simultaneous motion-cycle chart of the multiple leg crab meat extraction suboperation -- improved method (tip meat extracted).

OPERATION: Mult. Leg Meat Extraction			TIME	IMPROVED METHOD	
ACTIVITY*	DESCRIPTION LEFT HAND	BASIC ACT	1 UNIT = 4 FRAMES	BASIC ACT	DESCRIPTION RIGHT HAND
1. Get Legs 6**	Move to R.H.	TE	6 — 6	TL	Move to L.H.
4. Tear Off Tip Shells And Joint Ends 13	Grasp and tear off tip shells and joint ends	P, G, U	19 — 19	P, H	Hold legs
	Discard shells	TL, P	22 — 20 — 22	P	Position to hit
5. Hit Out Joint Meat 13	Wait	UD,	32	U	Hit out joint meat (3 hits)
	Move to R.H.	TE	35 — 35	TL	Move to L.H.
6. Crack Ham Shells	Grasp legs	P, G	37 — 37	P, RL	Transfer legs to L.H.
	Position legs on anvil	P	43 — 40 — 43	P, G, TL	Get hammer
	Hold legs	H	49 — 49	P, U	Crack body end of ham shells (1-2 hits)
20			52	TL, P	Discard hammer
7. Tear Off End Of Ham Shells	Move to R.H.	TL	55 — 55	TE	Move to L.H.
7	Hold hams	P, H	59 — 59	P, G, U	Grasp and tear off ham shells
8. Hit Out Ham Meat	Position to hit	P	63 — 60 — 63	TL, P	Discard end of ham shells
17	Hit out ham meat (3 hits)	U	76 — 76	TE	Move to next group of legs
9. Discard Ham Shells 4	Discard shells	TL, P	80 — 80	P, G	Grasp group of legs

* Acts 2 and 3 dealing with tip meat extraction have been omitted.

** This figure represents the simulated activity frame-count of a skilled operator. (24 frames = 1 second)

Figure 46. Simultaneous motion-cycle chart of the multiple leg crab meat extraction suboperation -- improved method (tip meat not extracted).

TABLE XIV. PROJECTED SAVINGS FOR THE SUBOPERATION OF CRAB BODY MEAT EXTRACTION

ACTIVITY	CURRENT INDUSTRY AVERAGE OF SKILLED OPERATORS	SIMULATED IMPROVED METHOD	SAVINGS	RECOMMENDED CHANGES
1. Get Crab	15*	6*	9*	Grasp next body section while other hand finishes hitting out body meat of previous section; grasp body portion of section with fingers; compress body portion in hand while moving section from table; pile of sections placed immediately adjacent to meat pan.
2. Tear Off Claw Leg	14	12	2	Eliminate transferring and regrasp body section, by originally grasping the body portion of the section.
3. Hit Out Body Meat From Claw Leg	18	12	6	Hit out body meat adhering to claw leg immediately after tearing off leg; use a firm hitting base (2 hits).
4. Compress Body Portion Of Section	16	--	16	Eliminate this activity by compressing the body portion of the section during the Get Leg activity.
5. Remove Key Bone	29	33	- 4	Additional time is allowed for complete and proper key bone removal.
6. Hit Out Body Meat	44	21	23	Hand should be on top of legs with bottom of crab pointing up; use a firm hitting base (3 hits); one hand should reach for the next body section while other hand finishes shaking out body meat.
7. Discard Legs	18	6	12	Discard the body section with the legs attached, instead of separating legs from section; while discarding section the other hand should be in the process of grasping the next crab section.
Total Frame-count	154	90	64	
Irregular Activities**	51	51	0	
Total Normal*** Picking Time Frame-count Per Section	205	141	64	
Total Normal Picking Time Per Section In Seconds	8.6	5.9	2.7	
Standard**** Picking Time Per Section In Seconds	10.3	7.6	2.7	

* This figure represents the activity time in frames. (24 frames equals 1 second)

** This figure is 33% of the Current Total Frame-count as suggested by Cholvanich (16).

*** Normal time is the total of regular and irregular activity times, without allowance for individual fatigue, delays, and personal time.

**** Standard time is the normal time plus 20% allowance for individual fatigue, delays, and personal time.

TABLE XV. PROJECTED SAVINGS FOR THE SUBOPERATION OF CRAB CLAW LEG MEAT EXTRACTION

ACTIVITY	CURRENT INDUSTRY AVERAGE OF SKILLED OPERATORS	SIMULATED IMPROVED METHOD	SAVINGS	RECOMMENDED CHANGES
1. Get Claw Leg	9*	3*	6*	Get the new claw leg while shaking out the meat from the previous leg; claw legs are in a separate pile placed immediately adjacent to meat pan; grasp claw leg by the point.
2. Tear Off Claw Point	17	10	7	Pick the claw meat before extracting the knuckle meat; eliminate transferring and regrasping claw leg by originally grasping claw point when getting leg from pile
3. Crack And Remove End Of Claw Shell	36	31	5	Crack the claw end by hitting the red dot on the end of the shell with hammer, preposition hammer so it is easily grasped; use one blow from the hammer to crack shell.
4. Tear Off Claw And End Of Knuckle Shell	18	18	0	Tear off the shell by bending the claw's flex joint in the direction opposite to its normal flex.
5. Hit Out Claw Meat	12	--	12	The claw and knuckle meat should be hit out simultaneously.
6. Hit Out Claw And Knuckle Meat	18	15	3	Hit out claw and knuckle meat at the same time; use a firm hitting base (2 hits).
7. Tear Off End Of Ham Shell	28	22	6	Eliminate the use of hammer by tearing off body end of ham shell; tear shell of by using a pinching, twisting, and pulling action.
8. Hit Out Ham Meat	20	14	6	Use a firm hitting base (2 hits); reach for the next claw leg while other hand hits out meat.
9. Discard Shell	6	4	2	Keep discarding distances at a minimum; while discarding the ham shells, the other hand should be in the process of grasping the next claw leg.
Total Frame-count	164	117	47	
Irregular Activities**	38	38	0	
Total Normal*** Picking Time Frame-count Per Claw Leg	202	155	47	
Total Normal Picking Time Per Claw Leg In Seconds	8.4	6.5	1.9	
Standard**** Picking Time Per Claw Leg In Seconds	10.1	8.2	1.9	

* This figure represents the activity time in frames. (24 frames equals 1 second)

** This figure is 23% of the Current Total Frame-count as suggested by Cholvanich (16).

*** Normal time is the total of regular and irregular activity times, without allowance for individual fatigue, delays, and personal time.

**** Standard time is the normal time plus 20% allowance for individual fatigue, delays, and personal time.

TABLE XVI. PROJECTED SAVINGS FOR THE SUBOPERATION OF CRAB LEG MEAT EXTRACTION

(Tip meat extraction and related activities have been omitted)

ACTIVITY	CURRENT MULTIPLE LEG METHOD OF SKILLED OPERATORS (2 leg average)	SIMULATED IMPROVED MULTIPLE LEG METHOD (2 leg average)	SAVINGS (per 2 legs)	RECOMMENDED CHANGES
1. Get Legs	11*	6*	5*	Grasp next body section while other hand finishes hitting out body meat of previous section; grasp body portion of section with fingers; compress body portion in hand while moving section from table; pile of sections placed immediately adjacent to meat pan.
2. Tear Off Tip Shells And Joint Ends	18	13	5	Eliminate transferring and regrasp body section, by originally grasping the body portion of the section.
3. Hit Out Joint Meat	19	13	6	Hit out body meat adhering to claw leg immediately after tearing off leg; use a firm hitting base (2 hits).
4. Crack Ham Shells	24	20	4	Eliminate this activity by compressing the body portion of the section during the Get Leg activity.
5. Tear Off Ends Of Ham Shells	12	7	5	Additional time is allowed for complete and proper key bone removal.
6. Hit Out Ham Meat	24	17	7	Hand should be on top of legs with bottom of crab pointing up; use a firm hitting base (3 hits); one hand should reach for the next body section while other hand finishes shaking out body meat.
7. Discard Ham Shells	5	4	1	Discard the body section with the legs attached, instead of separating legs from section; while discarding section the other hand should be in the process of grasping the next crab section.
Total Frame-count	113	80	33	
Irregular Activities**	46	46	0	
Total Normal*** Picking Time Frame-count Per 2 Legs	159	126	33	
Total Normal Picking Time Per 2 Legs In Seconds	6.6	5.3	1.3	
Standard**** Picking Time Per 2 Legs In Seconds	7.9 (4.0 per leg)	6.6 (3.3 per leg)	1.3 (.7 per leg)	

* This figure represents the activity time in frames. (24 frames equals 1 second)

** This figure is 41% of the Current Total Frame-count as suggested by Cholvanich (16).

*** Normal time is the total of regular and irregular activity times, without allowance for individual fatigue, delays, and personal time.

**** Standard time is the normal time plus 20% allowance for individual fatigue, delays, and personal time.

TABLE XVII. PROJECTED SAVINGS FOR THE SUBOPERATION OF CRAB LEG MEAT EXTRACTION

ACTIVITY	CURRENT SINGLE LEG INDUSTRY AVERAGE OF SKILLED OPERATORS	SIMULATED IMPROVED MULTIPLE LEG METHOD (2 leg average)	SAVINGS (Per 2 legs)	RECOMMENDED CHANGES
1. Get Legs	6*	6*	6*	Pick multiple crab legs; one hand should grasp for the next group of legs while the other hand finishes shaking out meat of previous section; legs are in a separate pile placed immediately adjacent to meat pan; grasp the legs by the tips.
2. Tear Off Points And Tip Ends	9	18	0	Eliminate the use of the hammer by tearing off the points and tip ends; eliminate transferring and regrasping legs by tearing off shells with opposite hand that grasps legs from pile.
3. Crack Tip Shells	7	--	14	Eliminate the use of hammer by tearing off points and tip ends.
4. Hit Out Tip Meat	13	13	13	Hit out meat using hand that held legs during tearing activity; push body end of ham shells against picker's body to reposition legs in fingers, so fingers are holding hams when hitting out meat; use a firm hitting base (3 hits).
5. Tear Off Tip Shells And Joint Ends	14	13	15	Eliminate transferring and regrasping legs by tearing off shells with opposite hand that held legs during the hit out meat activity; use a single back and forth motion in tearing off shells.
6. Hit Out Joint Meat	10	13	7	Reposition legs so fingers are holding ham shells during meat removal; use a firm hitting base (3 hits).
7. Crack Ham Shells	22	20	24	Hammer should be prepositioned for easy grasping; crack the body end of the ham shells (1-2 hits).
8. Tear Off End of Ham Shells	10	7	13	Tear off body end of ham shells using a twisting-pulling action.
9. Hit Out Ham Meat	12	17	7	Use a firm hitting base (3 hits); while one hand is hitting out ham meat, the other hand should reach for the next group of legs.
10. Discard Ham Shells	5	4	6	Keep discarding distances at a minimum; while one hand is discarding the shell, the other hand should be in the process of grasping the next group of legs.
Total Frame-count	108	111	105	
Irregular Activities**	44	44	44	
Total Normal*** Picking Time Frame-count	152	155	149	
Total Normal Picking Time In Seconds	6.3	6.5	6.2	
Standard**** Picking Time In Seconds	7.6	9.0 (4.5 seconds/leg)	6.2 (3.1 seconds/leg)	

* This figure represents the activity time in frames. (24 frames equals 1 second)

** This figure is 41% of the Current Total Frame-count as suggested by Cholvanich (16).

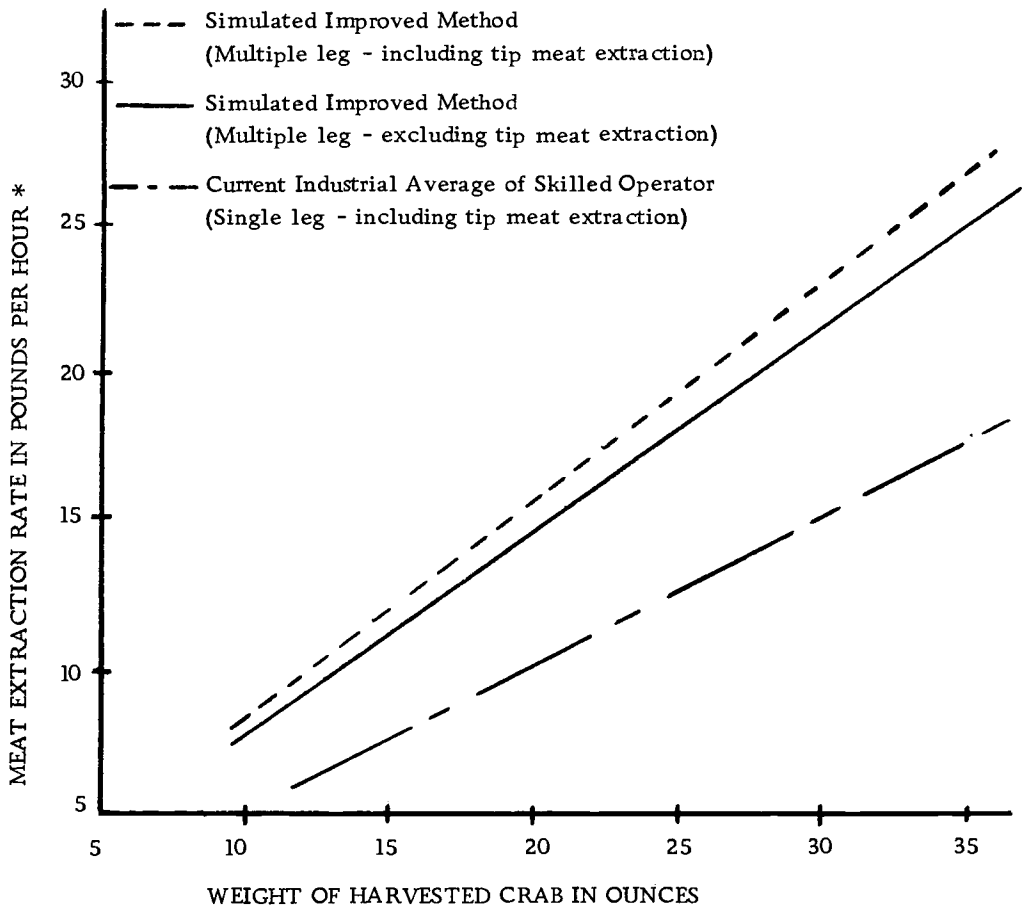
*** Normal time is the total of regular and irregular activity times, without allowance for individual fatigue, delays, and personal time.

