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SPECIAL REPORT

EVALUATION OF LOW-COST EXTRUSION COOKERS FOR USE IN LDC'S

Departments of Agricultural and Chemical Engineering
and Food Science and Nutrition
Colorado State University
Fort Collins, Colorado 80523

July, 1977

LEC REPORT 3

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SPECIAL REPORT

Evaluation of Low-cost Extrusion Cooker in Sri Lanka

by

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and Food Science and Nutrition
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July, 1977

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SPECIAL REPORT

Evaluation of Low-cost Extrusion Cooker in Sri Lanka

I. SUMMARY OF THE REPORT

A. Evaluation Objectives

A low-cost extrusion cooker (LEC) system has been in operation at Kundesale, Sri Lanka for one year, as of March, 1977. The principal purpose of the installation was to demonstrate the suitability of such a system for the conversion of indigenous grains into low-cost, nutritious, palatable foodstuffs in less developed countries (LDC's).

The investment costs were funded by the U. S. Agency for International Development and CARE, as a joint venture. The USDA Nutrition and Agribusiness Group has provided counsel and administrative direction for the USAID interest. Colorado State University's Department of Agricultural and Chemical Engineering has provided engineering and technical assistance. CARE/Sri Lanka arranged for the installation in an existing rice mill. The Government of Sri Lanka has furnished the raw material grains for processing at its expense. CARE/Sri Lanka has provided general management and product distribution direction for the project. Cereal Products Factory, a private business and owner of the rice mill, has provided housing and production services for the project, under an agreement for payment on the basis of finished product throughput.

A Mission composed of three people, long experienced in grain process engineering, management, and quality control in U. S. private industry, and as consultants to international agencies, was employed to evaluate the system, and the results of its operation in Sri Lanka, for suitability for use in LDC's, and proof of suitability by reason of demonstrated performance. The Mission's agreement required recommendations for continued development work, if needed.

The Mission was employed February 28 - March 20, 1977, in briefings in the United States by those having direct technical knowledge of the project, 10 days of observation and analysis in Sri Lanka, and related travel. This report represents the findings of that Mission.

B. Suitability

The system clearly produces an entirely satisfactory food product, which should be quite acceptable as a means of conversion for indigenous grains in LDC's.

The system has the capacity to meet the initial goal of processing 1000 pounds of a cereal-soybean mixture into about 925 pounds of finished product per operating hour.

The present system is an intermittent duty system. It is estimated that its annual capacity is a minimum of 2,400,000 pounds for a 2-shift operation, or 3,600,000 pounds for a 3-shift operation in a 250-day operating year. So operated, it is estimated that the intermittent duty components of the system will have a life expectancy of five years.

The system is a low investment cost system. The Mission estimates that new installations at an installed cost in the magnitude of $100,000 for process equipment will cost no more than 40% of the installed costs

for conventional, competing systems. Operating expense, largely by reason of low overhead costs for ownership, will be low, and within the range of $0.012 and $0.023 per pound of finished product.

The intermittent duty performance characteristics of the existing system will not meet all LDC needs when high production dependability and lowest operating expense are important requirements. These potential problems can be corrected by developing the system into a continuous duty system, or ameliorated by adding standby equipment and/or larger inventories of finished products, in order to bridge production gaps.

c. Demonstration - Proof of Suitability

The experience in Sri Lanka has clearly demonstrated the ability of the system to produce the kind and quality of product sought, from a wide range of formulations. All of the product from one year of intermittent operation has been quite acceptable, according to the record.

Over a six-day, 96-hour work schedule in March, 1977, the capacity of the system to produce at a 1000 pounds per hour raw material feed rate was proven with 100% performance in production over that time.

Over a longer term studied, October 1976 through the first six scheduled days in March, 1977, the dependability of the system to produce at an acceptable intermittent rate has not been demonstrated. It was determined clearly that by far the major problem, and perhaps the only significant problem, in attaining a satisfactory intermittent-duty performance was maintenance system performance--a quite common problem in LDC's. Significant correction of the maintenance function would result in bringing production up from the 40% of expectancy attained

in that period to over 70%, a level at which operating expense becomes reasonable and alternative solutions to meeting feeding program delivery demand become reasonably available.

Low investment cost potential for the system has been demonstrated adequately in Sri Lanka. The Mission is quite satisfied that modest increases in investment costs will be well justified by incremental cost-benefit ratio analysis. Fully developed to continuous-duty status, the system will remain a very low investment cost system, by reason of the unique simplicity and low cost of the cooker-extruder. Low operating expense has not been adequately demonstrated, by reason of the low production experience and its maintenance source.

Although not fully demonstrated in Sri Lanka, technology transfer to LDC peoples poses no unusual problems or high costs--just the usual requirements for technical assistance and training, and in scope approximately commensurate with the smaller size of the operation.

D. Recommendations

The LEC system is an unsophisticated, low-cost processing method for conversion of grains into foods. It appears, to the Mission, to fit neatly into the USG stated policy of assisting LDC's toward permanent internal solutions to food problems.

With that perspective, and based upon the Mission's detailed findings, it is strongly recommended that work continue to improve and prove the system, for early use in LDC's.

It is recommended that a temporary, complete unit be installed at a U.S. site where experienced engineers, chemists, and grain enterprise managers can efficiently assist in completion of the development work. It is recommended that the goals of the development work remaining be:

1. Convert the system from an intermittent-duty system to a dependable continuous-duty system.
2. Refine existing, and prepare new, written material to serve as training aids and continuing guides to all functions of the enterprise.
3. The total goal of the development activity would be to prepare an enterprise "package" which one qualified man could have in satisfactory continuous-duty operation in a LDC within six months after training starts.

The most likely alternative to the recommended, integrated approach is to solve problems on a priority basis, at a U. S. location, and provide technical assistance at the Sri Lanka demonstration installation to implement the solutions. The Mission suggests the following priorities to be in order:

1. Improved maintenance plan (critical for any major improvement in performance).
2. Convert the Brady cooker from intermittent-duty status to continuous-duty status.
3. Replace auxiliary intermittent duty equipment with available continuous-duty equipment.
4. Test the improved Brady cooker under operating variables--formulations, raw material moisture content, raw material granulation, heat application, machine speed, etc. The purpose would be to establish operating parameters that would result in the greatest production at the lowest cost.

5. Preparation of the needed written material can progress in concert with, and much of it independently of, the above priorities.

Significant improvement in the maintenance plan, and its performance, appears to be a prerequisite to satisfactory implementation of the LEC system in a LDC.

II. INTRODUCTION

A. Evaluation Objectives

The Mission's charter has required it to evaluate a low-cost extrusion cooking (LEC) system presently installed in Sri Lanka, with the following major questions to be answered:

1. Is the existing system suitable for use in the manufacture of cooked food commodities in less developed countries?
2. Has the Sri Lanka installation adequately demonstrated the suitability of that system, for that purpose?
3. If either objective, suitability or demonstration have not been attained, what changes or additional development work may be required to attain the desired result?

B. Historical Background of the Process

For many years, at least as far back as the early 1930's, continuous extrusion processes have been successfully used to compress animal foods, cooked human foods, and other industrial materials. Examples are breakfast cereals, snack foods, pelleted animal feeds, and artificial fireplace logs. Continuous process oil expellers go back further. Early systems, and many excellent present day systems, employ water and steam with which to cook; extrusion as a means of concentrating or compressing; and heat as a drying agent to provide storage life for the product. The nature of the raw materials and the intended use of the finished products have always tended to determine the exact processes, and the degree of treatment needed.

Within the past 10 years, machines have been developed to utilize only the heat of friction, from the mechanical energy dissipated in the

extrusion process, to cook the material extruded. The Brady #206 Crop Cooker, which is the heart of the Sri Lanka system herein evaluated, is such a machine.

The Brady machine was designed to cook raw soybeans so as to make the inherent nutrients of the soybean available to farm animals, parts of which cannot be utilized by the animal if the beans are fed raw.

This team agrees on the following axioms as generally true, but not immutably so, based upon long experience:

1. Cooking and extrusion of agricultural commodities, and certainly cereals and pulses, <u>remains largely an art</u> in the actual process control. This is true because no two lots of raw materials are exactly the same. No two formulations respond to the process in exactly the same manner. The experienced artisan process operator must adjust the process to meet varying raw material and ambient operating conditions. The process designer and the operator are materially aided by the physical laws expressed in the psychrometric chart; the laws of heat transfer, including particularly the specific heat of the material; the laws of power application; and the fairly precise science of material strength. It is proper application of the precise science available to the designer that permits the artisan operator to successfully respond to changing raw materials and operating conditions.
2. Typically, as granulation of the raw material is made finer, cooking time and energy input to cook and extrude are lower.
3. Typically, as moisture content of the raw material increases (within limits), cooking time and energy to cook and extrude

are lower. Cooking and extrusion may benefit from both uniformly absorbed (tempered) moisture additions and free surface water. Free surface water, in particular, may require increased energy input to attain cooking temperature.

4. Typically, heating of raw materials, either dry or wet, will reduce cooking time and extrusion energy requirements.
5. Typically, as fat content of the raw materials increases, cooking time and energy input to extrude are lower.
6. Typically, cooking time and temperature are dependent variables. Within limits, either may be lowered by increasing the other in order to attain a satisfactory product. If either time or temperature are fixed, then the other variable must provide the entire compensation for changing raw material requirements. Total energy input may remain constant as time is lengthened but typically is lower due to physical changes in the raw material which facilitate moisture and heat penetration.
7. Successful cooking of cereal products is usually measured by the degree of starch gelatinization attained. Visual and taste testing are usually accepted as satisfactory measures of cooking results. Visually, absence of "white caps" (white starchy spots) is indicative of satisfactory gelatinization of the starch. Uncooked starch has a raw taste readily recognizable to an experienced taster. Absence of that flavor is an acceptable indication of satisfactory starch gelatinization.

C. Historical Background of the Project

In recognition of the potential benefits of extrusion cooking for the production of palatable, nutritious foods, and food intermediates, from indigenous cereals, oil seeds and legumes available in the LDC's, the Office of Nutrition in the Agency for International Development (USAID) has provided funds to Colorado State University (CSU), through the U. S. Department of Agriculture's Nutrition and Agribusiness Group, for the development of suitable LEC systems.

The criteria for a suitable system are:

1. Low capital cost for fixed assets, defined as a complete plant ready to run at an investment cost not to exceed $100,000 for 1000 pounds per hour of capacity.
2. Low throughput costs.
3. Technological competence requirements at a level that could be reasonably obtained in the LDC's.
4. Production of a highly nutritious, palatable food.

Work started at CSU under its agreement in the fall of 1974, toward the development of such a system.

CARE/Sri Lanka was in need of production capacity to utilize indigenous cereals and pulses to blend with, or replace, P.L. 480 Title II commodities it distributes to needy infants, pregnant women, and lactating mothers. A joint venture agreement was reached between CARE and the above described participants, wherein CARE and USAID would supply funds to construct a plant with a nominal capacity of 1000 pounds per hour. CSU provided technical assistance. The USDA Nutrition and Agribusiness Group continued to provide the project administrative direction for USAID.

The LEC plant was installed in a building owned by a private firm, Cereal Products Factory (CPF), which is part of a rice mill located at Kundesale, Sri Lanka. The rice mill is used as a LEC grain cleaning and storage facility. The plant was ready for beneficial use in March 1976. It has thus been in operation for one year. Cereal Products Factory operates the plant as a contractor to CARE/Sri Lanka.

We commend the people of the USDA Nutrition and Agribusiness Group and USAID's Office of Nutrition for recognition of the potential of low-cost extrusion cooking, and their promotion of its development for use in LDC's. The Agricultural and Chemical Engineering Department at Colorado State University developed and guided the implementation of an operating system in a most expeditious manner. CARE headquarters and CARE/Sri Lanka have provided a signal service in providing a practical test of the system, including beneficial use of the finished product, plus part of the funding.

III. INVESTIGATIVE PROCEDURES

This section of the report describes the sources of information and on-site investigations utilized by the Mission in reaching its conclusions.

A. Colorado State University Briefing

On March 1 and the morning of March 2, 1977, the evaluation team was at Colorado State University, Agricultural and Chemical Engineering Department, Fort Collins, Colorado, 80523, for project briefing. The briefing was presented by:

Dr. Judson M. Harper, Head of Department

Ronald E. Tribelhorn, Research Associate

Marvin L. Stone, Research Associate

Dr. G. Richard Jansen, Head, Dept. of Food Science and Nutrition.

The briefing at CSU provided the following background:

1. A review of the history of the project.
2. A review of process and maintenance experience to date.
3. A review of product quality considerations, including formulation.
4. A review of the scope of work expected from the evaluation team.
5. Observation of the Brady cooker in operation for approximately one hour, including a demonstration of the recommended operating procedure for soybean-cereal blends.
6. The following documents were provided to the team, which proved to be of great value in rapidly understanding the project:

a. "Scope of Work for Evaluation Team"

b. "Evaluation of Simple Cooker Extruders for Use in LDC's," Tribelhorn, Stone, and Harper, July 31, 1975

c. "Instructions for Brady Evaluation Sites," Tribelhorn, Stone, and Harper, Nov. 10, 1975

d. "Inspection Trip - Sri Lanka," J. M. Harper, May 2-5, 1976

e. "Follow-up and Evaluation Trip to Sri Lanka," R. E. Tribelhorn, Nov. 8, 1976

f. "Analysis of the Production Operation," Justin R. Jackson, Dec. 9, 1976

g. "Trip Report - Sri Lanka," G. R. Jansen, Dec. 27, 1976

h. "Repair and Rebuilding Procedures for Rotor Weldment," R. E. Tribelhorn, Undated

i. "Design and Installation of a Production Facility in Sri Lanka," Tribelhorn, Harper, and Stone, Undated

j. "Thriposha Quality Control Manual - Sri Lanka," 1976

k. "Low-cost Extrusion Cookers - International Workshop Proceedings," June 2-5, 1976

l. "Evaluation of Low-cost Extrusion Cookers for Use in LDC's," Stone et al., July 31, 1976.

B. Koehring Farm Division Briefing

During the afternoon of March 2, 1977, the team visited the office of the maker of the Brady 206 Crop Cooker, the Koehring Farm Division, Des Moines, Iowa, 50305. Mr. Gerald Williamson, Chief Engineer, fully

conversant with the design of, and experience with, the Brady Crop Cooker, conducted the briefing.

The briefing at Koehring provided the following information:

1. A most important document, "Brady 206 Crop Cooker - Operator's Manual - Parts Catalog."
2. A quite relative document, "Effect of Elevated Input Temperature on the Processing Efficiency of a Soybean Extruder," E. L. Swenson and W. F. Buchele, Paper No. J-7997, ASAE.
3. Mr. Williamson stated:
   a. The Brady 206 Crop Cooker was designed for intermittent farm duty, primarily for the cooking of raw soybeans for animal feed.
   b. The manufacturer's "rated" (instantaneous) capacity is approximately 1400 pounds per hour of soybeans, at 540 rpm operating speed, requiring 90 to 100 hp energy input, and 230-290°F cooking temperature, depending upon soybean moisture content.
   c. An estimate of "rated" (instantaneous) capacity for 15-20% soybean - 80-85% blends:

      1200 pounds per hour,

      540 rpm,

      90 to 100 hp,

      340-360°F cooking temperature.
   d. An estimate of "rated" capacity for 100% cereals plus vegetable oil or water:

1000 pounds per hour,

540 rpm,

90 to 100 hp,

340-360°F cooking temperature.

e. Having had no experience with the Brady cooker as a continuous-duty industrial machine, the manufacturer has no estimate of the "continuous-duty" capacity of the machine.

f. The manufacturer has designed for, and expects, an average production, or life, of the principal wear parts, the extruder cone and matching cup, between 50 and 100 tons of soybeans. He is aware of actual field results ranging between 10 and 350 tons of soybean production per set of extruder cones. Abrasiveness of the soybeans, and particularly the level of foreign matter content, has been the principal determinant of the life expectancy of these important machine elements.

g. Koehring Farm Division is basically organized for assembly line mass production, at low unit cost. It is not "job shop" oriented, to custom fit machinery for specific customer requirements. Production runs of 500 units would probably be a minimum requirement for units designed to maximize the continuous-duty potential of the Brady cooker concept. Job shop modification of the standard production unit is likely to be the most economical method of maximizing the inherent potential of the Brady cooker for continuous industrial duty.

C. USDA Nutrition and Agribusiness Group Briefing

The evaluation team spent the afternoon of March 3 and the morning of March 4, 1977, in the office of the USDA, Economic Research Service, Nutrition and Agribusiness Group, 500 - 12th St. S.W., Washington, D. C., 20250. The briefing was conducted by:

P. R. Crowley, Group Head

Al Lachmann

David Wilson.

The briefing in Washington provided the following background:

1. A history of the project, including the goals and roles of the participating agencies,
2. The objectives of the evaluation team, as incorporated in the above statement (Ref. II.A.),
3. The definition of a LEC, as stated hereinbefore (Ref. II.C.),
4. A discussion of product character and specifications for which the LEC system has been developed, all as defined in the Quality Control Manual (Ref. III.A.6.j).

