FPC: THE NMFS EXPERIMENT & DEMONSTRATION PLANT PROCESS

Robert C. Ernst Jr.

The National Marine Fisheries Service (NMFS) has constructed an experiment and demonstration plant at Aberdeen, Washington,[1] as part of a research and development program to demonstrate the feasibility of producing and using fish protein concentrate (FPC). The plant was constructed under Public Law 89-701[2] for about $2 million.

This 'semi-works plant' (less than commercial size) was built to demonstrate an isopropyl-alcohol extraction process and to produce sufficient quantities of FPC for utilization studies by U.S. industry and the Agency for International Development.

The plant was designed, constructed, and is being operated under contract by Ocean Harvesters, Inc., a joint enterprise of SWECO, Inc., Los Angeles, Calif., and Star-Kist Foods, Inc., Terminal Island, Calif.

FISH PROTEIN CONCENTRATE

The basic concept of FPC derives technically and logically from a need to utilize our fishery resources more economically and efficiently as a source of animal protein for human nutrition. FPC is the term used for a broad class of nutritious fish products that can be used in human foods.[3] These concentrates are primarily animal protein and are characterized by high nutritional quality and stability under a wide range of storage conditions. Variations in processing methods may result in products with many different organoleptic (determined by subjective testing: odor, flavor) and physical characteristics. The concentrates, for example, may be liquids, pastes, or powders. Also, they may be completely odorless and tasteless--or be highly flavorful with cheese or meatlike flavors.

MANY FPC PROCESSES POSSIBLE

Many processing methods[4] may be used to produce FPCs: some are chemical or biological hydrolysis; protein isolation by extraction and precipitation; vacuum drying and extraction; cooking, pressing, drying, and extraction; and dehydration and extraction with solvents. Whatever method is used, the object is to obtain a concentrated, stabilized form of high-quality animal protein either by isolation of the protein or adequate removal of water, lipids, and any other components considered undesirable in the final product.

DEMONSTRATION PLANT & PROCESS

The process used in the demonstration plant design is a multistage, continuous flow, countercurrent extraction of fresh, ground, whole fish with 91% by volume isopropyl alcohol. The design is based on research and development by NMFS[3] and by subcontractors[5,6]. Since the plant will be operated for a very limited period, about two years, many compromises were made to lower capital costs at expense of operating costs. The plant is designed to process up to 50 tons of whole fish per day into 7½ tons of FPC that will meet the standards approved by the U.S. Food and Drug Administration[7].

Mr. Ernst is Research Chemical Engineer, National Center for Fish Protein Concentrate, National Marine Fisheries Service, College Park, Maryland 20740.

