# INVESTIGATION OF SOME FACTORS AFFECTING PHYSIOLOGICAL LOAD AND WORK PERFORMANCE OF FISH FILLETING OPERATORS



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by

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## ABSTRACT

The primary objective of this study was to observe the relationships between operator's work performance (speed of filleting and actual output rate of round codfish as well as of fillets) and his physiological parameters (mean heart rate, blood pressure and product of mean heart rate and blood pressure) during codfish filleting operation, and at the same time collect sufficient data to observe the effect of factors, such as speed of filleting and size of fish on the actual output rate and percentage yield of filleting. The effect of size of round codfish filleted on mean heart rate and normal output rate (round fish as well as fillets) of the filleting operator was also investigated.

This study was carried out at a small fish processing plant. Four average skilled male filleting operators were selected with the help of plant supervisors. Each subject was asked to work at five different filleting speeds, on an individual type filleting table layout. "Head on-gut in" codfish was supplied to each operator in 75 lb. boxes. A total of about 2625 lbs. of round codfish was processed during this study. A total of 35 individual experiments were performed. The actual time of filleting each box of 75 lbs. round codfish, performance rating (speed of filleting), number of codfish/75 lb. box, weight of skin-on fillets, operator's mean heart rate and blood pressure (both systolic and diastolic) were recorded for each filleting experiment.

Within the range and scope of this study, the analysis of the results indicated following trends:

1. Significant linear positive relationship between speed of filleting and mean heart rate of the operator.

2. Significant linear positive relationship between speed of filleting and systolic blood pressure of the operator.

3. Significant linear positive relationship between speed of filleting and product of mean heart rate and systolic blood pressure of the operator.

4. Significant linear negative relationship between speed of filleting and percentage yield produced.

5. Significant linear positive relationship between speed of filleting and actual output rate (round fish as well as fillets) produced.

6. Significant linear positive relationship between actual output rate (round fish as well as fillets) and mean heart rate of filleting operator.

7. Significant linear positive relationship between size of round fish filleted and actual output rate (round fish as well as fillets) produced.

8. Significant linear positive relationship between size of round fish filleted and mean heart rate of the operator.

9. Significant curvilinear positive relationship between size of round fish filleted and normal output rate (round fish as well as fillets) produced.

Management, in fish plants, could use the relationships between work performance (actual output rate etc.) and physiological parameters (mean heart rate etc.) to design a better method of filleting, working height and work layout etc., and therefore improve the efficiency of the plant, without causing unnecessary higher physiological loads on the operator.

This study also suggests that management in fish plants should set work standards by establishing relationships between size of fish and normal output rate for a range of different species of fish, input quality of fish, offshore -- inshore fish, and dressed -- undressed condition of the fish.

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# CHAPTER I

## INTRODUCTION

### 1.1 CANADIAN FISHING INDUSTRY

The waters off Canada's coasts, which rank among the most productive fishing grounds in the world, support the country's oldest primary industry. In 1975, the annual catch of fish in the world amounted to 69.73 million metric tons (Table 1). The landed live weight of fish in Canada alone in 1975, was 1.024 million metric tons.[1] Table 2 gives a breakdown of 1976 fish nominal catches (live weight) in metric tons by species and province. Groundfish comprised the most important portion of the Atlantic catches, contributing nearly one-half of the total value of landings.

Canada's role in the world fisheries is that of a major exporter since Canada's production is principally for international trade. Canada ranks third in the world in value of its fishery exports. In 1975, Canadian exports of fish products amounted to $442 million (Table 3).

Canadian sea fish mainly consist of four different kinds of species:[2] 1) Groundfish -- mainly consists of cod, haddock, redfish,

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[1]See Table 1.

[2]See Table 2.

Table No. 1: Nominal catches by major countries[a)], 1969-1975
Quantities in thousand metric tons, live weight.

| COUNTRY | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975[b)] |
|---|---|---|---|---|---|---|---|
| Japan | 8,629 | 9,371 | 9,959 | 10,275 | 10,748 | 10,804 | 10,508 |
| U.S.S.R. | 6,496 | [illegible] | 7,337 | 7,757 | 8,619 | 9,243 | 9,976 |
| China | 6,090 | 6,255 | 6,880[c)] | 6,880[c)] | 6,880[c)] | 6,880[c)] | 6,880[c)] |
| Peru | 9,244 | 12,535 | 10,529 | 4,724 | 2,367 | 4,150 | 3,447 |
| United States | 2,489 | 2,776 | 2,820 | 2,695 | 2,670 | 2,773 | 2,799 |
| Norway | 2,491 | 2,980 | 3,075 | 3,163 | 2,974 | 2,645 | 2,550 |
| India | 1,607 | 1,756 | 1,852 | 1,637 | 1,958 | 2,255 | 2,328 |
| Republic of Korea | 879 | 948 | 1,076 | 1,322 | 1,662 | 2,023 | 2,133 |
| Denmark | 1,275 | 1,226 | 1,401 | 1,443 | 1,465 | 1,835 | 1,767 |
| Thailand | 1,270 | 1,448 | 1,587 | 1,679 | 1,675 | 1,516 | 1,370 |
| Spain | 1,522 | 1,539 | 1,505 | 1,617 | 1,570 | 1,513 | 1,533 |
| South Africa | 1,850 | 1,212 | 1,162 | 1,115 | 1,334 | 1,401 | 1,315 |
| Indonesia | 1,214 | 1,228 | 1,244 | 1,268 | 1,300 | 1,336 | 1,390 |
| Philippines | 978 | 1,004 | 1,044 | 1,126 | 1,245 | 1,291 | 1,342 |
| Chile | 1,095 | 1,186 | 1,481 | 792 | 664 | 1,128 | 1,128 |
| United Kingdom | 1,093 | 1,099 | 1,107 | 1,082 | 1,133 | 1,087 | 980 |
| CANADA | 1,405 | 1,389 | 1,290 | 1,169 | 1,157 | 1,037 | 1,024 |
| Iceland | 690 | 734 | 685 | 726 | 902 | 945 | 995 |
| France | 770 | 782 | 758 | 797 | 823 | 808 | 806 |
| Dem. Pop. Rep. of Korea | 800[c)] | 800[c)] | 800[c)] | 800[c)] | 800[c)] | 800[c)] | 800[c)] |
| Rep. of South Viet-Nam | 464 | 517 | 588 | 678 | 714 | 714[c)] | 714[c)] |
| Nigeria | [illegible] | 543 | 593 | 640 | 665 | 685 | 507 |
| Poland | 408 | 469 | 518 | 544 | 580 | 769 | 801 |
| Brazil | 493 | 517 | 581 | 605 | 605[c)] | 674[c)] | 674[c)] |
| Fed. Rep. of Germany | 652 | 612 | 508 | 473 | 478 | 526 | 442 |
| All other countries[d)] | 8,674 | 9,941 | 9,843 | 10,673 | 11,092 | 11,745 | 11,623 |
| WORLD TOTAL | 62,700 | 69,335 | 70,193 | 65,635 | 56,034 | 70,493 | 69,732 |

(a) Countries are listed in order of 'Quantity of fish, marine mammals etc. landed in 1974
(b) Preliminary.
(c) Unofficial estimate calculated by F.A.O. (Food and Agricultural organization of United Nations)
(d) Includes approximately 190 countries
Source: Annual Statistical Review of Canadian Fisheries, Fisheries and Environmental Canada, (1955-1976), Vol. 9.

Table No. 2: Sea fisheries - catches and landed values, by species and province, 1976 (preliminary) Nominal catches (live weight) in metric tons.

| SPECIES/ESPÈCES | Nova Scotia / Nouvelle-Écosse | New Brunswick / Nouveau-Brunswick | Prince Edward Island / Île-du-Prince-Édouard | Quebec / Québec | Newfoundland / Terre-Neuve | ATLANTIC TOTAL / ATLANTIQUE TOTAL | British Columbia / Colombie-Britannique | CANADA TOTAL / CANADA TOTAL |
|---|---|---|---|---|---|---|---|---|
| FISH AND SHELLFISH - TOTAL / POISSONS, MOLLUSQUES ET CRUSTACÉS - TOTAL | 367,883 | 114,709 | 17,134 | 41,955 | 339,211 | 880,892 | 180,902 | 1,061,794 |
| Groundfish - Total - Poissons de fond - Total | 160,781 | 16,245 | 7,496 | 28,919 | 256,224 | 469,666 | 31,349 | 501,015 |
| Cod - Morue | 50,952 | 3,936 | 1,282 | 17,213 | 119,567 | 193,550 | 12,203 | 205,753 |
| Haddock - Aiglefin | 19,010 | 42 | 27 | 0 | 247 | 19,326 | -- | 19,326 |
| Redfish - Sébaste | 34,937 | 5,870 | 1,873 | 6,899 | 40,075 | 89,654 | 3,986 | 93,640 |
| Halibut - Flétan | 928 | 8 | 1 | 54 | 331 | 1,322 | 7,349 | 8,671 |
| Small flatfish - Petits poissons plats | 17,545 | 5,232 | 1,691 | 3,298 | 82,607 | 110,373 | 5,195 | 115,568 |
| Greenland Turbot - Turbot du Groenland | 355 | 292 | 0 | 1,120 | 9,748 | 11,515 | 1,317 | 12,832 |
| Pollock - Goberge | 22,454 | 181 | 14 | 0 | 89 | 23,238 | 1,299 | 24,537 |
| Hake - Merluche | 7,476 | 382 | 1,647 | 258 | 814 | 10,577 | -- | 10,577 |
| Cusk - Brosme | 3,217 | 0 | -- | -- | 3 | 3,220 | -- | 3,220 |
| Catfish - Poisson-chat | 1,363 | 9 | 2 | 17 | 2,724 | 4,115 | -- | 4,115 |
| Tomcod - Poulamon | -- | 175 | 106 | 0 | -- | 281 | -- | 281 |
| Other - Autres | 2,044 | 119 | 253 | 60 | 19 | 2,495 | -- | 2,495 |
| Pelagic and Estuarial - Total / Poissons pélagiques et d'estuaire - Total | 109,260 | 85,960 | 3,226 | 5,717 | 66,613 | 270,776 | 140,546 | 411,322 |
| Herring - Hareng | 96,293 | 75,301 | 667 | 4,281 | 48,922 | 225,461 | 81,105 | 306,566 |
| Mackerel - Maquereau | 7,985 | 659 | 1,364 | 395 | 5,352 | 15,755 | -- | 15,755 |
| Tuna - Thon | 180 | 6,599 | 257 | -- | -- | 7,036 | 335 | 7,371 |
| Alewife - Gaspareau | 3,325 | 1,997 | 166 | -- | -- | 5,488 | -- | 5,488 |
| Eel - Anguille | 27 | 120 | 94 | 275 | 11 | 527 | -- | 527 |
| Salmon - Saumon | 51 | 12 | 1 | 120 | 2,012 | 2,196 | 57,462 | 59,658 |
| Shad - Alose | 44 | 38 | -- | 7 | -- | 89 | -- | 89 |
| Skate - Raie | 1,186 | 0 | -- | 1 | 492 | 1,679 | 738 | 2,417 |
| Smelt - Éperlan | 61 | 1,200 | 569 | 294 | 27 | 2,151 | 10 | 2,161 |
| Capelin - Capelan | -- | 11 | -- | 334 | 9,613 | 9,958 | -- | 9,958 |
| Other - Autres | 111 | 23 | 108 | 10 | 184 | 436 | 896 | 1,332 |
| Molluscs and Crustaceans - Total / Mollusques et crustacés - Total | 97,842 | 17,503 | 6,412 | 7,319 | 16,374 | 140,450 | 9,007 | 149,457 |
| Clam - Coque | 958 | 777 | 294 | 366 | 0 | 2,395 | 1,179 | 3,574 |
| Mussel - Moule | 3 | 79 | -- | 2 | 1 | 85 | -- | 85 |
| Oyster - Huître | 16 | 325 | 772 | -- | -- | 1,113 | 3,036 | 4,149 |
| Scallop - Pétoncle | 89,415 | 1,249 | 1,481 | 1,221 | 30 | 93,400 | -- | 93,400 |
| Squid - Encornet | 1,010 | 15 | -- | -- | 9,927 | 10,952 | -- | 10,952 |
| Lobster - Homard | 5,909 | 2,754 | 3,859 | 1,306 | 2,254 | 16,082 | -- | 16,082 |
| Crab - Crabe | 11 | 85 | 6 | -- | -- | 102 | 995 | 1,097 |
| Queen Crab - Crabe des neiges | 468 | 6,086 | 0 | 1,496 | 2,668 | 10,738 | -- | 10,738 |
| Shrimp and Prawn - Crevette et crevette rose | 2 | 1,079 | -- | 2,442 | 1,494 | 5,017 | 3,503 | 8,520 |
| Other - Autres | 26 | 54 | -- | 486 | -- | 566 | 294 | 860 |
| Other items - Autres items | — | — | — | — | — | — | — | — |
| Cod livers - Foie de morue | 0 | 3 | -- | -- | 448 | 451 | -- | 451 |
| Other livers - Autres foies | 24 | 6 | -- | -- | -- | 30 | -- | 30 |
| Irish Moss - Mousse d'Irlande | 10,726 | 564 | 13,083 | -- | -- | 24,373 | -- | 24,373 |
| Other marine plants - Autres plantes marines | 6,402 | 22 | -- | -- | -- | 6,424 | -- | 6,424 |
| Seal (no.) - Loup-marin (no.) | 24,591 | -- | -- | 7,939 | 94,617 | 127,147 | -- | 127,147 |

Source: Annual Statistical Review of Canadian Fisheries, Fisheries and Environmental Canada, (1955 - 1976), Vol. 9.

Table No. 3: Export values by major producing countries[a)], 1969–1975
Values in million U.S. dollars.

| COUNTRY | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 |
|---|---|---|---|---|---|---|---|
| Japan | 282 | 335 | 367 | 467 | 554 | 609 | 490 |
| Norway | 232 | 260 | 300 | 362 | 514 | 517 | 515 |
| Denmark | 141 | 166 | 194 | 242 | 377 | 440 | 427 |
| CANADA | 250 | 257 | 282 | 343 | 491 | 433 | 442 |
| Peru | 220 | 339 | 338 | 281 | 152 | 256 | 207 |
| United States | 98 | 112 | 136 | 152 | 285 | 253 | 298 |
| Iceland | 87 | 113 | 125 | 140 | 213 | 246 | 245 |
| Netherlands | 95 | 112 | 129 | 162 | 208 | 216 | 258 |
| Spain | 67 | 95 | 114 | 151 | 169 | 209 | 182 |
| Republic of Korea | 29 | 42 | 44 | 70 | 146 | 168 | 360 |
| U.S.S.R. | 85 | 90 | 93 | 96 | 123 | 162 | 212 |
| Fed. Rep. of Germany | 59 | 63 | 75 | 94 | 128 | 155 | 137 |
| United Kingdom | 38 | 55 | 70 | 74 | 114 | 138 | 139 |
| South Africa | 62 | 45 | 39 | 63 | 84 | 130 | 123 |
| France | 27 | 37 | 49 | 65 | 97 | 110 | 111 |
| Mexico | 60 | 71 | 79 | 90 | 115 | 104 | 151 |
| Australia | 42 | 44 | 65 | 89 | 104 | 97 | --- |
| India | 41 | 41 | 47 | 73 | 96 | 95 | --- |
| Thailand | 16 | 18 | 24 | 39 | 81 | 76 | --- |
| Morocco | 32 | 35 | 38 | 39 | 80 | 79 | 64 |
| Faeroe Islands | 24 | 32 | 36 | 43 | 68 | 75 | --- |
| Indonesia | 1 | 5 | 18 | 32 | 62 | 74 | 83 |
| Portugal | 47 | 47 | 42 | 51 | 66 | 56 | --- |
| Chile | 27 | 27 | 46 | 28 | 20 | 54 | --- |
| Angola | 18 | 19 | 19 | 37 | 53 | --- | --- |
| All other countries[b)] | 361 | 435 | 574 | 739 | 946 | 1,212 | 1,664 |
| WORLD TOTAL | 2,441 | 2,895 | 3,343 | 4,022 | 5,346 | 5,964 | 6,108 |

a) Countries are listed in order of 'Value' of fisheries products exported in 1974
b) Includes approximately 130 countries

Source: Annual Statistical Review of Canadian Fisheries, Fisheries and Environmental Canada, (1955–1976), Vol. 9.

small flatfish and others. 2) Pelagic and Estuarial -- mainly consists of herring, mackerel, tuna, salmon and others. 3) Molluscs and Crustaceans -- consists of clam, scallop, lobster, crab, shrimp and others. 4) Miscellaneous items -- such as Irish moss, seal, cod liver, etc.

Dependence on fisheries varies in different parts of Canada. The Atlantic region including Newfoundland, the Maritimes and the coastal areas of Quebec, depends heavily on fishing. About 75% of the communities in this region take part in commercial fishing.[1] The Pacific area is less dependent on the fisheries. Much of the industry on the West Coast of Canada is centred in Prince Rupert and Vancouver. Nearly as many people work in freshwater fisheries of Canada as in the sea fisheries of the Pacific Coast. Dependence on fishing is especially high in some indian communities of the Northwest Territories, in the northern parts of Manitoba, Saskatchewan and Alberta, and in north-western Ontario.

In Canada, the fishery provides a livelihood to some 58,688 fishermen (Table 4). In addition, it provides employment to 18,774 persons who work in fish processing plants across the country.[2]

The Canadian fishing industry, particularly North Atlantic fishing industry, is divided into 3 distinct divisions: inshore and *coastal, medium range and deep sea or long distance fisheries.*[3]

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[1] Policy for Canada's Commercial Fisheries, Environmental Canada, May 1976, p. 7.

[2] Annual statistical review of Canadian Fisheries, Fisheries and Environmental Canada (1955-1976), Vol. 9.

[3] Journal of the Fisheries research board of Canada, Environmental Canada, Vol. 30, No. 12, Part 2, Dec. 1973, pp. 2404, 2405. -- "Management and Development of Fisheries in the North Atlantic" by G. Mocklinghoff.

Table No. 4: Number of fishermen, by province and region, 1955-1974

| Year / Année | Nova Scotia / Nouvelle-Écosse | New Brunswick / Nouveau-Brunswick | Prince Edward Island / Île-du-Prince-Édouard | Quebec / Québec | Newfoundland / Terre-Neuve | ATLANTIC TOTAL / ATLANTIQUE TOTAL | British Columbia / Colombie-Britannique | SEA FISHERIES TOTAL / PÊCHES MARITIMES TOTAL | Freshwater Fisheries / Pêches d'eau douce | CANADA TOTAL / CANADA TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1955 | 14,221 | 9,634 | 2,863 | 5,147 | 16,000 | 47,865 | 12,836 | 60,701 | 17,810 | 78,511 |
| 1956 | 14,379 | 9,399 | 2,967 | 5,290 | 14,956 | 46,991 | 11,851 | 58,842 | 15,781 | 74,623 |
| 1957 | 15,265 | 7,815 | 3,000 | 5,[illegible]78 | 16,469 | 48,127 | 12,999 | 61,126 | 17,918 | 79,044 |
| 1958 | 13,747 | 6,060 | 3,209 | 6,213 | 18,364 | 47,593 | 15,263 | 62,856 | 20,074 | 82,930 |
| 1959 | 13,012 | 6,211 | 3,260 | 5,387 | 18,430 | 46,300 | 15,456 | 61,756 | 18,307 | 80,063 |
| 1960 | 12,780 | 6,012 | 3,274 | 4,989 | 18,291 | 45,346 | 15,159 | 60,505 | 17,666 | 78,171 |
| 1961 | 12,578 | 6,083 | 3,464 | 3,771 | 18,756 | 44,652 | 16,805 | 61,457 | 16,903 | 78,360 |
| 1962 | 12,711 | 6,016 | 3,367 | 3,786 | 19,817 | 45,697 | 16,437 | 62,134 | 16,684 | 78,818 |
| 1963 | 13,467 | 5,833 | 3,372 | 3,674 | 21,407 | 47,753 | 16,624 | 64,377 | 17,305 | 81,682 |
| 1964 | 13,333 | 5,790 | 3,329 | 3,512 | 22,615 | 48,579 | 13,300 | 61,879 | 16,246 | 78,125 |
| 1965 | 14,049 | 6,102 | [illegible]566 | 3,917 | 21,701 | 49,335 | 13,000 | 62,335 | 15,822 | 78,157 |
| 1966 | 13,067 | 5,642 | 3,220 | 3,703 | 20,286 | 45,918 | 12,000 | 57,918 | 15,328 | 73,246 |
| 1967 | 12,589 | 5,518 | 3,369 | 3,920 | 19,814 | 45,210 | 12,117 | 57,327 | 13,931 | 71,258 |
| 1968 | 13,108 | 5,766 | 3,301 | 4,179 | 19,355 | 45,709 | 12,133 | 57,842 | 11,350 | 69,192 |
| 1969 | 11,717 | 5,358 | 2,965 | 5,121 | 17,770 | 42,931 | 10,942 | 53,873 | 11,110 | 64,983 |
| 1970 | 11,018 | 5,081 | 2,801 | 5,092 | 17,765 | 41,757 | 11,647 | 53,404 | 9,741 | 63,145 |
| 1971 | 10,688 | 5,148 | 2,677 | 5,252 | 15,961 | 39,726 | 11,015 | 50,741 | 8,104 | 58,845 |
| 1972 | 11,735 | 5,067 | 3,210 | 5,277 | 14,452 | 39,741 | 9,902 | 49,643 | 7,741 | 57,384 |
| 1973 | 10,600 | 4,997 | 2,636 | 5,450 | 15,313 | 38,996 | 11,717 | 50,713 | 7,975 | 58,688 |
| 1974 | 10,460 | 4,898 | 2,610 | 5,703 | --- | --- | 11,906 | --- | 7,489 | --- |

Note: Figures for Newfoundland are not available for 1974

Source: Annual Statistical Review of Canadian Fisheries, Fisheries and Environmental Canada, (1955-1976), Vol. 9.

Inshore fishermen use relatively small vessels using fixed gear, driftnets, trawls, purse seines, and hooks. They fish individually or, more often, in small crews on a share basis. Their catch is usually highly seasonal. It consists mostly of low-value cod, the major portion of which is cleaned and salted by the fishermen and sold as 'salt bulk.' In several areas, catches of the high value lobster and salmon are also of some significance. The weight displacement of inshore vessels is usually not over 150 gross tons.[1] Inshore fishermen often have second occupations on shore, in farming or industry.

Medium range vessels, mostly used in Maritime states, are vessels under 500 gross tons. They can remain at sea for days and can carry out a wide range of fishing methods. The fleets are largely bound to their regular fishing grounds. These vessels are owned mostly by individual fishermen, families or small groups of associated fishermen. These are mainly vessels landing fresh fish for human consumption and, to some extent, pelagic fish for the fish meal industry.

Deep-sea or Long-distance fishery is pursued mostly in trawlers and draggers, over 500 gross tons.[2] These vessels bring in fresh fish and their operating range and the time they can remain at sea are limited to 12-14 days, that fresh catches will keep. These vessels are operated mostly by the processing plants, with crew members drawing shares on the basis of the value of the fish landed.

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[1]Journal of the Fisheries research board of Canada, Environment Canada, Vol. 30, No. 12, Part 2, Dec. 1973, p. 2404.

[2]Ibid.

Until the 1950's, the product of the fishing industry was confined largely to salt cod. Most of the processing, i.e., salting and drying, was done by the fishermen themselves. A substantial fish freezing industry has since developed, as well as smaller processing sectors engaged in salt fish drying and herring reduction to meal and oil. Table 5 shows the value of sea products in thousand dollars by main categories and by region. Both fish freezing and herring reduction are strongly associated with the offshore or deep-sea fishery, although the freezing plants do take a considerable amount of fish from inshore fishermen as well. Salt fish drying is linked to the inshore fishery that supplies "wet" salted cod.

During the past few years, Canadian fishery has been facing some serious problems. Table 1 shows that the total fish landing in live weight has been declining since 1969. Steady offshore exploitation of the continental shelf, particularly North Atlantic, by foreign vessels and bad ice conditions at the opening of the season in the northern areas, contributed towards this decline.[1] This decline in the catch and the rapid cost increases in the recent years attributed to the income drop in the primary sector.[2]

In 1975, the federal government decided on a new approach to fisheries management and development, with aims of creating a climate

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[1]Policy for Canada's Commercial Fisheries, Environmental Canada, May 1976.

[2]Ibid.

Table No. 5: Value of products, main catagories, by region 1966-1976.
Values in thousand Dollars.

| PRODUCTS - PRODUITS | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ATLANTIC COAST - CÔTE DE L'ATLANTIQUE | | | | | | | | | | | |
| Round or dressed, fresh and frozen<br>Entiers ou habillés, frais et congelés | 22,844 | 20,858 | 22,241 | 16,562 | 22,521 | 24,512 | 24,921 | 31,693 | 29,949 | 52,929 | 58,494 |
| In shell and shucked, fresh and frozen<br>En carapace et écaillés, frais et cong. | 42,171 | 43,200 | 58,606 | 70,207 | 67,195 | 76,561 | 91,755 | 110,222 | 105,376 | 137,154 | 173,813 |
| Fillets, fresh<br>Filets frais | 8,424 | 8,232 | 7,481 | 12,680 | 7,561 | 10,327 | 16,511 | 22,428 | 17,456 | 21,869 | 25,514 |
| Fillets, frozen<br>Filets congelés | 40,410 | 34,385 | 40,329 | 53,354 | 60,401 | 64,084 | 82,438 | 111,399 | 92,358 | 115,505 | 152,262 |
| Blocks, frozen<br>Blocs congelés | 26,350 | 21,427 | 24,340 | 24,671 | 23,113 | 42,365 | 33,905 | 52,241 | 28,800 | 25,959 | 47,782 |
| Smoked<br>Fumés | 4,991 | 4,625 | 4,720 | 3,997 | 3,462 | 4,627 | 3,627 | 4,885 | 6,267 | 5,546 | 6,323 |
| Salted<br>Salés | 19,142 | 22,459 | 20,273 | 19,911 | 16,003 | 20,230 | 19,447 | 25,969 | 30,470 | 30,983 | 43,517 |
| Pickled and vinegar cured<br>Saumurés et marinés | 2,872 | 3,181 | 2,109 | 2,586 | 6,202 | 7,882 | 9,914 | 11,761 | 12,954 | 11,875 | 18,316 |
| Canned<br>En boîte | 19,330 | 18,404 | 22,108 | 21,602 | 26,800 | 25,982 | 32,568 | 40,383 | 49,634 | 38,145 | 45,798 |
| Meal<br>Farine | 10,877 | 12,175 | 18,195 | 22,179 | 20,958 | 16,161 | 15,776 | 19,313 | 13,160 | 10,946 | 16,542 |
| Oil<br>Huile | 2,357 | 3,711 | 4,851 | 5,191 | 5,790 | 5,420 | 3,097 | 3,695 | 5,149 | 4,186 | 2,969 |
| Miscellaneous products<br>Produits divers | 12,470 | 16,530 | 15,041 | 18,025 | 17,772 | 18,251 | 20,722 | 28,733 | 31,129 | 28,409 | 34,482 |
| All products<br>Tous les produits | 212,238 | 209,187 | 240,374 | 270,965 | 277,778 | 316,402 | 354,681 | 462,722 | 422,712 | 483,485 | 625,812 |
| PACIFIC COAST - CÔTE DU PACIFIQUE | | | | | | | | | | | |
| Round or dressed, fresh and frozen<br>Entiers ou habillés, frais et congelés | 31,692 | 26,826 | 35,942 | 38,876 | 46,567 | 36,807 | 64,975 | 87,356 | 45,483 | 60,500 | --- |
| In shell and shucked, fresh and frozen<br>En carapace et écaillés, frais et cong. | 2,209 | 2,356 | 2,260 | 2,817 | 2,033 | 1,892 | 3,039 | 4,136 | 4,701 | 4,760 | --- |
| Fillets and blocks, fresh and frozen<br>Filets et blocs frais et congelés | 5,715 | 4,069 | 5,428 | 5,234 | 5,471 | 5,436 | 6,948 | 6,346 | 6,852 | 8,093 | --- |
| Canned<br>En boîte | 68,513 | 62,081 | 72,586 | 33,903 | 60,983 | 67,123 | 56,544 | 129,085 | 115,297 | 45,448 | --- |
| Meal<br>Farine | 5,888 | 2,284 | 443 | 107 | 183 | 352 | 1,856 | 2,812 | 2,568 | 1,775 | --- |
| Oil<br>Huile | 3,244 | 824 | 89 | 15 | 39 | 84 | 245 | 337 | 324 | 474 | --- |
| Fish Roe<br>Oeufs de poisson | 268 | 1,427 | 2,665 | 1,474 | 3,592 | 5,013 | 19,664 | 28,464 | 38,391 | 29,951 | --- |
| Miscellaneous products<br>Produits divers | 6,152 | 4,590 | 4,511 | 5,426 | 4,429 | 3,460 | 5,851 | 26,461 | 6,816 | 16,016 | --- |
| All products<br>Tous les produits | 123,681 | 124,457 | 123,959 | 87,852 | 123,297 | 120,167 | 159,132 | 284,997 | 220,452 | 167,017 | 297,621 |
| TOTAL SEA FISHERIES<br>TOTAL DES PÊCHES TIMES | 335,919 | 313,544 | 364,333 | 358,217 | 401,075 | 436,569 | 513,613 | 742,719 | 643,164 | 650,502 | 923,433 |

Source: Annual Statis ical Review of Canadian Fisheries, Fisheries and Environmental Canada, (1955 - 1976) Vol. 9.

of prosperity and security for all who participate in the commercial fisheries. As a result, Canada concentrated its efforts on two major issues: international recognition of the need to balance fishing levels and the condition of resources, and the rehabilitation of the Canadian fishing industry.[1]

During the fourth international Law of the Sea Conference, Canada reaffirmed its support to the 200 mile coastal economic zone concept. Also at Canada's lead, ICNAF (International Commission for Northwest Atlantic Fisheries) member countries[2] agreed to a substantial reduction in total allowable catches for certain important species as well as a reduction in their fishing activities.

At the domestic level, Canada established a temporary assistance programme for fishing enterprise and processing plants, especially in groundfish sector, to supplement low incomes. For the period July, 1974 - March, 1977, the government allocated about $130 million for special aid to fisheries. This was in addition to normal expenditures estimated at more than $200 million per year, by the federal and provincial governments.[3] At the same time, during 1975, the government formulated a series of long term plans to revitalize the fishing industry. These plans, dealing with a wide variety of areas such as fleet development, the improvement of product quality, etc., will be progressively implemented over the next few years. Some special expen-

[1] Policy for Canada's Commercial Fisheries, Environmental Canada, May 1976, p.5.

[2] Belgium, Denmark, France, Federal Republic of Germany, Iceland, Ireland, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, United Kingdom and the USSR. Journal of the Fisheries Research Board of Canada, Environment Canada, Vol. 30, No. 12, Dec. 1973, p. 2405.

[3] Policy for Canada's Commercial Fisheries, Environmental Canada, May 1976, p. 1.

diture may be expected to continue, though on a reduced scale, until the measures now being planned result in the emergence of an industry that can stand on its own feet.[1]

## 1.2 FISH PROCESSING IN NEWFOUNDLAND

Historically the primary fishing industry, especially the inshore fisheries in Newfoundland, has remained a 'traditional' or 'subsistance' sector in the economy. A downturn in the overall economy and subsequent job losses in the industrial sector has resulted in more and more people turning to fishing. In output value, the Newfoundland fisheries rank far behind forestry, mining and construction. Despite this, the fisheries continue to provide employment to far more Newfoundlanders than any other industry.[2]

The raw material processed by this industry consists of landing mainly cod, flatfish, redfish, herring, salmon, lobster and seal, of which cod is the most important species comprising 19.38% of landed weight.[3] In general, all plants buy some raw materials, mostly inshore cod, directly from the fishermen, while some employ fishermen to work on company owned boats. Some plants are served by a fleet of offshore[4] boats to supplement the supply of raw cod purchased from the private

[1] Annual Statistical Review of Canadian Fisheries, Fisheries and Environment Canada, Vol. 8, 1975, pp. 10,11.

[2] The Resettlement of Fishing Communities in Newfoundland by Parzival Copes, April, 1972.

[3] See Table 2.

[4] Includes medium range and deep-sea or long-distance fishery.

fishery enterprises during the short summer season.

The degree of mechanization varies from plant to plant. The plants, which operate large offshore vessels, usually use either mechanized bucket conveyor or vacuum unloading system to unload their raw material in convenient boxes. The raw material is then either held in storage or delivered through the conveyor for filleting. However, plants depending on inshore supplies from small boat fishermen do not use these facilities. This leads to unnecessary handling and often spoilage of the delicate raw material in the process.

A fish handling and unloading system, to increase the productivity of the inshore fishery in Newfoundland, has been designed by Newbury and Amaria (1974). This materials handling system includes facilities for fast, non-damaging removal of fish from boats and for immediate gutting of trapfish to avoid the deterioration in quality of fish.

Figure 1 shows a diagramatic view of this system. Under this system, small open boats carry nets or bags, each net with a fish holding capacity from 500 to 1000 lbs. These nets, with fish placed one upon the other, are laid in the boat till all fish are taken or the boat is filled. When the boat arrives in port, a hoist of suitable capacity (electric or gas engine driven) lifts the nets with fish from the boat. Fish can be removed from open trapboats, by this method, at a rate of 25/30,000 pounds per hour. A scale set on the hoisting cable weighs the fish as it is being lifted. The net of fish is next dumped into an elevated holding bin, providing temporary storage while the fish is being gutted on tables located at the outlet end of the bin. After the fish is gutted, it is placed in large (approximately 1500 lbs. capacity),

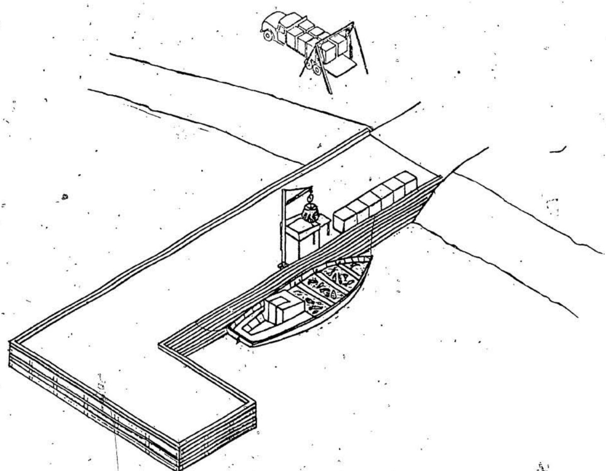

Figure 1 : Integrated Inshore Fish Handling System by D. Newbury.

insulated containers with ice, for shipment by truck to a processing plant.

In general, most of the filleting of fish is performed manually. The failure to mechanize this operation fully could be attributed to the seasonal fluctuations in the raw material supply and the need for operational flexibility. The inshore cod fishery has been practically restricted to a five-month period each year. The three months, June, July and August, between them have accounted for more than two-thirds of the landing during any year.[1] Therefore, if the filleting operation were fully mechanized, the filleting machines would be fully employed during a short season, but would be used at very low percent of their full operational capacity because of the low landings of the raw material (seasonal fluctuations in raw material supply), for a considerable period. This would lead to high overheads.[2] In the case of hand filleting, however, working hours may be lengthened during the peak season while workers may be layed off during the slack months, where this is possible. In recent years, a few plants have started using a small number of cod filleting machines as stand-by equipment, to fillet the inshore cod supplied during the peak season, as the quality of raw material is likely to deteriorate if held in storage for long. The filleting rates of such machines range from 30 to 40 fish per minute and their output rate and yield mainly depend on the size (length) of the

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[1]Canadian Fisheries Report No. 11, Department of Fisheries and Forestry, Ottawa, p. 11.

[2]Ibid., pp. 3-11.

fish and the feeding of the whole fish to the machine by hand.[1] Other plants freeze the excess supply of fish during the summer season to be processed later for the winter.

Most plants use skinning machines and also conveyor systems for the movement of raw material through various stages of processing. The output rate and yield from the skinning machine are mainly dependent on the size (length) of the fish and the rate of manually feeding of fillets to the machine.

In fish processing plants, usually two types of filleting table layouts (individual and group types) are used.

### 1.2.1 Description of an Individual Filleting Table

Figure 2 and Figure 3 show an individual type filleting table similar to the one used in this study. The layout of the table normally consists of eight to nine individual cutting stations[2] set up on either side of a centrally located conveyor system. The 75 lb. (34 kg) of fish is weighed in an empty plastic fish box[3] at the front of the line and the box is supplied to the filleter on the roller conveyor. The operator slides the fish box onto his cutting table. He picks up one fish from the fish box, fillets it and places the cut fillet in an empty fillet pan and puts the skeleton and waste in the skeleton hole, on the right hand side of filleter, beside the cutting board, in the filleting table.

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[1]J. Drews (1974), "Mechanized Fish Processing, Aboard Ship and Ashore," Fishing News International, November.

[2]Smaller number of cutting stations are also in use.

[3]Empty plastic fish box weighs about 6 lbs.

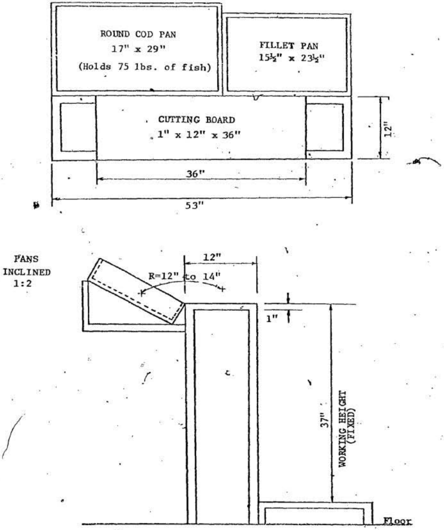


Figure No. 2: Individual Filleting Table Layout

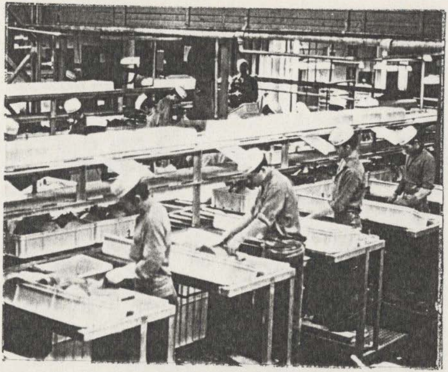

Figure 3. Individual filleting table layouts.

Figure 4. Group filleting table layout.

When the operator has filleted all the fish from the fish box, he returns the empty fish box for cleaning (using a lower level conveyor belt) and places the fillet pan on the top conveyor belt to be weighed at the end of the line.

In individual type layout, continuous monitoring of the amount of whole fish filleted per hour, i.e., output rate of whole fish (lbs./hr.), weight of skin-on fillets produced per hour, i.e., output rate of skin-on fillets (lbs./hr.), and percentage yield[1] of skin-on fillets can be maintained for each operator.

1.2.2 Description of a Group Filleting Table

Figure 4 and Figure 5 show a group filleting table layout. The layout of the table normally consists of eight to nine cutting table stations set up on either side of a centrally located fish trough. The fish are supplied from the holding room and placed in the trough which is filled with cold water ($4^{o}$ to $6^{o}C$). All the operators obtain fish by dipping their hands in the central trough and fillet the fish on their individual cutting boards. The fillets are placed in the fillet chute, where a flow of running water moves the fillets to the end of the table, and then weighed before skinning.

In group filleting table layout, since all operators obtain the fish from one source and the fillets are all weighed together at the end

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[1]Yield is the ratio of weight of the fillets obtained (lbs.) to the weight of the whole fish processed (lbs.). In fish processing yield is affected by skill of operator, speed of filleting, quality of input, type of cut, size of fish and type of species. A recent study by Research and Productivity Council (R.P.C.), New Brunswick (1977), shows that finished product yield for cod varies from 23.8% to 39.0%, for redfish it varies from 18.5% to 37.1% and for flatfish it varies from 13.6% to 32.2%.

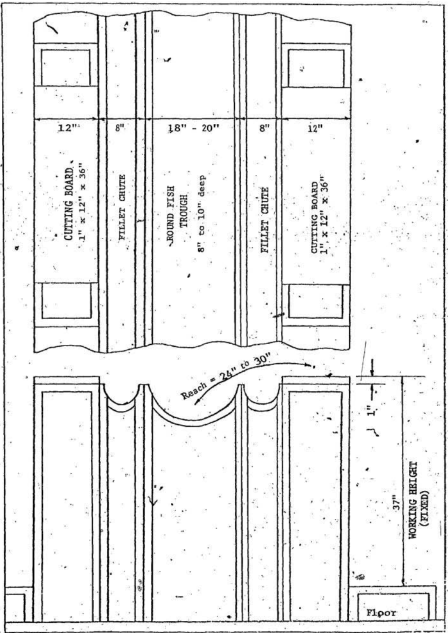


**Figure No. 5:** Group Filleting Table Layout (normally used in the plant) of the line, it is not possible to measure the output rate of whole fish (lbs./hr.) and output rate of fillets (lbs./hr.), for each individual filleting operator. However, in group filleting table layout, the output rate of whole fish and of fillets can be measured for the whole group. For example, the actual output rate of skin-on fillets for a group is determined by dividing total weight of the skin-on fillets produced by the group by actual total time of filleting. The actual output rate of the group can then be divided by the total number of persons in that particular group to give the average actual output rate of the operator in that group. In group filleting table layout, the output rate of group on each side of filleting table can also be measured separately.

Work sampling can also be used to determine the percentage productive working time, the percentage non-productive time, the average performance rating or filleting speed of the group working on a group type table layout and the standard output of the processed fish as well as of fillets (lbs./hr./operator) (refer to Chapter 3, p.51, of this report).

1.2.3 Fish Processing Operation

Various operations performed during fish processing are shown in Figure 6.

Offshore fish, usually gutted and washed on offshore vessels, are stowed with ice in boxes or compartments below deck, to keep the temperature of the fish close to $0^{o}C$. About one part of ice to 3 parts of fish by weight is normally used to protect fish for up to 5 days and

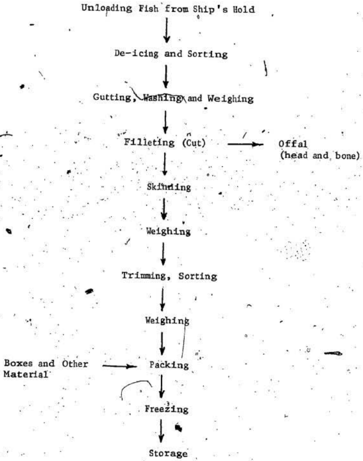


Figure 6. Operation Chart for the Fish Processing Operation

NOTE: Offshore fish is usually gutted. Inshore fish is often not gutted and therefore requires gutting on shore.

one part of ice to 2 parts of fish is needed for longer voyages.[1] Inshore fish are gutted by the fishermen on the plant wharf and are sold to the company in this condition, commonly known as 'gutted head-on.' Gutting operation for cod includes the slitting of the belly from throat to vent, removing the liver and cutting out the guts to leave the belly cavity empty. Gutting helps to preserve the fish by removing the main source of spoilage bacteria and digestive juices which attach to the flesh of the fish after death. The gutted fish are washed to remove traces of blood and to wash away most of the bacteria present on the skin and in the gills of the fish.

From the wharf, the fish are taken to the holding room and iced. The fish and ice are stored in layers to ensure that all the fish are chilled. The fish may remain in the holding room from one to four days, depending on the rate of processing in the plant. In order to minimize the seasonal variation in production, some plants, which process both inshore and offshore fish, freeze part of the catch into 'round' frozen blocks during the summer season. These frozen blocks are then thawed and processed during the winter season.