D. CARE/Sri Lanka Briefing and Observations Schedule

The evaluation Mission arrived in Colombo, Sri Lanka, on March 7, 1977. Mr. Justin R. Jackson, Assistant Director, CARE/Sri Lanka, 27 Alfred Place, (P. O. Box 1024), Colombo 3, Sri Lanka, provided arrangements for all aspects of the team's stay in Sri Lanka and briefed us on CARE's experience in the construction and operation of the LEC system in Sri Lanka. The schedule of the team's effort in Sri Lanka was as follows:

1. The morning of March 8, Mr. Jackson briefed the Mission on:

a. Production schedule attainment,

b. Maintenance supply matters,

c. Plant personnel matters

d. Plant operation contract matters,

e. Raw material supply matters,

f. Finished product usage and quality matters,

g. Tentative longer term plans for plant and product requirements to meet the CARE/Sri Lanka program needs.

2. The business hours of March 9-10, 1977, were spent in the Kundesale plant for the following purposes:

a. One or more of the team members were in constant observance of the process plant operation for 16 hours, more or less.

b. Plant production and quality control records were studied.

c. Maintenance methods, parts supply, and available tools were investigated.

d. The plant flow diagram was traced, and the major process control parameters in use were investigated.

e. Machinery condition, and suitability for the use, were appraised.

f. The quality and condition of the product was organoleptically monitored throughout the 16 hours of observation.

g. Sanitation, foreign matter, and employee safety hazards were investigated.

h. Two meetings were held with Mr. M. B. Alahakoon, owner of Cereal Products Factory, and members of his staff, for the purpose of:

i. Learning of CPF's experiences in operating the system and their views, if any, of needed changes,

ii. Their views of personnel numbers and skill requirements to operate the system,

iii. Their cost experience and partial estimates of cost to operate an independent LEC plant of the same capacity and configuration,

iv. Their views concerning an acceptable contract basis for the operation of such a plant.

3. The period March 11-16, 1977, was reserved by the Mission for the analysis of collected data, and the preparation of a first draft report.

4. On March 17, 1977, the Mission participated in a debriefing meeting with Mr. Jackson, CARE/Sri Lanka, in which the findings of the Mission were reviewed, and plans for continued operations of the LEC system in Sri Lanka were discussed.

E. Debriefing - Fort Collins

On March 28, 1977, a debriefing meeting was held in Fort Collins, Colorado, at Colorado State University for the purpose of reviewing the findings of the Mission, and its first draft report. As a result of that meeting, this report is issued. In attendance were:

P. R. Crowley, USDA

Al Lachmann, USDA

J. M. Harper, CSU

R. E. Tribelhorn, CSU

M. L. Stone, CSU

E. E. Kuphal, Consultant

R. E. Gaylord, Consultant

A. A. Ackels, Consultant.

F. Time of the Mission

The total time of the Mission for its evaluation trip was February 28 - March 19, 1977. The Mission time in Sri Lanka was March 7-17, 1977.

G. Reference Material Usage

In keeping with the terms of reference for the team's scope of work (Ref. III.A.6.a.), no effort has been made in this report to include all of the useful information from the prior publications cited. A study of these documents will prove to be helpful to one who wishes to have a more complete background in the history and technology of the LEC system than this report provides.

H. Acknowledgment

The members of the evaluation team wish to express their deep appreciation to those people who are named in this chapter of the report, and to the many others who assisted us in the prosecution of the work. Without their help in effectively supplying information and arrangements, completion of the assignment in the alloted time would

have been impossible. With their diligent effort to assist in the work and their kind hospitality, we, the team members, believe that they have made it possible for use to produce a definitive report, and enjoy an interesting assignment.

IV. THE SRI LANKA PLANT AND PROCESS

OBSERVATIONS OF THE EVALUATION TEAM

A. Raw Materials - Formulation

The principal purpose of CARE in making the LEC installation in Sri Lanka was, and remains, utilization of indigenous grains in State-supported feeding programs. The Paddy Marketing Board, a Government agency, supplies domestic grain to CARE/Sri Lanka under a contract providing for its processing and distribution. It is believed that a commercial market may also be developed with benefit to the people. That prospect is in the planning stage for future implementation.

Three principal formulae have been used at Kundesale, as follows:

1. 95% whole cleaned sorghum
   5% whole cleaned soybeans
2. 80% whole cleaned corn
   20% whole cleaned soybeans
3. 76% whole cleaned corn
   19% whole Navy beans
   5% coconut oil.

Deviations from these formulae have been frequent. The prime reason for diversity in formulae, and deviations from the stated formulae, has been insufficient domestic supplies of specific cereals and pulses to meet scheduled production requirements.

Decortication of sorghum and corn has been tried, using a Schule rice mill as the processing medium. Discussions, in lieu of statistical data, indicated that the recoveries of usable product from cleaning and decortication averaged about 90% for sorghum and 65% for corn. Decorticated sorghum was used in the scheduled production program. The loss

in decortication of corn was deemed to be excessive and, therefore, whole cleaned corn has been the principal cereal base for the major volume of the plant's production to date. Whole cleaned soybeans are used to provide the pulse base as the standard ingredient. Navy beans and coconut oil were used to maintain production during a period when soybeans were unavailable. The present standard formula is 80% whole clean corn/20% whole cleaned soybeans.

B. The Plant and its Process

The major longer term supply of grain for the LEC facility is maintained by the Paddy Marketing Board. The supply at Cereal Products Factory is a short-term operating supply maintained at a level consistent with a need to assure continuity of plant operation.

Grain Cleaning--

Cleaning is accomplished, at present, by passing the grain through a one-ton capacity Schule rice mill, adjusted so that the abrasive devices barely touch the grain. Adjustment of these machines to abrade the grain would result in high losses to animal feed. Its flow is as follows:

1. Two-sieve reciprocating scalper - coarse and fine clothed
2. Rice sheller - adjusted for very light abrasion
3. One-sieve rotating scalper - fine clothing
4. Aspirator
5. Paddy separator
6. Gravity separator - stoner
7. First pass rice huller - adjusted for very light abrasion
8. Second pass rice huller - adjusted for very light abrasion

9. One-sieve rotary scalper - clothed fine

10. Aspirator

11. Bagging spout.

This system is doing a satisfactory job of cleaning grains. The cleaned corn was free of foreign matter. It is removing some loose fibrous material (bran parts) from the corn tips. It is removing the observable evidence of infestation, including thin bran and endosperm.

Management Control of Grain Cleaning--

The weight of materials cleaned out of the grain is not recorded. Clean grain is packed in 100-pound weighed bags. Management's only measurement of the efficiency of the cleaning system is visual inspection of the separates. Presently, there is no consistent evaluation of cleaning efficiency.

Clean Grain Movement and Storage--

Bags of cleaned cereal grain are fed in the storage area. The process supply bins are filled by a drag conveyor (trade name Cablevey). This conveyor has been a constant source of trouble to the operators, due to breakage of the conveying elements, and to a lesser extent overloading of the drive elements. It is presently being used for the movement of corn only because it will not withstand the feed rates necessary to supply both corn and beans. Soybeans are being hand fed from bags to an auxiliary hopper for the first process machine, the Modern Mill.

Two free-standing, hoppered, steel, farm-type bins provide the process supply of grain. Each has a nominal capacity of 10 tons. Each is discharged by a farm-type, tube-enclosed screw conveyor, angled

upward, to provide vertical as well as horizontal conveyance. Within the bins, under the conveyor is dead space, from which perhaps 50 to 100 pounds of grain will not discharge to the conveyor. The operators report that the material in this dead space in cleaned out each time the bins are empty.

Modern Mill--

This trade named unit is a combination volumetric proportioning system and hammer mill. The Sri Lanka unit has two small hoppers fed from the grain bins automatically and two side hoppers that may be hand fed. The proportioning devices are variable speed screw feeders, one under each hopper. They are dial adjusted for feed rates; however, the actual feed rate must be checked and adjusted to requirements by catching and weighing timed samples from each screw in use. The hammer mill is a small, conventional swinging hammer unit powered by a 5 hp electric motor. The Modern Mill is a lightweight machine of a type similar to farm machinery in construction. It is compatible in construction with most of the process equipment. It should have an operating life and maintenance requirements reasonably equivalent to the balance of the intermittent duty, farm-type machinery installed.

The Modern Mill has been an infrequent cause of system stoppages for maintenance.

Brady Cooker--

The Brady Cooker employed in Sri Lanka is a standard Model 206, except that the wheel carriage has been removed, and it is solidly mounted on a frame attached to the building floor. The standard feed and discharge conveyors are not used.

The basic operating principle of the machine is as follows:

1. The extruder rotor is directly connected to the power source. It is designed to operate at standard tractor power take-off speeds of 540 or 1000 rpm. The unit in Sri Lanka is operating at an indicated speed of 504 rpm, calculated from:

$$\frac{\text{1950 rpm engine speed}}{\text{3.87 gear reduction}}$$

2. A spline shaft and housing assembly permits the rotor assembly to move horizontally for cooker adjustment.

3. The rotor is a steel cylinder on which a helical screw conveyor flight has been welded. Near the extrusion end, parallel interrupter bars are also welded to the cylinder which have the effect of slowing product movement and thus increasing extrusion pressure. On the drive end of the cylinder, a drive gudgeon (shaft) is mounted. This shaft is linked to the power train and carries two opposed roller bearings which provide the entire support, and thrust resistance, for the operating rotor. There is no outboard bearing support. The entire bearing assembly is clamped to the rotor by a lock nut threaded on the shaft.

4. The bearing housing is a cylindrical steel piece, threaded on one end, and it has a roller chain sprocket welded on the drive end. This housing screws into a fixed collar, attached to the machine frame, through attachment to the rotor enclosing cylinder. The screw threads on the housing and in the collar provide a loose fit and some self-centering movement of the rotor. Rotation of the housing within the collar, in or out,

provides the adjustment of the extrusion clearance, and thus controls the cooking action.

5. The rotor is mounted in a steel enclosing cylinder of greater diameter, which also contains three parallel ribs. These ribs limit eccentric movement of the rotor, serve as replaceable wear plates, and assist is building extrusion pressure.

6. Mounted on the extrusion end of the rotor is a truncated cone of hardened material, probably steel. Mounted on the end of the enclosing cylinder is a stationary cup of the same conical angle. Horizontal movement of the entire rotor assembly, through turning the threaded bearing housing described above, provides adjustment of the clearance between the actual extruding surfaces--the cone and the matching cup. Although started by the arrangement of the welded breaker bars, and an increased diameter of the rotor at the cone end, the major work of extrusion and cooking occurs between these conical surfaces.

7. A variable speed feed auger, operated by a hydraulic motor, is located under the feed hopper. It is provided to control the feed rate of raw materials to the machine. In practice in Sri Lanka, the feed rate to the cooker is controlled by the proportioning devices in the Modern Mill. Only during start-up and shut down procedures, when straight soybeans are fed through the hopper by hand, is the feeder device actually serving as the feed control, although it is adjusted to feed at about the same rate as the Modern Mill.

8. The machine has no potential for significant adjustment of cooking time. Cooking is practically instantaneous within the last few inches of the cylinder and between the conical surfaces. Rotor speed will alter time, but not within a significantly useful range. The significant control on cooking thus becomes temperature only. Exact cooking temperatures of the product within the machine are unknown. Control of temperatures is accomplished by the cone clearance adjustment, based upon visual observation of a thermometer mounted on the stationary rotor housing near the extrusion surfaces. The mechanical energy dissipated in forcing the material between the extrusion surfaces provides the entire cooking energy input. Because time is so short in the cooking zone, the product response to changes in raw materials and feed rates is rapid. The machine must be constantly monitored for changes in temperature and maintenance of rotor speed. Excessively high temperatures, and significant loss of operating speed, will result in machine stoppage. Low temperatures result in undercooked product. Operator response to changing conditions needs to be prompt, but judicious. The Brady cooker is a sensitive device, and the operator must be sensitive to its operating conditions if satisfactory results are to be attained.

Cooking Performance. During the time the Mission members were in the Sri Lanka plant, an 80% corn/20% soybean mixture and an 85% corn/15% soybean mixture were being processed. Cooking was being accomplished at indicated temperatures of 350-360°F. During 16 hours, more or less, of observed operation, the Brady machine performed satisfactorily

and no significant operator error was observed. The operators were attentive to the process needs. The Mission members deemed the product being made to be slightly undercooked by reason of observable routine inclusion of uncooked starch "white caps" and a recognizable raw starch taste.

Cooking Experiment. As a result of that product quality finding, the Mission instituted a water addition test. Water (3.9%) was added at the Brady feeder screw. The indicated cooking temperature was 350°F. The tested moisture gain in the finished product was 1% over the dry-cooked product, 7% versus 6%. The finished product was free of white caps and raw starch flavor. The product emerged from the extruder in longer strips, perhaps averaging 6 inches in length, and having a somewhat rubbery texture. Product thickness was satisfactorily uniform. The Mission members deemed the product to be superior to the dry-cooked product, and satisfactorily cooked, as measured by the visual and taste tests. The extruder functioned satisfactorily during the very short test--20 to 30 minutes. The test was stopped because of failure of the tube-type screw conveyor to carry the altered product away from the Brady discharge hopper. The longer product would not feed into the conveyor satisfactorily and its rubbery consistency, when hot, apparently resulted in a motor overload. The water addition was reduced gradually until the conveyor would function normally. The moisture addition level at which the conveyor would function was about 1%--a level producing no discernable improvement in the product.

Feeder-Rotor Transition. Although the Mission personnel observed no failures, the record clearly shows choke-up problems in the transition between the Brady feeder and the extruder rotor, both in Sri Lanka

and at CSU. This matter has limited processing alternatives. The transition is small in cross-sectional dimensions, and the product is dependent upon gravity for its flow through it.

Cummins Diesel Engine--Cooker Power Source--

A Model V504-210P Cummins diesel engine supplies power for the Brady cooker. The engine is rated at 210 hp at 3300 rpm maximum and 163 hp at 2250 rpm operating speed. We calculated crudely (in the absence of a power curve for the unit) that it delivers in the range of 124 to 143 hp at the operating rate used--1950 rpm. The governor effect of the variable fuel injection system holds the engine speed very close to the 1950 rpm setting. Adjustments to a varying load are quite rapid. This makes a valuable contribution to uniform cooker performance. In so adjusting to a varying load, the enginer applies an unknown increase in torque to the drive train.

The Brady cooker was designed to operate with up to 90 hp applied at 540 rpm. With higher horsepower application, the manufacturer recommends that the Brady be operated at 1000 rpm PTO speed. With the Cummins operating at 1950 rpm and the cooker at about 504 rpm the governor effect of the diesel fuel injection system probably results in periodic torque loading well above the recommended level and probably quite well above the design capacity of the drive train components. The record shows numerous drive train failures in the shear plate, universal joints, splined couplings, and enginer clutch.

Dorsey-McComb Cooler--

This unit is a rotary, inclined cylinder with internal flights that lift the product and drop it through an air stream. The flow of air

passes in the same direction as the product. Measurements were taken to determine the cooling effect of this unit, with findings as follows:

	Test March 8	Test March 9 (3.9% water to Brady)
Product inlet temperature	60°C	58°C
Product outlet temperature	50°C	48°C
Reduction	10°C	10°C

Prater G6HS Hammer Mill--

This is a standard 15 hp swinging hammer mill. The unit is discharged by a screw conveyor. The grinding chamber is exhausted by a low volume suction system. This machine is used to grind the product to its final granulation.

The record shows three matters of interest with respect to operation of this unit:

1. On one occasion tramp metal, originating in the Brady cooker, entered the grinding chamber, causing damage.
2. The exhaust air system has not proven to be adequate to keep the screen from blinding under all formulations, particularly those containing high oil or surface oil additions. System stoppages have infrequently occurred from screen blinding.
3. The low volume air system has a low cooling effect in the grinding chamber, and on the product. Approximately 15 hp is being dissipated in product grinding. Approximately 38,000 BTU of heat per hour must be removed from the hammer mill by the air system, by convection from the machine and motor surfaces, and <u>by the product</u>.

Auxiliary Conveyors--

All of the processing area conveyors for both vertical and horizontal movement are intermittent-duty, pipe enclosed, farm-type screw conveyors. They are consistent with the low investment cost concept.

Magnetic Separators--

The Modern Mill has built-in magnetic separators that appear to be quite adequate and functional.

There is a bar magnet available which may be attached to the underside of the round spout leading to the Brady cooker. It was not in use.

The Prater hammer mill has a magnetic separator; however, its effectiveness is questionable. There is a record of "tramp" metal having passed over it, causing machine damage.

There is no magnetic protection immediately preceding the finished product packer.

Packer--

The Schule packer installed is an automatic scale packer. It appears to be quite suitable for the application.

Bags--

Polyethylene lined jute bags, 100 pounds net weight, are used for packing the finished product. The poly liner is sealed on a Sargeant heat sealer. The jute bag is hand sewn with cotton twine. This package appears to be quite adequate for product protection.

Two tests, on consecutive days during our visit, showed the product temperature in the bag to be 44°C. The record shows other readings in the past, indicating temperatures were in the range of 55-65°C.

Plant Production Results--

A study of the production records for October through the first six production days in March showed the data presented in Table 1. The nominal raw material input rate was 1000 pounds per hour.

