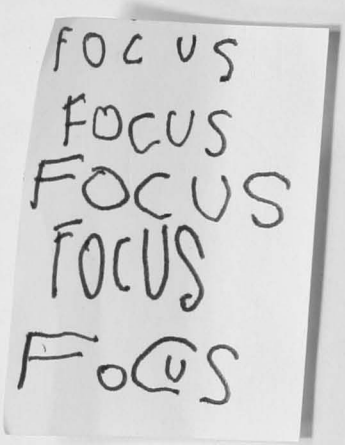
ANNUAL REPORT of the BUREAU OF COMMERCIAL FISHERIES TECHNOLOGICAL LABORATORY, GLOUCESTER, MASS.

Fiscal Year 1962

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

Circular 182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UNITED STATES DEPARTMENT OF THE INTERIOR
Stewart L. Udall, *Secretary*
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ANNUAL REPORT OF THE BUREAU OF COMMERCIAL FISHERIES TECHNOLOGICAL LABORATORY, GLOUCESTER, MASS. FOR FISCAL YEAR ENDING JUNE 30, 1962

Joseph W. Slavin
Laboratory Director
Technological Laboratory
Bureau of Commercial Fisheries
Gloucester, Massachusetts

Circular 182

Washington, D.C.
August 1964

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MESSAGE FROM LABORATORY DIRECTOR

by

Joseph W. Slavin

As a part of its broad responsibilities, the Bureau of Commercial Fisheries carries out technological research that will enable the American fishing industry to utilize our nation's vast aquatic resources more effectively for the well being of the nation. At six regional laboratories located adjacent to the major fisheries, the Bureau conducts fundamental and applied research on the utilization of fish meal, oil, and other fishery industrial products; the microbiology of seafood; the chemical alterations in fishery products; the preservation of seafood; and the development of U.S. grade standards and specifications for seafood products. The Bureau also maintains the USDI (United States Department of the Interior) fishery product inspection and certification service.

Our laboratory, located in the fishing port of Gloucester, Mass., specializes in investigations on improving the quality of those fish and shellfish indigenous to the North Atlantic area of the country. The major fisheries of this region include groundfish, sea herring, lobsters, sea scallops, oysters, and clams.

MAJOR PROBLEMS

Some notable advances have been made in the processing of fishery products during the past decade, particularly in the field of new product development; but the industry is still faced with problems of unpredictable supply of raw material, loss of product quality, and increased competition with other food products. These problems are not uniquely different from those encountered in other major world fisheries. Vessel operators in the groundfishing industry are still hampered by the short storage life of fresh fish kept in ice. Some improvements have been made in construction of fish holds on trawlers. There, however, is still no completely satisfactory method for significantly extending the quality of fresh fish. Developmental work on freezing fish at sea has been completed, but the U.S. industry has not as yet adopted this method of preservation.

Representatives of State and Federal Governments and consumer organizations report that many of the frozen foods and seafoods reaching the consumer are of only borderline acceptability because of the severe quality changes that take place during preprocessing handling and distribution. The Association of Food and Drug Officials of the United States developed a frozen-food code calling for the storage and handling of all frozen foods at a temperature of 0° F. Several States have adopted this code, and more than usual interest is being shown in improving the quality of frozen seafoods.

The need for a better understanding of the more basic chemical changes that take place in fish became more apparent this year than ever before. The vagueness of subjective methods for evaluating odor and flavor continues to be a problem with the industry and also with fishery inspectors and researchers. Many fish undergo profound textural changes during extended storage, but still little is known about the actual nature of these changes or the phenomena that cause them. In addition, the absence of fundamental biochemical information on each species of fish makes it necessary to carry out many laborious organoleptic tests to determine benefits or shortcomings of new preservation methods.

The efficiency of fish processing and the influence of filleting, sanitation, and general handling procedures on the quality of raw fish is also of importance. This year, the growing New England whiting industry was affected by processing problems further aggravated by variations in seasonal production and variations in supply. It requested assistance from the laboratory in this matter.

The production of fish sticks, portions, and other convenience frozen seafoods continues to increase. Improvements in processing equipment and methods resulted in introduction of a number of widely different types of fishery products, and it became necessary to revise existing USDI grade standards of quality to suit changing industrial practices and to develop new standards for additional products.

LABORATORY ACCOMPLISHMENTS

In carrying out its aim of providing research information of value to the industry the laboratory, in fiscal year 1962, continued its basic chemical investigations on the denaturation of proteins during freezing and frozen storage and on the identification of the compounds that constitute the flavor and odor of fresh and processed fish. Research was completed on chilling fish in refrigerated sea water, and with our new low-temperature storage facilities, we placed more effort on investigations of frozen fishery products. We started work on developing an objective test for measuring quality of frozen seafood, and in cooperation with scientists of the Fisheries Research Board of Canada, we began a study on the freezing and thawing of fish. A special engineering study was started on improving the efficiency of handling and processing whiting. Some of the earlier U.S. grade standards and specifications were revised, and new ones were published for the more prominent items.

The most important single accomplishment this year was in the program on preserving chilled fish by means of pasteurizing doses of radiation. We found that soft-shell clam meats and haddock fillets were quite amenable to low levels of radiation and that they could be irradiated at levels of 450,000 and 250,000 rads (units of radiation energy), respectively, and stored successfully at 33° F. for up to 30 days. No off odors or flavors were imparted to the irradiated product and its nutritional value was not adversely affected.

Laboratory personnel participated in meetings of national and international scope. Among the more important conferences attended were the FAO Conference on Fish and Nutrition held in Washington, D.C.; the Atlantic Fisheries Technological Conference in Northampton, Mass.; the Atlantic States Marine Fisheries Commission meeting in New York City; the National Meeting of the American Chemical Society in Chicago, Ill.; and the Annual Meeting of the Institute of Food Technologists in Miami Beach, Fla. At these and other meetings, the laboratory staff presented 16 informal papers on various aspects of their work, and in addition 16 reports were published in various scientific and trade journals.

The following reports give a more detailed description of the laboratory's program for the period July 1, 1961 to July 1, 1962. They are intended to familiarize you with some of the highlights of our work. We will be glad to answer any questions you may have concerning the program.

RESEARCH ON THE CHEMISTRY AND BIOCHEMISTRY OF FISH

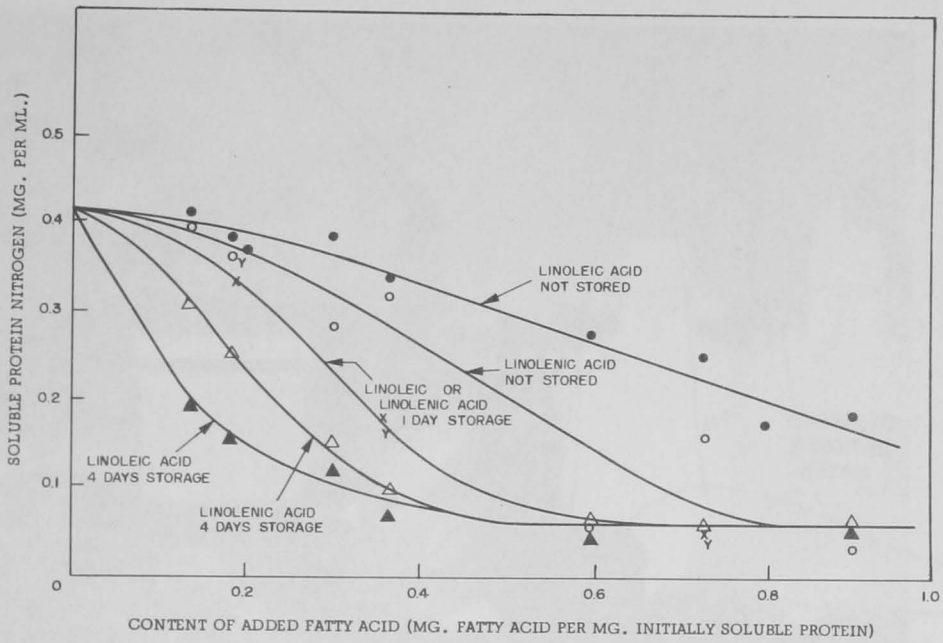
by

Maynard A. Steinberg, Assistant Laboratory Director

Our research efforts on the chemistry and biochemistry of fish are of a fundamental nature. They are directed toward obtaining a better understanding of the mechanisms involved in the denaturation of fish muscle protein during frozen storage and in the changes during storage of the compounds that cause the flavors and odors of fishery products.