COMMERCIAL FISHERIES REVIEW
Reprint No. 902

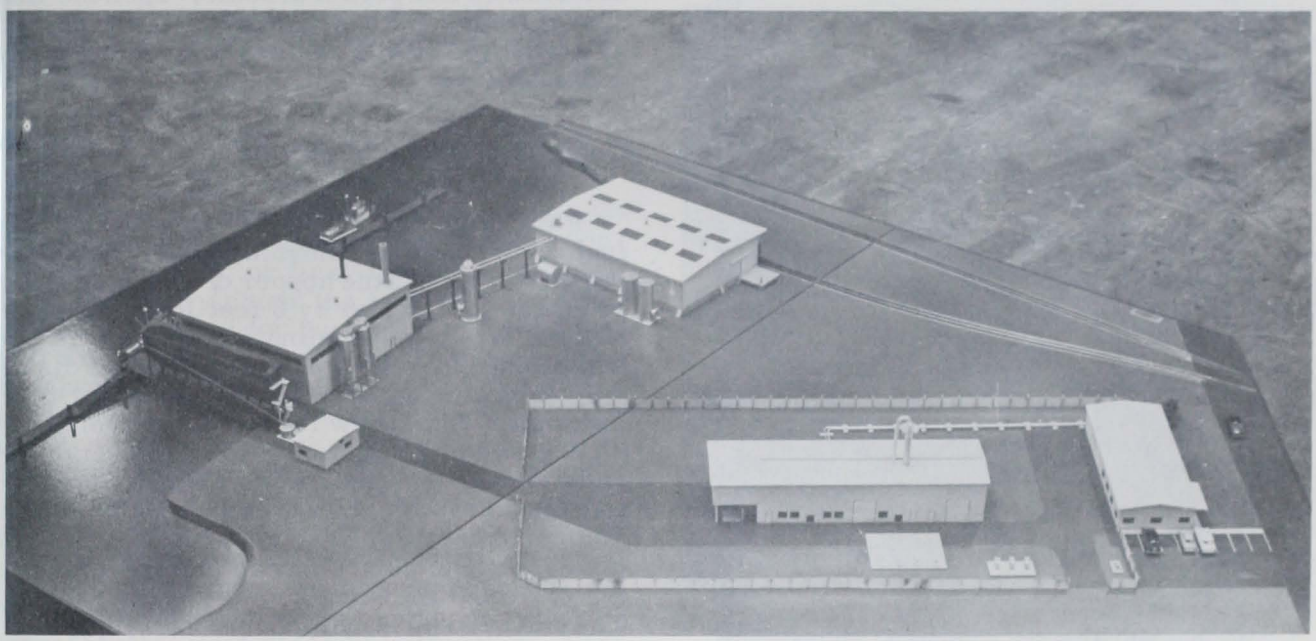

Fig. 1 - Model of Experiment & Demonstration Plant shown in relation to Port of Grays Harbor dock (Washington State) and former Pacific Protein facilities.

In the process, fresh fish are ground and extracted with azeotropic isopropyl alcohol to remove water and lipids. Extraction is performed in a 4-stage countercurrent series of mixing tanks and separating operations, using screens and presses. The extracted solids are desolventized, milled, and bagged, producing FPC. Oil is separated from the extract, and solvent is recovered by distillation for re-use. The following is a step-by-step description of the processing operation.

Unloading

Fresh fish received by boat at the plant are first inspected to see that they meet food quality standards. Then the fish are unloaded by a vacuum, fish-unloading system, which was part of the former Pacific Protein Plant. The system has a capacity of 75 tons of fish per hour. The fish are drained, washed, and conveyed from the fish pump to a calibrated volumetric fish meter. Then the fish are conveyed to the chilled brine-storage system.

Brine Storage of Fish

One hundred and fifty tons of fresh fish can be stored at 32° F in the chilled brine-storage system. This will sustain continuous plant operation up to 3 days. The storage tank is

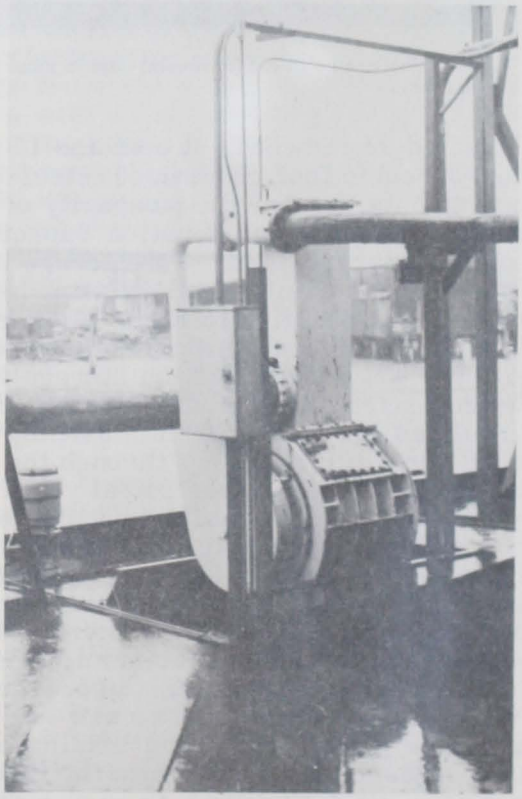

Fig. 2 - Fish are unloaded from holds of boats by fish pump operating on vacuum principle.