**** Standard time is the normal time plus 20% allowance for individual fatigue, delays, and personal time.

TABLE XVIII. SUMMARY OF PROJECTED SAVINGS AND OF STANDARD TIMES* REQUIRED TO EXTRACT THE MEAT FROM A SINGLE CRAB IN SECONDS

STANDARD TIME	CURRENT METHOD OF SKILLED OPERATORS		SIMULATED IMPROVED METHOD		PROJECTED SAVINGS	
	Including Tip Meat Extraction (Single Leg)	Excluding Tip Meat Extraction (Multiple Leg)	Including Tip Meat Extraction (Multiple Leg)	Excluding Tip Meat Extraction (Multiple Leg)	Including Tip Meat Extraction	Excluding Tip Meat Extraction
Body Meat Extraction (for 2 sections)	20.6	20.6	15.2	15.2	5.4	5.4
Claw Leg Meat Extraction (for 2 claw legs)	20.2	20.2	16.4	16.4	3.8	3.8
Leg Meat Extraction (for 8 legs)	60.8	31.6	36.0	26.4	24.8	5.2
TOTAL STANDARD TIME REQUIRED TO EXTRACT THE MEAT FROM A SINGLE CRAB (seconds)	101.6	72.4	67.6	58.0		
PROJECTED SAVINGS WHEN USING IMPROVED METHOD (seconds)					34.0	14.4
PROJECTED PRODUCTION RATE INCREASE WHEN USING SIMULATED IMPROVED METHOD (percentage)					50.0	25.0

* Standard time is the total of regular and irregular activity times, plus a 20% allowance for individual fatigue, delays, and personal time.



* Curves are based on an average meat yield to harvested crab weight ratio of 23%. The above curves may level off rapidly as the size of the harvested crab increases due to manipulation difficulties. It has been assumed that the size of the crab did not increase the cycle time.

Figure 47. Production rate comparison of improved method with current method of crab meat extraction.

for the respective suboperations. The improved method's irregular activity time is assumed to be that of the current method. There is a question whether the irregular activity times would be reduced, and if reduced, what the percentage of reduction would be. Furthermore, the amount of time added to the normal time to get the standard time is also based on the current method's times. Again, it is questionable as to the amount of reduction in the elements of fatigue, delays, and personal time. Until further studies can be made in these areas, the amount of time added to the improved method's normal time to approximate the standard time will be the same as that added to the current method.

The Standard Time Model of the current method performed by a skilled operator, Table XVIII, was compared to actual production rates. The management of two of the original three participating seafood processing plants, Plant F and Plant D, were asked to compare the standard times with their present operations. Both plant managers concurred that the model adequately represented the crab meat extraction production rates of their highly skilled operators. Three other Oregon plants also accepted the model as applicable to high-skilled workers.

VII. IN-PLANT EXPERIMENTATION OF THE IMPROVED METHOD

In-Plant Trial Application of the Improved Method

The improved method of crab meat extraction was tested in one plant to evaluate its merits before releasing the method to the seafood processing plants at large. The management of Plant F was so favorably impressed with the results of the control group, (Table XII, p. 172), that they immediately agreed to implement the improved method on a plant-wide basis. Two of the ladies that participated earlier in the evaluation of the proposed improved method were chosen to instruct the other pickers. A total of 36 pickers with varying degrees of experience were exposed to the improved method.

As in the previous picking rate test which was conducted at Plant F, most phases of the improved method, in terms of the basic skill factors, were implemented on a plant-wide basis. The people skill factor remained unchanged. The pickers also continued to use the same type of domestic-household rubber gloves. Although the hammer and anvil were not made of plastic, they were modified to conform dimensionally to the improved tools. The currently used meat pan was made of a heavy gauge stainless steel and met the requirement for a firm hitting base. The crab sections were cooked

in a continuous cooker according to the suggested rule of thumb (p. 183) and cooled by a water spray. Major emphasis was placed on the implementation of the improved motion pattern to be used in meat extraction.

Statistical data was kept on each of the 36 pickers during the 1970-1971 crab season. At the end of the season, the data was analyzed to determine the overall effect of the improved method.

Analysis of the statistical picking data from December 7, 1970 through April 13, 1971, indicated that the overall meat extraction rate had increased 20 percent with the implementation of the improved method. The data used to calculate this increase is in Appendix II. Also included in this appendix is the picking rates during the training period of the operators. All days that "boat run crab" (i.e. days in which larger crabs were not sorted out to be sold as whole or shell crab) were processed were excluded when determining the new plant average picking rate. The employees' new average picking rates were then compared with their average picking rates prior to use of the improved method. The relative increase in production depended upon the individual's original skill level. Thus, some individuals increased their production significantly and others only marginally. The picking rate statistical data of several women are listed below to illustrate this fact (Table XIX).

TABLE XIX. VARIATIONS IN IMPROVEMENT AMONG INDIVIDUALS AFTER BEING EXPOSED TO THE IMPROVED METHOD.

Employee Number	Original Avg. Rate (lbs./hr.)	Improved Avg. Rate (lbs./hr.)	Max. Daily Rate (impr. method) (lbs./hr.)	Percent of Increase
2	11.60	15.42	17.95	33
3	14.09	17.24	22.57	22
6	13.50	14.20	16.31	5
7	14.47	15.84	19.43	10
18	9.44	13.64	17.29	40
29	9.79	15.36	17.38	57
36	17.30	17.50	21.79	1

Besides the meat extraction rate increases, the meat yield (the ratio of the extracted meat weight to the butchered and cooked section weight) increased an average of three percent. Such an increase in meat yield would mean that the plant's production would increase approximately 1.5 percent of the total harvested crab weight processed solely as the result of placing emphasis upon proper care in the cooking, handling, and meat extraction procedures.

Numerous observations of the pickers were made throughout the season. Very few of the pickers were observed using the complete motion pattern described as the improved method. This incomplete use of the improved motion patterns could have been the result of the individual's need to change the method due to

physiological or psychological reasons, or inadequate training. Closer conformity to the improved motion patterns may yield a much higher overall plant increase than the recorded 20%.

During the period from December 1970 to April 1971, the average overall labor cost attributed to the crab meat extraction process, in the control "test plant," decreased after implementation of the improved method. The average original picking labor costs was 60 percent of the overall labor costs attributed to crab meat processing (see Figure 7 , p. 13). At the end of April, picking labor costs were an average of 57 percent of the overall labor costs.[28/] This represents a savings of approximately $0.02 per pound of meat processed.[28/]

Statistical Testing of the In-Plant Experimentation's Results

A statistical test was performed on the before and after overall plant meat extraction averages, in order to make inference concerning the difference between the means. The objective of the test was to determine if the 20 percent increase in the plant's average picking rate was sufficient evidence to conclude that using the improved method significantly increased production. The Student's *t* test was

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28/ From confidential data given to author by Plant F's management.

used to compare the before and after overall mean picking rates.[29/] The results of the t test indicated that there was sufficient evidence to conclude with a 99 percent confidence level that the improved method of meat extraction yielded a significantly higher picking rate. (See Appendix II for the *SIPS computer data used in the t test and the numerical results of the test.)

The improved method appears to have the potential of increasing the overall average picking rates of seafood processing plants. Statistical tests have substantiated the fact that Plant F's production rate was increased by the implementation of the improved method. It can be inferred from this that other seafood processing plants can also benefit from using the improved method. The degree that each plant can increase their production rates will vary, and will depend on the methods and employees presently used in the individual plants.

29/ W. Mendenhall (24) discusses the Student's t test on pages 223-248.

VIII. IMPLEMENTATION OF THE IMPROVED METHOD

"A carefully developed method of doing work is of little value unless it can be put into effect," asserts Barnes (17, p. 6). The vehicle by which the improved method can be put into effect is a training program with appropriate training aids. McLarney defines training and its benefits in the following passages (13, p. 350):

> "Training is passing along 'know-how' through carefully selected methods, ... , to shorten learning time or experience. Training is telling-plus showing-plus supervised practice, until the desired change is achieved in the learner's skill, attitude, or behavior.
>
> "Employees, both new and old, benefit by training. No matter how carefully an employee is selected, he still needs some training. And the present employees, if they are to be developed to their capacities, they too need training. Training builds morale by enabling the employee to do his assigned work properly; it increases his skill, his value, his security, ... It lets him know more clearly what is expected of him and thereby reduces his uncertainty, his errors, fears, and tensions."

The time period over which the indirect skill factors of plan and control affect the operator's performance is influenced by training as alluded to earlier, pages 48 to 50. The importance of reducing this influential time period is emphasized by an investigation conducted by Barnes. "This study shows that in this case two-thirds of the increase in output during the learning period can be attributed to the elimination of fumbles, delays, and hesitations on the part of the operator, ..." (17, p. 631). It is apparent that an effective method

of conveying a new procedure must be provided.

Training Aids

To better convey the improved method and reduce the time spent training each operator, the in-plant trainer should be provided with appropriate training aids. During the initial in-plant evaluation of the improved method at Plant F, the author exposed the "test group" to such training aids as simo charts[30/] and written step-by-step procedures. Both of these methods proved ineffective. The very appearance of the simo chart puzzled the operators and the written procedure, even though set down in detail, did not enable them to visualize the described motions. After further discussions with the "test group," it was concluded that instruction using the audio-visual media would be more beneficial.

Training Film

Effort was turned to developing a sound-color motion picture. The objectives of the training film were as follows:

1. Introduce the operator to the improved method of crab meat extraction in such a way that it carried no

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30/ The simo chart is a right- and left-hand description which shows both the motion patterns and the times required for each motion.

implication of criticism of the operator or his supervisors.

2. Present the benefits of using the improved method.

3. Have a skill oriented training film.

4. Break down intricate procedures into easy to follow details.

5. Produce a training aid that can stand alone in presenting the improved method.

After a script was written which met the objectives set forth above, a 16 mm motion picture film was produced at Oregon State University, Corvallis, Oregon, in the Industrial Engineering Department, with the help of several commercial seafood processors (Figure 48). During March 1971, this initial production, along with a cassette recording of the script,

Figure 48. Bill Reasons and Terry Johnson film the author who is extracting crab meat using the improved method.

was shown to numerous Oregon seafood processors to introduce them to the improved method, see pages 173 to 177. It was stressed at this time that the method was still in the formulation stages, and suggestions for improvements were solicited. Continuous interaction with the seafood industry during the developmental stages was essential to make the improved method and training aids acceptable upon completion. When asked if such a film would be beneficial as a training aid, the seafood processors and employees replied in the affirmative.

With such an enthusiastic reception of the notion of a training film, the effort was continued. The script was rewritten to conform with the final form of the improved method.[31/] Necessary changes were also made in the film. These efforts culminated in the production of a 16 mm sound-color motion picture training film, entitled "Crab Meat Extraction," which describes the improved method in detail, each movement at regular and slow motion speeds.[32/] The film was ready for viewing in September 1971.

31/ The film script appears in Appendix III.

32/ In October 1971 the training film was entered in national film competition, and received the first place award in the University Division of film competition sponsored by the Industrial Management Society. Awards presented are shown in Appendix IV.

Training Manual

During the production of the training film, the need for another type of training aid appeared. Optimally the training film should be at the disposal of the trainee. Practically speaking, at least initially, this was impossible. Thus, the need arose for a means of reinforcing the procedures the trainee had seen while viewing the film.

A pictorial instruction manual seemed to fit the need of a complementary training aid. The objectives used in developing the training film were also applied to the manual's formulation.

Formulation of the training manual proceeded. During the final filming of the training film, still pictures were taken of the picking operation. These pictures were then put with a narrative to form the main body of the manual. Thus, a pictorially-illustrated training manual with written instructions, entitled "Dungeness Crab Meat Extraction," was published in November 1971 to be used in conjunction with the training film.[33/]

Reaction To Training Aids

What did the seafood processing community think of these training aids? An effort was made during December 1971 to expose the management and employees to the film and manual, and to gather

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[33/] The training manual appears in Appendix I.

their responses. A questionnaire was given to those exposed to the training aids.

Responses to the training aids were favorable. Twelve seafood processing plants participated in the evaluation. The management agreed that the training aids would be beneficial. A detailed listing of replies to the questionnaire is shown in Figure 49.

After such a welcome reception, the training aids were made available to the seafood processing community through the Audio-Visual Department, Oregon State University, Corvallis, Oregon 97331 on a purchase or rental basis. The training manual was obtainable through the Engineering Experiment Station, Oregon State University, Corvallis, Oregon 97331.

Training Program

In order to present a complete training package to the seafood processors, a training program outline was prepared. The program was developed with the beginner in mind, but could be easily adapted to retrain the veteran employee. A combination of classroom and on the job practice was felt to be the most beneficial type of program in which to present the improved method. McLarney sets forth such a program which he calls "The Four-Step Method of Job Training" (13, p. 355-357). This four-step method was tailored to fit the needs of the seafood industry. The modified program follows:

During the period between December 21-30, 1971, an effort was made to make the crab meat extraction training film and training manual available for viewing to Oregon's crab processing plants' managers, superintendants, foremen, floor ladies, and pickers.

The questionnaires were filled in by those attending the training aids' presentation. The following seafood companies participated:

Astoria Seafoods (Astoria), Ocean Foods of Astoria (Astoria), Point Adams Packing Co., (Astoria), Union Fish (Astoria), New England Fish (Warrenton), Hoy Brothers Fish and Crab (Garibaldi), Sea Rations (Garibaldi), Edmund's Fish and Crab (Garibaldi), Bell Buoy Crab Co. (Seaside), Peterson Seafoods, Inc. (Charleston), Hallmark Fisheries (Charleston), and Eureka Fisheries, Inc. (Coos Bay).