PROTEIN RESEARCH

During extended frozen storage, fish flesh tends to become tough and dry. These characteristics are reflections of fundamental changes in the arrangement of the molecules that comprise the protein of the muscle. We are investigating the molecular changes in order to acquire insight into the



The effect of added linoleic and linolenic acids on the solubility of fish muscle protein.

mechanisms involved. Information derived from this research may ultimately enable us to develop methods for minimizing the adverse textural changes that now take place in frozen stored fish.

It appears that lipoidal substances have a significant influence on the stability of actomyosin (the major protein component of the flesh). For example, our findings show that low concentrations of linoleic and linolenic acids decrease the stability of soluble actomyosin and that this phenomenon depends on the anionic properties of these fatty acids. Neither the methyl ester of linolenic acid nor Triton X-100, a nonionic surfactant, is effective in precipitating actomyosin from solution.

We have found that p-chloromercuribenzoic acid, which was previously shown to reduce spontaneous insolubilization of actomyosin in extracts, was effective in inhibiting the rate of insolubilization of actomyosin by linolenic acid. The mechanism of the inhibition is not yet understood.

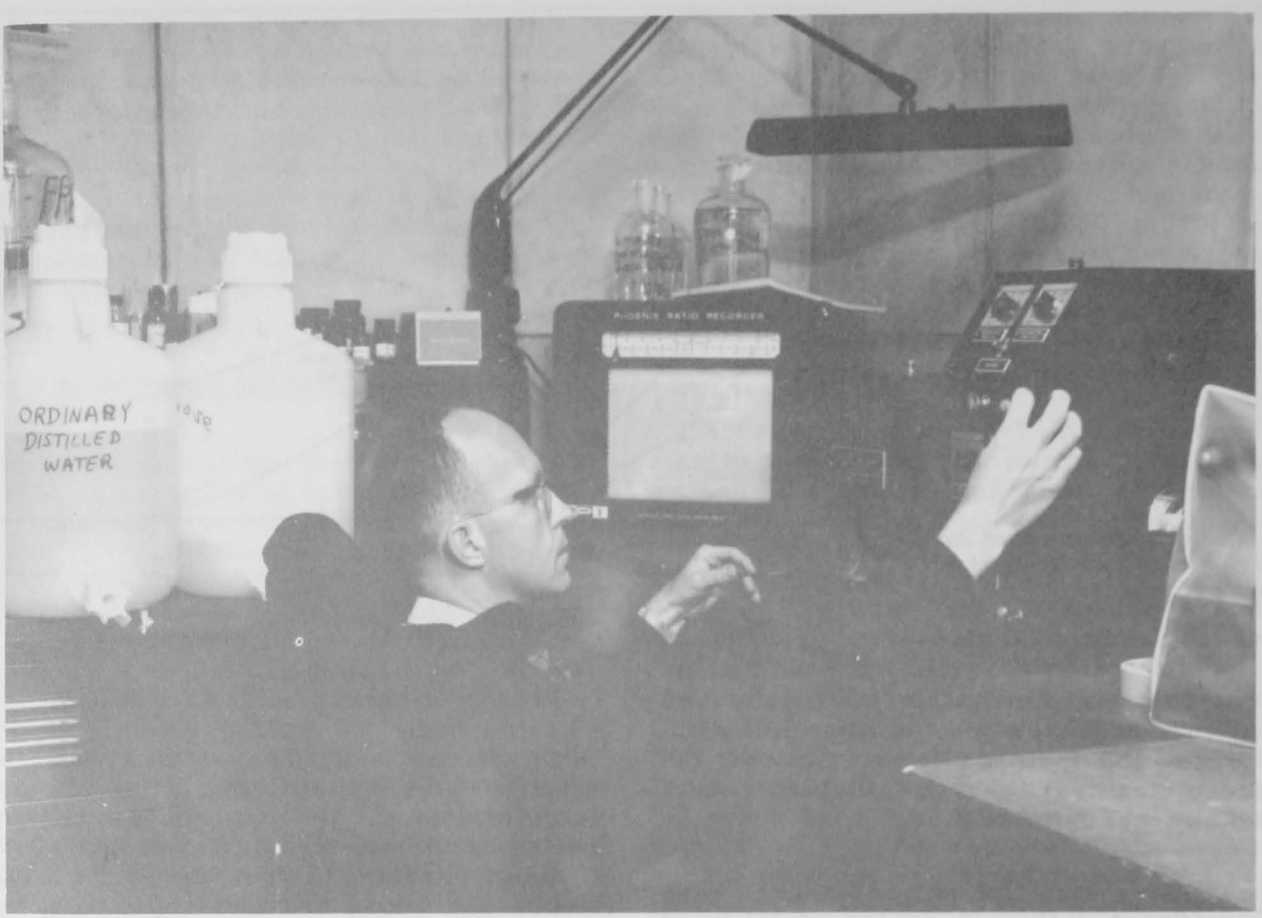
Our findings on the relation of fatty acid to actomyosin indicate that the protein-extractability test, which has been the generally accepted criterion of protein denaturation in fish muscle during frozen storage, needs corroboration by a technique that unequivocally measures protein denaturation in situ.

FLAVOR AND ODOR RESEARCH

Our flavor and odor studies have as objectives the separation, detection, and identification of the compounds causing the characteristic fresh flavor and odors of fishery products and the undesirable flavors and adors that develop during extended frozen storage. This information will lead to an understanding of the fundamental chemistry involved in flavor and odor changes and to the development of methods that minimize such changes in frozen storage.

A systematic investigation of techniques for removing volatile compounds from fish flesh was undertaken to find the most suitable means for preparing samples for analysis by the gas chromatograph and the mass spectrometer. Results showed that high-vacuum distillation provided the most concentrated and most easily handled samples.

Changes in the complex mixture of volatile compounds causing the flavor and odor of haddock were studied by using the low-temperature-programmed gas chromatographic technique described in our annual report for fiscal year 1961. (Slavin, 1962.) A study of haddock stored at refrigerator temperatures for 10 days showed that the volatiles increased in both number and concentration during that time. Cooking the samples resulted in the formation of a larger number of volatiles, present in



Light-scattering measurements, made at temperatures just above freezing, provide information on the effects of fatty acids on the size and shape of actomyosin from fish muscle.

higher concentration. Some of the compounds found in haddock flesh in relatively high concentration have been identified by their chemical reaction and by the mass spectrometer. These compounds are hydrogen sulfide, dimethyl sulfide, dimethyl disulfide, and acetone.

As an outgrowth of the storage study on haddock, an investigation was made of the development of volatile carbonyls formed in haddock during storage at 2° C. Results showed that the carbonyls collected were in two different ranges of molecular weight. The amount of lower molecular-weight carbonyls collected increased linearly with storage. The amount of higher molecular-weight carbonyls collected reached a maximum between the 8th and 11th day of storage.