Material Balance - Product Yields--

By researching the CARE files, an approximate, useful material balance and finished product yield could be determined (Table 2). At present, data is not collected or collated with which to do so. An effort was made to determine the "process" yield (excluding grain cleaning). The daily production forms do show the production in bags, and a calculated input based on the Modern Mill calibration checks. All shift reports did not contain the data. Very short time calibration checks, multiplied by operating time, will produce indicative data only.

C. Plant Maintenance

Table 1 shows that of 111 available production days, 50 days (45%) were lost production days. Of those production days lost, 48 days were recorded as having been lost due to maintenance related matters. This represents 96% of the days lost and 43% of the available production days.

Furthermore, while statistical presentation of the recorded reasons for low production on days operated was deemed inappropriate for lack of specificity, examination of the daily reports, coupled with discussions with the operators, clearly indicated that an unknown high percentage of the reasons for low production and stoppages were maintenance related. For example, a notation such as "Brady failure" on an operating report,

Table 1. Production Data for the Sri Lanka Plant from October, 1976, to March, 1977.

Month	Available prod. days	Days down	Days worked	Total pounds produced	Average system output lbs/hour/ 16 hr day
Oct 76	22	10	12	82,800	431
Nov 76	22	11	11	98,100	557
Dec 76	22	10	12	136,300	710
Jan 77	19	4	5	48,500	606
Feb 77	20	5	15	165,100	688
Mar 77	6	0	6	85,000	885
TOTAL	111	50	61	615,800	631

Down days - 45% of available days

Oct - 10 days - 8 repairing or obtaining parts; spares not on hand

2 Tribelhorn testing new formulas

Nov - 11 days - Repairing or waiting for parts; spares not on hand

Dec - 10 days - Repairing or waiting for parts; spares not on hand

Jan - 14 days - Waiting for parts; no spares on hand. Used down time to repair and rearrange other equipment.

Feb - 5 days - Securing parts; spares not on hand.

Table 2. Indicated Process Yield, February 1977*

Date	Shift	Pounds finished product	Pounds feed-in	Pounds gain or loss	Percentage gain or loss
2/ 1	1	700	881	- 181	-20.5
	2	6,700	7,800	-1,100	-14.1
2/ 2	1	6,800	7,800	-1,000	-12.8
	2	4,300	4,643	- 343	- 7.4
2/ 4	1	6,000	7,029	-1,029	-14.6
	2	7,400	8,058	- 658	- 8.2
2/ 7	1	3,000	3,128	- 128	- 4.1
2/ 8	1	700	915	- 215	-23.5
	2	7,500	8,761	-1,261	-14.4
2/ 9	1	6,200	7,362	-1,162	-15.8
	2	4,600	4,727	- 127	- 2.7
2/10	1	1,500	1,892	- 392	-20.7
	2	7,200	8,622	-1,422	-16.5
2/21	1	5,200	5,865	- 665	-11.3
	2	4,000	4,187	- 187	- 4.5
2/22	1	5,100	5,417	- 317	- 5.9
	2	7,800	8,401	- 601	- 7.2
2/23	1	7,600	7,734	- 134	- 1.7
	2	8,000	8,023	- 23	- 0.3
2/24	2	7,600	7,408	+ 192	+ 2.6
2/25	2	8,200	8,255	- 55	- 0.7
2/26	2	8,100	8,636	- 536	- 6.2
2/27	2	4,300	4,474	- 174	- 3.9
2/28	2	8,700	9,241	- 541	- 5.9
3/ 1	1	6,700	7,833	-1,133	-14.5
Total		143,900	157,092	13,192	
Yield			91.6%		
Loss				8.4%	

*Excludes shifts for which no data was provided on the shift reports.

if traced to its source, would frequently prove to be a failure in maintenance procedure, maintenance materials, or use of improper tools.

Observations from one maintenance incident will serve to illustrate the team's impression of plant maintenance performance. The incident started with a routine shutdown for lubrication and a check of the extruder cone bolts for tightness. One cone bolt broke at 40 ft-lbs of applied torque, well below the expected capacity of the bolt. During the shutdown period, the Mission members observed:

1. Improper tools in use - 7 instances,
2. Nonstandard parts in use - 3 instances,
3. Needed parts missing from the machine - 2 instances,
4. Damaged parts in use - 5 instances,
5. Improper repair machine work - 2 instances,
6. Improper maintenance procedures - 7 instances.

Each of these 26 observations were of a nature that would either result in, or materially increase the likelihood of, an unscheduled breakdown repair situation. Each of these instances will result in longer time loss for accomplishment of maintenance, with resultant production and maintenance cost penalties.

Table 1 clearly illustrates the production losses that have accrued due to parts shortages.

The spare parts stock room, its inventory and the inventory control methods in use were investigated. The observations of the Mission members were:

1. An effective inventory control system for spare parts, which recognizes usage experience, delivery lead time, and inventory reorder levels, does not exist. Orders are placed for

quantities of some parts, requiring fairly routine replacement, beyond the immediate need.

2. The parts inventory is not properly stored and inventoried. The same part was observed in several locations, some of which would require considerable search and time to find.
3. Damaged, worthless parts were observed in the storeroom.
4. Damaged, repairable parts were observed in the storeroom, in their damaged state, instead of repaired and ready for reuse.
5. There was dirt and trash on and about the inventory.

Two preventive maintenance measures are known to be routinely scheduled during down time:

1. The Brady Crop Cooker is scheduled to be lubricated at not more that five-hour operating intervals.
2. Cooker cone bolts <u>are scheduled</u> to be checked for tightness at the same time.

Briefings and literature supplied to the team indicate that these general maintenance problems have existed from the start of operations. There is evidence that the CSU personnel have recognized problems in this area, and took corrective measures in training, tool supply, and recommended improvements in inventory control. It is reported that some of the people trained have left the operation, and their places filled with untrained people. At present, the problems persist.

D. <u>Plant Environment - Employee Safety</u>

In general the plant is a safe and reasonably comfortable place in which to work. The following observations are worthy of note:

1. A severe accident hazard and practice exists in the Brady cooker feed hopper. Choke-ups occur in the feeder-rotor transition. The Brady operators visually monitor the feeder operation to avoid choke-ups at that point. Product builds up along a line parallel to the feeder auger. Employees were routinely observed pushing such accumulations of material into the feed auger with their hands. Severe finger lacerations and amputations are a probability if the practice continues. One severe laceration has occurred.
2. A similar condition exists in the Brady discharge hopper. Brady operators monitoring the discharge conveyor were seen to push product from the hopper into the discharge screw conveyor with their hands. Continuation of this practice will surely result in severe lacerations and amputations.
3. Containers of gasoline, used for parts cleaning, were observed open to the atmosphere in the parts store room. This practice constitutes a severe fire and explosion hazard.
4. Employees monitoring the Brady cooker are exposed to temperatures well above ambient conditions. The principal sources of the elevated temperatures are the cooker and the diesel engine. Humidity is also increased by water vapor released in the cooking process. During the Mission's visit to Kundesale, these conditions were judged to represent an uncomfortable working environment, but not an oppressive situation. Because of these conditions the employees did not wear the uniforms provided for them.

5. Noise levels in the area of the diesel engine and the Brady cooker are high. Decibel ratings in that area are not known to the team. It was observed that some employees in that area were wearing ear plugs to reduce sound levels. Neighbors of the plant have complained about noise from the plant. It was the team's observation that the diesel engine contributes most of the potentially troublesome noise.
6. Dust in the atmosphere is under reasonable control.

E. Sanitation - Foreign Matter

The following conditions were observed:

1. One lot of infested corn containing live infestations has been rejected for use, and resold.
2. One lot of corn entering the cleaning system had been infested, as determined by observations of webbing, cast skins, and frass. There was no live infestation observed in that lot. The Paddy Marketing Board fumigation practice had apparently killed all observable insect forms. The cleaning system effectively removed visual evidence of prior infestation of that lot.
3. Live stored grain insects were observed on the outside of bags in the CPF inventory.
4. Insect webbing, live insects, and dirt-creating insect harborages were observed in the whole grain storage and rice mill areas of the Cereal Products Factory.
5. The processing area was free of insect infestation as observed by the team members.

6. The entire plant interior was free of evidence of rodent and bird contamination; however, the grain storage and rice mill section is open and subject to such infestations. The processing building is capable of excluding these pests. Rodent burrows were noted around the plant periphery.
7. Cats and dogs, potential sources of contamination, were observed in both areas of the plant.
8. The process equipment generally is well enclosed preventing extraneous matter from entering the product flow. Two locations--the Brady feed hopper and the Brady discharge hopper--are presently open to permit constant monitoring of the machine by its operators. These locations present significant risks of foreign matter entry to the product.

It is reported that the Paddy Marketing Board has adopted a fumigation program in which grain is fumigated with Phostoxin (phosgene gas), under tarpaulins, three times during the first month after it is received in the warehouses, and every 28 days thereafter.

An organized comprehensive sanitation and pest control program does not presently exist in the Kundesale plant.

F. The Product - Quality Control

Based upon the record and the team's interviews, all of the product manufactured at Kundesale has been quite acceptable as a palatable, nutritious food. There is no record of consumer complaints or product rejections due to quality deficiencies. Formulation changes have not measurably detracted from the product's acceptability. The product does contain the full fiber of the grain bran coats.

Quality control standards are contained in the volume, "Thriposha Quality Control Manual - Sri Lanka," 1976 (Ref. III.A.6.j.) and will not be repeated in detail herein. Table 3 contains a summary of recorded process control data compared to Manual standards for the period November 1 - December 21, 1976. It will be noted that product manufactured was consistently out of the Manual acceptability range in consistometer measurement and particle size during the period studied. Product density and moisture levels recorded were generally within the Manual acceptability range. Extrapolation of the moisture data quoted indicates a mean moisture loss of 7.3% in processing during the period.

An Ohaus Moisture Meter is used in the CPF plant for process control. A calibration test showed the following result:

	CPF Ohaus Meter (% moisture)	Agricultural Research Farm Moisture Oven (% moisture)
Ground grain mix	12.0	10.91
Finished product	6.0	4.96

Table 4 illustrates "outside" laboratory test results on Kundesale product for the period of October 15 - December 27 1976.

The standards for Kundesale production are quoted as "proximate" analysis. "Proximate" is not defined. Standard proximate range standards are quoted. The moisture basis for proximate standards is not quoted; i.e., dry basis, 14% moisture basis, as is, etc.

The data contained in Table 4 is not summarized and compared with the standards for two reasons:

1. There are quoted standards for only one of the formulae tested.

Table 3. Finished Product Process Control Test Summary, Kundesale Plant (November 1- December 21, 1976)

Parameters	Bulk Density, g/cc	Consistometer Measurement, inches	Particle Size % On 30 W	Particle Size % On 60 W	Particle Size % Pan	Flour Moisture, %	Grain Moisture %
Dates: 11/1-11/16-76							
Formula: 76% corn, 19% navy beans, 5% coconut oil							
Standard	0.60	7.5	8.0	75.0	17.0	<8.0	12.0
Standard range	0.55-0.65	7.0-8.0	4.0-10.0	60.0-85.0	12.0-22.0	4.0-8.0	8.0-14.0
No. of tests	46	46	46	46	46	46	46
Mean result	0.59	6.08	12.26	55.83	31.93	5.54	12.83
Actual range	0.529-0.626	5.1-7.0	5.0-22.0	14.0-76.0	15.0-68.0	5.0-6.0	12.0-14.0
No. of samples out of standard	5	42	26	24	29	0	0
Percentage of samples out of standard	11	91	57	52	63	0	0
Dates: 11/17-12/15/76							
Formula: Sorghum and soybeans							
Standard	0.60	5.0	12.0	30.0	57.0	<8.0	10.0
Standard range	0.55-0.65	4.75-5.25	10.0-15.0	25.0-36.0	48.0-60.0	4.8-8.0	8.0-14.0
No. of tests	8	8	8	8	8	8	8
Mean result	0.611	4.7	8.75	44.13	47.13	5.13	13
Actual range	0.598-0.622	4.5-5.0	4.0-11.0	40.0-59.0	33.0-50.0	5.0-6.0	(all 13)
No. of samples out of standard	0	4	4	8	8	0	0
Percentage of samples out of standard	0	50	50	100	100	0	0
Dates: 12/16-21/76							
Formula: Sorghum, cooked corn and soybeans							
*Standard	0.60	5.0	12.0	30.0	57.0	<8.0	10.0
Standard range	0.55-0.65	4.75-5.25	10.0-15.0	25.0-36.0	48.0-60.0	4.0-8.0	8.0-14.0
No. of tests	31	31	31	31	31	31	31
Mean result	0.604	4.83	8.13	52.68	39.19	5.32	12.52
Actual range	0.555-0.630	4.5-5.5	1-18	42-71	22-45	5.0-6.0	12-13
No. of samples out of standard	0	12	22	31	31	0	0
Percentage of samples out of standard	0	39	71	100	100	0	0
Calculated processing moisture loss		7.31%					

*A special set of standards for the sorghum-cooked corn-soybean formula used is not included in the "Quality Control Manual." The standards shown are the "Manual" standards for 95% cereal-5% soybean formulations.

Table 4. Kundesale Product Outside Laboratory Tests (by Medical Research Institute, October 15-December 27, 1976)

Quality Control Manual Formulae	Standard Range: Flour Moisture, %	Protein, %*	Ash,%	Fat, %	Fiber, %	Calories/100 g	Plate Count
95% cereal-5% soybean	4-8	9.0-11	0.8-1.2	2.3- 2.7	0.8-1.2	370-400	0.0-10,000
80% corn-20% soybean	4-8	11.0-13	0.9-1.1	6.0-10.0	2.5-3.0	360-400	0.0-10,000
76% corn-19% navy bean-5% coconut oil	4-8	9.5-11	1.5-1.85	8.0- 8.8	1.5-2.7	350-400	0.0-10,000

Medical Research Institute Findings (duplicate samples)

Formula	Date	Flour Moisture**		Protein, %		Ash, %**		Fat, %**		Fiber, %**	Calories/100 g**		Plate Count**	
76% corn-19% navy bean-5% coconut oil	10/15/76	NA		11.0	11.4	2.0	2.2	4.2	4.5	NA	385	386	985	1,028
	10/26/76	"		12.1	12.4	3.2	NA	4.0	NA	"	378	NA	1,010	NA
	10/27/76	"		10.9	11.7	1.75	3.8	2.5	7.0	"	376	408	1,805	1,850
	11/ 1/76	"		10.9	11.6	1.3	1.6	3.5	8.0	"	320	416	1,175	1,250
	11/ 2/76	"		11.1	11.6	2.1	5.2	3.0	5.0	"	386	NA	990	NA
	11/ 3/76	"		10.6	10.9	1.6	2.6	4.1	6.5	"	375	395	1,430	1,500
	11/11/76	"		9.5	10.0	1.8	2.2	4.0	6.2	"	381	389	1,300	1,320
	11/12/76	"		12.0	12.4	1.6	2.0	5.2	6.2	"	386	NA	1,500	1,560
66% sorghum-15% corn-19% soybeans	12/16/76	4.3	4.9	12.0	13.1	NA	NA	3.7	4.5	"	401	420	NA	NA
	12/20/76	3.6	4.5	12.1	14.9	NA	NA	5.0	7.2	"	388	432	NA	NA
80% sorghum-20% sobyeans	11/17/76	NA	NA	14.5	15.2	2.0	2.3	1.5	2.1	"	376	NA	535	1,400
	12/22/76	3.5	4.8	8.7	13.0	NA	NA	0.9	5.8	"	378	397	NA	NA
	12/27/76	5.0	5.2	12.4	12.6	NA	NA	2.8	4.2	"	369	425	NA	NA

*Protein % = N x 6.25

**NA = not available

2. There are wide differences in the results quoted for duplicate samples in some tests, raising a question as to the adequacy of the test procedures.

Comparison of the results from duplicate samples shows reasonable agreement for calories and plate count. In varying degrees, the results shown for moisture, protein, ash, and fat on duplicate samples deviate significantly from expected replication results. There was no record found of fiber tests on the Kundesale product.

The Quality Control Manual specifies the Kjeldahl method of measuring protein content, and sets standards based upon multiplication of the nitrogen content derived therefrom, by a factor of 6.25.

The plate counts reported have been entirely free of the dangerous, illness-related species of bacteria.

It is noted in Table 3 that the product made at Kundesale is well cooked, as measured by the consistometer tests, when compared to the consistometer standards. The Mission members did observe during their 16 hours observation of Kundesale production:

1. Inclusion of "whitecaps" in the cooked product, defined by the team as ungelatinized (undercooked) particles of corn starchy endosperm.
2. Inclusion in the cooked product of large yellow particles of corn horny endosperm which appear to be undercooked. It is believed that this finding was caused, or aggravated, by a worn hammer mill screen in the Modern Mill.
3. By taste, the team members noted a slight raw starch flavor indicative of the presence of some ungelatinized starch.

4. In a short test (Ref. IV.B. Cooking Experiment), 3.9% water was added at the Brady cooker. The product made during that test was free of "whitecaps" and the flavor of raw starch. The larger particles of yellow, horny endosperm remained in evidence. The moisture addition in the finished product was 1-7% versus 6%, a result within specifications.