Fish from the holding room are supplied to filleters either in weighed boxes, usually in 60 lbs., 75 lbs., or 100 lbs. of fish, on the roller conveyor in individual type filleting table layouts or placed in the trough filled with cold water ($4^{o}$ to $6^{o}C$) in case of group filleting table layouts.

Figure 7 and Figure 8 show the filleting operation of cod.

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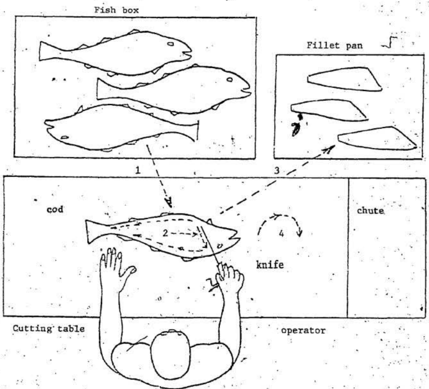
[1] P. J. Amaria (1974), "Productivity Studies in Fish Processing."



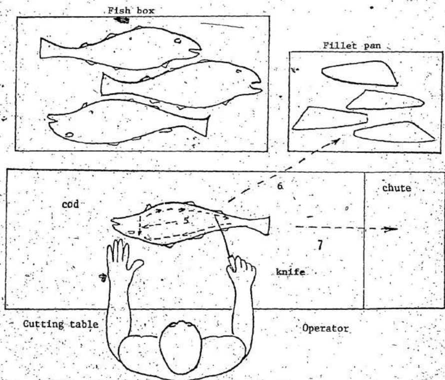

Filleting operation:

1) Get and put fish on table (L.H)
2) Fillet side no. 1 (L.H & R.H)
3) Place fillet in pan (L.H)
4) Turn fish 180° (L.H & R.H)

L.H: Use of left hand
R.H: Use of Right hand.

Figure No. 7: Filleting operation - cod

Source : 'Productivity studies in fish processing' by Amaria, P.J. (1974)




Filleting operation:

5) Fillet side no. 2 (L·H & R·H)
6) Place fillet in pan (L·H)
7) Place head and bone in the chute (R·H)

L·H: use of left hand
R·H: use of right hand

Figure No. 8: Filleting operation – cod
Source : 'Productivity studies in fish processing' by Amaria, P.J. (1974)

Amaria (1974) observed that though there are variations in the type of filleting cut performed, the basic methods of filleting cod involves the following seven operations for a right-handed person:[1]

1. Get, orient and position fish on the cutting board, with the head of the fish on the right side, the tail on the left, the back towards the operator and the belly away from him (L.H.).[2]
2. Fillet one side using a very sharp knife (L.H.) and (R.H.).[3]
3. Place fillet in the pan or in the chute (L.H.).
4. Turn fish 180° so that the head of the fish is now on the left side and the tail on the right, with the back towards the operator and the belly away from him (L.H.) and (R.H.).
5. Fillet second side using a very sharp knife (L.H.) and (R.H.).
6. Place fillet in the pan or in the chute (L.H.).
7. Place head and bone (offal) in the chute (R.H.).

Operations 6 and 7 are performed simultaneously.

When a filleting machine is used, one to three persons feed the fish into the machine. The filleting rates of these machines range from 30 to 40 fish per minute.[4] The skin-on fillets are then carried by a belt conveyor to the skinning machine which skins the fillets and drops them to another belt conveyor, to be taken to the trimming table. The skinned fillets are then trimmed by hand to remove fins, pin bones, lugs

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[1] During the whole filleting operation, the fish is held in left hand and the cutting knife is held in right hand by the right-handed filleter.

[2] (L.H.) means use of left hand only.

[3] Both hands required during filleting — fish held by left hand and filleted by a knife in the right hand.

[4] J. Drews (1974), "Mechanized Fish Processing, Aboard Ship and Ashore," Fishing News International, November.

and the blood marks which might have been left on the fillets during the filleting operation. The trimmed fillets are then taken to the candling table in fish pans, holding about 15 lbs. of fillets. The candling process is done to detect any possible parasites that may be in the flesh of the fillet.

The fillets are then taken to the packaging tables where the fillets are packed either individually or in 1 lb., 5 lb. or 10 lb. boxes or in blocks weighing 13½ or 16½ lbs. The fillet boxes or blocks are frozen in the plate freezers. The individual fillets are frozen by passing them through a tunnel of cold air, temperature ranging from $-40^{\circ}$ to $-60^{\circ}C$ and air velocity greater than 400 ft. per minute. Frozen fish must be continually maintained at the lowest practical temperature. A temperature of not higher than $-25^{\circ}C$ is recommended during frozen storage.[1]

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[1] Information obtained from Information Branch, Fisheries and Marine Service, Environmental Canada, St. John's, Newfoundland.

# CHAPTER 2

# OBJECTIVES

## 2.1 PURPOSE OF THE STUDY

### 2.1.1 Problems of Work Environment in Fish Processing Industry.

The human operator in a fish processing industry has been observed to work in an environment which is cold, humid and wet. His work is highly repetitive and he is not usually free to work at his own natural pace. He is often pressured by the management to work at maximum speed as well as to remove the maximum amount of meat (yield) from the fish. He is also under pressure from his work colleagues to work at a rate which will provide a smooth and continuous flow of material for successive operations. Besides, he has to work at a rate so as to earn a reasonable wage at the end of the day. In other situations, the operator is subjected to the speed restriction of a conveyor belt or a machine and may sometimes have a maximum period of time within which he has to complete a specified amount of work. An operator working under such speed restrictions is termed as being paced.

Though an operator working under such types of paced work would normally give higher output, he may achieve this at the expense of greater physical and mental stress.

When working under this type of condition, Siddall[1] (1954) found markedly unstable patterns of motion time in the operator's performance while performing an industrial task. Other studies related to machine paced work has been investigated by Murrell (1963), Franks and Sury

[1] Variations in Movement Time in an Industrial Task, Medical Research Council, Cambridge, Report No. 216.

(1966). These investigations made comparisons of cycle times, cycle time variability, and effect of tolerance under paced and unpaced industrial work situations. Amaria (1973) observed the effect of conveyor paced and self paced industrial work situations and found that the heart rate and the heart rate variability of operators were higher for paced as compared to self paced work for faster, same, and even for slower conveyor speeds.

In a mental addition experiment by Dudley (1962), a fall in quality of operator's performance was observed for even small increases in speed of work. Aberdeen (1961)[1], conducted an experiment relating to certain physiological effects of pacing. He observed greater changes in muscular tension, skin resistance and particularly pulse rate during paced work than during unpaced work. The findings of the above mentioned studies causes a concern when the production planner creates an atmosphere of a paced work situation in order to increase production.

Amaria (1974b,c) and Newbury and Amaria (1974) studied the effect of fish size and input quality on work performance and observed the relationship between the speed, yield and quality of filleting. Also examined was the model for optimum speed for minimum cost of filleting, and the limitations of such a model under an incentive and non-incentive system.

Amaria (1974) concluded that for total minimum cost of filleting, the operator should move the knife through the fish as slowly as possible so as to remove the maximum amount of meat but greatly increase his speed when performing various manipulative motions such as obtain fish, place fillets, turn fish, and place head and bone in the chute. It appeared that the best combination of speed-yield relationship was for

[1] Physio-Psychological Differences Between Paced and Unpaced Work, Department of Production Engineering, University of Birmingham, March 1961.

the operator to slow down during the actual cutting process but increase his speed while performing other manipulative operations.

In practice such a slow-fast tempo may be difficult to achieve within the short cycle time of the filleting operation (between 20 to 22 seconds per fish) unless the operator conscientiously changes his tempo of work. It is expected that the operator would normally maintain his speed or tempo for each cycle, since sudden change in acceleration or deceleration of hand movements would contradict his smooth rhythm of working.

Other limitations imposed on the model for optimum speed of filleting are the findings of the investigation of the effect of input quality on normal output and yield of filleting. It was concluded (Newbury and Amaria, 1974) that fish held for several days would give lower yield, lower output and poorer quality of fish.

Thus, on one hand the optimum speed for minimum cost of filleting (labour and material) indicates a slower tempo of work; on the other hand, lower yield, lower output and poor quality results from not processing the fish soon enough.

In fish processing plants where productivity and earnings for the company and workers depend on both higher yield and faster throughput, the human operator often has to work under a speed restriction created due to the pressures of both the management and his work colleagues, to fillet at maximum speed and maximum yield. This he may attempt to achieve at the expense of higher physiological and mental loads.

### 2.1.2 Work Load on the Human Operator during Fish Filleting

In a fish filleting operation, the daily work-time varies from 8-10 hours and sometimes more, since during the peak season, it is highly desirable that the fish are processed on the same day[1] rather than leaving them overnight to be processed on the next day.

The normal practice on an individual filleting table layout (Figs. 2 and 3) is to present the fish to the operator in 75 lb. (34 kg) boxes. The normal time to fillet each box depends mainly on the size of the fish. The results discussed in Amaria (1974b) showed that normal time varies from 5 minutes for large fish (14 undressed fish per 75 lb. box) to about 13 minutes for filleting small size fish (92 undressed fish per 75 lb. box).

During the normal course of work throughout the day, the operator would process, on an average, forty 75 lb. boxes. Besides filleting, the operator has to perform other tasks connected with the main operation such as:

1. Slide a loaded fish box (75 lbs. of fish plus 6 lbs. for the plastic box) from the roller conveyor on to the filleting table.
2. Place loaded fillet pan (about 34 lbs. (16 kg) of fillets plus 2 lb. (1 kg) for the plastic pan) from the table onto the conveyor belt.
3. Place empty plastic fish box (6 lbs. or 3 kg) from the filleting table onto the conveyor belt.
4. Bring empty fillet pan (2 lb. or 1 kg) from the conveyor belt

[1] Quality of fish deteriorates with time.

onto the filleting table.

5. Sharpen knife. Amaria (1974a) showed that operators normally took 3/4 minute to sharpen their knives, at an average frequency of five times per hour. This amounts to an average of ½ hour for an 8-hour working shift or 6-7% of the normal time.

6. Clean the cutting board with a spray of water to remove slime and guts. The frequency of this operation depends on the quality standards in the processing plant. It varies from twice a day (before lunch break and at the end of the day) to about 2 or 3 times per hour.

For individual table layout, the first four tasks are performed after each 75 lb. box of fish is filleted. However, the set-up of supplying the fish to the operator on a group filleting table layout (Figs. 4 and 5) is different to that for the individual table layout (Figs. 2 and 3). Here the fish is supplied in the trough, the amounts vary from 1500 to 2500 lbs. depending upon the design of the filleting table. The secondary tasks which the operator has to perform are that of cleaning the cutting board and sharpening the knife.

Filleting operators usually take rest pauses during such secondary activities. The frequency of such pauses for an individual layout would mainly be dependent upon the size (length) of the fish since this determines the number of fish per 75 lb. box and consequently determines the length of time the operator continuously performs the filleting operation. In case of the group layout the frequency of rest pauses would mainly be dependent upon the frequency of knife sharpening (i.e., when the operator feels that the knife has become blunt).[1]

[1] In case of individual layout, the operator usually sharpens his knife after the completion of each box.

Most of the manual jobs carried out in the fishing industry involve one or two handed manipulative activity such as reach to an object, grasp, move an object, position and release an object. These activities involve the movements of fingers, wrist, forearm and upper arm. Other activities such as bending and walking involve body, legs, neck and head movements. The difficulty or ease with which these activities are carried out largely depends upon the immediate work layout and the general work environment.

When a person moves his arm upward, the amount of work load on the arm would mainly be the resistance of moving the arm against gravity. If he moves his arm upward with a load, then the amount of work load on the arm would mainly be the resistance of moving the arm as well as the load against gravity. This concept of work load appears to be unsatisfactory from the standpoint of physiology.

If, however, the manipulative two-handed task is broken down into various elemental motions such as "reach," "grasp," "move," "position," used by Methods-Time Measurement System[1] and according to the difficulty with which these movements are made, as well as the resistance against which they are performed, then a manipulative work load could be estimated for the task by knowing the resistance and distance moved, time taken and the frequency of such movements. It is recognized that this method would not give a complete measure of total work done by a person, since it does not take into account the perceptual[2] and

[1] Methods-Time Measurement System (Karger and Bayha, 1966) is a system which can predetermine standard times using standard motion-pattern data tables.

[2] Perceptual load during filleting is discussed in Amaria (1975), "Effect of Training Methods on Output Rate and Yield of Filleting."

other mental loads.

The level of achieved performance in any man-machine system is determined by a number of interacting factors. The factors, which may bring about optimum performance, or, conversely, the deterioration of performance, can be grouped into different categories or systems like human system, organizational environment system, general and immediate work environment systems, and raw material input system. It is obvious that an almost limitless possible number of combinations of environment man-task factors can occur. The effect on work performance of some of these important factors can be studied by varying some of the individual factors or combination of different factors in various systems, while keeping most of the remaining factors more or less under the same conditions. Figure 9 shows a concept of one such man-machine interaction model for a fish processing operation.

As discussed earlier, while working in a fish processing plant, the human operator is often under a pressure from the management to work at a maximum speed, as well as to remove the maximum amount of meat (yield) from the fish. His work is highly repetitive and he is not usually free to work at his own natural pace. He is also pressured by his work colleagues to work at a rate which will provide a smooth and continuous flow of material for successive operations. Besides, he has to work at a rate so as to earn a reasonable wage at the end of the day. In an average size fish plant which processes 12 to 14 million kg of finished product per year, and where the productivity and earnings for the company and the workers depend on higher yield and faster throughput, the human operator is often subjected to perform work at maximum speed and maximum yield. This he may achieve at the expense of higher physiological

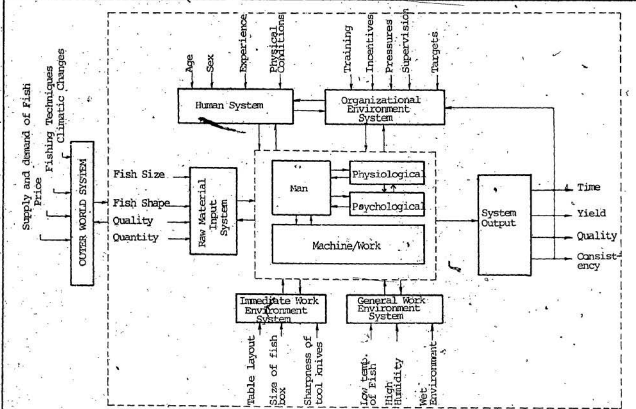


**Figure 9:** Man-Machine interaction model for a fish filleting operation.
Source: 'Productivity studies in fish processing' by Amaria, P.J. (1974).

loads.[1]

Therefore, part of the objective of this study was to observe some of the relationships between work performance (performance rating or speed of filleting and actual output rate) and physiological parameters (heart rate, blood pressure, and product of heart rate and blood pressure), which could later be developed to evaluate such factors as work load levels, job evaluation, equipment comparison and relative task difficulties. Physiological measurements of men at work can be used to judge the degree of stress on the human body and to design the work method so that the operator can perform the task 8 hours per day, 5 days per week, without undue fatigue.

The existing working conditions in the fish plants are observed to be poor when compared to other types of food processing and manufacturing industry. Apart from working in cold, humid and wet environment, the general work layouts and methods of processing are not so efficient. With the increasing shortage of food and cost of processing, the industry as it stands, needs to have another look at making better use of the existing resources of men, materials and equipment, so as to increase productivity, reduce processing cost and improve working conditions of operators in the plant. The fish processor, the manufacturer of fish processing equipment and the worker representative should earnestly consider the application of the concepts of "Operations Research" and "Work Systems Design" for better utilization of the limited resources.

2.1.3 Productivity Studies in Fish Processing Industry

A productivity study of the frozen fish industry in Newfoundland

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[1]Refer to Chapter 3, p. 64 of this report.

was carried out in 1968 by INBUCON.[1] The following were the conclusions of that report:

"1. Labour productivity in the industry is low, the productivity index of the plants ranging from 39 to 82. It is significant to note that in those plants handling a multiplicity of species and pack, the productivity is lower than those plants which concentrate on fewer species and pack. These differences are not necessarily reflected in profitability, or lack of it.

2. The greatest factor contributing to the low productivity of the labour itself is that of the underlying social structure on environment. At the present time, it is not sufficiently developed to provide the needed motivation.

3. The basic measurements needed to identify and isolate the various factors contributing to labour productivity, control of yield and effective work organization and planning are, with one exception, missing or are not used.

4. In general, the basic methods and techniques employed compare favourably with those seen in Nova Scotia, England and Europe. The main differences are matters of detail.

5. There is a danger for new plants to be "over engineered" in that the degree of automation, mechanical handling, etc., being introduced is not commensurate with the operating flexibility required, the skills presently available to service and maintain the equipment, and the type of labour available to effectively

[1]"Report on a Productivity Study of the Frozen Fish Industry in Newfoundland, Phase II," by INBUCON Services Ltd. (1968).

use the equipment.

6. For better control of productivity and product yield, individual cutting as opposed to the current practice of group cutting can yield significant benefits.
7. This industry must set up material and cost control systems to measure productivity and throughput at all critical parts of the operation. This requires the provision of weighing of input and output, development of work standards, development of yield standards, mechanical improvements, recording systems and information feed-back for management control.
8. The individuals holding supervisory positions lack the necessary technical background. Out of 79 supervisory positions analyzed, 61 are filled by men under 45 years of age. Of this 61, 33 have received formal education beyond grade 8, and only 3 have post high school training, this non-related to the Industry. There is a great need for strengthening the supervisory skills in this area."

In 1977, another report called "Canadian East Coast Ground Fish Processing Investigation" was prepared by Research and Productivity Council (R.P.C.), a consultant firm from New Brunswick, for Environment Canada. The conclusions of that report were as follows:

"1. A study of thirty-nine East Coast groundfish plants, for three species (cod, redfish and flatfish), reveals that quality of management more than anything else dictates the efficiency with which the plants compete in the industry. No dominant pattern of advantage stems from location, size, extent of capital investment, or length of season.

2. Contrary to widely held belief, some of the seasonal plants proved more efficient in many respects, than other plants operating year-round. This comparison applies to such indices as labour cost per pound of product, overall cost per pound of product, production time per pound of product and production per dollar of capital investment.
3. There is a capability within approximately 50% of the surveyed plants to increase output from 10% to over 100%, if more fish were available and the plants recruited production operators to use fully the existing plant facilities.
4. Many plants incur additional labour costs in some stages of the process due to the difficulties in organizing and balancing labour to match the lower production flow when flatfish are being processed or some other feature occurs. There appears to be a need for more all-around flexibility of labour so that packers, etc. should also be able to fillet the fish.
5. The study has revealed wide ranges of performance by individual plants within the existing cost structure of the industry. A rough approximation of the cost structure of the industry would see values represented somewhat like this: Raw Material = 50%, Direct Labour = 12.5%, Direct Materials = 5%, Distribution = 7.5%, and overheads = 25%. Training and motivation of plant personnel, as well as of plant supervisors, matched with greater cost control can narrow the great cost spread evident between the experience of the worst performers and the top performers.
6. As raw material costs represent the greatest single factor within the cost structure, the greatest single cost cutting

opportunity for the industry would be the improvement of yields. The labour cost increase which can result from accepting slower production rates to obtain higher yields is minimal as compared with the benefits to be obtained from lower material costs."

Some of the important recommendations by INBUCON and Research and Productivity Council (R.P.C.), 1977, studies as noted above, refer to increasing yields and output rates of work performance. However, before one can proceed to increase productivity, it would be essential to understand the various factors which affect work performance and examine the interrelationships between work layouts, size of fish, yields, speed of filleting and physiological loads on the operator working in the fish processing industry.

## 2.2 SPECIFIC OBJECTIVES OF THE STUDY

The primary objective of this study was to observe the relationships between operator's work performance (speed of filleting[1] and actual output rate[2]) and his physiological parameters (mean heart rate, blood pressure[3] and product of mean heart rate and blood pressure) during fish filleting operation, and at the same time collect sufficient

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[1] Performance rating system was used to determine speed of filleting. Refer to Chapter 3, p. 45 of this report.

[2] Both actual output rate of round fish (lbs./hr.) processed and actual output rate of fillets (lbs./hr.) produced were considered for investigation.

[3] Both systolic blood pressure and true mean blood pressure (T.M.B.P.) values were considered. "The Mechanisms of Body Function," by Vander, Sherman, Luciano, 1975, p. 249.

$$\text{T.M.B.P.} = \frac{\text{Systolic} + 2\ \text{Diastolic}}{3}$$

The above systolic and diastolic blood pressure values are those which were recorded just after the completion of each experiment. "Physiology and Biophysics of the Circulation", by Burton, A.C., 1968, p. 86.

data to observe the effect of factors, such as speed of filleting and size of filleting round fish, on the actual output rate and percentage yield[1] produced. The effect of size of filleting round fish[2] on operator's mean heart rate and normal output rate (both round fish and fillets) was also considered for investigation.

The specific objectives of the study were to observe the relationships between:

1. Speed of filleting and mean heart rate of the operator.
2. Speed of filleting and blood pressure of the operator.
3. Speed of filleting and product of mean heart rate and blood pressure of the operator.
4. Speed of filleting and actual output rate produced.
5. Speed of filleting and percentage yield produced.
6. Actual output rate[3] and mean heart rate of filleting operator.
7. Actual output rate and blood pressure of filleting operator.
8. Actual output rate and product of mean heart rate and blood pressure of filleting operator.
9. Size of filleting round fish and mean heart rate of the operator.
10. Size of filleting round fish and actual output rate produced.
11. Size of filleting round fish and percentage yield produced.
12. Size of filleting round fish and normal output rate (both round fish and fillets) produced.

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[1] Yield is the ratio of the weight of fillets produced to weight of round fish processed.

[2] Refer Article 3.5.3., p. 93 of this report.

[3] Actual output rate of both round fish and skin-on fillets.

# CHAPTER 3

## MATERIALS AND METHODS

### 3.1 METHODS OF MEASUREMENT OF OPERATOR'S PERFORMANCE FOR INDUSTRIAL WORK TASK

#### 3.1.1 The Need for Workstudy in Fish Processing Plants

A productivity study of the frozen fish industry in Newfoundland, conducted by INBUCON (1968), showed that productivity in the industry was low, the productivity index in the plant ranged from 39 to 82, and the average productivity of the industry was 57.8%.

One of the most important recommendations pertaining to plant operation was: "This industry must set up material and cost control systems to measure productivity and throughput at all critical parts of the industry. This would require the provision of weighing of input and output, development of work standards, development of yield standards, mechanical improvements, recording system and information feed-back for management control."

Another recent study of "Canadian East Coast Ground Fish Processing" by Research and Productivity Council (R.P.C.), 1977, showed that if proper measures were taken by the management, then the output of at least half of the existing East Coast fish plants could be increased from 10 percent to over 100 percent.

With statistics such as these, it is of the utmost importance that the management of the fish processing facility be concerned with the utilization of all the available resources such as material, equipment, space, labour, and capital in a most efficient manner, so as to reduce the operating cost and increase output. For management to analyse the operations in the plant, it must be capable of understanding the human and physical limitations of the system concerned. It must also be able to determine the potential of the existing systems and this can be done by studying the various work activities in the plant. Work standards must be found for the different work tasks. Rates of output should be found and standards established for the existing layouts and improvements made which would help to increase production and improve working conditions.

A technique which has been used very successfully in many manufacturing and processing industries to increase productivity is Work Study. Work study consists of two components: 1) Method study, 2) Work measurement.

Method study and work measurement techniques could be used to increase productivity, for establishing a standard cost of manufacture, for payment of wages to workers and as an effective management control tool.

Method study is defined as: "The systematic procedure for subjecting all direct and indirect operations to close scrutiny and introducing improvements resulting in making work easier to perform and allowing work to be done in less time and with less investment per unit" (Niebel, 1962, p. 4).

Work measurement is defined as: "The application of techniques designed to establish the time for a qualified worker to carry out a specific job at a defined level of performance" (Nadler, 1955).

There are a number of methods which can be used for establishing work standards in the fishing industry. Some of these methods are:

1. Time Study
2. Work Sampling
3. P.M.T.D. (Predetermined Motion-Time Data)

### 3.1.2 Time Study Procedures

Time study is used to determine the "time" required by a qualified and well trained person working at a "normal pace" to do a specific task (Barnes, 1968, p. 342). This measurement of time is called the standard time for the specific task or operation.

Normal pace is defined as: "The pace or speed that is neither fast nor slow, but one which may be considered representative of all-day performance by the experienced, co-operative employee" (Niebel, 1962, p. 216). Normal pace or speed is also defined as "the speed expected of a qualified person working without incentive or at a day work pace, using a standardized method, under average working conditions" (Barnes, 1968, p. 385).

The normal procedure used in making time studies may vary somewhat, depending upon the type of operation being studied and the application that is to be made of the data obtained. The following are the eight steps which are usually required for a time study:[1]

1. Secure and record information about the operation and operator being studied.
2. Divide the operation into elements and record a complete description of the method.
3. Observe and record the time taken by the operator.
4. Determine the number of cycles to be timed.

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[1] "Motion and Time Study", by Barnes 1968, p. 349.

5. Rate the operator's performance (this is considered a very important factor in establishing standards).
6. Check to make certain that a sufficient number of cycles have been timed.
7. Determine the allowances for personal needs, unavoidable delays, fatigue, etc.
8. Determine the time standard for the operation using the following formula:

$$\text{Standard time for a job} = \frac{\text{observed time x observed rating}}{\text{normal rating}^{1}} + \text{Compensating relaxation allowances}$$

When the time study is undertaken, measurements of the actual time to perform the various tasks have to be observed. This recording must be done by a stop watch and the introduction of such a device into the job situation must be fully explained to all those involved. This would include the plant management, the workers and worker representatives. All three should be brought together to discuss the object of the study and how the resulting information can be useful to both workers as well as management.

The concept of 'rating' is used in time study to set time standards. 'Rating' is that process during which the time study analyst compares the performance (speed or tempo) of the operator under observation with the observer's own concept of normal performance (Barnes, 1968, p. 375). Rating, therefore, is a matter of judgement on the part of the time study analyst. As the results of the study depend on the observer's judgement, the observer has to be properly trained[2] such that his interpretations of a normal performance are correct. The concept of what is normal performance has been set by certain known performances

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[1]In performance rating system, normal rating is represented by 100 percent. "Motion and Time Study", by Barnes, 1968, p. 380.

[2]Training programs in time and motion study are offered by many university Departments of Industrial Engineering.

or bench marks. Walking on a straight level path at 3 miles an hour is frequently used to represent normal tempo. A person dealing a deck of cards into 4 equal piles at a radius of 10½ inches in 0.50 minutes is considered to be performing normal pace (Barnes, 1968, p. 386). These bench marks, representing normal performance, are used in the beginning for training people in performance rating. Further training is provided by using specially made rating films and on actual industrial tasks under the supervision of an experienced time study analyst. Basically, the concept of fair day's pay for a fair day's work has to be understood as it underlies the whole work study approach to a job analysis. If a worker performs at a normal pace then he should conceivably be working at a level which he can maintain during the work period and his output shall be what his employer can reasonably expect.

The two rating systems commonly used are described below:

3.1.3 Performance Rating System

This is the most widely used system of rating. In this system, a single factor, i.e., operator speed,[1] pace or tempo is rated. The performance rating is expressed in percentage or in points per hour, with normal performance equal to 100 percent (Barnes, 1968, p. 380).

As discussed earlier, normal performance or normal speed is the speed expected of a qualified person working without incentive or at a day work pace, using a standardized method, under average working conditions. Walking on a straight level path at 3 miles an hour and dealing a deck of cards into 4 equal piles at a radius of 10½ inches in 0.50 minutes are

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[1]The terms speed, pace, effort and tempo all refer to the rate of speed of the operator's motions. Speed and effort are terms commonly used by time study analysts, and the term performance is gaining in favour ("Motion and Time Study," by Barnes, 1968, p. 375). In this report, all these terms have but a single meaning -- speed of movement.

used as bench marks to represent normal speeds. A number of motion picture films have been made of various individual operations containing a different sequence of body, arm and leg motions commonly found in factory work, at speed levels above normal, normal and below normal with 100 percent as normal speed. These speed levels or ratings have been established by a large number of time study analysts (S.A.M. - The Society for Advancement of Management, performance rating films, 1950). These films are used for training other time study personnel. Once a time study man is properly trained and has a clear concept in his mind of what a normal 100 percent performance is, he can then compare this concept of normal pace with the working speed of the operator and determine the performance rating of the operator.

### 3.1.4 Training for Performance Rating

Motion-picture films, illustrating diversified factory-work operations at different speeds, are widely used for purposes of training personnel in performance rating. Each film has a known level of performance or true rating which is established by a number of time study analysts. For "rating-training" purposes, the instructor shows each of these films to the trainee and then compares the true rating value with the observed rating value as established by the trainee, for each film presentation. If any of the trainee's values deviates substantially from the true rating value, then specific information is given by the instructor to the trainee so as to justify the true rating. For example, the trainee may have been misled because of the high performance in the handling of the material to and from the work station, while poor performance prevailed during the cycle at work station.

Since the results of the time-study depend on the observer's judgment in rating the operator, it is therefore very important that the observer should be consistent and accurate in his rating. In general, the observer or time study analyst is expected to be regularly able to establish standards within plus or minus 5 percent of the true rate (Niebel, 1962, p. 284). To achieve this, two widely considered rating analysis techniques used in "rating-training" programmes are described below.

### 3.1.5 Graph of True Rating Versus Observer's Rating--Rating Analysis Technique

Figure 10 shows the usual graphic presentation wherein ±5 percent error limit lines, OX and OY, go through the origin O. This graph indicates to each trainee the trend of his ratings (Niebel, 1962, p. 285). A straight line would indicate consistency whereas high irreg-

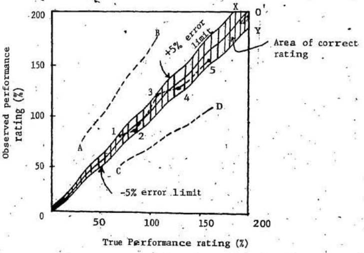


Fig. 10. Graph shows the trend of ratings for three different observers. Also shows area of correct rating.

ularities in both directions would indicate inconsistency as well as inability to evaluate performance. For example, line AB indicates that the observer is consistently overrating or rating at a higher level than what he should. The corrective action for him would be to lower down his concept of normal performance level and bring it closer to the true normal performance level of 100 percent. On the other hand, line CD indicates that the observer is consistently underrating or rating at a lower level than what he should. The corrective action for him would be to bring up his concept of normal performance level closer to the true normal performance level of 100 percent. Line 12345 indicates that the observer is quite within the acceptable rating standard and thus has a good concept in his mind of what a normal or 100 percent performance is.

3.1.6 Average Percent Error--Rating Analysis Technique

First of all, percent error of the observer for each film shown to him is calculated by the formula (Nadler, 1955, p. 436):

$$\text{percent error} = \frac{\text{observed rating} - \text{true rating}}{\text{true rating}} \times 100$$

The percent errors for all observations or movie picture films are added, including the plus or minus sign of each percent error. The total value is divided by the total number of observations to give average percent error of the observer. For example, an average percent error of +8 means that on the average, the observer was rating 8 percent higher than the true ratings. The average percent error therefore indicates to the observer whether he is overrating or underrating and by how much. The corrective action can then be taken by the observer. This process is repeated till the observer has a good concept of normal or 100 percent performance in his mind.

Figure 11 (Niebel, 1962, p. 286) shows the successive ratings on X-axis and magnitude of error, either positive or negative, from the

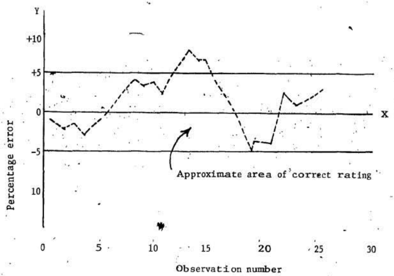


Fig. 11. Record of an analyst's rating factors, i.e. percentage error on 26 studies.

true rating on the Y-axis. The closer the time study analyst or observer comes to X-axis with his rating, the more correct he will be.

The use of motion picture films and evaluation of one's ratings by the above rating analysis techniques therefore helps the trainee to achieve the required consistency and accuracy in his ratings, in due course of time.

3.1.7 Westinghouse System of Rating[1]

Four-factor system: 1) Skill, 2) Effort, 3) Working conditions, and 4) Consistency of the operator, is used for rating operator performance.

After extensive studies at Westinghouse plant, scales of numerical values for each factor were developed, as shown in Table 6. The time-study

Table 6: Performance rating table (Lowry, Maynard, Stegemerten, 1940)

| Skill | | | Effort | | |
|---|---|---|---|---|---|
| +0.15 | A1 | Superskill | +0.13 | A1 | Excessive |
| +0.13 | A2 | | +0.12 | A2 | |
| +0.11 | B1 | Excellent | +0.10 | B1 | Excellent |
| +0.08 | B2 | | +0.08 | B2 | |
| +0.06 | C1 | Good | +0.05 | C1 | Good |
| +0.03 | C2 | | +0.02 | C2 | |
| 0.00 | D | Average | 0.00 | D | Average |
| -0.05 | E1 | Fair | -0.04 | E1 | Fair |
| -0.10 | E2 | | -0.08 | E2 | |
| -0.16 | F1 | Poor | -0.12 | F1 | Poor |
| -0.22 | F2 | | -0.17 | F2 | |
| **Conditions** | | | **Consistency** | | |
| +0.06 | A | Ideal | +0.04 | A | Perfect |
| +0.04 | B | Excellent | +0.03 | B | Excellent |
| +0.02 | C | Good | +0.01 | C | Good |
| 0.00 | D | Average | 0.00 | D | Average |
| -0.03 | E | Fair | -0.02 | E | Fair |
| -0.07 | F | Poor | -0.04 | F | Poor |

analyst when conducting the studies also determines the level of skill, effort and consistency of the operator and also the conditions under which he is working.

There are six classifications of skill: poor, fair, average, good, excellent, and superskill. Skill may be defined as proficiency at

[1] First developed at Westinghouse (1927). First described in "Time and Motion Study" by Lowry, Maynard and Stegemerten (1940), p. 223.

following a given method. Skill or proficiency at following a given method is influenced partly by natural ability and partly by experience or practice. Skill at any given moment cannot be varied at will by the operator. The operator may slow down or speed up, but this is changing effort.

Effort is classified into: Poor, fair, average, good, excellent, and excessive. It may be defined simply as the will to work. Effort is not related to the amount of foot pounds of work exerted during a given period, but rather to the zest or energy with which the task at hand is undertaken.

In addition to skill and effort, working conditions which affect the operator are such things as light, heat, ventilation, noise and vibrations. For example, the temperature in the fish plant is usually low, where the hands and fingers have to grasp the ice-cold fish, which causes numbness to the fingers. Therefore, it is necessary to make some adjustment to compensate for the effect of the poor and unusual conditions which exist at the particular moment the study is made. There are six classifications of working conditions: poor, fair, average, good, excellent and ideal.

In judging consistency, the nature of the element should be considered. It must be weighed in light of the skill and effort of the operator. Operators of high skill usually work more consistently than less skilled operators. At the same time, high effort tends to disturb consistency, particularly if the operator is not highly skilled.

When skill, effort, working conditions and consistency have been determined, the performance rating table (Table 6) is used to convert the different observed factors on a point scale. The algebraic sum of these four points is then used as a leveling factor for normalizing the time. For example, if the selected time for an operation was 0.65 minutes and if the ratings for 4 factors were: 1) Excellent skill, $B_2$ = +0.08, 2) Good effort, $C_2$ = +0.02, 3) Good condition, C = +0.02, 4) Excellent consistency, B = +0.03, then the normal time of the operation = selected time x (sum of the ratings of the four factors)

= 0.65 x 0.15 = 0.975 minutes. Standard time is then calculated as:

$$\text{Standard time per job} = \text{Normal time per job} \times \frac{100}{100 - \text{percent compensating relaxation allowances}}$$

3.1.8 Work Sampling[1]

Work sampling is a measurement technique for quantitative analysis, in terms of activity of men, machines and any observable condition of the operation. In industry, it is used for:

a) to measure the activities and delay of men or machines, such as to determine the percentage of the day that an operator is working and percentage that he is not working.

b) to establish a performance index or performance level of an operator or a group of operators.

c) to establish a time standard for an operation.

Work sampling is based upon the laws of probability. A sample taken at random from a large group tends to have the same pattern of distribution as the large group. The work sampling procedure in its simplest form consists in making observations at random intervals of one or more operators or machines and noting whether they are working or not. If the operator is working, a tally mark is placed under 'working.' If he is idle, a tally mark is made under 'idle.' The percentage of the day that the worker is working is the ratio of the number of working tally marks to the total number of working and idle tally marks.

[1]Work sampling was first used by L.H.C. Tippett in the British Textile Industry (1934). Described in "Motion and Time Study" by Barnes (1968), p. 511.

Table 7 shows that there are 24 working observations and 6 idle observations, or a total of 30 observations. In this example, the

Table 7. A work sampling tally sheet

| State | Tally Mark | Total | Percentage |
|---|---|---|---|
| Working | ~~1111~~ ~~1111~~ ~~1111~~ ~~1111~~ 1111 | 24 | 80% |
| Idle | ~~1111~~ 1 | 6 | 20% |
| | Total | 30 | 100% |

operator was productively working for $\frac{24}{30} \times 100 = 80\%$ of the time and was non-productive for $\frac{6}{30} \times 100 = 20\%$ of the time. If these 30 observations were made at random intervals through a normal working day, then the actual amount of 'time' of the day he was working, and the amount of 'time' he was not working can be calculated. For an 8-hour day, the predicted amount of time the operator would be working is $\frac{80}{100} \times 480 = 384$ minutes, and idle for $\frac{20}{100} \times 480 = 96$ minutes. The reliability of prediction is higher as the number of observations increases. In work sampling, the performance index of an operator is calculated as follows:

$$\text{Performance index} = \frac{\text{Number of pieces produced during day} \times \text{Standard time per piece in minutes}}{(\text{Hours worked during day}) \times 60} \times 100$$

where standard time per piece is given by:

$$\text{Standard time per piece} = \frac{\text{Total time in minutes} \times \text{Working time in percent} \times \text{Average performance rating in percent}}{\text{Total number of pieces produced}} + \text{Compensating relaxation Allowances}$$

The working time in percent is found using work sampling and average performance rating in percent is determined by a time study analyst, using performance rating system.

Work sampling can be used profitably for measuring long-cycle operations, work where people are employed in groups and activities which do not easily lend themselves to time study.

In fish filleting, work sampling can be used to determine the work performance of a number of filletors, working on a group type table layout. By studying all the operators in the group, the percentage working time, the percentage non-productive time, and the average performance rating or filleting speed of the group can be determined. The standard filleting time for a given weight of processed fish or fillets obtained can be calculated as follows:

$$\text{Standard time per 75 lbs. of processed fish/fillets obtained per operator (in minutes)} = \frac{\text{Total time in minutes} \times \text{Productive working or filleting time in percent} \times \text{Average performance rating in percent}}{\text{Total weight of processed fish/fillets obtained}} \times 75 + \text{Compensating Relaxation Allowances}$$

Standard output of processed fish as well as of fillets can then be determined. For example,

$$\text{Standard output of processed fish (lbs./hr./operator--group layout)} = \frac{\text{Weight of fish processed (lbs.)}}{\text{Standard time (minutes) to fillet the processed weight}} \times 60 \text{ minutes}$$

### 3.1.9 Predetermined Motion-Time Data (P.M.T.D.) System

Predetermined motion-time system, in a broad sense, can be defined as a standardization of times required to perform basic human motions. Though there are a number of motion-time systems available, the one most widely used is called Methods Time Measurement (M.T.M.), developed by Maynard, Stegemerten and Schwab (1948).

The Methods-Time-Measurement (M.T.M.) system was developed from motion picture studies of a great number of industrial operations, and time standards were first published in 1948. This system is defined as a procedure which analyses any manual operation or method into the basic motions required to perform it, and assigns to each motion a predetermined time standard which is determined by the nature of the motion and the conditions under which it is made (Barnes, 1968, p. 496). The basic motions considered by Methods Time Measurement (M.T.M.) system are: reach, move, grasp, position, release, turn and apply pressure, disengage, eye travel, body, leg and foot motions. The unit of time used is one hundred-thousandth of an hour (0.00001hour), and is referred to as one time-measurement unit (T.M.U.).

The present study involved the measurement of parameters such as performance rating; number of fish per 75 lb. box; output rate of skin-on fillets, i.e, pounds of skin-on fillets produced per hour; and percentage yield of skin-on fillets, for a set of experiments so that the effect of size of fish and performance rating on actual output rate (whole fish and fillets) and percentage yield could be studied. Under these circumstances, work sampling and Predetermined-Motion-Time Data (P.M.T.D.) systems could not be used because these systems, though useful for establishing time standards, do not involve the actual measurements of parameters such as weight of fillets, performance rating, speed - yield effect and therefore it was not possible to study the relationships between different parameters, as outlined before, for this investigation.

Performance rating system was used to rate the speed of filleting of the operators in this study.[1] The investigator was well-acquainted

[1] An investigation of time study practices among 72 companies showed that 80% used the 100% system, 12% used the point system, 7% used the Westinghouse system and 1% used other systems. "Motion and Time Study," by Barnes, 1968, p. 380.

with performance rating concept and was given proper training about performance rating by his supervisor, Dr. Amaria. Different rating films along with a set of "Rating of Time Study Films" by S.A.M. (The Society for Advancement of Management), showing different sequences of body and arm motions commonly found in factories and showing operator performing the same operation and different operations at different speeds from 75 percent to 150 percent (already rated by the experienced time study analysts), with 100 percent as the normal speed, were studied by the author under supervision of Dr. Amaria. Film loops showing the details of fish filleting operation were also studied carefully. Various rating analysis techniques, as described earlier, were used to achieve the consistency and desired accuracy (±5 percent error) in rating, before this investigation was carried out. The time duration for this whole rating-training was about 2 months. After this training, the investigator was also involved in rating the subjects, with other experienced time study analysts, performing actual filleting operations on an individual type table layout in a Newfoundland fish plant. The average rating of the investigator when compared with those of other time study analysts of the group, was found satisfactory, i.e., within ±5 percent error of the group average.

3.1.10 Establishing Work Standards for an Industrial Task

Once the rating factor for a task is determined, it can then be used to determine the normal time and the standard time for the task involved.

Normal time for a task is defined as time required by a qualified and well-trained person working at a normal pace, to do a specified task. In equation, normal time is as follows:

$$\text{Normal time per job} = \frac{\text{Actual time per job x observed rating of the person performing the task}}{\text{Normal rating}}$$

where

a) Actual time is the stop watch value recorded for the work period.

b) Observed rating of the operator is the average of the ratings recorded by the time-study analyst during the work period.

c) Normal rating is established as 100%.

3.1.11 Compensating and Relaxation Allowances

The normal time for an operation does not contain any kind of allowances. The standard time for an operation is equal to the normal time plus the allowances. The operator may take time out for his personal needs, for rest and for reasons beyond his control. Allowances for such interruptions to production may be classified as: 1) personal allowance, 2) fatigue allowance, 3) delay allowance, 4) miscellaneous activities allowance.

Personal allowance: The amount of personal time required will vary with the individual more than with the kind of work. For light work where the operator works 8 hours per day, 2 to 5% per day is all that the average worker will use for personal needs (Barnes, 1968, p. 395).

Fatigue allowance: Fatigue results from a number of causes, some of which are physical as well as mental. A person needs rest when his work involves heavy physical exertion. Time needed for rest varies with the individual, with the length of the interval in the cycle during which the person is under load and with the conditions under which the work is done.