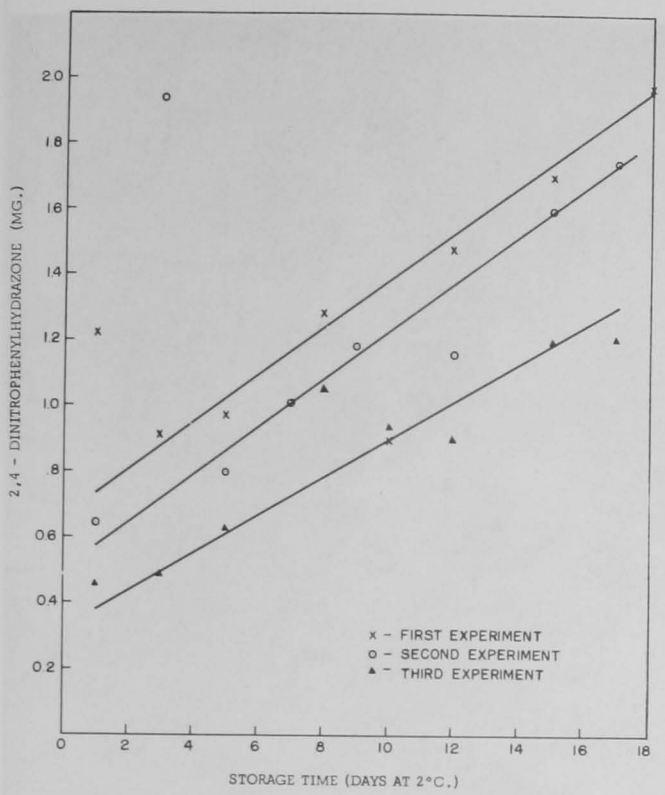
RADIATION-PASTEURIZATION RESEARCH

by

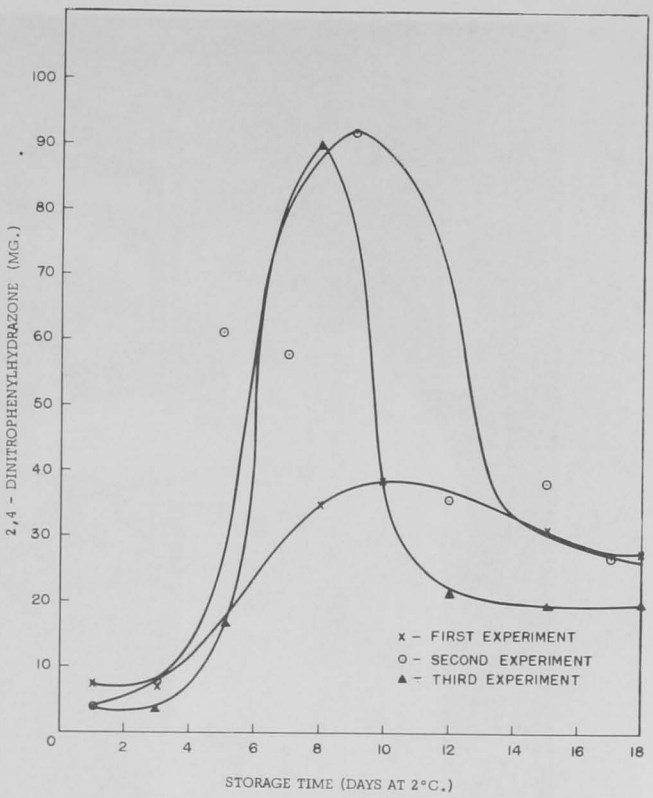
Maynard A. Steinberg, Assistant Laboratory Director

Radiation-pasteurization offers promise in making fresh or freshlike fish available in areas where such fish are not now generally available. Successful development of this process will also stabilize the fresh fish market and expand national markets for fresh seafood.

This laboratory, under contract with the U.S. Atomic Energy Commission, investigated the effect of low levels of radiation on (1) the extension of the refrigerated shelf life of haddock fillets and soft-shell clam meats, (2) the acceptability of these products during storage, and (3) the amino



Low molecular weight carbonyl development in stored haddock.



High molecular weight carbonyl development in stored haddock.

acids and vitamins of haddock fillets and clam meats.

SHELF LIFE

We established that both haddock fillets and soft-shell clam meats can be held for 30 days at 33° F. and for half this time at 42° F. The optimum radiation level for haddock is 250,000 rads when packed in air and 350,000 rads when packed under vacuum.

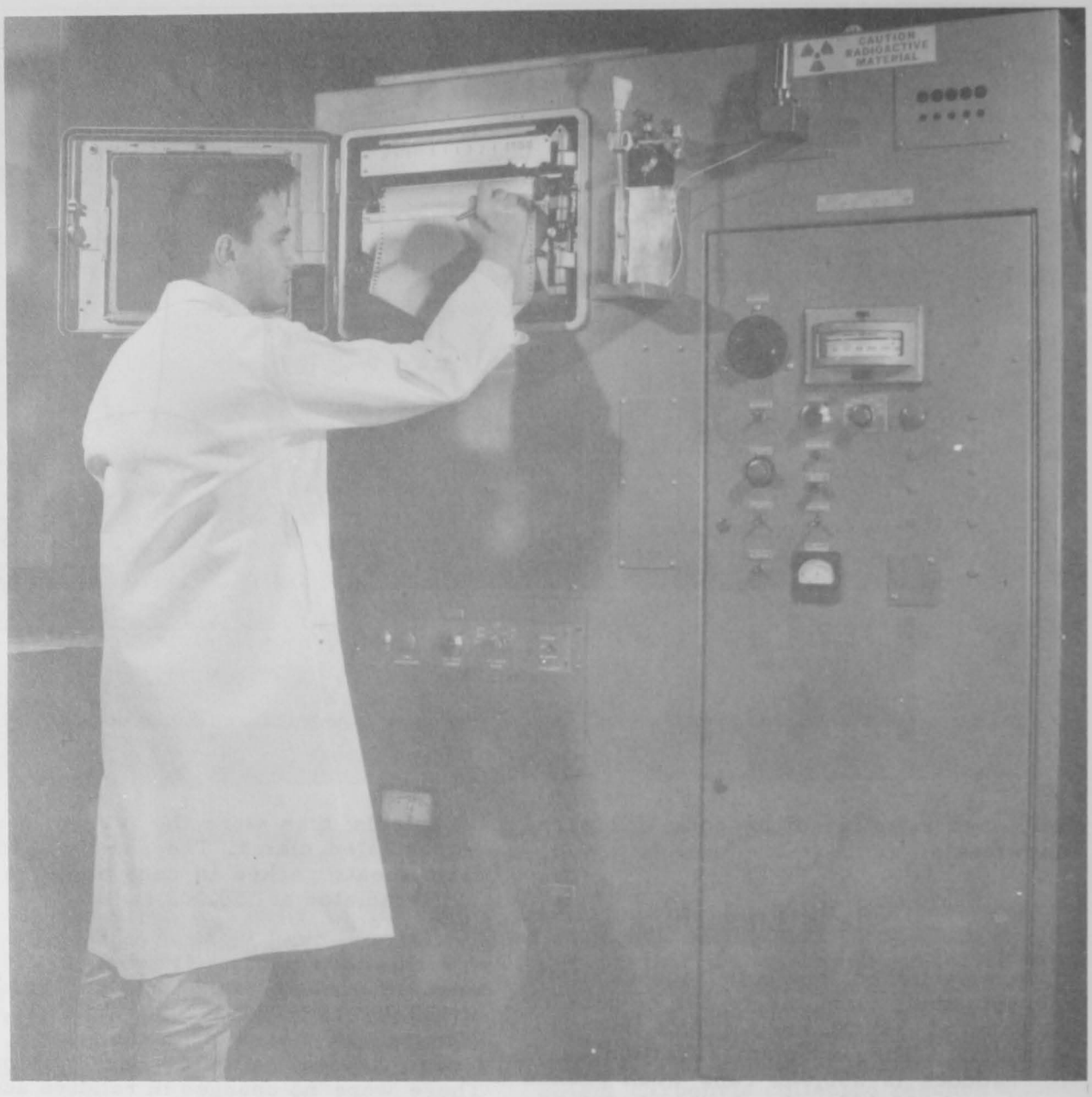
ACCEPTABILITY

Acceptability tests showed that during the first 20 days of storage at 33° F., clam meats packed in cans under air and irradiated at 450,000 rads were just as acceptable as were freshly shucked unirradiated clams. On the 30th day of storage the irradiated clams were slightly less acceptable than were the freshly shucked unirradiated clams. The same was true of clam meats packed in cans under vacuum and irradiated at 350,000 rads.

Air-packed haddock irradiated at 250,000 rads and vacuum packed haddock irradiated at 150,000 rads, both stored at 33° F., were very slightly less acceptable than were frozen haddock after 10 days of storage. There were no changes in relative acceptability until the 30th day of storage, at which time a further slight decline in acceptability was noted.

AMINO ACIDS AND VITAMINS

Results of nutritive studies showed that the amino acids or B vitamins of clams and haddock were not adversely affected by gamma radiation at the pasteurization levels employed.



The gas chromatograph separates the complex mixture of volatile compounds that contribute to the flavor and odor of fishery products.