In closing this section on finished product quality, it should be emphasized that all observations of the team indicate that a satisfactory, nutritious, palatable food product has been made at Kundesale.

G. Technical Assistance and Training

It appears to the Mission personnel that the technical assistance given to CARE/Sri Lanka for design, installation and process know-how was satisfactory and adequate, within the planned scope of the operation. Plant design, equipment procurement, and the equipment installations were expeditiously handled. The process operators were attentive to the equipment, and were in control of the process during the operating time observed by the team.

As presently constituted, maintenance training and competence is quite inadequate. We understand that there has been personnel turnover, resulting in the loss of trained men. We do not know what the result might have been if these people had remained in the operation. It is our observation that the current state of maintenance performance is intolerable--that the plant operation will continue to be buffeted by costly stoppages and expensive, unnecessary machine damage until the plant has competent mechanics, proper tools, an adequate parts inventory, and a maintenance plan with which to maintain the plant. Our

conferees have stated a belief to us that capable auto mechanics could be found in Sri Lanka to serve as supervisors and mechanics, requiring modest training time to transfer their skills to the LEC system.

H. Management Control - Costs and Operating Expense

Up to this time, management of the Sri Lanka plant development and operation has been a multi-faceted cooperative venture involving, in some measure, all of the following agencies:

1. USAID
2. USDA
3. CSU
4. CARE/New York
5. CARE/Sri Lanka
6. CPF
7. Sri Lanka Ministry of Planning and Economic Affairs
8. Sri Lanka Ministry of Health
9. Sri Lanka Paddy Marketing Board
10. Lesser contributions from other agencies.

There has been no accumulation of the total costs and expenses of these agencies in support of the project. The Mission team did not attempt to do so, and considered it redundant to make the effort. Nevertheless, it is perhaps pertinent to remark that the interest displayed by these agencies, with both their financial and physical support of the effort, is indicative of the potential value of the process in LDC's.

Operation of the Kundesale plant has been under Cereal Products Factory management. Cereal Products Factory provides:

1. Plant management
2. Labor
3. Buildings and rice mill for grain cleaning
4. Diesel fuel
5. Electric power
6. Minor repair services.

For those materials and services, CPF is paid Rupees 0.03 per pound of finished product. In addition, CPF is paid Rupees 0.03 per pound of finished product for truck delivery of the finished product from Kundesale to Colombo.

During the time that sorghum and corn were decorticated on the rice mill, the offal from that operation was retained by CPF for sale as animal feed for the account of CPF. As presently operated, according to CPF management, refuse from the cleaning operation averages 2-3%, is worthless for animal feed, and is disposed of as trash, without financial benefit.

The agreement between CPF and CARE/Sri Lanka is verbal, contains no clear cut expiration date, and it is reported to have resulted from an unsuccessful effort to attain a written contract. Neither party is satisfied with the results of the agreement.

Clear cut delineation of the costs incurred by CPF solely for the benefit of the LEC was not attainable; therefore, the Mission effort with CPF management was to delineate a pro forma expense estimate for an independent LEC operation, based upon the CPF experience. Because the data is an estimate and because such compiled, pro forma estimates require assumptions, the results of these investigations are included in Section V, Analysis of the Observations, in order to save repetition.

In addition to maintenance costs forming a part of the CPF charge for production services, the following costs chargeable as maintenance expense are reported:

CARE/Sri Lanka - Rupees 15,922.2

CSU - U. S. $9,061.53

(Official rate of exchange during this 1976-1977 time period, U. S. $1 = R. 8.72).

The Mission considers these operating expense items to be indicative rather than definitive. They were extracted from lists of expenditures containing capital items and expense items. The Mission made allocations between capital and expense.

At the present time an integrated internal management control accounting system does not exist for the LEC system. Management does not have the accumulated information and ratio analysis available with which to manage the operation as a business enterprise.

V. ANALYSIS OF THE OBSERVATIONS

A. General Findings

In general, in the successful effort to produce a low investment cost LEC system, light-weight intermittent-duty equipment was selected. In practice, the benefits of having selected heavier, continuous-duty industrial equipment have been sought after. While these goals are in opposition, the degree of opposition is small, in terms of investment cost, in the judgement of the Mission. It is the judgement of the Mission that a most worthwhile, low-cost extruder cooking method has been identified.

In general, it is the judgement of the Mission that the applied research devoted to the project has in fact produced an intermittent-duty system, capable of producing a predictable quantity of satisfactory product in unit time, when adequately managed, operated, and maintained.

It is the judgement of the Mission, based upon long experience in such matters, that the transitional phase of process development between research and operations, sometimes (and herein) called the "pilot plant" stage of development, has not been accomplished. This is the phase in process development where equipment is "debugged" and operating parameters are established, resulting in a reliable system. This is preferably accomplished in a low-capacity plant on which there is no pressure for finished product distribution to interfere with development effort. People skilled in engineering and food technology usually direct such effort.

It is within the framework of these general assessments, and with the original concept goals of low-cost plant and expense in mind, that the following more detailed appraisals of our observations are offered.

B. Raw Materials - Formulation

Experience at Kundesale has demonstrated the inherent capability of the system to manufacture an acceptable product using a fairly wide ranging formulary. Study of the results at Kundesale indicate that suitable formulations meeting nutrition standards could be processed into an entirely satisfactory foodstuff from the usual indigenous cereals, pulses, and vegetable oils found in LDC's.

Williamson (Ref. III.B.3.) estimated capacities of the Brady cooker at constant energy input and constant speed using formulations in descending order of fat content. As fat content is lowered, estimated capacity is lower and required cooking temperatures are higher. Interpreting those estimates to the Kundesale experience, in which the feed rate has been kept constant at 1000 pounds per hour and the speed constant at 504 rpm, energy input and machine stress should be higher as fat content decreases.

As hereinbefore stated, the precise reasons for down time and lost production cannot be accurately ascertained from the record. Study of the record does tend to validate the Williamson theorem--as fat content in the formula goes down, plugging of the Brady cooker and breakage of machine parts (due to automatic energy input increases) tend to increase. Study of the data available indicates that this result begins to accrue when the fat content of the formula drops below about 5-6%.

Appraisal of the production records indicates that no discernable increase in lost time that might be attributable to formulation has been incurred from formulations that contained 80-85% cereals and 15-20% soybeans.

The record indicates that fairly radical changes in formulation have caused problems with plugging in the Brady cooker. The Brady cooker is relatively sensitive to changes in its operating conditions. Part of the problem undoubtedly arose from the relative inexperience of the operators with the machine. Two proven methods of reducing the risk of stoppage due to formula changes are:

1. Change the formula over a period of several days, reducing the old ingredients by 10-20% and adding the new in similar amounts. Obviously the transitional formulae must be kept in nutritional balance.
2. Establish a file of operating parameters for all formulae used, clearly describing the operating conditions found to be best for it. Over a period of time such a file will permit acceptance of formula change without the risk of production losses when the same or closely similar formulations are to be processed.

Formulations presently in use at Kundesale contain the bran coat and germ--the entire fiber content of the whole cleaned grain. Clearly expert medical and nutrition consultants should consider and specify the level of such fiber acceptable for the intended use of the end product. If reductions in bran and germ fiber are necessary, decorticating equipment must be added to the plant flow diagram. The level of fiber content approved and the specific cereals to be used will determine the kind of equipment employed. For example, in an LDC where barley is to be used, barley pearlers will be the preferred device, but they will not decorticate corn economically. In an LDC where a wide range of cereals

and pulses will be used, more than one method of decortication may be required for economic utilization.

The Mission members are quite well satisfied that proper pilot plant investigation of cooking conditions discussed before (Ref. II.B.2-5) would result in greater formulation latitude with benefit to the product, plant production, and the economy of the operation. These conditions are:

1. granulation reduction,
2. moisture addition,
3. heat addition,
4. fat content,
5. [illegible]ine speed.

C. The Plant and Its Process

Without a question of doubt, the people who conceived, designed and installed the Sri Lanka processing system have succeeded in attaining a low investment cost extrusion cooking process. The installed cost of about U.S. $50,000 in Sri Lanka is far below the cost of conventional cereal cooking and extruding processes. It is unlikely that a continuous system of the same capacity, using conventional food processing equipment, could be installed in a LDC with the most stringent design criteria for less than $250,000. Some of the better systems would exceed $1,000,000 in installed investment cost. Based upon 1976 pricing, the time of the Sri Lanka installation, the addition of cleaning, and probably decorticating equipment, would still have resulted in an investment cost well below the $100,000 goal established at that time.

The basic questions to be explored in this subsection of the report are the suitability of the system--its equipment and flow diagram--for the intended result. In considerable measure, the correct analysis of the observations would depend upon the needs and goals of the LDC with respect to production requirements and required reliability of supply. Engineering economy (cost-benefit) analysis is the proper way to determine the benefits available through incremental additions to the plant investment. That analysis is beyond the scope of the work assigned.

The major choices, or alternatives, for future design and development activity for new installations appear to be:

1. Shall the system be an intermittent duty, short-lived facility, with a relatively low reliability factor?
2. Shall the system be a continuous duty, longer-lived facility, with a relatively high reliability factor?

"Life," as used herein, is interpreted to mean the weight of material of like kind that may be processed through a machine without replacement, or major overhaul equivalent thereto.

"Intermittent duty," as used herein, is interpreted to mean a piece of equipment that is built of light-weight materials and components, having either a requirement for "shutdown" maintenance, or a reliability factor of less than 99% over a 120 hour weekly continuous production schedule, when properly operated and maintained.

"Continuous duty," as used herein, is interpreted to mean a piece of equipment built of heavier weight materials and components, having no requirements for "shutdown" maintenance and a reliability factor of 99%

or better over a 120-hour weekly continuous production schedule, when properly operated and maintained.

"Reliability factor," as used herein, is intended to mean the percentage of the operating time scheduled that a machine or system can be depended upon to perform its function when properly operated and maintained.

Most commercially operated cereal grain processing equipment will meet that "continuous duty" definition and do so with a "life" expectancy of 15 to 40 years, in the absence of obsolescence.

"System reliability," as used herein, is a compounded factor, representing the net effect to production of operating a group of machines, all essential to production, and each having a stated "reliability factor."

System reliability is high in established, commercial, continuous cereal grain processing systems. Perhaps the norm is 98-99.5% over extended time. As experienced operators, the Mission members would expect to attain such results. In such well established situations, failure to attain actual performance approximating these levels may usually be traced to human failures--either operator error or an inadequate maintenance program. Attainment of that level of system reliability is usually accomplished by one or more of the following actions:

1. Replacement of an undependable machine with one with a high reliability factor.
2. Debugging--replacement or alteration of machine components causing failures.
3. Addition of standby machines, thus permitting the system to operate while a failed machine is repaired. This is usually a "last resort" alternative.

Attainment of such performance levels is accomplished, typically, because the economic rate of return is high enough to make it pay to do so.

It is with these general criteria in mind that the observed equipment, process and operating results are interpreted.

Cleaning--

The cleaning equipment at Kundesale, an existing rice mill, is not, and was not thought to be, an entirely proper system for widespread use for LEC's in LDC's. It is doing an entirely acceptable cleaning job; however, it is not designed for the purpose, and purchase of a rice mill for cleaning in new LDC locations would not be cost effective.

The minimal equipment required to clean properly harvested and stored grains would be:

1. A milling separator supplied with interchangeable screens of the proper dimensions to clean the various grains to be used in the LEC.
2. A gravity stoner used to remove heavy material of about the same dimensions as the grain.

Grain in LDC's is <u>not</u> dependably harvested and stored properly. Lots containing as much as 35% foreign matter have been observed elsewhere, and in that country very high foreign matter content was the rule. One passage through the minimal equipment will not suffice to clean such grain. Consideration of the grain quality to be handled should be a requirement for the designers of LEC systems. If very dirty grain must be handled, three additions are indicated for a minimal system:

1. Facilities to permit recleaning (recycling). Usually a bin, and possibly a conveyor and/or a bucket elevator would suffice.
2. The capacities of the cleaning equipment would have to be higher, as much as 100% higher, in order to service processing.
3. A steel or carborundum scourer, having adjustment capabilities to properly scour the various grains to be processed, without kernel breakage, should be added. Such a machine would be quite a desirable addition to the bare minimal system and this report would include it in that category if bare minimum investment cost is not a design constraint.

The capacity of the cleaning system should exceed the capacity of the process system by at least 20% to provide "catch up" capacity after changing lots, adjusting machines, and minor flow stoppage for any reason. This is considered by most knowledgeable people to be standard practice in grain cleaning systems preceding processing, in order to insure a supply meeting process requirements.

Scale Weights--

Grain will represent the major product cost item in most, if not all, LEC products in LDC's. As such, it is incumbent upon management to control its use, and losses from it. Typically that control is on an operating basis. It is usually exercised in two ways:

1. By taking scale weights of grain fed into the system, scale weights of cleaned grain, and scale weights of offal removed from the grain.
2. By supervisory inspection of both the cleaned grain and of the offal. This matter will be discussed in the later subsection having to do with process control.

Although proximate data could be extracted from the files, present methods do not result in timely, shift-by-shift evaluation of grain cleaning efficiency.

For economic control of operating results in new installations, scale weights of dirty grain as received, as fed in, and clean grain passing to the process should be a requisite. A scale for offal is quite helpful to the operators, but is not essential to a small capacity, low-cost system as long as the needed information can be obtained by subtraction. The choice of scale types to be used is not critical as long as they produce accurate weights. Automatic scales are the usual choice for continuous flow measurements.

Decortication--

If competent medical and nutrition authority requires finished product fiber levels below whole grain levels, then decortication equipment will be required in the process flow diagram. The degree of fiber reduction required will tend to determine machine selection. The grains to be processed will also control machine selection.

For grains with skin-like bran coats, such as corn and sorghum, significant reductions in fiber may be attained with small combination corn cutter/separator machines common to the animal feed industry. A small enclosed rotary sifter would be expected to be a paying addition for the reclamation of fine broken endosperm from the offal. Maximum reduction in fiber from such grains would require "degermination" equipment.

Grains with tightly adhering bran coats such as barley, wheat and milled brown rice require pearlers. The machines of choice are usually

carborundum pearlers, and the machine design should have sufficient adjustment latitude to handle any of the grains to be used. Pearlers may also be considered for sorghum and the millets of Africa and the Middle East. They are not likely to process corn satisfactorily without excessive losses to the offal, which could only be reclaimed with a more extensive system than the LEC concept would embrace.

Bins - Process Supply--

The type of the bins used in Sri Lanka should prove to be entirely satisfactory for use in new installations.

The dead space under the conveyor discharge conveyors should be eliminated in new installations.

Better design for new installations would provide a transition fitting from the bin bottom to the conveyor feed zone with sufficient pitch that the entire bin content would discharge by gravity. Even better design, and recommended for consideration, would be to mount the bins on a framework above the proportioning equipment, discharge them by gravity, and eliminate the existing discharge screw conveyors from the flow diagram.

Modern Mill - Proportioning and Grinding--

The Modern Mill has been an infrequent source of breakdown problems, although there have been some maintenance stoppages. It appears to do a satisfactory job of proportioning and grinding ingredients. Because it is of light-weight construction it is not likely to meet the criteria for continuous-duty service. It presently shows deterioration of some of its light-weight components. In continuous duty, its life will be be short--we estimate about five years.

For new installations, it is suggested that design consideration be given to long available, proven, continuous-duty proportioning and grinding equipment. The flow diagram could include:

1. Bins and ingredient hoppers mounted on a framework, gravity discharge to feeders.
2. Volumetric feeders mounted under the bins and hoppers, gravity discharge to hammer mill. Draver-type feeders would be suitable for grains; Novadelox type should prove to be suitable for enrichment concentrates, if needed.
3. A conventional, continuous-duty, swinging-hammer hammer mill equipped with a magnetic separator and an elevating fan system. If enrichment concentrates of very fine granulation are to be added, design consideration has to be given to the ability of the cyclone collector, furnished with such mills, to separate all of the micronutrients from the air stream. If that should prove to be a constraint, the enrichment concentrate feeder may be located so as to enter the flow after the dust collector.

The Brady Cooker--

This machine is doing a good job of cooking at present and is capable of doing a better job with pilot plant development of process parameters and machine debugging. The machine was designed for intermittent duty only, with one processing material (soybeans) in mind. It is a unique, innovative device, and those who recognized its potential for low-cost cereal cooking are entitled to commendation.

Said simply, if continuous-duty performance, as defined herein, or a reasonably high percentage of that standard, is wanted from that

machine, it is the judgement of the Mission members that a modest investment in pilot plant effort will be required. Koehring, the manufacturer, is not likely to be willing to undertake that work.

The apparent mechanical (debugging) work that needs to be done on the Brady cooker to attain continuous-duty performance includes:

1. Elimination of the long drive train and its universal joints. Close couple the machine to its power source.
2. Redesign the feeding device, and the transition between it and the rotor, so that these components will tolerate a much wider range of raw materials and operating conditions, at least equivalent to the parameters established by the process development next discussed. Replace the hydraulic motor, driving the feeder, with either a mechanical or electrical variable speed drive.
3. Design and install a lubrication method that will permit lubrication of all components requiring lubrication while the machine is in operation.
4. Design and install a discharge hopper and conveyor system which will dependably remove the hot Brady product produced under any parameter resulting from the process development next discussed.

