TECHNICAL REPORT
NATICK/TR-83/040

ADA136635

AN AUTOMATED FIELD BAKERY SYSTEM FOR BREAD

BY
RICHARD J. LANZA
AND
ROBERT V. DECAREAU

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

October 1983

UNITED STATES ARMY NATICK
RESEARCH & DEVELOPMENT CENTER
NATICK, MASSACHUSETTS 01760

FOOD ENGINEERING LABORATORY

DTIC FILE COPY

84 01 09 037

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER NATICK/TR–83/040	2. GOVT ACCESSION NO. AD-A136 635	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN AUTOMATED FIELD BAKERY SYSTEM FOR BREAD		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Richard J. Lanza and Robert V. Decareau		8. CONTRACT OR GRANT NUMBER(s) N/A
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Natick Research & Development Laboratories Natick, MA 01760		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1G263747D610–01
11. CONTROLLING OFFICE NAME AND ADDRESS Food Sys. Equip. Div., Food Engineering Lab US Army Natick Research & Development Laboratories Kansas St., Natick, MA 01760		12. REPORT DATE October 1983
		13. NUMBER OF PAGES 50
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approval for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

BREAD
BAKERY SYSTEM
AUTOMATION
AUTOMATED BAKERY SYSTEM
FIELD CONDITIONS
BAKING
SLICING
BAGGING
DEPANNING
COOLING
COST(S)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Army needs a field bakery system that can produce bread of consistent quality with less labor and with less skill than is required by the present M–1945 Mobile Bakery Plant system. This report describes the testing of a continuous, automated bakery system based on commercial practice but designed for operations under field conditions. The basic automated elements of the system are; continuous dough making and panning; continuous proofing and baking; depanning; cooling; slicing; and bagging. All elements are interconnected so that the

20. Abstract (cont'd)

only labor in the process is that required to keep the ingredient hoppers filled and to handle the individual bagged loaves of bread at the end of the process.

Results demonstrated the feasibility of this concept and, indicated a substantial reduction in labor over the current system. The cost per pound of bread based on equipment, vehicles, personnel, and fuel is almost six cents per pound less than the current system.

This work was carried out under Project 1G263747D610, Task 01.

SUMMARY

A feasibility model for an automated bread bakery was developed in response to an Army requirement for a field bakery to replace the aging M–1945, Mobile Bakery Plant. Named the Automated Bakery System (ABS), the bakery demonstrated to be able to make, proof and bake bread dough, continuously, at a rate of approximately 850 lbs of dough per hour. Depanning, cooling, slicing, and bagging capabilities were also provided so that, with the exception of labor to fill the ingredient hoppers and box the finished product, only monitoring labor was required.

The entire system was housed in a series of International Standard Organization (ISO) containers (8′ x 8′ x 20′) for arrangement onsite into the functional bakery. Cost estimates based on equipment cost, fuel and labor indicate that the cost of the finished product would be at least four cents per pound less than the bread produced by the M–1945 Bakery Plant.

PREFACE

In 1968 a study on bread making techniques, was initiated by the Food Systems Equipment Division, Food Engineering Laboratory, to investigate the feasibility of an automated, mobile, field bread-making system utilizing new techniques. Among the techniques examined were a gas-injection proofing system, vacuum proofing and microwave proofing. The gas injection approach was subsequently discarded because commercial equipment never became available. Vacuum proofing was evaluated on a small scale; however, this method must be combined with the baking step otherwise the product will collapse. Microwave proofing and baking were successfully accomplished in standard metal loaf pans but the technique was discarded because, at the time it was too costly to pursue.

Studies of forced convection baking were also carried out and it was shown that one-pound loaves could be baked in about 15 to 20 minutes. To pursue these studies and develop a continuous bread-making system, two continuous-roll baking ovens from an earlier project were modified: one became a continuous proofing cabinet and the other a continuous, forced-air convection oven. The conveying means were adapted to carry one-pound loaf pans. Together with continuous dough-making machinery, a total bread-making process of about one hour was demonstrated. It became clear that a continuous baking system from raw ingredients to sliced, bagged bread could be developed for field use in which the components in individual shelters, van or shipping containers could be assembled on site.

This information came to the attention of The Army Chief of Staff for Force Development who requested a review of the need for field bakery equipment. The Combat Development Command (CDC) subsequently, concluded in 1972 that the M–1945 Mobile Bakery Plant satisfactorily met current requirements, but added that major product improvement of the bakery equipment and process will be needed in the future. Among suggestions listed were: use of premixes, the vertical cutter mixer (VCM), strapped loaf pans, water chilling equipment and forced convection baking. Accordingly, CDC was to prepare a Required Operational Capability (ROC) for the M–1945 product improvement. CDC also recommended continuation of the in-house exploratory development of a new bakery system.

This study was funded under Project Number 1L26374D61001006 and DOD requirement JSR AM6–1.

Because the application of the Automated Bakery System is in United States Military Installations only, United States customary units, not metric, are used throughout this paper.

The authors gratefully acknowledge the assistance over the years of the following NLABS individuals: Dennis Crockett, Joseph Doyle, Domingos Teixeira, John Caya, and Michael Damiano of the Prototype Shop; Henry Russell, Linnae Hallberg, John Swift, and Angelo Testa of the Food Technology Division; and George Alexander, Richard Bernazzani, Robert Buffone, Dominic Bumbaca, Harry Dostourian, Fred Fillo, Douglas Haigh, Francis Mullen, Christopher Rees, and Vincent Ricardi of the Food Systems Equipment Division. Inevitably in attempting to acknowledge the assistance of so many, some names may be inadvertently left out. The assistance of everyone who participated in any way in the evaluation is sincerely appreciated.

TABLE OF CONTENTS

LISTS OF ILLUSTRATIONS

AN AUTOMATED FIELD BAKERY SYSTEM FOR BREAD

INTRODUCTION

The M–1945 System

All rations used by the Army in the field specify bread and/or bread products as components of the daily menu. Present equipment for field-baked bread is the M–1945 Mobile Bakery Plant (LIN M18647). The M–1945 Mobile Bakery Plant consists of a machinery and make-up trailer, three trailer ovens, and associated diesel generators, water tanks and tentage. It is an entirely manual system with the exception of mixing, dividing and forming of the dough. Two 486-pound batches of dough can be made per hour. Each batch is transferred to a dough trough for approximately two hours fermentation; after which the dough is divided, shaped, panned (six – 36 oz pieces per pan) and placed in a proofing cabinet. Proofing takes about one hour. Pans are then transferred to the oven for approximately one hour for baking. The bread is then depanned onto cooling racks and later bagged (one six-loaf cluster per bag).

Although no firm data on the Mobile Bakery Plants production capability over prolonged periods of time exist, the system's operating manual (FM 10–22) indicates a capacity of approximately 11,000 pounds of bread in a 20-hour period. There is some variability in product quality with the M–1945 system(because of the variability in product quality with the M–1945 system) because of the variation in the skills of bakery personnel working with the several bread formulas and because of variations in ambient temperature and humidity, which influence the process, in many geographical areas. Contributing to the lack of skilled bakery personnel was the elimination of the Army's Baker Military Occupational Specialty.

The M–1945 equipment is not in keeping with the current state-of-the-art. Commercial bakery equipment today produces bread and bread products of consistent quality and at production rates of 14,000 pounds/hour or more.

The Army in the field has an operational need for an improved bakery system that can produce bread of consistent quality using less skilled labor.