Amino acid analyses show that low levels of radiation from cobalt-60 have no significant effect on the amino acid content of haddock fillets and soft-shell clam meats.

PRESERVATION AND PROCESSING RESEARCH

by

John A. Peters, Program Leader

The Preservation and Processing Unit undertakes research on problems in handling fish from the time they are caught until the finished product reaches the consumer. These investigations are designed to improve quality and efficiency through the industrial application of new or improved techniques in preservation and processing. This year the unit worked on two major projects: (1) improving the quality of whiting and (2) determining the time-temperature tolerance of frozen seafoods.

IMPROVING THE QUALITY OF WHITING

The research on improving the quality of whiting was undertaken in response to requests for assistance from both fishermen and processors in the whiting industry. The problems, which had culminated in an unfavorable economic climate in the industry, appeared to stem largely from two factors: (1) the nature of whiting itself, a delicately flavored and textured fish that tends to lose quality rapidly unless handled with more than usual care, and (2) the industry's dependence on one product form--that is, headed and eviscerated fish. Our work was directed toward pinpointing sources of loss of quality aboard the vessel and in the processing plant and toward developing new products to broaden the market.

All major whiting processors in the New England area were visited to observe handling practices and to obtain ideas from management on new products. The findings were then analyzed and recommendations for improved handling practices aboard the vessel were proposed, and improved handling methods and devices were developed to increase processing efficiency and reduce quality loss in the plant.

New whiting products were tested at the laboratory for both acceptability and storage life. Most of the whiting products compared favorably with similar foods prepared from haddock, and many of the products were preferred to their haddock counterparts.

As the final step in this project, the results of our work were presented to industry members at a meeting held at the Laboratory. A comprehensive report of the work done has been prepared and, when published, will be distributed to assist the whiting industry to improve its economic position.

TIME-TEMPERATURE TOLERANCE OF FROZEN FISHERY PRODUCTS

Extensive studies on the time-temperature tolerance of frozen fruits and vegetables have shown that even slight mishandling at any point in the distribution chain has a cumulative, adverse effect on the quality of the product reaching the consumer. Very little information is available, however, on the quality changes that occur in the many different types of domestic frozen fishery products. Since an increasingly large proportion of the fishery products marketed in this country are in the frozen form, it is extremely important that information on the individual and cumulative effect of prefreezing quality and postfreezing temperature, humidity, and general handling on widely different types of seafood be made available to the industry. The current multiphase, time-temperature project on frozen fishery products was started to provide this information.

Effect of Distribution on Quality

A mail survey was made to obtain information on the temperatures occurring and general handling conditions used during the commercial distribution of frozen fish. The returns from questionnaires sent to processors, cold storage warehousemen, distributors, and retailers showed that (1) many processors regularly receive complaints on the quality of frozen seafood, (2) many processors do not know the treatment their products receive after leaving the plant, and (3) time-temperature conditions experienced by seafoods in distribution vary considerably. Under the best conditions of time-temperature, fishery

products will move from processor to consumer with almost unmeasurable change in quality; but under the worst conditions reported the products will deteriorate so much that they will be of marginal acceptability when they reach the consumer.

After completion of the mail survey, temperature recorders and time-temperature indicators were shipped along with fishery products to various parts of the country. Samples of the products were returned to the laboratory for taste-panel evaluation and frozen-storage-stability tests. Early tests showed no significant quality loss in the products used for our test shipments.

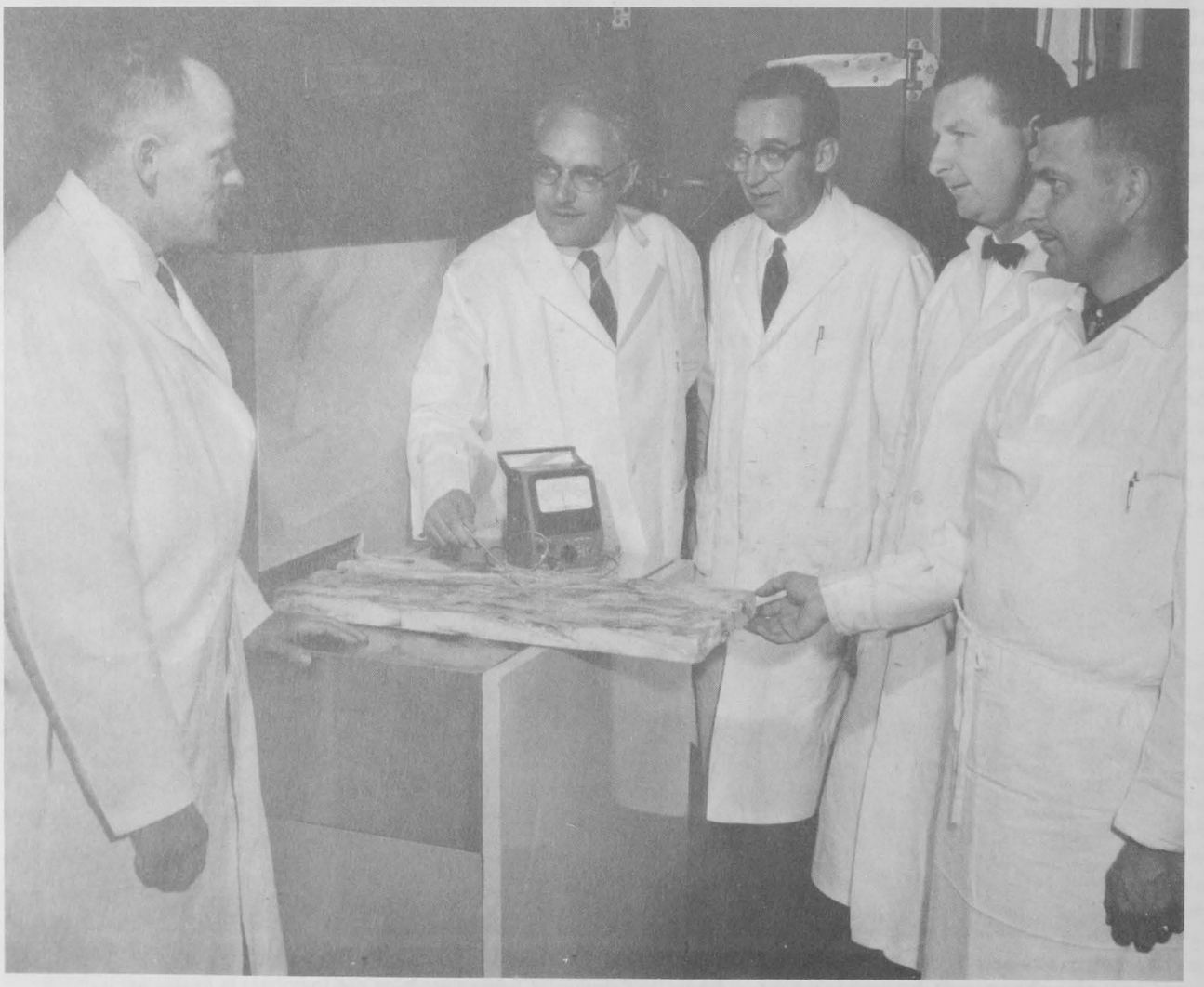
Laboratory Studies on Factors Affecting Quality

In our studies of factors affecting quality, we are attempting to determine the effect of various preprocessing-handling practices and postprocessing storage conditions on the quality of frozen fish.

Sensory determinations of the appearance, odor, flavor, and texture of fishery products are important in evaluating different processes and handling techniques.

One of these studies is on a problem that has been of interest to this laboratory for many years: namely, the techniques of freezing whole fish at sea for later processing ashore. We have not previously found a wholly satisfactory solution for one aspect of this problem--the method of thawing the fish in preparation for processing. Since Canadian fishery researchers are also currently interested in this problem, a cooperative project involving this laboratory and the laboratories at Halifax, Nova Scotia, and St. John's, Newfoundland was undertaken to compare the effect of thawing cod electrically with microwave energy and of thawing them in circulating water. Also being investigated in this project is the effect of such variables as freezing cod prerigor mortis and postrigor mortis and freezing in sodium chloride brine and in a plate freezer. The information obtained in this work will contribute greatly toward the solution of problems that are of concern to all fishery scientists.