It is the judgement of the Mission members that the machine development needed to upgrade the Brady cooker to continuous-duty status should not be difficult for competent engineers experienced in cereal processing. While it is not the duty of the Mission to estimate the costs of this indicated development work, it is our judgement that neither the development work, nor the resulting changes to the Brady

machines should culminate in costs that violate the low-cost extrusion cooker concept, in any material sense.

The opportunities to improve the LEC operation for continuous duty by pilot plant activity in process development would be expected to result in:

1. Reduced operating stress on the Brady cooker, thus increasing its reliability factor, and reducing the operating expense of the entire operation.
2. Improved tolerance of the Brady cooker to formulation deviations, and particularly high cereal ratio formulations, thus improving the capacity of the system to produce satisfactory food from available supplies of ingredients at lower material costs--a distinct benefit to a LDC.
3. A collateral, modest improvement in the quality of the finished product resulting from more complete gelatinization of the starchy materials. For example, when processing corn, elimination of inclusions of particles of ungelatinized starchy endosperm, a material reduction and possibly elimination of inclusions of particles of yellow horny endosperm, and elimination of any raw starch flavor.

Process variables worthy of testing extensively in search of the above benefits include:

1. Granulation of the raw material fed to the cooker. The Mission members expect smaller particle size to make a contribution.
2. Water additions to the grain mixture, either uniformly imbibed (tempered) or free surface water, and possibly both are expected to contribute.

It is known that higher ingredient moisture levels have required higher energy input levels to reach a prescribed temperature indication on the Brady in experimental work. The thesis that the Mission proposes for confirmation is that superior starch gelatinization can be attained at lower temperatures in the presence of added water. In the very short-term tests observed at CSU and Kundesale, that result seemed evident.

3. The addition of heat to the raw material before cooking is expected to help. An experiment reported by Swenson and Buchele (Ref. III.B.2.) produced such a result and the Mission members concur.

4. Higher fat content ingredient mixtures would be expected to result in reduced machine stress and improved cooker reliability with consequent expense savings; however, typically there would be a countervailing increase in ingredient costs. The experimental design would be structured to indicate the optimum balance (least total cost) between these factors, for the guidance of management in LDC's who must consider nutritional balance, costs and available sources of fat in their formulation effort.

5. Combinations of process parameters are expected to result from this work that would be intended to optimize Brady cooker performance in terms of reliability and operating expense. Such indicated optimum combinations would be confirmed by extended continuous operation.

Modest investments in added equipment would be required in the pilot plant to test and develop the process as proposed. It is expected that favorable results from that development work would indicate quite modest increases in investment costs for new LEC installations in LDC's. The Mission members believe that the design and implementation of the suggested process development work would prove to be quite routine for engineers and food technologists experienced in cereal food production matters.

If the requirement in a given LDC does not include continuous, industrial duty over a long life, the Brady cooker as it is factory delivered could well serve a most useful purpose. For example, it can easily be visualized as an excellent tool for the preparation of palatable, nutritious food in almost any kind of an emergency feeding situation. The principal prerequisites to satisfactory use for intermittent duty would be well trained operators and an effective maintenance plan.

Diesel Engine - Cooker Power Source--

The team considers the Cummins engine in use at Kundesale to be suitable for continuous duty operation.

As observed, it may be responsible for the troublesome drive train failures that have occurred by reason of its capacity to compensate for increasing loads, up to a load above the Brady cooker design capacity. It is suggested that the designers of new LEC installations including such engines seek to find an appropriate indicating device with which to guide the operators, when such overload conditions occur.

In locations where dependable electric power is available at reasonable prices, substitution of a 100 hp electric motor for the diesel should prove to be a desirable alternative with respect to capital cost and maintenance expense. The power input indicator problem can be easily solved by installation of an ammeter. High torque motors should be considered.

An engineering economy analysis should provide the best basis for selection between engines and electric motors.

Dorsey-McComb Cooler--

This machine should prove to be suitable for continuous-duty operation.

The product temperature reduction, as noted by team member tests, was 10°C. A greater reduction is desirable to help insure product quality stability.

Better design would provide for the flow of air counter to the flow of the product in this machine, thus taking advantage of the psychrometric properties of air. Better cooling would result, but whether it would make a significant difference is unknown. Unavailable data would be required to calculate an expected result. Determination of the required data would be more costly than changing the air to counter flow and recording the result. It is suggested that this change may be made at Kundasale and the results determined.

Bakery machinery manufacturers would be a logical source to investigate for alternative equipment for new installations. Dryer manufacturers also produce coolers using ambient air as the coolant. Criteria for judging cooler designs for this application should logically include:

1. Thin layer, constant product exposure to the air flow.
2. 100% air passage around the product--no air bypassing the product.
3. Long product exposure time.
4. Use of high volume, low velocity air. High velocity as a means of gaining volume will result in too much fine material entering the air stream and discharging to the atmosphere.

These are dependent variables for the machine designer. All other things being approximately equal, the machine more nearly optimizing these criteria is likely to be the most efficient choice.

Attainment of close-to-ambient air temperatures would be a desirable product result. The risk of product deterioration due to high temperature is dependent on formulation, packaging, ambient storage conditions, and time in storage. The only temperature specification the Mission can suggest with those variables unknown is general--the closer to ambient air temperature, the better.

Prater Hammer Mill--

This mill is judged to be suitable for continuous duty service as it is used in the system.

Two auxiliary components require comment:

1. The magnetic separator on the machine has permitted tramp metal to pass over it, resulting in machine damage. This deserves engineering attention to assure that the existing separator has adequate strength and is properly installed. The Mission members did not see this magnet, and believed the machine to be unprotected.

2. A pneumatic pickup and elevating system would be preferable to the screw conveyor take off and minor air relief suction system that has been installed. A change to that system is recommended for future installations. The finished product will be cooler, the mill will function better, and a screw conveyor will be eliminated. Two disadvantages will probably accrue--the dust collector will probably discharge a bit more very fine dust to the atmosphere, and power consumption may increase slightly as a small net increase for the fan power requirement over the conveyor motor saved.

Conveyors--

In the judgement of the Mission members, all of the conveyors used for both conveying and elevating at Kundesale are intermittent duty units, as herein defined. They have been a frequent cause of system stoppage.

If continuous-duty performance is wanted from new installations the Mission suggests:

1. The operating records and the comments of all who have had experience with it indicate that the Cablevey is not a suitable machine for continued use. The Mission concurs. It should be replaced. The logical replacement would be a standard continuous-duty bucket elevator and screw conveyor designed with food factory sanitation in mind.
2. Suggestions contained in this section of the report can result in the elimination of four tube-type conveyors found in the Kundesale flow diagram, a desirable result.

3. A belt conveyor would be a better choice than a screw conveyor for the Brady discharge. It, too, can be low cost. For example, entirely suitable tea conveyors are available in Sri Lanka that could be readily adopted for this use at a cost of $500-$1,000 for the unit. A rotary brush would possibly be necessary on the discharge end.
4. If for any reason of plant configuration product elevations or horizontal conveyance are needed, it is suggested standard, continuous-duty bucket elevators and screw conveyors designed for food plant sanitation be considered the first choice.

Magnetic Separators--

In new installations the Mission suggests protection as follows:

1. If decortication is required, there should be an industrial-type magnet properly installed at near minimum angle, above the angle of repose of the grain, with the flow spread in a thin layer directly over the magnetic surface, and immediately before that machine in the flow.
2. Hammer mills must be adequately protected. They can become a total loss from a single instance of tramp metal passing into them. Hammer mill suppliers generally can provide entirely satisfactory built-in magnets meeting the criteria suggested in #1 above. If the Modern Mill is used in new installations, the magnets supplied with them appear to provide adequate protection.
3. The magnet available at Kundesale for protection of the Brady cooker is inadequate. The Brady should be protected as outlined in #1 above.

4. Although it is not considered by the Mission to be absolutely essential, it is suggested that a magnet be installed, such as in #1 above, immediately before the finished product packer. This magnet would be provided for consumer protection. It is particularly indicated if the end use includes infant feeding.

Packing--

Low-capacity, low-cost automatic scale packers such as the Schule in use at Kundesale are entirely satisfactory for new continuous-duty systems if large bag packaging is suitable for the distribution method planned. The packaging materials in use at Kundesale are also judged to be an excellent choice.

If consumer size packaging is the distribution mode from the LEC, two major choices are available:

1. In a great many LDC's, labor intensive packaging often provides the greatest economic return to the nation, particularly if the owner and operator is a State enterprise. For such installations, the designers may wish to consider a series of small bins mounted above a table, filled continuously from the process line. A small, adjustable volume box, with a slide top and bottom, provides a volumetric measurement of package quantity. A small test scale and sealer may be provided at each station, or one inspector may test weight the product from all stations. Unsealed packets may be placed on a belt and all sealed at one station. The product will have a tendency to separate by particle size in such bins. Inverted cones in the bin hoppers should be sufficient to produce a homogenous flow.

2. Capital intensive, automatic packaging machinery, at reasonable costs, is available in the United States. One man can operate such equipment. Triangle Package Machinery Co. is one well known supplier of such equipment.

In either case, heat sealable polyethylene, or similar films such as used in the Sri Lanka Thriposha program, would be the most likely choice for consumer size packaging.

D. Process Yield - Material Balance

Although the Mission has demonstrated lack of accuracy in the base data, it is possible to credit the cumulative data with a degree of accuracy useful in this analysis. Table 2 shows a cumulative process yield (not including cleaning losses) as follows:

Finished product process yield	91.6%
Loss in process	8.4%
Material Processed	100.0%

Table 3 shows a calculated mean moisture loss of 7.31%. The loss unaccounted for by moisture loss thus becomes:

Indicated loss in process	8.4 %
Indicated moisture loss	7.31%
Unexplained Process Loss	1.09%

In the absence of any observation that would be likely to result in a loss equal to 1%, the Mission judges the probable process yield during the time studied to have been within the range of 90-92.5%.

There are three potential sources of deviations observed:

1. Inaccurate data,
2. Cooler/hammer mill pneumatic system discharge of fines to the atmosphere,

3. The obvious potential of petty theft of materials - a common hazard in LDC's.

As hereinbefore indicated, yield data based both upon raw materials purchased, and upon raw materials processed, is essential to the economic management of a cereal processing enterprise. The basic raw material data needed for both measurements has been discussed in an earlier subsection (Ref. V.C. Scale Weights). The matter to be addressed here in the discussion is how to best measure processed quantities so as to clearly tie the process input to the process output.

Probably the best means would be to insert an automatic scale between the proportioning equipment and the Brady cooker.

Probably the lowest investment cost method, quite reasonably accurate in the long term, but injecting a minor error for shift or daily data, can be attained as follows:

Clean grain scale weights to supply bins	=	x pounds
Minus supply bin inventory as measured and compared with calibration charts	=	y pounds
Process Usage	=	2 pounds

The minor error injected comes about because of extrapolation of a volume measurement to a weight declaration when the weight per unit volume of the material measured is not constant.

For the needed internal process control information, the latter method, carefully established, should suffice for the smaller capacity LEC's, presently contemplated.

E. Plant Production Results

Study of the records indicate that rather steady improvements in daily and monthly plant production are accruing at Kundesale. This

result is summarized in Table 1. We would expect these results to continue to improve markedly if the level of maintenance performance is improved, as hereinafter discussed.

Production expectancy, or capacity of the system to produce, is needed information in order to plan installations, evaluate installation proposals, and to effectively schedule production to meet distribution needs from the completed plant.

There are two principal components to attainment of capacity expectancy:

1. The mechanical capacity of the equipment, and its reliability factor over an extended period of time.
2. Management of the system by its operators and maintenance personnel so as to attain the output potential of the installed system.

This subsection of the report analyzes item 1. Item 2 will be covered in subsequent discussions.

It is possible to calculate the mechanical capacity of the Kundesale system at 100% reliability factor, and validate the result based upon the current operating schedule and the observations of the Mission. It is:

Work day		16 hours
Daily lost time scheduled -	Start-up 0.25 hours	
	Lubrication 0.50 hours	
	Shutdown 0.25 hours	
Total lost time scheduled		1 hour
Daily productive time		15 hours

Daily raw materials processed - 15 hours x 1000 lbs/hr	15,000	pounds
Moisture loss (Ref. IV.F.) - 7.31% x 15,000	1,096.5	pounds
Daily finished product turn out	13,093.5	pounds
Maximum finished product capacity per work hour	869	pounds
Maximum finished product capacity per production hour	927	pounds

Table 1 shows actual production per work hour for the six-day period in March, 1977, to have been 885 pounds, 1.8% higher than the expected result as calculated above. A longer productive time, higher hourly raw material throughput rates, better product yields, inaccurate data, or a combination thereof could account for the small 1.8% deviation noted. The Mission considers the actual recorded experience to be reasonable verification of the calculated maximum capacity of the Kundesale plant as now scheduled, at a 100% reliability factor.

The actual Kundesale plant reliability factor, as herein defined, cannot be ascertained by observation of the record, by reason of the intervention of management matters into the recorded result. Calculating on the basis of the total experience shown in Table 1, including management factors, the ratio becomes 40%, an unacceptable assumption by reason of the gross problem with the total maintenance function. If one ignores the major parts supply component of the maintenance problem, then the overall reliability factor experienced, including management factors, becomes 631/869 or 72.6%. That ratio is not a truly useful assumption either, since it ignores a major factor bearing on the product distribution, and it gives inadequate credit for system management improvements that have been made over the time recorded.

An effort was made to estimate the reliability factors of the individual machines, and calculate a system reliability factor on the basis of the Mission member's experience. Table 5 illustrates the result of that effect.

Table 5. Equipment Reliability Factor Estimate--Kundesale*

Unit	Factor in %
Cablevey	65
Bulk tanks	100
Conveyors to Modern Mill	95
Modern Mill (including vertical conveyor)	85
Brady cooker	65
Diesel engine	100
Conveyor to cooler	95
Cooler	100
Prater Mill	97
Conveyor to packer	95

*Estimated reliability

Compounding the entire list yields a reliability factor of 30%. Eliminating the first three items from the compounding, which can be supplanted by labor, yields 48%. Since the system, with new equipment, has produced higher reliability when one eliminates waiting for parts, these estimates should be considered to be relative values over a short life span, with system management functioning about as it has in the review period.

Table 6 illustrates a series of estimates of output capacity, attainable under various assumptions, for possible implementation in new installations.

To summarize the Mission's analysis of productive capacity:

1. It is deemed to be impractical to attempt to judge the actual productive capacity of the Kundesale plant from the record, due to unresolved maintenance problems. It can be said with some assurance that solution of the parts supply problem alone would increase the reported 111 day productivity from 40% to over 70% of expectancy. Certainly the intermittent system reliability factor, as defined herein, excluding system management factors, presently exceeds 70%--by how much we cannot estimate with logical reasoning.
2. Greatly improved plant productivity over a much longer plant life can be readily attained from new installations, and partially attained at Kundesale by:
   a. Materially improving systems management, and particularly with respect to maintenance matters;
   b. Substitution of continuous duty equipment for intermittent duty equipment;
   c. Satisfactory completion of the pilot plant development work, discussed in this report.

These potential areas for plant productivity improvement are not fully interdependent. Effective work in any of these areas should result in measurable increases in plant production.

Columns 2 and 3 of Table 6 represent entirely rational goals for attainment in LDC's. Column 4 represents a difficult, longer-term,

Table 6. Estimates of System Capacity

System criteria	Columns 1	2	3	4
System management status	maintenance improved	fully functional	fully functional	ultimate
Work day, hours	16	16	24	24
Production day, hours	15	16	24	24
System duty classification	intermittent	continuous	continuous	continuous
Reliability factor, %	70	98	98	98
Feed rate, lbs per hour	1,000	1,000	1,000	1,200
Process yield, %	92.5	92.5	92.5	92.5
Product rate, lbs per hour	925	925	925	1,110
Daily production, lbs	9,712	14,504	21,756	26,107

Assumptions:

Column 1 -- New installations, intermittent duty equipment, material reduction in maintenance supply problem.
Column 2 -- New installations, continuous duty equipment, maintenance problems solved.
Column 3 -- Same as column 2.
Column 4 -- Excellent system management in every respect, continous duty equipment, "pilot plant" development fully explored.
All columns -- Preventive and deferable maintenance scheduled on a non-scheduled production day; for example, on the 6th day following a 5-day production week.
All columns -- Calculated basis 80-85% cereals/15-20 soybean formulations.

NOTE: Column 1 represents a 175% improvement in production over the 5,548 pounds mean of 111 days reported in Table 2.

ultimate goal with a probable requirement for entirely successful accomplishment of all three of the above items of development.

F. Plant Maintenance

Maintenance of equipment attains a degree of importance in most LDC's far beyond that required in most industrialized nations. Most people, experienced in industrial work in LDC's, know of forced plant shutdowns of three months or more awaiting replacements from distant sources, for even the most reliable equipment. Sri Lanka is no different.