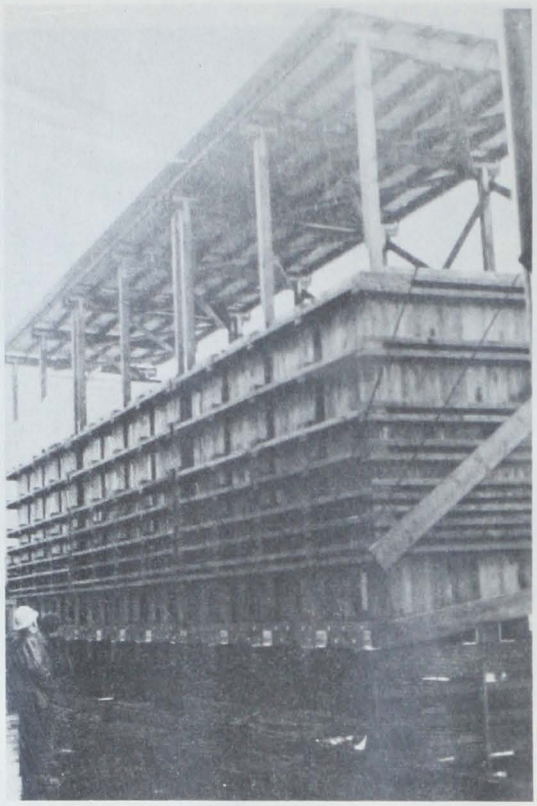

Fig. 3 - Fish can be stored for several days in these redwood tanks.

constructed of redwood. It contains 12 separate, 750-cubic foot, galvanized, steel-lined compartments, each with a capacity of 12.5 tons of fish. The refrigeration capacity is approximately 100 tons. The storage tanks are partly filled with prechilled brine before being charged with fish to obtain more rapid chilling and to reduce physical damage to the fish. Fish are loaded into the storage tanks by deflection from a belt conveyor. The brine is circulated continually from a settling tank through the chiller and up through the fish. Brine quality is checked pariodically by NMFS Support Laboratory to maintain a low-solids content and low-bacterial count. An automatic brine make-up system supplies brine from fresh potable water and salt. No bactericides or inhibitors are used in the brine. When plant demands fish, a compartment of fish is drained of brine, and the fish discharged by gravity into 260-gallon, galvanized steel, drop-bottom, tote bins each holding about 2,000 pounds of fish. The bins of fish are transported by fork-lift truck to processing building, where the exact net weight of fish is determined on a platform scale. Then the fish are unloaded onto a conveyor-elevator and are washed with fresh water to remove any adherent brine.

Comminution and Slurrying

Fish from the conveyor-elevator--a 24-inch-wide, inclined, cleated rubber, belt conveyor--are fed to the hopper of a screw feeder 18 inches in diameter by 6 feet long. Comminution (reduction to minute particles) is accomplished in a 40-h.p. Reitz inclined disintegrator using an 18-inch screen with $\frac{1}{4}$-inch openings. The screw feeder is controlled by a current meter on the disintegrator. A reversible screw conveyor from the disintegrator discharges to either of two 1,000-gallon slurry mix tanks, where the ground fish is mixed with a controlled amount of miscella (M-2) from the second stage of extraction. The mix tanks are equipped with 10 h.p., 125-rpm turbine-type agitators, and each contains 4 removable baffles. Associated with each tank is a 10-h.p. centrifugal pump for transfer or recirculation of the slurry.

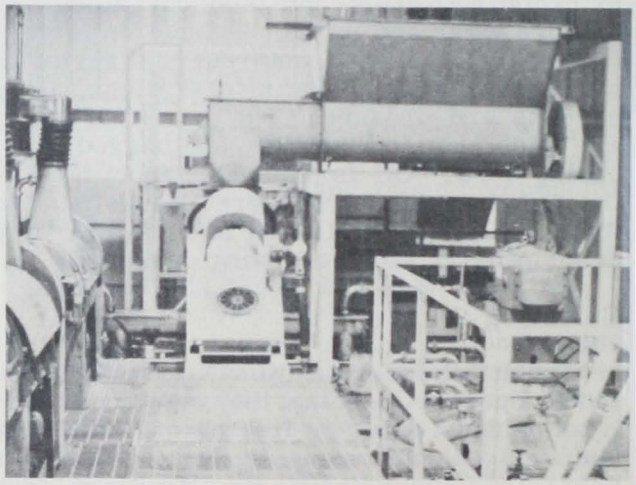

Fig. 4 - Several tons of fish per hour can be ground in this large comminutor.