NOTE: Responses are shown in percentages
Management - 17 participants
Crab Pickers - 20 participants

TRAINING FILM QUESTIONS

	Management		Crab Pickers	
	Yes	No or No Response	Yes	No or No Response
1. Do you feel the training film will benefit you?	100%	0%	85%	15%
2. Do you feel that the film will shorten training time?	88	12	100	0
3. Can the film increase the picking rate of a veteran picker?	82	18	65	35
4. Can the film increase the yield of a veteran picker?	70	30	45	55
5. Would you be willing to purchase the film for $180?	24	76	—	—
6. Would you be willing to rent it for $8 (2 days)?	82	18	—	—
7. What changes would you like to see in the final edited copy? For Example:				
(a) Should the film be divided into three separate segments for the body, claw and legs?	18	82	40	60
(b) Should portions of the film be changed to fit your practices?	18	82	20	80

TRAINING MANUAL QUESTIONS

8. Are the pictures detailed enough to show each operation:	94	6	90	10
9. What procedures would you like to see changed or inserted? Note: Whenever possible--give the manual page and picture number when referring to specific changes. Use the opposite side of this page for your comments.	6	94	0	100
10. After changes are made, would you be willing to pay a nominal cost (approx. 40 cents) for the written manuals?	53	47	45	55

11. If such a training manual was used in your plant, how many copies could you use each year?
1 to 25____ 25 to 50____ 50 to 100____ 100 to 150____

From the 12 participating plants:
7 plants - 1 to 25 copies
2 plants - 25 to 50 copies
3 plants - No response

Figure 49. Summary of responses to training aids' questionnaire.

Training Program Outline

First Day of Training

Step 1. Preparation of the trainee.

1. Provide a tension-free atmosphere for the trainee.
2. Explain the reason for his being trained.
3. Explain the reasons for the improved method.
4. Make reference to the two training aids - the film and manual. The introduction given the trainee should follow that which is written on pages 1 and 2 of the manual.

Step 2. Presentation of the operation. (Body meat extraction)

1. Show the entire film for orientation purposes.
2. Show the body meat extraction section of the film again.
3. Discuss the body meat extraction section of the manual.
4. Go to the work area and go through the operation. (Trainee should bring manual.)
5. Go through the operation at a reduced speed several times, explaining each step. Explain the difficult procedures or ones in which errors are likely to be made.
6. Go through the operation at a reduced speed several times, explaining the key points.

Step 3. Performance tryout.

1. Have the trainee go through the operation several times, slowly, explaining to you each step. Correct his mistakes and if necessary you, the trainer, go through the steps of the complicated procedures again.
2. Go through the operation at the normal pace.
3. As soon as the trainee demonstrates that he can do the operation, put him on his own but do not abandon him.
4. Give the trainee time to practice.

Step 4. Presentation of the operation. (Claw leg meat extraction)

1. Go back to the projection room.
2. Show the portion of the film dealing with claw-leg meat extraction.
3. Discuss the claw leg meat extraction portion of the manual.
4. Proceed as indicated in Step 2, items 4 through 6; and Step 3, items 1 through 4.

Step 5. Presentation of the operation. (Multiple crab leg meat extraction)

1. Go back to the projection room.
2. Show the portion of the film dealing with multiple crab leg meat extraction.
3. Discuss the multiple crab leg meat extraction portion

of the manual.

4. Proceed as indicated in Step 2, items 4 through 6; and Step 3, items 1 through 4.

Step 6. Follow-up.

1. Inform each trainee from whom he may seek help or ask any necessary questions.
2. As he becomes skilled in using the improved method his work will only need occasional checking.
3. Make him aware of the advantages to himself in fully accepting and practicing the improved method.
4. Let him know you appreciate his efforts and are pleased with his good work.

Second Day of Training

Step 7. General review of operations.

1. Show the entire film and answer questions.
2. Go to the work area and go through the complete crab meat extraction operation.
3. Have the trainee continue to practice. (Trainee should bring manual.)

Step 8. Follow-up.

1. Proceed as indicated in Step 6.

IX. EVALUATION OF THE EFFECTIVENESS OF THE IMPROVED METHOD

The need was felt for further evaluation of the improved method, along with the newly developed training package. Several questions could be answered with such an evaluation. They are as follows:

1. Will the introduction of the improved method into a seafood processing plant consistantly increase the production rate of some of the operators?

2. What is the approximate overall plant production rate increase to be expected with the introduction of the improved method?

3. Can the training aids stand alone in providing instruction in the improved method?

4. Is the learning period for a beginner reduced when using the training aids?

In-plant testing was required to answer these questions satisfactorily.

Design of Experiment

Due to the nature of the seafood industry's economy, some plants cannot afford to participate in lengthy, involved experimentation. Thus, two in-plant experimental programs evolved. The programs follow:

Experimental Program I

1. The processor will be given the film and manual.

2. The method of training will be left up to the individual processor.

3. Daily records will be kept on each picker - e. g. total amount of meat extracted (leg and body meat totals kept separate) during a specific time period, and amount of crab given to each picker.

4. Past records will be compared with records during and after training.

Experimental Program II

1. The processor will pick two work groups (test group and control group) from random. (Number employees and then draw numbers from a hat -- a hat for veteran pickers and a hat for beginning pickers.)

2. The minimum number in each group should be 10 employees -- for example, 5 veteran pickers and 5 beginning pickers.

3. One group (test group) of 10 employees will be trained according to a program similar to the Training Program Outline. The second group (control group) will continue their normal work habits, under normal working conditions.

4. Daily records should be kept on each individual in the two groups. The records should show the total amount of meat extracted (body and leg meat totals kept separate) during a specific time period.

5. The employees being trained should be paid an hourly wage for the training duration. After this period the pickers should be put on a poundage wage rate.

6. Length of test -- open.

In-Plant Experimentation

Several of Oregon's seafood processors were approached with the idea of participating in the experimental programs. Of those approached, four plants agreed to participate in the evaluation experiment. These plants will be referred to by code names as follows: Plant D, Plant R, Plant S, and Plant T. Plants R, S, and T chose to participate in experimental program I, while Plant D chose program II.

The implementation of the experimental programs commenced in January 1972. On Monday, January 17, 1972, the author conducted an all day training session with Plant D's "test group" which consisted of 12 pickers, three of whom were beginners. The day's training followed the Training Program Outline set forth earlier on page 213. Plant D's "control group" was made up of 12 pickers, also composed of three beginning operators. In February, 1972, Plants R,

S, and T were provided with the training film and manual.

These processors were conferred with numerous times during the testing. All agreed the method was proving beneficial, but that it could not be given a fair chance due to the scarcity of crabs.

Experimental Results

In April, 1972, the plants were requested to submit their experiment records for evaluation. As far as recorded data, Plant R's manager said that since it was such a poor year he would rather not submit what might be misleading data. He did indicate that the method and training aids helped "bring up speed to poundage."[34/] Furthermore, Plant T's manager did not submit records due to the poor season, but related that the method was helpful in increasing production rates. Plant S's manager kept records of only two of his operators. He reported a 100 percent increase in their production rate, with an average increase of three percent in meat yield. The manager from Plant D stated that the shortage of crabs made it impossible to maintain a full work force and keep the "test group" and "control group" separated. Thus, there was an intermixing of the groups and the "control group" became exposed to the improved method. This exposure nullified any valid comparison

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34/ From correspondence received from Plant R's manager.

being made between the two groups. Therefore, only the "test group's" statistical data will be analyzed.

Plant D's overall production rate increased with the introduction of the improved method. Records for nine of the original twelve operators composing the "test group," were submitted for evaluation. Analysis of the statistical picking data indicated that the overall meat extraction rate had increased 19 percent.[35/] As in the case of Plant F's in-plant picking test, the percent increase in individual picking rates varied considerably. It varied from a low of eight percent to a high of 45 percent, see Table XXV, Appendix V, for more details.

Due to the scarcity of crabs it was not possible to further evaluate the effectiveness of the improved method and training aids to the desired extent as set forth in the in-plant experimental programs. However, each manager of the four test plants did indicate emphatically that the improved method increased the production rate of their operators. The overall plant production rate increase using the improved method can be expected to be about 20 percent, from the test data evaluated from Plants F and D. The replies from Plants R, S, and T would suggest that the training aids can stand alone in providing instruction in the improved method. No evidence was

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35/ Table XVIII predicted a 25 percent production rate increase, when the improved method was adopted in plants already picking multiple legs and excluding tip meat extraction, such as Plant D.

obtained on whether the learning period for a beginner was reduced when using the training aids.

Comparison of Actual Performance with the Simulated Improved Method

A comparison of activity and suboperation times between an actual performance of the improved method of crab meat extraction and the simulated improved method was made. At the time of this comparison, however, only one sufficiently skilled operator was available for analysis. Motion pictures were taken of this operator performing the improved method.[36/] Tables XX, XXI, XXII, and XXIII compare the results of the film analysis of the operator using the improved method with the simulated improved method in terms of the time required to perform the activities composing each suboperation of crab meat extraction. As more operators become proficient in the improved method, more comparisons should be made, and an Industrial Average Model be made of the improved method.

36/ Motion pictures were taken at 24 frames per second, using a Braun-Nizo, Model S-80, Super 8 movie camera.

TABLE XX. COMPARISON OF THE SIMULATED IMPROVED METHOD WITH ACTUAL PERFORMANCE FOR THE SUBOPERATION OF CRAB BODY MEAT EXTRACTION.

Activity	Simulated Improved Method	Actual Performance
1. Get Crab	6*	16*
2. Tear Off Claw Leg	12	14
3. Hit Out Body Meat From Claw Leg	12	17
4. Remove Key Bone	33	35
5. Hit Out Body Meat	21	26
6. Discard Section	6	7
Total Frame-count	90	115
Irregular Activities**	51	51
Total Normal Picking Time Frame-count Per Section	141	166
Total Normal Picking Time Per Section in Seconds	5.9	6.9
Standard Picking Time*** Per Section in Seconds	7.6	8.6

---

* This figure represents the activity time in frames. (24 frames equals 1 second)

** This figure is the Irregular Activity frame-count set forth in Table XIV, and will be assumed applicable until further studies.

*** Standard time is the normal time plus an allowance for individual fatigue, delays, and personal time. It will be assumed that an appropriate estimate of this allowance is 1.7 seconds (as used in Table XIV), until further studies can be conducted.

TABLE XXI. COMPARISON OF THE SIMULATED IMPROVED METHOD WITH ACTUAL PERFORMANCE FOR THE SUBOPERATION OF CLAW LEG MEAT EXTRACTION.

Activity	Simulated Improved Method	Actual Performance
1. Get Claw Leg	3*	4*
2. Tear Off Claw Point	10	8
3. Crack And Remove End Of Claw Shell	31	30
4. Tear Off Claw And End Of Knuckle Meat	18	15
5. Hit Out Claw And Knuckle Meat	15	16
6. Tear Off End Of Ham Shell	22	23
7. Hit Out Ham Meat	14	19
8. Discard Ham Shell	4	5
Total Frame-count	117	120
Irregular Activities**	38	38
Total Normal Picking Time Frame-count Per Claw Leg	155	158
Total Normal Picking Time Per Claw Leg In Seconds	6.5	6.6
Standard Picking Time*** Per Claw Leg In Seconds	8.2	8.3

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* This figure represents the activity time in frames. (24 frames equals 1 second)

** This figure is the Irregular Activity frame-count set forth in Table XV, and will be assumed applicable until further studies.

***Standard time is the normal time plus an allowance for individual fatigue, delays, and personal time. It will be assumed that an appropriate estimate of this allowance is 1.7 seconds (as used in Table XV), until further studies can be conducted.

TABLE XXII. COMPARISON OF THE SIMULATED IMPROVED METHOD WITH ACTUAL PERFORMANCE FOR THE SUBOPERATION OF MULTIPLE CRAB LEG MEAT EXTRACTION.

Activity	Simulated Improved Method (2 leg average)	Actual Performance (2 leg average)
1. Get Legs	6*	8*
2. Tear Off Points And Tip Ends	18	22
3. Hit Out Tip Meat	13	26
4. Tear Off Tip Shells And Joint Ends	13	19
5. Hit Out Joint Meat	13	22
6. Crack Ham Shells	20	33
7. Tear Off End Of Ham Shells	7	14
8. Hit Out Ham Meat	17	24
9. Discard Ham Shells	4	6
Total Frame-count	111	174
Irregular Activities**	44	44
Total Normal Picking Time Frame-count	155	218
Total Normal Picking Time In Seconds	6.5	9.1
Standard Picking Time*** In Seconds	9.0 (4.5 seconds/leg)	11.6 (5.8 seconds/leg)

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* This figure represents the activity time in frames. (24 frames equals 1 second)

** This figure is the Irregular Activity frame-count set forth in Table XVII, and will be assumed applicable until further studies.

*** Standard time is the normal time plus an allowance for individual fatigue, delays, and personal time. It will be assumed that an appropriate estimate of this allowance 2.5 seconds (as used in Table XVII), until further studies can be conducted.

TABLE XXIV. SUMMARY OF THE COMPARISON MADE BETWEEN THE SIMULATED IMPROVED METHOD AND ACTUAL PERFORMANCE FOR EXTRACTING THE MEAT FROM A SINGLE CRAB IN SECONDS

Time	Simulated Improved Method	Actual Performance	Time Difference (Actual performance time exceeds simulated improved method time.)
Body Meat Extraction (for 2 sections)	15.2	17.2	2.0
Claw Leg Meat Extraction (for 2 claw legs)	16.4	16.6	0.2
Leg Meat Extraction (for 8 legs)	36.0	46.4	10.4
TOTAL STANDARD TIME REQUIRED TO EXTRACT THE MEAT FROM A SINGLE CRAB (seconds)	67.6	80.2	
TIME DIFFERENCE BY WHICH ACTUAL PERFORMANCE TIME EXCEEDS SIMULATED IMPROVED METHOD (seconds)			12.6
PERCENTAGE BY WHICH ACTUAL PERFORMANCE TIME EXCEEDS SIMULATED IMPROVED METHOD			18.6

X. AREAS FOR FURTHER STUDY

The improved method of crab meat extraction can be bettered by further investigations and studies. Several specific areas recommended for further consideration are:

1. The Workplace

   Alternate seating and standing facilities should be evaluated for their affect on picking rates.

2. Cooking

   Cooking times and temperatures are currently ill defined. Their affect on meat yield, crab size, and quality deserves considerable evaluation.

3. Cooling

   Cooling is essential in keeping bacteria counts at a minimum after cooking. Cooling also affects meat yield and removal. The critical time and temperature which will optimize yield and meat removal still remains an unknown.

4. Motion Pattern and Analysis

   In-plant evaluations of the improved method should be conducted, and standard data established. An investigation of the causes for irregular acts, and a search for and development of more affective picking techniques should be continued.

5. Training

The value of each training aid requires confirmation at several plants, to determine its effectiveness both for the beginning and veteran picker.

6. Partial Mechanization

Standard time data estimates for manual crab meat extraction should be used as an aid in partial mechanization decision making and in future facility planning.