Prior discussions with respect to other matters in this report have repeatedly illustrated the effect of an inadequate maintenance system performance on production and probably machine life. The Mission members are quite certain that the greatest single benefit that can accrue to the Kundesale operation will be vigorous effort to establish an effective maintenance system. Using the present intermittent duty equipment, production expectancy can surely be increased from the 40% performance level calculated from the data in Table 1 to somewhere in the range of 70-90% solely by solving the maintenance problems. Perfection is not likely to be attained, and is not required to attain that result.

Maintenance of the Kundesale system, and any other system likely to result from new installation designs, presents only the usual problem in LDC's. There are no exotic requirements. One machine, the Brady Crop Cooker, is highly sensitive at present to operating technique and maintenance performance. If developed into a continuous-duty machine, it would be much less sensitive, but would still require greater attention

than the other system components. There is nothing unique in the Brady Crop Cooker elements requiring highly sophisticated maintenance procedures. Because it is more highly stressed, it will require more specialized attention than the other machines.

It is the judgement of the Mission members that the mechanical skill and knowledge levels required to successfully maintain the LEC system are about equal to those required by a first class automobile or farm machinery mechanic. A reasonable training program is a requisite to transfer those skills to the LEC system. Nothing difficult or unique is required in that training.

The elements that need to be included in an upgrading of the maintenance system for any location are:

1. An inventory control system for parts, including:
    a. A clean storeroom, with bins, or a specific place for all parts - a place for everything and everything in its place, properly identified.
    b. A bookkeeping system that shows current inventory at all times, that shows reorder levels, clearly taking lead time for delivery into account, that immediately initiates orders, and that follows up orders before the plant is out of stock.
    c. A work order method, as part of the bookkeeping system, that causes all repairable parts to be repaired and returned to working inventory promptly. Assemblies, such as the Brady rotor assembly, should be available at all times, and the bookkeeping system should control such assemblies, as it would a part.

2. A preventive maintenance plan which takes into account the needs of all machines for specific checking and specific work. This plan should have two elements:

   a. Operating time checking and work, such as lubrication. Check lists with a place for initials, to indicate performance, are suggested.

   b. Down time checking and work, such as replacement of worn parts. Here, too, performance check lists are suggested. It is suggested that a valuable goal for maintenance performance shall be that all down time maintenance requirements may be deferable to a nonscheduled production day; i.e., the 6th day after a 120-hour, 5-day operating week. The potential benefits in production are illustrated in Table 6 for attainment of continuous duty status. Maintenance costs per unit of production will also benefit markedly.

3. A supply of proper tools, in good condition, should be available at all times. Each machine in the system should be carefully reviewed to determine the tools required, in house, for proper maintenance, including the disassembly and reassembly. The required tools should be provided. Damaged tools should be promptly replaced. The machines in use, and likely to be used, if USAID equipment purchase rules apply, use U.S. standard sizes. In most of the LDC world metric sizes prevail. Tool replacement, like parts, will require a long lead time, when the United States is the source. Because LDC machine shops typically do not have U.S. standard taps and

dies, a set meeting the needs of the plant is an example of tools that should be on hand. There should be a clean specific storage space for each tool, and they should be cleaned and returned to that space after every use.

4. Employees having the skill levels suggested should be employed, if available, in order to minimize training requirements. It is believed, based upon our conferees' statements that such people may be employed in Sri Lanka without difficulty. Training will be discussed in a later subsection. Suffice it to say here that these people must be sensitive to the maintenance needs of the equipment, particularly the Brady Crop Cooker, and well trained in the techniques of meeting those needs.

In summary: A more formalized, more skilled, and much more effective maintenance program will be a requisite to satisfactory results from a LEC in a LDC. Attainment of that result does not present difficult problems for solution--just competent man hours of time available for technical assistance and training.

It should be stated that maintenance system development and employee training was undertaken at Kundesale. Employee turnover resulted in the loss of some employees exposed to that effort. The Mission members have no basis for judgement of the result that might have accrued, had these employees remained.

G. Plant Environment - Employee Safety

Observations were reported (Ref. IV.D.) of two serious accident hazards at the Brady Crop Cooker--from the feeder auger, and from the

discharge auger. In this analytical chapter of the report suggestions are offered for development work (Ref. V.C. The Brady Cooker) to eliminate the need for constant surveillance of these two augers. With that need removed, a removable enclosure (cover) over the feed and discharge areas would reduce these hazards to normal and acceptable risks.

An observation of open gasoline containers was also reported within the plant (Ref. IV.D.) presenting an unacceptable fire and explosion hazard. Gasoline is an effective cleaning agent for greasy machine parts. Most safety-conscious maintenance people have eliminated it from their usage because of the extreme hazard. Other petroleum-based hydrocarbons, about equally efficient in cleaning but with much lower volatility and flash points, are kerosene and petroleum-based paint thinner. Paint thinner appears to be the choice, both for safety and cleaning efficiency. Both are widely distributed and one, or both, will be found in LDC's. There are many proprietary cleaners offered, but suitable ones would not be commonly found to be available in many LDC's.

While kerosene and/or paint thinner materially reduce the hazard compared to gasoline, they do not eliminate it. They are flammable, and while the rate is acceptably low, they are volatile. Suggested rules for their use:

1. They should always be stored in a sound metal container with a gasketed cap in place, preferably a heavy gauge can made for gasoline. The can should be conspicuously labeled, with cautionary language understandable to the plant employees. Preferably, all such materials should be stored in a fire resistant locked cabinet or shed, outside the main buildings.

2. When in use, the work area should be well ventilated--outdoors is preferable.
3. Flammable cleaning materials should never be used in the presence of a source of ignition--an open fire, a welder in use, a soldering iron in use, an arcing electrical device, a very hot machine part, etc.
4. All dirty cleaning materials should be promptly and safely removed from the plant immediately after use.
5. Employees using hydrocarbon solvents for cleaning should use protective gloves, resistant to the material in use. If solvent gets on the skin, it should be promptly washed off. If clothing should become wet with solvent, it should be changed immediately.

It was reported (Ref. IV.D.) that an uncomfortable, but not oppressive temperature and vapor condition exists at the Brady cooker operator's work station. There is no obvious low-cost method to eradicate that condition, but it can be significantly ameliorated at low cost. An electric fan located at about 60° behind and to the right of the operator, blowing a sizable volume of low velocity air past the man and machine should significantly improve the comfort level at that most important work station. It is reasonable to expect that increased comfort will result in increased attention to the details of this critical job, with benefits to production and maintenance costs.

An observation was reported (Ref. IV.D.) that noise levels around the diesel engine Brady cooker are high. It is a judgement, unsupported by tests, that the sound level is high enough to damage hearing with continuous exposure over a period of time. It was noted that some

employees in that area are wearing ear protection. The easiest amelioration of the hazard is to simply require that all employees in the area wear ear protection of a type recommended by competent authority for the hazard.

A better course of action would be to determine the noise levels by proper testing procedures, and then have competent authority specify the protection required.

In new installations requiring an engine, isolation of the engine in a sound-proofed cubicle merits engineering consideration.

It is the Mission members' opinion that selection of an electric motor for the Brady drive (Ref. V.C. Diesel Engine - Cooker Power Source) would reduce noise to levels that would obviate the need for ear protection. Competent authority's views, or testing after installation, would be better assurance of safety than the Mission members' opinion in this field.

It was reported that neighbors have complained of the diesel engine exhaust noise. The Mission estimated that it probably would be irritating to nearby neighbors. The supplier, Cummins, can undoubtedly suggest muffler equipment that will ameliorate the exhaust noise, at some penalty in engine fuel efficiency. In new locations, where an electric motor is the prime mover of choice, we would expect no neighborhood noise problem of consequence.

H. Sanitation - Foreign Matter

The fumigation procedures outlined to us by CARE personnel, which are being carried out at present by the Paddy Marketing Board (Ref. IV.E.) should provide quite adequate raw material infestation control,

if those procedures are carried out effectively, so as to retain killing gas concentrations, for the required time. Its effectiveness can best be measured by the data resulting from the routine inspection program recommended in the following subsection. Any raw materials held in store at Kundesale should be Phostoxin fumigated every 28 days after the last PMB fumigation.

The warehouse space and grain cleaning area for raw materials at Kundesale needs a sanitation program. Building surfaces at any installation should be cleaned routinely, at least once per week, and sprayed at least once per month with an insecticide such as Malathion. Care must be exercised not to spray the raw material bags.

Cleaning and processing equipment interiors need fumigation at least once per month. This equipment should have dormant stock cleaned from it and that material fumigated. The equipment must then be sealed and fumigated wtih a gaseous material. Probably the best material is methyl bromide; however, it is highly toxic and should only be applied by a highly qualified professional fumigator. In lieu of such services the best materials known to the Mission personnel for application by plant personnel are the carbon tetrachloride preparations. Application of these materials should follow directions to the letter. It must always be remembered that any material that will kill insects can also harm human beings.

New installations should be made in buildings from which rodents, birds, domestic animals and fowl may be excluded; and they should be excluded in practice. The processing building at Kundesale is capable of doing so with minor effort and expense. The raw material storage and cleaning area cannot be easily made pest-proof, and it would only be

reasonable to undertake the construction to do so, if the CPF factory is to remain a processing site for a long term.

Even in the best facilities, mice will gain entry on occasion. Trapping usually suffices to eradicate them.

The only materials that the Mission can recommend for plant personnel use to kill rats that may gain entry, or be found around the building perimeter, are the anticoagulants, such as Warfarin, and they should be used in strict accordance with instructions, under tight supervision.

Routine inspection, elimination of harborages, elimination of available food and water supplies, rodent-proofed buildings, and prompt control response to any adverse findings, are the means by which food plant operators successfully control rodents. This is a matter requiring an effective program in most, if not all, LDC's.

It is expected that a plan developed for insect and pest control, following the suggestions herein, would prove to be effective in a LEC in any LDC.

Inclusion of foreign matter into the product is of some concern. We have discussed the removal of tramp iron (Ref. V.C. Magnetic Separators). Glass and glass devices such as bottles, etc., should not be allowed in the processing areas unless essential to the operation. If essential, they should be protected so that accidental breakage will not result in product contamination. This includes light globes. Body hair from operators is a constant source of potential contamination. All openings to the product flow should be covered. Presently, at Kundesale, this would not be practical at the extruder feed and discharge hoppers. These hoppers must be constantly monitored by the Brady operator. A

discussion of this condition is found in Ref. V.C. The Brady Cooker, and in the first paragraph of this subsection, Ref. V.G.

I. The Product - Quality Control

In Ref. IV.F., the team reported its observations to be that the product made at Kundesale has been an acceptable, nutritious, palatable food product. The Mission accepts that finding as factual; therefore, this subsection will be concerned with:

1. Process control analysis, as an aid to the operators in meeting production schedules, and in meeting quality standards.
2. Finished products standards and analysis as a means of quality assurance.
3. Activities or changes that may contribute incremental improvements to the finished product, presently judged to be satisfactory.

The Thriposha Quality Control Manual, Sri Lanka, 1976, is a document of the kind that is needed to provide assistance in processing, and standards of acceptability for finished product. It is not truly fulfilling these needs, as presently written, because:

1. Many of the standards and ranges stated are not realistic, and are not likely to be attained. For example, in Ref. 3.3.1.3 in that Manual, the standard for indigenous raw cereals moisture in 8% and the acceptability range is 6-10.6%. Table 3 shows that no single test in the 85 reviewed showed the grain mix to be as low as the highest acceptable moisture for cereals and soybeans. In the same Manual reference the standard for density is quoted to be 60 pounds per bushel for cereals, with

a range of 56 to 60 pounds. None of the cereals most likely to be used in LDC's, including Sri Lanka, will attain an average of even 56 pounds per bushel, the minimum acceptable. In the industrial world unattainable, meaningless standards are usually ignored, and too often this attitude carries over to other realistic, important standards.

2. Meaningful standards have a rational valid reason for their acceptable range--usually, either a quality factor or an economic factor. Many of the standards quoted in the Manual have no observable, rational reason, and are being ignored. For example, the consistometer test is being used as a measurement of adequate cook, as reflected by gel formation. Table 3 shows an observation of 85 tests with 58% or 68% reflecting a result below the acceptable minimum. The rational inference is that such a product is overcooked and should be rejected. None of that product was rejected, and there is no evidence that its quality was questioned as a result of the test findings. Neither is there evidence that the Brady operators could have reasonably changed the result.

In organoleptic testing of such a cereal product, overcooking would typically be recognized to be present when the light brown amorphous color and bittersweet flavor of caramelization appears. There is no evidence to suggest that the 68% of the product outside the acceptable range was in any sense an inferior product--in fact, the Mission members estimate that it was probably superior to the 32% falling within

the acceptable range, by reason of more thorough gelatinization, without evidence of caramelization.

The above examples are cited in order to support the Mission's general analysis of the Manual and quality control administration, as the Mission interprets its observations. The general views are:

1. The Manual approach to quality control is desirable, and the format adopted in the existing Manual is excellent. The Mission deems the existing Manual to be a first draft for LEC control purposes. In the light of one year's operation at Kundesale, it is believed that it is time to update the first draft to make it a meaningful, actionable, administrative tool. While a Manual developed for Sri Lanka may not totally fill the needs in other LDC's, with other end goals and raw materials, it should serve as a most useful guide to, and shorten the time of preparation for, other locations.
2. In updating the Manual it is suggested that the following considerations be taken into account:
   a. Every standard and acceptance parameter should be realistic and attainable within the environment, and material supply potential, of the LDC.
   b. Every standard and acceptance parameter should have a valid reason for its establishment. The parameters should be actionable parameters--reasons for product rejection. The reason for establishment should preferably be stated in the Manual, and well known to all concerned operators and administrators. By so doing, maximum acceptance and cooperation toward attainment is

promoted. Unnecessarily tight standard ranges, established for police power alone, result in inexcusably poor economy.

c. It is essential in establishing standards that are expected to be meaningful, that means of dependably measuring the variable be available--human technical skills and equipment. In many of the test requirements, it is not even essential to have real accuracy as long as a reproducible index number, bearing a direct relationship to the values sought, can be attained. Our observations in Sri Lanka (Ref. IV.F.) indicate that replication test results do not dependably produce either accurate results or a known reliable index. Work needs to be done to validate the usefulness of test results.

d. The testing frequency required needs to be reexamined for each test on the basis of the uses made of the test results, and in particular the timeliness of results for effective action. For example, it is of little practical use to learn that a food product was low in protein or calories 30 days after it has been consumed.

e. In the manufacture of products such as the LEC produces, by far the greater quality assurance, at reasonable costs, comes from excellence of process control, starting with formulation, than is ever gained by the somewhat sterile police action of post production testing. It is suggested that particular emphasis be placed on process control in an updated manual, with finished product

analysis accomplished much less frequently, only by dependable well-qualified laboratories, and the results primarily used to provide a specific historical record of the continuing suitability of the product for its food use.

3. In a small plant such as one with the Kundesale capacity, it is suggested that the shift supervisor be charged with the process control test work. Independent quality control operators should not be required. The plant manager must take an active, positive interest in quality matters.

4. In addition to the technical assistance contributions needed from competent nutrition and medical authority in establishing standards of identity for the product, it is suggested that an experienced managing cereal chemist, or an experienced cereal plant manager who has supervised quality control directly, would be of valuable technical assistance in updating the quality control program from a practical operating viewpoint.

It is not within the Mission's scope of work to update the Manual. The following comments on quality control matters discuss specific analysis of observations, but no attempt is made to cover the suggested updating in full detail.

Process Control Activity--

1. Raw Grain Inspection. Based upon the extremely low microorganism plate counts found and the absence of known pathogens in those counts (Table 4), required consideration of pest contamination in the raw material, as a health hazard to the consumer, seems remote. The

high cooking temperature appears to effectively kill microbes, and particularly the pathogenic species.

Each lot of grain received into the plant should be sampled and inspected. It is suggested that a trier sample be taken from 10% of the bags, or bulk lot, spaced to roughly represent equal sample distribution from the lot. Composite the sample, and test it for:

1. Visible live stored grain insects - no. per unit of volume.
2. Insect damaged kernels - no. per unit of weight.
3. Broken grain (less than 1/2 kernel) - % by weight.
4. Foreign matter (non-grain) - % by weight.
5. Heat damaged grain - % by weight.
6. Density - weight per unit volume.
7. Smell for off odors.
8. Test for moisture.

Such a test procedure provides a reasonably complete record of grain quality, and permits action if it does not meet acceptance standards. In practice, in LDC's, much defective grain will be used in spite of quality defects. It is suggested that any of the above tests, on which action will not be taken, be removed from the procedure.

2. Moisture Testing. The use of moisture meters, such as the Ohaus in use at Kundesale, should prove to be satisfactory; however, the operators must be able to reproduce results on it, and the real value of the resulting numbers should be known. Such meters need to be calibrated with tests in standard moisture ovens, dependably operated, in order to evaluate the resulting index number. One such test (Ref. IV.F.) indicates that the Kundesale meter may be reading about 1% high. Although Table 3 shows consistent plant performance for both the grain

mix and finished product within the Manual standards, there is not reason apparent to the Mission members why finished product moisture should be limited to less than 8%. A top limit of 12% would be expected to result in an entirely satisfactory product, perhaps a bit better in eating quality and storage life in the 10-12% range, than the present mean of 5-5.5%. This matter will become important only when development work demonstrates distinct advantages from added moisture to the process mix, or when grain from a wet harvest must be processed.