Organized rest periods during which time all employees in a department are not permitted to work provide one of the best solutions to the problem. The optimum length and number of rest periods must be determined. The most common plan is to provide one rest period during the middle of the morning and one during the middle of the afternoon. The length of these periods ordinarily varies from 5 to 15 minutes each (Barnes, 1968, p. 396).

Delay allowance: Delays do occur from time to time, caused by the machine, the operator, or some outside force. It is expected that machines and equipment will be kept in good repair. The kind and amount of delays for a given class of work can be determined from an all-day time study or work sampling studies made over a sufficient period of time.

Miscellaneous work allowances: The amount of miscellaneous allowances will depend on the type of work involved. For example, in fish processing, during the filleting and trimming operations, operators have to sharpen their knives at regular intervals. Other miscellaneous work involves the sliding of empty and loaded fish boxes and fillet pans to and from the conveyor belt to the filleting work table and also cleaning the cutting table with a spray of water to remove slime and guts.

Amaria (1974) showed that filleting operators normally took 3/4 minute to sharpen their knives, at an average frequency of five times per hour. This amounts to an average of ½ hour for an 8-hour working shift, or 6 to 7% of the normal time. He also observed that the frequency of cleaning operation, i.e., cleaning the cutting table with spray of water, depended on the quality standards in the fish processing plant and it varied from twice a day (before lunch break and at the end of the day) to about 2 or 3 times per hour.

Standard time can be established when the compensating and relaxation allowances are considered for the particular job. In equation,

$$\text{Standard time per job} = \text{Normal time per job} \times \frac{100}{100\text{-percent allowances}}$$

When a standard time for a task is established, it is used to determine the standard output for that particular task. In fish plants, the actual, normal and standard outputs of roundfish as well as of fillets are calculated as follows:

$$\text{Actual output (roundfish) (lbs./hr.)} = \frac{\text{Weight of round fish processed (lbs.)}}{\text{Actual time (minutes) to fillet the processed weight}} \times 60 \text{ minutes}$$

$$\text{Actual output (fillets) (lbs./hr.)} = \frac{\text{Weight of fillets obtained (lbs.)}}{\text{Actual time of filleting (minutes)}} \times 60 \text{ minutes}$$

The actual output of roundfish represents the actual quantity of round or whole fish cut by the operator per hour. This depends mainly on the effort or the speed of filleting used by the operator. The actual output of fillets represents the actual quantity of fillets obtained from roundfish by the operator per hour. This depends on the skill, effort and experience of the operator if other factors such as size (length) of fish, work layouts and general working conditions, etc., are kept the same.

$$\text{Normal output (roundfish) (lbs./hr.)} = \frac{\text{Weight of round fish processed (lbs.)}}{\text{Normal time (minutes) to fillet the processed weight}} \times 60 \text{ minutes}$$

$$\text{Normal output (fillets) (lbs./hr.)} = \frac{\text{Weight of fillets obtained (lbs.)}}{\text{Normal time (minutes) of filleting}} \times 60 \text{ minutes}$$

and

$$\text{Standard output (roundfish) (lbs./hr.)} = \frac{\text{Weight of round fish processed (lbs.)}}{\text{Standard time (minutes) to fillet the processed weight}} \times 60 \text{ minutes}$$

$$\text{Standard output (fillets) (lbs./hr.)} = \frac{\text{Weight of fillets obtained (lbs.)}}{\text{Standard time (minutes) of filleting}} \times 60 \text{ minutes}$$

The standard output (roundfish or fillets) is the output expected of an average skilled operator, working at a normal pace under average working conditions and using a standardized method. This can be used for establishing a standard cost of manufacture, for payment of wages and as an effective management control tool.

Another factor frequently used as a measure of operator's performance in the fish plants is percentage yield. Yield is defined as the ratio of weight of fillets produced (lbs.) to weight of whole fish processed (lbs.).

$$\text{Yield \%} = \frac{\text{Weight of fillets produced (lbs.)}}{\text{Weight of whole fish processed (lbs.)}} \times 100$$

In fish processing, where the cost of material is considerably higher than the cost of labour, the amount of meat that can be filleted from a fish is more important than rate of output. Yield, therefore, is an important factor in the overall work performance of the fish processing plant.

### 3.1.12 Sample Calculations of a Fish Filleting Experiment, Conducted during this Investigation

Sample calculations have been carried out here to illustrate the use of above mentioned formulas, for experiment 1 of subject number 1.

Data available for this filleting experiment (Tables 9 and 17):

a) Weight of whole codfish processed = 75 lbs.

b) Actual observed time to fillet codfish of processed weight = 5.35 minutes

c) Average observed rating of filleter during this filleting experiment = 117.1 %

d) Weight of fillets obtained (skin-on weight) = 33.5 lbs.

e) Mean heart rate of filleting operator during this experiment = 124.8 beats/minute

f) Average diastolic blood pressure ($D_A$) of the operator, recorded just after the completion of this experiment = 110.5 mm of Hg

g) Average systolic blood pressure ($S_A$) of the operator, recorded just after the completion of this experiment = 171.5 mm of Hg

Calculations performed (refer Table 17)

(1) Actual output rate of round codfish (lbs./hr.)

$$= \frac{\text{Weight of round codfish processed (lbs.)}}{\text{Actual time (minutes) to fillet the processed weight}} \times 60 \text{ minutes}$$

$$= \frac{75}{5.35} \times 60$$

$$= 841.1 \text{ (lbs./hr.)}$$

(2) Actual output rate of fillets (skin-on weight)(lbs./hr.)

$$= \frac{\text{Weight of (skin-on) fillets obtained (lbs.)}}{\text{Actual time of filleting (minutes)}} \times 60 \text{ minutes}$$

$$= \frac{33.5}{5.35} \times 60$$

$$= 375.7 \text{ (lbs./hr.)}$$

(3) Normal time of filleting

$$= \frac{\text{Actual time of filleting} \times \text{Average observed rating of the operator}}{\text{Normal rating}^{1}}$$

---

[1] In performance rating systems, normal performance or rating is represented by 100 percent (Barnes, "Motion and Time Study," 1968, p. 380).

$$= \frac{5.35 \times 117.1}{100}$$

$$= 6.265 \text{ minutes}$$

(4) Normal output rate of round codfish (lbs./hr.)

$$= \frac{\text{Weight of round codfish processed (lbs.)}}{\text{Normal time (minutes) to fillet the processed weight}} \times 60 \text{ minutes}$$

$$= \frac{75}{6.265} \times 60$$

$$= 718.3 \text{ (lbs./hr.)}$$

(5) Normal output rate of (skin-on) fillets (lbs./hr.)

$$= \frac{\text{Weight of (skin-on) fillets obtained (lbs.)}}{\text{Normal time (minutes) of filleting}} \times 60 \text{ minutes}$$

$$= \frac{33.5}{6.265} \times 60$$

$$= 320.8 \text{ (lbs./hr.)}$$

(6) Percentage yield (skin-on fillets)

$$= \frac{\text{Weight of (skin-on) fillets produced (lbs.)}}{\text{Weight of whole fish processed (lbs.)}} \times 100$$

$$= \frac{33.5}{75} \times 100$$

$$= 44.67\%$$

(7) T.M.B.P.[1] (true mean blood pressure)

$$= \frac{\text{Systolic blood pressure } (S_A) + 2X \text{ Diastolic blood pressure } (D_A)}{3}$$

---

[1]"Human Physiology," by Vander, Sherman and Luciano (1975), p. 249. "Physiology and Biophysics of the Circulation", by Burton, A.C., (1968), p. 86. "Review of Medical Physiology", by Ganong, W.F., (1971) p.421.

$$= \frac{171.5 + 2(110.5)}{3}$$

$$= 130.8 \quad \text{(mm. of Hg)}$$

(8) Mean heart rate (H/R) x Systolic blood pressure ($S_A$) = 124.8 x 171.5

= 21403 (beats/min x mm. Hg)

(9) Mean heart rate (H/R) x True mean blood pressure (T.M.B.P.) = 124.8 x 130.8

= 16323 (beats/min x mm. Hg)

## 3.2 METHODS OF MEASUREMENT OF OPERATOR'S PHYSIOLOGICAL LOAD FOR INDUSTRIAL WORK TASK

One of the most important processes in the human organism is the change of the chemical energy of food into heat and mechanical work. For normal functioning, the tissues of the body require a reasonable degree of consistency with respect to certain factors like temperature, acidity, food supply and oxygen. The primary function of the circulation of the blood is to ensure the preservation of the constant internal environment by transporting oxygen, high energy food material and hormones to the tissue cells, which obtain energy from them by breaking them down through definite pathways to end products which are low in energy, such as water, carbon dioxide and urea. By these metabolic processes, energy is liberated and used for mechanical work via the chemical pathways in the muscles (Grandjean, 1971, p. 43).

Oxygen and glucose, the most important substances for the development of energy, are stored in very limited amounts in the muscle. Therefore, both must be continuously supplied to the muscular system by the blood. Thus, the supply of blood to the working muscle can limit muscular performance. During work, the demand for blood in a muscle rises ten to twenty fold. Physical work demands the following adjustments and adaptations in nearly all body organs, tissues and fluids (Grandjean, 1971, pp. 2, 53, 54):

1. Deeper, more rapid breathing.
2. Increase in heart rate and cardiac output.[1]
3. Vasometer changes which consist of dilations of blood vessels to the affected organs (muscles and heart) and contraction of other organs (skin and gut). This causes extensive haemodynamic changes in the circulation, shunting blood from the resting to the active tissues to increase their supply of oxygen and other energy-giving materials.
4. Rise in body temperature, which accelerates the chemical reactions in metabolism and this aids the transformation of chemical into mechanical energy.
5. Rise of blood pressure by which the pulse volume rises and with

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[1]Cardiac output = stroke volume x heart rate
(ml/minute) (ml/beat) (beats/min.)
"Human Physiology", by Vander, Sherman and Luciano (1975), p. 241
whereas stroke volume : is the volume of blood ejected into the main artery by each ventricular beat (ml/beat)
heart rate : is the number of ventricular beats per minute
cardiac output: is the volume of blood ejected into the main artery by each ventricular (ml/minute).

it the blood flow from the big arteries to the working organs.

6. Rise in blood sugar to increase the rate of sugar delivery from the liver to the tissues.

As physical work continues, secondary effects occur. Most important are changes in the chemical composition of the body fluids. End-products of metabolism (e.g., lactic acid) increase, and the kidneys have to eliminate more waste products. With muscular work, the internal temperature of the body rises and overheating is avoided by increasing the rate of heat loss by increasing the blood flow to the skin, and by sweating (Grandjean, 1971, p. 54).

One of the most important problems of industrial physiology is to design the work method so that the operator can perform the task 8 hours per day, 5 days per week, without undue fatigue. Physiological measurements of the worker on the actual job or on a simulated operation can provide useful information pertaining to such problems. In work physiology, the physiological load or physiological cost of the work is used to judge the degree of stress or total energy expenditure by the human body during work and is measured by the parameters such as oxygen consumption, heart rate, blood pressure, ventilation, rectal temperature, skin resistance, etc. Out of these various physiological parameters, oxygen consumption, heart rate and blood pressure are the most common to be used in industry, mainly because they are easily measured. Grandjean (1971, pp. 46,47) states that energy expenditure as measured by $O_2$ consumption is only a measure of physical work. It does not tell us anything about mental stress, about fatigue of sense organs or of skills, or about special physical stresses like heat or one-sided static stress. Thus energy expenditure should only be used for critical examination of heavy physical work and not on research into mental activities and skilled work. He also observes that in activities involving special stresses, as mentioned above, in addition to the physical work, heart rate, blood pressure, etc. give a better measure of total stress on the operator, than given by energy expenditure only.

In fish processing, the work is repetitive and highly skilled and the operators are also subjected to pressures from management and certain requirements from incentive systems to work for maximum output and for maximum yield. Under these conditions heart rate and blood pressure of the operator could represent a better measure of total stress or physiological load on the operator than given by $O_2$ consumption, etc. For this investigation heart rate and blood pressure were chosen as the physiological parameters and their relationships with work performance (speed of filleting and actual output rate) were studied. Another physiological parameter, i.e., $O_2$ consumption, could not be studied along with heart rate and blood pressure. The main reason was that the use of $O_2$ measurement equipment would have seriously interfered with the filleting work and could cause a serious accident since the operator was using a sharp knife. It was much easier to measure blood pressure and heart rate using a telemetry device.

At rest, man has a constant energy consumption whose magnitude depends on weight, height and sex. Energy consumption, expressed in Kilo-calories (K cal) is measured indirectly by means of $O_2$ consumption.[1]

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[1]For each litre of $O_2$ consumed by the human body, there is an average energy turnover of 4.8 K cal. This is called calorific value of oxygen. Oxygen consumption is usually measured by gas-meters, carried on the back of the subject. "Fitting the Task to the Man", by E. Grandjean, 1971, p. 43.

At rest, a man weighing 70 Kg has energy-consumption of about 1700 K cal per 24 hours, and a woman weighing 60 Kg has energy-consumption of about 1400 K cal per 24 hours (Grandjean, 1971). As soon as physical work is performed, the energy expenditure rises. The difference between the energy consumption at work and at rest is expressed in work calories.

Lehmann and his co-workers (1953) measured the energy expenditure in different occupations and found that for men the values vary from 2400 K cal/day to 5100 K cal/day for light manual work, e.g., bookkeeping, and for extremely heavy body work, e.g., farm harvesting, respectively. He concluded that the work calories indicated the extent of physical stress and could be used to evaluate the work. An energy consumption of 4800 K cal per working day (yearly average) is accepted today by most work physiologists as a maximum value for heavy work (Grandjean, 1971, p. 48).

The heart is a muscular pump that imparts sufficient kinetic energy to the blood to move it through the capillaries (Figs. 11A and 11B). Blood carries oxygen to the brain and all other parts of the body. Tubes called veins bring blood to the heart. Other tubes called arteries carry blood away from the heart. Regulators called valves control the flow of blood through the heart itself. The walls of the heart are made of a special kind of muscle. The heart muscle contracts and relaxes regularly and continuously. One heart or ventricular beat is a complete contraction and relaxation of the heart muscle. Heart rate is defined as the number of heart beats per minute. A man's heart normally beats about 70 times a minute, but the rate changes to provide as much oxygen as his body

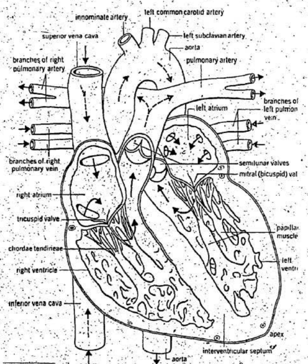


Figure 11A: Diagram of the Heart and its major blood vessels.

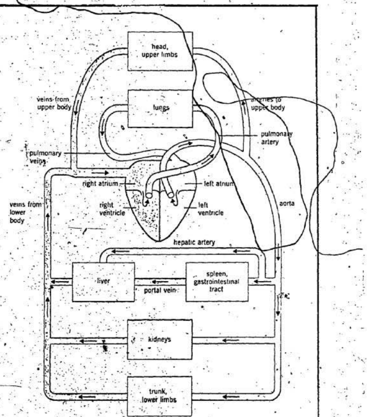


Figure 11B: A schematic representation of the circulatory system.

Source: 'Physiology of the Human Body' by McClintic, J. 1973, pp 134, 136.

needs (Vander, Sherman, Luciano, 1975).

Karrasch and Muller (1951)[1] found that within certain limits, working pulse rate and body temperature show a linear relation with energy expenditure or performed work. They defined the upper limit of stress as a work output in which the pulse rate does not continue to rise, which results in a return to the resting pulse rate within 15 minutes of the end of the work period. Most work physiologists agree that this optimum limit of performance is reached when the average pulse rate[2] during work lies 30 beats/minute above the resting pulse rate (Grandjean, 1971, p. 56). It has been shown by experiments that work pulse depends not only on energy consumption, but also on the heat load and the type of muscular activity. Thus, heart rate, a measure of both heat load and muscular load, is regarded as a better guide to total body stress than measurements of energy expenditure (Grandjean, 1971, p. 57).

The values of various physiological factors at different work loads as found by Christensen (1964)[3] are tabulated below:

Table 8. Criteria for critical examination of work loads.

| Work Load | Oxygen Consumption litre/min | Lung Ventilation litre/min | Heart Rate beats/min | Rectal Temperature °C |
|---|---|---|---|---|
| Very low (resting) | 0.25-0.3 | 6-7 | 60-70 | 37.5 |
| Low | 0.5-1.0 | 11-20 | 75-100 | 37.5 |
| Medium | 1.0-1.5 | 20-31 | 100-125 | 37.5-38.0 |
| High | 1.5-2.0 | 31-43 | 125-150 | 38.0-38.5 |
| Very high | 2.0-2.5 | 43-56 | 150-175 | 38.5-39.0 |
| Extremely high (sport) | 2.5-4.0 | 60-100 | Over 175 | Over 39 |

[1] Discussed in "Fitting the Task to the Man", by E. Grandjean, 1971, p. 55.

[2] In medical physiology, the terms 'average pulse rate during work' and 'mean heart rate during work' are same in value.

[3] Discussed in "Fitting the Task to the Man", by E. Grandjean, p. 54.

Christensen stated that the heart rate and other physiological parameters such as oxygen consumption, rectal temperature, etc., could be used to judge the degree of stress on the human body.

The blood in a circulating system is always under pressure. Blood pressure is the pressure that blood exerts against the walls of the arteries. Blood pressure depends upon pumping action of the heart, the peripheral resistance offered to the outflow of blood from the arteries, which varies with elasticity, and the volume of the circulatory blood. The blood pressure is varied during physical activity to provide an adequate blood supply. Arterial blood pressure of man is usually measured in the brachial artery of the arm. The maximum pressure caused by the systole (contraction period) of the heart is termed as systolic pressure and the minimum pressure in the artery between the heart beats, i.e., pressure at the end of the diastole (relaxation period) of the heart, is known as diastolic pressure. The difference between systolic and diastolic pressure is called a pulse pressure. The systolic pressure is considered as an index of heart energy expended and indicates the strain to which the arteries are subjected. The diastolic pressure is generally considered as a measure of peripheral resistance to the circulation of the blood. In general, it is shown that limits in normal individuals at rest range for systolic pressure from 110 to 135 mm Hg. and for diastolic pressure from 60 to 99 mm Hg. and for pulse pressure from 30 to 55 mm Hg. (Guyton, 1974).

Bevegard (1963) found that systolic pressure taken at the apparently steady state level was roughly proportional to the intensity of work. At maximal exercise, systolic pressure may reach levels well above 200 mm Hg. or 50 percent higher than at rest.

Feinberg, H (1958)[1] has suggested "Cardiac Effort" as an indicator of work required of muscle tissue. He has shown that reasonably good estimate can be made of cardiac effort from the product of heart rate and systolic blood pressure.

Some studies have been carried out in the past to observe the effect of some environmental factors such as noise, temperature, etc. on the physiological loads of the operator. Grandjean (1971, pp. 118-135) observes that the noise can cause a rise in blood pressure; acceleration of heart rate; increased metabolic rate and increased muscular tension. In both the laboratory and the industrial situations, noise is looked upon as uncomfortable. Noise causes an impairment in attentiveness and requires increased efforts for the execution of difficult tasks and this induces increased mental stress. The following noise levels have been suggested as maximal for factories:[2]

1. Frequencies mainly in excess of 1000 Hz: 85 decibles
2. Frequencies mainly below 1000 Hz: 95 decibles

These maximal values are valid for long-lasting exposure (up to a year) to noise for 8 hours a day.

Brouha, L. (1960) observed a progressively increasing cardiac cost during work as the environmental temperature increased. For a fifteen minute work and twenty minute recovery period, the total number of heart beats more than doubled when the thermal load was increased from environmental temperature 75 Fahrenheit to environmental temperature 90 Fahrenheit.

Because of very limited research conducted in cold environmental conditions, the effect of cold temperature on the physiological measurements of the operator is not well known. However, it has been noticed

[1] Also Discussed in "Laboratory Experiments in Physiology of Exercise" by De Vries, H.A. 1971, pp. 48-50.

[2] Discussed in "Fitting the Task to the Man" by E. Grandjean, 1971, p. 123.

that even a small drop in internal body temperature is sufficient to initiate shivering which can interfere with co-ordinated muscular activity. Cold weather clothing, if adequate to prevent excessive body heat loss, is heavy and bulky and results in an increased energy cost to perform a task and in a reduction in speed of movement. Another problem confronting individuals who must perform work in the cold is that of keeping the hands and fingers warm without interfering with their use. Handwear with sufficient insulating value to prevent excessive cooling of the fingers will usually, because of thickness and type of material, reduce finger dexterity and decidedly limit the operator's performance in tasks requiring fine manipulative finger movements (Simonson, 1971, pp. 345).

## 3.3 PREVIOUS WORK RELATED TO HEART RATE, BLOOD PRESSURE AND OTHER PHYSIOLOGICAL CORRELATES

Maitra and Koyal (1971) studied the effect of increasing work by 1 Kg/sec. per minute on healthy males, age ranging from 18 to 23 years. The work was carried out in a hot environment (34° Centigrade with relative humidity 90 percent) and was measured on Muller's magnetic type bicycle ergometer. The total work done varied from 6570 to 17280 Kg with corresponding duration of time varying from 15 to 20 minutes for the individual subject. The heart rate per minute was found to increase in different phases. At the start of exercise, the rise in heart rate was rather small. Four to five minutes after the onset of exercise, there was a gradual increment of heart rate/minute maintaining a linear relationship with work load. The systolic blood pressure was measured every 5 minutes and at the point of exhaustion systolic blood pressure showed a linear rise with work load.

In another experiment by De Vries and Adams (1972) a total of twenty-four healthy men, twelve old (mean age 69.2 years) and twelve young (mean age 16.7 years), were asked to exercise for six minutes at each work load on a bicycle ergometer at 60-70-80-90-100 watts. Heart rate, systolic blood pressure and oxygen consumption were measured at steady state (6th minute) and cardiac effort was estimated from heart rate and systolic blood pressure product in order to examine the nature of 1) the systolic blood pressure/work load relationship, and 2) the cardiac effort/total body effort relationship for the two age groups. The regression lines found for both relationships in both age groups were linear with a high level of confidence (p< 0.001). Although there was a consistently higher blood pressure response at all work loads for the older men, there was no difference in the rate of increase in systolic blood pressure with increases in work load. The regression for cardiac effort/total body effort was not significantly different between the two age groups, although a trend towards a steeper regression in older men was observed.

To determine the relation between perceived exertion and physiological indicator of exertion during exercise, Gamberale (1972) analysed the results for twelve healthy male subjects (age 20 to 35 years, body weight 56 to 82 Kgs, height 165 to 190 cms) working with a wheelbarrow, with lifting of weights and on a bicycle ergometer. Heart rate was measured and rating of perceived exertion (RPE) was recorded at different work loads. The results showed that rating of perceived exertion (RPE) was related to heart rate in a fairly linear way irrespective of the kind of work.

Tarriere and Andre (1970)[1] carried out shopfloor and laboratory studies in a French car manufacturing company, to evaluate the energy expenditure brought about by certain postures and the effort required to work at various levels above the heart level and at various rates of work. They found out that the energy expenditure for different basic rest postures varied greatly and the increase in heart rate during effort varied accordingly to the posture adopted. If work at 'heart level' is taken as reference, it has to be increased by 20 percent at 'eye level' and by 65 percent at the maximum height above the 'head'.

Pirnay, Petit and Deroanne (1969)[2] carried out a study in which heart rate and body temperature were measured in twenty-three men walking on a treadmill during half an hour in a very hot environment ($t_a$ 46°C, $t_{wb}$ 35°C)[3] with an energy expenditure of about 1 litre $O_2$/minute. A linear positive relationship was found between the two parameters. From one subject to another, the extent of cardiac reaction varied considerably. On the average, when body temperature increased by 1°C, heart rate increased by 32.3 beats/minute, but extreme values were 21 and 46 beats/minute. The linearity of these observations justified the use of heart rate as a reference of a thermal overloading during muscular exercise in a hot environment.

Burger (1969) pointed out that the measurement of heart rate has a high validity when heavy, dynamic, muscular work is considered. However, there are many restrictions on its validity when muscular work of a static type and other types of work load such as climate and mental conditions are considered. He put forward a new concept of circulatory

[1] Abstract given in "Ergonomics Abstracts", 1971, Vol. 3, No. 3, p. 235.
[2] Ibid, 1970, Vol. 2, No. 1, p. 60.
[3] $t_a$ = Dry bulb temperature; $t_{wb}$ = Wet bulb temperature

load[1] and suggested that other physiological measurements such as blood pressure and stroke volume combined with heart rate be used to give a better indication of the circulatory load.[2]

Ettama and Zielhuis (1971) used mental load[3] for the implications of tasks calling on the information handling capacity of man. An experiment using 24 subjects (12 male and 12 female students, age 20 to 25 years) was conducted where a simple binary choice task was used, with several frequencies of signals to be answered, thus providing different loads. A rise in heart rate and systolic blood pressure was found during mental load. The effect was larger when the mental load, i.e., number of signals/minute was higher, with significant values at a level of $p < 0.05$.

The effect of physical training on physiological adjustments to work in older men was studied by Tzankoff (1972). Fifteen sedentary men aged 44-66 years were given average two sessions of 55 minutes each per week for six months in vigorous physical training programmes. Activities included tennis, handball, paddleball, swimming, jogging and walking. Before and at the middle and end of the training period, their adjustments to a standard ten-minute walk at 5.6 Km/hr. up a 9% grade and to exhausting work on treadmill were determined. The energy cost of the ten-minute walk was unchanged, but blood lactate and heart rate in this work decreased on the average by 36.0 and 8.62% respectively, with

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[1]Circulatory load is expressed as a product of mean heart rate, blood pressure and stroke volume.

[2]Note: modified concept from Feinberg, H (1958).

[3]Mental load was expressed not by the complexity of the task but by the intensity of the task (i.e. the amount of information handled per unit time).

training.

An investigation was made by Nemecek (1976) in a textile factory of strenuous task performed by women, in which 2200–3000 Kg per day were moved by each head. The work was characterized by a high proportion of static muscular effort and by an unnatural posture. Twenty-nine women were studied. During work, pulse rate was recorded by telemetry. It was observed that working pulse of 30 beats/min. was exceeded in about one-third of all cases. Feelings of fatigue, pains in the shoulder and the wrist, total work performance and working pulse seemed to be related to the degree of training and adaptation to the specific work.

Kamon (1972) carried out an experiment in which twelve male and nine female normal subjects climbed up a motor-driven ladder and of this group nine males and six females also paddled a cycle ergometer, all at sub-maximal work loads. For climbing the ladder at an inclination of $30^{\circ}$ from the vertical, the whole body oxygen uptake was linearly related to both work rate in Kg m/min and body weight in Kg, with regression coefficients for work rate higher and for body weight lower for males than females. No correlation with body weight was found for cycling and the regression co-efficient for work rate was found to be practically the same for males and females. A linear relationship between heart rate and work rate was observed. For an individual, the regression co-efficients were quite similar for cycling and climbing. No relationship between heart rate and body weight was found, but it was observed that most of the females showed higher heart rate at a given oxygen uptake.

Most of the previous studies relating work performance and physiological measurements of human operator, as mentioned above, have been carried out in controlled conditions free from thermal, environmental and psychological stresses. Results have shown linear relationships between energy input levels and work output levels. Various physiological measurements such as mean heart rate, blood pressure, etc. have been used as a measure of energy expenditure and work output rate. Studies[1] have also shown that in activities involving special stresses such as mental stress, fatigue of skills, heat stress, one-sided static stress, etc., in addition to the physical work, it is the heart rate and blood pressure that give a better indication of total physiological load on the operator than given by energy expenditure which is only a measure of physical work.

The existing working conditions in the fish plants are observed to be poor. The operators have to work in cold, wet and humid conditions. The general work layouts and methods of processing are not so efficient. The operators are also subjected to pressures from management, speed restriction from conveyor belts and certain requirements from incentive systems, to work for maximum output and for maximum yield. The work is repetitive and highly skilled as compared to other processing operations since not only it is demanded of the operator to fillet as fast as he can but also to remove the maximum amount of meat (yield) from the fish. The operators working under such conditions could be asked to give higher output, but they might achieve this at the cost of higher physiological loads.

The existing work standards in the fish plants are based on the skill and effort put forth by the operator during filleting operation, but it does not take into account the various types of stresses imposed

[1] "Fitting the Task to the Man," by E. Grandjean, 1971.

on the operator. A need was therefore felt to observe some of the relationships between work performance (speed of filleting, actual output rate) and physiological parameters (mean heart rate, blood pressure, etc.) of the filleting operator. These relationships would help management to judge the level of physiological loads imposed on the operators. Management could use these relationships to design a better method of filleting, working height and work layout, etc., and therefore improve the efficiency of the plant, without causing unnecessary higher physiological loads on the operator.

## 3.4 APPARATUS USED IN THE MEASUREMENT OF HEART RATE AND BLOOD PRESSURE

### 3.4.1 Blood Pressure Measuring Device

The instrument used to measure blood pressure was ARTERIOSONDE[1] (1216) Blood Pressure Monitor by Hoffman-La Roche Inc., (Fig. 13). This is an electronic instrument that measures systolic and diastolic

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[1] Accuracy of Arteriosonde 1216: An experiment was conducted by Hochberg and Salomon (1971), sponsored by Roche Medical Electronics Division, New Jersey, in which blood pressures values measured by Arteriosonde (R) 1216 were compared with those obtained by Korotkoff and Intra-arterial Catheterization methods. Two hundred and ninety-nine patients accounted for a total of 1903 comparisons, 1708 in 244 persons measured by Korotkoff and ABPS (automatic blood pressure system) or Arteriosonde 1216 method and 195 in 58 individuals subjected to intra-arterial and ABPS determinations. Results showed that the mean systolic pressure difference between two indirect methods of blood pressure determinations (ABPS and Korotkoff) was 0.5 mm Hg (standard deviation: 7.4 mm Hg, correlation coefficient: 0.96) and diastolic pressure comparisons produced a mean difference of 0.1 mm Hg (standard deviation: 6.2 mm Hg, correlation coefficient 0.95). Also it was observed that mean systolic pressure difference between ABPS and intra-arterial measurements was 0.5 mm Hg (standard deviation: 7.3 mm Hg, correlation coefficient: 0.96) and mean end diastolic pressure difference was 7.6 mm Hg (standard deviation: 5.7 mm Hg, correlation coefficient: 0.92). The observed correlations between the Arteriosonde and the Korotkoff or intra-arterial pressure were found to be within the clinical range of accuracy established by the American Heart Association.

blood pressure by means of an indirect, ultrasonic method. Blood pressure determinations are made by ultrasonically detecting arterial wall motion, interpolating this motion into a blood pressure measurement, and displaying the measurement via 2 front-panel, mercury type manometers.

Figure 12 depicts the principle of operation of Arteriosonde (R) (1216). An assembly containing ultrasonic transducers, connected to the monitor, is placed under a standard blood pressure cuff and positioned over the brachial artery. The unit's pump automatically inflates the cuff to a variable preset level of maximal pressure. Ultrasound crystals imbedded in the transducer emit a field into the arm. As the cuff pressure automatically "bleeds down"[1] (according to rates recommended by the American Heart Association), the receiving ultrasound crystals reflect arterial-wall motion. When the maximal intra-arterial pressure barely exceeds cuff pressure, the lumen of the artery quickly snaps open for a brief moment. The instant of this change in ultrasonic frequency (Doppler shift) is recorded by the unit and shown and held on the mercury manometer of the panel as the systolic pressure. The cuff continues to deflate, and the system interprets the last significant signal sensed as the diastolic pressure. Blood pressure readings can be initiated manually or made automatically at 1, 2, 5, 10, etc. minute intervals. Two illuminated front-panel mercury manometers display the measured systolic and diastolic blood pressures (Fig. 13) and retain the readings until the start of the next measurement cycle.

The Arteriosonde 1216 incorporates special circuitry to minimize

[1]Cuff bleed rate: Adjustable from 2.0 to 7.0 mm Hg/sec. for adult cuff. "Arteriosonde 1216, Technical Manual," Hoffman-LaRoche Inc., pp. 1-2.

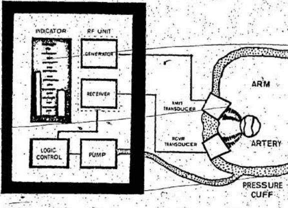


Figure 12: Principle of operation of Arteriosonde. The pump inflates a pressure cuff to a preset level. The logic control then bleeds the cuff at a standard rate. The "RF unit" generates ultrasound which is beamed toward the artery by the transmit transducer (XMIT transducer). Motion of the wall shifts the frequency and the phase of the reflected beam which is detected by the receiver (RCVR transducer). Thus the receiver detects these shifts and a logic control finds systolic and diastolic pressures for display on the indicator.

Source: 'Comparison of Automated Doppler Ultrasound and Korotkoff Measurements of Blood Pressure of Children', by, Zahed, Sadove and Wu 1971, 'Anesthesia and Analgesia journal, pp. 699-704. Sept-Oct, vol. 50, no. 5.

its response to spurious signals (i.e., artifacts). Artifacts are unwanted signals which can have an adverse affect on the accuracy of the ultrasonic blood pressure measurement. Artifacts occurring before true systole can cause an erroneous systolic pressure indication, those occurring between systole and diastole have no effect on the measurement, whereas artifacts occurring at diastole produce a lower-than-normal diastolic pressure.

In general, artifacts originate from two major areas: external causes and subject motion. External causes includes factors such as physical contact with or motion of cuff/transducers; movement of cable interconnecting subject to instrument; electrical interference from other inadequately shielded equipment, etc. Subject motion includes factors such as general restlessness; shivering, etc., When excessive artifacts are detected, the Arteriosonde (1216) gives a signal (via a front panel Artery Pulse/Suspecious Reading indicator) that the displaced blood pressure may be in error and the measurements should be repeated.

The Arteriosonde (1216) set[1] (Fig. 13) consists of the Arteriosonde (1216) assembly, an occlusive cuff assembly, the transducer assembly, a 7½ ft. cuff-to-unit cable assembly and one tube of Gelisonde.[2]

For this investigation, Arteriosonde (1216) Blood Pressure Monitor was maintained in proper working condition and any special precautions, as specified by the manufacturers of the equipment, were taken.[3] The following are some of the important precautions which should

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[1]The detailed description of various parts (assemblies) of Arteriosonde (1216), its operation and maintenance instructions are given in "Arteriosonde (1216) Technical and Operator Manuals," Roche Medical Electronics Division, Hoffman-La Roche Inc., New Jersey.

[2]Gelisonde is an ultrasonic coupling jelly medium which is applied to the transducer to efficiently couple ultrasound between the transducer and the skin.

[3]Arteriosonde (1216) was calibrated and was being used

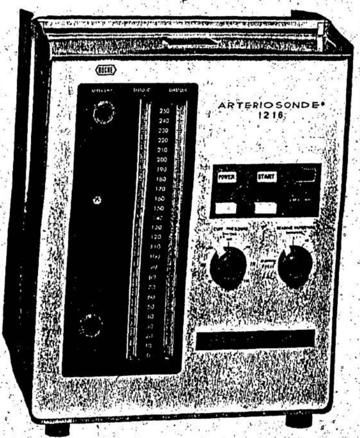


Figure 13: Arteriosonde (1216) blood pressure monitor.

Source: Arteriosonde (1216) Operator's Manual, Hoffmann-La Roche INC., New Jersey, USA.

by Dr. Amaria for other experiments when this investigation began. The instrument was sample checked few times during this investigation by using a standard sphygmomanometer on the operator, when the operator was in resting position. This check was conducted under the supervision of Dr. Amaria.

be maintained during the use of Arteriosonde (1216):[1]

1. Arteriosonde (1216) should not be used in the presence of flammable anesthetics.
2. The Arteriosonde (1216) should be mounted on a level surface. The selected mounting height should permit the operator to read the meniscus without creating parallax errors.[2]
3. When connected to an alternating current source, the Arteriosonde (1216) must be properly grounded at all times to aviod any potential shock hazard. Check and make certain that air fitting and electrical contacts are properly aligned before mating connectors.
4. The Arteriosonde (1216) may be used in the manual or automatic mode. If the subject's approximate systolic pressure is not known, the manual mode should be employed to determine it.
5. Before taking the first readings, check that the mercury level is at or slightly below 0 mm Hg in both manometers. If not, check to make certain the instrument is at level.
6. Different selectors should be set at appropriate levels (e.g., cuff pressure selector should be set at least 20 mm Hg above anticipated systolic pressure). Different indicators should be checked carefully while taking the readings.
7. The transducer is the sensing element of the instrument. It should be handled with reasonable care, making sure it is not subjected to abuse.
8. For subject comfort, cuff wrapping should be checked periodically

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[1]"Arteriosonde (1216) Operator's Manual," by Hoffman-La Roche Inc.

[2]Ibid, p. 13

if frequent, repeated measurements are planned.

### 3.4.2 Heart Rate Measuring Device

Hewlett Packard (HP) Telemetry system consisting of Model 78100A pocket-sized transmitter and Model 78101A modular receiver (Fig. 15)[1] was used to obtain continuous heart rate of filleting operators, for a set of experiments, during this investigation. Another unit (HP) model 7828A (Fig. 16), Heart rate and alarm module[2] was used in conjunction with the Hewlett Packard telemetry system.

The transmitter was carried by the operator in a pocket or pouch. Three disposable surface electrodes attached to the chest of the subject, i.e., two electrodes attached on either side below the mid rib and the third on the right-hand side just below the collar bone, pick up the Electrocardiogram (ECG) signal (Fig. 14).[3] The transmitter amplifies the signal and sends it, by radio waves, to the telemetry receiver. The receiver translates the radio signal into an ECG waveform. Special innovations contribute to an ECG signal[4] with outstanding accuracy. The

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[1]The detailed description of equipment parts, its operation and maintenance instructions are given in manual: Telemetry Transmitter 78100A, Telemetry Receiver 78101A, and H/R and Alarm module 7828A. (1971). Hewlett-Packard/Medical Electronics Division, Massachussetts, U.S.A.

[2]Ibid.

[3]Locations of electrodes are selected so that the ECG waveform will have recognizable P, Q, R, S and T portions of the cardiac cycle, and so the R-wave will have at least twice the amplitude of any other portion of the waveform. (Hewlett Packard Telemetry transmitter 78100A and Telemetry receiver 78101A--Operating manual) p. (3-3).

[4]The electrocardiogram (ECG) is a very important tool for assessing the ability of the heart to transmit the cardiac impulse. When the impulse travels through the heart, electrical current generated by the ionic charges at the surface of the heart muscle spreads into the fluids surrounding the heart, and a minute portion of the current actually

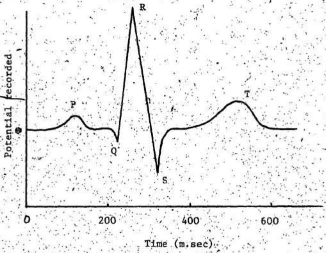


Fig. 14. Typical Electrocardiogram

transmitter minimizes false indications due to motion and pacing artifacts. For this investigation, the output from receiver was continuously recorded on a magnetic tape, using a magnetic tape recorder[1] (Fig. 17). PDP 12 computer was then used to convert this heart beat (analogue) signal[2], recorded on magnetic tape, to digital output heart beat interval frequency distribution (Fig. 17A).

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flows as far as the surface of the body. By placing electrodes on the skin over the heart on any two sides of the heart and connecting these to an appropriate recording instrument, the impulse generated during each heart beat can be recorded. In the normal Electrocardiogram illustrated in Figure 14, the curve labeled 'P' is caused by electrical current generated by passage of the impulse through the atria. The curves marked 'Q', 'R' and 'S' are caused by passage of the impulse through the ventricles, and the curve 'T' is caused by return of the membrane potential in the ventricular muscle fibers to its normal resting level at the end of contraction ("Function of the Human Body," by Guyton, 1974, p. 99).

[1]Grundig Cassette Tape Recorder; Model DC 90; Multiplex device with calibration and Zeroing circuit designed by Electronics Department,

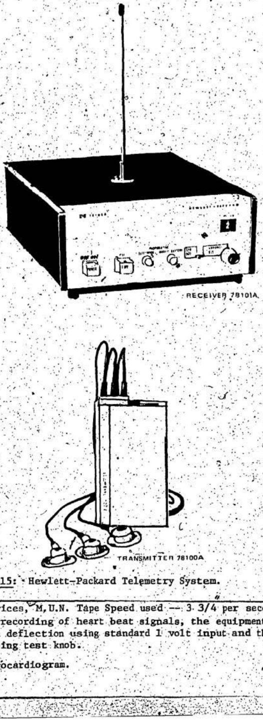


Figure 15: Hewlett-Packard Telemetry System.

Technical Services, M.U.N. Tape Speed used — 3 3/4" per second.

Before recording of heart beat signals, the equipment was calibrated for full scale deflection using standard 1 volt input and the scale zeroed using the zeroing test knob.

[2]Electrocardiogram.

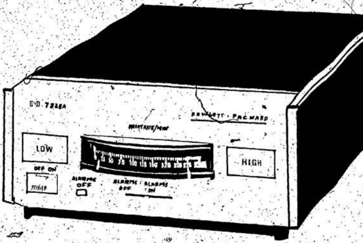


Figure 16: Hewlett-Packard heart rate and alarm module - model 7828 A.

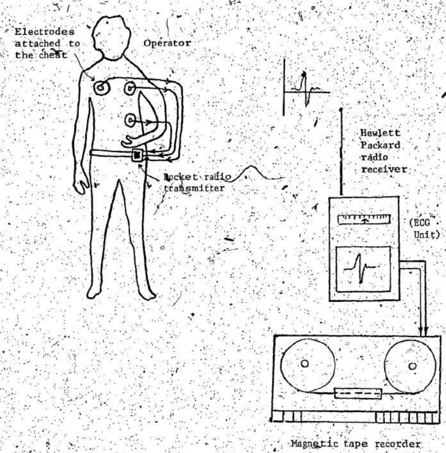


Figure 17: Recording of Heart Beat Signals (Electrocardiogram) on a Tape Recorder using Hewlett Packard Radio Telemetry System.

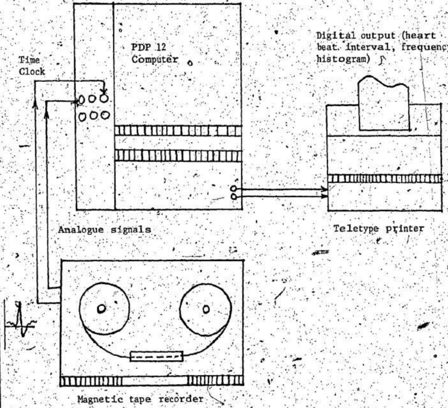


Figure 17 A: Conversion of Heart Beat (Analogue) Signals to Digital Output (Heart Beat Interval Frequency Histogram) using PDP 12 computer

The unit (HP) model 7828A heart rate and alarm module (Fig. 16) accepts a high level ECG signal, converts it to a dc level proportional to heart rate and displaces it continuously on a horizontally mounted front-panel meter. This unit also provides visual alarm displays when preset heart rate limits are exceeded. An automatic threshold circuit ensures reliable operation with wide variation in input signal level and provides extremely effective rejection of artifacts.

During the whole investigation, the heart rate measuring equipment was maintained in proper working condition and due attention was given to take any special precautions, as specified by the manufacturers of the equipment.[2] Some of the important precautions which should be maintained during the use of Hewlett Packard (HP) telemetry system are as follows:[1]

1. The telemetry receiver location should be reasonably free of vibration, dust, corrosive or explosive gasses or vapours and extremes of temperature and humidity.
2. The radio-frequency output of the 78100A transmitter is sufficient to interfere with some non-fixed rate pacemakers, thus endangering paced subjects. Evaluation should be made of such pacemakers for susceptibility to radio-frequency interference, using proper instructions provided in the operating manual.
3. Electrodes should be attached securely and at right locations to the subject. A loose electrode can cause artifacts. Also to reduce motion artifacts, electrodes should be kept away from

[1] Hewlett Packard, "Operating Manual for Telemetry Transmitter 78100A and Telemetry Receiver 78101A." (1971). Hewlett-Packard/Medical Electronics Division, Massachussetts, U.S.A.