The fish can be deboned, if desired, by processing through a Zebarth Beehive deboning machine. In this case, fish are fed to the deboner from the disintegator and then pumped to the slurry mix tanks.

Batching of the feed slurry (comminuted fish and miscella M-2) permits periodic shutdown of the disintegrator for cleaning, replacing screen, or other servicing without

interrupting continuous flow of extraction system. Over an hour of down time can be available at design capacity (50 tons of fish per day).

Extraction

Batches of fish and M-2 slurries are prepared and pumped intermittently to the 1,500-gallon feed tank or first-stage mixing tank. Flow of slurry from the tank is maintained constant and marks beginning of continuous extraction system. The first-stage mixing tank contains a level indicator and alarm, but the level must be maintained manually. Suspension of the slurry is maintained by a turbine-type agitator driven by a 10-h.p. motor. The mixing vessel is jacketed, and the temperature of the slurry can be automatically controlled up to 180° F. Present operating conditions, however, specify no heat addition beyond that introduced by the warm miscella (M-2) for this first stage of extraction. Normal operating temperature should be approximately 120° F. The slurry is pumped from the first-stage mixing tank to a SWECO Separator (60-inch diameter, 200-mesh vibrating screen) for primary separation of solids from miscella. Discharge rates from the tank are maintained by manual control of a 2-h.p. variable-speed rotary pump and establish the feed rate to the extraction system. The design rate is about 30 gallons per minute.

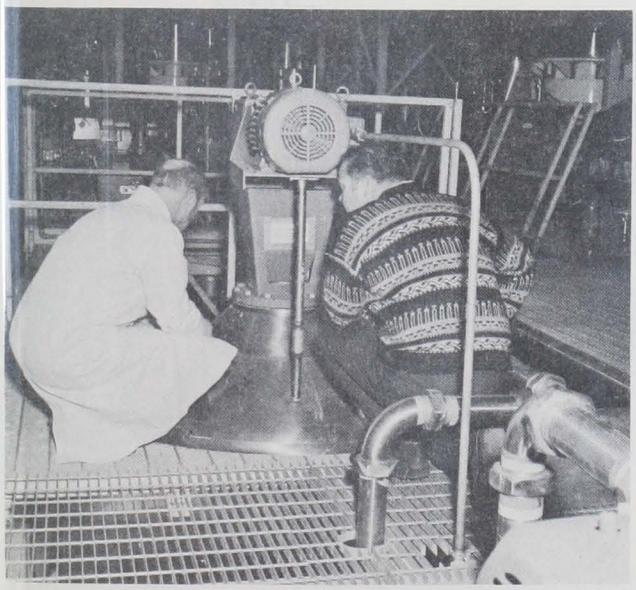

Fig. 5 - The comminuted (pulverized) fish is mixed with isopropyl alcohol in large slurry tanks.