The M–1945 bakery system is more than 30 years old and spare parts are procurable at a high cost. A Product Improvement Proposal (PIP) to upgrade this system was prepared in 1971 as a first approach to fielding an improved field bakery system. Analysis indicated that the PIP would neither be cost effective nor eliminate the disadvantages of a low production rate and a high labor requirement.

Product Improvement of the M–1945 Bakery Plant

Studies were carried out in 1974 along the lines suggested by CDC; i.e., use of the vertical cutter mixer (VCM), strapped pans and forced convection baking. The VCM did produce a satisfactory product. There was, however, some concern about heat build-up in the mixing bowl, which might affect subsequent mixes and which might require a jacketed cooling system. Variations in mixing time require considerable skill in judging when the dough is ready. The capacity of the VCM is only one third that of the current M–1945 mixer. Space does not permit placing more than one VCM on the machinery trailer, thus heat build-up becomes serious because the single mixer must operate almost continuously.

Strapped pans do result in some reduction in the proofing and baking time, but not enough to eliminate a single oven. Proof time for two-pound loaves was found to be about 55 minutes and forced convection baking about 40 minutes. The use of strapped pans results in increased handling because one-third more pans (162 vs 108) are required to obtain the same production rate. If one-pound loaves were to be produced, then it would be necessary to handle three times as many pans (324 vs. 108). The proof time for one-pound loaves is about 50 minutes and the bake time is less than 25 minutes so that theoretically two batches could be baked per oven per hour. However, because of the long proof time and the larger number of pans which must be used, six proof boxes are needed to go along with the three ovens. The dimensions of the strapped one-pound loaf pans are not much smaller than the standard loaf pans so that only two additional pans can be placed in the ovens. Because any change to smaller loaves only increases the labor requirement, it was felt that a comparison based on two-pound strapped loaf pans was the best compromise.

The major advantage to be gained from the modifications tested in this feasibility study is the elimination of the fermentation step and associated equipment (dough troughs and overhead track). Thus the use of the VCM and premixes means that the first loaf of bread is out of the oven in under two hours and subsequent batches about every ten minutes thereafter. Allowing one hour for cooling, slicing and bagging, the first 72 two-pound loaves are ready for issue in under three hours.

Labor is the major factor that will be affected by these modifications. Although this can be determined accurately only from actual operations, the additional mixing operations, pan handling into and out of the proofer and into and out of the ovens, and the slicing and bagging operations require a minimum of six men per platoon. Other cost elements include the slicing and bagging equipment and redesign needed to permit containerization of the equipment for shipping, and the forced convection oven design.

Other Systems

Two other approaches were taken to define a specific method for furnishing bread in the field.

The first approach analyzed every method available to supply bread for the field soldier. Table 1 summarizes the updated 1978 cost level results. Details covering cost levels that prevailed in 1975 are provided in Appendix A. The data indicate that the M–1945 field bakery was the most economical approach.

The second approach continued the research and development work unit initiated in 1968 entitled, "Investigation of Unique Bread Making Techniques."

Because the M–1945 system requires approximately two hours for fermentation and an hour for pan proofing, a number of approaches that shorten the dough proofing were examined. Of these approaches, gas injection, vacuum and microwave proofing were determined to need

Table 1

Options for Providing Bread in the Field

Basic Form of Bread	Baking Location	Point of Use Cost ($/lb)	Comments
Fresh	CONUS w/ air transport	1.00 1.28	Need committed air transportation; specific cost depends on aircraft used.
	Field Kitchens	0.51	Based on 5 man-hours labor/100 lbs bread.
	Field Bakery	0.25	M–1945 Baking plant
Frozen Whole	CONUS	0.79	Needs freezer storage
Frozen Dough	Field Kitchen	0.59	Needs freezer storage
	Field Bakery	0.50	Needs freezer storage
Frozen Brown & Serve	Field Kitchen	0.78	Needs freezer storage
	Field Bakery	0.76	Needs freezer storage
Shelf Stal... (Canned or Pouch)	CONUS	1.27	Has yet to be completely and successfully developed.

extended developmental effort. Microwave proofing in metal bread pans demonstrated that the quality of the baked bread compared favorably with the controls, but the cost of such a system ruled out this approach. The dough used in this proofing study was made with a laboratory continuous dough maker (AMFlo300, manufactured by American Machine and Foundry Co.) and could be immediately panned and proofed. No intermediate fermentation step was required. Continuous dough making seemed desirable because of the dough maker's simplicity and consistency in producing a good quality product.

Two continuous roll baking ovens, used in an earlier project, were modified: one into a cabinet for dough proofing and the other as an oven for continuous forced convection baking. The conveyors were adapted to carry one pound loaf bread pans. The laboratory continuous dough making equipment, the AMFlo300, and the modified ovens were capable of reducing the total bread-making process to about one hour.

To confirm the cost effectiveness of the continuous and optimally mechanized approach, a cost analysis was carried out based on a 20-year life cycle. The updated 1980 cost results are given in Table 2, with details presented in Appendix B. It should be noted that the continuous system, referred to as the Automated Baking System (ABS), and the M–1945I both included slicing and bagging equipment that was not a part of the basic M–1945 Bakery Plant.

To determine the magnitude of labor reduction possible with the continuous system, production was scaled up to field bakery levels. Procurement action was initiated to purchase a continuous dough maker/pan depositor to operate at 800 pounds/hour. A contract was awarded in 1973. The equipment was delivered in 1975. Procurement action was initiated in 1974 for design and fabrication of the continuous proofer and oven to mate with the dough maker.

The initial concept for mounting the components of the ABS in trailer vans was discarded in favor of mounting them in a container system. This approach is described in the Letter of Agreement (LOA) that was completed and approved April 1977. The LOA emphasized reduction in manpower, reduced need for skilled bakers, environmental protection, and incorporation of slicing and bagging equipment.

In keeping with these requirements, funds were made available to have the proofing and baking ovens housed in containers and to procure containerized equipment to perform the depanning/cooling and slicing/bagging operations. The general arrangement of the ABS is shown in Figure 1.

The Draft Outline Development Plan for the ABS was written in 1979. Due to delays in receipt of the depanner/cooler and slicing/bagging units from the contractor, development testing of the initial prototype, originally scheduled for 2Q80, was postponed to 4Q80. The units still had not arrived by 4Q80. Through an agreement with Testing Commands, testing of available components began at Natick Laboratories. Eventually, the equipment was delivered in March 1981.

During the delay, TRADOC's position had changed and a need for a greater degree of field mobility of the units was expressed. A special In-Process Review (IPR) on the ABS

Table 2

Comparison of Production Costs of Three Field Bread Systems ($/lb)

	M–1945 Field Bakery Plant	M–1945 Improved*	Automated Bakery System
Equipment & Vehicles**	$0.00544	0.00470	$0.00789
Fuel	0.00641	0.01281	0.01282
Personnel	0.09587	0.08760	0.04343
Total	$0.10772	$0.10512	$0.06414

*Incorporation of vertical cutter mixer, strapped pans, power unit and slicing and bagging operation.