[2] During this investigation, the heart rate measuring instrument was sample checked few times by using a stop watch and actual

skeletal muscles.

4. To minimize the excess electromagnetic radiation, battery from the transmitter should be removed to turn off the transmitter as soon as the transmitter is removed from the subject.

5. Various selectors and control indicators should be set at proper levels, as instructed in the operating manual. These indicators should be checked carefully while taking the readings.

6. The transmitter, carried in a pocket or worn in a cloth pouch, should be supported so that no strain is placed on the electrode adhesive discs attached to the subject.

3.4.3 Conversion of Analog Heart Beat Signals to Digital Output

A special computer program[1] was written for use on PDP 12 to convert the subject's heart beat (analog) signals[2] recorded on magnetic tape recorder for each filleting experiment, into digital output. The heart rate telemetry data recorded on the magnetic tape was replayed back to computer PDP 12 (Figure 17A). At the same time, an oscilloscope was used to observe the continuous pattern of the subject's recorded electrocardiograms during each experiment. Oscilloscope served to observe the presence of spurious signals (e.g., subject's sudden and

counting of pulsations in the radial artery at the wrist of the operator when the operator was in resting position. This check was conducted under the supervision of Dr. Amaria.

[1] See Appendix B, Table B-3. pp 205, 206.

[2] Electrocardiogram.

unexpected movements, some electrical inference from surroundings, etc.). The rejection of unwanted signals from the final output was taken care of by the computer program. In general, very few spurious signals were observed. For each experiment, the output from the computer was a frequency distribution of the subject's heart beat interval in seconds (Appendix B, p. 206)

Another computer program[1] on PDP 12 was then used to get mean heart beat interval (seconds) of the subject for each filleting experiment from the above frequency distribution of heart beat interval (Appendix B). Mean heart rate (beats/minute) of the subject during each experiment was then calculated from the mean heart beat interval (seconds) using the following formula:

$$\text{Mean heart rate (beats/ minute)} = \frac{1}{\text{mean heart beat interval (seconds)}} \times 60$$

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[1] See Appendix B, Table B-4, p. 207

## 3.5 PROCEDURE USED FOR SELECTION OF SUBJECTS AND METHOD OF WORK LOAD MEASUREMENT,

### 3.5.1 Selection of Filleters

This investigation was carried out at Witless Bay Fish Plant in the late summer of 1974. At that time, individual filleting type table layout was in operation, with 9 filleters on each side of the table. The investigator, with the help of Dr. Amaria, was able to contact the subjects through the owner or manager of the fish plant.

The criteria used to select filleters for the study of an individual filleting table was as follows (Niebel, 1962):

1. The subjects should be in good health condition.
2. The subjects should be co-operative and qualified workers.
3. The subjects should perform the work consistently and systematically.

Out of eighteen operators who were asked to participate in this investigation, only four persons volunteered. They were healthy male filleters with age ranging from 16 to 37 years and working experience in filleting ranging from 1 to 10 years. The plant manager and the subjects were verbally explained in detail about the purpose of the study, the procedure in which the experiments were to be conducted and about the heart rate and blood pressure measuring devices. Any questions or doubts were answered as far as possible to the satisfaction of each subject.

Each subject was also informed verbally that he could withdraw from the project at any time without prejudice and this was also made amply clear to the owner and plant managers that the subjects were in no way obliged to comply with the investigator's request and that if the subject wished to withdraw at any time during the investigation he would be allowed to do so and that the plant manager should not penalize the subject in any way whatsoever.

As far as the investigator could visualize, there did not seem to be any risk involved during the study. However, the following precautions were taken:

1. *Subjects were asked if they had any kind of heart or blood pressure problems.* These subjects would not have been suitable for the experiment.
2. The subjects were asked if they had any skin allergy and particularly skin irritations on the chest. These subjects were not suitable for the experiment.
3. All subjects were informed, particularly those having hair on their chest, that their hair would be pulled and pain would result when removing the surface electrodes. This pain would be similar to when an *ELASTO PLASTER* (similar to a BANDAID) was removed from the skin.
4. All equipment that was used for this investigation was maintained in proper working condition and any special precautions that the manufacturers of the equipment specified were taken.

3.5.2 Quality of Fish Utilized

Grade number one codfish were selected for this investigation. The characteristics of this type of codfish were as follows: Appearance of eyes of the fish was bright, glossy and full. The gills were bright red to slight pinkish red. Odour of the fish was fresh to faintly neutral.

For this investigation fresh iced and inshore (trap) 'head on – gut in' round codfish were used.

3.5.3. Size of Fish and Number of Fish/75 lb. box, concepts in this Study.

In the fish industry, the size of fish is given by the overall length of fish in inches, i.e., fish of larger size will have a longer length in inches as compared to fish of smaller size. The normal procedure followed in the industry on an individual filleting table layout is to present the fish to the operator in 75 lb. or 100 lb. boxes. Since size of fish represents fish length and consequently the weight of each fish, i.e., fish of a larger size will have more weight than that of smaller size, therefore size of fish indirectly also gives an idea about the number of fish per box and vice versa. It should be pointed out that the number of fish per box and size of fish are inversely related to each other as far as general meaning is concerned, i.e., a larger number of fish per box represents fish of smaller average size and a smaller number of fish per box represents fish of larger average size.

For this investigation, the number of fish per 75 lb. box[1] and not the length of fish in inches, was determined for each experiment and its effect on some other parameters such as normal output rate (lbs./hr.),

[1]Each box contains 75 lbs. of fish.

yield, heart rate, etc. was investigated. Since the term 'size of fish' is more common and easily understood in everyday life, than the term 'number of fish per box,' therefore some results of the above analysis have also been interpreted in terms of size of fish, i.e., in terms of smaller or larger size fish.

### 3.5.4. Conducting the Experiments

The total weight of codfish used for this investigation was limited by research grant to about 3000 lbs. An attempt was made to distribute this amount of codfish evenly among the four selected subjects, for filleting experiments. The choice for 75 lb. fish box rather than 100 lb. fish box for each experiment was made mainly because the Witless Bay Fish Plant, where this study was conducted, was using 75 lb. fish boxes for its daily filleting operations.

An attempt was also made to have a wider range of number of fish per box for different experiments for each subject. This was done so that the relationship between number of fish per box and other parameters such as normal output rate (lbs./hr.), percentage yield, heart rate, etc., of filleting operator could be observed more clearly.

### 3.5.5 Description of the Individual Filleting Table Used in this Study.

Figures 2 and 3 show the individual type filleting table similar to the one used in this study. The layout of the table consists of nine individual cutting stations, set up on either side of a centrally located conveyor system. Plastic fish boxes, each containing 75 lbs. of round fish are supplied to the filleters on a roller conveyor. The filleter picks up one fish box and places it in an inclined position, in front of and to the left of himself, on the filleting table. The fillets are placed in a plastic fillet pan located next to the fish box. The hand motion distances for the "get fish" and "place fillet" motions are 12 to 14 inches and 10 to 12 inches, respectively. The height of the workplace[1] is fixed (37 inches) for all the filleting stations. When the operator has filleted all the fish from the box, he returns the empty fish box for cleaning (using a lower level conveyor belt) and places the fillet pan, with his identity slip in it, on the top conveyor belt to be weighed at the end of the line. Here each individual fillet pan is weighed and work performance (actual output rate of fillets, actual output rate of roundfish and percentage yield) of each individual filleter is calculated.

3.5.6 Work Task for Experiment

Four skilled male operators, in good health condition, were asked to perform thirty-five experiments in total, on an individual type filleting table layout. The codfish was supplied to the operators in 75 lb. fish boxes. The number of codfish per 75 lbs. varied from fourteen to fifty-six. About 3000 lbs. of codfish were used for this investigation.

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[1] In fish filleting, the height of the workplace is the distance from foot stand to top of the cutting board.

Nadler, in his book "Motion and Time Study," 1955, p. 205, states: "It is desirable to have the height of the workplace arranged to allow the operator to sit or stand with the workplace 2 or 3 inches below the level of the elbow when the upper arm is stationary alongside the body." Barnes, in his book "Motion and Time Study," 1968, p. 284, states: "Although it would be preferable to have the height of the work place and the chair fit the particular operator who has to use them, this cannot always be done. It may be necessary in many cases to make the work benches of such height that they will be most suitable for the worker with average elbow height."

Experiment Nos. 1 to 8: Subject no. 1 was asked to fillet 600 lbs. (8 fish boxes of 75 lbs. each), grade no. 1,[1] undressed, one and one-half days old,[2] fresh iced, inshore (trap) cod.

Experiment Nos. 9 to 17: Subject no. 2 was asked to fillet 675 lbs. (9 fish boxes of 75 lbs. each), grade no. 1, undressed, seven hours old, fresh iced, inshore (trap) cod.

Experiment Nos. 18 to 25: Subject no. 3 was asked to fillet 600 lbs. (8 fish boxes of 75 lbs. each), grade no. 1, undressed, ten hours old, fresh iced, inshore (trap) cod.

Experiment Nos. 26 to 35: Subject no. 4 was asked to fillet 750 lbs. (10 fish boxes of 75 lbs. each), grade no. 1, undressed, one day old, fresh iced, inshore (trap) cod.

Each filleting operator under this investigation was asked to work at five different work paces in the following sequence:

a) Operator's own[3] or usual pace of filleting (2 experiments)

b) Faster than the operator's own pace of filleting (1 to 2 experiments)

c) Filleting for maximum yield (operator slows down) (2 experiments)

d) Fastest speed at which the operator can safely work (1 to 2 experiments)

e) Slower than the operator's own pace of filleting (1 to 2 experiments)

During each experiment, the operator was asked to maintain consistency with his speed of work, no matter what filleting speed (own pace, faster or slower than own pace, etc.) he was asked to work at for

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[1]Refers to quality of fish.

[2]Fish was caught one and one-half days before and was chilled

that particular filleting experiment. The wide range of filleting speeds helps in visualizing relationships between speed of filleting and other parameters such as mean heart rate, blood pressure, actual output rate, yield, etc. of the filleting operator in a much better way. The reason for choosing the above sequence of speeds was to make it easier for each operator to perform his experiments in a smooth and consistent way. Each operator was asked to fillet the first two experiments at his own pace. As each operator had a good concept in his mind of his own pace, he therefore worked in a consistent way. At the same time, the operator got used to the blood pressure and heart rate devices attached to him. Furthermore this speed, i.e., his own pace, served as a reference for other speeds (e.g., faster or slower than his own pace, etc.) of other experiments. Consistency was important during the filleting experiments from physiological point of view. For example, if the operator worked in a consistent and smooth way, his heart rate and blood pressure would represent the true work load on the operator. On the other hand, if the operator worked in a inconsistent way, his heart rate and blood pressure probably would not be true indicators of

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with ice to avoid deterioration.

[3] Operator's own pace or speed is the speed most often used by the operator during a working day. This differs from operator to operator.

the work load on the operator.[1]

### 3.5.7 Method of Measurement

Before the start of each set of experiments, permission was obtained from the plant manager. The selected operator was then explained in detail about the purpose of this study, the procedure in which the experiments were to be conducted and about the heart rate and blood pressure measuring devices. The subject was then advised of the work paces he should be working at for different experiments, and was asked to be consistent with his work speed, whatever it might be (own pace, faster or slower, etc.) during any experiment.

The surface electrodes were then attached to the chest of the subject in a private room.[2] The pocket size telemetry transmitter was connected to the electrodes and was worn around the waist by the subject. The transmitter was so supported that no strain was placed on the electrode adhesive discs. The blood pressure cuff was then placed around the brachial artery at the upper left arm of the subject. The subject was then asked to come and stand at his filleting station. Blood pressure measuring device, Arteriosonde (1216) was then mounted on the level table nearby the filleting station. The mounting height was chosen so as to permit the investigator to read the meniscus without

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[1]The heart rate and blood pressure readings are affected by spurious signals (i.e., artifacts), caused due to inconsistency in the work (Arteriosonde 1216, Technical and Operator Manuals, Hoffman-La Roche Inc. and Hewlett Packard Operating Manual for Telementry Transmitter 78100A).

[2]A small room, about 15 feet away from the individual filleting station on the same ground level. The telementry receiver and magnetic tape recorder were placed in this room to monitor continuously the heart rate of the operator during filleting operation.

creating parallax errors.[1] Arteriosonde was then connected to the blood pressure cuff, placed around the upper left arm of the subject. The cord leading to the blood pressure device was securely attached to the subject's arm to allow him freedom of movement while filleting. At this point, readings on the blood pressure and the heart rate instruments were checked to make sure that everything was perfectly in order. The subject was then advised of the speed at which he should fillet, i.e., his own pace, faster or slower than his own pace, etc.

The subject was allowed to sharpen his knife[2] and asked to relax for some time in a sitting position. For each experiment 75 lbs. of round codfish, already weighed and put in appropriate fish box, was then supplied to the filleter who was working on individual type filleting table layout. Just before the start of filleting operation, subject's blood pressure was measured while he was still in a relaxed sitting position. Two sets of blood pressure readings[3] (both systolic and diastolic) were taken and recorded.

The subject was then asked to start the filleting operation. The heart rate of the subject was recorded continuously with the help of a telemetry system on a four-channel magnetic tape deck. Total time of filleting for each experiment was noted with the help of a stop

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[1]Arteriosonde (1216) Operator's Manual, p. 13.

[2]Filleting operators usually take rest pauses during secondary activities, i.e., the activities connected with the main filleting operation such as sliding 75 lb. fish boxes from the conveyor, placing about 34 lbs. of fillet pan on conveyor, sharpening knife, cleaning the cutting board, placing the empty fillet pan on the filleting table, etc. The frequency of such pauses for an individual layout is mainly dependent upon the size of fish since this determines the number of fish per 75 lb. fish box and consequently determines the length of time the operator continuously performs the filleting operation.

[3]Systolic and diastolic blood pressure readings, recorded just before the start of each experiment, were not used during the analysis of the results of this study. These readings were recorded to make sure that the blood pressure measuring instrument was in working order during each filleting experiment.

watch. During each filleting experiment, the subject's speed or effort was rated by the investigator using performance rating system. Average rating, i.e., the average of all the above rated readings, for each experiment, was calculated later.

As soon as the operator had completed the filleting operation, his systolic and diastolic blood pressures were measured using Arteriosonde (1216) equipment. During this measurement the operator was asked, while still in a standing position, to make as little movements as possible. The subject was then asked to relax for about 15 to 20 minutes before the next filleting operation. For each experiment, the fillets (skin-on) were collected and weighed by the investigator.

3.5.8 Experimental Controls

The following experimental controls were maintained during this investigation.

1. The work layout, i.e., the individual type filleting table layout (Figs. 2 and 3) was kept the same for all the subjects.
2. The workplace height, i.e., the distance from foot of the table frame to top of the cutting table was the same (37 inches) for all the experiments (Fig. 2), while the foot stool adjusted to maintain approximately 4 inches between operator's elbow and top of the cutting board.
3. The same type of cut, i.e., conventional straight cut was used for all the filleting experiments.
4. The same method of filleting, as explained in Figs.7 and 8, was used by all the operators.
5. The same input quality of fish, i.e., grade no. 1, undressed, inshore (trap) cod was supplied to all the filleting operators.
6. The devices for measurement, i.e., weighing scale for measuring

input weight of whole codfish (75 lbs. per fish box), weighing scale for measuring weight of skin-on fillets and stop watch to record the filleting time were kept the same for all the experiments.

7. The same blood pressure measuring device, i.e., Arteriosonde (1216) and the same heart rate measuring device, i.e., Hewlett Packard Telemetry system were used for all the experiments.

3.5.9 Measurements

The actual time of filleting 75 lbs. of round codfish, number of codfish per box, performance rating sampled at different times during each experiment, and weight of fillets (skin-on) were recorded for each experiment. Two sets of readings, for systolic and diastolic blood pressures, both at the beginning and at the end of each experiment were taken and continuous recording of heart rate for the operator during each experiment was made.

The various measurements of work layout,[1] workplace height,[2] surrounding room temperature[3] in the plant etc., were made and the data about the four selected subjects[4] was also recorded.

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[1]Refer Figure 2, p. 16 of this report.

[2]Ibid.

[3]Surrounding room temperature in the fish filleting plant, during this investigation was in the range: 65°F to 70°F.

[4]Subject No. 1: Age: 37 years; filleting experience: 10 years; average performance rating (speed of filleting) range during this investigation: 98.7 to 117.1% ; mean heart rate: range during this investigation: 103.5 to 124.8 beats/min; average systolic blood pressure, recorded just after each filleting experiment, range: 140 to 178 mm. Hg.

The average performance rating of the subject during each experiment, the actual output rate of roundfish (lbs./hr.), the actual output rate of fillets (lbs./hr.), normal output rate of roundfish (lbs./hr.), normal output rate of fillets (lbs./hr.), percentage yield (skin-on fillets) were calculated for each experiment. The mean heart rate (beats/min.) of the operator, the average values of both systolic and diastolic blood pressures[1] (mm of Hg), true mean blood pressure (T.M.B.P.)[2] (mm of Hg.) were also calculated for each experiment. The product of mean heart rate and blood pressure (both systolic blood pressure after experiment and T.M.B.P.) were also found for each experiment.

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Subject No. 2: Age: 22 years; filleting experience: 4 years; average performance rating range: 95 to 127.5%; mean heart rate not recorded-- failure of equipment; average systolic blood pressure range: 145 to 164 mm. Hg.

Subject No. 3: Age: 18 years; filleting experience: 2 years; average performance rating range: 99 to 120%; mean heart rate range; 94.8 to 118.7 beats/min; average systolic blood pressure: 138.5 to 166.5 mm. Hg.

Subject No. 4: Age: 16 years; filleting experience: 1 year; average performance rating range: 75 to 123.6%; mean heart rate range: 94.8 to 114.3 beats/min.; average systolic blood pressure: 127 to 151 mm. Hg.

Refer Tables 17-20, pp. 141-144.

[1]Average blood pressure value: During the experiments, two sets of systolic and diastolic blood pressure readings, at an interval of one minute, were recorded just before the start of the experiment and just after the completion of the experiment. The mean value of these systolic and diastolic blood pressure readings were termed as average systolic and diastolic blood pressure values before and after the experiment.

[2]T.M.B.P.: 'True mean blood pressure.' Also termed as 'mean arterial pressure' or 'mean pressure.' It is the arterial pressure averaged during a complete pressure pulse cycle.

$$\text{T.M.B.P.} = \frac{\text{Systolic} + 2\,\text{diastolic pressure}}{3}$$

So far as the circulatory system is concerned, T.M.B.P. is more important than is either systolic or diastolic pressure, because it is the mean pressure that determines the average rate at which blood will flow through the systemic vessels. "Human Physiology," by Vander, Sherman and Luciano (1975), p. 249. "Physiology and Biophysics of the Circulation", by Burton, A.C., (1968) p. 86.

# CHAPTER 4

## RESULTS AND ANALYSIS

### 4.1 RELATIONSHIP BETWEEN SPEED OF FILLETING (PERFORMANCE RATING) AND THE MEAN HEART RATE, BLOOD PRESSURE AND THE PRODUCT OF MEAN HEART RATE AND BLOOD PRESSURE OF THE FILLETING OPERATOR

Scatter diagrams[1] (Figs. 18 to 21) were drawn between speed of filleting and the mean heart rate, blood pressure[2] and the product of mean heart rate and blood pressure of filleting operators. These diagrams were drawn to observe the nature of relationship (i.e., linear, curvilinear or no relationship, etc.) between the independent variable and dependent variable. For this investigation, straight line or linear relationships were observed between the above mentioned variables. It was also observed from the scatter diagrams that as the operator increases his speed of filleting, his mean heart rate, blood pressure and product of mean heart rate and blood pressure also increase.

Linear regression and correlation analysis was therefore used to obtain a coefficient of correlation (R) and a linear regression equation $Y = a+b(X)$. The coefficient of correlation (R) is a measure of association indicating the strength and direction of a linear rela-

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[1] A scatter diagram is a plot of all observations between independent and dependent variables, for a particular experiment or set of experiments.

[2] Both systolic blood pressure and true mean blood pressure (T.M.B.P.) values (i.e., after experimental values) were used for linear regression analysis purpose.

tionship between independent and dependent variables. The equation $Y = a+b(X)$ enables us to estimate the value of dependent variable 'Y' for any given value of independent variable 'X'. The constants 'a' and 'b' are called regression coefficients. A computer programme called CALCPLOT was used on PDP 12 for linear regression and correlation analysis purpose (Appendix A, p 194 Appendix B, p 198)

Significant positive linear relationships were found between speed of filleting (performance rating) and the mean heart rate for each of the subjects[1], Subject 1 ($p < 0.05$, d.f. = 6, Fig. 18, Table 21), Subject 3 ( $p < 0.05$, d.f. = 6, Fig. 18, Table 21), and Subject 4 ($p < 0.01$, d.f. = 8, Fig. 18, Table 21). The coefficient of determination ($R^2$) shows that 57.6% for filleter 1, 50.4% for filleter 3, 76.6% for filleter 4 of the total variation in mean heart rate can be accounted for by the linear relationship with speed of filleting (Table 21).

It was observed that significant positive linear relationships existed between speed of filleting and the systolic blood pressure ($S_A$) for the subjects 1, 2 and 4: Subject 1 ($p < 0.01$, d.f. = 6, Fig. 19, Table 21), Subject 2 ($p < 0.05$, d.f. = 7, Fig. 19, Table 21), Subject 4 ($p < 0.05$, d.f. = 8, Fig. 19, Table 21). However, no significant relationship was observed between speed of filleting and the systolic blood pressure for Subject 3. The total variation in systolic blood pressure that could be explained by the linear relationship with speed of filleting for Subjects 1, 2 and 4 was 71.7%, 59.9% and 52.1% (Table 21). No significant relationship was observed between speed of filleting and T.M.B.P. (true mean blood pressure) for any of the four subjects (Table 22). To the knowledge of the author, no previous work has been carried out for fish processing operation, to observe the effect of work

[1]Heart rate for Subject 2 could not be recorded -- failure of the heart rate recording electrodes.

performance on the true mean blood pressure (T.M.B.P.) of the operator. Since the energy expenditure of the operator increases as his speed of filleting increases, therefore under the present working conditions in fish plants, mean heart rate (H/R) and systolic blood pressure ($S_A$) could be considered as indicators of energy expenditure or physiological load on the operator.

Relationships obtained between speed of filleting and the product of heart rate and blood pressure[1] were linear and significant for Subjects 1, 4, i.e., Subject 1 ($p < 0.01$, d.f. = 6, Fig. 20, Table 21), and Subject 4 ($p < 0.01$, d.f. = 8, Fig. 20, Table 21). No significant relationship was observed for Subject 3.

The different linear relationships tested between speed of filleting (performance rating) and mean heart rate, blood pressure (systolic as well as true mean blood pressure) and product of mean heart rate and blood pressure are as follows:

Heart Rate (beats/minute) = $a_1$[2] + $b_1$ (Performance Rating)[3]

Blood Pressure (mm of Hg.) = $a_2 + b_2$ (Performance Rating)

Heart Rate x Blood Pressure (beats/minute x mm of Hg.) = $a_3 + b_3$ (Performance Rating)

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[1]Both systolic blood pressure ($S_A$) and true mean blood pressure (T.M.B.P.) were considered for analysis purpose.

[2]In equation $Y = a+b(X)$ 'a' and 'b' are called regression coefficients. The values of 'a' and 'b' could be attributed to a number of factors such as physical condition of the operator, skill and experience, work layout, method of filleting, workplace height, immediate and general environmental conditions, etc. 'a' is the Y intercept or the estimated value of Y when X=0. 'b' is the slope of the line or the average change in Y for each change of one (either increase or decrease) in X.

[3]In performance rating system, performance rating is expressed in percentage.

The significant linear relationships obtained for different subjects are as follows:

| Heart Rate (beats/minute) (Dependent Variable) | Vs. | Performance Rating % (Independent Variable) | (Table 21) |
|---|---|---|---|

Sub. No. 1 Heart Rate = 29.97 + 0.76 (Performance Rating)
($R^{1}$ = 0.759, $p < 0.05$, d.f.[2] = 6)

Sub. No. 3 Heart Rate = 31.03 + 0.71 (Performance Rating)
(R = 0.710, $p < 0.05$, d.f. = 6)

Sub. No. 4 Heart Rate = 69.70 + 0.34 (Performance Rating)
(R = 0.875, $p < 0.01$, d.f. = 8)

| Blood Pressure (mm of Hg.) (Dependent Variable) | Vs. | Performance Rating % (Independent Variable) | (Table 21) |
|---|---|---|---|

Sub. No. 1 Systolic blood pressure ($S_A$) = -2.58 + 1.528 (Performance Rating)
(R = 0.847, $p < 0.01$, d.f. = 6)

Sub. No. 2 Systolic blood pressure ($S_A$) = 115.00 + 0.339 (Performance Rating)
(R = 0.774, $p < 0.05$, d.f. = 6)

Sub. No. 4 Systolic blood pressure ($S_A$) = 109.97 + 0.274 (Performance Rating)
(R = 0.722, $p < 0.05$, d.f. = 8)

also

Sub. No. 1 True mean blood pressure (T.M.B.P.) = 78.12 + 0.449 (Performance Rating)
(R = 0.688, $p < 0.10$, d.f. = 6)

| (Heart Rate x Blood Pressure) (beats/minute x mm of Hg.) (Dependent Variable) | Vs. | Performance Rating % (Independent Variable) | (Tables 21 and 22) |
|---|---|---|---|

Sub. No. 1 $(H/R \times S_A)^3$ = -13560 + 294.6 (Performance Rating)
(R = 0.947, $p < 0.01$, d.f. = 6)

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[1] R is called coefficient of correlation. It is a measure of association indicating the strength and direction of a linear relationship between the two variables. "General Applied Statistic" by Zuwaylif, 1970.

[2] d.f. is called the degree of freedom. In linear regression, its value is equal to (n-2) where n is the no. of observations recorded.

[3] H/R = mean heart rate
$S_A$ = Systolic blood pressure, recorded just after the completion of each filleting experiment.

Sub. No. 4 $(H/R \times S_A) = 6807 + 74.71$ (Performance Rating)
$(R = 0.980,\ p < 0.01,\ d.f. = 8)$

Sub. No. 1 $(H/R \times T.M.B.P.) = -1532 + 145.8$ (Performance Rating)
$(R = 0.881,\ p < 0.01,\ d.f. = 6)$

Sub. No. 4 $(H/R \times T.M.B.P.) = 6555 + 38.9$ (Performance Rating)
$(R = 0.836,\ p < 0.05,\ d.f. = 8)$

This study has shown that in fish plants under present working conditions, as the operator increases his speed of filleting his mean heart rate, blood pressure and product of mean heart rate and blood pressure increase linearly ($p<0.05$ to $p<0.01$; Tables 21 and 22). This could be explained in the following way. As the operator increases his speed of filleting, he would have to put some extra effort or spend some extra work energy. This extra work expenditure causes a rise in the demand for blood in the muscle from ten to twentyfold,[1] depending on the intensity of work. This increased blood supply demand is met by the increased pumping output of the heart which causes an increase in the mean heart rate and blood pressure of the operator.

### 4.2 RELATIONSHIP BETWEEN ACTUAL OUTPUT RATE[2] AND THE MEAN HEART RATE, BLOOD PRESSURE AND THE PRODUCT OF MEAN HEART RATE AND BLOOD PRESSURE OF THE FILLETING OPERATOR

Scatter diagrams (Figs. 22 to 24) were drawn between above mentioned variables and straight line relationships were observed. It was also observed from the scatter diagrams that as the filleting operator

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[1] E. Grandjean, "Fitting the Task to the Man--An Ergonomic Approach," 1971, p. 2.

[2] Both actual output rate of round codfish processed and actual output rate of fillets produced were considered for regression analysis purpose. The effect of each of them on the different physiological parameters was investigated separately.

works for higher output rates, his mean heart rate, blood pressure[1] and product of mean heart rate and blood pressure also increase. Linear regression and correlation analysis was therefore used.

Significant positive linear relationships were observed between actual output rate (both roundfish and fillets) and the mean heart rate for each of the filleters. For example, for roundfish: subject 1 ($p < 0.05$, d.f. = 6, Fig. 22, Table 24), subject 3 ($p < 0.05$, d.f. = 6, Fig. 22, Table 24), and subject 4 ($p < 0.01$, d.f. = 8, Fig. 22, Table 24). The total variation in mean heart rate that could be explained by the linear relationship with actual output rate of fillets, for subjects 1, 3 and 4, was 60.5%, 36.5% and 66.9%, respectively (Table 22).

The increase in mean heart rate with increase in actual output rate could be explained. Actual output rate (fillets and whole fish) depends mainly on speed of filleting and size of fish,[2] each of which causes an increase in the mean heart rate of the operator.[3]

Results from the linear regression analysis (Tables 23 to 25) indicated a linear relationship trend with positive slope between actual output rate (fillets as well as round fish) and blood pressure (both systolic and true mean blood pressure) of each operator. However, no significant relationship was observed between actual output rate and operator's blood pressure for all the four subjects (Tables 23 to 25).

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[1]Both systolic as well as true mean blood pressure.

[2]Refer p. 130 of this report.

[3]Refer pp. 104, 111, of this report.

It was also observed that relationships obtained between actual output rate (both fish and fillets) and product of mean heart rate (H/R) and systolic blood pressure ($S_A$) were linear and significant for Subjects 1 and 4. For example, for roundfish: Subject 1 ($p < 0.05$, d.f. = 6, Fig. 24, Table 24), and Subject 4 ($p < 0.05$, d.f. = 8, Fig. 24, Table 24). The coefficient of determination ($R^2$) shows that 49.6% for filleter 1 and 40.4% for filleter 4 of the total variation in ($H/R \times S_A$) can be accounted by the linear relationship with actual output rate (roundfish) (Table 24).

The significant linear relationships obtained for different subjects are as follows:

| Mean Heart Rate[1] (beats/minute) (Dependent Variable) | Vs. | Actual Output Rate (lbs./hr.) (Independent Variable) | (Tables 22 and 24) |
|---|---|---|---|

Sub. No. 1 Heart Rate = 87.09 + 0.032 (Actual output rate of roundfish)
($R^2$ = 0.786, $p < 0.05$, d.f.[3] = 6)

Sub. No. 3 Heart Rate = 42.78 + 0.137 (Actual output rate of roundfish)
(R = 0.717, $p < 0.05$, d.f. = 6)

Sub. No. 4 Heart Rate = 94.18 + 0.019 (Actual output rate of roundfish)
(R = 0.823, $p < 0.01$, d.f. = 8)

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[1] Heart rate for subject 2 could not be recorded. Failure of recording electrodes making adequate electrical contact during the performance of actual experiments.

[2] R is called the coefficient of correlation. It is a measure of association indicating the strength and direction of a linear relationship between the two variables.

[3] d.f. is called the degree of freedom. In linear regression, its value is equal to (n-2) where n is the no. of observations recorded. "Statistical Techniques in Business and Economics", by Mason, R., 1974, p. 494.

also

Sub. No. 1  Heart Rate = 85.00 + 0.076 (Actual output rate of fillets)
($R = 0.778$, $p < 0.05$, d.f. = 6)

Sub. No. 3  Heart Rate = 48.2 + 0.34 (Actual output rate of fillets)
($R = 0.604$, $p < 0.10$, d.f. = 6)

Sub. No. 4  Heart Rate = 93.6 + 0.06 (Actual output rate of fillets)
($R = 0.818$, $p < 0.01$, d.f. = 8)

(Heart Rate (H/R) x Systolic Blood Pressure ($S_A$)  Vs.  Actual Output Rate
(beats/minute x mm of Hg.)  (lbs./hr.)
(Dependent Variable)  (Independent Variable)

(Tables 23 and 24)

Sub. No. 1  ($H/R \times S_A$) = 11278 + 8.93 (Actual output rate of roundfish)
($R = 0.704$, $p < 0.05$, d.f. = 6)

Sub. No. 4  ($H/R \times S_A$) = 12830 + 2.87 (Actual output rate of roundfish)
($R = 0.636$, $p < 0.05$, d.f. = 8)

also

Sub. No. 1  ($H/R \times S_A$) = 11438 + 19.14 (Actual output rate of fillets)
($R = 0.628$, $p < 0.10$, d.f. = 6)

Sub. No. 4  ($H/R \times S_A$) = 12751 + 8.27 (Actual output rate of fillets)
($R = 0.629$, $p < 0.10$, d.f. = 8)

In fish processing, there are number of factors other than speed of filleting (performance rating) such as size of fish, work layout, workplace height, physical condition of operator, skill, training, environmental conditions, etc., which may affect the work performance (actual output rate) and the physiological load of the operator. Some of the above factors such as work layout, workplace height, training, immediate and environmental conditions could be controlled to some extent, but factors like size of fish becomes difficult to control in actual practice. In individual type filleting table layouts, fish are supplied to the filleting operator in 75 or 100 lb. boxes, i.e., weight of the fish supplied is constant per box, but number of fish per box varies according to the size of fish. A larger number of fish per box represents a smaller size (length) fish in the box and vice versa.[1]

Scatter diagram (Figure 25), drawn between number of round codfish per 75 lb. box and the physiological parameter such as mean heart rate, showed in general linear relationship trend. Linear regression and correlation analysis was therefore used. It was observed that the mean heart rate of the operator increases as he fillets a bigger size fish or less number of codfish per 75 lb. box. The following significant linear relationships were obtained for Subjects[2] 1 and 4 (Table 25).

Sub. No. 1 Heart Rate = 178.3 - 2.66 x (no. of codfish per 75 lb. box)
(beats/min.)

$(R = -0.837,\ p < 0.01,\ d.f. = 6)$

Sub. No. 4 Heart Rate = 114.2 - 0.29 x (no. of codfish per 75 lb. box)
(beats/min.)

$(R = -0.621,\ p < 0.05,\ d.f. = 8)$

An increase in the mean heart rate of filleting operator, with a decrease in number of codfish per box or with an increase in size (length) of fish, could be explained in the following way. As the number of fish per box decreases, the operator would have to fillet bigger size fish or the average weight of each fish supplied to the operator becomes more. Therefore, the operator would have to spend

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[1]Refer Chapter 3, p. 93, of this report.

[2]Heart rate for Subject 2 could not be recorded. Failure of heart rate recording equipment during the performance of actual experiments.

extra work energy or put some extra effort to overcome this additional weight in handling and filleting. This extra work effort put forth by the operator causes an increase in his heart rate.

No significant relationships were observed between number of codfish per 75 lb. box and systolic blood pressure and product of mean heart rate and systolic blood pressure of the operator (Tables 25 and 26).

This study has shown that under the present working conditions in fish plants, speed of filleting and number of codfish per 75 lb. box, or in other words size (length) of fish, are the two important factors which affect the physiological load on the filleting operator. Therefore, in order to evaluate the effect of speed of filleting (independent variable) along with size of fish (another independent variable) on the physiological load (represented by physiological parameters such as heart rate, etc.) of the filleting operator, multiple linear regression analysis was used. Multiple linear regression and correlation analysis enables us to evaluate two important facts:[1]

1. It gives us a multiple coefficient of correlation '$R_m$' between independent and dependent variables, a test statistic called 'overall F-ratio' and a multiple linear regression equation. Both '$R_m$' and 'overall F-ratio' represent the overall dependence of a variable on a set of other variables. In general, if two

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[1]"Statistical Package for the Social Sciences" (SPSS) by Nie, Hull, Jenkins and Bent; "Statistical Techniques in Business and Economics" by R. Mason (1974), pp. 513-530; and "BMD02R--STEPWISE REGRESSION," Computer Programme, University of California, (Appendix A, p. 195).

independent variables are linearly related to a dependent variable, then two variables together will yield a much better prediction of dependent variable than either variable alone.

2. The computer output gives a 'partial correlation' and also a 'partial F-ratio' value for each of the independent variables. Partial correlation provides a single measure of association describing the relationship between two variables while adjusting for the effects of one or more additional variables. In partial correlations, this adjustment or control is statistical and is based on the simplifying assumptions of linear relationships among the variables.

Once one knows the linear relationship among the independent, dependent and control variables,[1] the partial correlation coefficient can be calculated by constructing (statistically) new independent and dependent variables with the effect of control variable(s) removed. The new or adjusted independent variable is constructed statistically by taking the difference between the actual value of the original independent variable (for each observation) and its value as predicted by the control variable. The new variable is, by definition, uncorrelated with each and/or all control variables which have been entered. The same procedure is then repeated for the dependent variable. The linear effect

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[1]Control variable is the variable whose effect, on dependent and independent variables during partial correlation analysis, has to be controlled statistically. For example, in order to obtain the partial correlation between Y and $X_1$, in multiple regression equation $Y = a + b(X_1) + c(X_2)$, the effect of $X_2$ on both Y and $X_1$ has to be controlled. $X_2$ is then called control variable. Similarly, $X_1$ is called control variable when a partial correlation between Y and $X_2$ is desired.

of the control variable(s) has now been removed from both the independent and dependent variables, and the simple correlation between these adjusted variables is the partial correlation.[1]

Partial correlation often deals with locating relationships between variables, when none appears to exist. One sometimes encounters situations where theory or intuitive judgment leads one to believe that there should be a relationship between two variables, but the data simply do not indicate any relationship. When this is the case, there is the possibility that some other variable or variables are acting to hide or suppress the relationship. These suppressor relationships often take the form of "A shows no relationship to B because A is negatively related to C, which in turn is positively related to B." Hence A is positively related to B when one controls for the effects of C.[2]

Thus partial correlation gives a better indication of the relationship between each independent variable with dependent variable than that given by simple linear regression analysis because in simple regression analysis, the effect of other independent variables on the dependent variable is not controlled.

In a multiple linear regression equation $Y = a + b\ (X_1) + c\ (X_2)$, Y is called dependent variable and $X_1$ and $X_2$ are independent variables, 'a' is a constant, 'b' and 'c' are the partial regression coefficients. For example, 'b' stands for the expected change in Y with a change of one unit in $X_1$ when $X_2$ is held constant. Expressed in another way, 'b'

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[1]"Statistical Package for the Social Sciences" (SPSS), by Nie, Hull, Jenkins and Bent (1975), p. 302.

[2]Ibid., p. 305.

is the expected difference in Y between two groups which are different on $X_1$ by one unit but are the same on $X_2$.

For this investigation, a computer programme called "BMD02R--STEPWISE REGRESSION"[1] was used to obtain: (1) 'Overall $R_m$'[2] and 'Overall F'[3], the test statistics to represent the overall dependence of physiological load on speed of filleting and number of codfish per 75 lb. box; (2) 'Partial F'[4] values of each of the two independent variables (speed of filleting and number of codfish per 75 lb. box) with dependent variable, i.e., physiological load parameter such as heart rate, blood pressure, etc. of the filleting operator; and (3) a multiple linear regression equation between physiological load parameter (dependent variable such as heart rate, blood pressure, etc.) and speed of filleting (independent variable) and number of codfish per 75 lb. box (another independent variable).

This study has shown significant positive relationships between work performance (performance rating, actual output rate) and physiological load (represented by physiological parameters such as heart rate, blood pressure, etc.) of the operator. In actual practice, where the operators are imposed to work pressures from the management and his colleagues (which are much more intense in practice than those imposed in this study) and also from certain requirements of incentive systems to fillet at maximum speed and for maximum yield, it is possible that the operators might be giving higher outputs at the cost of higher physiological loads. Management in fish plants can, therefore, use the multiple regression analysis to evaluate factors such as work load levels, equip-

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[1] Appendix A. p. 195 ; Appendix B, pp. 199-204.

[2] Overall Rm is called multiple co-effieient of correlation.

[3] Overall F relates to the test statistic, called overall F-ratio. Overall Rm and overall F are computed to test the significance of regression coefficients in the multiple regression equation.

[4] Partial F is the F-ratio between two variables (dependent and independent) while adjusting for the effects of one or more additional independent variables on the dependent variable.

ment comparison, job evaluation and relative task difficulties,[1] thus improving the overall efficiency of the plant without causing any unnecessary higher physiological loads on the operator.

The significant multiple linear relationships obtained for different subjects are as follows:

| Mean Heart Rate (beats/minute) (Dependent Variable) | Vs. | Performance Rating[2] % (Independent Variable) | , No. of Codfish per 75 lb. box (Independent Variable) |
|---|---|---|---|

(Refer Table 30)

Sub. No. 1 Heart Rate = 111.07 + 0.459 (Performance Rating) − 1.948 (No. of codfish per 75 lb. box)

($R_m$ = 0.927, F = 15.317, $p<0.01$, d.f. = 2,5)[3]

Sub. No. 3 Heart Rate = 28.06 + 0.941 (Performance Rating) − 0.475 (No. of codfish per 75 lb. box)

($R_m$ = 0.758, F = 3.370, $p<0.10$, d.f. = 2,5)

Sub. No. 4 Heart Rate = 79.85 + 0.29 (Performance Rating) − 0.15 (No. of codfish per 75 lb. box)

($R_m$ = 0.916, F = 18.322, $p<0.01$, d.f. = 2,7)

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[1]Refer Chapter 5, p. 180 of this report.

[2]In performance rating systems, performance rating is represented by percentage. "Motion and Time Study" by Barnes (1968), p. 380.

[3]$R_m$ is called multiple coefficient of correlation. F relates to the test statistic, called overall F-ratio. $R_m$ and F-ratio are computed to test the significance of regression coefficients in the multiple regression equation. The degrees of freedom (d.f.) associated with overall F are K and (N−K−1) where N = sample size and K = number of independent variables in the equation. "Statistical Package for the Social Sciences", by Nie, Hull, Jenkins, Bent, 1975, p. 335.

Systolic Blood Pressuse ($S_A$) (mm of Hg.) (Dependent Variable) Vs. Performance Rating, % (Independent Variable) No. of Codfish per 75 lb. box (Independent Variable)

(Refer Table 30)

Sub. No. 1 Systolic Blood Pressure ($S_A$) = -82.91 + 1.827 (Performance Rating) + 1.931 (No. of codfish per 75 lb. box)
($R_m$ = 0.897, F = 10.302, $p < 0.05$, d.f. = 2, 5)

Sub. No. 2 Systolic Blood Pressure ($S_A$) = 115 + 0.339 (Performance Rating) + 0.095 (No. of codfish per 75 lb. box)
($R_m$ = 0.774, F = 10.490, $p < 0.05$, d.f. = 2,6)

Sub. No. 4 Systolic Blood Pressure ($S_A$) = 97.43 + 0.337 (Performance Rating) + 0.181 (No. of codfish per 75 lb. box)
($R_m$ = 0.805, F = 6.431, $p < 0.05$, d.f. = 2,7)

Mean Heart Rate (H/R) x Systolic Blood Pressure ($S_A$) (beats/min. x mm of Hg.) (Dependent Variable) Vs. Performance Rating, % (Independent Variable) No. of Codfish per 75 lb. box (Independent Variable)

(Refer Table 30)

Sub. No. 1 (H/R x $S_A$) = -8952 + 277.45 (Performance Rating) - 110.7 (No. of codfish per 75 lb. box)
($R_m$ = 0.952, F = 23.973, $p < 0.01$, d.f. = 2,5)

Sub. No. 4 (H/R x $S_A$) = 6807 + 74.78 (Performance Rating) - 7.18 (No. of codfish per 75 lb. box)
($R_m$ = 0.980, F = 194.25, $p < 0.001$, d.f. = 2,7)

The 'partial F-ratio'[1] values, of independent variables, i.e., performance rating and number of codfish per 75 lb. box with different physiological parameters, such as mean heart rate, blood pressure, etc., were obtained using multiple regression analysis and are presented in

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[1]Partial F is the F-ratio between two variables (dependent and independent) while adjusting for the effects of one or more additional independent variables on the dependent variable.