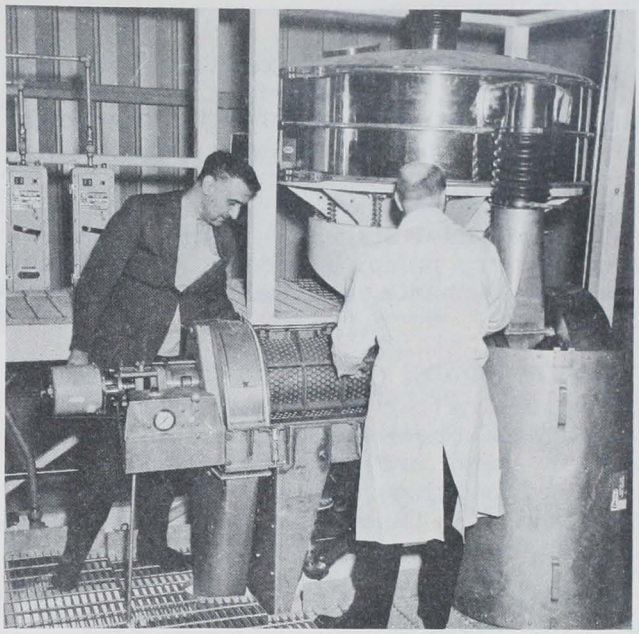

Fig. 6 - The protein portion of fish slurry is separated from this miscella in a series of shaker screens and pulp presses. The top of pulp press has been removed for inspection.

The solids from the screen discharge to a Brown International Pulp Press, which reduces further the liquid content of the solids. Solids from the press discharge by gravity to the next extraction vessel. Volatile content of the solids from this first-stage press are approximately 60%. Lipids content of the solids, when using a 2:1 overall alcohol to fish ratio, are about 4% on a dry basis. The liquid effluents from the press and screen are combined and referred to as first-stage miscella (M-1). This miscella is pumped to a 300-gallon vessel and processed further to recover solvents and by-products. The feed tank, pump, screen, and press constitute the first stage of extraction.

Solids from the first stage of extraction are mixed with miscella (M-3) from the third stage of extraction in the second-stage, 800-gallon, agitated, jacketed vessel. Temperature is maintained automatically at 165° F. Slurry flow from this vessel is controlled manually, but it is constant once the system is operating under steady-state conditions. The tank level is indicated and changes must be compensated by manual control of the discharge pump. The level in any of the extractors and the discharge flow rate establish an average residence time or extraction time. The extraction time can be altered by changing the operating level. A 600-gallon level

results in an extraction time of about 20 minutes for that stage.

At present, 4 stages of extraction are used in the system. The equipment used in the 4 stages are similar. A 1,500-gallon extraction vessel and a 60-inch-diameter vibrating screen are used in the first stage; 800-gallon extraction vessels and 48-inch screens are used in the 3 later stages. An extraction vessel, a slurry pump, a screen, and a press constitute the basic equipment for an extraction stage.

Fresh solvent (new or reclaimed) is introduced to the fourth or last stage of extraction through a heat exchanger. Temperature and flow rates are automatically controlled to preset conditions. The solvent rate is commensurate with the solvent ratio desired and the fish feed rate to the first stage.

Desolventizing

Desolventization of the solvent wet solids is accomplished by introducing steam countercurrently to the solids in a Strong-Scott Solidaire Processor Model SJS 24-16, followed by final redrying and conditioning of the solids in additional units. Four units 16 feet long and 24 inches in diameter are used in series. Final moisture is controlled below 9% and residual alcohol below 250 parts per million. Uncondensed steam and volatilized solvent are condensed and sent to solvent recovery. The desolventized solids are conveyed to the milling room in a 6-inch screw converyor.

Milling and Bagging

The dry solids from desolventizing are received in the hopper of a variable-speed screw feeder to the mill. The mill is a Pulverizing Machinery Company Model 60 ACM mill driven by a 75-h.p. motor. The solids are milled to pass 200 mesh, then received in a Micro-Pulsaire bag collector; they are bagged in 50-pound, polyethylene-lined, multiwall paper bags. After check-weighing and sealing, the bags are palletized

Fig. 8 - The solvent is recovered by distillation in 54-foot tower that extends above roof line of plant.