**Vehicle life assumed as 5 years; baking equipment life assumed as 20 years.

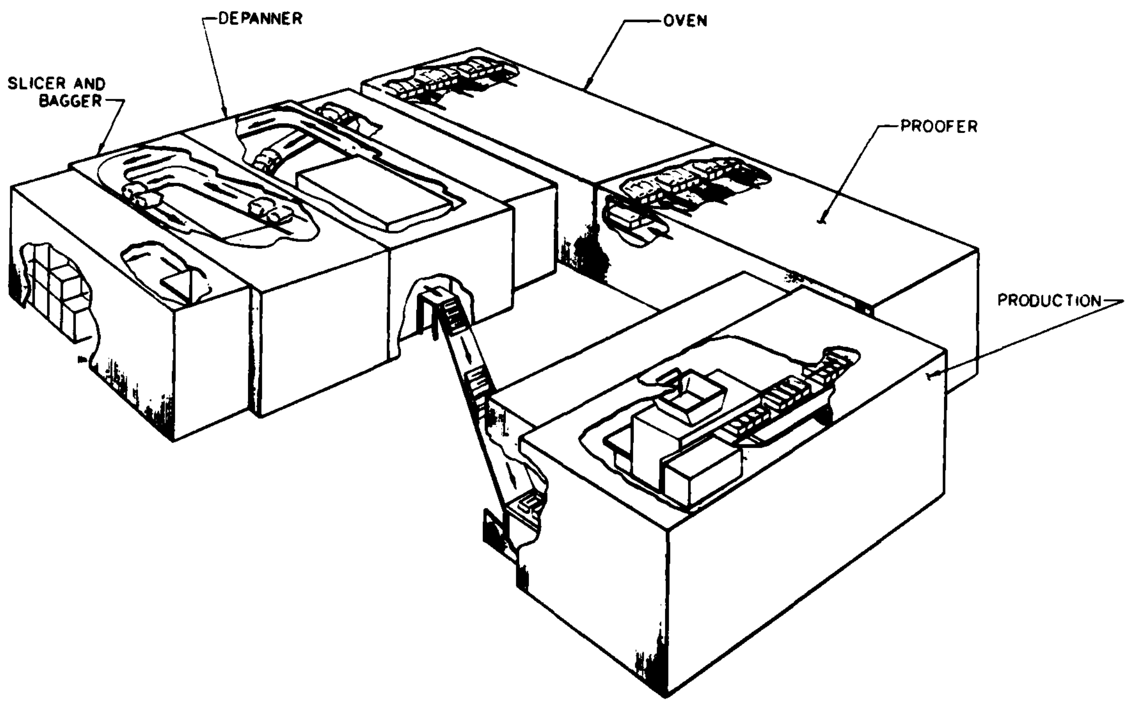

Figure 1. Layout of the Automated Bakery System

was requested and held March 18, 1981. The IPR concluded that the ABS, though responsive to the LOA, was no longer valid. In order to accumulate valuable data that might still prove useful in development of a battlefield bakery system, a continuation of testing was recommended.

AUTOMATED BAKERY SYSTEM

Dough Maker/Pan Depositor

The continuous dough maker/depositor is shown in Figures 2, 3, and 4. This unit of the system performs the following functions: metering and mixing flour and other dry ingredients, shortening and yeast brew; mechanically developing the mixture into a properly textured viscous dough; and depositing measured amounts into sets of strapped bread pans.

Variable-speed, belt-driven pumps deliver the shortening and yeast brew to the premixer. The flour mixture is delivered by a helical screw driven by a variable-speed motor. The premixer is a covered, stainless steel trough with twin auger impellers that mix the ingredients and deliver the mixture to the dough pump. The dough pump is variable speed, belt driven, and delivers the dough mixture to the developer. The unit has two star-shaped impellers (four stainless steel lobes per impeller) built into a machined stainless steel housing that blends, kneads, and develops the dough for pan proofing. Under pressure of the dough pump that feeds it, the developer delivers dough continuously to the pan depositor section of the developer, which by means of a pair of cam actuated jaws that cut off precise quantities of dough and, aided by gravity, delivers the dough pieces a few inches below to indexing bread pans on a conveyor.

Proofing Oven

A view of the proofing oven is shown in Figure 5. It consists of two levels of powered roller conveyors housed in an 8' x 8' x 20' container. The double tier conveyors, which are alternately fed the baking pans provide adequate proofing space for the maximum output of the dough maker/pan depositor. Known for their ruggedness and stability, roller conveyors were selected as suitable components for movable field equipment. The strapped dough pans are alternately delivered three at a time to the two levels of the proofer by an hydraulically actuated, interconnecting feed conveyor. A pusher bar actuated by three micro switches pushes the three strapped dough pans at each level into the proofer. The effectiveness of the proofer can be seen in Figure 6.

The proofing oven has its own fuel-fired, powered burner for providing a suitable proofing temperature with some additional heat being diverted from the oven. Humidity control was provided by piping steam into the oven through a series of manifolded nozzles.

Baking Oven

The baking oven (Figure 7) also has the double tier, powered roller conveyor design. The conveyors are aligned with those in the proofer. The space between the two is bridged by a foldable connecting conveyor section that is physically a part of the proofer oven during transport.

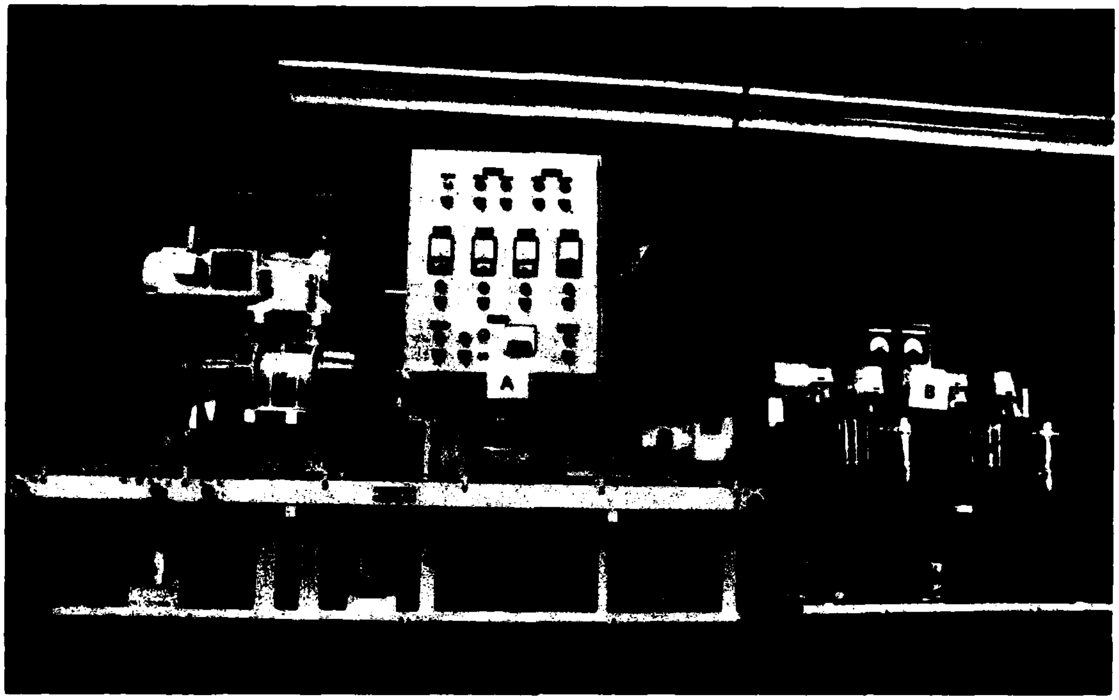

Figure 2. View of continuous dough maker showing control panel (A). Separate yeast brew kettle components (B) shown at the right.