Tables 33 and 34.

The multiple regression analysis showed that predictions for physiological load parameters such as mean heart rate, blood pressure and product of mean heart rate and blood pressure were improved, as noted by the increase in the value of coefficient of determination ($R^2$),[1] when both performance rating and number of codfish per 75 lb. box were used together than when performance rating was used alone, as in simple linear analysis. For example, the value of coefficient of determination ($R^2$) for dependent variable mean heart rate increased from 0.576 (Table 21), when only one independent variable speed of filleting was used as in linear regression analysis, to 0.859 (Table 30) for Subject 1, when two independent variables (speed of filleting and number of codfish per 75 lb. box) were used together as in multiple regression analysis. The reason for this improvement in prediction for physiological load parameter such as mean heart rate, etc. is that in this investigation, as discussed earlier, both speed of filleting (performance rating) and number of codfish per 75 lb. box were independently observed to be in linear relationship with physiological load parameter such as mean heart rate, etc.[2] Therefore, when these two independent variables (speed of filleting and number of codfish per 75 lb. box) are grouped together, as in multiple regression analysis, they together give a better prediction of dependent variable such as heart rate, etc. than either variable alone.

The multiple regression analysis also showed that positive significant linear relationships existed between speed of filleting (perform-

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[1] Coefficient of determination ($R^2$) is a test statistic which enables us to state the relative amount of variation in the dependent variable which has been explained by the estimating equation. 'Applied General Statistics' by Croxton, Cowden and Klein 1967, p. 393.

[2] Refer pp. 104, 111, of this report.

ance rating) and mean heart rate for Subjects 1, 3 and 4 (Table 33), and between speed of filleting and systolic blood pressure for Subjects 1, 2 and 4 (Table 34), and between speed of filleting and product of mean heart rate and systolic blood pressure for Subjects 1 and 4 (Table 33), after the effect of number of codfish per box on the above mentioned physiological load parameters was controlled. Number of codfish per 75 lb. box was found to have negative linear significant relationship with mean heart rate for Subjects 1 and 4 (Table 33)[1], but no relationship was observed between number of codfish per 75 lb. box and systolic blood pressure and product of mean heart rate and systolic blood pressure (Tables 33 and 34), after the effect of speed of filleting on the above mentioned physiological correlates was controlled.

For this investigation, altogether 35 experiments were performed on an individual type filleting table layout by four subjects. It was observed from multiple regression analysis that in some cases relationships between two variables were significant for two or three subjects but not for all the subjects. For example, the partial relationship between speed of filleting (performance rating) and systolic blood pressure was significant for Subjects 1, 2 and 4 but not significant for Subject 3 (Table 30). Now because other variables such as work layout, method of filleting, general environmental conditions, etc. have been kept constant for all the subjects and independent variable size of fish, or in other words number of codfish per 75 lb. box, has been controlled statistically,[2] therefore this variation in the results may be because

[1]For explanation, refer p.111, of this report.

[2]Refer p.113, of this report.

of subject variation or because of some other factors unaccounted for.

A multiple linear regression analysis, using dummy variables,[1] was therefore used to pool all the experiments conducted by different subjects, in a special way, so as to give the overall trend or relationship between performance rating (speed of filleting), size of codfish and physiological parameters such as mean heart rate, systolic blood pressure, etc. Using dummy variables, it was possible to adjust or control the effect of the subject (a nominal scale variable) on the response (mean heart rate, blood pressure, etc.). Therefore, 4 different blocks of data from 4 different subjects could be grouped together and treated as one group. For this investigation, a set of dummy variables represented different subjects. The multiple linear regression equation used was of the form:

$$Y = a + b_1 (X_1) + b_2 (X_2) + b_3 D_1 + b_4 D_2 + b_5 X_1 D_1 + b_6 X_1 D_2 + b_7 X_2 D_1 + b_8 X_2 D_2$$

where $Y$ = Dependent variable (mean heart rate (H/R), blood pressure (B/P), etc.)

$X_1$ and $X_2$ = Independent variables (performance rating, number of codfish per 75 lb. box)

$a$ = a constant

$b_1$, $b_2$, etc. = partial regression coefficients associated with independent variables $X_1$, $X_2$, etc.

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[1] "Statistical Package for the Social Sciences" (SPSS) by Nie, Hull, Jenkins, Steinbrenner and Bent (1975), pp. 373–383; "Applied Regression Analysis" by Draper and Smith (1966), pp. 134–141; see Appendix A, p195; Appendix B, pp208–221

$D_1$ and $D_2$[1] = a set of dummy variables[2] representing three subjects as in the case of H/R and (H/R x B/P) analysis

$X_1D_1$ and $X_1D_2$ = the variation in rating associated with subject variation

$X_2D_1$ and $X_2D_2$ = the variation in number of codfish per 75 lb. box associated with subject variation

The overall correlation or overall F,[3] given by this equation, would show the overall dependence of the dependent variable (mean heart rate (H/R), blood pressure (B/P), etc.) on the three independent variables (performance rating, number of codfish per 75 lb. box, and subject) for the combined experiments. The overall partial correlations of different independent variables with different dependent variables were obtained by entering different set of variables in the above multiple regression equation. For example, the overall partial correlation or overall partial F for performance rating with mean heart rate was obtained by first entering the variables Y, $X_1$, $X_2$, $D_1$, $D_2$, $X_2D_1$, and $X_2D_2$ in the multiple regression equation and then getting the regression of Y with $X_2$, $D_1$, $D_2$, $X_2D_1$ and $X_2D_2$. The partial correlation of variable not in

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[1] $D_1$ and $D_2$ are used for subject identification as follows:

for 3 subjects:

| $D_1$ | $D_2$ | | |
|---|---|---|---|
| 1 | 0 | = | Subject No. 1 |
| 0 | 1 | = | Subject No. 2 |
| 0 | 0 | = | Subject No. 3 |

"Applied Regression Analysis" by Draper and Smith (1966), p. 136.

[2] Another dummy variable ($D_3$) and its corresponding products with independent variables ($X_1$ and $X_2$) are added in the above multiple regression equation when four subjects are to be represented, as in the case of blood pressure (B/P) analysis.

[3] Overall F relates to the test statistic 'overall F-ratio,' computed to test the significance of regression coefficients, in the multiple regression equation.

the equation,[1] which in this case is $X_1$, i.e., performance rating, gives the required overall partial correlation of performance rating (speed of filleting) with mean heart rate while adjusting or controlling for the effect of independent variables, i.e., number of codfish per 75 lb. box and subject on the dependent variables, i.e., mean heart rate of the operator.

The significant multiple relationships obtained using dummy variables are as follows:

Heart Rate (H/R) Vs. Performance Rating ($X_1$), No. of Codfish per 75 lb. box ($X_2$), Subject

(Refer Table B-5, p. 214)

$$\text{Heart Rate (H/R)} = 111.01 + 0.46\,(X_1) - 1.95\,(X_2) - 82.94\,(D_1) - 31.16\,(D_2) + 0.48\,(X_1D_1) - 0.17\,(X_1D_2) + 1.47\,(X_2D_1) + 1.80\,(X_2D_2)$$

$(R_m = 0.896,\ F = 8.733,\ p < 0.01,\ d.f. = 8/17)$

Systolic Blood Pressure ($S_A$) Vs. Performance Rating ($X_1$), No. of Codfish per 75 lb. box ($X_2$), Subject

$$\text{Systolic blood pressure } (S_A) = 97.43 + 0.34\,(X_1) + 0.18\,(X_2) - 180.3\,(D_1) + 18.58\,(D_2) + 48.62\,(D_3) + 1.49\,(X_1D_1) + 0.002\,(X_1D_2) - 0.33\,(X_1D_3) + 1.75\,(X_2D_1) - 0.20\,(X_2D_2) + 0.008\,(X_2D_3)$$

$(R_m = 0.8972,\ F = 8.6255,\ p < 0.01,\ d.f. = 11/23)$

Heart Rate (H/R) x Systolic Blood Pressure ($S_A$) Vs. Performance Rating ($X_1$), No. of Codfish/75 lb. box ($X_2$), Subject

$$\text{Heart rate} \times \text{Systolic blood pressure} = -8952 + 277.4\,(X_1) - 110.7\,(X_2) + 12344\,(D_1) + 15793\,(D_2) - 131.8\,(X_1D_1) - 202.9\,(X_1D_2) + 58.6\,(X_2D_1) + 110.2\,(X_2D_2)$$

$(R_m = 0.9238,\ F = 12.364,\ p < 0.01,\ d.f. = 8/17)$

[1] Appendix B, p. 212

The overall partial F values of independent variables (performance rating and number of codfish per 75 lb. box) with different physiological parameters (mean heart rate, systolic blood pressure, etc.) were obtained using multiple regression analysis with dummy variables and are presented in Table 37.

The above multiple linear regression analysis using dummy variables showed that for this study as a whole, significant positive relationships existed between speed of filleting (performance rating) and mean heart rate, systolic blood pressure and product of mean heart rate and systolic blood pressure of the filleting operator, once the effect of the number of codfish per 75 lb. box (or in other words size of fish), and also the effect of subject variation on the above mentioned physiological parameters were controlled. Thus, in this investigation, an increase in the speed of filleting causes a significant increase in the mean heart rate and systolic blood pressure of the operator and vice versa (Table 37).

The multiple linear regression analysis using dummy variables also showed that for this study as a whole, negative significant relationship existed between number of codfish per 75 lb. box and the mean heart rate of the filleting operator, once the effect of speed of filleting and subject variation on the mean heart rate was controlled statistically (Table 37). The mean heart rate of the filleting operator increases significantly as he fillets a lower number of codfish per 75 lb. box or a bigger size codfish. No significant relationship was observed between number of codfish per 75 lb. box and systolic blood pressure and product of mean heart rate and systolic blood pressure of the operator for this investigation (Table 37).

## 4.3 RELATIONSHIP BETWEEN NUMBER OF ROUND CODFISH PER 75 LB. BOX AND NORMAL OUTPUT RATE[1] (LBS./HR.)

Scatter diagram (Fig. 32) shows a curvilinear relationship between number of codfish per box (or in other words size of fish), and the normal output rate (lbs./hr.). It was observed that a decrease in number of codfish (or an increase in the size of codfish), resulted in an increase in the normal output rate (roundfish as well as fillets (skin-on)) of the filleting operator and vice versa. However, the rate of decrease of normal output per hour for the small size (large number of fish per given weight) was observed to be not as high when compared to the large size (small number of codfish per given weight).

Output of fillets per hour for a certain size of fish is the function of the speed of filleting and the amount of meat removed as a ratio of the total weight of the fish, i.e., yield. Speed is directly related to the pace and effort, whereas yield seems to depend on many factors such as skill of the operator, speed of filleting, size of the fish, etc. Here since the output per hour for all the observations were normalized so as to give normal output rate and that all the operators filleted a wide range of fish size, the factor which could contribute to the slow rate of reduction of the normal output per hour for small size fish is the effect of size of fish on yield. It was observed from scatter diagram (Figure 27) drawn between number of codfish per 75 lb. box and percentage yield and also from linear regression analysis results (Table 27) that percentage yields were slightly higher for the small size codfish (large number of fish per 75 lb. box) as compared to the

[1] Normal output rates of both round codfish and fillets were considered for this investigation.

large size codfish (small number of fish per 75 lb. box) for Subjects 1, 2 and 4. However, no significant relationship was observed between size of fish and percentage yield for any of the four subjects.

Table 26 and Figure 32 show that significant non-linear (curvilinear) relationships existed between number of codfish per 75 lb. box and normal output rates (both roundfish and fillets) for each of the subjects, i.e., Subject No. 1 ($p < 0.01$, d.f.=6), Subject No. 2 ($p < 0.05$, d.f. = 7), Subject No. 3 ($p < 0.05$, d.f. = 6) and Subject No. 4 ($p < 0.001$, d.f. = 8).

The normal output rate of round codfish[1] varied from 287 lbs. per hour for the small size inshore (trap) undressed cod, i.e., 43 number of fish per 75 lb. box to 1032 lbs. per hour for large size inshore (trap) undressed codfish, i.e., 21 number of fish per 75 lb. box.

The normal output rate of fillets (skin-on)[2] varied from 114.7 lbs./hr. for the small size inshore (trap) undressed codfish (43 number of fish per 75 lb. box) to 461 lbs./hr. for large size inshore (trap) undressed codfish (21 number of fish per 75 lb. box).

The significant relationship observed between size of codfish and normal output rate suggests that management in fish plants should also establish the above relationship for a range of different species, input quality of fish, offshore-inshore fish and the dressed or undressed condition of the fish.

The non-linear relationship tested between size of codfish and normal output rate was as follows:

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[1]Refer Tables 17 to 20.

[2]Ibid.

Non-Linear Form (Converted to Linear Form)

$$\text{Normal output rate (lbs/hr)} = a \times (\text{No. of codfish/75 lb. box})^{b}$$ [1]

Or

$$\log_{10}(\text{Normal output rate (lbs/hr)}) = \log_{10}(a) + b \log_{10}(\text{No. of codfish/75 lb. box})$$

The following significant relationships were obtained: (Table 26)

Sub. No. 1 $\log_{10}$ (Normal output rate of fillets) = 4.839 − 1.672 $\log_{10}$ (no. of codfish per 75 lb. box)

($R = -0.905$, $p < 0.01$, d.f. = 6)

Sub. No. 2 $\log_{10}$ (normal output rate of fillets) = 3.783 − 0.94 $\log_{10}$ (no. of codfish per 75 lb. box)

($R = -0.713$, $p < 0.05$, d.f. = 7)

Sub. No. 3 $\log_{10}$ (normal output rate of fillets) = 3.069 − 5.249 $\log_{10}$ (no. of codfish per 75 lb. box)

($R = -0.833$, $p < 0.05$, d.f. = 6)

Sub. No. 4 $\log_{10}$ (normal output rate of fillets) = 3.405 − 0.78 $\log_{10}$ (no. of codfish per 75 lb. box)

($R = -0.973$, $p < 0.01$, d.f. = 8)

also

Sub. No. 1 $\log_{10}$ (normal output rate of codfish[2]) = 5.343 − 1.790 $\log_{10}$ (no. of codfish per 75 lb. box)

($R = -0.905$, $p < 0.01$, d.f. = 6)

Sub. No. 2 $\log_{10}$ (normal output rate of codfish) = 4.369 − 1.046 $\log_{10}$ (no. of codfish per 75 lb. box)

($R = -0.670$, $p < 0.05$, d.f. = 7)

Sub. No. 3 $\log_{10}$ (normal output rate of codfish) = 3.124 − 0.292 $\log_{10}$ (no. of codfish per 75 lb. box)

($R = -0.605$, $p < 0.10$, d.f. = 6)

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[1] 'a' and 'b' are the regression co-efficients of the equation

[2] Head-on, gut-in round codfish.

Sub. No. 4 $\log_{10}$ (normal output rate of codfish) = 3.890 − 0.820 $\log_{10}$ (no. of codfish per 75 lb. box)

$$(R = -0.963,\ p < 0.01,\ d.f. = 8)$$

## 4.4 RELATIONSHIP BETWEEN SPEED OF FILLETING, NUMBER OF ROUND CODFISH PER 75 LB. BOX AND YIELD OF FILLETING

Linear relationships were observed between speed of filleting (performance rating in percent) and percentage yield (Figure 26). It was observed that percentage yield decreased as speed of filleting increased and vice versa. The trend was the same for all the experiments.

The following significant linear relationships were observed for all the subjects (Table 27):

Sub. No. 1 Yield % = 63.4 − 0.16 (performance rating in percent)
$(R = -0.699,\ p < 0.05,\ d.f. = 6)$

Sub. No. 2 Yield % = 46.6 − 0.08 (performance rating in percent)
$(R = -0.825,\ p < 0.01,\ d.f. = 7)$

Sub. No. 3 Yield % = 47.2 − 0.02 (performance rating in percent)
$(R = -0.561,\ p < 0.20,\ d.f. = 6)$

Sub. No. 4 Yield % = 43.4 − 0.06 (performance rating in percent)
$(R = -0.64,\ p < 0.05,\ d.f. = 8)$

The decrease in yield with the increase in speed of filleting could be explained in the following way. Yield is defined as the ratio of weight of fillets obtained to the weight of fish processed. As the operator increases his speed of filleting, the operator slightly deviates from using the prescribed sequence of all the different hand motions required for filleting the fish correctly and in the process sometimes skips a few required hand motions and so is able to extract less amount of meat from the fish, thereby giving a decrease in the yield.

It was also observed that the average percentage yield (skin-on fillets) of Subject No. 1 with 10 years of filleting experience was higher, i.e., 45.75%, as compared to the average yields of 37.72% for Subject No. 2 with four years of filleting experience, and 37.06% for Subject No. 4 with about one year of filleting experience.[1] The increase in yield with experience is to be expected since one of the main factors affecting yield is skill.

Multiple linear regression analysis was used to evaluate the affect of speed of filleting (independent variable) and number of codfish per 75 lb. box (another independent variable), on the percentage yield (dependent variable) of the filleting operator. The following multiple regression equation was used:

Yield % = a + b (performance rating%) + c (no. of round codfish per 75 lb. box)

where a = constant
b and c = partial regression coefficients associated with independent variables, i.e., performance rating and number of codfish/75 lb. box

The 'partial F-ratio' values of performance rating and number of codfish per 75 lb. box with percentage yield for different subjects are presented in Table 35. This study showed that speed of filleting (performance rating %) had significant negative linear relationship with percentage yield for Subject Nos.[2] 1, 2 and 4, once the effect of number of codfish per 75 lb. box (or in other words size of fish), on percentage yield was controlled statistically.[3] Table 35 also showed that no significant relationship existed between number of codfish per 75 lb. box and

[1]Refer Table 27.

[2]Subject No. 2 ($p < 0.01$), Subject Nos. 1 and 4 ($p < 0.10$) -- Table 35.

[3]Refer p. 113, of this report.

percentage yield for Subject Nos. 1, 2, 3 and 4.

The multiple linear regression analysis, using dummy variables for subjects, showed that for this study as a whole, a significant negative linear relationship ($p < 0.01$) existed between speed of filleting and percentage yield (Table 37). However, no significant relationship was observed between number of codfish per 75 lb. box and percentage yield, for this study as a whole (Table 37).

The present investigation has shown that as the operator increases his speed of filleting, his yield decreases. It has also shown that an increase in the speed of filleting causes a significant increase in the mean heart rate of the operator.[1] Scatter diagram (Figure 28) was, therefore, drawn between percentage yield and mean heart rate of the operator.

Results from the above scatter diagrams and linear regression analysis (Table 29) indicated a linear relationship trend with negative slope between percentage yield and mean heart rate of each operator.[2] However, no significant relationship was observed between percentage yield and operator's mean heart rate for all the subjects (Table 29).

In fish processing plants, where the productivity and earnings of the company depend on both higher yield and faster throughput, the cost of the raw material is much higher than the cost of labour. Results from the above analysis therefore suggest that working for higher yields,

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[1] Refer p. 104, of this report.

[2] Heart rate for subject 2 could not be recorded -- failure of heart rate recording electrodes.

which is associated with lower speed of filleting and consequently with lower mean heart rates of the operators, is important both from economical as well as physiological point of view.

### 4.5 RELATIONSHIP BETWEEN SPEED OF FILLETING, NUMBER OF ROUND CODFISH PER 75 LB. BOX AND ACTUAL OUTPUT RATE[1]

Scatter diagrams (Figs. 29 to 31) showed straight line relationships between speed of filleting (performance rating %), number of codfish per 75 lb. box and actual output rate (lbs./hr.). It was observed that actual output rate (round fish as well as fillets) increased as speed of filleting of the operator increased and vice versa (Tables 27 and 28). It was also observed that as the operator filleted a smaller number of round codfish per 75 lb. box (or a bigger size fish), his actual output rate increased (Table 28). The linear regression of speed of filleting on actual output rate (round codfish) (Table 28) was significant at $p < 0.01$ (Subject No. 2); and $p < 0.05$ (Subject Nos. 3 and 4). The linear regression of number of codfish per 75 lb. box on actual output rate (round codfish) was significant at $p < 0.01$ (Subject Nos. 1 and 4) (Table 28).

An increase in the actual output rate with an increase in speed of filleting is obvious. Actual output rate of roundfish or fillets is given by total amount of fish processed or fillets obtained per hour. As the operator increases his speed of filleting, he is able to process a given weight of fish (or produce a given weight of fillets) in less time, thereby increasing actual output rate (lbs./hr.).

The increase in the actual output rate of the operator as he fillets a smaller number of round codfish per 75 lb. box (or a bigger size fish), could be explained in the following way. As the number of codfish per 75 lb.

[1]Actual output rates of both roundfish and fillets were considered for this investigation.

box decreases, even though the fish will be of larger size, the operator will be able to process the fish in a shorter time because the total number of hand motions involved during the whole filleting operation will be reduced. Less number of codfish means the operator would be doing the whole filleting operation in less amount of time. This saving of time will give rise to higher output rate of the filleting operator.

Multiple linear regression analysis was used to evaluate the effect of number of round codfish per 75 lb. box (independent variable) and speed of filleting (another independent variable) on the actual output rate (dependent variable) of the filleting operator. The following multiple regression equation was used:

Actual output rate (lbs./hr.) = a + b (performance rating %) + c (no. of round codfish per 75 lb. box)

where a = constant
b and c = partial regression coefficients associated with independent variables, i.e., performance rating and no. of codfish/75 lb. box

The 'partial F-ratio'[1] values of performance rating and number of codfish per 75 lb. box with actual output rate for different subjects are presented in Table 36. It was observed that speed of filleting had significant positive linear relationship with actual output rate of fillets, once the effect of size of fish on actual output rate was controlled statistically ($p < 0.01$, for subjects 2 and 3; $p < 0.05$ for subject 4). Table 36 also showed that once the effect of speed of filleting on actual output rate is controlled, an increase in the number of codfish per 75 lb. box (or a decrease in size (lenght) of fish), causes a significant decrease in the

[1] 'Partial F-ratio' is the 'F-ratio' value between 2 variables (independent and dependent) while adjusting statistically, for the effects of one or more additional independent variables on the dependent variable. Refer p. 113, of this report.

actual output rate of fillets ($p < 0.01$ for subjects 1,2 and 4; $p < 0.05$ for subject 3).

This study (Table 32) also showed that the nature of the relationship and the significant levels of speed of filleting and number of codfish per 75 lb. box with actual output rate remained almost the same when dependable variable actual output rate of fillets (lbs./hr.) was replaced by actual output rate of round codfish (lbs./hr.), in the above multiple linear regression analysis.[1]

The multiple linear regression analysis using dummy variables for subjects showed that for this study as a whole, the speed of filleting (performance rating%) and size (length) of round codfish had significant positive linear relationships with actual output rate (cod fillets) of the filleting operator ($p < 0.001$, Table 37).

Since both speed of filleting and size of fish are significantly related to actual output rate (fillets and roundfish) individually, multiple regression analysis gives a much better prediction of actual output rate (Table 32), than given by simple linear analysis (Tables 27 and 28), when only one of the above independent variables could be used.[2] The analysis of multiple regression should, therefore, help management in understanding the various factors affecting the work performance of the operator.

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[1]This is because in fish filleting, the amount of meat that could be extracted from a fish (i.e. weight of fillets) is a certain fixed proportion of the total weight of the round fish. Therefore, the ratio of actual output rate of fillets to actual output rate of round fish remains almost constant.

[2]This is noted by the increase in the value of coefficient of determination ($R^2$), when both performance rating and number of round codfish per 75 lb. box were used together as in multiple regression analysis (Table 32), than when performance rating or no. of round codfish per 75 lb. box was used alone, as in simple linear regression analysis (Tables 27 and 28). Also refer footnote 1 of page 118, of this report.

OBSERVATIONS:

Species: Cod

Offshore/Inshore: Inshore-Trap

Input Quality: Grade No. 1, Undressed, [1]
Fresh - 1½ days old iced.

Date: 12 June, 1974.

Place: Witless Bay
Fish Plant, Nfld.

Subject No.: 1

| Expt. No. | Weight of Fish (lbs.) | No. of Fish /75 lb. box | Time to Fillet (mins.) | Performance Rating Sample (%) | Blood Pressure (mm Hg) | | | | Wt. of Fillets (lbs.) | Mean H/R (beats/ minute) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Before | | After | | | |
| | | | | | S | D | S | D | | |
| 1 | 75 | 23 | 5.35 | 115, 115, 120, 115, 120, 115, 120 | 168<br>165 | 105<br>109 | 162<br>181 | 112<br>109 | 33.5 | 124.8 |
| 2 | 75 | 21 | 4.00 | 105, 110, 110, 110, 110 | 157<br>140 | 110<br>112 | 178<br>150 | 102<br>112 | 33.5 | 120.4 |
| 3 | 75 | 25 | 7.25 | 105, 100, 100, 100, 100 | 176<br>140 | 79<br>106 | 158<br>132 | 108<br>114 | 35.5 | 106.5 |

Table No. 9: Shows various measurements recorded during fish filleting experiments.

S = Systolic
D = Diastolic
H/R = Heart rate

1 Fish was caught one and one-half days before and was chilled with ice to avoid deterioration. Undressed means 'head on-gut in' round cod fish.

Subject No. 1
Data continued from Table No. 9

| Expt. No. | Weight of fish (lbs.) | No. of Fish/ 75 lb. box | Time to Fillet (mins.) | Performance Rating Sample (%) | Blood Pressure (mm. Hg) Before S | Before D | After S | After D | Wt. of Fillets (lbs.) | Mean H/R (beats/ minute) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 75 | 25 | 6.42 | 95, 100, 100 100, 95, 95, 100, 105 | 145<br>158 | 104<br>101 | 144<br>136 | 102<br>114 | 36.5 | 108.1 |
| 5 | 75 | 25 | 5.30 | 105, 110, 110, 115, 115, 115, 120, 120 | 141<br>147 | 99<br>100 | 176<br>180 | 107<br>110 | 32.5 | 110.4 |
| 6 | 75 | 24 | 5.13 | 110, 110, 115 120, 115, 120, 120, 125 | 137<br>140 | 103<br>106 | 170<br>178 | 107<br>106 | 34 | 115.6 |
| 7 | 75 | 28 | 7.42 | 95, 100, 95, 100, 100, 105, 105, 105 | 150<br>143 | 112<br>110 | 160<br>168 | 118<br>110 | 33.75 | 103.5 |
| 8 | 75 | 28 | 7.63 | 100, 105, 105, 105, 110, 100, 110, 110 | 143<br>136 | 104<br>103 | 172<br>150 | 110<br>101 | 35.25 | 106.9 |

Table No. 10: Shows various measurements recorded during fish filleting experiments.

S = Systolic
D = Diastolic
H/R = Heart rate

OBSERVATIONS:

Species: Cod

Offshore/Inshore: Inshore - Trap

Input Quality: Grade No. 1, Undressed, Fresh -7 hours old iced.

Date: 26 June, 1974.

Place: Witless Bay Fish Plant, Nfld.

Subject No.: 2

| Expt. No. | Weight of Fish (lbs.) | No. of Fish/75 lb. box | Time to Fillet (mins.) | Performance Rating Sample (%) | Blood Pressure (mm. Hg) Before S | Blood Pressure (mm. Hg) Before D | Blood Pressure (mm. Hg) After S | Blood Pressure (mm. Hg) After D | Wt. of Fillets (lbs.) | Mean H/R (beats/ minute) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 75 | 32 | 7.47 | 100, 100, 105, 100, 105 | 148<br>146 | 107<br>97 | 159<br>146 | 81<br>111 | 28.62 | - |
| 2 | 75 | 34 | 8.67 | 95, 95, 90, 95, 100, 95 | 150<br>144 | 98<br>104 | 148<br>142 | 84<br>98 | 28.87 | - |
| 3 | 75 | 27 | 7.3 | 95, 100, 95, 100 | 150<br>141 | 104<br>111 | 147<br>152 | 91<br>107 | 28.37 | - |

Table No. 11: Shows various measurements recorded during fish filleting experiments.

S - Systolic
D - Diastolic
H/R - Heart rate

Note: Heart rate not recorded for this subject. (failure of heart rate recording equipments)

Subject No. 2
Data continued from Table No. 11

| Expt. No. | Weight of Fish (lbs.) | No. of Fish /75 lb. box | Time to Fillet (mins.) | Performance Rating Sample (%) | Blood Pressure (mm Hg) | | | | Wt. of Fillets (lbs.) | Mean H/R (beats/minute) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Before | | After | | | |
| | | | | | S | D | S | D | | |
| 4 | 75 | 35 | 5.75 | 110, 115, 120, 125, 130, 125, 125 | 160<br>145 | 90<br>111 | 157<br>150 | 95<br>94 | 27.31 | - |
| 5 | 75 | 32 | 5.30 | 110, 115, 120, 125, 125, 125, | 148<br>145 | 109<br>108 | 150<br>152 | 103<br>104 | 27.75 | - |
| 6 | 75 | 38 | 10.2 | 105, 105, 105, 100, 105, 105 | 154<br>149 | 94<br>92 | 159<br>149 | 93<br>91 | 29.62 | - |
| 7 | 75 | 41 | 9.83 | 100, 100, 100, 100, 100, 100 | 154<br>148 | 92<br>80 | 149<br>143 | 97<br>98 | 29.57 | - |
| 8 | 75 | 30 | 4.83 | 115, 120, 125, 130, 130, 135, 135, 130 | 150<br>136 | 108<br>117 | 166<br>148 | 88<br>98 | 27.62 | - |
| 9 | 75 | 35 | 5.06 | 115, 120, 120, 125, 130, 135, 130, 135 | 148<br>147 | 100<br>102 | 172<br>156 | 83<br>102 | 26.94 | - |

Table No. 12: Shows various measurements recorded during fish filleting experiments.

Note: Heart rate not recorded (failure of equipments)

S = Systolic
D = Diastolic
H/R = Heart rate

**OBSERVATIONS:**

**Species:** Cod

**Offshore/Inshore:** Inshore - Trap

**Input Quality:** Grade No. 1, Undressed
Fresh - 10 hours old iced.

**Date:** 3 July, 1974

**Place:** Witless Bay Fish Plant, Nfld.

**Subject No.:** 3

| Expt. No. | Weight of Fish (lbs.) | No. of Fish/75 lb. box | Time to Fillet (mins.) | Performance Rating Sample (%) | Blood Pressure (mm. Hg) Before S | Before D | After S | After D | Wt. of Fillets (lbs.) | Mean H/R (beats/minute) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 75 | 43 | 9.27 | 100, 100, 105, 105, 100, 100 | 161<br>153 | 100<br>95 | 156<br>155 | 93<br>83 | 26.75 | 110.4 |
| 2 | 75 | 50 | 11.17 | 100, 100, 100, 105, 105, 105 | 160<br>172 | 77<br>82 | 162<br>171 | 70<br>65 | 26.38 | 105.1 |
| 3 | 75 | 47 | 8.88 | 105, 105, 110, 110, 110, 115, 115, 115, 120, 120 | 148<br>152 | 78<br>72 | 162<br>158 | 80<br>76 | 26.75 | 111.9 |

Table No. 13: Shows various measurements recorded during fish filleting experiments.

S = Systolic
D = Diastolic
H/R = Heart rate

Subject No. 3
Data continued from table No. 13

| Expt. No. | Weight of Fish (lbs.) | No. of Fish/75 lb. box | Time of Fillet (mins.) | Performance Rating Sample (%) | Blood Pressure (mm. Hg) Before S | Before D | After S | After D | Wt. of Fillets (lbs.) | Mean H/R (beats/minute) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 75 | 56 | 9.68 | 105, 105, 110, 110, 115, 120, 115, 120, 115 | 153<br>161 | 92<br>92 | 160<br>152 | 80<br>93 | 26.75 | 108.1 |
| 5 | 75 | 39 | 10.13 | 95, 100, 100, 100, 100 | 160<br>142 | 92<br>85 | 140<br>149 | 90<br>94 | 27.88 | 100.4 |
| 6 | 75 | 40 | 10.40 | 100, 95, 100, 100, 100 | 149<br>139 | 90<br>74 | 170<br>155 | 86<br>83 | 29.38 | 100.8 |
| 7 | 75 | 49 | 8.60 | 110, 115, 115, 120, 120, 125, 125, 125, 125 | 159<br>156 | 95<br>93 | 164<br>149 | 101<br>108 | 26.38 | 118.7 |
| 8 | 75 | 49 | 9.85 | 105, 105, 105, 105, 110 | 135<br>132 | 105<br>92 | 143<br>134 | 95<br>82 | 26.25 | 94.8 |

Table No. 14: Shows various measurements recorded during fish filleting experiments.

S = Systolic
D = Diastolic
H/R = Heart rate

OBSERVATIONS:

Species: Cod

Offshore/Inshore: Inshore - Trap

Input Quality: Grade No. 1, Undressed, Fresh -1 day old iced.

Date: 17 July, 1974

Place: Witless Bay Fish Plant, Nfld.

Subject No.: 4

| Expt. No. | Weight of Fish (lbs.) | No. of Fish/75 lb. box | Time to Fillet (mins.) | Performance Rating Sample (%) | Blood Pressure (mm. Hg) Before S | Before D | After S | After D | Wt. of Fillets (lbs.) | Mean H/R (beats/minute) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 75 | 45 | 13.37 | 90, 90, 90, 90, 95, 95, 95, 95, | 152<br>130 | 82<br>87 | 134<br>133 | 76<br>80 | 26.75 | 99.7 |
| 2 | 75 | 24 | 8.65 | 95,90,90,95, 90,95 | 153<br>121 | 86<br>91 | 138<br>130 | 70<br>90 | 28.5 | 104.0 |
| 3 | 75 | 27 | 6.92 | 110,110,105, 110,115,105, 110 | 129<br>128 | 71<br>82 | 138<br>138 | 90<br>90 | 27.62 | 109.2 |

Table No. 15: Shows various measurements recorded during fish filleting experiments.

S = Systolic
D = Diastolic
H/R = Heart rate

Subject No. 4
Data continued from table No. 15

| Expt. No. | Weight of Fish (lbs.) | No. of Fish/75 lb. box | Time to Fillet (mins.) | Performance Rating Sample (%) | Blood Pressure (mm. Hg) Before S | Before D | After S | After D | Wt. of Fillets (lbs.) | Mean H/R (beats/minute) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 75 | 48 | 10.23 | 110,110,115, 115,110,115, 120,120,115 | 155<br>135 | 94<br>88 | 154<br>129 | 87<br>72 | 27.75 | 110.2 |
| 5 | 75 | 46 | 16.93 | 85,80,85,85, 80,80,75,80, 80,80 | 136<br>124 | 60<br>86 | 147<br>130 | 88<br>83 | 28.5 | 94.8 |
| 6 | 75 | 46 | 19.30 | 75,80,75,75, 70,75,75,75 | 133<br>118 | 90<br>78 | 122<br>132 | 85<br>90 | 28.5 | 95.3 |
| 7 | 75 | 37 | 8.85 | 110,115,115, 120,125,125, 125,130,130, 135,130 | 151<br>148 | 70<br>84 | 138<br>164 | 70<br>86 | 26.62 | 105.1 |
| 8 | 75 | 14 | 4.15 | 110,115,120, 125,125 | 118<br>136 | 80<br>87 | 142<br>130 | 75<br>94 | 25.75 | 114.3 |
| 9 | 75 | 15 | 5.52 | 100,105,105, 100,100,105 | 138<br>136 | 75<br>77 | 146<br>128 | 79<br>75 | 28 | 105.8 |
| 10 | 75 | 43 | 16.87 | 100,95,90, 90,95,95,90, 90 | 130<br>150 | 82<br>86 | 146<br>130 | 88<br>76 | 30 | 101.2 |

<u>Table No. 16</u>: Shows various measurements recorded during fish filleting experiment.

S = Systolic
D = Diastolic
H/R = Heart rate

| Experiment No. | No. of cod fish/75 lb box | Performance rating (average) (%) | Normal time to Fillet (min.) | Actual output rate (lbs/hr) | | Normal output rate (lbs/hr) | | Yield(%) (undressed cod, skin-on fillets) | Blood Pressure (average) (mm.Hg) | | Mean H/R (beats/min) | T.M.B.P. = $\frac{S_A+2D_A}{3}$ mm.Hg | H/R x $S_A$ (beats/min x mm.Hg) | H/R x T.M.B.P. (beats/min x mm.Hg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Fillets | Fish | Fillets | Fish | | $S_A$ | $D_A$ | | | | |
| 1 | 23 | 117.1 | 6.26 | 375.7 | 841.1 | 320.8 | 718.3 | 44.67 | 171.5 | 110.5 | 124.8 | 130.8 | 21403 | 16323 |
| 2 | 21 | 109 | 4.36 | 502.5 | 1124.9 | 461.2 | 1032 | 44.67 | 164 | 107 | 120.4 | 126 | 19745 | 15170 |
| 3 | 25 | 101 | 7.32 | 293.8 | 620.1 | 291.0 | 614 | 47.33 | 145 | 111 | 106.5 | 122.3 | 15442 | 13024 |
| 4 | 25 | 98.7 | 6.34 | 341.4 | 699.8 | 345.9 | 709 | 48.67 | 140 | 108 | 108.1 | 118.1 | 15134 | 12820 |
| 5 | 25 | 113.7 | 6.03 | 367.8 | 848.2 | 323.5 | 746 | 43.33 | 178 | 108.5 | 110.4 | 131.7 | 19651 | 14563 |
| 6 | 24 | 116.9 | 6.00 | 397.8 | 877.5 | 340.3 | 751 | 45.33 | 174 | 106.5 | 115.6 | 129 | 20114 | 14912 |
| 7 | 28 | 100.6 | 7.46 | 273.0 | 605.6 | 271.4 | 602 | 45.00 | 164 | 114 | 103.5 | 130.6 | 16974 | 13517 |
| 8 | 28 | 105.6 | 8.06 | 277.2 | 589.3 | 262.5 | 558 | 47.00 | 161 | 105.5 | 106.9 | 124 | 17210 | 13255 |

Table No. 17 : Calculations of average performance rating, actual and normal output rates, yield, average blood pressure etc., using Tables 9 and 10

Subject No.: 1

$S_A$ = Systolic blood pressure, recorded just after each filleting experiment

$D_A$ = Diastolic blood pressure, recorded just after each filleting experiment

H/R = Heart rate

T.M.B.P. = True mean blood pressure

| Experiment No. | No. of cod fish/75 lb box | performance rating average) (%) | Normal time to Fillet (min.) | Actual output rate (lbs/hr) | | Normal output rate (lbs/hr) | | Yield(%) (undressed cod, skin-on fillets | Blood pressure (average) (mm.Hg) | | T.M.B.P. $=\frac{S_A+2D_A}{3}$ (mm.Hg) | Mean heart rate[1] (beats/minute) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Fillets | Fish | Fillets | Fish | | $S_A$ | $D_A$ | | | | |
| 1 | 32 | 102 | 7.62 | 229.8 | 602 | 225.3 | 590 | 38.16 | 152.5 | 96 | 114.8 | – | | |
| 2 | 34 | 95 | 8.24 | 199.8 | 519 | 210.3 | 545 | 38.49 | 145 | 91 | 109 | – | | |
| 3 | 27 | 97.5 | 7.12 | 233.4 | 616 | 239.4 | 632 | 37.83 | 149.5 | 99 | 115.8 | – | | |
| 4 | 35 | 121.5 | 6.99 | 285 | 782 | 234.6 | 644 | 36.41 | 153.5 | 94.5 | 114.2 | – | | |
| 5 | 32 | 120 | 6.36 | 314.4 | 849 | 262 | 708 | 37.00 | 151 | 103.5 | 119.3 | – | | |
| 6 | 38 | 104.2 | 10.63 | 174.2 | 441 | 167.2 | 423 | 39.49 | 154 | 92 | 112.7 | – | | |
| 7 | 41 | 100 | 9.83 | 180.6 | 458 | 180.6 | 458 | 39.43 | 146 | 97.5 | 113.7 | – | | |
| 8 | 30 | 127.5 | 6.16 | 343.2 | 931 | 269.2 | 730 | 36.83 | 157 | 93 | 114.3 | – | | |
| 9 | 35 | 126.3 | 6.39 | 319.2 | 889 | 252.7 | 704 | 35.92 | 164 | 92.5 | 116.3 | – | | |

Table No. 18 : Calculations of average performance rating, actual and normal output rates, yield, average blood pressure etc., using Tables 11 and 12

Subject No. : 2

$S_A$ = Sytolic blood pressure, recorded just after the experiment

$D_A$ = Diastolic blood pressure recorded just after the experiment

T.M.B.P. = True mean blood pressure

[1]Note : Heart rate not recorded (failure of equipments) for this subject.

| Experiment No. | No. of cod fish/7.5 lb box | Performance rating (average) (%) | Normal time to fillet (mins.) | Actual output rate (lbs/hr) | | Normal output rate (lbs/hr) | | Yield undressed cod skin-on fillets (%) | Blood pressure (average) (mm.Hg) | | Mean H/R (beats/min) | T.M.B.P. $=\frac{S_A+2D_A}{3}$ (mm.Hg) | $H/R \times S_A$ (beats/min x mm.Hg) | H/R x T.M.B.P (beats/min x mm.Hg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Fillets | Fish | Fillets | Fish | | $S_A$ | $D_A$ | | | | |
| 1 | 43 | 101.7 | 9.43 | 173.4 | 485 | 170.5 | 477 | 35.67 | 155.5 | 88 | 110.4 | 110.5 | 17167 | 12199 |
| 2 | 50 | 102.5 | 11.45 | 141.6 | 402 | 138.1 | 392 | 35.17 | 166.5 | 67.5 | 105.1 | 100.5 | 17499 | 10562 |
| 3 | 47 | 112.5 | 9.99 | 180.6 | 507 | 160.5 | 451 | 35.67 | 160 | 78 | 111.9 | 105.3 | 17904 | 11783 |
| 4 | 56 | 112.8 | 10.92 | 165.6 | 464 | 146.8 | 411 | 35.67 | 156 | 86.5 | 108.1 | 109.6 | 16863 | 11847 |
| 5 | 39 | 99 | 10.03 | 165 | 444 | 166.7 | 448 | 37.17 | 144.5 | 92 | 100.4 | 109.5 | 14507 | 10993 |
| 6 | 40 | 99 | 10.30 | 169.4 | 432 | 171.5 | 436 | 39.17 | 162.5 | 84.5 | 100.8 | 110.5 | 16380 | 11138 |
| 7 | 49 | 120 | 10.32 | 184.0 | 523 | 153.3 | 436 | 35.17 | 156.5 | 104.5 | 118.7 | 121.8 | 18576 | 14458 |
| 8 | 49 | 106 | 10.44 | 159.6 | 456 | 150.6 | 430 | 35.00 | 138.5 | 88.5 | 94.8 | 105.2 | 13129 | 9972 |

Table No. 19 : Calculations of average performance rating, actual and normal output rates, yield, average blood pressure etc., using Tables 13 and 14.