3. Grain Mix Granulation. The particle size of the ground grains entering the cooker has a bearing both upon finished product quality, and stress on the cooker. It is suggested that, once per shift, a particle size test be made on the ground grains entering the cooker in order to detect hammer mill screen deficiencies. The acceptable ranges should be developed by test. The following is offered as a starting point for present operations:

On 6 W - 0%

On 30 W - 60-75%

On 60 W - 20-35%

Through 60 W - 5% Max.

A one sieve test may well suffice.

In Ref. V.C. The Brady Cooker, it has been suggested that process development work on granulation of the mix is expected to show that a finer granulation than is presently used will both reduce machine stress and result in a collateral improvement in product quality.

4. Gelatinization Test. The consistometer, in use for measuring the degree of cook, has one distinct advantage. It produces an objective number. It is the opinion of the Mission members that the Manual

standards have not been calibrated to properly reflect acceptable product, as is shown on Table 3. That should be done.

Another test used for measuring gelatinization is a simple sedimentation test resulting in an objective number reading. It too would need to be developed to reflect meaningful, actionable parameters, based upon the needs of the consumer. A suggested starting point for test development and evaluation is:

> Thoroughly stir 50 grams of finished flour into 250 cc of tap water. Place mixture in a graduated beaker. Let stand for one hour. Read the sediment in cc's.

The best tests, most reliable, and most sensitive to cooked quality of cereal products, are visual and taste examinations by experienced quality control people. These tests have the distinct disadvantage of being subjective. If management has confidence in the judgement of the quality control people the objective tests may safely be eliminated. Visual and taste tests and recording of the findings should be routine, in addition to any objective test used. Visual and taste examination of the product should be made on unground material (cake) after the extruder. Suggested examination criteria:

Overcooked	Appearance	Brownish amorphous color of caramelization.
	Taste	Bittersweet flavor of caramelization.
Undercooked	Appearance	Inclusions of particles of white starchy endosperm, yellow horny endosperm, and/or unreduced bean particles.
	Taste	Presence of raw starch or bitter bean flavor.

It is expected, on the basis of observations, that the best product will show a uniform, slight puffing in the extruded cake. Observations

of product made when the cone and cup were not concentric in the cooker showed evidence of lack of uniformity in the cooked product. Under constant formulation, constant feed rate, and with temperature the prime control variable, measurement of cake thickness could prove to be useful information to assure cone-cup concentricity and indicate "puff" consistency. Only a bit of test development work could determine whether such measurements would be of real value in helping to assure product uniformity.

5. Bulk Density. The bulk density in grams per cubic centimeter of the finished product (Table 3) has been quite uniform under varying formulations. It is unlikely that this test needs to be run. If the cooker produces an acceptable product, the hammer mill with its fixed screen will almost certainly turn out a ground product of uniform density--at least sufficiently uniform for practical purposes.

6. Granulation Test - Finished Product. Such a test is needed to check for hammer mill screen failures--either breakage or wear. Table 3 shows a wide range of results, largely out of the standards tolerance. The prime concern with granulation is assurance that the hammer mill is properly grinding all of the product, that the resulting grind results in a uniform density so that volume-filled packages contain uniform weights, and so that the consumer enjoys eating quality free of grit-like characteristics. The Mission's observations indicate that the product has met the needs in these three areas in spite of the indication of major deviations from established standards. The Mission members believe that much of the indicated deviations result from sampling error rather than lack of process uniformity. Cereal products ground to such a wide granulation curve separate by gravity in handling. In order

to replicate results, the entire stream of product must be cut to the sample container. The sample container should hold about the exact amount wanted for the test. No effort should be made to divide the sample to attain an exact sample weight. Weigh and sieve the entire sample. Calculate percentages based on the entire sample weight. Charts may be prepared from which percentages may be read within reasonable ranges. Those who update the manual should carefully consider whether any more data is really needed than a one-sieve test to assure that the hammer mill screen is sound. We suspect that nothing more is really useful as a routine test procedure.

7. Finished Product Taste Test. Mixtures of cereal products and water, particularly when hot water is used, enhance odor and taste perception well beyond the levels perceived when dry product is smelled and tasted. It is suggested that a finished product final taste test be designed to take advantage of this factor. It is suggested that this test be used to detect:

1. Foreign odors and flavors,
2. Palatability, as measured by absence of raw starch and bitter bean flavors,
3. Palatability, as measured by freedom from gritty eating texture.

Finished Product Quality Control--

The Mission members agree that periodic evaluation of the products of an LEC should continue, primarily for the purpose of assurance that the products do, in fact, contain the nutrients intended to be made available to the consumer. To have real value as confirmation of product identity, one must be able to have confidence in the test results

reported. Table 4 shows the results of the testing of duplicate samples of Kundesale product by the agency used. The results in general are so skewed that they cannot serve the manufacturing agency either as confirmation of the validity of its calculated values, or as a basis for action to change production. In order to serve as a useful control, results must also reach management promptly. This has not been the case in Sri Lanka. Unless reasonable accuracy is obtained from the testing laboratory the results have no value, and the expenditures for testing are wasted. Unless acceptable accuracy and prompt response from the testing laboratory are attained, such testing has no value as a quality control mechanism.

Attaining accurate and prompt results will prove to be difficult in most LDC's. It is suggested to those who develop manuals that the frequency of such tests be dependent on the source of accurate results, the time required, and the consumer end use of the products. Said differently, it is quite practical to expect to do very well with only calculations, and the in-process controls suggested, if the outside laboratory testing does not provide truly useful data in a timely manner, severely limit the testing frequency, or eliminate them altogether.

With respect to specific tests, the Mission comments:

1. Protein. The Kjeldahl test result is an index. It does not measure protein--it measures nitrogen. The index number, or protein estimate, is attained by multiplying the nitrogen found, by a factor which has been found by more detailed research. This approximately reflects the ratio of protein to nitrogen, thus attempting to exclude non-protein nitrogen from the resulting index number. In updating the Manual it is

suggested that consideration be given as to the propriety of uniform use of 6.25 as the nitrogen multiplicand. Of the formulations studied, a lower multiplicand, perhaps of the order of 5.7, would appear to be more appropriate.

2. Ash. There is no reason advanced in the Manual, or hypothesized by the Mission, as to what contribution ash analysis has, or is likely to make to quality control or nutritional evaluation for the LEC product. It appears to be a redundant test. In updating the Manual its use should be justified, or in lieu thereof, eliminated.

3. Fiber. The present Kundesale product contains the full fiber of the cleaned grains. It is suggested that competent medical and nutrition authorities evaluate the fiber levels included in LEC products, particularly if infants are among the targeted consumers. There were no fiber test results observed in Sri Lanka. If the evaluation suggested results in an upper parameter on fiber inclusion, routine analysis for it may become a requirement, and grain quality (grade) may become a more important element in finished product quality. Decortication may become a requirement.

4. Calories. The Mission raises a question that should be, and may have been, answered by competent nutrition authority. Does the bomb calorimeter method provide a dependable index number, that correlates directly with available calories? The calorimeter will measure calories that are not available to human digestion.

5. Micro-ingredient Control. For installations in which complete consumer products are to be made, which includes a vitamin-mineral premix, spot tests will be needed for process control. It is suggested that initial tests be made to determine losses of heat sensitive vitamins, if such are in the premix, in passing through the cooking process. Outside laboratories used for periodic product analysis should also include quantitative tests to measure the presence of the micro-ingredient premix in the product.

6. When LEC installations are responsible for the manufacture of complete consumer foods, samples should be picked up in the field periodically, and returned for examination. It is suggested that these samples be examined for:

   a. flavor
   b. odor
   c. color
   d. granulation
   e. package appearance
   f. package seal
   g. moisture.

   Rancidity, due to fat deterioration, is a hazard to such products, usually resulting from poor and/or overlong storage. Management needs to know that the palatable, nutritious product manufactured actually reaches the consumer in that condition.

J. Organization Requirements

An effort has been made to define the organization that would be required to operate an LEC system with one Brady Crop Cooker in LDC's.

We shall define it under two sets of conditions, assuming in both cases that the operation is a fully independent, self-sustained unit.

1. Under the present state-of-the-art, using an intermittent-duty system:

   One manager--A good businessman, also thoroughly knowledgeable in all plant operations, by training.

   One clerk--Bookkeeping, including inventory control.

   One plant supervisor per shift--A skilled mechanic who will also do maintenance work. Also trained to do process control testing.

   Three machine operators per shift--All trained to operate all machinery.

   One packer per shift--Pack, weigh and stack finished product. (Does not provide for labor intensive consumer size packaging.)

   One watchman per shift--Clean plant, grounds, and clean empty bags, in addition to watching.

   Two loaders, day shift only--Load and unload trucks.

   Total for 3-shift operation--25 people.

2. Under a fully trained, debugged condition, using a continuous-duty system:

   Reduce the machine operators to two per shift; total for 3-shift operation--22 people.

Under both conditions the shift supervisors would perform required process control testing, and down time maintenance.

These are reasonable expectations for LDC's. In more developed countries, more plant sophistication could materially reduce the staff.

K. Management Control - Financial

A properly integrated, unsophisticated management control system needs to be developed and installed for new LEC systems. The complete details of the system needed will depend in considerable measure upon the ownership and goals of the operation. For example, the needs of a government enterprise, processing government-owned raw materials for an indigent target group, will differ from the needs of a private entrepreneur seeking profit. This discussion will center on the common elements of a management control system suggested for interval management control of the operation, irrespective of the total goals of the ownership. There are two major elements of internal control for such an operation--raw material costs per unit of production, and operating expense per unit of production.

Information Needs for Major Elements of Control--

Raw material cost per unit:

1. Raw material usage, by kind, in weight,
2. Delivered cost of raw material used, by kind, per unit of weight,
3. Offal removed from raw material used, by weight,
4. Value of offal removed, per unit of weight,
5. Clean raw materials to process, by weight,
6. Finished product, by weight.

With these data, a material balance or yield may be calculated as follows:

Offal	%
Cleaning loss	%
Process loss	%
Finished product	%
Raw Material	100%

Available shift process control yields of clean grain from dirty grain, and finished product from clean grain, may then be calculated to measure shift performance.

From these data material cost per unit of finished product may be calculated, in either of two ways:

1. $\frac{a - b}{c} = x$, in which:

   a = total delivered cost of raw materials used,

   b = total recovery from sale of offal,

   c = finished product units produced,

   x = net raw material cost per unit produced.

2. $\frac{a}{b}(c - d \cdot e) = x$, in which:

   a = pounds per unit weight of finished product,

   b = decimal yield of finished product,

   $\frac{a}{b}$ = pounds of raw materials required per unit of finished product,

   c = delivered cost per pound of raw materials,

   $\frac{a}{b} \cdot c$ = delivered cost of raw materials required to produce a unit of finished product,

   d = decimal yield of offal,

   $\frac{a}{b} \cdot d$ = pounds of offal produced per unit of product,

   e = recovery value per pound of offal produced,

   $\frac{a}{b} \cdot d \cdot e$ = recovery value of offal produced per unit of finished product,

   x = net raw material cost per unit of product.

Equation 1 is the simple method of determining historical material costs. Equation 2 is the usual method of projecting future costs for

budget or sales costing purposes. Both determinations are useful and data to produce them should be available.

Because there are widely varying costs between ingredients used, a monthly variance report should be considered. The data base suggested above, coupled with formula data, can provide such efficiency measurements for internal control. Table 7 is a pro forma example of such a report.

Operating Expense--

Expense reporting, by a chart of accounts representing major expense categories for the entire LEC operation, should be a requisite to satisfactory management control. Such accounting does not presently exist for the Sri Lanka operation. CARE/Sri Lanka has no record of many costs incurred for its benefit by U.S. associates. Operating expense should be reported at least monthly, in both money amounts and cost per unit of weight, to provide adequate management control.

Table 8 is an estimate of operating expense on a pro forma basis for a completely independent operation in a LDC. The table shows estimates under different assumptions--the same assumptions as are used in Table 6 to estimate system capacity. It should be clearly recognized that each LDC proposal will present different cost factors than those shown. These data represent an approximate average of expected costs in three LDC's. The magnitudes shown should be reasonable. The prime value of the exercise is to indicate the high value of system development work if the resulting product volume can be used. Examples of other charges frequently encountered are interest, ad valorem taxes, enterprise owned automotive equipment, etc.

Table 7. Pro Forma Example, Monthly Ingredient Variance Report*

Ingredients	Clean ingredients disappearance by formula, lbs	Cleaning yield, %	As received ingredients disappearance by formula, lbs	As received ingredients disappearance by inventory, lbs	Variance, ± lbs	Cost/ lb $	Variance, ± $
Corn	172,973	97	178,323	176,823	-1,500	0.04	- 60.00
Sorghum	0	0	0	0	0	0.00	0
Soybeans	43,243	98	44,126	46,332	+2,206	0.13	+268.78
V-M Premix	125	100	125	129	+ 4	5.00	+ 20.00
Totals	216,341		222,574	223,284	+ 710		+246.78
Per lb of product							+ 0.0012

Production finished product, 200,000 lbs: clean grain mix calculation $\frac{200{,}000 \text{ lbs}}{0.925 \text{ process yield}}$ = 216,216 lbs

*Package materials are often included on such a report to provide a control on all materials entering the finished product.

Table 8. Pro Forma Statement--Estimated Annual Operating Expense in a LDC (new installations, 1978 prices)

Parameters	Columns 1	2	3	4
System Criteria				
System management status	maintenance improved	fully functional	fully functional	ultimate
System duty classification	intermittent	continuous	continuous	continuous
Work day, hours	16	16	24	24
Production day, hours	15	16	24	24
Production days, year	250	250	250	250
Annual production, pounds	2,428,000	3,626,000	5,439,000	6,526,750
Fixed Expense	US$	US$	US$	US$
1 manager @ $2,400	2,400	2,400	2,400	2,400
1 clerk @ $1,200	1,200	1,200	1,200	1,200
2 shift supervisors @$1,500/shift	3,000	3,000	4,500	4,500
Machine operators @ $550 ea	3,300	2,200	3,300	3,300
Watchmen @ $500/shift	1,500	1,500	1,500	1,500
Employment tax @ 10%	1,140	1,030	1,290	1,290
Insurance--building and equipment @ 0.5%	1,000	1,040	1,040	1,040
inventory @ 0.5%	210	320	480	570
Workmen's compensation @ 1%	110	100	130	130
Depreciation--building, $100,000 @ 4%	4,000	4,000	4,000	4,000
equipment (col. 1) $96,800 @ 10%	9,680	0	0	0
equipment (cols. 2, 3, 4)$108,900 @ 6.67%	0	7,260	7,260	7,260
Real property tax, investment @ 3%	6,500	6,870	6,870	6,870
Office supplies	340	410	450	480
Telephone	250	250	250	250
Travel and miscellaneous transportation	300	300	300	300
Total Fixed Expense	$34,930	$31,880	$34,970	$35,090
Fixed Expense per pound	$ 0.0144	$ 0.0088	$ 0.0064	$ 0.0054
Variable Expense				
Loading and unloading labor @ $0.30/2,000 lbs	770	1,150	1,730	2,070
Packing labor (100 lbs) $1.20/man day	600	600	900	900
Overtime maintenance labor per man day	940	470	470	470
Employment tax @ 10%	230	220	310	340
Diesel fuel @ $0.65 per U.S. gallon	6,550	9,170	13,760	16,510
Electric power @ $0.02 per kwh	1,470	2,940	4,410	5,290
Maintenance materials and services	11,000	8,700	10,000	11,000
Total Variable Expense	$ 21,560	$ 23,250	$ 31,580	$ 36,580
Variable Expense per pound	$ 0.0089	$ 0.0064	$ 0.0058	$ 0.0056
Total Expense	$ 56,490	$ 55,130	$ 66,550	$ 71,670
Total Expense per pound	$ 0.0233	$ 0.0152	$ 0.0122	$ 0.0110

NOTE: For Sri Lanka consideration, official exchange rate as of March 12, 1977 -- US $1 = 7.28 rupees.

A standard annual operating statement (profit and loss statement), and a standard annual balance sheet should be prepared for an LEC enterprise, irrespective of its ownership. Any competent accountant could easily establish the basic financial accounting system for such a small business. Even very low-cost over-the-counter systems (example: Ideal System Book No. 3131 or Book No. 5131) will provide adequate financial accounting methods and forms for any LEC needs that can presently be foreseen.

The agreement between Cereal Products Factory and CARE/Sri Lanka has proven to be unsatisfactory to both parties. It is the judgement of the Mission, on the basis of its findings, that over its life it has been inequitable to both parties--inequitable to CPF on the basis of payment, and thus the amount of payment; and inequitable to CARE/Sri Lanka on the basis of raw material accounting, particularly with respect to offal recoveries. Since it was irrelevant to the purpose of the study, no effort was made to calculate the degree of inequity to either party. It can be said, with assurance, that the amounts in either case would be substantial, with the net unknown. A fair written contract, equitable to both parties, and with all its implications well understood by both parties, should be negotiated and signed before undertaking such joint ventures in LDC's.