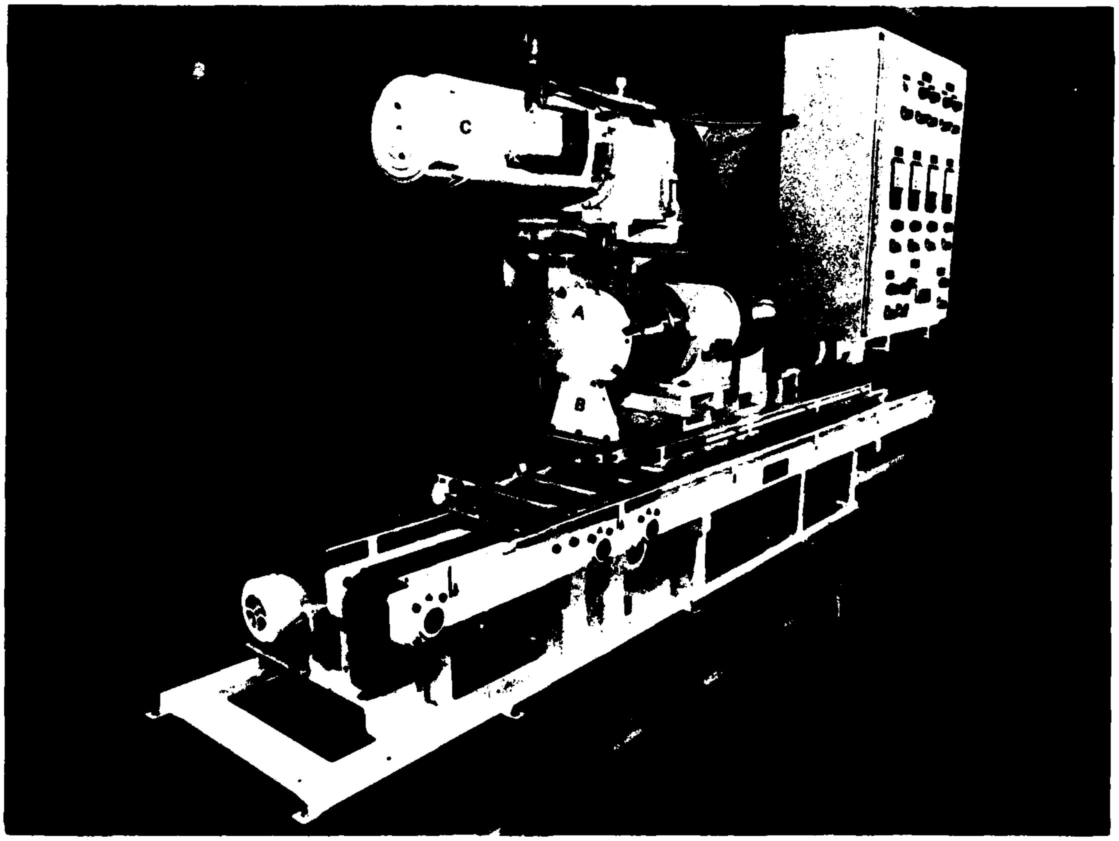

Figure 3. This view of the dough maker shows the dough developer (A), divider and panner (B) and the developer drive motor (C).

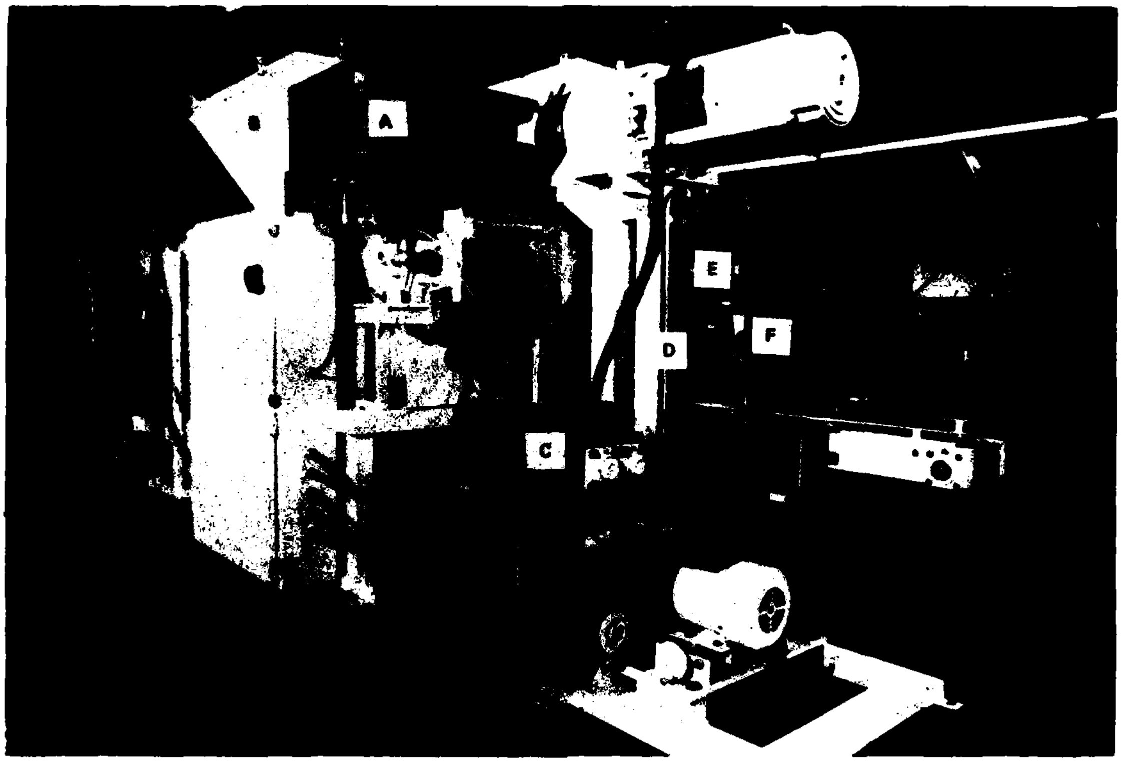

Figure 4. This view from the side opposite Figure 3 shows the shortening tank (A), dry ingredient hopper (B), premixer or incorporator (C), and lines (D) from the dough pump (not visible, but located below the incorporator), to the dough developer (E), and divider/panner (F).

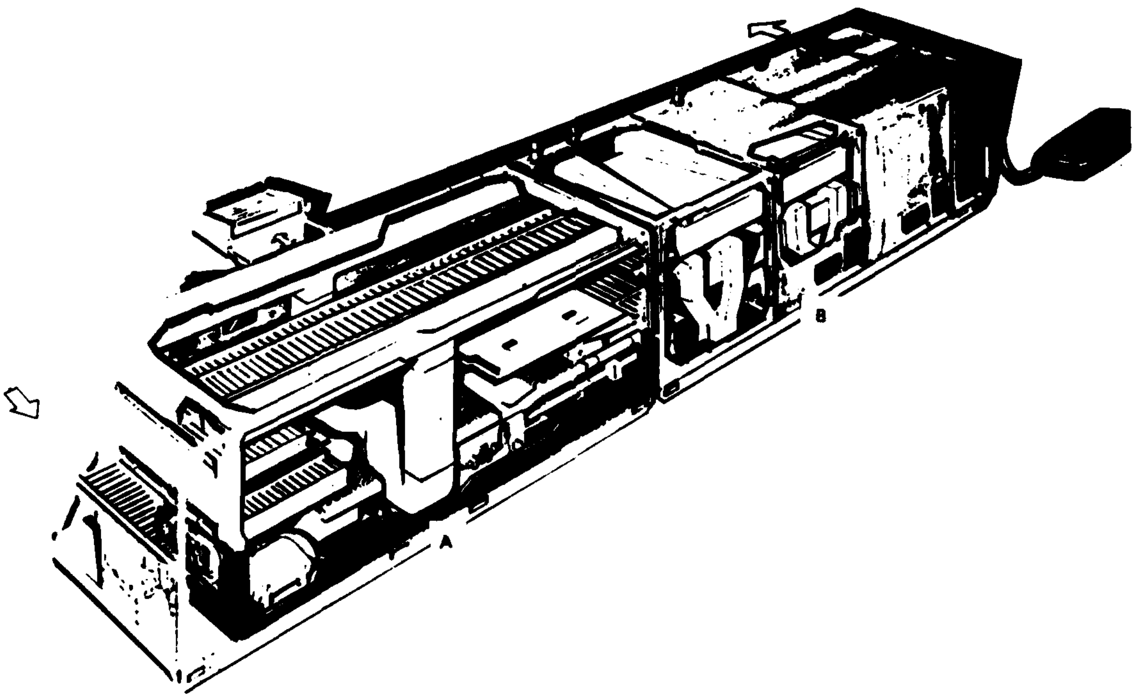

Figure 5. Artist concept of continuous proofer (A) and bake oven (B). Bread from the dough maker enters proofer at the left.