Subject No. : 3

$S_A$ = Systolic blood pressure, recorded just after each filleting experiment

$D_A$ = Diastolic blood pressure, recorded just after each filleting experiment

H/R = Heart rate

T.M.B.P. = True mean blood pressure

| Experiment (No.) | No. of cod fish/75 lb box | Performance rating (average) (%) | Normal time to fillet (mins.) | Actual output rate (lbs/hr) Fillets | Actual output rate (lbs/hr) Fish | Normal output rate (lbs/hr) Fillets | Normal output rate (lbs/hr) Fish | Yield undressed cod, skin-on fillets (%) | Blood pressure (average) (mm.Hg) $S_A$ | Blood pressure (average) (mm.Hg) $D_A$ | Mean H/R (beats/min) | T.M.B.P. $=\frac{S_A+2D_A}{3}$ (mm.Hg) | H/R x $S_A$ (beats/min x mm.Hg) | H/R x T.M.B.P (beats/min x mm.Hg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 45 | 92.5 | 12.37 | 120.0 | 336 | 129.7 | 363 | 35.67 | 133.5 | 78 | 99.7 | 96.5 | 13309 | 9621 |
| 2 | 24 | 92.5 | 8.00 | 197.4 | 520 | 213.4 | 562 | 38.00 | 134 | 80 | 104 | 98 | 13936 | 10192 |
| 3 | 27 | 109.3 | 7.56 | 239.4 | 650 | 219 | 595 | 36.83 | 138 | 90 | 109.2 | 106 | 15069 | 11575 |
| 4 | 48 | 114.4 | 11.70 | 162.6 | 441 | 142.1 | 385 | 37.00 | 141.5 | 79.5 | 110.2 | 100.2 | 15593 | 11042 |
| 5 | 46 | 81 | 13.71 | 100.8 | 265 | 124.4 | 327 | 38.00 | 138.5 | 85.5 | 94.8 | 103.2 | 13129 | 9783 |
| 6 | 46 | 75 | 14.48 | 88.6 | 233 | 118.2 | 311 | 38.00 | 127 | 87.5 | 95.3 | 100.6 | 12103 | 9587 |
| 7 | 37 | 123.6 | 10.94 | 180.6 | 507 | 146.1 | 410 | 35.49 | 151 | 78 | 105.1 | 102.3 | 15870 | 10751 |
| 8 | 14 | 119 | 4.94 | 372 | 1083 | 312.6 | 910 | 34.33 | 136 | 84.5 | 114.3 | 101.7 | 15544 | 11624 |
| 9 | 15 | 102.5 | 5.66 | 304.2 | 815 | 296.8 | 795 | 37.33 | 137 | 77 | 105.8 | 97 | 14494 | 10262 |
| 10 | 43 | 93.1 | 15.71 | 106.8 | 267 | 114.7 | 287 | 40.00 | 138 | 82 | 101.2 | 100.7 | 13965 | 10190 |

Table No. 20 : Calculations of average performance rating, actual and normal output rates, yield, average blood pressure etc., using Tables 15 and 16

Subject No. : 4

$S_A$ = Systolic blood pressure, recorded just after each filleting experiment

$D_A$ = Diastolic blood pressure, recorded just after each filleting experiment

H/R = Heart rate

T.M.B.P. = True mean blood pressure

| | Subject No. | No. of observations (N) | Degrees of freedom (N-2) | X mean (Independent variable) | Y mean (Dependent variable) | a | b | R | $R^2$ | T |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean heart rate (Y) (beats/min) | 1 | 8 | 6 | 107.83 | 112.02 | 29.97 | 0.76 | 0.759 | 0.576 | 2.852* |
| Vs. | 3 | 8 | 6 | 106.69 | 106.27 | 31.03 | 0.71 | 0.710 | 0.504 | 2.470* |
| Performance rating (X) (%) | 4 | 10 | 8 | 100.29 | 103.96 | 69.70 | 0.34 | 0.875 | 0.766 | 5.052** |
| Systolic blood pressure (Y) (mm.Hg) | 1 | 8 | 6 | 107.83 | 162.19 | -2.58 | 1.528 | 0.847 | 0.717 | 3.911** |
| Vs. Performance rating (X) (%) | 2 | 9 | 7 | 110.44 | 152.50 | 115.0 | 0.339 | 0.774 | 0.599 | 3.239* |
| | 3 | 8 | 6 | 106.69 | 155.00 | 144.87 | 0.095 | 0.078 | 0.006 | 0.193 |
| | 4 | 10 | 8 | 100.29 | 137.45 | 109.97 | 0.274 | 0.722 | 0.521 | 2.948* |
| Mean heart rate x systolic blood pressure (Y) (beats/min x mm.Hg) | 1 | 8 | 6 | 107.83 | 18209 | -13560 | 294.6 | 0.947 | 0.897 | 7.191** |
| Vs. | 3 | 8 | 6 | 106.69 | 16503 | 3736 | 119.6 | 0.503 | 0.253 | 1.425 |
| Performance rating (X) (%) | 4 | 10 | 8 | 100.29 | 14301 | 6807 | 74.71 | 0.980 | 0.960 | 13.931** |

Table No.: 21 Shows Linear Regression Analysis Results

Equation Used: $Y = a + b\,(X)$

R : Correlation Co-efficient
$R^2$: Co-efficient of Determination
T : T-value
* : Significant at $P < 0.05$
** : Significant at $p < 0.01$
X : Independent variable
Y : Dependent variable

| | Subject No. | No. of Observations (N) | Degree of Freedom (N-2) | X mean (Independent Variable) | Y mean (Dependent Variable) | a | b | R | $R^2$ | T |
|---|---|---|---|---|---|---|---|---|---|---|
| True mean blood pressure (Y) (mm.Hg) | 1 | 8 | 6 | 107.83 | 126.58 | 78.12 | 0.449 | 0.688 | 0.473 | 2.322 |
| Vs. | 2 | 9 | 7 | 110.44 | 114.46 | 102.2 | 0.110 | 0.521 | 0.271 | 1.616 |
| Performance rating (X) (%) | 3 | 8 | 6 | 106.69 | 109.11 | 65.4 | 0.41 | 0.506 | 0.256 | 1.436 |
| | 4 | 10 | 8 | 100.29 | 100.62 | 96.5 | 0.04 | 0.227 | 0.05 | 0.658 |
| Mean heart rate x true mean blood pressure (Y) (beats/min x mm.Hg) | 1 | 8 | 6 | 107.83 | 14198 | -1532 | 145.8 | 0.881 | 0.776 | 4.557** |
| Vs. | 3 | 8 | 6 | 106.69 | 11619 | 1753 | 125.3 | 0.705 | 0.497 | 2.347 |
| Performance rating (X) (%) | 4 | 10 | 8 | 100.29 | 10463 | 6555 | 38.9 | 0.836 | 0.699 | 4.315** |
| Mean heart rate (Y) (beats/min) | 1 | 8 | 6 | 353.64 | 112.02 | 85.0 | 0.076 | 0.778 | 0.605 | 3.031* |
| Vs. | 3 | 8 | 6 | 167.41 | 106.27 | 48.2 | 0.34 | 0.604 | 0.365 | 1.857 |
| Actual output rate (cod fillets) (X) (lbs/hr) | 4 | 10 | 8 | 187.24 | 103.96 | 93.6 | 0.06 | 0.818 | 0.669 | 4.026** |

Table No.: 22 Shows Linear Regression Analysis Results

Equation Used: $Y = a + b\ (X)$

R : Correlation Co-efficient
$R^2$: Co-efficient of Determination
T : T-value
* : Significant at $P < 0.05$
** : Significant at $p < 0.01$
X : Independent variable
Y : Dependent variable

| | Subject No. | No. of Observations (N) | Degree of Freedom (N-2) | X mean (Independent Variable) | Y mean (Dependent Variable) | a | b | R | $R^2$ | T |
|---|---|---|---|---|---|---|---|---|---|---|
| Systolic blood pressure (Y) (mm.Hg) Vs. Actual output rate (cod fillets) (X) (lbs/hr) | 1 | 8 | 6 | 353.64 | 162.19 | 140.86 | 0.06 | 0.342 | 0.117 | 0.891 |
| | 2 | 9 | 7 | 253.29 | 152.50 | 137.57 | 0.059 | 0.652 | 0.425 | 2.278 |
| | 3 | 8 | 6 | 167.41 | 155.00 | 159.77 | 0.028 | 0.041 | 0.002 | 0.099 |
| | 4 | 10 | 8 | 187.24 | 137.45 | 135.93 | 0.008 | 0.124 | 0.015 | 0.353 |
| Mean heart rate x systolic blood pressure (Y) (beats/min x mm.Hg) Vs. Actual output rate (cod fillets) (X) (lbs/hr) | 1 | 8 | 6 | 353.64 | 18209 | 11438 | 19.14 | 0.628 | 0.394 | 1.980 |
| | 3 | 8 | 6 | 167.41 | 16503 | 8112 | 50.12 | 0.364 | 0.132 | 0.958 |
| | 4 | 10 | 8 | 187.24 | 14301 | 12751 | 8.27 | 0.629 | 0.396 | 2.293 |
| True mean blood pressure (Y) (mm.Hg) Vs. Actual output rate (cod fillets) (X) (lbs/hr) | 1 | 8 | 6 | 353.64 | 126.58 | 122.92 | 0.01 | 0.162 | 0.026 | 0.401 |
| | 2 | 9 | 7 | 253.29 | 114.46 | 107.86 | 0.026 | 0.595 | 0.354 | 1.957 |
| | 3 | 8 | 6 | 167.41 | 109.11 | 51.4 | 0.34 | 0.735 | 0.540 | 2.657* |
| | 4 | 10 | 8 | 187.24 | 100.62 | 100.4 | 0.001 | 0.032 | 0.001 | 0.0903 |

Table No.: 23 Shows Linear Regression Analysis Results

Equation Used: $Y = a + b\ (X)$

R : Correlation Co-efficient
$R^2$: Co-efficient of Determination
T : T-value
* : Significant at $P < 0.05$
** : Significant at $p < 0.01$
X : Independent variable
Y : Dependent variable

| | Subject No. | No. of observations (N) | Degree of freedom (N-2) | X mean (Independent variable) | Y mean (Dependent variable) | a | b | R | $R^2$ | T |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean heart rate (Y) (beats/min) Vs. Actual output rate (cod fish) (X) (lbs/hr) | 1 | 8 | 6 | 775.81 | 112.02 | 87.09 | 0.032 | 0.786 | 0.618 | 3.115* |
| | 3 | 8 | 6 | 464.13 | 106.27 | 42.78 | 0.137 | 0.717 | 0.514 | 2.522* |
| | 4 | 10 | 8 | 511.70 | 103.96 | 94.18 | 0.019 | 0.823 | 0.677 | 4.094** |
| Systolic blood pressure (Y) (mm.Hg) Vs. Actual output rate (cod fish) (X) (lbs/hr) | 1 | 8 | 6 | 775.81 | 162.19 | 136.29 | 0.033 | 0.454 | 0.206 | 1.249 |
| | 2 | 9 | 7 | 676.33 | 152.50 | 138.73 | 0.02 | 0.671 | 0.450 | 2.392 |
| | 3 | 8 | 6 | 464.13 | 155.00 | 167.19 | 0.026 | 0.113 | 0.013 | 0.278 |
| | 4 | 10 | 8 | 511.70 | 137.45 | 135.97 | 0.003 | 0.129 | 0.017 | 0.367 |
| Mean heart rate x systolic blood pressure (Y) (beats/min x mm.Hg) Vs. Actual output rate (cod fish) (X) (lbs/hr) | 1 | 8 | 6 | 775.81 | 18209 | 11278 | 8.93 | 0.704 | 0.496 | 2.429* |
| | 3 | 8 | 6 | 464.13 | 16503 | 7908 | 18.52 | 0.405 | 0.164 | 1.085 |
| | 4 | 10 | 8 | 511.70 | 14301 | 12830 | 2.87 | 0.636 | 0.404 | 2.329* |
| | | | | | | | | | | |

Table No.: 24 Shows Lineer Regression Analysis Results

Equation Used: $Y = a + b(X)$

R : Correlation Co-efficient
$R^2$: Co-efficient of Determination
T : T-value
* : Significant at $P < 0.05$
** : Significant at $p < 0.01$
X : Independent variable
Y : Dependent variable

| | Subject No. | No. of Observations (N) | Degrees of Freedom (N-2) | X mean (Independent Variable) | Y mean (Dependent Variable) | a | b | R | $R^2$ | T |
|---|---|---|---|---|---|---|---|---|---|---|
| True mean blood pressure (Y) (mm.Hg) Vs. Actual output rate (cod fish) (X) (lbs/hr) | 1 | 8 | 6 | 775.81 | 126.58 | 120.58 | 0.007 | 0.290 | 0.084 | 0.743 |
| | 2 | 9 | 7 | 676.33 | 114.46 | 108.6 | 0.009 | 0.588 | 0.346 | 1.925 |
| | 3 | 8 | 6 | 464.13 | 109.11 | 62.00 | 0.101 | 0.652 | 0.425 | 2.106 |
| | 4 | 10 | 8 | 511.70 | 100.62 | 100.3 | 0.001 | 0.041 | 0.002 | 0.129 |
| Mean heart rate (Y) (beats/min) Vs. No. of cod fish/75 lb. box (X) | 1 | 8 | 6 | 24.87 | 112.02 | 178.3 | -2.66 | -0.837 | 0.700 | -3.749** |
| | 3 | 8 | 6 | 46.62 | 106.27 | 89.01 | 0.37 | 0.277 | 0.077 | 0.706 |
| | 4 | 10 | 8 | 34.50 | 103.96 | 114.2 | -0.29 | -0.621 | 0.386 | -2.423* |
| Systolic blood pressure (Y) (mm.Hg) Vs. No. of cod fish/75 lb. box (X) | 1 | 8 | 6 | 24.87 | 162.19 | 185.1 | -0.92 | -0.161 | 0.026 | -0.399 |
| | 2 | 9 | 7 | 33.78 | 152.50 | 157.6 | -0.15 | -0.109 | 0.012 | -0.290 |
| | 3 | 8 | 6 | 46.62 | 155.0 | 146.12 | 0.190 | 0.117 | 0.014 | 0.288 |
| | 4 | 10 | 8 | 34.50 | 137.45 | 137.14 | 0.009 | 0.019 | 0.0004 | 0.095 |

Table No.: 25 Shows Linear Regression Analysis Results

Equation Used: $Y = a + b\ (X)$

R : Correlation Co-efficient
$R^2$: Co-efficient of Determination
T : T-value
* : Significant at $P < 0.05$
** : Significant at $p < 0.01$
X : Independent variable
Y : Dependent variable

| | Subject No. | No. of Observations (N) | Degree of Freedom (N-2) | X mean (Independent Variable) | Y mean (Dependent Variable) | a | b | R | $R^2$ | T |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean heart rate x systolic blood pressure (Y) (beats/min x mm.Hg) | 1 | 8 | 6 | 24.87 | 18209 | 31735 | -543.8 | -0.551 | 0.303 | -1.616 |
| Vs. | 3 | 8 | 6 | 46.62 | 16503 | 12829 | 78.80 | 0.246 | 0.061 | 0.621 |
| No. of cod fish/75 lb. box (X) | 4 | 10 | 8 | 34.50 | 14301 | 15632 | -38.58 | -0.417 | 0.174 | -1.297 |
| | | | | MEAN $\log_{10}(X)$ | MEAN $\log_{10}(Y)$ | $\log_{10}(a)$ | b | R | $R^2$ | T |
| Normal output rate (cod fillets) (Y) (lbs/hr) [Non-Linear] $Y = a\,(X)^b$ | 1 | 8 | 6 | 1.394 | 2.508 | 4.839 | -1.672 | -0.905 | 0.819 | -5.216** |
| In Linear Form $\log_{10}(Y) = \log_{10}(a)+b\ \log_{10}(X)$ | 2 | 9 | 7 | 1.526 | 2.350 | 3.783 | -0.94 | -0.713 | 0.508 | -2.686* |
| Vs. | 3 | 8 | 6 | 1.666 | 2.195 | 3.069 | -5.249 | -0.833 | 0.694 | -3.688* |
| No. of cod fish/75 lb. box (X) | 4 | 10 | 8 | 1.499 | 2.228 | 3.405 | -0.78 | -0.973 | 0.946 | -11.943** |
| Normal output rate (cod fish) (Y) (lbs/hr) | 1 | 8 | 6 | 1.394 | 2.848 | 5.343 | -1.790 | -0.905 | 0.819 | -5.221** |
| [Non-Linear] $Y = a(X)^b$ In Linear Form $\log_{10}(Y) = \log_{10}(a)+b\ \log_{10}(X)$ | 2 | 9 | 7 | 1.526 | 2.774 | 4.369 | -1.046 | -0.670 | 0.449 | -2.389* |
| Vs. | 3 | 8 | 6 | 1.666 | 2.638 | 3.124 | -0.292 | -0.605 | 0.366 | -1.859 |
| No. of cod fish/75 lb. box (X) | 4 | 10 | 8 | 1.499 | 2.661 | 3.890 | -0.820 | -0.963 | 0.927 | -10.093** |

Table No.: 26 Shows Linear Regression Analysis Results

Equations Used: $Y = a + b\ (X)$
and $Y = a(X)^b$
i.e. In Linear Form $\log_{10}(Y) = \log_{10}(a) + b\ \log_{10}(X)$

R : Correlation Co-efficient
$R^2$: Co-efficient of Determination
T : T-value
* : Significant at $P < 0.05$
** : Significant at $p < 0.01$
X : Independent variable
Y : Dependent variable

| | Subject No. | No. of Observations (N) | Degree of Freedom (N-2) | X mean (Independent Variable) | Y mean (Dependent Variable) | a | b | R | $R^2$ | T |
|---|---|---|---|---|---|---|---|---|---|---|
| Yield (undressed cod, skin-on fillet) (Y) (%) Vs. Performance rating (X) (%) | 1 | 8 | 6 | 107.83 | 45.75 | 63.4 | -0.16 | -0.699 | 0.488 | -2.395* |
| | 2 | 9 | 7 | 110.44 | 37.72 | 46.6 | -0.08 | -0.825 | 0.680 | -3.86** |
| | 3 | 8 | 6 | 106.69 | 36.08 | 47.2 | -0.02 | -0.561 | 0.315 | -1.659 |
| | 4 | 10 | 8 | 100.29 | 37.06 | 43.4 | -0.06 | -0.64 | 0.409 | -2.34* |
| Yield (undressed cod, skin-on fillet) (Y) (%) Vs. No. of cod fish/75 lb. box (X) | 1 | 8 | 6 | 24.87 | 45.75 | 40.37 | 0.22 | 0.292 | 0.085 | 0.747 |
| | 2 | 9 | 7 | 33.78 | 37.72 | 30.05 | 0.14 | 0.451 | 0.203 | 1.337 |
| | 3 | 8 | 6 | 46.62 | 36.08 | 44.15 | -0.17 | -0.694 | 0.482 | -2.359 |
| | 4 | 10 | 8 | 34.50 | 37.06 | 35.56 | 0.04 | 0.362 | 0.131 | 1.097 |
| Actual output rate (cod fillets) (Y) (lbs/hr) Vs. Performance rating (X) (%) | 1 | 8 | 6 | 107.83 | 353.64 | -234 | 5.454 | 0.534 | 0.285 | 1.546 |
| | 2 | 9 | 7 | 110.44 | 253.29 | -229 | 4.374 | 0.903 | 0.815 | 5.550** |
| | 3 | 8 | 6 | 106.69 | 167.41 | 70.1 | 0.91 | 0.527 | 0.277 | 1.519 |
| | 4 | 10 | 8 | 100.29 | 187.24 | -189 | 3.75 | 0.647 | 0.419 | 2.400* |

**Table No.: 27** Shows Linear Regression Analysis Results

**Equation Used:** $Y = a + b\ (X)$

R : Correlation Co-efficient
$R^2$: Co-efficient of Determination
T : T-value
* : Significant at $P < 0.05$
** : Significant at $p < 0.01$
X : Independent variable
Y : Dependent variable

| | Subject No. | No. of Observations (N) | Degrees of Freedom (N-2) | X mean (Independent Variable) | Y mean (Dependent Variable) | a | b | R | $R^2$ | T |
|---|---|---|---|---|---|---|---|---|---|---|
| Actual output rate (cod fish) (Y) (lbs/hr) | 1 | 8 | 6 | 107.83 | 775.81 | -812 | 14.73 | 0.601 | 0.361 | 1.839 |
| Vs. | 2 | 9 | 7 | 110.44 | 676.33 | -772 | 13.12 | 0.908 | 0.824 | 5.750** |
| Performance rating (X) (%) | 3 | 8 | 6 | 106.69 | 464.13 | 48.3 | 3.89 | 0.748 | 0.559 | 2.764* |
| | 4 | 10 | 8 | 100.29 | 511.70 | -607 | 11.16 | 0.662 | 0.438 | 2.497* |
| Actual output rate (fillets) (Y) (lbs/hr) | 1 | 8 | 6 | 24.87 | 353.64 | 1092 | -29.7 | -0.916 | 0.839 | -5.607** |
| Vs. | 2 | 9 | 7 | 33.78 | 253.29 | 500 | -7.33 | -0.480 | 0.230 | -1.449 |
| No. of cod fish/75 lb box (X) | 3 | 8 | 6 | 46.62 | 167.41 | 186 | -0.42 | -0.180 | 0.032 | -0.449 |
| | 4 | 10 | 8 | 34.50 | 187.24 | 412 | -6.52 | -0.925 | 0.856 | -6.890** |
| Actual output rate (fish) (Y) (lbs/hr) | 1 | 8 | 6 | 24.87 | 775.81 | 2502 | -69.4 | -0.892 | 0.796 | -4.832** |
| Vs. | 2 | 9 | 7 | 33.78 | 676.33 | 1389 | -21.09 | -0.464 | 0.215 | -1.387 |
| No. of cod fish/75 lb box (X) | 3 | 8 | 6 | 46.62 | 464.13 | 419 | -0.96 | -0.136 | 0.018 | -0.337 |
| | 4 | 10 | 8 | 34.50 | 511.70 | 1150 | -18.52 | -0.904 | 0.817 | -6.003** |

Table No.: 28 Shows Linear Regression Analysis Results

Equation Used: $Y = a + b\,(X)$

R : Correlation Co-efficient
$R^2$ : Co-efficient of Determination
T : T-value
* : Significant at $P < 0.05$
** : Significant at $p < 0.01$
X : Independent variable
Y : Dependent variable

| | Subject No. | No. of Observations (N) | Degree of Freedom (N-2) | X mean (Independent Variable) | Y mean (Dependent Variable) | a | b | R | $R^2$ | T |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean heart rate (Y) (beats/min) Vs. Yield (undressed cod, skin-on fillets) (X) (%) | 1 | 8 | 6 | 45.75 | 112.02 | 57.31 | -0.10 | -0.441 | 0.195 | -1.205 |
| | 3 | 8 | 6 | 36.08 | 106.27 | 172.81 | -1.84 | -0.344 | 0.118 | -0.897 |
| | 4 | 10 | 8 | 37.06 | 103.96 | 183.6 | -2.15 | -0.545 | 0.297 | -1.873 |

Table No.: 29 Shows Linear Regression Analysis Results

Equation Used: $Y = a + b\,(X)$

R : Correlation Co-efficient
$R^2$: Co-efficient of Determination
T : T-value
* : Significant at $P < 0.05$
** : Significant at $p < 0.01$
X : Independemt variable
Y : Dependent variable

| | Subject No. | No. of Experiments | Degrees of Freedom | Mean Y | Mean $X_1$ | Mean $X_2$ | a | b | c | $R_m$ | $R_m^2$ | F | $f_{(X_1)}$ | $f_{(X_2)}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean heart rate (Y) (beats/min) Vs. Performance rating ($X_1$) (%) and No. of cod fish/75 lb. box ($X_2$) | 1 | 8 | 2/5 | 112.02 | 107.83 | 24.87 | 111.07 | 0.459 | -1.948 | 0.927 | 0.859 | 15.317** | 5.653 | 10.123 |
| | 3 | 8 | 2/5 | 106.27 | 106.69 | 46.62 | 28.06 | 0.941 | -0.475 | 0.758 | 0.574 | 3.370 | 5.840 | 0.822 |
| | 4 | 10 | 2/7 | 103.96 | 100.29 | 34.50 | 79.85 | 0.29 | -0.15 | 0.916 | 0.839 | 18.322** | 19.812 | 3.422 |
| Systolic blood pressure (Y) (mm.Hg) Vs. Performance rating ($X_1$) (%) and No. of cod fish/75 lb. box ($X_2$) | 1 | 8 | 2/5 | 162.19 | 107.83 | 24.87 | -82.91 | 1.827 | 1.931 | 0.897 | 0.805 | 10.302* | 19.940 | 2.212 |
| | 2 | 9 | 2/6 | 152.50 | 110.44 | 33.78 | 115 | 0.339 | 0.095 | 0.774 | 0.599 | 10.490* | 10.490 | 0.006 |
| | 3 | 8 | 2/5 | 155.00 | 106.69 | 46.62 | 146.12 | 0.190 | 0.026 | 0.117 | 0.014 | 0.083 | 0.083 | 0.0001 |
| | 4 | 10 | 2/7 | 137.45 | 100.29 | 34.50 | 97.43 | 0.337 | 0.181 | 0.805 | 0.648 | 6.431* | 12.855 | 2.520 |
| Mean heart rate x systolic blood pressure (Y) (beats/min/ x mm.Hg) Vs. Performance rating ($X_1$) (%) and No. of cod fish/75 lb. box ($X_2$) | 1 | 8 | 2/5 | 18209 | 107.83 | 24.87 | -8952 | 277.45 | -110.7 | 0.952 | 0.906 | 23.973** | 31.890 | 0.505 |
| | 3 | 8 | 2/5 | 16503 | 106.69 | 46.62 | 3392 | 145.65 | -52.07 | 0.518 | 0.268 | 0.915 | 1.418 | 0.100 |
| | 4 | 10 | 2/7 | 14301 | 100.29 | 34.50 | 6807 | 74.78 | -7.18 | 0.980 | 0.960 | 194.25** | 194.25 | 0.004 |

Table No: 30 Shows Multiple Linear Regression Analysis Results

Equation Used: $Y = a + b(X_1) + c(X_2)$

$R_m$ : Multiple Correlation Co-efficient
F : Multiple 'F-ratio' value
$f(X_1)$ : Partial 'F-ratio'. Effect of $X_1$ on Y
$f(X_2)$ : Partial 'F-ratio'. Effect of $X_2$ on Y
$X_1$, $X_2$ : Independent variables
Y : Dependent variable
* : Significant at $p<0.05$
** : Significant at $p<0.01$
$R_m^2$ : Multiple co-efficient of determination

| | Subject No. | No. of Experiments | Degrees of Freedom | Mean Y | Mean $X_1$ | Mean $X_2$ | a | b | c | $R_m$ | $R_m^2$ | F | $f_{(X_1)}$ | $f_{(X_2)}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| True mean blood pressure (Y) (mm.Hg) Vs. Performance rating ($X_1$) (%) and No. of cod fish/75 lb. box ($X_2$) | 1 | 8 | 2/5 | 126.58 | 107.83 | 24.87 | 46.02 | 0.568 | 0.778 | 0.762 | 0.581 | 3.466 | 6.599 | 1.286 |
| | 2 | 9 | 2/6 | 114.46 | 110.44 | 33.78 | 108.9 | 0.104 | -0.176 | 0.583 | 0.339 | 1.546 | 2.157 | 0.623 |
| | 3 | 8 | 2/5 | 109.11 | 106.69 | 46.62 | 60.09 | 0.827 | -0.842 | 0.765 | 0.585 | 3.535 | 6.972 | 3.983 |
| | 4 | 10 | 2/7 | 100.62 | 100.29 | 34.50 | 93.66 | 0.055 | 0.041 | 0.284 | 0.081 | 0.308 | 0.588 | 0.223 |
| Mean heart rate x true mean blood pressure (Y) (beats/min x mm.Hg) Vs. Performance rating ($X_1$) (%) and No. of cod fish/75 lb. box ($X_2$) | 1 | 8 | 2/5 | 14198 | 107.83 | 24.87 | 5346 | 120.24 | -165.36 | 0.922 | 0.851 | 14.263** | 13.393 | 2.517 |
| | 3 | 8 | 2/5 | 11619 | 106.69 | 46.62 | -2657 | 197.02 | -144.63 | 0.837 | 0.700 | 5.838* | 11.370 | 3.380 |
| | 4 | 10 | 2/7 | 10463 | 100.29 | 34.50 | 7289 | 35.29 | -10.59 | 0.853 | 0.728 | 9.382* | 12.163 | 0.744 |
| Yield (undressed cod, skin-on fillets) (Y) (%) Vs. Performance rating ($X_1$) (%) and No. of cod fish/75 lb. box ($X_2$) | 1 | 8 | 2/5 | 45.75 | 107.83 | 24.87 | 65.59 | -0.172 | -0.052 | 0.701 | 0.491 | 2.421 | 4.071 | 0.037 |
| | 2 | 9 | 2/6 | 37.72 | 110.44 | 33.78 | 42.42 | -0.076 | 0.110 | 0.899 | 0.808 | 12.636** | 18.906 | 4.004 |
| | 3 | 8 | 2/5 | 36.08 | 106.69 | 46.62 | 46.27 | -0.033 | -0.144 | 0.706 | 0.498 | 2.483 | 0.171 | 1.834 |
| | 4 | 10 | 2/7 | 37.06 | 100.29 | 34.50 | 42.46 | -0.059 | 0.014 | 0.646 | 0.417 | 2.504 | 3.834 | 0.127 |

Table No. 31 Shows Multiple Linear Regression Analysis Results

Equation Used : $Y = a + b(X_1) + c(X_2)$

$R_m$ : Multiple Correlation Co-efficient
F : Multiple 'F-ratio' value.
$f(X_1)$ : Partial 'F-ratio'. Effect of $X_1$ on Y
$f(X_2)$ : Partial 'F-ratio'. Effect of $X_2$ on Y
$X_1$, $X_2$ : Independent variables
Y : Dependent variable
* : Significant at $p<0.05$
** : Significant at $p<0.01$
$R_m^2$ : Multiple co-efficient of determination

| | Subject No. | No. of Experiments | Degree of Freedom | Mean | | | a | b | c | $R_m$ | $R_m^2$ | F | $f_{(X_1)}$ | $f_{(X_2)}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Y | $X_1$ | $X_2$ | | | | | | | | |
| Actual output rate (cod fillets) (Y) (lbs/hr) | 1 | 8 | 2/5 | 353.6 | 107.83 | 24.87 | 928 | 1.118 | -27.96 | 0.921 | 0.848 | 14.040** | 0.301 | 18.654 |
| Vs. | 2 | 9 | 2/6 | 253.2 | 110.44 | 33.78 | -10.35 | 4.164 | -5.809 | 0.978 | 0.956 | 57.333** | 102.21 | 20.104 |
| Performance rating ($X_1$) (%) and No. of cod fish/75 lb. box | 3 | 8 | 2/5 | 167.4 | 106.69 | 46.62 | 56.16 | 2.02 | -2.23 | 0.887 | 0.787 | 9.284* | 17.804 | 12.024 |
| ($X_2$) | 4 | 10 | 2/7 | 187.24 | 100.29 | 34.50 | 197.54 | 1.817 | -5.581 | 0.967 | 0.935 | 50.721** | 8.762 | 56.045 |
| Actual output rate (undressed cod fish) (Y) (lbs/hr) | 1 | 8 | 2/5 | 775.81 | 107.83 | 24.87 | 1729 | 5.25 | -61.12 | 0.911 | 0.829 | 12.213** | 1.025 | 13.790 |
| Vs. | 2 | 9 | 2/6 | 676.33 | 110.44 | 33.78 | -147.1 | 12.51 | -16.53 | 0.977 | 0.954 | 65.137** | 100.885 | 17.788 |
| Performance rating ($X_1$) (%) and No. of fish/75 lb. box | 3 | 8 | 2/5 | 464.13 | 106.69 | 46.62 | 196.8 | 61.70 | -45.86 | 0.893 | 0.797 | 9.833* | 19.205 | 5.854 |
| ($X_2$) | 4 | 10 | 2/7 | 511.70 | 100.29 | 34.50 | 471.9 | 5.76 | -15.58 | 0.956 | 0.914 | 37.325** | 7.831 | 38.896 |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |

Table No : 32 Shows Multiple Linear Regression Analysis Results.

Equation Used : $Y = a + b(X_1) + c(X_2)$

$R_m$ : Multiple Correlation Co-efficient
F : Multiple 'F-ratio' value
$f(X_1)$ : Partial 'F-ratio'. Effect of $X_1$ on Y
$f(X_2)$ : Partial 'F-ratio'. Effect of $X_2$ on Y
$X_1$, $X_2$ : Independent variables
Y : Dependent variable
* : Significant at $p<0.05$
** : Significant at $p<0.01$
$R_m^2$ : Multiple co-efficient of determination

| | Degrees of Freedom(d.f.) | Mean Heart Rate (beats/min) Dependent Variable | | $(H/R \times S_A)$ (beats/min x mm. Hg) Dependent Variable | |
|---|---|---|---|---|---|
| Independent Variable → | | Performance Rating (%) | No.of codfish /75 lb. box | Performance Rating (%) | No.of codfish /75 lb. box |
| Sub. No. 1 | 1/5 | 5.653* (+ve)[1] | 10.123* (-ve)[2] | 31.890** (+ve) | 0.505 (-ve) |
| Sub. No. 3 | 1/5 | 5.840* (+ve) | 0.822 (+ve) | 1.418 (+ve) | 0.100 (+ve) |
| Sub. No. 4 | 1/7 | 19.812** (+ve) | 3.422* (-ve) | 194.25** (+ve) | 0.004 (-ve) |

Table 33. Shows 'Partial F-ratio'[3] values of performance rating and number of codfish/75 lb. box with mean heart rate and product of mean heart rate and systolic blood pressure for subjects 1, 3 and 4. Refer Table 30.

*Significant at $p < 0.10$

**Significant at $p < 0.01$

H/R: Mean heart rate

$S_A$: Systolic blood pressure

| | Degrees of Freedom (d.f.) | Systolic Blood Pressure (mm. Hg) (Dependent Variable) | |
|---|---|---|---|
| Independent Variable → | | Performance Rating (%) | No. of codfish/ 75 lb. box |
| Sub. No. 1 | 1/5 | 19.940** (+ve) | 2.212 (-ve) |
| Sub. No. 2 | 1/6 | 10.490* (+ve) | 0.006 (-ve) |
| Sub. No. 3 | 1/5 | 0.083 (+ve) | 0.0001 (+ve) |
| Sub. No. 4 | 1/7 | 12.855** (+ve) | 2.520 (+ve) |

Table 34. Shows 'Partial F-ratio' values of performance rating and number of codfish/75 lb. box with systolic blood pressure for subjects 1, 2, 3 and 4. Refer Table 30.

[1] (+ve) means positive linear relationship existed between independent and dependent variables.

[2] (-ve) means negative linear relationship existed between independent and dependent variables.

[3] Partial F-ratio' is the 'F-ratio' value between 2 variables (independent and dependent) while adjusting statistically for the effects of one or more additional independent variables on the dependent variable. Refer p. 113, of this report.

| Independent Variable → | Degrees of Freedom (d.f.) | Yield (undressed cod, skin-on fillets) (Dependent Variable) (%) | |
|---|---|---|---|
| | | Performance Rating (%) | No. of codfish/ 75 lb. box |
| Sub. No. 1 | 1/5 | 4.071* (-ve)[1] | 0.037 (+ve)[2] |
| Sub. No. 2 | 1/6 | 18.906** (-ve) | 4.004* (+ve) |
| Sub. No. 3 | 1/5 | 0.171 (-ve) | 1.834 (-ve) |
| Sub. No. 4 | 1/7 | 3.834 (-ve) | 0.127 (+ve) |

Table 35. Shows 'Partial F-ratio'[3] values of performance rating and number of codfish/75 lb. box with percentage yield (undressed cod, skin-on fillets), subjects 1, 2, 3 and 4. Refer Table 31.

*Significant at $p < 0.10$

**Significant at $p < 0.01$

| Independent Variable → | Degrees of Freedom (d.f.) | Actual Output Rate (undressed cod fillets) Dependent Variable (lb./hr.) | |
|---|---|---|---|
| | | Performance Rating (%) | No. of codfish/ 75 lb. box |
| Sub. No. 1 | 1/5 | 0.301 (+ve) | 18.654** (-ve) |
| Sub. No. 2 | 1/6 | 102.21** (+ve) | 20.104** (-ve) |
| Sub. No. 3 | 1/5 | 17.804** (+ve) | 12.024* (-ve) |
| Sub. No. 4 | 1/7 | 8.762* (+ve) | 56.045** (-ve) |

Table 36. Shows 'Partial F-ratio' values of performance rating and number of codfish/75 lb. box with actual output rate (cod fillets) for subjects 1, 2, 3 and 4. Refer Table 32.

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[1] (-ve) means negative linear relationship existed between independent and dependent variables.

[2] (+ve) means positive linear relationship existed between independent and dependent variables.

[3] Refer Chapter 4, p. 113, of this report.

| Parameter | Degrees of Freedom (d.f.) | Pooled Analysis[1] | | | | |
|---|---|---|---|---|---|---|
| | | Overall Partial 'F-ratio' value | | Overall Correlation Coefficient (Rm) | Overall 'F-ratio' Value | Degrees of Freedom (d.f.) |
| | | Performance Rating (%) | No. of cod-fish/75 lb box | | | |
| Mean Heart Rate (beats/min) | 1/19 | 17.253** (+ve)[2] | 3.200 (-ve)[3] | 0.8968 | 8.7327 | 8/17 |
| Systolic Blood Pressure (mm. Hg) | 1/26 | 10.883** (+ve) | 1.384 (-ve) | 0.8972 | 8.6255 | 11/23 |
| Mean Heart Rate x Systolic Blood Pressure (beats/min x mm. Hg) | 1/19 | 16.251** (+ve) | 0.064 (-ve) | 0.9237 | 12.3637 | 8/17 |
| True Mean Blood Pressure (mm. Hg) | 1/26 | 5.312* (+ve) | 0.109 (-ve) | 0.9596 | 24.3048 | 11/23 |
| Mean Heart Rate x True Mean Blood Pressure) (beats/min x mm. Hg) | 1/19 | 12.760** (+ve) | 1.851 (-ve) | 0.9620 | 26.3935 | 8/17 |
| Actual Output Rate (cod fillets) (lbs./hr.) | 1/26 | 37.250** (+ve) | 47.618** (-ve) | 0.9801 | 50.9145 | 11/23 |
| Yield (%) (undressed cod, skin-on fillets) | 1/26 | 13.713** (-ve) | 0.078 (+ve) | 0.9689 | 32.0789 | 11/23 |

Table 37. Summary -- Multiple regression analysis, using dummy variables. Shows 'Overall Partial F-ratio'[4] value of performance rating and number of codfish/75 lb. box (effect of subject is controlled in both cases) with different parameters. Also shows Overall Correlation Coefficient and 'Overall F-ratio Value' for each parameter. Refer Appendix B, Table B-5
*Significant at $p < 0.05$ **Significant at $p < 0.01$

[1] Using multiple regression analysis with dummy variables, it was possible to pool all four distinct blocks of data, from four different subjects into one group. Refer p. 120, of this report.

[2] (+ve) means positive linear relationship existed between independent and dependent variables for the pooled analysis.

[3] (-ve) means negative linear relationship existed between independent and dependent variables for the pooled analysis.

[4] Refer Chapter 4, p. 121, of this report.

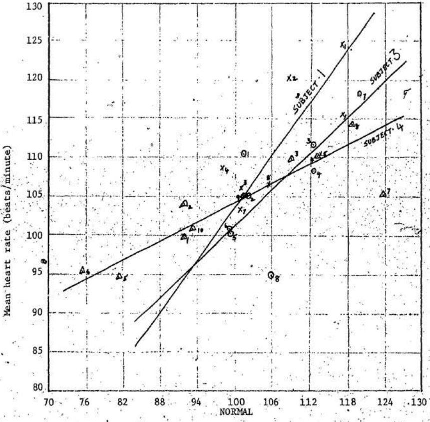


Fig. 18. Mean heart rate as a function of performance rating.

| Subject No.[1] | Experience rate (years) | MEAN: Mean heart rate (Beats/min) | MEAN: Performance rating (%) | Total Round Codfish Cut (lbs.) | No. of Experiments (N) | Degree of freedom (N-2) | Correlation Coefficient (R) | Significant Level |
|---|---|---|---|---|---|---|---|---|
| 1 X | 10 | 112.02 | 107.83 | 600 | 8 | 6 | 0.759 | $p < 0.05$ |
| 3 ʘ | 2 | 106.27 | 106.69 | 600 | 8 | 6 | 0.716 | $p < 0.05$ |
| 4 Δ | 1 | 103.96 | 100.29 | 750 | 10 | 8 | 0.875 | $p < 0.01$ |

Note: each of the numbers 1,2,3....etc., in the above graph, refers to a particular experiment.

[1]Heart rate for subject 2 could not be recorded -- failure of heart rate recording equipment.

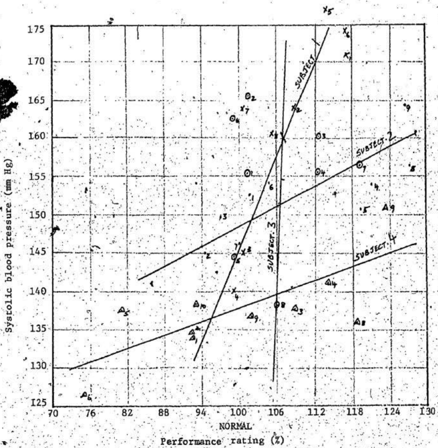


Fig. 19. Systolic blood pressure as a function of performance rating.

| Subject No. | Experience | MEAN Systolic blood pressure | MEAN Performance rating | Total Round Codfish Cut | No. of Experiments | Degree of freedom | Correlation Coefficient | Significant Level |
|---|---|---|---|---|---|---|---|---|
| | (years) | (mm Hg) | (%) | (lbs.) | (N) | (N-2) | (R) | |
| 1 X | 10 | 162.19 | 107.83 | 600 | 8 | 6 | 0.847 | $p < 0.01$ |
| 2 • | 4 | 152.50 | 110.44 | 675 | 9 | 7 | 0.774 | $p < 0.05$ |
| 3 ʘ | 2 | 155.00 | 106.69 | 600 | 8 | 6 | 0.078 | NOT SIGNIFICANT AT $P < 0.10$ |
| 4 △ | 1 | 137.45 | 100.29 | 750 | 10 | 8 | 0.722 | $p < 0.05$ |

Note: each of the numbers 1,2,3....etc., in the above graph, refers to a particular experiment.

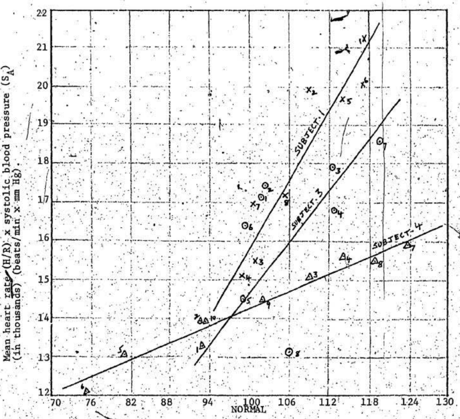


Fig. 20. Mean heart rate X systolic blood pressure as a function of performance rating.

| Subject No. | Experience | MEAN (H/R x $S_A$) | MEAN Performance rating | Total Round Codfish Cut | No. of Experiments | Degree of freedom | Correlation Coefficient | Significant Level |
|---|---|---|---|---|---|---|---|---|
| | (years) | (Beats/min x mm Hg) | (%) | (lbs.) | (N) | (N-2) | (R) | |
| 1 X | 10 | 18209 | 107.83 | 600 | 8 | 6 | 0.947 | $p < 0.01$ |
| 3 ⊙ | 2 | 16503 | 106.69 | 600 | 8 | 6 | 0.503 | NOT SIGNIFICANT AT $p < 0.10$ |
| 4 △ | 1 | 14301 | 100.29 | 750 | 10 | 8 | 0.980 | $p < 0.01$ |

Note: each of the numbers 1,2,3....etc., in the above graph, refers to a particular experiment.