XI. SUMMARY AND CONCLUSION

Summary

Traditionally, fresh marketable Dungeness crab meat processed in seafood plants has been hand picked. Manual meat extraction has been the greatest single cost in processing marketable meat, amounting to an average of 63 percent of the total labor cost. Furthermore, the industry will be characterized by manual picking for some years, as complete mechanization does not seem imminent due to the complexity of meat extraction. This restriction has drawn attention to the necessity of understanding skill attributes and raising the skill levels of crab meat shakers.

This paper has investigated the economic problem of manual crab meat extraction in terms of skill, time, and cost. The three elements most affecting the economic problem of meat extraction are: 1) the labor force; 2) processing techniques; and 3) equipment employed by the seafood processors. These three areas have been examined in detail by the identification of the following six skill factors: individual aptitude, plan and control, materiel, necessity of motion, rhythm and speed.

After extensive analysis of the crab meat extraction process, an improved method has been designed and evaluated in terms of the skill factors. Individual aptitudes contributing to effective crab meat

extracting have been identified and tests are being developed to evaluate crab picking applicants prior to their employment. Proper and adequate training programs will reduce the time period over which the skill factors of plan and control affect skill. The most effective tools, equipment, workplace arrangement and methods in handling and preparing the crab have been designed and evaluated. Improved motion patterns and meat extraction techniques have been developed. The necessary basic acts of motion have been arranged so that a natural rhythm can be maintained. Speed of meat extraction will follow with exposure to adequate training and practice.

Thirteen Oregon seafood processors participated not only in the development, upgrading and refinement of the improved method of meat extraction, but also in the evaluation of its effectiveness. Simulated meat extraction models indicated an overall plant increase in picking rate of 25 percent, in terms of pounds of meat per hour extracted. Actual in-plant tests produced an overall increase of 20 percent for several participating plants. Beside the meat extraction rate increase, the meat yield increased an average of three percent in one plant. This plant also reported a reduction in picking labor costs of $0.02 per pound of meat processed, after using the improved method for the last portion of a season. The labor cost improvements were due to higher group level productivity rates, which in turn increased the daily take home pay of the pickers.

A training program and training aids have been developed to implement the improved method in seafood processing plants. The training aids consist of a sound-color motion picture training film which demonstrates the improved method in minute detail, and a pictorial instruction manual which complements the film.

Although significant and far reaching improvements have been discussed in this paper, more refinements and contributions can be made to further perfect the processing of marketable crab meat. Areas identified for further study included: 1) the workplace, 2) cooking, 3) cooling, 4) motion pattern analysis, 5) training and 6) partial mechanization.

Conclusions

It is imperative that something be done immediately to counteract the increasing costs of meat extraction presently plaguing the Dungeness crab processing industry. Complete mechanization is not the answer at this time. Furthermore, it may never be the answer for plants employing fewer than 20 pickers, due to the high initial equipment investment. Hence, there is only one direction in which to turn, that of improving the current manual method of crab meat extraction in terms of skill, time and cost.

The improved method of crab meat extraction presented in this paper should be considered for adaption in whole, or part, by all

Dungeness seafood processors. The improved method appears to have the potential of significantly increasing a plant's overall average picking rate. The degree to which each plant can increase its production rates may vary and will depend on the methods and employees presently used in the individual plants.

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APPENDICES

APPENDIX I

Dungeness Crab Meat Extraction Training Manual

DUNGENESS CRAB MEAT EXTRACTION

by

Professor William F. Engesser, Industrial Engineering

and

Viravat Cholvanich, G. Paul Willis, Graduate Students, Industrial Engineering
Terry W. Johnson, Senior-Student Technician

This training manual is intended to be used in conjunction with the film CRAB MEAT EXTRACTION, produced by the Industrial Engineering Department, Oregon State University, Corvallis, Oregon. The film, may be purchased (approximately $200.00) or rented (approximately $3.00 per week) from the Audio-Visual Department, Oregon State University, Corvallis, Oregon 97331.

The procedures presented are not THE BEST WAY or THE ONLY METHOD of crab meat extraction, since some plants may have different process requirements. By following this method, however, you will find that it is easier to remove the meat from a crab, and that you will be able to pick more meat in a work day. You may also find that your work is less tiring. If you have never picked a crab before, this manual will illustrate the procedures and techniques that are necessary to pick a crab with a minimum amount of effort and fatigue while yielding a quality product. Should you be a veteran picker, the motion picture and this manual will give you something with which to compare your present picking method. Such a comparison will show whether you can improve your skill level and thus increase your earnings. Keep in mind, that the picture sequences and narrative that follow, "ONLY PARTIALLY" illustrate the desired movements. The 16mm sound-color film describes in considerable detail each movement at regular and slow motion speeds.

The development of these training aides has largely been made possible by the cooperation and participation of the management and employees of numerous seafood processing plants. These contributions are greatly appreciated. The cooperation of the National Marine Fisheries Service, OSU's Marine Advisory Staff and other cooperating departments is also gratefully received.

This publication is supported in part by the National Oceanic and Atmospheric Administration (maintained by the U.S. Department of Commerce) Institutional Sea Grant 2-37187.

PREFACE

This "NEW METHOD" was developed after studying motion pictures taken of low, average and highly skilled pickers. In-plant discussion sessions were also conducted with employees to get their ideas and reactions on various picking techniques and procedures. To test the value of this "NEW METHOD", an overall in-plant training program was established in an Oregon seafood processing plant. (The training film was not available at that time.)

The group used to test this method consisted of thirty-six women of various age, and with various degrees of experience in crab meat extraction. Every woman extracted the meat from all body parts of the crab, including the tip meat. The testing was conducted over a sixty day period. (The women did not work every day during that period.) At the end of the testing period there was an average plant production increase of 20% over the previous year's rate. (Using only production records for employees involved in the test.) In addition, the average meat yield increased from 50 to 54 percent (this percentage is the amount of meat per total body weight recovered from a cooked-crab section.)

The relative increase in production and yield depends upon the existing skill level of the individual. Thus, some individuals will increase their production significantly and others only marginally. The test data of several women are listed below to illustrate this fact.

Employee's Number	Previous Year's Ave. (lbs/hr)	Testing Year's Ave. (lbs/hr)	Testing Year's Daily Max. (lbs/hr)	Percent Increase
2	11.60	15.42	17.95	33
3	14.09	17.24	22.57	22
6	13.50	14.20	16.31	5
29	9.79	15.36	17.38	57
36	17.30	17.50	21.79	1

Note: Data for days on which "Boat Run" crab was processed was not included in these figures, hence, the average live-crab weights were less than two pounds. ("Boat Run" crab processing occures when the larger crabs, usually sold whole, are hand picked along with the smaller crabs.)

YOU CAN HELP!

With the aid of the training film and this manual, individual skill levels can be raised and overall plant averages increased. However, we need your comments as we continue our in-plant training tests. Your suggestions on other methods for crab meat extraction and means by which we can improve this "NEW METHOD" will definitely be taken into consideration in the next edition of the manual and film.*

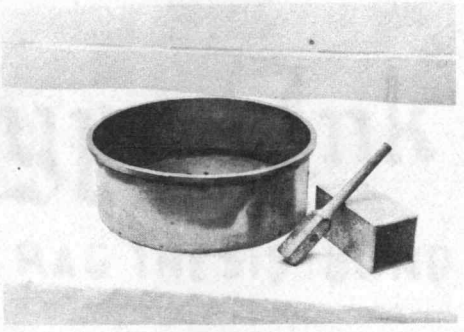
* All correspondence should be sent to: Professor William F. Engesser, Engineering Experiment Station, Oregon State University, Corvallis, Oregon 97331.

EQUIPMENT AND WORK PLACE DESIGN

The worker must be provided with the proper equipment for efficient meat extraction. Rubber gloves are usually worn while picking. They should fit tightly and be as thin as possible for proper feel.

The meat pan should be built with a flat base so that it will not rock back and forth while it is being used as a hitting base. Any movement in the pan will require extra hits to remove the meat from the crab body part. The number of hits can be further reduced by using a heavy pan or placing a firm hitting edge next to the pan. When shallow pans are used, a deflector shield should be used. Such a shield will deflect flying meat back into the container.

The hammer and anvil are required for leg picking. The hammer should be light, non-corrosive, and fit comfortably into the operator's hand. The anvil should be stable and non-corrosive. The top surface of the anvil should be about 3 inches from the table. This distance is required for the hand when placing crab body parts upon the anvil. The work place below illustrates the above mentioned characteristics.

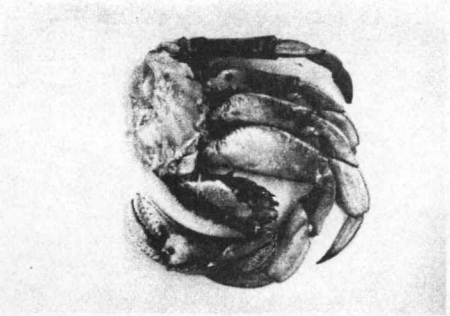


CRAB MEAT EXTRACTION WORK PLACE

Note the relative position of the equipment to the crab and the crab parts in the picture sequences on the following pages. The equipment should be as close to you as possible to minimize the distance traveled by your hands during meat extraction. Proper location of the crab and crab parts will enable you to establish desirable motion patterns. These motion paths are clearly illustrated in the slow-motion picture sequences of the crab meat extraction training film.

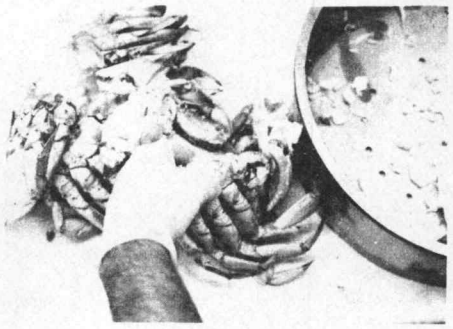
The motion patterns are described for a right-handed person, but they may be easily modified for the left-hander.

The crab meat extraction process will be divided into three parts: 1) body meat extraction, 2) claw leg meat extraction, and 3) leg meat extraction.



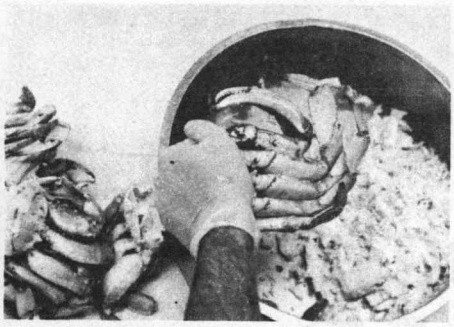
1. Crab body section

A crab body section is composed of 1/2 of the crab's body, four legs and a claw leg.



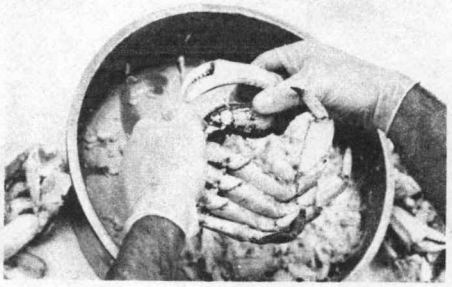
2. Grasp crab section

Grasp the body portion of the crab section with the fingers of the left hand.



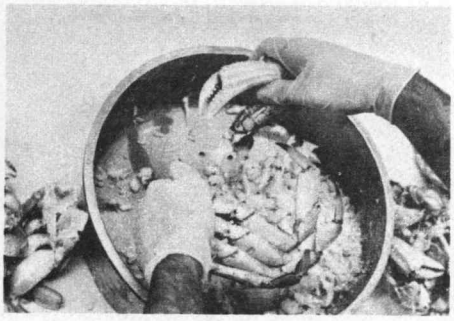
3. Squeeze body portion of section

While moving the crab section from the table to the right hand, the fingers of your left hand should press the body portion against the palm of your hand.



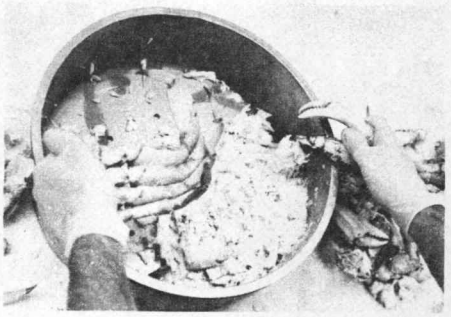
4. Grasp claw leg

When the section meets the right hand, grasp the claw leg with the right hand.



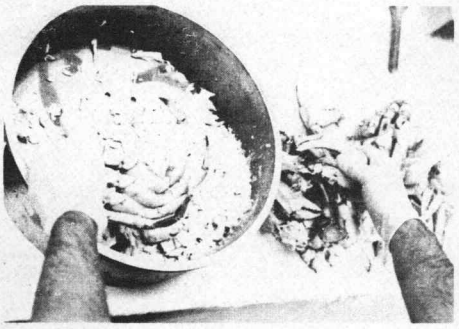
5. Tear off claw leg

Using your right hand, tear off the claw leg.



6. Hit out body meat

Using a firm hitting base, hit out the body meat sticking to the claw leg in 2 hits or less.

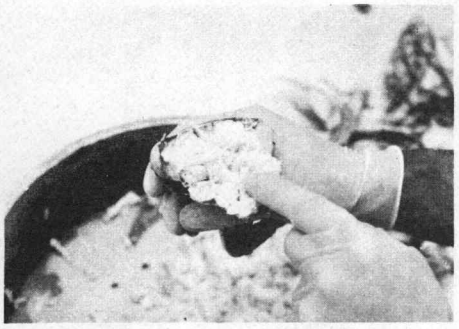


7. Discard claw leg

Discard the claw leg into a pile just to the right of the meat pan.

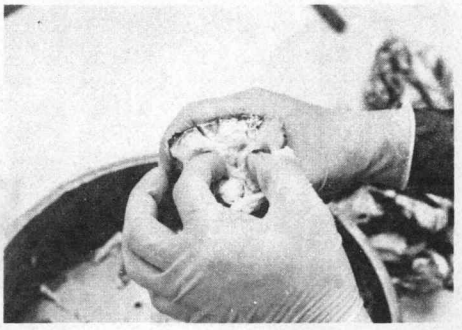
8. Grasp legs

With your right hand, move to and grasp the legs of the crab section. (Your hand should be on top of the legs, and the bottom of the crab facing up.)