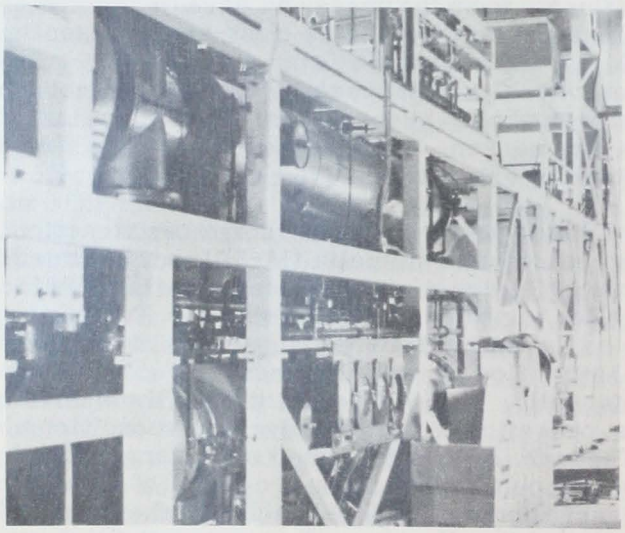

Fig. 7 - The wet solids are desolventized in a series of 4 large steam-heated drying units. The equipment is arranged compactly in a steel framework designed to facilitate transport from its fabrication point in Los Angeles, Calif.

Fig. 9 - Pulverized FPC is milled and bagged in a separate room.