Basic to any research project on time-temperature tolerance of frozen foods is the information obtained on the frozen storage life of the product at various temperatures. To determine and evaluate the present state of knowledge on this subject, we made a search of the literature for reports of past work on the storage life of frozen seafoods. The search indicated that there is little information available on the time-temperature tolerance of frozen seafoods as such, and even the information on storage life that is available is confusing, owing to the large number of variables investigated and the differing bases for quality judgments used by the many workers in this field.



Canadian and U.S. scientists and engineers discuss the rate of heating of a block of cod fillets thawed by microwave energy.

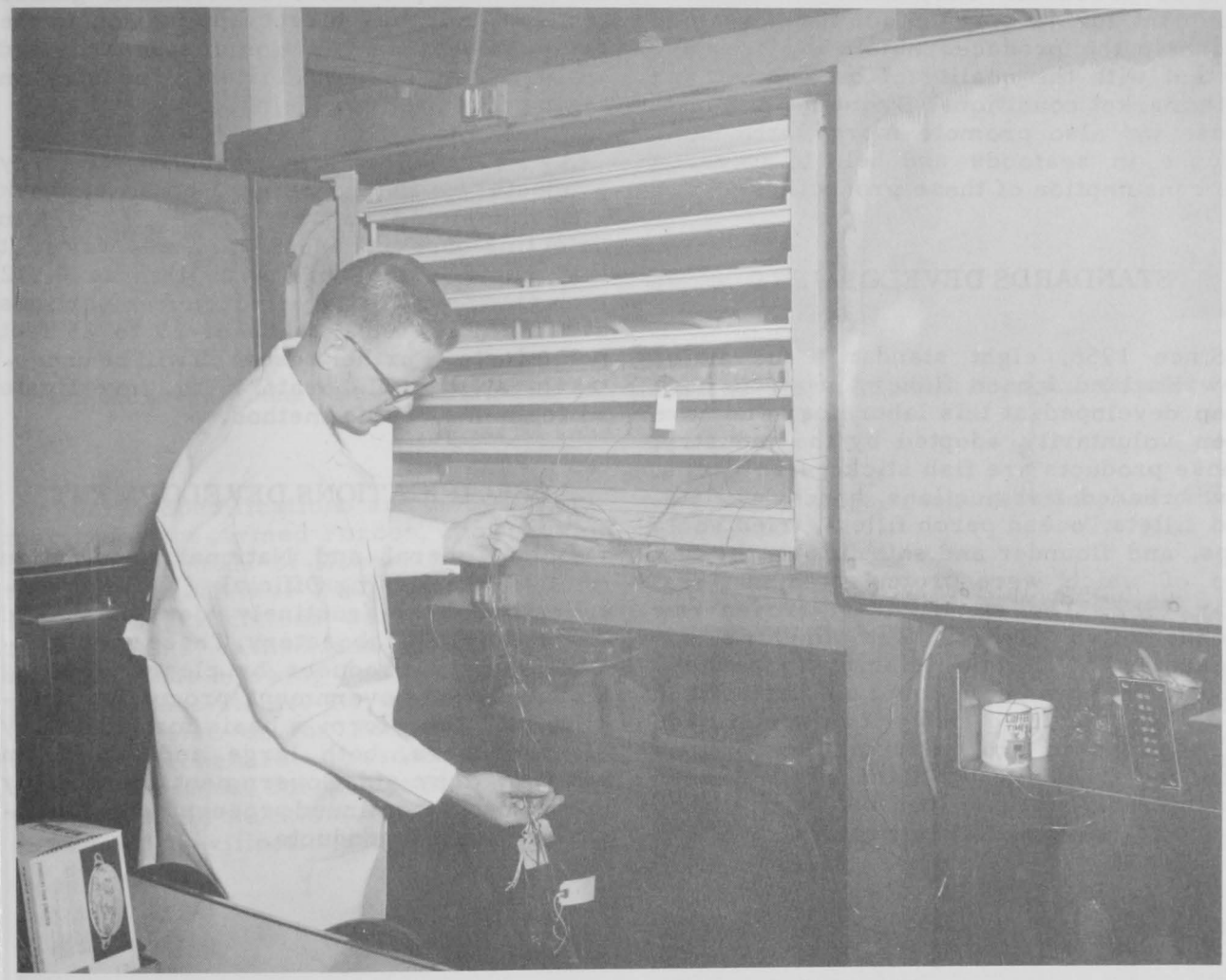
In our work on time-temperature tolerance, we plan to investigate how the quality of different species of fish is affected by prefreezing storage in ice for 1 to 15 days and different constant storage temperatures from -20° F. to +20° F. on the quality of different species of fish. Taste panel evaluations and objective tests for quality will be made periodically, and the storage life at the various temperatures will be determined.

Biochemical Indices of Quality

An ever-present problem in the evaluation of freshness in fish is the formulation or adaptation of biochemical tests to serve as accurate, objective indices of loss of early quality. Toward this end, a comprehensive survey of the literature was undertaken and completed; and the findings were appraised for possible use with frozen fishery products.

Engineering Studies on Freezing and Cold Storage Systems

Methods for calculating the freezing times of fishery products are necessary for accurately predicting product-freezing requirements and for designing freezing equipment. Since 1913, when Plank developed his basic equation, numerous modifications have been proposed; of these modifications, the one developed by Neumann appears to offer the most promise in calculating freezing times of rectangular packages of fish. To determine the suitability of Neumann's equation, we conducted experiments at our laboratory in cooperation with the Massachusetts Institute of Technology on freezing cod fillets in brine air-blast, and contact-plate freezers. Good agreement was found between the calculated and observed freezing times.



Thermocouples are used to record freezing rates of fish fillet blocks being prepared for time-temperature tolerance studies in the laboratory plate freezer.

Engineering studies are being continued on the laboratory's hot-gas bypass capacity control system for variable-temperature cold storage rooms. In these tests we are comparing the efficiency and operating costs of the hot-gas bypass system with that of a conventional thermostatically controlled system.

To obtain the necessary data, we installed pressure gauges and specially designed flow meters to measure refrigerant flow rates under various operating conditions, thermocouples to measure heat leakage through all room surfaces, and electrical instruments to measure power consumption. The tests with the capacity-control system have been completed, and present efforts are directed toward completing the tests with the thermostatic control system.

STANDARDS AND SPECIFICATIONS RESEARCH

by

Joseph H. Carver, Program Leader

Grade standards aid the orderly marketing and efficient buying and selling of fishery products. They offer an unbiased blueprint for judging the quality of seafood and help the producer obtain a price consistent with the quality of his product and with market conditions. By means of standards, we also promote more public confidence in seafoods and help to increase the consumption of these products.