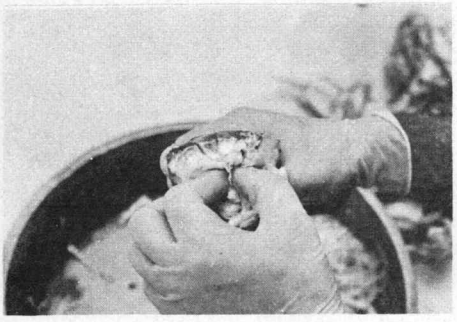
9. Key bone

Remove the key bone with the fingers of your left hand, as follows:



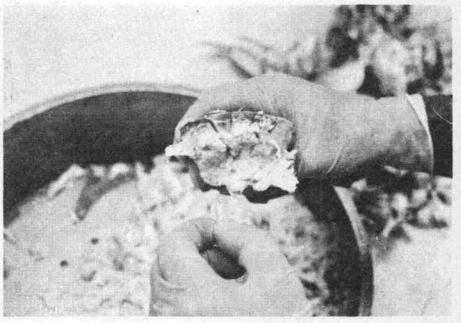
10. Insert fingers around key bone

First, insert your fingers into the area around the key bone;



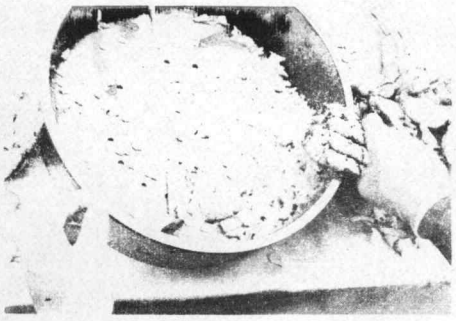
11. Grasp key bone

Second, grasp the bone;



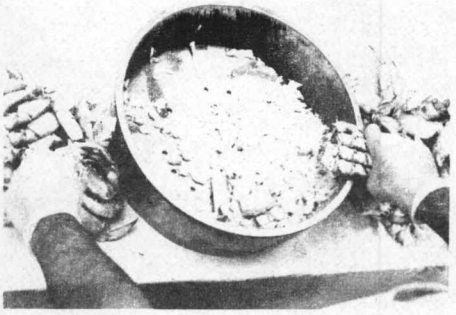
12. Remove key bone

Third, remove the bone by a twisting-pulling action.



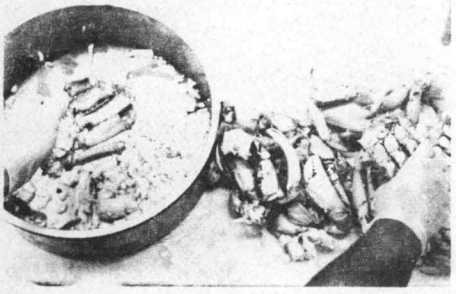
13. Discard bone - Hit out meat

Discard the key bone, while the right hand hits out the body meat in 3 hits or less.



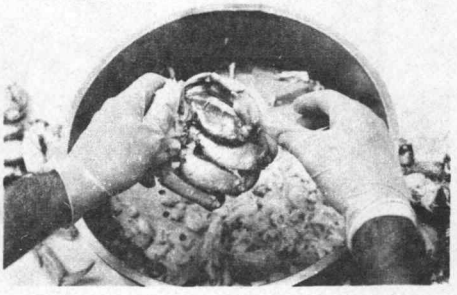
14. Grasp next section

With the left hand, reach for and grasp the next body section, while the right hand completes the body meat removal.



15. Discard section - squeeze new section

After body meat removal, discard the present body section with the legs attached, into a pile just to the right of the pile of claw legs.



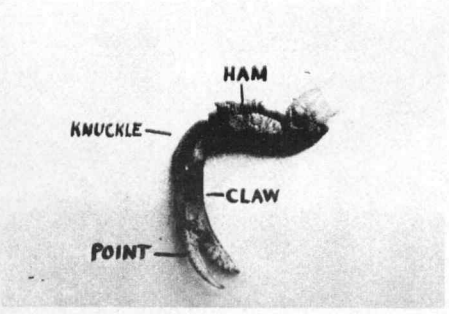
16. Begin new cycle

Bring your hands together and begin another picking cycle. (see picture 2).

BODY PICKING - POINTS TO REMEMBER

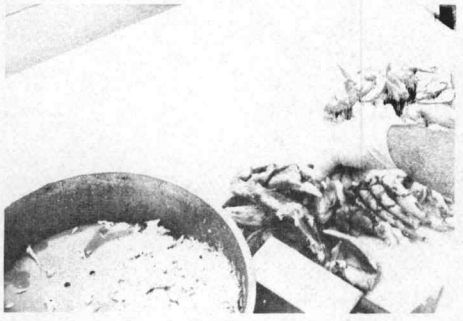
1. The claw legs and the discarded body sections with the legs attached should be placed in separate piles. Separate piles for body parts will enable you to keep a constant picking rhythm for each part, which would otherwise be interrupted if the claw legs and legs were mixed. (pictures7, 15).
2. All distances moved should be as short as possible. (pictures 2, 7, 8, 14, 15).
3. Loosen the body meat by squeezing the body portion of the section between the fingers and palm of the left hand while moving the body section from the table to the right hand. Too much squeezing pressure will break up the meat. (picture 3).
4. Use a firm hitting base for meat removal with a minimum number of hits. (pictures 6, 13).
5. Complete and proper key bone removal allows all the meat to come out in high quality chunks. (pictures 9, 10, 11, 12).
6. When hitting the body meat, the right hand should be on top of the legs with the bottom of the crab facing up. (pictures 13, 14).
7. Use both arm and rapid wrist movements when hitting out the body meat. (pictures 13, 14).
8. Keep both hands in motion doing different jobs. (pictures 13, 14, 15).

PART II CLAW-LEG MEAT EXTRACTION



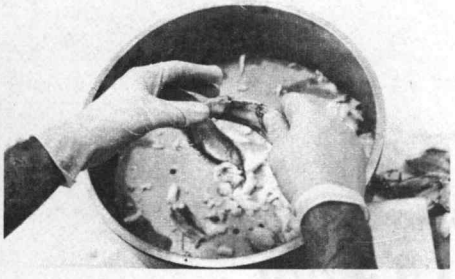
1. Crab claw leg

A claw leg consist of the ham section, joint, tip and point.



2. Grasp point

Grasp the point of the claw leg with the fingers of your right hand, when getting a leg from the pile.



3. Transport leg

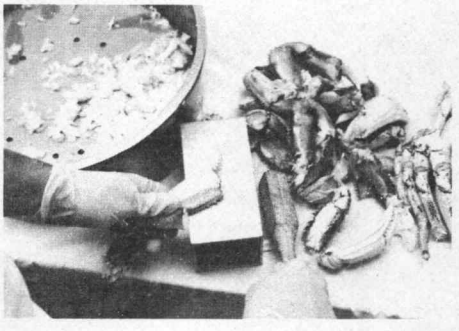
Move the claw leg from the pile to your left hand.

4. Grasp leg

Grasp and hold the ham end of the claw leg with your left hand.

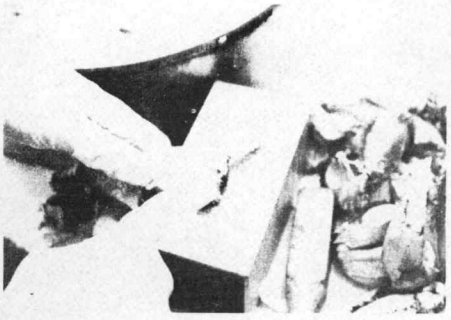
5. Tear off point

Tear off the point held in your right hand. by bending it away from the claw.



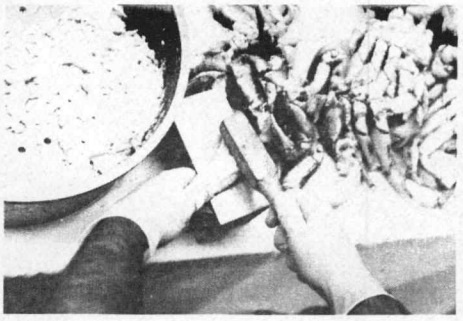
6. Get hammer - position leg on anvil

Discard the point and grasp the hammer, while your left hand positions the claw end of the claw leg on the anvil.



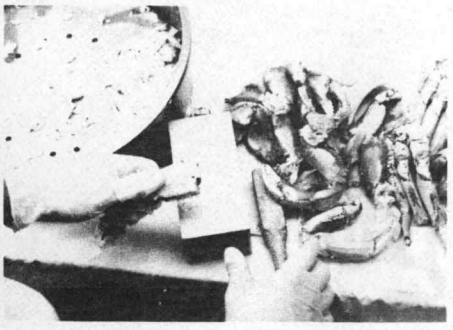
7. Red dot on claw

Hit the red dot on the end of the claw shell.



8. Crack claw shell

Using 1 blow from the hammer strike the red dot and crack the shell as close to the point end as possible.

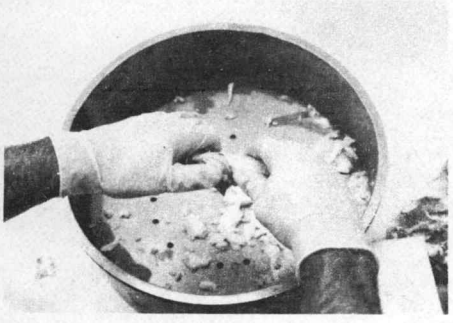


9. Discard hammer

Discard the hammer.

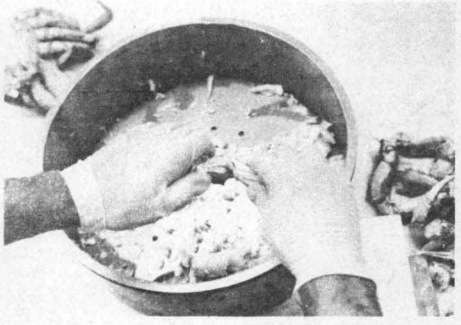
10. Remove point end

Remove and discard the cracked point end of the claw shell.



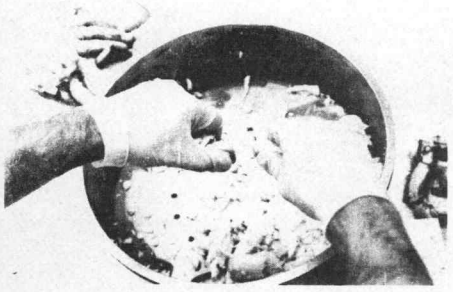
11. Grasp claw

Tear off the claw shell and knuckle end as follows: First, grasp the claw end of the leg with your right hand.



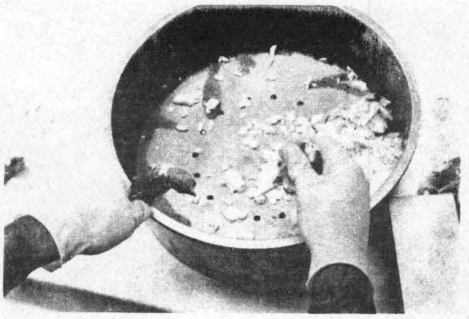
12. Bend claw's joint

Second, bend the claw's flex joint in the direction opposite to its normal flex.



13. Tear off claw shell

Third, tear off the claw shell and knuckle end.

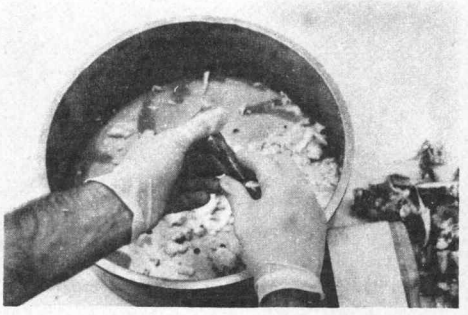


14. Hit out meat

With your left hand hit out the knuckle meat, while your right hand hits out the claw meat using 2 hits or less.

15. Discard shell

Discard the claw shell.

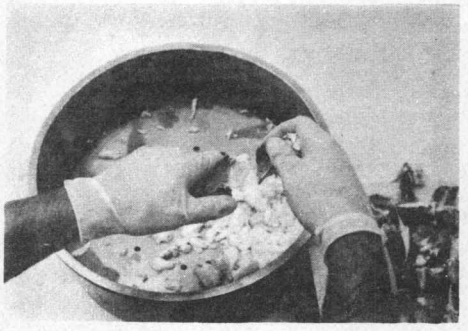


16. Grasp ham shell

Reposition the remaining parts of the claw leg as follows: First, with the fingers of your right hand grasp the body end of the ham shell.

17. Regrasp knuckle end

Second, regrasp the knuckle end of the ham section with your left hand.

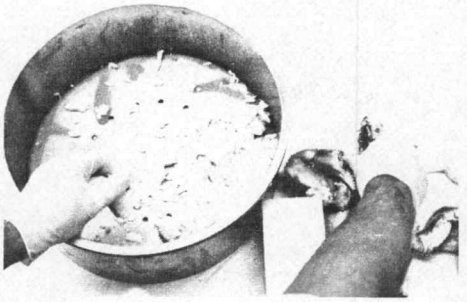


18. Remove ham shell

Remove the body end of the ham shell by a pulling, pinching and twisting action.

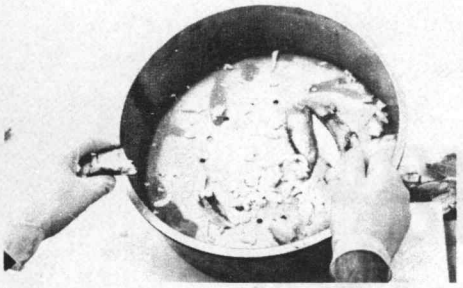
19. Discard shell - Hit out meat

Discard the body end of the ham shell, while your left hand hits out the ham meat using 2 hits or less.



20. Grasp next claw leg

With your right hand reach for and grasp the next claw leg, while your left hand completes the ham meat removal.



21. Discard shell

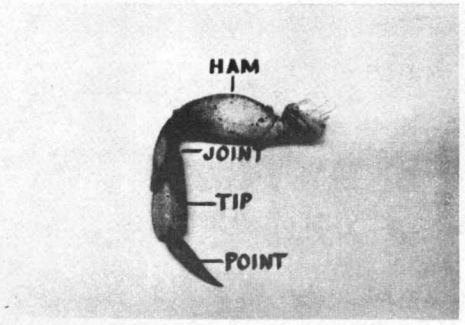
Discard the ham shell.

22. Begin new cycle

Bring your hands together and begin another picking cycle.