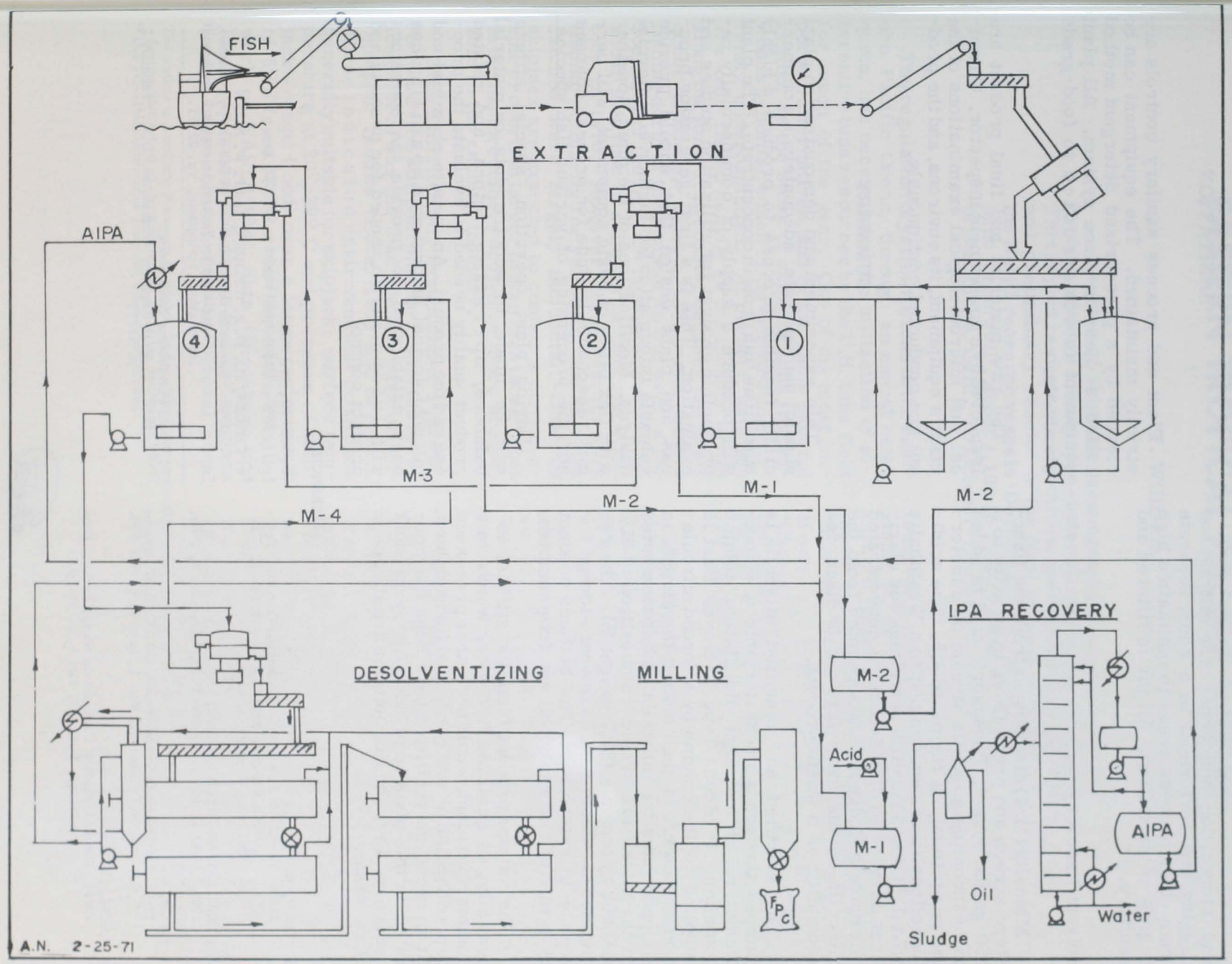

Fig. 10 - Experiment and demonstration plant flow diagram.

and stored for shipment. The milling and bagging are performed in a room separate from other process areas to maintain a high degree of sanitation. All air is filtered and sanitary.

Solvent Recovery

Miscella (M-1) discharged from the first-stage screen and press flows by gravity to a 250-gallon vessel. Phosphoric acid is added to the incoming miscella stream by a metering pump to adjust the pH to 4.5. The acidified miscella is then pumped to a Westphalia Model SOAH-5036-SLS centrifuge for clarification prior to distillation. A concentrated oily protein sludge is thus separated from the miscella by the centrifuge and is discarded soon after as a waste product.

The acidified and clarified miscella is pumped through a preheater into a 4-foot-diameter, 54-foot-high distillation column containing 24 Koch, Type T trays. Heat is supplied to the column by a forced-circulation reboiler. In the column, the alcohol is stripped from the miscella and concentrated to the water azeotropic composition of 91% alcohol by volume (87.7 weight %). The reclaimed alcohol is sent to solvent storage for re-use in extraction. The bottoms product is a mixture of water, oil and fish solubles.

The bottoms product from the still is, essentially, an acidified fish water which, in a commercial plant, would be further processed to produce fish oil and condensed fish solubles. At present, no facilities have been incorporated in this plant to provide for by-product recovery. Present still bottoms are disposed of as waste.

SANITATION

Plant and process sanitary controls are strictly maintained. The equipment can be cleaned by a pressurized detergent method called a clean-in-place system. All plant equipment is constructed to food-grade standards.

The raw material and final product are inspected by a government inspector. Chemical and microbiological examinations of the plant's equipment, its environs, and the product are conducted continuously.

SUMMARY

This experiment and demonstration plant should demonstrate adequately a commercially feasible process to produce a highly nutritious fish protein concentrate. The plant will produce a supply of commercially reproducible product for utilization studies and evaluation. This is a first-generation process and plant design that should provide valuable information for further commercial designs. Modifications of the plant, together with flexibility of basic equipment, will permit reasonable latitude for process changes and the processing of various fish species.

During plant operation, special efforts will be made to acquire data on material balances, operating factors, and related product quality needed to evaluate the process and the product. An on-site chemical and microbiological laboratory capability has been established to provide the operators with information needed for process and product control.

REFERENCES

1. FINCH, R.
   1969. The U. S. Fish Protein Concentrate Program. Commercial Fisheries Review, Vol. 31, No. 1, p. 25-30. Also Reprint No. 832.

2. PUBLIC LAW 89-701 (as amended)
   1966. U.S. Congress, 80 Stat 1089, November 2, 1966.

3. FINCH, R.
   1970. Fish Protein for Human Foods, CRC Critical Reviews in Food Technology, Vol. 1, Issue 4, p. 519-580.

4. KNOBL, G. M., Jr.
   1967. The Fish Protein Concentrate Story, Part 4. Food Technology, Vol., 21, No. 8, p. 56-59.

5. MEINKE, W. W.
   1968. Unpublished report to SWECO, Inc.

6. CIPRIOS, G., D. P. COTRUPE, and P. W. ALLEN
   1969. Studies for the Purification of Isopropyl Alcohol, Clearinghouse for Federal Scientific & Technical Information, Springfield, Va. 22151.

7. Whole Fish Protein Concentrate
   1967. Federal Register, Washington, D.C., February 2, p. 1173.