L. Technical Assistance - Training

It is the judgement of the Mission that CSU has provided an excellent, expeditious technical service for the Sri Lanka LEC in:

1. Engineering
2. Procurement
3. Installation supervisory assistance

4. Mechanical trouble shooting

5. Parts resupply.

Prior discussions, in this analysis chapter, relate findings and suggestions, with respect to added technical assistance needs, for the Sri Lanka LEC and new installations in LDC's. They are, primarily:

1. Development and implementation of an effective maintenance system (Ref. V.F.). This is deemed to be essential.
2. Development and implementation of an in-plant sanitation system (Ref. V.H.).
3. Updating and validation of the quality control system (Ref. V.I.).
4. Development and implementation of a small manufacturing business, simple accounting system, including the specialized internal controls needed for a grain processing enterprise (Ref. V.K.).

Although 16 hours of observation is a very short period to reach a positive conclusion, the Mission members gained the impression that the machine operators knew how to operate the plant equipment and were attentive to it--that they were adequately trained in the machine operation.

Adequately trained maintenance personnel were not found in the Kundesale plant. The Mission considers elimination of the deficiency to be critical to attainment of satisfactory results from either an intermittent-duty or a continuous-duty system. Technical assistance in the development of an integrated maintenance program (Ref. V.F.), and its implementation by training the people in the plant in its use, should

prove to be the most beneficial activity that can be undertaken for the Sri Lanka LEC.

A very small manufacturing operation, processing in the range of 1200 to 3300 tons of food annually, cannot afford specialists in all of the disciplines related to the operation--in fact, it can't afford a single one. What it does need very much is one man--the manager--who knows every operation in that specific small enterprise. He should know each operation well enough so that he can perform them creditably himself, can train new employees, and can evaluate the performance of the plant and its people, by reason of that specific knowledge. This means that a manager, selected for leadership qualities and intelligence, should participate in the training activity for practically every job in the plant. He tends to become the indispensable man. To insure that potential replacements are available, all supervisors should also be trained in all activities. From these ranks, illness and vacation relief may also be found.

Most of the technical assistance development work may quite logically be done in the United States by such people as those available at CSU, with perhaps a bit of specialist's counsel. Implementation, trouble shooting during the start-up period, and employee training must be performed in-plant. One man, an expatriate, well qualified to serve as the manager, as that job is defined above, can quite satisfactorily perform these in-plant implementation and training activities. The time required will vary in LDC's, depending primarily upon trainee quality and language barriers. It is suggested that, for most installations, six months time be budgeted. It is suggested that the training begin about 30 days before start-up time. It is suggested that the criteria for

satisfactory completion of technical assistance and training is a plant performing as it was designed to perform, and the trained people able to operate it as well without the trainer's presence, as with it--with the nominated manager able to correct deficiencies as they occur. Based solely on experience in various LDC's, that time requirement could easily vary from a low of three man months to a high of 12 man months.

VI. CONCLUSIONS RELATIVE TO THE STUDY OBJECTIVES

A. LEC System Suitability

The suitability of the LEC system observed in Sri Lanka, for use in manufacture of cooked food commodities in LDC's, cannot be logically answered with a simple "yes" or "no." The LDC goals have to be defined, in addition to investment and operating cost goals. The Mission reached the following conclusions regarding suitability:

1. The system will dependably produce an entirely satisfactory, palatable, nutritious food product.
2. An intermittent duty system, such as the Sri Lanka system, can be expected to produce, on average, 4850 to about 6200 pounds of finished product per scheduled eight-hour work shift--70-90% of the 100% maximum capacity of 6950 pounds per scheduled eight-hour shift (Ref. V.E. and V.F.). The difference between 70% and 90% is a system management efficiency factor estimate. No demonstrable proof is illustrated above the 70% magnitude level. Annual expectancy, with assurance, becomes about 3,600,000 pounds on a 3-shift basis, or 2,400,000 pounds on a 2-shift basis for a 250-day production year.
3. The Mission estimates the intermittent duty components of the Sri Lanka system to have an average life expectancy of five years, and a total new intermittent duty system including cleaning equipment to have an average life expectancy of 10 years, when operated as in #2 above.
4. Investment costs for the process installed (excluding land, site development, buildings) ranging between $95,000 and

perhaps, $120,000 (1978 prices) for either an intermittent-duty or continuous-duty system certainly will meet any reasonable criteria for low investment cost. Only engineering estimates would provide definitive comparisons; however, our experienced judgement is that the minimum comparable cost using conventional equipment would be in the magnitude of $250,000. The likelihood is that definitive engineered estimates would be considerably higher for conventional cooking and extruding.

5. Operating expense per unit of product, as shown in Table 8, represents a low unit expense, with the major contribution to that result being the low annual overhead costs of ownership, due to low investment costs.

6. Summarized, an intermittent-duty LEC system would be expected to function in a LDC satisfactorily only where its capacity limitation as outlined in #2 above is acceptable, and when the unit expense shown in Column 1, Table 8 of $0.0233 per pound is acceptable. These factors can be improved by:

   a. adding standby equipment, and/or

   b. maintenance of a 60-day finished product inventory.

The more satisfactory, and much lower cost method is to develop the LEC system into a continuous-duty system. Table 8, Columns 2, 3, and 4 illustrate the very attractive expense savings potential available to justify a small increase in investment cost for that conversion. A continuous-duty system is expected to have a minimum average life expectancy of 15 years when operated as in Columns 2, 3, and 4 of Table 8.

If continuous duty is needed, continuous-duty systems should be economically attractive.

USAID and USDA need to estimate the number of LEC units that may be needed in order to estimate the per-unit development cost of the continuous duty unit. The Mission members, experienced in LDC's, believe that the concept has wide economic potential and, therefore, the per-unit capital development cost should be quite low. It should be low-cost in finite terms as well.

B. Demonstration of Suitability at Kundesale

Here again, a simple "yes" or "no" answer will not rationally suffice. To be useful, the Mission must define what has been adequately demonstrated, and what has not, in the members' judgement.

1. It has been demonstrated, clearly and adequately, that the LEC will produce an entirely satisfactory, palatable, nutritious product.
2. It has been demonstrated that the system has the capacity for a short time period to meet the stated goal of processing 1000 pounds per hour. During the first six days in March, 1977, the system did produce at 100% of its scheduled 1000 pounds per hour feed rate with the resulting 885 pounds per work hour of finished product being equivalent to 100% production (Ref. IV.B. Plant Production Results, and V.E.).
3. It has not been demonstrated that the system, as currently managed, will produce dependably. In the six month's production time investigated (Ref. IV.B. Plant Production Results) it has been shown that the system produced at 40% of its scheduled capacity (Ref. V.E.).

4. It has been demonstrated (Ref. V.E.) that correction of one management factor only--provision of an adequate spare parts inventory--would increase the level of production to the 70% magnitude, a level judged by the Mission to be the minimum system capability.

5. It has been demonstrated to the satisfaction of the Mission, but without documentation to support the opinion, that the intermittent-duty equipment will suffice to meet a continuous-duty LDC need only if:

   a. standby equipment is provided, and/or

   b. long-term finished product inventories are maintained to bridge production gaps.

6. Low LEC system investment cost potentials bearing a reasonable relationship to the stated goal have been demonstrated (Ref. II.C., V.K. and VI.A.). There is no evidence observed that total investment costs have ever been estimated on an engineered basis, or the total investment costs, from all sources collected for the Kundesale plant. The elements of investment costs observed requiring consideration for total investment requirements, from all sources, are:

   a. engineering

   b. land

   c. site development, including utility connections

   d. buildings, including building equipment

   e. office, plant, laboratory and automotive equipment

   f. initial spare parts and supplied inventory

g. technical assistance and training

h. working capital.

7. The Kundesale plant has not demonstrated that it can operate at a low throughput expense. The reason that it has not done so is the low production attained--40% of expectancy. It has demonstrated, to the satisfaction of the Mission, that correction of one function alone--maintenance--would result in per-unit expense equal to or below conventional competing systems. The Mission is also well satisfied that upgrading of the system from intermittent-duty to continuous-duty status, combined with system management improvements suggested herein, would result in clear cut, low expense per unit of finished product, as is illustrated in Table 8.

8. Adequate technology transfer to indigenous people has not been demonstrated at Kundesale. The Mission hastens to add that there is no observable reason why that cannot and should not occur in any LDC, including Sri Lanka. Management arrangements, employee selection, employee turnover, and training (particularly in manangement and maintenance) are the observed areas of the operation deserving added effort to attain adequate technology transfer.

VII. RECOMMENDATIONS

A. Perspective Preamble

The Mission's terms of reference for its investigations, and the requests of the parties at interest for specific converage of the Mission's findings, in the depth and outline provided, has resulted in a long report, containing a large amount of technical rhetoric. In order to properly understand and evaluate the Mission's recommendations, it is important that the length and depth of the report be brought into perspective. We believe the following to be factual:

1. The LEC system, as it presently exists and as proposed herein, is a simple grain processing operation, presenting no problems of a unique nature. Competent engineers, chemists, and plant managers, experienced in grain processing, would be expected to find the needs of the LEC operation usual and routine.
2. The Brady Crop Cooker, the heart of the process, has been described to be unique and innovative. It is so by reason of its simplicity and low cost. Its mechanical elements are common mechanisms. No sophisticated solutions are required to better fit it for continuous-duty cereal processing--just engineering application of common grain processing and mechanical knowledge. All other machines required in the system are standard designs, for practical purposes available over the counter. All that is suggested in this area is engineering investigation of the alternative designs and selection of the more cost-effective units.

3. Maintenance needs have been emphasized. The suggested maintenance system is common to industry of all kinds. The emphasis is a common need in LDC's because of lead time for re-supply and lack of available local services.

4. The environmental, sanitation, quality control, and management control suggestions and minor problem areas are all usual matters requiring attention in an agribusiness, wherever it is located. Nothing unusual, sophisticated, or difficult about attainment is required.

5. Technical assistance and training of the type and magnitude suggested herein is entirely consistent with the usual findings of requirements for technology transfer to LDC's by the international agencies, including USAID, IBRD and UN-FAO. No more, or less, is required for the LEC.

6. Perfection in all of the areas of development and control discussed herein is seldom, if ever, attained in developed industrial countries; and perfection will not be attained in LDC's. What can be sought after, and attained, is a high level of performance, measured against known capacities, if cost effective production systems and management controls are provided and used. The thrust of the Mission's recommendations is to that end result.

B. General Recommendations

Statements of public policy, and the scope of work for other USAID agribusiness projects have clearly impressed the Mission members with the desire of the USG to assist LDC's in the development of permanent

improvements to their internal food supply problems, and reduce dependence on P.L. 480 as a solution to those problems.

It is the finding of the Mission that the LEC system can and should make a significant contribution toward that goal, at low costs. We strongly recommend that development and distribution of the system and its technology continue.

C. Specific Recommendations

Chapter V has stated the Mission's analysis of its observations with respect to all facets of the LEC operation, and suggestions for change have been included for those items where the Mission can foresee beneficial results from changes. The detailed suggestions covered in Chapter V will not be repeated in this chapter. This chapter will primarily discuss procedural and implementation matters for attainment of the benefits forecast for changes.

Pilot Plant Development Program--

Because of the high potential for the LEC system to make significant contributions to the goal of improved quantity and quality of internal food supplies in LDC's, the Mission strongly recommends the prompt initiation of a pilot plant development program. The goals of that program would be:

1. Development of a continuous-duty LEC system, with a high reliability factor, based upon the findings from the intermittent-duty experience.
2. Investigate and select equipment components on a basis of cost effectiveness.

3. Debug equipment--in this case the only known item requiring significant effort is the Brady Crop Cooker.
4. Determine optimum operating parameters by test, including moisture, heat, granulation, formulation, and speed.
5. Update the Quality Control Manual.
6. Produce a sanitation plan in manual form.
7. Produce a process operating plan in manual form, including parameters.
8. Produce a maintenance plan in manual form, fully covering the requirements of every machine for preventive and breakdown maintenance, tools required, and parts inventory control.
9. Produce an enterprise accounting plan in manual form.
10. Prove the work by continuous operation for perhaps 60 to 90 days.

The total goal for the effort would be to produce a dependable packaged enterprise that one qualified expatriate could be expected to have in satisfactory operation on an average of six months time and expense budget for technical assistance and training, in-country, starting 30 days before scheduled start-up. The manuals produced would be both training aids and continuing guides to operations.

It is recommended that such a development project be undertaken at a United States location where qualified engineers, cereal chemists, and people with relevant management experience may be brought to bear on the development. Dependable laboratory and machine shop assistance will be requisites. Colorado State University would be a most logical site. Other universities having strong food technology departments, including particularly Kansas State University, are potential sites. The USDA

laboratories at Peoria and Albany possess the technical competence and overall facilities.

The Mission cannot reasonably project time and costs, under its charter. It is practical to expect completion of the facility within six months time and completion of all the work in 12 months total time. Salvage of machinery units for use in a LDC could reduce investment costs for the effort. Use of manufactured product in the P.L. 480 program, use in university animal unit feeding programs, or sale for feedstuffs could reduce the raw material costs of the program.

It would be entirely possible to do the pilot plant development work in a LDC, but only with difficulty and inefficiency. The problem areas are:

1. At least one expatriate engineer with management experience and one experienced expatriate cereal chemist or food technologist would be needed for part of the effort.
2. The long lead time for receiving materials from the United States or other industrial areas would create gross inefficiency.
3. Lack of efficient machine shop service in most LDC's would lead to inefficiency.
4. Lack of accurate laboratory services in most LDC's would result in efficiency and could cast doubt on the validity of parts of the results.
5. The unit could not be considered to be a dependable production unit available to meet feeding program needs on a scheduled basis, and at the same time effectively permit the pilot plant development work recommended.

Trouble Shooting--

The alternative to an effective, integrated pilot plant development project appears to the Mission to be, attack each area of needed work on a trouble shooting basis, generally developing the solution at CSU, and conveying that solution to Sri Lanka (as the demonstration unit), with technical assistance and training effort. Continue that process until the demonstration unit meets, by actual performance over a period of time, production of 900 to 910 pounds per hour of a reasonable cereal-soybean formulation per scheduled work hour. When that level of production is attained the plant will have adequately demonstrated the status of a well-managed, dependable, continuous-duty system from a production viewpoint. To follow this approach to development, in order to attain adequate demonstration, priorities should be assigned to the effort. We recommend:

1. The highest priority unquestionably should be an improved maintenance program (Ref. V.F). Increased production from an average of 40% to 70% of present maximum capacity should be the minimum expectancy for satisfactory maintenance management. Without such an improvement, and based on the Mission's observations (Ref. IV.C.), the LEC system has little prospect of becoming a viable operation. Taking into account plans for continuation of operations at Kundesale, consideration should be given to immediate, emergency action to ameliorate the maintenance situation through technical assistance and training at Kundesale.
2. The second highest priority is surely debugging the Brady Crop Cooker to make it suitable for continuous duty operation (Ref.

V.C. The Brady Cooker). It is the judgement of the Mission that this machine has the inherent capability, with that work, to attain a 98% reliability factor, when properly managed, over a 120-hour continuous work week. The development work could quite logically be accomplished, and laboratory proven at CSU, with longer term demonstration of its efficacy in Sri Lanka. A concomitant need would be to work out a plan for conversion of standard farm units with a dependable job machine shop, well located with respect to the source of supply for the base unit.

3. The third priority in terms of production volume and cost-effectiveness is investigation, selection, and installation of standard continuous-duty auxiliary equipment in order to attain a system-wide 98%, 120-hour equipment reliability factor (Ref. V.C.). CSU may logically provide these engineering services, and is engaged in parts of that effort, as this is written. Because of the severe damage hazard, early attention should be given to magnetic protection (Ref. V.C. Magnetic Separators).

4. Of about equal priority with #3 and no lower than fourth, the Mission would rate process development as described in V.C. The Brady Cooker. This effort is expected to be quite cost-effective in terms of return for the money spent. The experimental designs and the experimental work may quite logically be accomplished at CSU with the longer term demonstration of its efficacy accomplished in Sri Lanka. This work is closely allied to the work covered as priority #2 above. It cannot be

fully completed before completion of that work; however, it can progress concurrently with that work.

5. Preparation of manuals for processing, quality control, sanitation, and accounting for plant operations guidance and training aids may progress concurrently with the above priority items. CSU is working in some areas of these needs.

For throughput cost and feeding program continuity reasons, wide distribution of LEC's in LDC's could prove to be counter productive until dependable finished product production at the 70% of expectancy, or better, level is demonstrated. This is an average minimum production level of 600-610 pounds per work hour scheduled over a five-day week. The Mission does not recommend such distribution until that level of demonstrated performance is attained. That level, or better, may be attained by:

1. satisfactory completion of priority #1 (as above), or
2. provision of standby equipment (not recommended).

At this minimum level of demonstrated system productivity, finished product inventories must be maintained to bridge production gaps, so that finished product deliveries meet requirements of the feeding program.

Summary--

Summarized, and in perspective, the Mission states its findings--the LEC system will be a valuable contribution to attainment of the USG policy with respect to food supplies in LDC's and, therefore, recommends that USAID, and its associates, get on with the logical development of its potential.