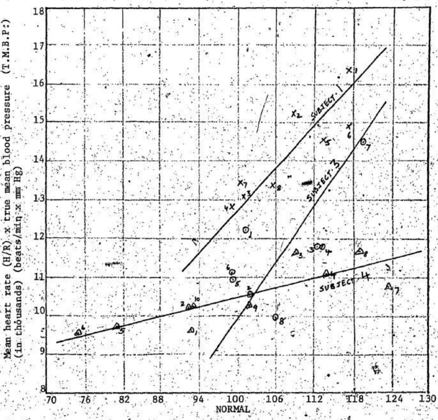


Fig. 21. Mean heart rate x true mean blood pressure (T.M.B.P.) as a function of performance rating.

| Subject No. | Experience | MEAN (H/R. x T.M.B.P.) | MEAN Performance rating | Total Round Codfish Cut | No. of Experiments | Degree of freedom | Correlation Coefficient | Significant Level |
|---|---|---|---|---|---|---|---|---|
| | (years) | (Beats/ min. x mm Hg) | (%) | (lbs.) | (N) | (N-2) | (R) | |
| 1 X | 10 | 14198 | 107.83 | 600 | 8 | 6 | 0.881 | $p < 0.01$ |
| 3 O | 2 | 11619 | 106.69 | 600 | 8 | 6 | 0.705 | $p < 0.10$ |
| 4 △ | 1 | 10463 | 100.29 | 750 | 10 | 8 | 0.836 | $p < 0.01$ |

Note: each of the numbers 1,2,3....etc., in the above graph, refers to a particular experiment.

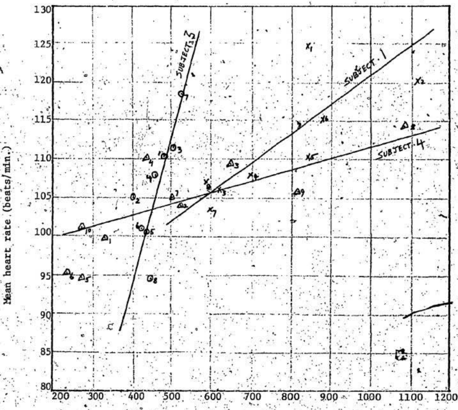


Fig. 22. Mean heart rate as a function of actual output rate (undressed cod fish)

| Subject No. | Experience | MEAN: Mean[1] heart rate | MEAN: Actual output rate | Total Round Codfish Cut | No. of Experiments | Degree of freedom | Correlation Coefficient | Significant Level |
|---|---|---|---|---|---|---|---|---|
| | (years) | (Beats/min) | (lbs./hr.) | (lbs.) | (N) | (N-2) | (R) | |
| 1 X | 10 | 112.02 | 775.81 | 600 | 8 | 6 | 0.786 | $p < 0.05$ |
| 3 Θ | 2 | 106.27 | 464.13 | 600 | 8 | 6 | 0.717 | $p < 0.05$ |
| 4 Δ | 1 | 103.96 | 511.70 | 750 | 10 | 8 | 0.823 | $p < 0.01$ |

Note: each of the numbers 1,2,3....etc., in the above graph, refers to a particular experiment.

[1]Heart rate for subject 2 could not be recorded -- failure of heart rate recording equipment.

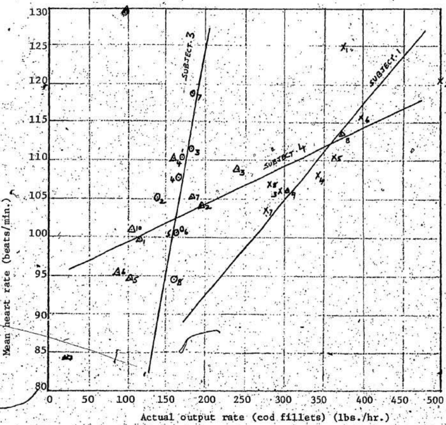


Fig. 23. Mean heart rate as a function of actual output rate (cod fillets).

| Subject No. | Experience rate | MEAN | | Total Round Codfish Cut | No. of Experiments | Degree of freedom | Correlation Coefficient | Significant Level |
|---|---|---|---|---|---|---|---|---|
| | | Mean heart rate | Actual output rate | | | | | |
| | (years) | (Beats/min.) | (lbs./hr.) | (lbs.) | (N) | (N-2) | (R) | |
| 1 X | 10 | 112.02 | 353.64 | 600 | 8 | 6 | 0.778 | $p < 0.05$ |
| 3 ⊙ | 2 | 106.27 | 167.41 | 600 | 8 | 6 | 0.604 | $p < 0.10$ |
| 4 Δ | 1 | 103.96 | 187.24 | 750 | 10 | 8 | 0.818 | $p < 0.01$ |

Note: each of the numbers 1,2,3....etc., in the above graph, refers to a particular experiment.

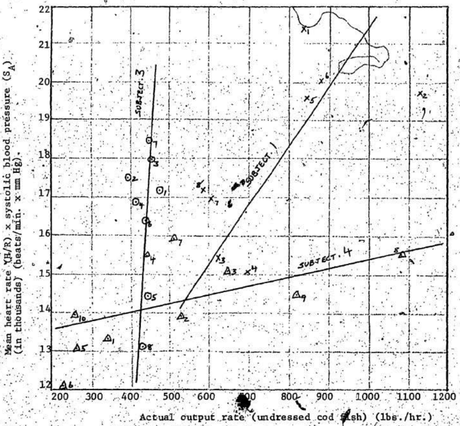


Fig. 24. Mean heart rate x systolic blood pressure as a function of actual output rate (undressed cod fish).

| Subject No. | Experience | MEAN (H/R x $S_A$) | MEAN Actual output rate | Total Round Codfish Cut | No. of Experiments | Degree of freedom | Correlation Coefficient | Significant Level |
|---|---|---|---|---|---|---|---|---|
| | (years) | (Beats/min x mm Hg) | (lbs./hr.) | (lbs.) | (N) | (N-2) | (R) | |
| 1 X | 10 | 18209 | 775.81 | 600 | 8 | 6 | 0.704 | $p < 0.05$ |
| 3 ⊙ | 2 | 16503 | 464.13 | 600 | 8 | 6 | 0.405 | NOT SIGNIFICANT AT $p < 0.10$ |
| 4 △ | 1 | 14301 | 511.70 | 750 | 10 | 8 | 0.636 | $p < 0.05$ |

Note: each of the numbers 1,2,3....etc., in the above graph, refers to a particular experiment.

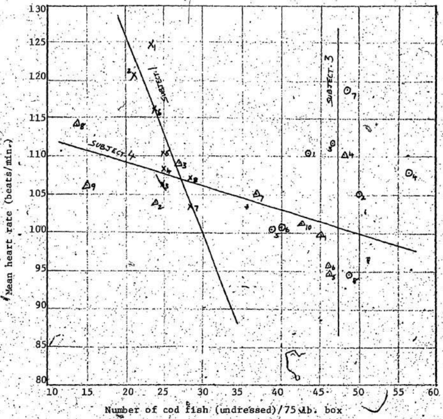


Fig. 25. Mean heart rate as a function of number of cod fish (undressed) per 75 lb. box.

| Subject No. | Experience | MEAN Mean heart rate | No. of fish/75 lb. box | Total Round Codfish Cut | No. of Experiments | Degree of freedom | Correlation Coefficient | Significant Level |
|---|---|---|---|---|---|---|---|---|
| | (years) | (Beats/min.) | | (lbs.) | (N) | (N-2) | (R) | |
| 1 X | 10 | 112.02 | 24.87 | 600 | 8 | 6 | -0.837 | $p < 0.01$ |
| 3 ⊙ | 2 | 106.27 | 46.62 | 600 | 8 | 6 | 0.277 | NOT SIGNIFICANT AT $P < 0.10$ |
| 4 △ | 1 | 103.96 | 34.50 | 750 | 10 | 8 | -0.621 | $p < 0.05$ |

Note: each of the numbers 1,2,3....etc., in the above graph, refers to a particular experiment.

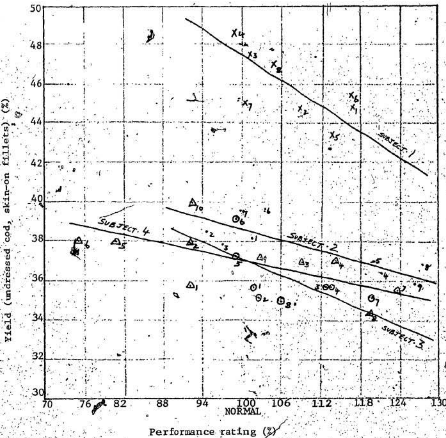


Fig. 26. Yield as a function of performance rating.

| Subject No. | Experience | MEAN | | Total Round Codfish Cut | No. of Experiments | Degree of freedom | Correlation Coefficient | Significant Level |
|---|---|---|---|---|---|---|---|---|
| | | Yield | Performance rating | | | | | |
| | (years) | (%) | (%) | (lbs.) | (N) | (N-2) | (R) | |
| 1 X | 10 | 45.75 | 107.83 | 600 | 8 | 6 | -0.699 | $p < 0.05$ |
| 2 | 4 | 37.72 | 110.44 | 675 | 9 | 7 | -0.825 | $p < 0.01$ |
| 3 ⊙ | 2 | 36.08 | 106.69 | 600 | 8 | 6 | -0.561 | $p < 0.20$ |
| 4 △ | 1 | 37.06 | 100.29 | 750 | 10 | 8 | -0.640 | $p < 0.05$ |

Note: each of the numbers 1,2,3....etc., in the above graph, refers to a particular experiment.

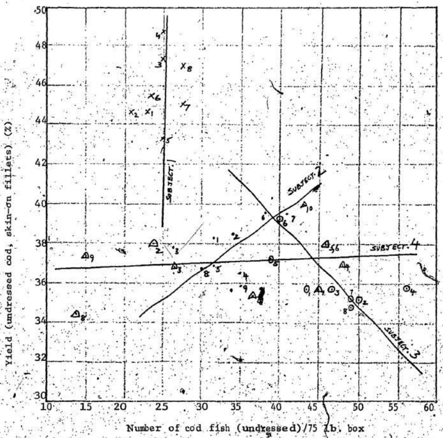


Fig. 27. Yield as a function of number of cod fish (undressed) per 75 lb. box.

| Subject No. | Experience | MEAN Yield | No. of fish/75 lb. box | Total Round Codfish Cut | No. of Experiments | Degree of freedom | Correlation Coefficient | Significant Level |
|---|---|---|---|---|---|---|---|---|
| | (years) | (%) | | (lbs.) | (N) | (N-2) | (R) | |
| 1 X | 10 | 45.75 | 24.87 | 600 | 8 | 6 | 0.292 | NOT SIGNIFICANT AT $p \leq 0.10$ |
| 2 · | 4 | 37.72 | 33.78 | 675 | 9 | 7 | 0.451 | NOT SIGNIFICANT AT $p \leq 0.10$ |
| 3 ⊙ | 2 | 36.08 | 46.62 | 600 | 8 | 6 | -0.694 | NOT SIGNIFICANT AT $p \leq 0.10$ |
| 4 Δ | 1 | 37.06 | 34.50 | 750 | 10 | 8 | 0.362 | NOT SIGNIFICANT AT $p \leq 0.10$ |

Note: each of the numbers 1,2,3....etc., in the above graph, refers to a particular experiment.

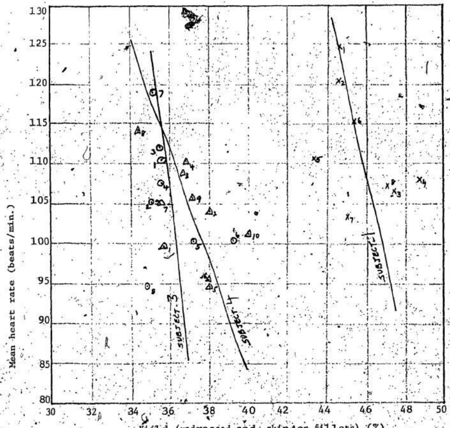


Fig. 28. Mean heart rate as a function of Yield.

| Subject No. | Experience | MEAN Mean heart rate | Yield | Total Round Codfish Cut | No. of Experiments | Degree of freedom | Correlation Coefficient | Significant Level |
|---|---|---|---|---|---|---|---|---|
| | (years) | (Beats/min.) | (%) | (lbs.) | (N) | (N-2) | (R) | |
| 1 X | 10 | 112.02 | 45.75 | 600 | 8 | 6 | -0.441 | NOT SIGNIFICANT AT p<0.10 |
| 3 O | 2 | 106.27 | 36.09 | 600 | 8 | 6 | -0.344 | NOT SIGNIFICANT AT p<0.10 |
| 4 △ | 1 | 103.96 | 37.06 | 750 | 10 | 8 | -0.545 | NOT SIGNIFICANT AT p<0.10 |

Note: each of the numbers 1, 2, 3, ... etc., in the above graph, refers to a particular experiment.

[1]Heart rate for subject 2 could not be recorded -- failure of heart rate recording equipment.

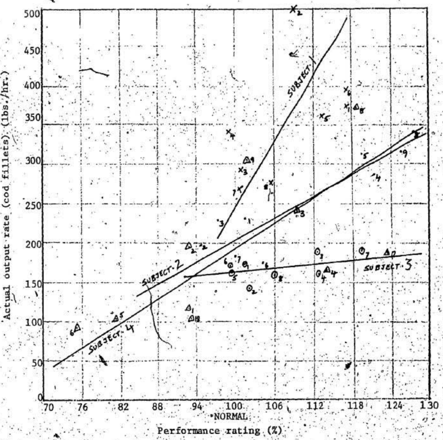


Fig. 29. Actual output rate (cod fillets) as a function of performance rating.

| Subject No. | Experience | MEAN Actual output rate | MEAN Performance rating | Total Round Codfish Cut | No. of Experiments | Degree of freedom | Correlation Coefficient | Significant Level |
|---|---|---|---|---|---|---|---|---|
| | (years) | (lbs./hr.) | (%) | (lbs.) | (N) | (N-2) | (R) | |
| 1 X | 10 | 353.64 | 107.83 | 600 | 8 | 6 | 0.534 | $p < 0.20$ |
| 2 • | 4 | 253.29 | 110.44 | 675 | 9 | 7 | 0.903 | $p < 0.01$ |
| 3 ⊙ | 2 | 167.41 | 106.69 | 600 | 8 | 6 | 0.527 | $p < 0.20$ |
| 4 △ | 1 | 187.24 | 100.29 | 750 | 10 | 8 | 0.647 | $p < 0.05$ |

Note: each of the numbers 1,2,3....etc., in the above graph, refers to a particular experiment.

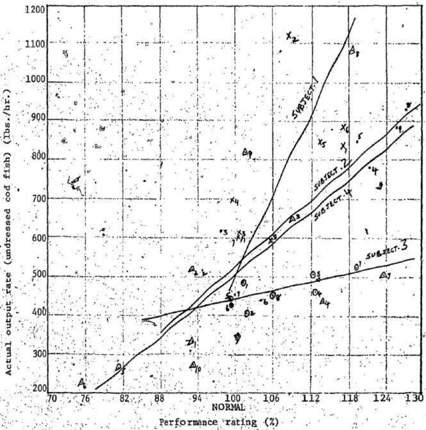


Fig. 30. Actual output rate (undressed cod fish) as a function of performance rating.

| Subject No. | Experience | MEAN Actual output rate | MEAN Performance rating | Total Round Codfish Cut | No. of Experiments | Degree of freedom | Correlation Coefficient | Significant Level |
|---|---|---|---|---|---|---|---|---|
| | (years) | (lbs./hr.) | (%) | (lbs.) | (N) | (N-2) | (R) | |
| 1 X | 10 | 775.81 | 107.83 | 600 | 8 | 6 | 0.601 | $p < 0.10$ |
| 2 • | 4 | 676.33 | 110.44 | 675 | 9 | 7 | 0.908 | $p < 0.01$ |
| 3 ⊙ | 2 | 464.13 | 106.69 | 600 | 8 | 6 | 0.748 | $p < 0.05$ |
| 4 △ | 1 | 511.70 | 100.29 | 750 | 10 | 8 | 0.662 | $p < 0.05$ |

Note: each of the numbers 1,2,3....etc., in the above graph, refers to a particular experiment.

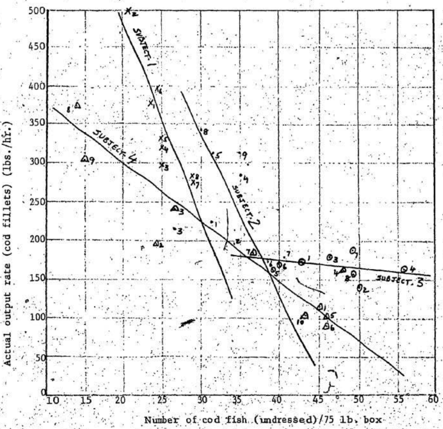


Fig. 31. Actual output rate (cod fillets) as a function of number of cod fish/75 lb. box.

| Subject No. | Experience | MEAN Actual output rate | No. of fish/75 lb. box | Total Round Codfish Cut | No. of Experiments | Degree of freedom | Correlation Coefficient | Significant Level |
|---|---|---|---|---|---|---|---|---|
| | (years) | (lbs./hr.) | | (lbs.) | (N) | (N-2) | (R) | |
| 1 × | 10 | 353.64 | 24.87 | 600 | 8 | 6 | -0.916 | $p < 0.01$ |
| 2 • | 4 | 253.29 | 33.78 | 675 | 9 | 7 | -0.480 | NOT SIGNIFICANT AT $p < 0.10$ |
| 3 ⊙ | 2 | 167.41 | 46.62 | 600 | 8 | 6 | -0.180 | NOT SIGNIFICANT AT $p < 0.10$ |
| 4 △ | 1 | 187.24 | 34.50 | 750 | 10 | 8 | -0.925 | $p < 0.01$ |

Note: each of the numbers 1,2,3....etc., in the above graph, refers to a particular experiment.

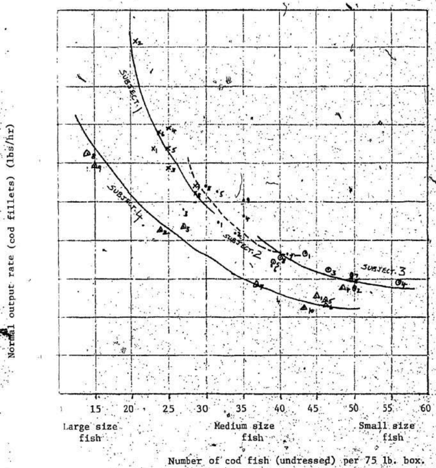


Fig. 32. Normal output rate (cod fillets) as a function of number of cod fish (undressed) per 75 lb. box.

Note: each of the numbers 1, 2, 3...... etc., in the above graph, refers to a particular experiment.

| Subject No. | Experience (years) | MEAN log(no. of fish /75lbs) | MEAN log(normal output rate) | Total Pound Codfish Cut (lbs) | No. of Experiments (N) | Degree of freedom (N-2) | Correlation Coefficient (R) | Significant Level |
|---|---|---|---|---|---|---|---|---|
| 1 x | 10 | 1.394 | 2.508 | 600 | 8 | 6 | -0.905 | $p < 0.01$ |
| 2 • | 4 | 1.526 | 2.350 | 675 | 9 | 7 | -0.713 | $p < 0.05$ |
| 3 ⊙ | 2 | 1.666 | 2.195 | 600 | 8 | 6 | -0.833 | $p < 0.05$ |
| 4 ▲ | 1 | 1.499 | 2.228 | 750 | 10 | 8 | -0.973 | $p < 0.01$ |

# CHAPTER 5

## SUMMARY AND CONCLUSIONS

### 5.1 Discussion and Conclusions

Workers in industry on repetitive tasks are usually free to work at their own natural pace. However, in many instances of repetitive tasks, operators are not free to work at their own pace, but may be subjected to some kind of speed restriction. They may be subjected to pressures of intense supervision, demands of work colleagues and group work, requirements of an incentive system, or they may have to work under speed restriction of a conveyor belt or a machine. Operators working under such speed restrictions are termed as being paced. Though operators working under such types of paced work would normally give higher outputs, they may achieve this at the expense of higher physiological stress.

Part of the objective of this study was to observe the relationships between work performance (speed of filleting and actual output rate) and the physiological parameters such as mean heart rate, blood pressure and the product of mean heart rate and blood pressure, of the filleting operator, working in a fish processing plant where the general working conditions(such as work layouts, methods of processing, cold and humid environment, etc.) are poor and the operators are subjected to various speed restrictions as mentioned above.

For this investigation each of the four filleting operators was asked to work at the following five different work paces:

a) Operator's own pace of filleting (2 experiments)

b) Faster than the operator's own pace of filleting (1 to 2 experiments)

c) Filleting for maximum yield (2 experiments)

d) Fastest speed at which the operator can safely work (1 to 2 experiments)

e) Slower than the operator's own pace of filleting (1 to 2 experiments)

The operators were asked to perform thirty-five individual filleting experiments in total, on an individual type filleting table layout. For each experiment, the undressed[1] codfish were supplied to the operator in 75 lb. fish boxes. Time taken by the subjects to fillet 75 lb. round codfish boxes varied from 4 to 19.30 minutes. The number of codfish per 75 lb. box varied from 14 to 56. During this study, the experimental controls such as work layout, method of filleting, the height of the workplace, type of cut, input quality of codfish, etc., were kept the same for all the subjects.

Much of the previous work relating to work performance and physiological measurements of the human operator has been carried out by a number of investigators such as Karrasch and Muller (1951); Lehmann (1953); Feinberg, H. (1958) Bevegard (1963); Pirnay, Petit and Deroanne (1969); Ettama and Zielhuis (1971); Maitra and Koyal (1971); De Vries and Adams (1972); Gamberale (1972); Kamon (1972); Nemecek (1976).

Linear relationships have been obtained between energy input levels and work output levels by many of the findings, in controlled work free from thermal, environmental and psychological stresses. Various physiological measurements such as mean heart rate, blood pressure, etc., have been used as a measure of energy expenditure and

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[1] Head on -- gut in round cod fish.

work output rate.

This study has shown significant linear positive relationships between speed of filleting and the mean heart rate for all the subjects[1] (correlation coefficient $R_1 = 0.759$, $p < 0.05$; $R_3 = 0.710$, $p < 0.05$; $R_4 = 0.875$, $p < 0.01$ -- Table 21).[2] It was also observed that an increase in speed of filleting causes a significant increase in the systolic blood pressure of the operator (Subject 1, $p < 0.01$; Subject 2, $p < 0.05$; Subject 4, $p < 0.05$ -- Table 21). No significant relationship was observed between speed of filleting and T.M.B.P. (true mean blood pressure) values for any of the four subjects (Table 22). Therefore, under the present working conditions in the fish plants, mean heart rate and systolic blood pressure ($S_A$) could be considered as indicators of energy expenditure or physiological load on the filleting operator.

The multiple linear regression analysis between speed of filleting, number of codfish per 75 lb. fish box and physiological parameters such as mean heart rate, systolic blood pressure, etc., showed that for this study as a whole, linear relationship existed between number of codfish per 75 lb. box and mean heart rate of the operator ($p < 0.10$, Table 37).[3] The mean heart rate of the operator increases linearly as the operator fillets a bigger size fish (or less number of codfish per 75 lb. box). However, no significant relationships were observed between size of filleting round fish and systolic blood pressure and product of mean heart rate and systolic blood pressure of the filleting operator (Tables 33, 34 and 37).

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[1]Heart rate for subject 2 could not be recorded -- failure of heart rate recording electrodes.

[2]$R_1$, $R_3$ and $R_4$ are correlation co-efficients between speed of filleting and mean heart rate for subject no. 1, subject no. 3 and subject no. 4 respectively.

[3]Also refer p. 213 of this report

This study has also shown significant linear relationship between actual output rate of fillets (lbs./hr.) and mean heart rate for all the subjects[1] (correlation coefficient $R_1 = 0.778$, $p < 0.05$; $R_3 = 0.604$, $p < 0.10$; $R_4 = 0.818$, $p < 0.01$ -- Table 22).[2] It was observed that an increase in actual output rate of cod fillets was associated with an increase in the mean heart rate of the filleting operator. However, no significant relationship was observed between actual output rate of fillets and blood pressure[3] (B/P) for all the four subjects (Table 23). It was also noted (Tables 22 to 25) that relationships obtained between actual output rate of round codfish and mean heart rate and blood pressure of the operator were almost the same as those obtained between actual output rate of cod fillets and mean heart rate and blood pressure of the operator. This is because in fish filleting, the amount of meat that could be extracted from a fish (i.e. weight of fillets) is a certain fixed proportion of the total weight of the round fish. Therefore, the ratio of actual output rate of fillets to actual output rate of round fish remains almost constant.

In this investigation, the product of mean heart rate (H/R) and blood pressure[4] (B/P), i.e., (H/R x B/P) was also used to represent the physiological load on the operator. Feinberg, H (1958) and De Vries and Adams (1972) had suggested that cardiac effort, represented by the product of mean heart rate and blood pressure, could be used as an indicator of work required of muscle tissue, i.e., work output rate. The results from this study have shown significant positive linear relationships between speed of filleting and (H/R x B/P) and also between actual output rate (fillets as well as fish) and (H/R x B/P) for subject 1 and subject 4 (Tables 21 to 24). However, no significant

[1] Heart rate for subject no. 2 could not be recorded -- failure of heart rate recording electrodes.

[2] $R_1$, $R_3$ and $R_4$ are correlation coefficients between actual output rate of fillets and mean heart rate for subject no. 1, subject no. 3 and subject no. 4 respectively.

[3] Both systolic blood pressure ($S_A$) and true mean blood pressure (T.M.B.P.).

[4] Ibid.

relationships could be observed between above parameters for subject 3. It was noted that the above relationships were more significant than those observed between work performance (speed of filleting and actual output rate) and blood pressure (B/P) of the operator (Tables 21 to 25) but were not as significant as observed between work performance and mean heart rate of the operator (Tables 21, 22 and 24), in which case significant results were obtained for all the subjects. Therefore, under the present working conditions in fish plants, of all the three physiological parameters (mean heart rate (H/R), blood pressure (B/P), and product of mean heart rate and blood pressure), mean heart rate could probably be considered as the best indicator for prediction of the physiological load on the filleting operator, when comparing it to work performance.

The working conditions in the fish plants are observed to be poor when compared to other types of manufacturing and food processing industry. The human operator works in an environment which is cold, humid and wet. The general work layouts and methods of processing are not so efficient. The present design of work layout and workplace height in fish industry has been maintained constant for filleting of all types of species and for all sizes of fish. In such a situation, tall operators have been observed to stoop down whereas short persons are observed to raise their upper arms during the filleting operation. The operators are also subjected to pressures from management and certain requirements from incentive schemes to fillet at maximum speed and also for maximum yield. Since this study has shown significant positive relationships between work performance (performance rating and actual output rate) and physiological parameters (mean heart rate, blood pressure, etc.), it is possible that the operator under present plant conditions of paced environment could be working at continuously higher physiological loads.

This study (Figure 28; Table 29) has also indicated a negative linear relationship trend between percentage yield and mean heart rate of each operator. However, no significant relationship was observed between percentage yield and operator's mean heart rate for all the subjects (Table 29).

In fish processing plants, the productivity and earnings of the company depend on both higher yield and faster throughput. One of the important recommendations pertaining to plant productivity by Research and Productivity Council (R.P.C.) in its recent report (1977) of "Canadian East Coast Ground Fish Processing Investigation" was: "As raw material costs represent the greatest single factor within the cost structure, the greatest single cost cutting opportunity for the industry would be the improvement of yields. The labour cost increase which can result from accepting slower production rates to obtain higher yields, is minimal as compared with the benefits to be obtained from lower material costs." Results from this investigation therefore suggest that working for higher yields, which is associated with lower mean heart rates of the operators (Figure 28; Table 29), is important both from economical as well as physiological point of view.[1]

The relationships obtained between work performance (speed of filleting and actual output rate) and physiological parameters (mean heart rate, blood pressure, etc.) could be developed to evaluate such factors as work load levels, equipment comparison, job evaluation and relative task difficulties. Multiple regression analysis shows that

[1] However, in actual practice, due to practical reasons (i.e. an effort to increase the yield will cause a decrease in the rate of output of

in fish processing, the heart rate of the operator depends on speed of filleting as well as on size of fish. The multiple linear equation Heart rate = a + b (speed of filleting) + c (no. of codfish per 75 lb. box) could be used to compare the physiological load imposed on the operator for different methods of filleting, for different heights of workplace, for different work layouts, for equipment comparisons, etc., in the following way. Suppose a decision is to be made about the selection of the better of two available methods of filleting. An average skilled operator can be asked to fillet a given size of fish at a certain speed, say normal speed[1] and using one particular method of filleting. His mean heart rate could be determined using the procedure used in this study. The same operator can then be asked to fillet the same size of fish, at the same speed but using the 'other' method of filleting. His mean heart rate in the second case could also be determined. The difference in the values of mean heart rates in the above two cases could be attributed to the difference in the values of constants (a, b and c) of the function, which depend on a number of factors such as physical condition of the operator, skill and experience, work layout, method of filleting, workplace height, immediate and general environmental conditions, etc. If all other factors except method of filleting were kept constant in the above two cases, then the difference in the observed mean heart rates of the filleter in the two cases would primarily be because of the difference in methods of filleting used. The method giving the lower mean heart rate and thus representing less physiological load on the operator would be

filleting operator considerably, since the operator slows down while filleting for increased yield), some speed or output incentive may need to be incorporated to achieve the optimum result both from economical and physiological point of view.

[1]In performance rating system, normal performance or speed is represented by 100 percent. "Motion and Time Study," by Barnes, 1968, p. 380.

considered the better[3] of the two methods from physiological aspects. The same above logic could be used to compare different workplace heights, work layouts and equipment comparisons, etc. This could result in the selection of the best method of filleting, optimum workplace height and work layout, etc., thus improving the overall efficiency of the plant without causing any unnecessary higher physiological loads on the operator.

Linear regression analysis between actual output rate and mean heart rate could be used to evaluate work load levels. The concept of optimum limit of performance for an 8-hour working day could be used for this purpose. Research investigators have generally agreed that this limit of performance is reached when the mean heart rate during work lies 30 beats/minute above the resting heart rate.[1] Using the above linear regression analysis, graphs could be drawn between actual output rate (roundfish as well as fillets) and mean heart rate of the operator[2] for different sizes of fish. Actual output rate corresponding to mean heart rate value during work, which lies 30 beats per minute above the resting mean heart rate value, would then represent the optimum level of performance for a given size of fish. The management in fish plants can then compare the actual output rates of filleters with the actual output rate of optimum level of

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[1]"Fitting the Task to the Man," by E. Grandjean, 1971, p. 56. Note: Resting heart rate means heart rate before the start of work.

[2]It is to be pointed out that since basic or resting heart rate levels differ from subject to subject, therefore graphs between actual output rate and mean heart rate should be plotted for a number of subjects. Good judgement could then be used in the selection of the actual output rate, representing the optimum limit of performance, from these various graphs. This limit should represent an average skilled worker as far as physiological load is concerned.

performance for different sizes of fish and determine whether the filleters are being subjected to higher physiological work load levels or not. If they are subjected to higher physiological work load levels then appropriate actions such as improvements in the working conditions, work layouts, methods of processing, imposition of less pressures from management, better employer-employee relations, etc., should be taken.

Work performance in a fish plant depends on many factors. This study has observed a curvilinear relationship between number of codfish per 75 lb. box and the normal output rate (roundfish as well as fillets) of the filleter (Table 26). A decrease in number of codfish per 75 lb. box (or an increase in the size of fish) resulted in a significant increase in normal output rate (roundfish as well as fillets) and vice-versa. This study has also shown that the rate of decrease of normal output rate (lbs./hr.) for the small size codfish, i.e., large number of fish per 75 lb. box, was not as high as when compared to the large size codfish, i.e., small number of fish per 75 lb. box (Figure 32).[1]

In fish processing, where the size of fish varies daily, the management should account for these variances when setting work standards. They should establish the relationships between size of fish and standard output rate of filleting for a range of different species, input quality of fish, offshore-inshore fish and the dressed-undressed condition of the fish. From these relationships the standard for the day, or for the hour if the daily variance is large, can be established by counting the average number of fish per given weight or per box and observing the standard output rate from the appropriate graph. The approach suggested above is considered to be proper and fair when establishing work standards, as compared to the setting of an arbitrary

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[1] Refer p.124, of this report.

figure based on the output values averaged over the range of fish size. It will also help the management from the point of view of industrial relations, standards and incentives, supervision and workers' understanding and acceptance of the work standards.

Multiple linear regression analysis between speed of filleting, number of codfish per 75 lb. box and actual output rate (roundfish as well as fillets) has shown that speed of filleting (performance rating) as well as size of fish has significant effect on actual output rate (lbs./hr.) (Tables 36 and 37). An increase in speed of filleting causes a significant increase ($p < 0.01$) in actual output rate whereas an increase in no. of codfish per 75 lb. box (or in other words, a decrease in size of fish) causes a significant decrease ($p < 0.01$) in actual output rate. This study has therefore shown that in a fish processing plant, size of fish and speed of filleting are the two main factors which affect the actual output rate (roundfish as well as fillets) of the filleting operator. In fish plants, the management should therefore account for these two factors carefully when looking for different ways to improve the work performance, i.e., actual output rate of fillets as well as of roundfish, of the filleting operator.

In fish processing, where the cost of material is considerably higher than the cost of labour, the amount of meat that can be filleted from a fish is more important than the rate of output. Though yield, to some extent, can be related to the skill of the operator, it has been observed that yield is also affected by the speed of filleting. This study has shown that an increase in speed of filleting causes a decrease in the yield (Tables 35 and 37).

The above speed-yield studies were conducted under a non-incentive set-up. Negative slopes were obtained under these conditions which ranged from 0.02 to 0.16.[1] The slopes and positions of these curves could be altered by offering money rewards, or by other forms of motivation, to the operators. Figure 33 shows the anticipated speed-yield relationship under three different incentive systems as well as the non-incentive system. It will be observed from the graph that the ideal incentive system should be based on yield alone, but due to practical reasons,[2] some speed incentive may need to be incorporated to achieve the optimum result.

## 5.2 Recommendations

This study has indicated linear positive relationships between work performance (performance rating and actual output rate) and physiological parameters (mean heart rate, systolic blood pressure etc.) of the filleting operator, for a given method of filleting,[3] workplace height (37") and work layout.[4] The management, in fish plants, should establish these relationships for different methods of filleting, workplace heights and work layouts. The method of filleting, workplace height and work layout, representing the least physiological load on the

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[1] Refer Table 27.

[2] An effort to increase the yield will cause a decrease in the rate of output of filleting operator considerably, since the operator slows down while filleting for increased yield.

[3] Refer Figures 7 and 8, pp. 23, 24 of this report.

[4] Refer Figures 2 and 3, pp. 16, 17 of this report.

filleting operator for a given work performance (output rate etc;), should be selected.

This study has shown a curvilinear relationship between number of fish count per 75 lb. box (or in other words, size of fish) and normal output rate (lbs/hr.) for filleting of cod. The management in fish plants should establish relationships between the above two factors for a range of different species of fish, input quality of fish, offshore -- inshore fish, and dressed -- undressed condition of the fish. These graphs should give a better indication of the standard for the day (or for the hour if the daily variance in fish is large) as compared to the arbitrary figure based on the output values averaged over the range of fish size.

The processing plant used in this study weighed out 75 lbs. of fish per box. One of its sister plants utilizes 100 lbs. of fish per box. The effect of quantity of fish per box (or in other words longer time to fillet per box) on the work performance and physiological load on the filleting operator should be investigated.

In fish plants there are usually two types of filleting table layouts (individual type and group type) used. This study was carried out in a fish plant using individual type filleting table layout. Further investigation of similar nature should also be carried out in fish plants, using group type filleting table layout.

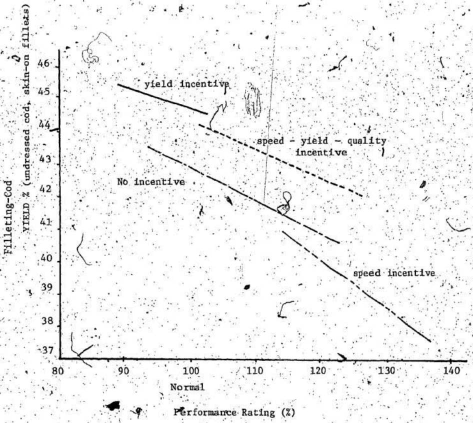


Figure 33: Anticipated relationship between performance rating (speed of filleting) and yield (undressed cod, skin-on fillets) under incentive and non-incentive conditions.

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# APPENDIX A

## COMPUTER PROGRAMS

# APPENDIX A

## COMPUTER PROGRAMS

Various computer programs used during this investigation are as follows:

### A-1 Linear Regression and Correlation Analysis

A linear regression computer program called CALCPLOT[1] was used on PDP 12, to compute linear correlation between work performance (speed of filleting, actual output rate) and physiological parameters (mean heart rate, blood pressure, etc.). Linear relationships were also computed between speed of filleting, number of codfish/75 lb. box, percentage yield and actual output rate, etc. A non-linear relationship between number of codfish/75 lb. box and normal output rate was also computed using CALCPLOT, by first converting the non-linear relationship into a linear log form. Input data information was provided using teletype unit. Output from this program included means of independent (X) and dependent (Y) variables, correlation coefficient (R), regression coefficients (a and b), the coefficient of determination ($R^2$), degree of freedom (d.f.), and a Test-statistic called Students' T-value, a measure of strength of the relationship between independent and dependent variables (Appendix B, Table B-1).

Relationships tested were of the form:

Linear Form: $Y = a + b\ (X)$

Non-Linear Form: $Y = a\ (X)^b$

Converted to Linear Form, it is: $\log_{10}(Y) = \log_{10}(a) + b\ \log_{10}(X)$

[1] "CALCPLOT" by Bobstock, 1971. Department of Physiology, University College London, England.

A-2 Multiple Linear Regression and Correlation Analysis

A computer program (BMDO2R - Stepwise regression)[1] for IBM-digit 370/150 was used to compute a sequence of multiple linear regression equations in a stepwise manner. At each step, one variable is added to the regression equations. The variable added is the one which has the highest partial correlation with the dependent variable. Input data is to be punched on cards. Output from the programme includes at each step multiple correlation coefficient (Rm), overall F-ratio value, correlation matrix, partial correlation coefficient and partial F-ratio value for each of the independent variables with dependent variable, and values of constants and regression coefficients, etc. (Appendix B, Table B-2). Multiple linear regression equation used was of the form:

$$Y = a + b(X_1) + c(X_2)$$

where $X_1$ = speed of filleting

$X_2$ = no. of codfish/75 lb. box

Y = mean heart rate, or blood pressure, or actual output rate or percentage yield, etc.

a = a constant

b, c = regression coefficients

A-3 Multiple Linear Regression and Correlation Analysis using Dummy Variables

A computer program (SPSS - Regression with dummy variables)[2] for IBM 370/150 was used. The detailed analysis is given in Chapter 4, "Results and Analysis" (pp. 120-122) of this report. In this investigation, there are four distinct blocks of data or, in other words, the data came from four different subjects. A set of dummy variables was, therefore, used to represent different subjects. Using dummy variables, it was possible to pool all four distinct blocks of data into one group

[1] "BMDO2R - stepwise regression," University of California, 1973. (Appendix B, Table B-2, p. 199)

[2] "Statistical Package for the Social Sciences" (SPSS) by Nie, Hull, Jenkins and Bent. 1975.

in a special way and then determine the overall correlation or overall F-ratio value of three independent variables (speed of filleting; number of codfish/75 lb. box; and the subject, a nominal variable) with dependent variables (mean heart rate, blood pressure, actual output rate, percentage yield, etc.). It was also possible to compute the overall partial correlation or overall partial F-ratio value of any of the independent variables (say, speed of filleting) with the dependent variable (say, mean heart rate), after controlling statistically the effects of other independent variables, i.e., number of codfish/75 lb. box and subject, on the dependent variable (mean heart rate), with the help of this computer program (Appendix B, Tables B-5, B-6)

A-4 Conversion of Analog Heart Beat Signals[1] to Digital Output

Discussed in section 3.4.3, p. 89 of this report. Also refer Appendix B, Tables B-3 and B-4, pp 205-207.

[1]Electrocardiogram

APPENDIX B

COMPUTER PRINT-OUTS

APPENDIX B

```
C7 B<140 >
JA
NEW DATA? YES ON TAPE? NO

NO. OF DATA POINTS = 8
X1 =117.1  Y1 =124.8
X2 =109  Y2 =120.4
X3 =101  Y3 =106.5
X4 =98.7  Y4 =108.1
X5 =113.7  Y5 =110.4
X6 =116.9  Y6 =115.6
X7 =100.6  Y7 =103.5
X8 =105.6  Y8 =106.9
ANY MISTAKES? NO
MEANS AND S.D.S? YES
 MEAN X=+1.0783E+2  S[X]=+7.4762E+0
 MEAN Y=+1.1202E+2  S[Y]=+7.4994E+0
Y[EST]=A+BX
 A=+2.9976E+1
 B=+7.6094E-1
CORRLN. COEFF.
 R=+0.7586 R[SQ]=+0.5754
 T=+2.8518 D.F.=6
[P<0.05 IF T>+2.443 , P<0.01 IF T>+3.714 ]
```

Note X: Performance rating (%)
(independent variable)

Y: Mean heart rate (beats/min.)
(dependent variable)

Table No. B-1: Linear regression analysis results (using CALCPLOT) between performance rating and mean heart rate for subject no. 1. Also refer Tables 17 and 21.