STANDARDS DEVELOPMENT

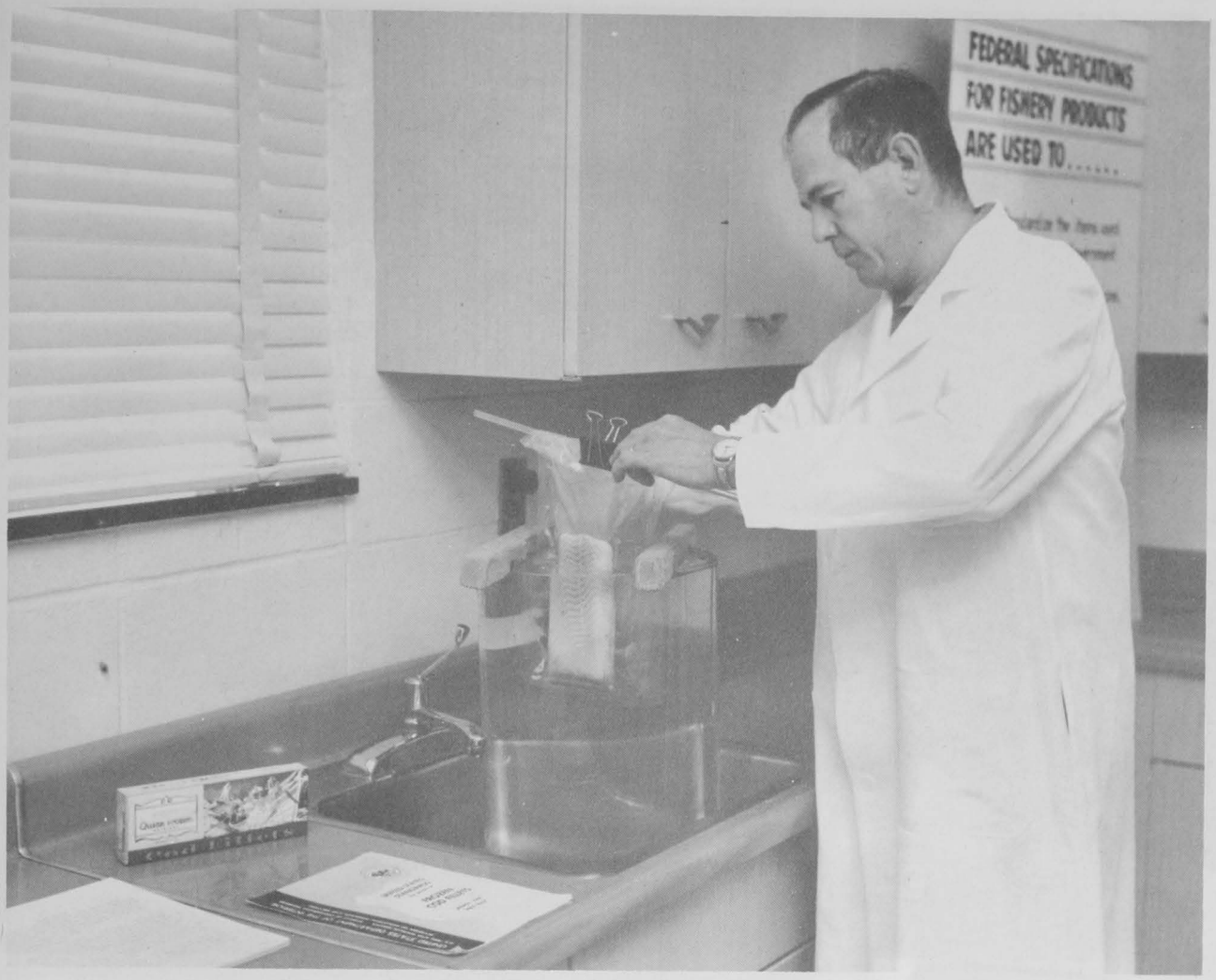
Since 1956, eight standards for major New England frozen fishery products have been developed at this laboratory and have been voluntarily adopted by the industry. These products are fish sticks, fish blocks, raw breaded fish portions, haddock fillets, cod fillets, ocean perch fillets, fried scallops, and flounder and sole fillets, the last two of which were promulgated in fiscal year 1962. The standard for frozen raw breaded fish portions was amended and presented at Public Hearings. Developmental work was completed on the revision of the frozen fried fish stick standard and on a proposed frozen fried fish portions standard. These newer standards have been considerably streamlined and will reduce grading time for USDI inspectors.

Work was begun on a new project to study factors that affect the pickup of breading on breaded products. Information gained in this study has direct application to the development and revision of standards and will also be used in advising industry on their production problems.

As a means of improving quality of fishery products to the consumer, contract work was completed on the use of X-rays in detecting bones. A laboratory unit was built that could detect bones as thin as 0.012 inch in 1/2-inch-thick frozen fish portions at assembly line speeds of 15 to 25 feet per minute. Further research will be undertaken at this laboratory to investigate refinements of this method.

SPECIFICATIONS DEVELOPMENT

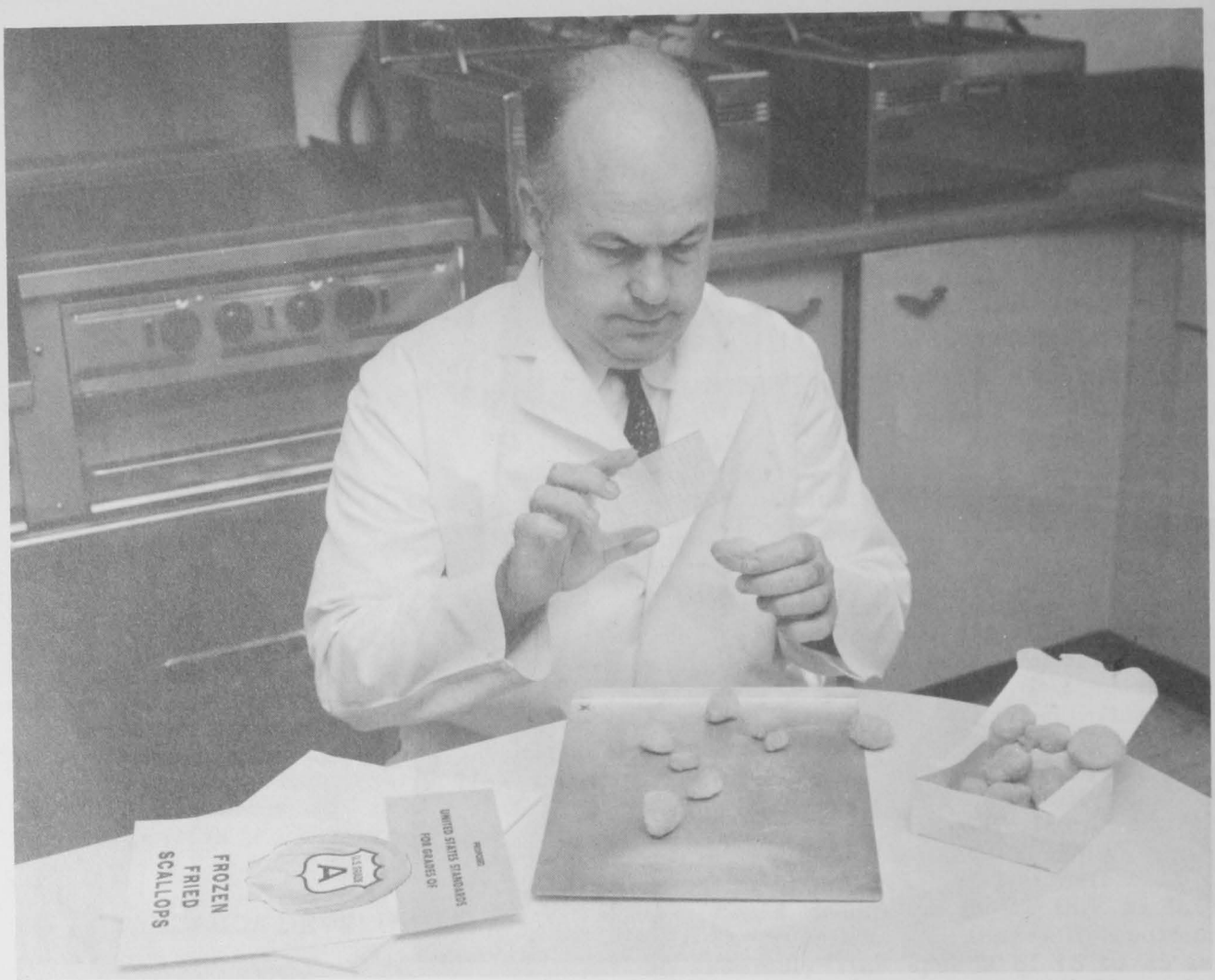
Both Federal and National Association of State Purchasing Officials (NASPO) specifications are routinely developed and revised at this laboratory. These specifications aid the producer by clearly defining the needs of Government procuring agencies, and they form a basis for bidding by all producers, both large and small. In addition, they aid Government agencies by ensuring the continued procurement of high-quality fishery products.



Controlled thawing of frozen fillets is an important step in evaluation of the quality of this product for purposes of standard development.

Federal Specifications are designed primarily for the Armed Forces, who consume 6 million pounds of fishery products annually. In fiscal year 1962, interim or trial Federal specifications were published for canned clams, canned tuna fish, and natural sponges, thus allowing Federal agencies to procure these items. Developmental work was completed on the Federal specifications for frozen raw breaded shrimp and canned sardines, for publication in fiscal year 1963. In addition, work was started on Federal specifications for shucked clams, shucked oysters, canned salmon, and canned shrimp.