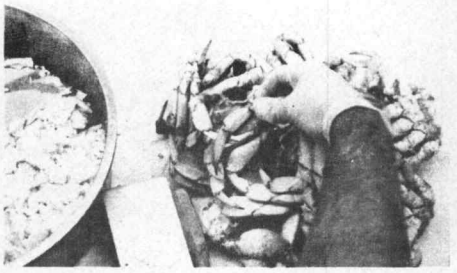
PART II CLAW-LEG PICKING - POINTS TO REMEMBER

1. Remember, place your crab parts and equipment so all distances moved are as short as possible. (pictures 2, 3, 6, 9, 20).
2. The fingers of the right hand should grasp the point of the claw leg when getting a leg from the pile. The point is now in the fingers that will tear it off.(pictures 2, 3, 4, 5).
3. When cracking the claw shell, hit the red dot to open up the claw shell for easy meat removal. (picture 7).
4. Crack the claw shell as close to the point end as possible to avoid meat damage and waste. (picture 8).
5. After the hammer is used it should be placed where it can be easily grasped. (picture 9).
6. Hit out the claw and knuckle meat at the same time. (picture 14).
7. Use a firm hitting base for meat removal with a minimum number of hits. (pictures 14, 19).
8. The body end of the ham shell is removed by a pulling, pinching and twisting action. Care must be taken or the meat will be broken and possibly wasted if the shell is opened improperly. Tearing off the body end of the ham shell makes a bigger opening for the meat to come out. (picture 18).
9. Keep both hands in motion doing different jobs. (pictures 6, 14, 19, 20).



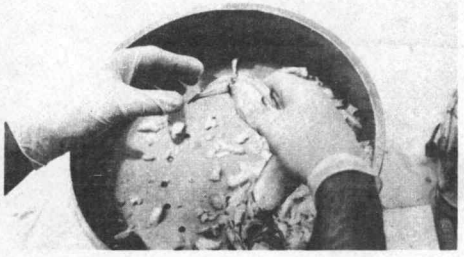
1. Crab leg

A leg is made up of the ham section, joint, tip and point.



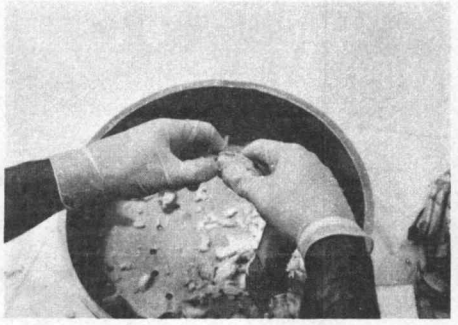
2. Grasp legs

Grasp the tip ends of a group of legs with your right hand.



3. Transport legs

Move the legs from the pile to your left hand.

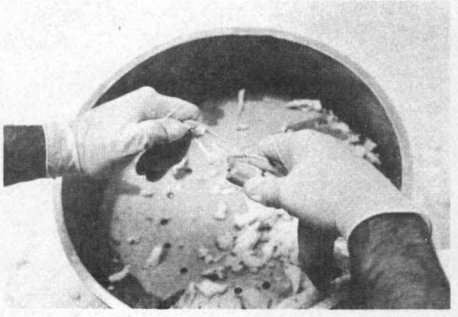


4. Grasp tip ends

As the hands are brought together, grasp the tip ends of the legs with your left hand.

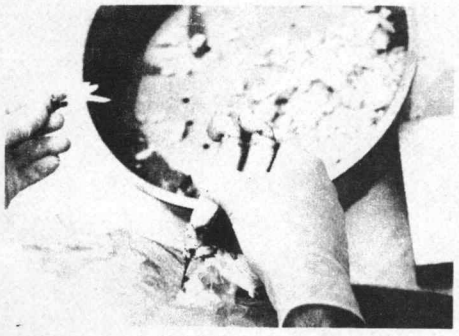
5. Bend points toward your body

With your right hand, support and hold the tip shells while your left hand tears off the points and tip ends as follows: First bend the points and tip ends toward your body.



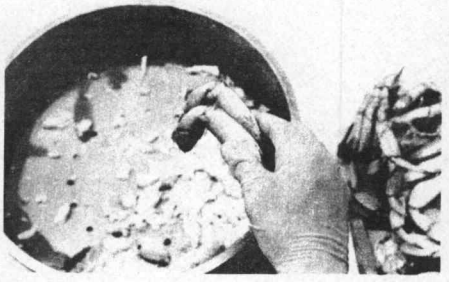
6. Tear off points and tip ends

Second, bend the points and tip ends away from your body and tear them off on this motion. The tip feathers should be clean with no meat sticking to them and the tip shell should be opened enough for easy tip meat removal.



7. Reposition legs

Discard the points and tip ends, while your right hand repositions the legs by pushing the body end of the legs against your body and allowing the legs to slide forward in your hand.

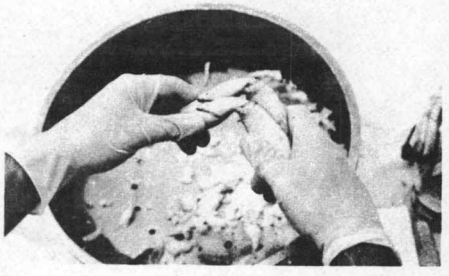


8. Hold ham portion of legs

Your fingers should now be holding the ham portion of the legs.

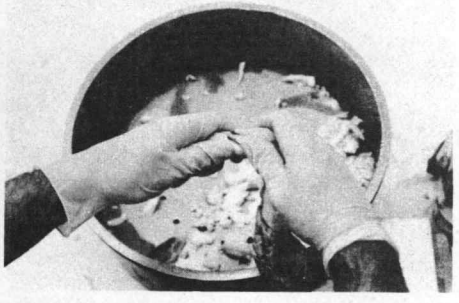
9. Hit out tip meat

Hit out the tip meat using 3 hits or less.



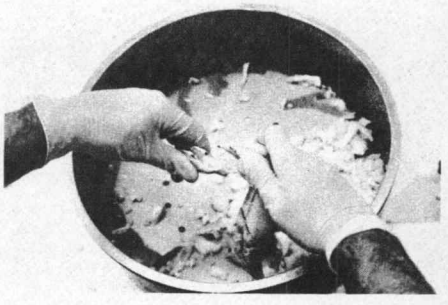
10. Grasp tips & joint ends

Bring your hands together and grasp the tip shells and joint ends with your left hand.



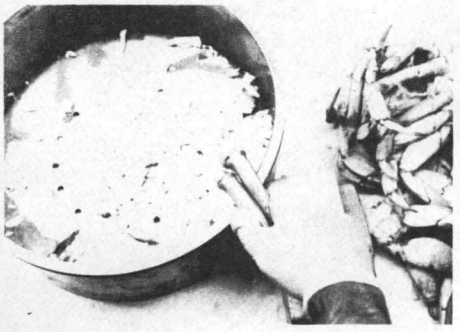
11. Hold legs at joints

Slide the fingers of your right hand forward to support and hold the joints.



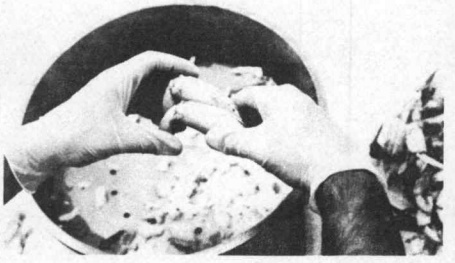
12. Tear off tips & joint ends

Tear off the tip shells and joint ends held in your left hand, using a single outward stroke.



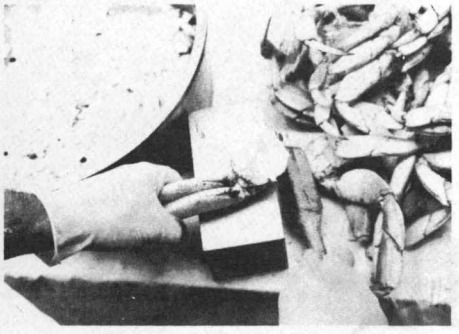
13. Discard shells - Hit out meat

Discard the tip shells and joint ends, while your right hand repositions the legs and hit out the joint meat using 3 hits or less.



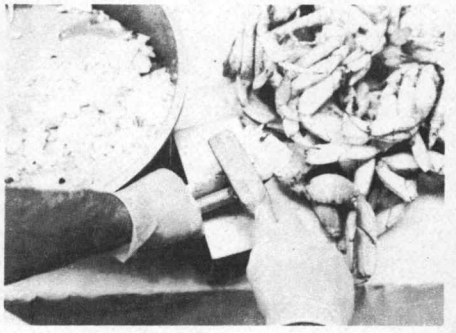
14. Transfer legs

Transfer the remaining leg parts to the left hand. Grasp the joint ends of the legs with your left hand.



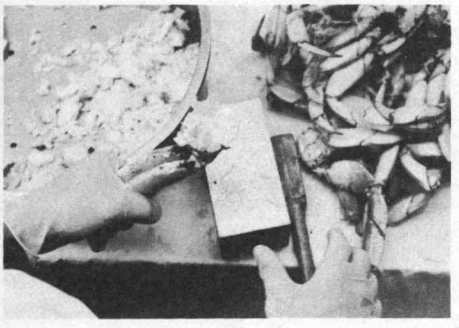
15. Position legs on anvil - Get hammer

Place the legs on the anvil, while your right hand gets the hammer.



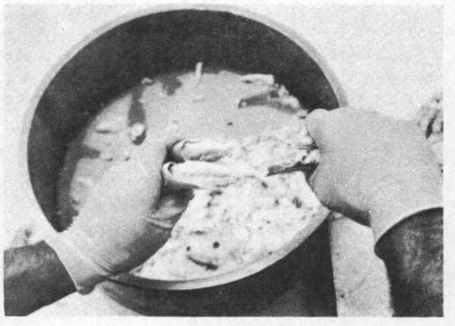
16. Crack ham shells

Crack the body end of the ham shells, using 2 hits or less.



17. Discard hammer

Place the hammer so it can be easily grasped, later.



18. Open ham shells

Grasp the body end of the ham shells and tear off the shells using a twisting - pulling motion.

19. Discard shells - Hit out meat

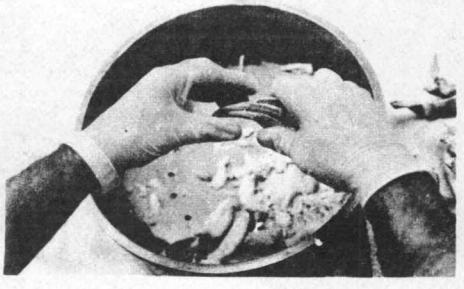
Discard the ham shells, while your left hand hits out the ham meat using 3 hits or less.

20. Grasp next group of legs

With your right hand grasp the next group of legs, while your left hand completes the ham meat removal.

21. Discard shells

Discard the ham shells.



22. Begin new cycle

Bring your hands together and begin another picking cycle.

MULTIPLE CRAB LEG PICKING - POINTS TO REMEMBER

1. Single crab leg picking is recommended in the first learning periods. After you become familiar with the techniques and procedures, the number of legs you pick at one time should increase. (pictures 2, 3).
2. When picking multiple legs, the legs are treated as a unit. In other words, the tips are lined up and torn off at the same time. (pictures 4, 5, 6).
3. Keep two things in mind when tearing off the point and tip end. First, open the tip shell as much as possible so that the meat will come out easily. Second, do not tear the tip shell off too far up the leg or the meat will be broken, and will stick to the point feathers and be thrown away. (pictures 5, 6).
4. Keep both hands in motion doing different jobs. (pictures 7, 13, 15, 19, 20).
5. When hitting out the tip and joint meat, be sure that you are holding the ham shell. Holding the ham shell allows the lower part of the leg to flop freely, thus aiding in meat removal. (pictures 9, 13).
6. Use a firm hitting base for meat removal with a minimum number of hits.(pictures 9, 13, 19).
7. After the hammer is used place it where it can be easily grasped. (picture 17).
8. Avoid removing any meat with the body end of the ham shell when it is torn off by a twisting-pulling motion and discarded after being cracked with the hammer. (pictures 18, 19).
9. Remember, all distances moved should be as short as possible. (pictures 2, 3, 7, 13, 15, 17, 19, 20, 21).

APPENDIX II

Student's *t* Test Conducted on Results of In-Plant Trial Application of the Improved Method in Plant F

The Student's *t* test[37] was used to indicate whether the implementation of the improved method of meat extraction in Plant F significantly increased the overall plant average meat extraction rate.

Table XXIV contains the statistical data for each employee using the improved method.

Let u_1 and u_2 equal the mean hourly picking rate when using Plant F's standard method and the improved method, respectively. It will be assumed that the variability in mean picking rate is essentially a function of individual differences and that the variability of measurements for the group before and after implementation of the improved method will be approximately equal.

The null hypothesis to be tested is

$$H_o: u_1 \geq u_2.$$

To determine if the improved method of meat extraction produces a higher production rate, the alternative hypothesis is

$$H_a: u_1 < u_2.$$

---

[37] W. Mendenhall (24) discusses the Student's *t* test on pages 223-248.

The above would imply the use of a one-tailed statistical test, and that the critical, of rejection, region for the test will be located in the upper tail of the *t* distribution.

The Statistics Instruction Programming System (SIPS) in Oregon State University's computer center was used to manipulate the data in Table XXIV and arrive at a *t* value. The commands for processing this set of data and their results are listed below.

Commands for Processing

```
# * SIPS
$ VAR, 2
$ INPUT
= (enter data- the original picking rate then the improved
   picking rate)
= END
$ COMPARE, 1, 2, C
$ HISTOGRAM, 1, S
$ HISTOGRAM, 2, S
# LOGOFF
```

TABLE XXIV. STATISTICAL RESULTS OF THE IN-PLANT TRIAL APPLICATION OF THE IMPROVED METHOD OF CRAB MEAT EXTRACTION.