## APPENDIX - B

```
//E3010AAB JOB (3010,4ABC,01,011),S.SARNA,CLASS=C,MSGLEVEL=1,REGION=120K JOB 384
//STEP1 EXEC NK00,PROGRAM=BMD02R
XXDATA   EXEC  PGM=&PROGRAM,REGION=120K                                  00000010
IEF653I SUBSTITUTION JCL - PGM=BMD02R,REGION=120K
XXSTEPLIB   DD   DSN=NLCS.LOADLIB2,DISP=SHR                              00000020
XXFT01F001 DD   UNIT=SYSDA,SPACE=(CYL,(1,1))                             00000030
XXFT02F001 DD   UNIT=SYSDA,SPACE=(CYL,(1,1))                             00000040
XXFT03F001 DD   UNIT=SYSDA,SPACE=(CYL,(1,1))                             00000050
XXFT04F001 DD   UNIT=SYSDA,SPACE=(CYL,(1,1))                             00000060
XXFT05F001 DD   DDNAME=INPUT                                             00000070
XXFT06F001 DD   SYSOUT=A                                                 00000080
XXFT07F001 DD   SYSOUT=B                                                 00000090
//DATA.INPUT DD *
//
IEF236I ALLOC. FOR E3010AAB DATA      STEP1
IEF237I 163    ALLOCATED TO STEPLIB
IEF237I 151    ALLOCATED TO FT01F001
IEF237I 151    ALLOCATED TO FT02F001
IEF237I 151    ALLOCATED TO FT03F001
IEF237I 151    ALLOCATED TO FT04F001
IEF237I 4A1    ALLOCATED TO FT05F001
IEF237I 40A    ALLOCATED TO FT06F001
IEF237I 4EC    ALLOCATED TO FT07F001
IEF142I - STEP WAS EXECUTED - COND CODE 0000
IEF285I   NLCS.LOADLIB2                                        KEPT
IEF285I   VOL SER NOS= VSLINK.
IEF285I   SYS78160.T082529.RV000.E3010AAB.R0003303      DELETED
IEF285I   VOL SER NOS= PRK002.
IEF285I   SYS78160.T082529.RV000.E3010AAB.R0003304      DELETED
IEF285I   VOL SER NOS= LRK002.
IEF285I   SYS78160.T082529.RV000.E3010AAB.R0003305      DELETED
IEF285I   VOL SER NOS= PRK002.
IEF285I   SYS78160.T082529.RV000.E3010AAB.R0003306      DELETED
IEF285I   VOL SER NOS= PRK002.
IEF373I STEP /DATA     / START 78160.1556
IEF374I STEP /DATA     / STOP  78160.1556 CPU    0MIN 00.68SEC STOR VIRT 120K
IEF375I  JOB /E3010AAB/ START 78160.1556
IEF376I  JOB /E3010AAB/ STOP  78160.1556 CPU    0MIN 00.68SEC

*****************************************************
*                                                   *
*     ACCOUNT ALLOCATION =    5.0000  UNIT(S)        *
*                                                   *
*     ACCOUNT UTILIZATION (UNITS)                   *
*                                                   *
*        PREVIOUS     3.3282                        *
*        THIS JOB     0.0006                        *
*                    -------                        *
*        TOTAL        3.3288    OR    66.58 %        *
*                                                   *
*****************************************************
```

Table B-2: Multiple linear regression analysis results (using BMD02R) between performance rating (independent variable), No. of cod-fish per 75 lb. box (independent variable) and mean heart rate (dependent variable) for subject no. 1. Refer Tables 17 and 30.

```
BMD02R - STEPWISE REGRESSION - REVISED MARCH 27, 1973
HEALTH SCIENCES COMPUTING FACILITY, UCLA

PROBLEM CODE                         HRRPEX
NUMBER OF CASES                           8
NUMBER OF ORIGINAL VARIABLES              3
NUMBER OF VARIABLES ADDED                 0
TOTAL NUMBER OF VARIABLES                 3
NUMBER OF SUB-PROBLEMS IS                 1
THE VARIABLE FORMAT IS   (F4.1,F2.0,F4.1)

   VARIABLE          MEAN        STANDARD DEVIATION
 RAINFG   1       107.82492          7.47637
 FISH/B   2        24.87500          5.35659
 H/RATE   3       112.02493          7.49887
```

Table B-2: (cont'd.) Multiple linear regression analysis results (using BMD02R).

COVARIANCE MATRIX

| VARIABLE NUMBER | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 55.896 | -8.668 | 42.535 |
| 2 | | 5.554 | -14.776 |
| 3 | | | 56.233 |

Table B-2: (cont'd.)

CORRELATION MATRIX

| VARIABLE NUMBER | 1 | 2 | 3 |
| --- | --- | --- | --- |
| 1 | 1.000 | -0.492 | 0.759 |
| 2 | | 1.000 | -0.837 |
| 3 | | | 1.000 |

Table B-2: (cont'd.)

```
SUB-PROBLEM        1
 DEPENDENT VARIABLE              3
 MAXIMUM NUMBER OF STEPS         6
 F-LEVEL FOR INCLUSION     0.010000
 F-LEVEL FOR DELETION      0.005000
 TOLERANCE LEVEL           0.001000

 STEP NUMBER        1
 VARIABLE ENTERED   2

 MULTIPLE R               0.8373
 STD. ERROR OF EST.       4.4287

 ANALYSIS OF VARIANCE
                  DF    SUM OF SQUARES    MEAN SQUARE    F RATIO
      REGRESSION   1        275.952         275.952      14.070
      RESIDUAL     6        147.679          19.613

          VARIABLES IN EQUATION                  :             VARIABLES NOT IN EQUATION
 VARIABLE     COEFFICIENT  STD. ERROR  F TO REMOVE :  VARIABLE   PARTIAL CORR.   TOLERANCE   F TO ENTER
                                                   :
 (CONSTANT     178.29924 )                         :
 FISHZR  2      -2.66424    0.71029   14.0696 (2)  :  RATING  1     0.72846        0.7580     5.6530 (2)

 STEP NUMBER        2
 VARIABLE ENTERED   1

 MULTIPLE R               0.9272
 STD. ERROR OF EST.       3.3236

 ANALYSIS OF VARIANCE
                  DF    SUM OF SQUARES    MEAN SQUARE    F RATIO
      REGRESSION   2        338.498         169.199      15.317
      RESIDUAL     5         55.233          11.047

          VARIABLES IN EQUATION                  :             VARIABLES NOT IN EQUATION
 VARIABLE     COEFFICIENT  STD. ERROR  F TO REMOVE :  VARIABLE   PARTIAL CORR.   TOLERANCE   F TO ENTER
                                                   :
 (CONSTANT     111.00726 )                         :
 RATING  1       0.45887    0.19306    5.6530 (2)  :
 FISHZR  2      -1.94812    0.61228   10.1234 (2)  :

F-LEVEL OR TOLERANCE INSUFFICIENT FOR FURTHER COMPUTATION
```

Table B-2: (cont'd.)

SUMMARY TABLE

| STEP NUMBER | VARIABLE ENTERED | VARIABLE REMOVED | MULTIPLE R | MULTIPLE RSQ | INCREASE IN RSQ | F VALUE TO ENTER OR REMOVE | NUMBER OF INDEPENDENT VARIABLES INCLUDED |
|---|---|---|---|---|---|---|---|
| 1 | FISH/H 2 | | 0.8373 | 0.7010 | 0.7010 | 14.0698 | 1 |
| 2 | RATING 1 | | 0.9272 | 0.8597 | 0.1586 | 5.6530 | 2 |

FINISH CARD ENCOUNTERED
PROGRAM TERMINATED

Table B-2: (cont'd.)

APPENDIX B

```
OS/8  FORTRAN IV  3.02
      DIMENSION ISTOR(160),JSTOR(70)
      RDOLD=0
      IRDOLD=0
3     CONTINUE
      DO 16 I=1,60
16    JSTOR(I)=0
      DO 17 I=1,150
17    ISTOR(I)=0
      CALL CLOCK(6,100)
10    CALL SYNC(3,I)
      CALL SSW(0,ING)
      IF(ING.EQ.1) GOTO 50
      IF(I.EQ.1) GOTO 40
      CALL SYNC(2,J)
      IF(J.EQ.0) GOTO 10
      IRDCLK=TIME(DUM)
      IRDTIM=IRDCLK-IRDOLD
      IRDOLD=IRDCLK
      JSTOR(IRDTIM)=JSTOR(IRDTIM)+1
      GOTO 10
40    RDCLK=TIME(DUM)
      RDTIM=RDCLK-RDOLD
      RDOLD=RDCLK
      IF(IRDTIM.LE.0.3) GOTO 10
      INT=RDTIM*100.
      CALL SSW(1,IMP)
      IF(IMP.EQ.1) GOTO 3
      IF(INT.LE.2) GOTO 10
      ISTOR(INT)=ISTOR(INT)+1
      CALL SSW (0,ING)
      IF(ING.EQ.1) GOTO 50
      GOTO 10
50    WRITE(3,13)
13    FORMAT(1H1,////'     TIME      FREQUENCY')
      DO 30 IH=40,150
      TIH=IH
      TIJ=TIH/100.
      WRITE(3,7) TIJ,ISTOR(IH)
7     FORMAT(1H+,F6.2,I10)
30    CONTINUE
      WRITE(3,13)
      DO 35 I=1,60
35    WRITE(3,9) I,JSTOR(I)
9     FORMAT(1H+,2I10)
      GOTO 3
      STOP
      END
```

TABLE B-3:

Computer program on PDP 12, used to convert subject's heart beat (analog) signals recorded on magnetic tape, into digital output (heart beat interval frequency distribution form). Refer p. 206.

APPENDIX B

TABLE NO. B-3: (Cont'd)

Conversion of recorded heart beat analog signals on magnetic tape to digital output - heart beat interval frequency distribution form.

Subject No. 3, Experiment No. 8.

| TIME[1] | FREQUENCY |
|---|---|
| 0.40 | 0 |
| 0.41 | 0 |
| 0.42 | 0 |
| 0.43 | 0 |
| 0.44 | 1 |
| 0.45 | 1 |
| 0.46 | 2 |
| 0.47 | 1 |
| 0.48 | 0 |
| 0.49 | 2 |
| 0.50 | 0 |
| 0.51 | 1 |
| 0.52 | 2 |
| 0.53 | 2 |
| 0.54 | 4 |
| 0.55 | 5 |
| 0.56 | 7 |
| 0.57 | 18 |
| 0.58 | 39 |
| 0.59 | 50 |
| 0.60 | 65 |
| 0.61 | 99 |
| 0.62 | 77 |
| 0.63 | 101 |
| 0.64 | 91 |
| 0.65 | 78 |
| 0.66 | 78 |
| 0.67 | 44 |
| 0.68 | 17 |
| 0.69 | 28 |
| 0.70 | 18 |
| 0.71 | 12 |
| 0.72 | 9 |
| 0.73 | 16 |
| 0.74 | 0 |
| 0.75 | 7 |
| 0.76 | 4 |
| 0.77 | 1 |
| 0.78 | 0 |
| 0.79 | 0 |
| 0.80 | 0 |

[1] Represents time between any two successive heart beats (in seconds).

## APPENDIX B

```
LIST
SARNA
10 N=41
20 A1=0.0
30 B1=0.0
40 FOR I=1 TO 41
50 READ X,F
60 DATA .40,0,.41,0,.42,0,.43,0,.44,1,.45,1,.46,2,.47,1,.48,0
70 DATA .49,2,.50,0,.51,1,.52,2,.53,2,.54,4,.55,5,.56,7,
80 DATA .57,18,.58,39,.59,50,.60,65,.61,99,.62,77,.63,101
90 DATA .64,91,.65,78,.66,78,.67,44,.68,17,.69,28,.70,18
100 DATA .71,12,.72,9,.73,16,.74,0,.75,7,.76,4,.77,1,.78,0
110 DATA .79,0,.80,0
120 A1=A1+F*X
130 B1=B1+F
140 NEXT I
150 C=A1/B1
160 PRINT "THE MEAN VALUE=";C

READY

RUN
SARNA
THE MEAN VALUE= .632909 ✓
     OF X
READY
```

X: represents time between any two successive heart beats (in seconds).

F: Corresponding frequency for each value of X.

$$\text{Mean heart rate} = \frac{1}{\text{(mean heart beat interval) (in seconds)}} \times 60$$

$$= \frac{1}{0.632909} \times 60 = 94.80 \text{ beats/min.}$$ (Refer Table 14)

TABLE B-4:

Calculation of mean heart rate for subject no. 3, experiment no. 8, using a computer program on PDP 12.

Note: Input data comes from heart beat interval, time-frequency distribution computer printout. Refer table B-3, p. 206.

## APPENDIX - B

```
//E30100AH JOB (3010,4ABC,1,3),S.SARNA,CLASS=C,REGION=193K          JOB 597
// EXEC SPSS30M,PARM=0000
XXSPSS700  PROC                                                      00000100
XXGO  EXEC  PGM=SPSS,REGION=220K                                     00000200
XXSTEPLIB  DD  DSN=SPSSLOAD,DISP=SHR                                 00000300
XXFT10F001  DD  DSN=MCS.UDCFILE.SPSSVER7,DISP=SHR,DCB=BUFNO=1)       00000400
XXFT01F001  DD  UNIT=SYSDA,SPACE=(CYL,(5,2))                         00000500
XXFT02F001  DD  UNIT=SYSDA,SPACE=(CYL,(5,2))                         00000600
XXFT03F001  DD  DDNAME=GETFILE                                       00000700
XXFT04F001  DD  DDNAME=SAVEFILE                                      00000800
XXFT05F001  DD  DDNAME=SYSIN                                         00000900
XXFT06F001  DD  SYSOUT=A                                             00001000
XXFT08F001  DD  DDNAME=INPUT                                         00001100
XXFT09F001  DD  DDNAME=OUTPUT                                        00001200
//SYSIN DD *
//
IEF236I ALLOC. FOR E3010AB GO
IEF237I 141   ALLOCATED TO STEPLIB
IEF237I 141   ALLOCATED TO FT10F001
IEF237I 150   ALLOCATED TO FT01F001
IEF237I 150   ALLOCATED TO FT02F001
IEF237I 4A2   ALLOCATED TO FT05F001
IEF237I 400   ALLOCATED TO FT06F001
IEF142I - STEP WAS EXECUTED - COND CODE 0000
IEF285I   SPSSLOAD                                       KEPT
IEF285I   VOL SER NOS= VS2RES.
IEF285I   MCS.UDCFILE.SPSSVER7                           KEPT
IEF285I   VOL SER NOS= VS2RES.
IEF285I   SYS78159.T130635.RV000.E3010AB.R0003428        DELETED
IEF285I   VOL SER NOS= TSTAF4.
IEF285I   SYS78159.T130635.RV000.F3010AB.R0003429        DELETED
IEF285I   VOL SER NOS= TSTAF4.
IEF373I STEP /GO      / START 78159.2212
IEF374I STEP /GO      / STOP  78159.2212 CPU   0MIN 01.43SEC STOR VIRT 212K
IEF375I  JOB /E3010AB/ START 78159.2212
IEF376I  JOB /E3010AB/ STOP  78159.2212 CPU   0MIN 01.43SEC

/*********************************************************************
*                                                                    *
*         ACCOUNT ALLOCATION =    5.0060  UNIT(S)                    *
*                                                                    *
*        ACCOUNT UTILIZATION (UNITS)                                 *
*                                                                    *
*            PREVIOUS      3.1325                                    *
*            THIS JOB      0.0016                                    *
*                          ------                                    *
*            TOTAL         3.1341      OR    62.68 %                 *
*                                                                    *
**********************************************************************
```

Table B-5: Multiple linear regression analysis results, using dummy variables, (SPSS). Shows Overall and Partial F-ratio values and correlation co-efficients (Rm) etc., of performance rating (independent variable) and No. of cod fish per 75 lb. box (another independent variable) (effect of subject is controlled in both cases) with mean heart rate (dependent variable) for group analysis. Refer Table 37.

```
STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES                                06/08/78        PAGE    1

SPSS FOR OS/360, VERSION H, RELEASE 7.0, MARCH 1977

DEFAULT SPACE ALLOCATION.        ALLOWS FOR..    100 TRANSFORMATIONS
WORKSPACE      76800 BYTES                       400 RECODE VALUES + LAG VARIABLES
TRANSPACE      10000 BYTES                      1600 IF/COMPUTE OPERATIONS

                    RUN NAME         MULTIPLE REGRESSION RUN USING DUMMY VARIABLES
                    FILE NAME        FISH PROCESSING  PHYSIOLOGICAL CORRELATES OF WORK PERFORMANCE
                    VARIABLE LIST    Y1,X1,X2,D1,D2,X101,X102,X201,X202
                    VAR LABELS       Y1 MEAN HEART RATE/
                                     X1 PERFORMANCE RATING/
                                     X2 NO OF COD FISH PERHOX
                    INPUT FORMAT     FIXED(2F4.1,F2.0,2F1.0,2F4.1,2F2.0)

                    ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

                    VARIABLE  FORMAT  RECORD   COLUMNS

                    Y1        F 4. 1     1       1-  4
                    X1        F 4. 1     1       5-  8
                    X2        F 2. 0     1       9- 10
                    D1        F 1. 0     1      11- 11
                    D2        F 1. 0     1      12- 12
                    X101      F 4. 1     1      13- 16
                    X102      F 4. 1     1      17- 20
                    X201      F 2. 0     1      21- 22
                    X202      F 2. 0     1      23- 24

THE INPUT FORMAT PROVIDES FOR   9 VARIABLES.   9 WILL BE READ
IT PROVIDES FOR   1 RECORDS ('CARDS') PER CASE.  A MAXIMUM OF   24 'COLUMNS' ARE USED ON A RECORD.

                    N OF CASES       26
                    REGRESSION       VARIABLES=Y1,X1,X2,D1,D2,X101,X102,X201,X202/
                                     REGRESSION=Y1 WITH X1(4),X2,D1,D2,X201,X202(6)/
                                     REGRESSION=Y1 WITH X1,D1,D2,X101,X102(6),X2(4)/
                                     REGRESSION=Y1 WITH X1,X2,D1,D2,X101,X102,X201,X202(2)
                    STATISTICS       ALL

***** REGRESSION PROBLEM REQUIRES   1872 BYTES WORKSPACE, NOT INCLUDING RESIDUALS *****

                    READ INPUT DATA
```

Table B-5: (cont'd.) Multiple linear regression analysis results, using dummy variables (SPSS).

MULTIPLE REGRESSION RUN USING DUMMY VARIABLES 06/08/78 PAGE 2

FILE FISH (CREATION DATE = 06/08/78) PROCESSING PHYSIOLOGICAL CORRELATES OF WORK PERFORMANCE

| VARIABLE | MEAN | STANDARD DEV | CASES |
|---|---|---|---|
| Y1 | 107.1538 | 7.6373 | 26 |
| X1 | 109.5769 | 11.7777 | 26 |
| X2 | 35.2692 | 12.2786 | 26 |
| D1 | 0.3077 | 0.4707 | 26 |
| D2 | 0.3846 | 0.4961 | 26 |
| X101 | 32.8269 | 50.3783 | 26 |
| X102 | 38.5731 | 50.6988 | 26 |
| X201 | 14.3462 | 22.1503 | 26 |
| X202 | 13.2692 | 18.8967 | 26 |

Table B-5: (cont'd.)

MULTIPLE REGRESSION RUN USING DUMMY VARIABLES 06/08/78 PAGE

FILE FISH-2 (CREATION DATE = 06/08/78) PROCESSING PHYSIOLOGICAL CORRELATES OF WORK PERFORMANCE

CORRELATION COEFFICIENTS

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.

| | Y1 | X1 | X2 | D1 | D2 | X101 | X102 | X201 | X202 |
|---|---|---|---|---|---|---|---|---|---|
| Y1 | 1.00000 | 0.73054 | -0.40687 | -0.07823 | -0.33715 | -0.09796 | -0.24745 | -0.05774 | -0.43666 |
| X1 | 0.73659 | 1.00000 | -0.19980 | 0.12183 | -0.29345 | 0.14904 | -0.12969 | 0.15183 | -0.41306 |
| X2 | -0.40687 | -0.19980 | 1.00000 | 0.62877 | -0.05051 | 0.63986 | -0.10221 | 0.65617 | 0.23051 |
| D1 | -0.07823 | 0.12183 | 0.62877 | 1.00000 | -0.52705 | 0.99677 | -0.51726 | 0.99075 | -0.47740 |
| D2 | -0.33715 | -0.29345 | -0.05051 | -0.52705 | 1.00000 | -0.52534 | 0.98144 | -0.52217 | 0.90581 |
| X101 | -0.09796 | 0.14904 | 0.63986 | 0.99677 | -0.52534 | 1.00000 | -0.51559 | 0.99482 | -0.47586 |
| X102 | -0.24745 | -0.12969 | -0.10221 | -0.51726 | 0.98144 | -0.51559 | 1.00000 | -0.51248 | 0.85479 |
| X201 | -0.05774 | 0.15183 | 0.65617 | 0.99075 | -0.52217 | 0.99482 | -0.51248 | 1.00000 | -0.47299 |
| X202 | -0.43666 | -0.41306 | 0.23051 | -0.47740 | 0.90581 | -0.47586 | 0.85479 | -0.47299 | 1.00000 |

Table B-5: (cont'd.)

MULTIPLE REGRESSION RUN USING DUMMY VARIABLES 06/08/78 PAGE 4

FILE FISH (CREATION DATE = 06/08/78) PROCESSING PHYSIOLOGICAL CORRELATES OF WORK PERFORMANCE

* * * * * * * * * * * * * * * * * * * * * * * * M U L T I P L E R E G R E S S I O N * * * * * * * * * * * * * * * * VARIABLE LIST 1
REGRESSION LIST 1

DEPENDENT VARIABLE.. Y1 MEAN HEART RATE

VARIABLE(S) ENTERED ON STEP NUMBER 1.. X2D2 NO OF COD FISH PERBOX
X2
D1
D2
X2D1

| | | | | | | |
|---|---|---|---|---|---|---|
| MULTIPLE R | 0.71472 | ANALYSIS OF VARIANCE | DF | SUM OF SQUARES | MEAN SQUARE | F |
| R SQUARE | 0.51082 | REGRESSION | 5. | 744.89335 | 148.97067 | 4.17698 |
| ADJUSTED R SQUARE | 0.38853 | RESIDUAL | 20. | 713.33139 | 35.66657 | |
| STANDARD ERROR | 5.97215 | | | | | |

| VARIABLES IN THE EQUATION | | | | | VARIABLES NOT IN THE EQUATION | | | | |
|---|---|---|---|---|---|---|---|---|---|
| VARIABLE | B | BETA | STD ERROR B | F | VARIABLE | BETA IN | PARTIAL | TOLERANCE | F |
| X2D2 | 2.366770 | 5.86093 | 0.96939 | 5.971 | X1 | 0.57192 | 0.68986 | 0.71172 | 17.253 |
| X2 | -2.664308 | -4.28343 | 0.95785 | 7.737 | | | | | |
| D1 | -89.28649 | -5.54260 | 30.32953 | 8.666 | | | | | |
| D2 | -64.14359 | -4.15671 | 24.54995 | 6.832 | | | | | |
| X2D1 | 1.034535 | 8.88095 | 1.03700 | 8.563 | | | | | |
| (CONSTANT) | 178.2997 | | | | | | | | |

Table B-5: (cont'd.)

MULTIPLE REGRESSION RUN USING DUMMY VARIABLES 06/08/78 PAGE 7

FILE FISH (CREATION DATE = 06/08/78) PROCESSING PHYSIOLOGICAL CORRELATES OF WORK PERFORMANCE

* * * * * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * * * * * VARIABLE LIST 1 REGRESSION LIST 2

DEPENDENT VARIABLE.. Y1 MEAN HEART RATE

VARIABLE(S) ENTERED ON STEP NUMBER 1.. X1 PERFORMANCE RATING
D1
D2
X1D1
X1D2

| | | | | | | |
|---|---|---|---|---|---|---|
| MULTIPLE R | 0.82989 | ANALYSIS OF VARIANCE | DF | SUM OF SQUARES | MEAN SQUARE | F |
| R SQUARE | 0.68872 | REGRESSION | 5. | 1004.31208 | 200.86242 | 8.85427 |
| ADJUSTED R SQUARE | 0.61090 | RESIDUAL | 20. | 453.91266 | 22.64563 | |
| STANDARD ERROR | 4.76399 | | | | | |

------------------ VARIABLES IN THE EQUATION ------------------

| VARIABLE | B | BETA | STD ERROR B | F |
|---|---|---|---|---|
| X1 | 0.7609608 | 1.17349 | 0.24084 | 9.983 |
| D1 | 1.063426 | 0.06559 | 36.20717 | 0.001 |
| D2 | 39.70666 | 2.57942 | 27.85800 | 2.032 |
| X1D1 | -0.5575909D-01 | -0.36775 | 0.33690 | 0.027 |
| X1D2 | -0.4171606 | -2.78251 | 0.26001 | 2.599 |
| (CONSTANT) | 59.47300 | | | |

------------ VARIABLES NOT IN THE EQUATION ------------

| VARIABLE | BETA IN | PARTIAL | TOLERANCE | F |
|---|---|---|---|---|
| X2 | -0.33883 | -0.37969 | 0.39087 | 3.200 |

Table B-5: (cont'd.)

MULTIPLE REGRESSION RUN USING DUMMY VARIABLES   PROCESSING   PHYSIOLOGICAL CORRELATES OF WORK PERFORMANCE-   06/08/78   PAGE 10

FILE   FISH   (CREATION DATE = 06/08/78)   * * * * * * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * * * * * *   VARIABLE LIST 1
REGRESSION LIST 3

DEPENDENT VARIABLE..   Y1   MEAN HEART RATE

VARIABLE(S) ENTERED ON STEP NUMBER 1..   X202   PERFORMANCE RATING
X1   NO OF COD FISH PERBOX
X2
D1
D2
X101
X102
X201

| | | | | | | |
|---|---|---|---|---|---|---|
| MULTIPLE R | 0.89682 | ANALYSIS OF VARIANCE | DF | SUM OF SQUARES | MEAN SQUARE | F |
| R SQUARE | 0.80429 | REGRESSION | 8. | 1172.83002 | 146.60375 | 8.73269 |
| ADJUSTED R SQUARE | 0.71219 | RESIDUAL | 17. | 285.39473 | 16.78793 | |
| STANDARD ERROR | 4.09731 | | | | | |

----------------- VARIABLES IN THE EQUATION -----------------

| VARIABLE | B | BETA | STD ERROR B | F |
|---|---|---|---|---|
| X202 | 1.001300 | 0.95688 | 0.16320 | 5.571 |
| X1 | 0.4588659 | 0.70763 | 0.23792 | 3.720 |
| X2 | -1.948129 | -3.13292 | 0.75481 | 6.661 |
| D1 | -82.94318 | -5.11161 | 44.27993 | 3.509 |
| D2 | -31.15717 | -2.02484 | 40.26029 | 0.599 |
| X101 | 0.4818189 | 3.17823 | 0.36130 | 1.778 |
| X102 | -0.1679570 | -1.11096 | 0.25592 | 0.432 |
| X201 | 1.673039 | 0.27239 | 0.83890 | 3.883 |
| (CONSTANT) | 111.6075 | | | |

------------ VARIABLES NOT IN THE EQUATION ------------

| VARIABLE | BETA IN | PARTIAL | TOLERANCE | F |
|---|---|---|---|---|

ALL VARIABLES ARE IN THE EQUATION

Table B-5 (cont'd.)

APPENDIX - B

```
//E3010 4AH JOB (3010,4ABC,1,3),S.SARNA,CLASS=C,REGION=193K              JOB  510
// EXEC SPSS300,PARM=80000
XXSPSS700  PROC                                                         00000100
XXGO   EXEC  PGM=SPSS,REGION=220K                                       00000200
XXSTEPLIB  DD  DSN=SPSSLOAD,DISP=SHR                                    00000300
XXFT10F001  DD  DSN=NLCS,UDCFILE.SPSSVER7,DISP=SHR,UCB=BUFNO=1          00000400
XXFT01F001  DD  UNIT=SYSDA,SPACE=(CYL,(5,2))                            00000500
XXFT02F001  DD  UNIT=SYSDA,SPACE=(CYL,(5,2))                            00000600
XXFT03F001  DD  DDNAME=GETFILE                                          00000700
XXFT04F001  DD  DDNAME=SAVEFILE                                         00000800
XXFT05F001  DD  DDNAME=SYSIN                                            00000900
XXFT06F001  DD  SYSOUT=A                                                00001000
XXFT08F001  DD  DDNAME=INPUT                                            00001100
XXFT09F001  DD  DDNAME=OUTPUT                                           00001200
//SYSIN DD *
//
IEF236I ALLOC. FOR E3010 4AB GO
IEF237I 141   ALLOCATED TO STEPLIB
IEF237I 141   ALLOCATED TO FT10F001
IEF237I 150   ALLOCATED TO FT01F001
IEF237I 150   ALLOCATED TO FT02F001
IEF237I 4A2   ALLOCATED TO FT05F001
IEF237I 400   ALLOCATED TO FT06F001
IEF142I - STEP WAS EXECUTED - COND CODE 0000
IEF285I   SPSSLOAD                                       KEPT
IEF285I   VOL SER NOS= VS2RES.
IEF285I   NLCS.UDCFILE.SPSSVER7                          KEPT
IEF285I   VOL SER NOS= VS2RES.
IEF285I   SYS78159.T130635.RV000.E3010 4AB.R0003456      DELETED
IEF285I   VOL SER NOS= TSTO04.
IEF285I   SYS78159.T130635.RV000.E3010 4AB.R0003457      DELETED
IEF285I   VOL SER NOS= TSTO04.
IEF373I STEP /GO      / START 78159.2213
IEF374I STEP /GO      / STOP  78159.2214 CPU   0MIN 01.70SEC STOR VIRT 212K
IEF375I  JOB /E3010 4AB/ START 78159.2213
IEF376I  JOB /E3010 4AB/ STOP  78159.2214 CPU   0MIN 01.70SEC

************************************************************
*         ACCOUNT ALLOCATION =    5.0000  UNIT(S)          *
*                                                          *
*         ACCOUNT UTILIZATION (UNITS)                      *
*                                                          *
*           PREVIOUS      3.1341                           *
*           THIS JOB      0.0019                           *
*                         ------                           *
*           TOTAL         3.1360    OR   62.72 %           *
************************************************************
```

Table B-6: Multiple linear regression analysis results, using dummy variables (SPSS). Shows Overall and Partial F-ratio values and correlation co-efficients (Rm) etc., of performance rating (independent variable) and No. of cod fish per 75 lb. box (another independent variable) (effect of subject is controlled in both cases) with actual output rate, (cod fillets) (dependent variable) for group analysis. Also refer Table 37.

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STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES                                    06/08/78        PAGE   1

SPSS FOR OS/360, VERSION H, RELEASE 7.0, MARCH 1977

DEFAULT SPACE ALLOCATION..     ALLOWS FOR..    100 TRANSFORMATIONS
WORKSPACE      75000 BYTES                     400 RECODE VALUES + LAG VARIABLES
TRANSPACE      10000 BYTES                    1000 IF/COMPUTE OPERATIONS

                  RUN NAME        MULTIPLE REGRESSION RUN USING DUMMY VARIABLES
                  FILE NAME       FISH PROCESSING  PHYSIOLOGICAL CORRELATES OF WORK PERFORMANCE
                  VARIABLE LIST   Y1,X1,X2,D1,D2,D3,X1D1,X1D2,X1D3,X2D1,X2D2,X2D3,Y2
                  VAR LABELS      Y1 BLOOD PRESSURE/
                                  Y2 ACTUAL OUTPUT RATE UNDRESSED COD FILLETS/
                                  X1 PERFORMANCE RATING/
                                  X2 NO OF COD FISH PER BOX
                  INPUT FORMAT    FIXED(2F4.1,F2.0,3F1.0,3F4.1,3F2.0,F4.1)

                  ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

                  VARIABLE  FORMAT  RECORD   COLUMNS

                  Y1        F 4. 1     1       1-  4
                  X1        F 4. 1     1       5-  8
                  X2        F 2. 0     1       9- 10
                  D1        F 1. 0     1      11- 11
                  D2        F 1. 0     1      12- 12
                  D3        F 1. 0     1      13- 13
                  X1D1      F 4. 1     1      14- 17
                  X1D2      F 4. 1     1      18- 21
                  X1D3      F 4. 1     1      22- 25
                  X2D1      F 2. 0     1      26- 27
                  X2D2      F 2. 0     1      28- 29
                  X2D3      F 2. 0     1      30- 31
                  Y2        F 4. 1     1      32- 35

THE INPUT FORMAT PROVIDES FOR  13 VARIABLES.   13 WILL BE READ.
IT PROVIDES FOR  1 RECORDS ('CARDS') PER CASE.  A MAXIMUM OF   35 'COLUMNS' ARE USED ON A RECORD.

                  N OF CASES      35
                  REGRESSION      VARIABLES=Y1,Y2,X1,X2,D1,D2,D3,X1D1,X1D2,X1D3,X2D1,X2D2,X2D3/
                                  REGRESSION=Y2 WITH X1,D1,D2,D3,X1D1,X1D2,X1D3(6),X2(4)/
                                  REGRESSION=Y2 WITH X2,D1,D2,D3,X2D1,X2D2,X2D3(6),X1(4)/
                                  REGRESSION=Y2 WITH X1,X2,D1,D2,D3,X1D1,X1D2,X1D3,X2D1,X2D2,
                                  X2D3(2)
                  STATISTICS      ALL

***** REGRESSION PROBLEM REQUIRES    3432 BYTES WORKSPACE, NOT INCLUDING RESIDUALS *****

                  READ INPUT DATA
```

Table B-6: (cont'd.) Multiple linear regression analysis results, using dummy variables (SPSS).

MULTIPLE REGRESSION RUN USING DUMMY VARIABLES 06/08/78 PAGE 2

FILE FISH (CREATION DATE = 06/08/78) PROCESSING PHYSIOLOGICAL CORRELATES OF WORK PERFORMANCE

| VARIABLE | MEAN | STANDARD DEV | CASES |
|---|---|---|---|
| Y1 | 112.0543 | 10.4204 | 35 |
| Y2 | 237.7228 | 98.3009 | 35 |
| X1 | 106.0857 | 12.2226 | 35 |
| X2 | 34.8857 | 10.7424 | 35 |
| D1 | 0.2286 | 0.4260 | 35 |
| D2 | 0.2571 | 0.4434 | 35 |
| D3 | 0.2286 | 0.4260 | 35 |
| X101 | 24.6457 | 46.0632 | 35 |
| X102 | 28.4000 | 49.3885 | 35 |
| X103 | 21.3857 | 45.5857 | 35 |
| X201 | 5.6857 | 10.6516 | 35 |
| X202 | 8.6857 | 15.1148 | 35 |
| X203 | 16.6571 | 27.0308 | 35 |

Table B-6: (cont'd.)

MULTIPLE REGRESSION RUN USING DUMMY VARIABLES 06/08/78 PAGE 3

FILE FISH (CREATION DATE = 06/08/78) PROCESSING PHYSIOLOGICAL CORRELATES OF WORK PERFORMANCE

CORRELATION COEFFICIENTS

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.

| | Y1 | Y2 | X1 | X2 | D1 | D2 | D3 | X1D1 | X1D2 | X1D3 | X2D1 | X2D2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y1 | 1.00000 | 0.66041 | 0.35500 | -0.38240 | 0.77026 | 0.13756 | -0.15591 | 0.77889 | 0.14514 | -0.14507 | 0.76525 | 0.13074 |
| Y2 | 0.66041 | 1.00000 | 0.54468 | -0.79498 | 0.65097 | 0.09449 | -0.39493 | 0.66307 | 0.13032 | -0.39133 | 0.61526 | 0.07339 |
| X1 | 0.35500 | 0.54468 | 1.00000 | -0.18634 | 0.07859 | 0.21288 | 0.02719 | 0.09882 | 0.27840 | 0.04873 | 0.06449 | 0.20283 |
| X2 | -0.38240 | -0.79498 | -0.18634 | 1.00000 | -0.51466 | -0.06157 | 0.60353 | -0.51687 | -0.06388 | 0.61397 | -0.50207 | -0.03573 |
| D1 | 0.77026 | 0.65097 | 0.07854 | -0.51466 | 1.00000 | -0.32026 | -0.29630 | 0.99728 | -0.31758 | -0.29544 | 0.99495 | -0.31737 |
| D2 | 0.13756 | 0.09449 | 0.21288 | -0.06157 | -0.32026 | 1.00000 | -0.32026 | -0.31039 | 0.99164 | -0.31933 | -0.31864 | 0.99094 |
| D3 | -0.15591 | -0.39493 | 0.02719 | 0.60353 | -0.29630 | -0.32026 | 1.00000 | -0.29549 | -0.31758 | 0.99710 | -0.29480 | -0.31737 |
| X1D1 | 0.77839 | 0.66307 | 0.09882 | -0.51687 | 0.99728 | -0.31939 | -0.29549 | 1.00000 | -0.31672 | -0.29465 | 0.98861 | -0.31650 |
| X1D2 | 0.14514 | 0.13032 | 0.27840 | -0.06388 | -0.31758 | 0.99164 | -0.31758 | -0.31672 | 1.00000 | -0.31666 | -0.31597 | 0.98068 |
| X1D3 | -0.14507 | -0.39133 | 0.04873 | 0.61397 | -0.29544 | -0.31933 | 0.99710 | -0.29465 | -0.31666 | 1.00000 | -0.29394 | -0.31645 |
| X2D1 | 0.76525 | 0.61526 | 0.06449 | -0.50207 | 0.99475 | -0.31854 | -0.29480 | 0.98861 | -0.31597 | -0.29394 | 1.00000 | -0.31576 |
| X2D2 | 0.13074 | 0.07339 | 0.20283 | -0.03573 | -0.31737 | 0.99098 | -0.31737 | -0.31650 | 0.98068 | -0.31645 | -0.31576 | 1.00000 |
| X2D3 | -0.15775 | -0.39306 | 0.05135 | -0.62939 | -0.29383 | -0.31759 | 0.99169 | -0.29304 | -0.31494 | 0.99535 | -0.29235 | -0.31473 |

| | X2D3 |
|---|---|
| Y1 | -0.15775 |
| Y2 | -0.39306 |
| X1 | 0.05135 |
| X2 | -0.62939 |
| D1 | -0.29383 |
| D2 | -0.31759 |
| D3 | 0.99169 |
| X1D1 | -0.29304 |
| X1D2 | -0.31494 |
| X1D3 | 0.99535 |
| X2D1 | -0.29235 |
| X2D2 | -0.31473 |
| X2D3 | 1.00000 |

Table B-6: (cont'd.)

MULTIPLE REGRESSION RUN USING DUMMY VARIABLES 06/08/78 PAGE 4

FILE FISH (CREATION DATE = 06/08/78) PROCESSING PHYSIOLOGICAL CORRELATES OF WORK PERFORMANCE

* * * * * * * * * * * * * * * * * * * * * * * * M U L T I P L E R E G R E S S I O N * * * * * * * * * * * * * * * * * VARIABLE LIST 1
REGRESSION LIST 1

DEPENDENT VARIABLE.. Y2 ACTUAL OUTPUT RATE UNDRESSED COD FILLETS

VARIABLE(S) ENTERED ON STEP NUMBER 1.. X1 PERFORMANCE RATING
D1
D2
D3
X1D1
X1D2
X1D3

| | | | | | |
|---|---|---|---|---|---|
| MULTIPLE R | 0.86578 | ANALYSIS OF VARIANCE | DF | SUM OF SQUARES | MEAN SQUARE | F |
| R SQUARE | 0.74957 | REGRESSION | 7. | 246467.73167 | 35209.67595 | 11.54499 |
| ADJUSTED R SQUARE | 0.68460 | RESIDUAL | 27. | 82344.05252 | 3049.77972 | |
| STANDARD ERROR | 55.22481 | | | | | |

------------------ VARIABLES IN THE EQUATION ------------------

| VARIABLE | B | BETA | STD ERROR B | F |
|---|---|---|---|---|
| X1 | 3.752295 | 0.46637 | 1.13598 | 10.911 |
| D1 | -45.72574 | -0.19812 | 322.93347 | 0.020 |
| D2 | -41.29542 | -0.18585 | 201.38354 | 0.042 |
| D3 | 259.2195 | 1.12382 | 313.76150 | 0.683 |
| X1D1 | 1.705074 | 0.79866 | 3.01412 | 0.320 |
| X1D2 | 0.6262136 | 0.31450 | 1.87039 | 0.112 |
| X1D3 | -2.[illegible]79 | -1.31674 | 2.95617 | 0.923 |
| (CONSTANT) | -1[illegible].0776 | | | |

------------- VARIABLES NOT IN THE EQUATION -------------

| VARIABLE | BETA IN | PARTIAL | TOLERANCE | F |
|---|---|---|---|---|
| X2 | -0.62811 | -0.80425 | 0.41058 | 47.618 |

Table B-6: (cont'd.)

MULTIPLE REGRESSION RUN USING DUMMY VARIABLES    06/08/78    PAGE 7

FILE FISH (CREATION DATE = 06/08/78) PROCESSING PHYSIOLOGICAL CORRELATES OF WORK PERFORMANCE

* * * * * * * * * * * * * * * * * * * * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * * * * * * * * * * * VARIABLE LIST 1
REGRESSION LIST 2

DEPENDENT VARIABLE.. X2 ACTUAL OUTPUT RATE UNDRESSED COD FILLETS

VARIABLE(S) ENTERED ON STEP NUMBER 1.. X203
X2 NO OF COD FISH PER BOX
D1
D2
D3
X201
X202

| | | | | | | |
|---|---|---|---|---|---|---|
| MULTIPLE R | 0.93017 | ANALYSIS OF VARIANCE | DF | SUM OF SQUARES | MEAN SQUARE | F |
| R SQUARE | 0.86521 | REGRESSION | 7. | 284492.81889 | 40641.83127 | 24.75982 |
| ADJUSTED R SQUARE | 0.83027 | RESIDUAL | 27. | 44318.96529 | 1641.44316 | |
| STANDARD ERROR | 40.51473 | | | | | |

------------------ VARIABLES IN THE EQUATION ------------------

| VARIABLE | B | BETA | STD ERROR B | F |
|---|---|---|---|---|
| X203 | 6.091125 | 1.24068 | 2.87947 | 4.475 |
| X2 | -6.512826 | -0.71122 | 1.01246 | 41.385 |
| D1 | 680.6732 | 2.94888 | 166.47830 | 16.717 |
| D2 | 89.98417 | 0.40170 | 122.41463 | 0.530 |
| D3 | -228.8949 | -0.97031 | 131.85695 | 2.989 |
| X201 | -23.19367 | -2.51218 | 6.57632 | 12.439 |
| X202 | -0.8211779 | -0.12621 | 3.57578 | 0.053 |
| (CONSTANT) | 3811.8635 | | | |

------------- VARIABLES NOT IN THE EQUATION -------------

| VARIABLE | BETA IN | PARTIAL | TOLERANCE | F |
|---|---|---|---|---|
| X1 | 0.32442 | 0.76742 | 0.75419 | 37.250 |

Table B-6: (cont'd.)

220.

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MULTIPLE REGRESSION RUN USING DUMMY VARIABLES                                06/08/78        PAGE  10
FILE   FISH     (CREATION DATE = 06/08/78)   PROCESSING  PHYSIOLOGICAL CORRELATES OF WORK PERFORMANCE
* * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * * * *   VARIABLE LIST  1
                                                                                                                      REGRESSION LIST 3
DEPENDENT VARIABLE..    Y2          ACTUAL OUTPUT RATE UNDRESSED COD FILLETS
VARIABLE(S) ENTERED ON STEP NUMBER  1..     X203
                                            X1          PERFORMANCE RATING
                                            X2          NO OF COD FISH PER BOX
                                            D1
                                            D2
                                            D3
                                            X101
                                            X102
                                            X103
                                            X201
                                            X202

MULTIPLE R            0.98008          ANALYSIS OF VARIANCE     DF      SUM OF SQUARES      MEAN SQUARE          F
R SQUARE              0.96055          REGRESSION               11.     315841.12958        28712.82996       50.91455
ADJUSTED R SQUARE     0.94109          RESIDUAL                 23.      12970.65461          563.94150
STANDARD ERROR       23.74745
```

| VARIABLE | B | BETA | STD ERROR B | F |
|---|---|---|---|---|
| X203 | 3.347903 | 0.68192 | 2.22028 | 2.274 |
| X1 | 1.817346 | 0.22588 | 0.53853 | 11.389 |
| X2 | -5.581720 | -0.60972 | 0.65400 | 72.842 |
| D1 | 730.3275 | 3.15800 | 233.39332 | 9.796 |
| D2 | -207.8916 | -0.93743 | 124.18392 | 2.802 |
| D3 | -141.3907 | -0.61252 | 142.94183 | 0.978 |
| X101 | -0.6945320 | -0.32532 | 1.48038 | 0.220 |
| X102 | 2.346561 | 1.17445 | 0.83897 | 7.823 |
| X103 | 0.2015259 | 0.09342 | 1.64559 | 0.015 |
| X201 | -22.37626 | -2.92300 | 4.92339 | 25.576 |
| X202 | -0.2302550 | -0.03508 | 2.12697 | 0.012 |
| (CONSTANT) | 197.5437 | | | |

| VARIABLE | BETA IN | PARTIAL | TOLERANCE | F |
|---|---|---|---|---|

ALL VARIABLES ARE IN THE EQUATION

Table B-6: (cont'd.)