NASPO specifications were published for frozen cod and haddock fillets. Specifications were prepared for frozen raw, raw breaded, and fried breaded portions, and they will be published in the coming fiscal year. Additionally, work was started on NASPO specifications for chilled or frozen raw and cooked shrimp and for frozen breaded shrimp.



Before a standard is developed, products in production are carefully examined to determine industry's capabilities.

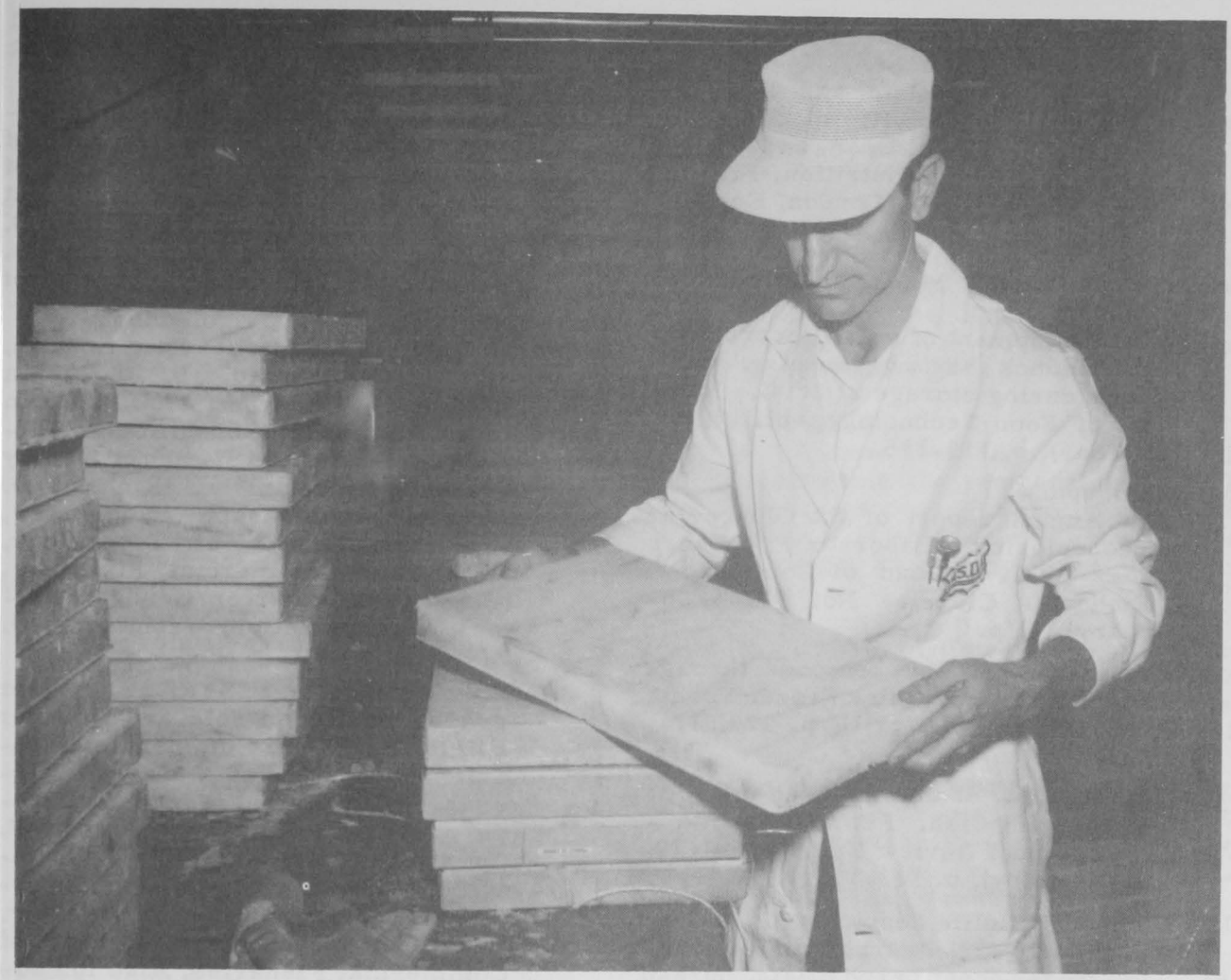
INSPECTION AND CERTIFICATION OF FISHERY PRODUCTS

by

Philip J. McKay, Supervisory Inspector

Inspection of fishery products in the North and Middle Atlantic areas is carried out by the U.S. Department of the Interior Inspection and Certification Service, which has its headquarters at the Bureau's Technological Laboratory in Gloucester, Mass. This service has 17 inspectors who perform continuous inspection in 10 processing plants in the area from Maine to Maryland. In fiscal year 1962, they inspected some 90 million pounds of fishery products in accordance with standards developed at Bureau laboratories.

This service also has an office in New York City at which lot inspections are performed at the request of steamship companies and State and Federal institutions.



In this plant, frozen blocks from which fish sticks and fish portions are made are inspected according to USDI standards for quality before being processed.

PUBLICATIONS

Anon.
1962. Fish get v.i.p. treatment at Gloucester Laboratory. Fishing Gazette, vol. 79, no. 4 (April), p. 38, 39, 41.

Brooke, Richard O.
1962. New frontiers in seafood preservation. Bureau of Commercial Fisheries Marketing Bulletin (FMB No. 62-5A), Seafood for Health and Nutrition, 24 p.

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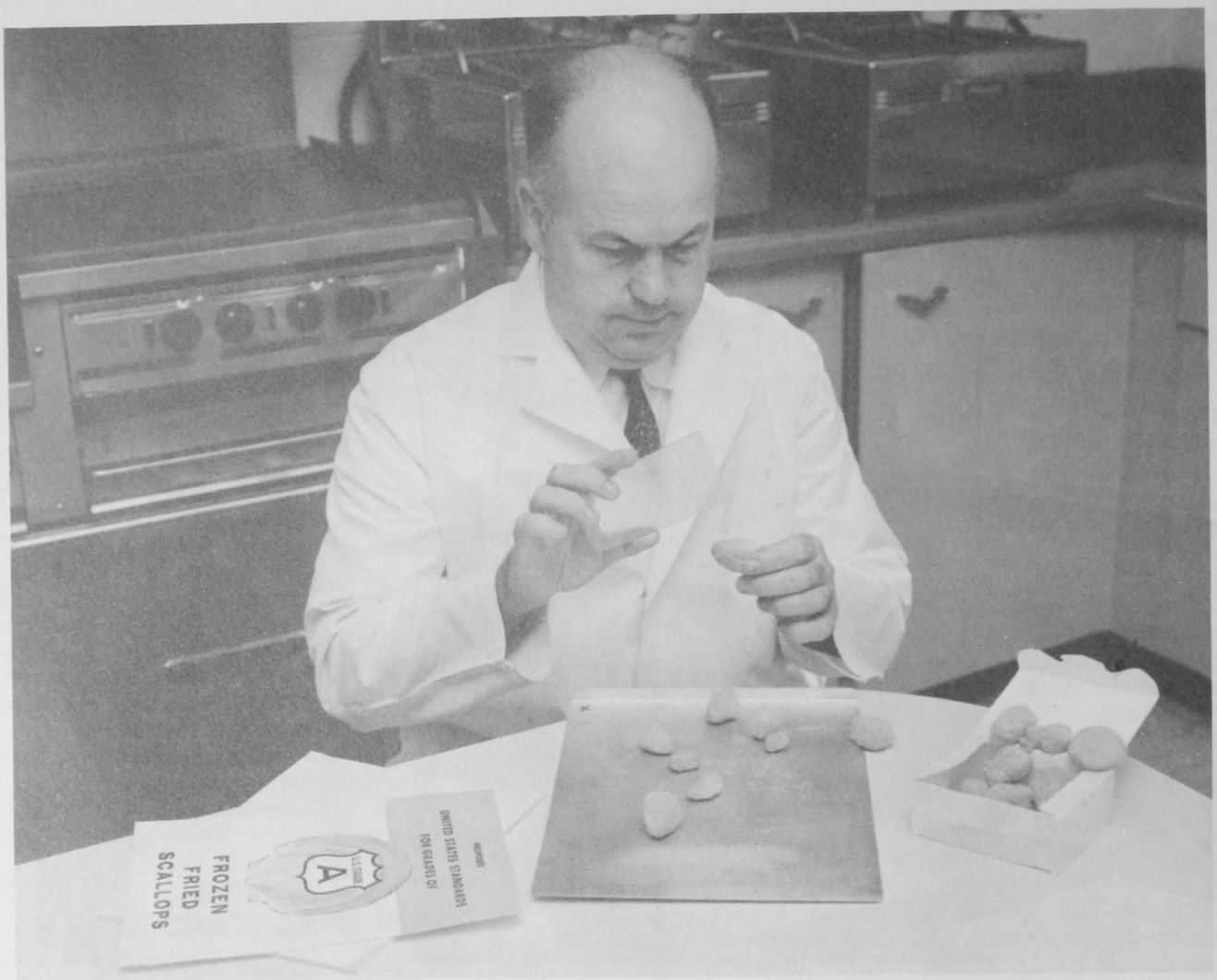