Employee Number	Original Avg. Rate (lbs./hr.)	Improved Avg. Rate* (lbs./hr.)	Max. Daily Rate (impr. method) (lbs./hr.)	Percent of** Increase
1	9.84	12.05	15.03	22
2	11.60	15.42	17.95	33
3	14.09	17.24	22.57	22
4	10.11	13.44	15.77	33
5	11.63	12.73	16.58	10
6	13.50	14.20	16.31	5
7	14.47	15.84	19.43	10
8	9.56	11.52	14.26	20
9	10.72	13.10	15.08	22
10	12.16	15.40	18.80	27
11	9.94	10.97	13.16	10
12	9.20	10.58	12.64	15
13	13.02	13.51	16.60	4
14	11.44	11.90	15.76	4
15	13.99	16.30	19.52	16
16	11.41	13.40	16.19	17
17	13.82	15.81	18.33	14
18	9.44	13.64	17.29	40
19	11.61	13.54	16.21	17
20	10.76	12.83	14.80	19
21	10.26	12.70	16.15	24
22	8.80	12.04	14.00	37
23	8.24	10.94	14.26	33
24	9.92	11.01	13.75	11
25	11.01	14.01	16.60	27
26	7.31	8.42	9.45	15
27	11.78	15.51	19.21	32
28	8.80	9.74	11.26	11
29	9.79	15.36	17.38	57
30	7.80	9.08	9.79	16
31	7.29	10.12	11.68	39
32	7.42	10.37	13.03	39
33	9.61	9.74	10.68	1
34	8.02	8.56	10.21	7
35	10.02	10.26	11.42	2
36	17.30	17.50	21.79	1

* The improved average meat extraction rate was based on data collected at Plant F from December 7, 1970 through April 13, 1971. The data excludes "boat run crab" processing days (i.e. days in which larger crabs were not sorted out to be sold as whole or shell crab).

** Percent of increase = $\frac{\text{Improved avg. rate} - \text{Original avg. rate}}{\text{Original avg. rate}} \times 100$

Listing of Results

COMPARE, 1, 2

	(1)	(2)
SAMPLE SIZE	36	36
MEAN.....	10.71333	12.74417
STD. ERR OF MEAN.....	.38091	.41175
VARIANCE.....	5.22337	6.10339
STANDARD DEVIATION..	2.28547	2.47050
RANGE.....	10.01000	9.08000