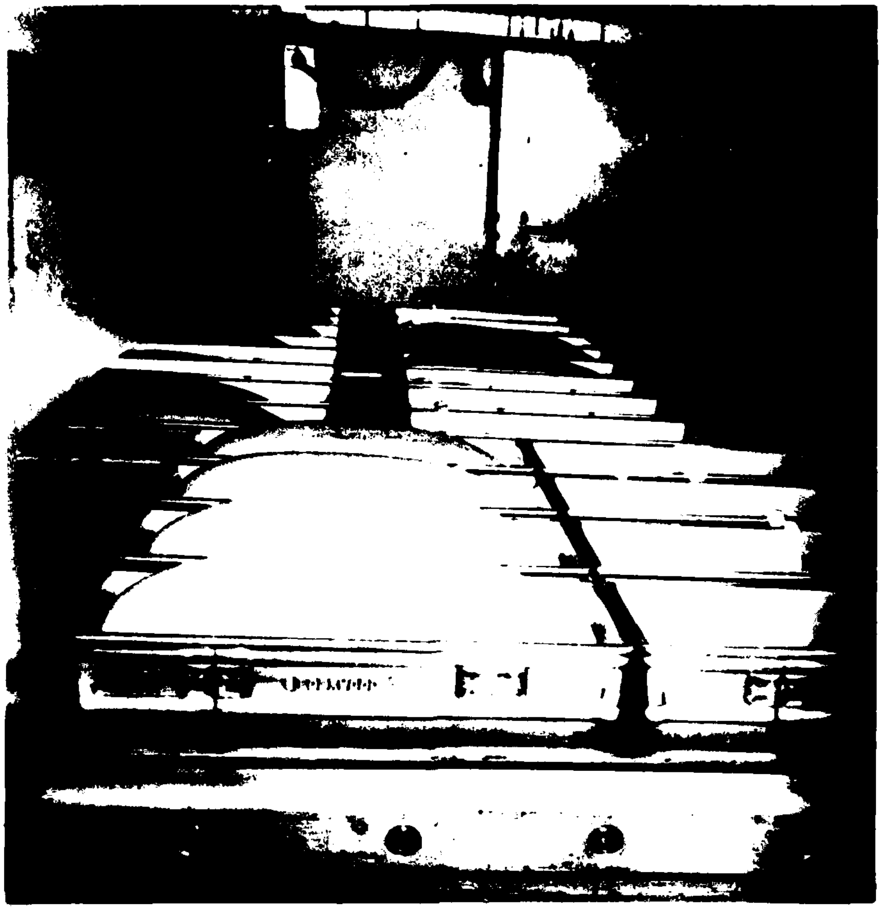

Figure 6. A look inside the proofer at the point where bread transfers to the bake oven.

Figure 7. An exterior view of the bake oven with the burner side open.

Heat for the oven is supplied by three fuel-fired, powered burners capable of burning any of four fuels: JP–4, kerosene, diesel, or gasoline. Each burner can be regulated independently to provide the proper oven temperature. Using three burners provides a degree of reliability. If one or two malfunction, some baking can still be performed. The speed of the oven is greater than the proofer to help prevent jamming in the oven.

Discharging from the oven includes a timed transfer of a row of pans to a periodically raised and lowered belt conveyor operating at right angles to the oven conveyor. Fully baked bread is shown (Figure 8) exiting from the oven. This photograph was taken prior to installing the transfer mechanism.

Figure 8. Bread as it exits from the oven. Photograph was taken before automatic depanning equipment was received.

Depanner/Cooler

The depanner/cooler is housed in a one-sided expandable container. The expandable side contains the accumulating conveyor, which receives the pans of bread from the oven and conveys them to the depanner mechanism.

Depanning is accomplished by elevating two strapped pans at a time to a position where flexible, suction appendages, connected to a vacuum system, engage eight loaves at a time. The pans are lowered and returned by conveyor to the dough maker/pan depositor unit. The loaves, conveyed over to the cooling conveyor, are released and conveyed to the end of each level where they slide onto an indexing tray before being transferred to the next lower level moving in the reverse direction. The bread loaves progressively move down the six levels of this cooling conveyor and at the end of the final pass are indexed by a pusher bar onto another conveyor, which carries them to the slicer/bagger section.

Slicer/Bagger

In this final operation, the individual loaves of bread are sliced and/or bagged. The shelter for this operation is a one-side expandable container. Bread from the cooling section is conveyed into the slicer/bagger shelter directly to the slicer. The slicer is a modified commercial band slicer. The modification was necessary to reduce the overall height of the slicer so that it would fit into the container. Both the slicer and the bagger are wheel-mounted allowing the slicer to be moved into or out of position, thus providing the option of delivering sliced or unsliced, bagged, bread. This operation is the first place where anyone handles the product since the raw ingredients were placed into the brew kettles, shortening pan, and dry materials hopper.

Support Module

This sixth component of the ABS was designed to house the two diesel electric generators that provide the power to operate the system and a small repair shop complete with tools, parts, and hardware to perform operational maintenance functions. Built according to International Standard Organization (ISO) dimensions for containers, i.e., 8' x 8' 20', it is essentially the ISO frame with mounted and exposed diesel generators, and a closed area, each occupying approximately half the frame.

OPERATIONAL CONSIDERATIONS

Dough Maker/Pan Depositor

The operation of the unit is described as follows: the basic ingredients – dough mix, yeast brew, and shortening, are delivered from the dry ingredient mix hopper, brew tanks, and shortening tanks at predetermined rates to a premixer (incorporator) located just below and in front of the shortening tank (Figure 4). When the dough level nears the top of the incorporator, the dough pump is turned on and the developer motor is set at maximum revolutions per minute. When the dough begins to flow through the developer by-pass, a three-way valve in the line is turned, diverting the dough into the developer. After approximately 30 seconds, the divider/panner drive motor is turned on and strapped pans begin indexing under the depositor. Properly developed dough will usually begin depositing after approximately a dozen pans have been filled. At this point, it should be necessary to keep only the individual component hoppers and tanks filled with ingredients.

Although the dough maker/pan depositor has performed essentially without a flaw, there are some aspects of its design that should be changed in any new production arrangement. A one-side expandable ISO shelter has been obtained for this unit but the unit has not yet been installed in the shelter.