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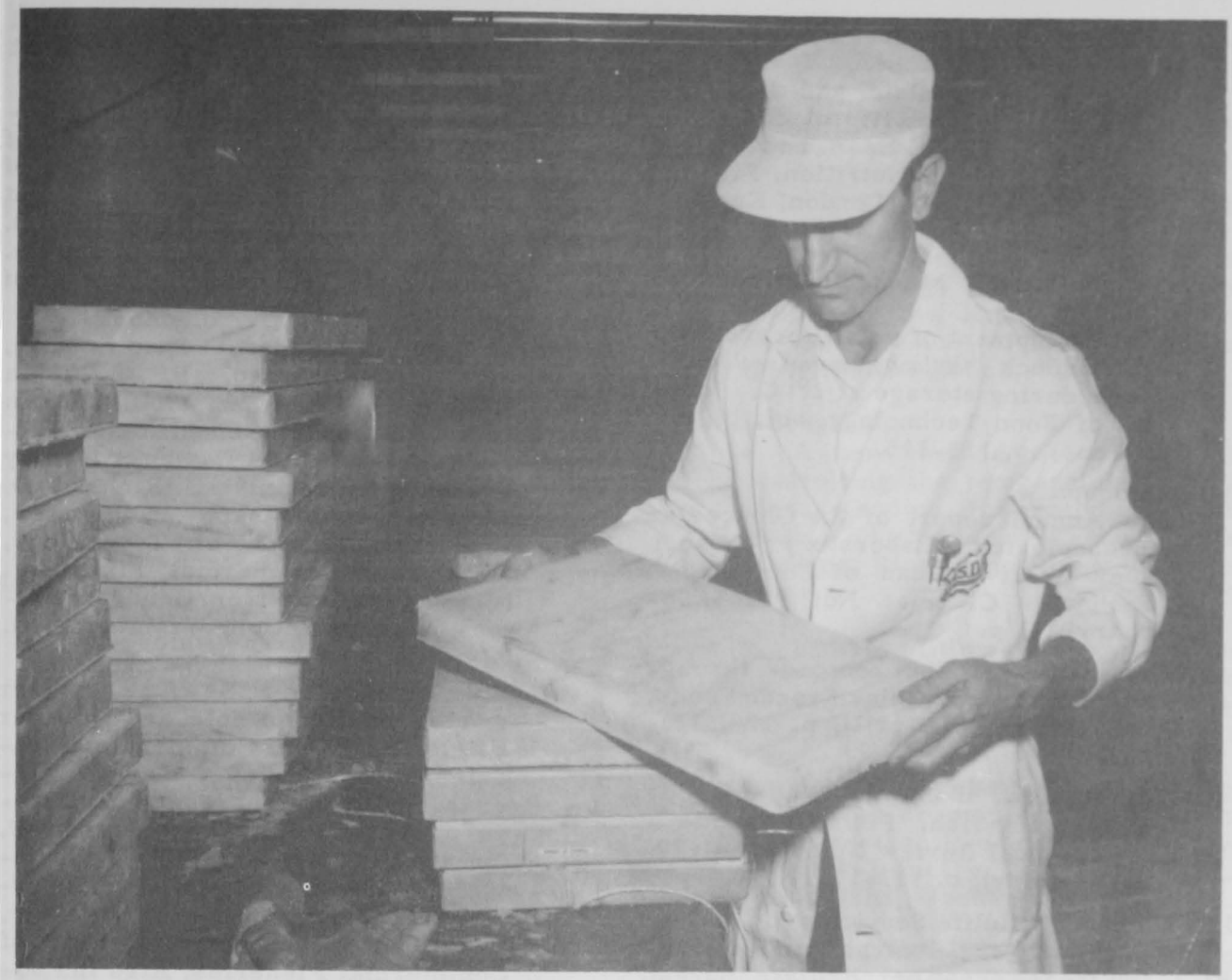

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1962a. Interim Federal Specification, tuna fish, canned, PP-T-00771a (INT-FWS), June 23, 1962. Interim revision of Federal Specification PP-T-771, March 31, 1931. Prepared by Clarence J. Carlson, Richard D. Tenney, and Joseph H. Carver, Chemists, Branch of Technology, Bureau of Commercial Fisheries. (Copies available from General Services Administration, Washington, D. C.)

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LIST OF PAPERS PRESENTED AT MEETINGS

Carver, Joseph H.
1961. The development of standards and their use as quality control guides. Presented at Seminar at Boston Fish Pier, Boston, Mass., December.

1962a. The Bureau of Commercial Fisheries' standards and inspection program. Presented at the Maryland Food Brokers' Association, Baltimore, Md., March.

1962b. Status of Federal sardine specification. Presented at the Annual Spring Meeting of the Maine Sardine Council, Bangor, Maine, May.

Frascatore, Anthony J.

1961. Detection of bones in fish portions and fillets with the use of X-rays. Presented at the Atlantic Fisheries Technologists' Meeting, Northampton, Mass., October.

1962. Detection of bones in fish portions and fillets with the use of X-rays. Presented at the 22nd Annual Meeting of the Institute of Food Technologists, Miami Beach, Fla., June.

Mendelsohn, Joseph M.

1962a. Gas chromatographic analysis of the volatiles from haddock. Presented at Seminar, U.S. Quartermaster Research Center, Natick, Mass., February.

1962b. Gas chromatographic separation of volatiles collected by different methods from haddock flesh. Presented at the 22nd Annual Meeting of the Institute of Food Technologists, Miami Beach, Fla., June.

Peters, John A.

1961. Causes of quality losses and spoilage of fish. Presented at Seminar at Boston Fish Pier, Boston, Mass., November.

Peters, John A., Edward H. Cohen, and Enrico E. Aliberte.

1962. Preliminary Report: Improving the quality of whiting. Presented at the Bureau-Industry Meeting on Improving the Quality of Whiting, Technological Laboratory, Gloucester, Mass., May.

Peters, John A., Edward H. Cohen, and Frederick J. King.

1962. Effects of chilled storage on the frozen storage life of whiting. Presented at the 22nd Annual Meeting of the Institute of Food Technologists, Miami Beach, Fla., June.

Slavin, Joseph W.

1961a. A new method of automatically controlling the temperature of cold storage rooms. Presented at the Atlantic Fisheries Technologists' Meeting, Northampton, Mass., October.

1961b. Effects of time-temperature and packing on the quality of frozen fish. Presented at Seminar at Boston Fish Pier, Boston, Mass., November.

1962a. Recent developments in refrigeration which may be applicable to tuna vessels. Presented at the Government-Industry Tuna Meeting, La Jolla, Calif., January.

1962b. Time-temperature tolerance of frozen seafood. Presented at the Annual Meeting of the National Association of Refrigerated Warehouses, New Orleans, La., May.

Steinberg, Maynard A.

1962. Low-level radiation preservation of clams *(Mya arenaria)*. Presented at the Massachusetts Shellfish Officers' Association, Boston, Mass., March.

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Maynard A. Steinberg, Assistant Laboratory Director

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Daniel T. McLane

Preservation and Engineering
John A. Peters, Program Leader

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Thomas J. Connors
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