T-VALUE = 3.620534
DEGREES OF FREEDOM = 70

$HISTOGRAM,1,S

HISTOGRAM OF VARIABLE 1

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FREQ  4  2  3  9  3  3  5  0  2  3  1  0  0  0  1
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   .        *        *
   .  *     *        *
   .  *     *  *  *  *        *
   .  *  *  *  *  *  *  *     *  *
   .  *  *  *  *  *  *  *     *  *  *           *
INT   1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
```

HISTOGRAM, 2,S

HISTORGRAM OF VARIABLE 2

FREQ	2	1	4	5	1	3	3	5	3	0	4	2	1	1	1
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.	*	*	*	*	*	*	*	*	*		*	*	*	*	*
INT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

As previously mentioned, the null hypothesis ($u_1 \geq u_2$) will be rejected if the calculated $\underline{t}$ value is greater than the critical value of $\underline{t}$ for a given confidence level. The $\underline{t}$ distribution table (25) indicates that the critical value of $\underline{t}$ for a 99 percent confidence level with 70 degrees of freedom is about 2.390. Therefore, if $\underline{t} > 2.390$ the null hypothesis will be rejected. Since the calculated value of $\underline{t}$ (3.620) exceeds the critical value of $\underline{t}$ (2.390), the null hypothesis is rejected. Hence, the alternative hypothesis ($u_1 < u_2$) is accepted. Notice the shift in the distribution of the histograms.

In summary, there is sufficient evidence to indicate that the improved method increased the overall plant average production rate at a .01 significance level (99 percent confidence level).

APPENDIX III
Crab Meat Extraction Film Script

VIDEO	AUDIO
1. Spiraling geometric design	1. Music
Fade out and into	
2. Title (A picture of a crab is used as the background): CRAB MEAT EXTRACTION Type 1-033	2. Music
Dissolve	
3. Credits (A picture of a crab is used as the background): "CREDITS This film has been partially supported by the National Science Foundation, Sea Grant GH97 and produced by the Industrial Engineering Department of Oregon State University. Appreciation is extended to the seafood industry for their participation."	3. Music
Dissolve	
4. "The cooperation of the National Marine Fisheries Service, OSU's Marine Advisory Staff and other cooperating departments	4. Music

VIDEO	AUDIO
is also appreciated." Fade out and into	
5. An overall shot of a crab picking room and operators.	5. Crab picking is one of the most difficult jobs in todays seafood industry, requiring a great deal of patience and manual dexterity.
6. Zoom in on a whole Dungeness crab on the picking table. Dissolve	6. How would you extract the meat from this crab? By following the picking procedures and techniques presented, you will find that it is easier to remove the meat from a crab, as well as being able to pick more meat. You may also find that your work is less tiring.
7. Scenes showing in-plant picking.	7. Although the described motion patterns are for a right-handed person, they are easily modified for the left-handed. This film does not present the ONE BEST WAY or THE ONLY METHOD of extracting the meat from a crab. The procedures used in picking a crab in todays seafood industry are as numerous as there are processing plants.

VIDEO	AUDIO
	So, if you have never picked a crab before, this film will introduce you to what's involved in crab meat extraction and show you how it can be done with a minimum amount of effort and fatigue while yielding a quality product.
	Now, if you are a veteran of a few years or many years, this film will be of certain interest to you. Because now you will have something with which to compare your present picking method. Such a comparison will show whether you can improve your skills and thus increase your earnings.
	Many experienced pickers, who have adopted some or all of the techniques that will follow, have increased their picking rates anywhere from 20 to 40 percent.
Dissolve	Let us go to the Oregon State University Industrial Engineeging Laboratory for a closer look at crab meat extraction.
8. Crab body parts and related terminology.	8. These crab body parts and names will be referred to throughout this program.

VIDEO	AUDIO
9. Picture of the crab body section.	9. A body section is composed of one half of the crab's body, four legs and a claw leg.
10. Picture of the crab claw leg.	10. A claw leg consists of the ham section, knuckle, claw and claw point.
11. Picture of the crab leg. Dissolve	11. A leg is made up of the ham section, joint tip and point.
12. CU[a/] An operator picking body sections at Oregon State University (showing hand working area).	12. The crab picking process will be divided into three parts; body picking, claw leg picking and leg picking.
13. CU An operator picking the crab body meat.	13. Many methods are used to pick crab body meat. To show all these methods would take a considerable amount of time. If you are an experienced picker, compare and test the method you are presently using with the one to be presented. Always keep in mind product yield, quality and sanitation.
14. CU An operator picking body meat. *Operator stops picking and picks up whole chunks of meat and displays on hand.	14. In picking the crab body, the meat must be extracted in such a manner as to avoid shredding it. *When properly picked the body meat will come out easily in high quality chunks.

VIDEO	AUDIO
15. MS[b/] The operator takes off a pair of rubber gloves and discards.	15. Rubber gloves are worn during meat extraction. However, in order to demonstrate detailed finger motions they will not be worn in this presentation.
16. MS The operator with hands immobile.	16. Before going through a crab body picking operation, lets look at several important tricks of the trade. Many of the motion patterns will be shown in slow motion so you can see every movement.
17. CU The operator picks up a body section and tears off claw leg. Operator then points to the body meat at end of the claw leg.	17. This body meat sticking to the claw leg must be removed.
18. CU The operator hits out the meat and lays the claw leg in a pile just to the right of the meat pan.	18. After the meat is removed, the claw leg should be discarded just to the right of the meat pan. This prepositioning will help you later.
19. CU The operator points to the body meat in the body section.	19. Most of the body meat is found in the body section.
20. CU The operator hits out the meat and discards the body section into a pile on the other side of the claw legs. *Operator steps back. Focus on separate piles.	20. After the body meat is removed, the section should be placed just to the right of the pile of claw legs. *The claw legs and the legs are now separated into piles.

VIDEO	AUDIO
	Separate piles for body parts will enable you to keep a constant picking rhythm for each part, which would otherwise be interrupted if the claw legs and legs were mixed.
21. CU The operator lays the body section down. Operator then goes through one motion of squeezing the body.	21. The body meat is loosened by squeezing the body portion of the section between the fingers and palm of the left hand while moving the body from the table to the right hand.
22. CU (SM)[c] The operator grasps the body section and squeezes while moving to the R. H.	22. The fingers of the left hand grasp the body portion of the section. The fingers then move the body against the palm of the hand and squeeze.
23. XCU[d] The operator points to the key bone.	23. The key bone locks in the body meat.
24. XCU The operator removes the key bone.	24. Watch how the key bone is carefully removed. First, the fingers are inserted into the area around the key bone. Second, the bone is grasped. Third, the bone is removed by a twisting and pulling action.
25. CU The operator points to the key bone, then removes it.	25. Avoid removing meat with the key bone. When gloves are worn, they should fit

VIDEO	AUDIO
	tightly and be as thin as possible for proper feel.
26. CU. With the body section in the right hand, a finger of the left hand shows proper curved position of the body section for body meat removal. Hit out the body meat (3 hits).	26. The body section should be held properly when hitting out the body meat. The curve of the body section should point down, and the hand should be on top of the legs. When the body curve is pointing down, the bottom of the crab is facing up. If the curve points up, the body meat will be hard to hit out and will fly in all directions.
27. MS. The operator puts down the body section. Operator puts his hands on the meat pan and tries to rock it.	27. The last point, which applies to all crab picking, is a firm hitting base for meat removal. The pan should not rock back and forth. Any movement in the pan will require more hits for removing the meat.
28. MS. The operator pointing to the area where a deflection shield would be located. Dissolve	28. A deflection shield can be placed behind the pan. Such a shield deflects flying meat back into the pan.
29. MS (SM) The operator picking.	29. We are now ready to go through a complete picking cycle in slow motion.

VIDEO	AUDIO
30. CU(SM) The operator reaches for and grasps a body section from the pile.	30. Grasp the body portion of the section with the fingers of the left hand.
31. CU(SM) The operator brings the body section from the pile to R.H. and squeezes the body portion of the section while moving.	31. Squeeze the body portion while moving to the right hand.
32. CU(SM) The operator grasps and tears off the claw leg with the right hand - operator hits out the body meat from the claw leg (2 hits max.).	32. Detach the claw leg and remove the body meat, using 2 hits or less.
33. CU(SM) The operator's right hand discards the claw leg and moves to the left hand, grasping the legs of the body section.	33. Transfer the section to the right hand.
34. CU (SM) The operator's left hand moves to the key bone and removes the key bone.	34. With the fingers of the left hand, remove the key bone.
35. CU(SM) The right hand hits out the body meat while the left hand discards the key bone (3 hits max.).	35. Using a combination of arm and rapid wrist movements, hit out the body meat with 3 hits or less.
36. CU (SM) The left hand reaches for and grasps the next body section while the right hand completes meat removal and discards the present body section.	36. Grasp the next body section, while the right hand completes the meat removal. Keeping both hands in motion, doing different jobs, is called overlapping motion.

VIDEO	AUDIO
37. CU(SM) The left and right hands move together and picking cycle continues.	37. All distance moved, in the crab picking process, should be as short as possible.
38. The operator continues picking cycle.	38. Let us now review the important points in crab body meat picking.
39. CU(SM) The left hand discards the key bone and reaches for and grasps the next body section while the right hand completes meat removal and discards the present body section.	39. The right hand should be on top of the legs and the curve of the body section pointing down.
SUPER* SLIDE Hand on top body curve down	
40. CU(SM) The right hand hits out the body meat, while the left hand discards the key bone.	40. Use a firm hitting base and a minimum number of hits.
SUPER SLIDE Firm hitting base	
41. CU(SM) The operator reaches for the next body section while discarding the picked section.	41. Keep both hands in motion doing different jobs.
SUPER SLIDE Use overlapping motion	* All super slides are to be dissolved into and out.

VIDEO	AUDIO
42. CU(SM) The left hand moves to the key bone and removes the key bone.	42. Concentrate on proper key bone removal.
SUPER SLIDE Proper key bone removal	
43. CU(SM) The right hand discards the body section with legs attached.	43. Discard the body section with the legs attached.
SUPER SLIDE Discard with legs attached	
44. CU(SM) Beginning of 4th picking cycle. MS(SM) The operator brings a body section from the pile to the right hand and squeezes the body portion of section in route.	44. Squeeze the body portion of the section between the fingers and palm while moving.
SUPER SLIDE Squeeze while moving	
Dissolve	
45. CU(SM) The operator continues picking. Start audio at the end of the SM just	45. Let's watch the body meat picking cycle at regular speed.

VIDEO	AUDIO
before going to regular speed.	
Dissolve	
46. Picture of the claw leg.	46. We will now consider the second area of crab picking, the claw leg.
47. Picture showing the crab claw leg and related terminology.	47. As stated earlier, the claw leg consists of the ham section, knuckle, claw and claw point.
Dissolve	
48. The operator showing the claw leg and associated meat.	48. Various methods are presently used in claw leg picking. Remember, if you are an experienced crab picker compare and test the method you are using with the one that will follow.
49. MS The operator is immobile with his hands on the table.	49. Before going through a crab claw leg picking sequence, let us look at several important details which will aid you in picking the claw leg.
50. CU Hammer and anvil. Operator picks up the hammer and points to the anvil.	50. The hammer and anvil are needed for leg picking. The hammer should be light and fit comfortably into the user's hand. The anvil should be stable and the top surface about 3" from the table. This distance is

VIDEO	AUDIO
	required for the hand when placing crab body parts on the anvil.
51. MS (SM) The operator reaches for and grasps the point of the claw leg with fingers of the right hand. The hands are then brought together.	51. The fingers of the right hand should grasp the point of the claw leg, when getting a leg from the pile. The point is now in the fingers that will tear it off.
52. CU (SM) The left hand grasps and holds the claw leg, while the right hand tears off the claw point.	52. The point is bent away from the claw and torn off. Point removal is required for future claw meat extraction.
53. CU (SM) The operator discards the claw point and points to red dot. Operator gets the hammer, while the left hand positions the claw leg on the anvil.	53. Notice the red dot on the end of the claw. This spot must be hit to open up the claw shell for easy claw meat removal.
54. CU (SM) The operator hits the point end of claw with edge of the hammer (1 hit).	54. Using one blow from the edge of the hammer strike the red dot and crack the claw shell as close to the point end as possible to avoid meat damage and waste.
55. CU (SM) The operator discards the hammer. The right hand grasps and tears off the claw shell and knuckle end with the right hand.	55. The claw shell and knuckle end are torn off to expose the knuckle meat. The claw shell is torn off by bending the claw's flex joint in the direction opposite to its normal flex.

VIDEO	AUDIO
56. CU(SM) The operator hits out the claw and knuckle meat.	56. Notice how the hands hold the claw and knuckle when hitting out meat from both leg parts at the same time.
57. MS(SM) The operator discards the claw shell. Both hands move together. The fingers of the right hand grasp the body end of the ham section of the claw leg, while the left hand regrasps the knuckle end of the ham section.	57. The remaining parts of the claw leg are repositioned. The fingers of the right hand grasp the body end of the ham shell while the left hand regrasps the knuckle end of the ham section.
58. CU(SM) The right hand pulls, twists and pinches off the body end of the ham shell. Operator discards the ham shell and points to the exposed ham meat in the left hand.	58. The body end of the ham shell is removed by a pinching, twisting, and pulling motion. All the ham meat should be left in the ham shell held by the left hand. Tearing off the body end of the ham shell makes a bigger opening for the meat to come out.
Dissolve	
59. CU(SM)*The operator reaches for and grasps the claw point with the fingers of the right hand.	59. Now we will go through a complete claw leg picking cycle. *Grasp the point of a claw leg with the fingers of the right hand.
60. CU(SM) The operator's hands move together. The left hand grasps the claw	60. Grasp and hold the claw leg with the left hand while the point is torn off and

VIDEO	AUDIO
leg and holds, while the point is removed by the right hand.	discarded.
61. CU(SM) The right hand discards the point and gets the hammer while the left hand positions the claw leg on the anvil.	61. Get the hammer while positioning the claw leg on the anvil.
62. CU(SM) The right hand hits the point end of the claw shell with the hammer (1 hit) and discards the hammer.	62. Crack the shell with one blow.
63. CU(SM) The right hand removes and discards the point end.	63. Remove the point end.
64. CU(SM) The operator's hands move together. The right hand grasps and tears off claw shell and knuckle end.	64. Tear off the claw shell and knuckle end.
65. CU(SM) The left hand hits out the knuckle meat while the right hand hits out the claw meat.	65. Hit out the claw and knuckle meat in 2 hits or less.
66. CU(SM) The operator's hands move together. The fingers of the right hand grasp the body end of the ham shell, while the left hand grasps the knuckle end of the ham section. The right hand	66. Reposition the claw leg and then pull, twist, and pinch off the body end of the ham shell and discard.

VIDEO	AUDIO
tears off the body end of ham shell.	
67. CU (SM) The right hand discards the ham shell and moves to the next leg in the piles, while the left hand hits out the ham meat (2 hits).	67. Move to the next leg in the pile, while the left hand hits out the ham meat in two hits or less.
68. The operator continues to pick.	68. Now to review the important points in crab claw leg picking.
69. CU (SM) The operator tears off the claw shell and knuckle end.	69. Remove the claw shell.
SUPER* SLIDE Remove claw shell	
70. CU (SM) The operator hits out the claw meat.	70. Use a firm hitting base and a minimum number of hits.
SUPER SLIDE Firm hitting base	
71. CU (SM) The operator pulls, twists, and pinches off the body end of the ham shell.	71. Pull, twist and pinch off the body end of the ham shell.
SUPER SLIDE Pull, twist and pinch.	

* All Super Slides are to be dissolved into and out.

VIDEO	AUDIO
72. CU (SM) The operator's right hand discards the ham shell, and grasps the next claw leg from the pile, while the left hand hits out the ham meat and discards the shell. SUPER SLIDE Use overlapping motion	72. Keep both hands in motion, doing different jobs.
73. The right hand grasps the claw leg by its point. SUPER SLIDE Grasp point Dissolve	73. Grasp the point of the claw leg.
74. CU The operator picking claw legs at regular speed. Dissolve.	74.
75. Picture of the crab leg and terminology.	75. The third area of crab picking is leg picking.
76. Picture of crab leg and related terminology. Dissolve	76. The leg is made up of the ham section, joint, tip and point.

VIDEO	AUDIO
77. CU The operator shows the ham meat.	77.
78. CU The operator is idle.	78. Now for a look at several important points in crab leg picking.
79. MS to CU The operator picks up a single crab leg. *Operator tears off the point and tip end, and discards. The operator picks up another leg.	79. It is desirable to open up the shell containing the tip meat by tearing off the point and tip end with the fingers of the left hand. *The point and tip end are first bent toward the picker and then are torn off on an outward bending motion.
80. CU The operator grasps and tears off the point and tip end and waits.	80. The fingers of both hands should be on the tip shell. The right hand supports and holds the leg, while the left hand tears off the point and tip end.
81. CU The operator discards the leg and grasps another; tears off point and tip end and discards. Operator points to the torn area on the leg to show the shell opening - discards leg.	81. Two things should be kept in mind when tearing off the point and tip end. First, open the tip shell as much as possible so the meat will come out easily. Second, do not tear the tip shell off too far up the leg or the meat will be broken and will stick to the point feathers and be thrown away.
82. CU The operator gets a leg and tears off the point and tip end correctly. Operator	82. This point and tip end have been torn off at the proper location. Notice that the

VIDEO	AUDIO
holds tip end to show no meat is adhering to feathers.	feathers are clean, in that no meat is sticking to them.
83. CU The operator grasps the tip with the left hand and moves the leg forward in the right hand, so the ham is held by the fingers. The operator flops the lower end of the leg while holding ham end.	83. The leg should be repositioned in the right hand for hitting out the tip meat. The leg must be pushed forward so the ham, the lower part of the leg is allowed to flop freely, thus aiding in meat removal.
84. CU The operator moves the leg so the fingers are holding the tip. Operator pushes the body end of the ham against the stomach area of the body, to move the leg into proper hitting position.	84. The leg can be repositioned by pushing it against your body.
85. CU(SM) The operator points to the tip shell and joint end. The left hand grasps the tip shell. The right hand moves toward the joint.	85. The remaining tip shell and the joint end are torn off to open up the cavity containing the joint meat. The right hand slides up to the joint to support and hold the leg.
86. CU(SM) The operator tears off the tip shell and joint end.	86. A single outward stroke is used to tear off the tip shell.
87. MS The hammer and anvil are in the work area.	87. The hammer and anvil will now be used to crack the ham shell.

VIDEO	AUDIO
88. CU The operator picks up the hammer and runs his finger along the hitting edge.	88. If the hammer is shaped like the one shown, it should be held so that an edge strikes the shell. This results in the shell being more easily broken off. After the hammer is used it should be placed where it can be easily grasped.
89. MS The operator discards the hammer. Operator picks up a leg (left hand) and CU points to the body end of the ham.	89. The ham shell is cracked at the body end of the ham, thus making a bigger opening for removing the meat.
90. CU The operator places the ham on the anvil and cracks the shell with the hammer. Operator lays the hammer down and points to the indentation caused by the hammer blow.	90. The shell will usually break at the point where the hammer edge struck.
91. CU The operator tears off the body end of the ham shell and discards. Operator points to the exposed ham meat being held in left hand.	91. The ham meat should remain in the shell held by the left hand. Avoid removing any meat with the shell that is torn off and discarded.
92. CU The operator picks up the ham meat and displays it in the left hand.	92. This method should also yield a better quality ham meat.
Dissolve	
93. CU(SM) The operator picking crab legs.	93. We are now ready to go through a complete

VIDEO	AUDIO
	picking cycle, with a single crab leg.
94. CU(SM) The operator starts picking by reaching for a leg with the right hand.	94. Grasp the tip end of the leg with the right hand.
95. CU(SM) The left hand and right hand are brought together. The left hand grasps and tears off the point and tip end.	95. Using the left hand, tear off and discard the point and tip end.
96. CU(SM) The operator discards the point and tip end held in the left hand. The ham end of the leg is moved into the hand by pushing it against the operator's body. The tip meat is then hit out (3 hits).	96. Reposition the leg and hit out the tip meat, using three hits or less.
97. CU(SM) The hands move together. The left hand grasps and tears off the tip shell and joint end.	97. Tear off and discard the tip shell and joint end.
98. MS(SM) The left hand discards the tip shell and joint end while the right hand repositions the leg and hits out joint meat.	98. Reposition the leg, and hit out the joint meat using three hits or less.
99. MS(SM) The hands move together. The left hand grasps the joint. The right hand releases the leg and gets the hammer, while the left hand holds the leg by the joint (the joint is hanging over side of anvil).	99. Using the left hand, grasp the leg at the joint and place it on the anvil.

VIDEO	AUDIO
100. CU(SM) The ham shell is cracked with the edge of the hammer - 2 hits.	100. Crack the shell with the hammer using 2 hits or less.
101. CU(SM) The right hand releases the hammer and both hands move toward each other. The right hand grasps and tears off the body end of the ham shell.	101. Tear off and discard the body end of the ham shell.
102. MS(SM) The right hand discards the ham shell and moves and grasps the next leg, while the left hand hits out the ham meat (3 hits) and discards.	102. Grasp the next leg while the left hand hits out the ham meat, using three hits or less.
103. CU(SM) The operator tears off the point end.	103.
104. CU(SM) The left and right hands move together and the picking cycle continues.	104. All distances moved in the crab picking process should be as short as possible.
105. CU(SM) The operator continues single leg picking, one complete cycle, then starts multiple leg picking.	105. After you become familiar with the techniques and procedures associated with crab leg picking, the number of legs you pick at one time should increase. Try picking two legs together, then three. When the body section with the legs attached is discarded into a pile, one or two legs will usually break off.

VIDEO	AUDIO
	Therefore, when you reach for a group of legs, there will usually be two or three legs together.
106. CU(SM) The operator picks multiple legs.	106. Remember when picking multiple legs, that the legs are treated as a unit. In other words, the tips are lined up and torn off in one operation. When using the hammer, the hammer blow should strike all the legs.
107. CU(SM) The operator continues multiple leg picking.	107. Let us now review the important points in multiple crab leg meat picking.
108. CU(SM) The operator hits out the tip meat.	108. Use a firm hitting base and a minimum number of hits.
SUPER* SLIDE Firm hitting base	
109. CU(SM) The operator holds the legs by the joints in the left hand.	109. Hold the leg at the joint.
SUPER SLIDE Hold joint	

* All Super Slides are to be dissolved into and out.

VIDEO	AUDIO
110. The operator cracks the ham shells with hammer.	110. Crack the body end of ham shell.
SUPER SLIDE Crack body end of ham shell	
111. The operator's right hand discards the ham shell and moves and grasps the next leg, while the left hand hits out the ham meat and discards the shell.	111. Keep both hands in motion doing different jobs.
SUPER SLIDE Use overlapping motion	
112. CU(SM) The operator grasps and tears off the point and tip end.	112. Tear off the point and tip end.
SUPER SLIDE Tear off point and tip end	
113. CU(SM) The operator grasps and tears off the tip shell and joint end.	113. Tear off the tip shell and the joint end.
SUPER SLIDE Tear off tip shell and joint end	
Dissolve	

VIDEO	AUDIO
114. CU The operator goes through several picking cycles at regular speed.	114.
Dissolve	
115. Whole crab laying on table. Miscellaneous shots of claw leg and leg picking at regular speed.	115. It is now up to you to take advantage of the techniques and procedures that have been presented on crab meat extraction. Only you can increase your skill level and earnings. Remember, practice makes perfect only if you practice the correct method that will improve your picking while yielding a quality product. Experiment a little. There is no question that following some of the methods shown may make your fingers sore, but with time they will toughen. And using your left hand may seem awkward, but continue to practice. When picking a crab, ask yourself the following questions about the method you are presently using or will be using.
116. Miscellaneous scenes SUPER* SLIDE Needless transfers?	116. Are needless transfers of the crab body parts between the hands eliminated?

VIDEO	AUDIO
117. Miscellaneous scenes SUPER SLIDE Distance moved short?	117. Are all distances moved as short as possible?
118. Miscellaneous scenes SUPER SLIDE 1st movement helps - 2nd	118. Does one movement help the second?
119. Miscellaneous scenes SUPER SLIDE Overlapping motion?	119. Are both hands kept in motion doing different jobs?
120. Miscellaneous scenes SUPER SLIDE Smooth motion pattern?	120. Are smooth motion patterns used?
121. Miscellaneous scenes SUPER SLIDE Extra activities?	121. Are all extra activities eliminated?

* All Super Slides are to be dissolved into and out.

VIDEO	AUDIO
122. Miscellaneous scenes	122. Crab picking, as with any job, is just what you make it. We hope this film has provided you with ideas that will make your job more enjoyable and profitable.
Fade out and into	
123. Closing credits (A picture of a crabe is used as the background. All credits on dissolved into and out):	123. Music
SUPER SLIDE Chief Investigator: William F. Engesser	
124. SUPER SLIDE Research Assistants: Viravat Cholvanich G. Paul Willis	124. Music
125. SUPER SLIDE Directed by: G. Paul Willis	125. Music
126. SUPER SLIDE Narrated by: Marv Ryum	126. Music
127. SUPER SLIDE Script by: G. Paul Willis	127. Music

	VIDEO		AUDIO
128.	SUPER SLIDE	Photography by: Bill Reasons	128. Music
129.	SUPER SLIDE	An illustrated training manual and further information on Dungeness crab processing may be obtained from William F. Engesser Professor of Industrial Engineering Engineering Experiment Station Covell Hall 219 Oregon State University Corvallis, Oregon 97331	129. Music
130.	SUPER SLIDE	The End	130. Music

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a/ CU indicates a close-up shot.

b/ MS indicates a medium distance shot.

c/ SM indicates slow motion.

d/ XCU indicates an extreme close-up shot.

APPENDIX IV

Awards Received in National Film Competition

Industrial Management Society

RALPH H. LANDES

FILM COMPETITION

Certificate of Merit

Awarded to

Paul Willis

In recognition of outstanding work which contributed greatly toward the Group IV - First Place award won by "Crab Meat Extraction"

In witness whereof signatures are affixed this 4th day of November, 19 71

Ralph H. Landes

Ralph H. Landes

President

Figure 50. Certificate of Merit received by the author for his contribution in the production of the prize winning film entitled, "Crab Meat Extraction."

Figure 51. A trophy is presented to the author by Herbert F. Frolander, coordinator of Oregon State University's Sea Grant program, for heading the production of a training film entitled, "Crab Meat Extraction," which was awarded first place in national film competition sponsored by the Industrial Management Society.

APPENDIX V

TABLE XXV. STATISTICAL RESULTS OF THE IN-PLANT EXPERIMENTAL PROGRAM CONDUCTED IN PLANT D.

Employee's Number	Original Avg. Rate (lbs./hr.)	Improved Avg. Rate (lbs./hr.)	Percent of Increase
9896	5.8	8.4	45
20880	17.4	20.4	17
25026	11.4	14.4	26
29650	19.2	20.8	8
37500	16.2	19.6	21
58654	6.6	8.9	35
66865	16.2	18.1	12
76700	16.0	17.8	11
80900	7.7	10.4	35