In addition to installing the dough maker/pan depositor, matters to be considered in outfitting the shelter include:

(1) A water heater to provide controlled-temperature water to the yeast brew tanks and hot water for sanitation purposes;

(2) A sink for cleaning components of the dough maker;

(3) A heat exchanger to control brew tank temperature during operation at extreme temperatures;

(4) Storage for spare parts, tools, etc.

Changes that should be made in the design of the dough maker include the following:

(1) **Feed Hopper.** In case pre-prepared mix is not available, the dry ingredient hopper should contain a system that can mix the basic dry ingredients. One suggestion is to mount a ribbon mixer above the feed trough with a sliding partition or gate between the two. The trough should be enlarged to hold enough dry ingredients for a 20-minute operation, while the ribbon mixer is being loaded and operated to prepare a batch of mix. Under normal conditions, using a pre-prepared mix, the mixer partition is left open and the mixer operated to prevent bridging of the dry ingredients. Alternatively, many of the dry ingredients could be fed in with the yeast brew. To provide sufficient space to load the hopper from above, the design should provide sufficient headspace to accommodate a container eight feet high.

(2) **Incorporator.** Since clean-up during shutdown is very difficult and time consuming, the design of this premixer is problematic. A preferred arrangement would be to include the

capability for removing the impeller so that it can be cleaned in the sink. Then, the mixer hopper can be easily cleaned out.

(3) **Dough Pump.** The location of the drive motor to the divider panner hinders the accessibility of the dough pump for cleaning. A larger drive belt would provide more working space.

(4) **Floor Drainage.** During clean-up, water accumulates on the floor and under the equipment. Some floor drains and grating should be provided. Grating should be easily removed to clean underneath.

(5) **Materiel Handling Equipment (MHE).** Some method should be provided to facilitate emptying bags of ingredients into the dry ingredient hopper. The difficulty at this stage is compounded by the lack of headspace.

Proofing Oven

Although the proofing oven performed satisfactorily, some design changes should be made. Humidity control by steam injection is effective but presents both maintenance as well as operational problems. A much simpler, heated water pan approach, originally built into the system, should be perfected.

In addition, the location of drive chains inside the proofer makes lubrication difficult.

Baking Oven

The two major deficiencies in this unit are (1) the drive chain's location inside the oven that makes maintenance and lubrication difficult, and (2) controlling oven temperature.

When the oven is operating at high temperatures, the drive chain at its present interior location is very difficult to lubricate. To relocate the drive mechanism outside the oven shell, a complete redesign is necessary. If a break should occur, it would be possible to repair the chain without having to shut down and cool the oven.

All petroleum-based lubricants charred, hardened, and coated the bearings, making them unacceptable. The only effective lubricant was a water-based graphite. The disadvantage of this lubricant was the lack of protection during long periods of inactivity.

Upper and lower oven temperature differences need to be corrected. The lower oven provides excessive heat to the bread surface and, as a result, often the crusts are charred while the loaf interiors may be underbaked.

The original oven design had heated air circulating through ducts. The hottest air was directed to the bottom of the upper oven while the opposite effect was planned for the lower oven. In order to balance temperatures and obtain uniform baking, a damper system in the ducts was provided to divert the air flow. The traditional and successful baking approach requires intensive heating from the bottom. The ABS oven results confirmed this approach.

The upper oven yielded an excellently browned and uniformly baked loaf; the lower oven frequently produced a charred and partially baked loaf. Adjustments to the damper system and minor ducting changes insufficiently reduced temperature variations.

Depanner/Cooler

The general performance of this unit must be considered unsatisfactory. The major components, the mechanism that places the pans from the two levels of the oven to a single level, the accumulating conveyor, and the depanner work exceptionally well, However, the cooling tier conveyor has numerous problems. The major deficiencies are in the mechanism that lowers the bread from tier to tier. Any change in bread consistency can create loaves that stick or hang up on the wire conveyor or slide eratically on the lowering shelves. One stuck loaf results in a chain reaction damaging many loaves and interrupting the operational system. Simpler and lighter conveyor cooling systems have been identified to replace the existing system.

Slicer/Bagger

There are a number of much simpler, lighter, and less costly bagging machines that can replace the high-speed machine selected. Also, a smaller, less costly slicer is available that would better suit the requirements of the ABS.

Support Module

Although the diesel generators and the repair shop were mounted on the ISO frame, this part of the system was not tested.

RESULTS OF PRODUCTION TESTING

The arrangement of the equipment for dough making is shown in Figure 9. Initially, a one-side expandable hard shelter (8′ x 8′ 20′) was presumed to provide adequate space to house the dough making operation. To expedite testing, an expanded 8′ x 8′ x 20′ shelter was marked out on the floor of the laboratory and an open wall of 2″ x 3″ lumber was erected to simulate the confines of this shelter. With the exception of the Support Module, all other elements of the ABS were assembled inside, as shown in Figure 1.

The start-up procedure is described in detail in Appendix C. The formulas used are given in Table 3. Based on the white bread formula, a quantity of bread dough mix (in 50 pound bags), was purchased from a local supplier. The feed rate of the various components of the dough are shown at the bottom of Table 3. Feed rates are calibrated by dispensing quantities of mix, brew, and shortening into tared containers for a set period of time, usually 30 seconds to one minute, then reweighing the container. Delivery rate changes are made by adjusting drive motor speeds or pump speeds until the required rates are obtained. Once feed rates have been set, they will remain reasonably constant but should be checked periodically, possibly, once. a day.

Table 3

White and Rye Dough Formulas

White Bread		Rye Bread	
White flour –	208.50 lb	White flour –	190.00 lb
Sugar	10.56 lb	White rye	47.50 lb
Salt	4.125 lb	Salt	5.00 lb
NFDM	6.56 lb	Sugar	6.00 lb
Yeast food	1.00		
Do-control	1.63		
	232.375 lb		248.50 lb
Brew		**Brew**	
Water	160.00 lb	Water	156.75 lb
Yeast	5.25 lb	Yeast	6.00 lb
Mix	23.50 lb	Mix	24.85 lb
Bromate	2 Tablets	Bromate	2 Tablets
Shortening	6.03 lb	Shortening	6.00 lb

Feed Rates

	White Bread	Rye Bread
Dry mix	6.96 lb/min	7.455 lb/min
Brew	6.30 lb/min	6.25 lb/min
Shortening	90 g/min	91 g/min

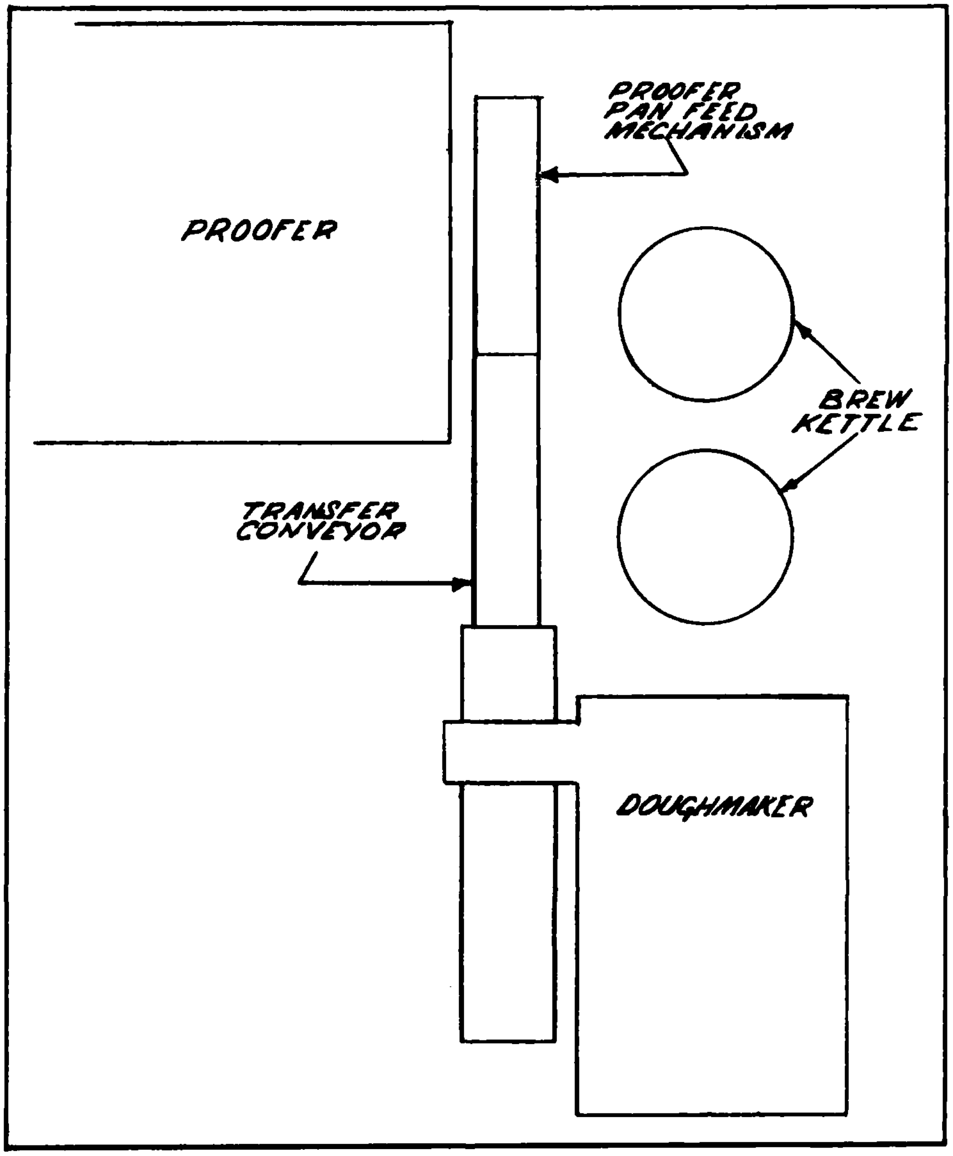

Figure 9. Layout of the dough-making equipment and relationship to the proofer.

Because bread loaves exiting the oven often had collapsed side walls, giving a keyhole-shaped cross section, a number of runs were made in which the developer speed was varied. Apparently, fully developed dough could be produced at almost any developer speed from 100 to 200 rpm. In most runs, a developer speed of 150 rpm was used. However, after several closely monitored runs, evidence indicated that only at 200 rpm, the upper speed limit of the developer, could straight side-walled loaves of bread be produced consistently (Figure 10). This developer speed yielded a very relaxed dough. The lower speeds produced a developed, but recognizably stiffer dough that proofed adequately. However, when this stiff dough entered the oven, the high temperature caused a rapid development of the dough in the pan resulting in collapsed sides. Commercial baking operations allow the dough to relax after panning so that this distortion does not occur during baking. The ABS process does not provide time or space for the relaxation step; therefore, a more relaxed dough must be produced by higher developer speeds.

Figure 10. Effect of the developer speed (rpm) on the shape of the bread loaf.

Brew kettle operations require proper timing of batch make-up for continuous dough making. A 20-gallon batch is adequate for 30 minutes of dough production. If 30 minutes of fermentation is desired and with only two 40-gallon kettles available, no time is allowed for making up a second batch. Since the yeast growth creates considerable carbon dioxide effervescence and overflows the kettles, a 28-gallon batch of yeast brew is almost too much. A third kettle of the same size (40 gallons) or possibly two larger size kettles (e.g., 60 gallons) would be needed.

Continuous runs of rye bread and white bread were carried out producing four complete batches without shut down. During white bread production, an attempt was made to make a few loaves of raisin bread by manually introducing the raisins into the incorporator. The developer, however, reduced the raisins to small specks, unrecognizable as raisins.

Dough production is limited to about 850 pounds of dough per hour by the speed of the dough pump. Since the various ingredient feed mechanisms all are operating below their maximum feed rates, a change in the gears that drive this pump could increase production to at least 1,000 pounds per hour. Also, the developer, proofer, and oven should be able to handle this higher volume. However, about 20% more brew kettle capacity would be required.

The processing time for each step of the ABS operation is given in Table 4. Total time from start of ingredient flow to bagged product is one hour and 49.4 minutes. This compares to the approximately seven hours for producing bread ready for delivery by the M–1945 Bakery Plant. Representative operating conditions for the ABS are given in Table 5.

Staffing considerations

A tentative staffing requirement for the ABS is given in Table B–3. Although based on limited operation of the ABS components in this laboratory, it appears that the following personnel are essential for successful operation:

(1) **Doughmaker operators.** After start up, which takes no longer than 40 minutes, the doughmaker operator is free to perform other tasks such as assisting in keeping the mix hopper and the shortening tank filled, making up kettles of yeast brew as needed, and adding shortening

Table 4

Automated Bakery System Processing Times for Each Step

Function	Time per Function (Minutes)	Cumulative Time (Minutes)
Dough Mix Development and Panning	4.0	4.0
Feed to Proofer	0.2	4.2
Proofing	35.0	39.2
Baking	25.0	64.2
Depan and Cool	45.0	109.2
Slice and Bag	0.2	109.4

Table 5

Automated Bakery System
Representative Operating Conditions

Operating Variable		Rate
Doughmaker:		
Dry mix feed		417 lb/hr
Brew feed		378 lb/hr
Shortening feed		1.2 lb/hr
Loaf Panning (18.0 oz/loaf)		690 loaves/hr
Proofer:		
Temperature		65–70°F
Relative Humidity		60–80%
Proofing time		35 min
Oven:		
Temperature	– Zone 1	400°F
	– Zone 2	450°F
	– Zone 3	400°F
Baking Time		28 min
Diesel fuel consumption		4 gal/hr
Depanner/Cooler:		
Air conditioning		2 ton unit
Suction blower		10 HP motor
Slicer/Bagger:		
Bag size		Standard 1 lb loaf
Power Module:		Fuel Consumption:
60 kW generator		4–6 gal/hr

to the pan greasing tank. The only other task for the doughmaker operator is to tear down and clean up the equipment when the baking day ends. Two persons should be more than adequate to operate this unit.

(2) **Packaging equipment operators.** Aside from general monitoring of the various operations, the only other laborious task is handling the bagged loaves of bread at the end of the run. Two men should be able to keep up with the output of the bagging equipment.

(3) **Maintenance person.** The maintenance person's responsibility would be to monitor proofer and oven conditions (temperature, humidity, conveyor speed), lubricate conveyor drive chains and motors, monitor burner unit performance during baking operations, and perform general maintenance on all components of the system. On the basis of actual operation of the ABS over several months, all bakery personnel should be trained for all positions including some of the simpler maintanance functions. For short runs of one to two hours it appears that the actual on-the-job personnel requirement during operation could be much less than indicated in Table B–3. The revised staffing is shown in Table 6 for a two-shift operation.

Table 6

Automatic Bakery System Staffing Based on Operating Experience

Platoon Ldr, Lt.	1
Platoon Sgt, E–6	1
Shift Ldr, E–5	2
Bakers, E–4	4
Mechanic, E–4	2
Heavy Truck Driver, E–4	1
Light Truck Driver, E–3	2
	13

DISCUSSION

During the investigation, all elements of the ABS operated continuously with only minor problems that were correctable. It should be noted that this unit was a "feasibility" model. Any deficiencies and shortcomings identified would be corrected in any follow-on model. The major deficiencies and areas that require improvement have been listed in previous sections describing the various system components.

In comparing the ABS with the M–1945, it is readily apparent that use of the ABS reduces labor and the number of skilled workers significantly. Also, there are fewer burdensome tasks, such as punching the fermented dough and manhandling heavy pieces of dough from the fermentation troughs to the dough divider. The numerous manual transfers of heavy dough pans into and out of the proofers and ovens are eliminated. Personnel who could be used more productively elsewhere are required for these tasks and there is also a degree of danger in handling the hot bread pans and manual depanning loaves onto cooling racks.

The effect of this lower staffing requirement over that originally estimated (Appendix B) is to reduce the personnel operating costs to $0.0253/pound of bread. The total cost (equipment, vehicles, fuel and personnel) is reduced to $0.04424/pound of bread or almost six cents per pound less than the M–1945 Bakery Plant. Even tripling the equipment costs adds less than two cents to the cost of bread produced by the ABS.

Some redesign is required to perfect the ABS. Specifically, the conveyor drive in the oven and proofer needs to be made more accessible for lubrication purposes; to obtain a more uniform temperature distribution in the upper and lower oven sections the heating air-ducting in the oven needs to be modified; and the bread cooling system needs to be simplified. None of the modifications is particularly difficult to accomplish.

CONCLUSIONS

It was demonstrated that the ABS model can produce, on a continuous basis, 850 lbs of bread dough or approximately 750 pounds of sliced and bagged bread each hour. White and rye bread were produced and it should be possible to produce whole-wheat bread without difficulty.

It was also shown that the ABS requires fewer, less skilled (except for maintenance) personnel to produce high-quality bread, efficiently, consistently, and at less cost compared to the M–1945 Bakery Plant. Trained bakers are not needed, since the operation of the dough-making equipment can be programmed so that, once ingredient feed rates have been calibrated, the operation can be started and maintained simply by activating a single switch.

RECOMMENDATIONS

The Automated Bakery System should be given serious consideration as a replacement for the M–1945 Bakery Plant.

To eliminate the deficiencies found in the feasibility model, the necessary modifications should be made and the system tested in the field.

APPENDIX A

Analysis in Support of Automated Field Bakery System

APPENDIX B

Production Costs of Field Bakery Systems

APPENDIX C

Instruction Manual — Operation of Continuous Dough Making and Dough Depositing Machine with Pan Indexing

APPENDIX A

Analysis in Support of Automated Field Bakery System

INTRODUCTION

The analysis that supported and helped justify the approved Letter of Agreement for an Automated Bakery System, consisted basically of two phases:

1. The initial considerations involved alternate methods for providing either ingredients, semi-prepared bread or prebaked bread to a theater of operations. It was assumed that fresh bread would not be available locally in a theater of operations.

2. Since the results of the basic logistical findings indicated that the most economical technique would be the use of a field bakery, the trade-off analysis then narrowed down to determining the most appropriate specific design for a field bakery. In addition to an economic measurement, expressed as Relative Worth, design selection was governed by:

   a. Recognition that skilled bakers would be scarce in the future;

   b. The need to furnish a finer textured, "commercial-style" bread of greater familiarity to the current generation of soldier;

   c. Establishment of baking parameters that were compatible with the needs for continuous operation.

OPTIONS FOR BREAD TO THEATER OF OPERATIONS

Table A–1 gives the point of use costs and lists special considerations for the basic methods of supplying bread to the field: baked fresh from ingredients; frozen in some form at some stage of the process; and shelf-stable, a method yet to be satisfactorily developed. Cost factors for the original analysis (1975) were as follows.

1. Base labor cost was figured as an E–3 plus 100% overhead. The base rate was $5.00/hour;

2. Material costs were based on typical bread formulas with ingredient prices as listed in the Federal Stock Catalog;

3. In some instances, where no data were available, a best "guesstimate" was made.

It was assumed that the distribution and storage system could accommodate the volumes and the shelf life limits of each alternate.

The figures used for the 1975 analysis were increased by seven percent per year for three years for inflation. Transportation costs were added, based on

Table A–1

Options for Providing Bread in the Field

Basic Form of Bread	Baking Location	Point of Use Cost ($/lb)	Comments
Fresh	CONUS w/ air transport	1.00–1.28	Need committed air transportation; specific cost depends on aircraft used.
	Field Kitchens	0.51	Based on 5 man-hours labor/100 lbs bread.
	Field Bakery	0.25	M–1945 Baking plant
Frozen Whole	CONUS	0.79	Needs freezer storage
Frozen Dough	Field Kitchen	0.59	Needs freezer storage
	Field Bakery	0.50	Needs freezer storage
Frozen Brown & Serve	Field Kitchen	0.78	Needs freezer storage
	Field Bakery	0.76	Needs freezer storage
Shelf Stable (Canned or Pouch)	CONUS	1.27	Has yet to be completely and successfully developed.

$169/40 ft^3 for perishables for 3,000 miles of sea transport, or

$ 65.69/40 ft^3 for nonperishables during sea transport.

FIELD BAKERIES

Because the basic analysis pointed towards a field bakery and exploratory development provided a basis for considering continuous processes, a comparison was made between the M–1945 mobile bakery and a concept for a continuous system. Preliminary considerations were:

1. A product improvement program for the M–1945 bakery was indicated to be non-cost effective;

2. The addition of depanning, cooling, slicing and bagging functions to field bakery operation would extend shelf life while saving bakery personnel;

3. The one half pound per man per day issue factor was based on unsliced bread. A reduction in the issue factor for sliced field bread was therefore considered a strong possibility.

Table A–2 presents costs to field an M–1945 bakery. Costs for 1978 were based on 1975 costs multiplied by 1.22 (7% per year increase). Table A–3 presents a similar break-out estimated for an automated field bakery system.

If, therefore, for a corps of 100,000 a comparison of field bakery needs is made, it would be:

1. On the basis of all procurement costs assumed in first year.

9 M–1945 bakeries per corps	$4,397,760
3 Automated field bakery systems	$2,730,381
The potential savings, on annual fielded basis is:	$1,667,379

2. If the major equipment items are given a 20-year useful life and vehicles are given a five-year life and a simple straight line amortization is assumed.

9 M–1945 bakeries per corps	$1,922,292
3 Automated field bakery systems	$ 486,246
Potential savings per year:	$1,436,046

The decision was made to proceed with the development of an automated field bakery system.

Table A–2

Cost to Field M–1945 Mobile Bakery System

Major End Items		
Mixing and Makeup Trailer		$ 83,407
Bakery Ovens (3)		60,932
Proof Cabinets (3)		11,276
Sifting Machine		5,725
	Subtotal	$161,340
Other Components		
Shelters (6)		6,622
Ancilliary Bakery Equipment		75,511
Vehicles		49,266
Adminstrative and Personal Equipment		5,928
	Subtotal, Equipment	$298,667
Personnel (19) (Annual)		189,973
	Total Cost	$488,640

Table A–3

Estimated Cost To Field the Automated Bakery System

Dough Developer		$ 91,500
Proofer		91,500
Oven		274,500
Depanning-Cooling Unit		30,500
Slicing-Bagging Unit		14,640
Power and Service Unit		42,700
Shelters (6)		226,920
	Subtotal	$772,260
Vehicles		13,786
Administrative and Personnel Equipment		3,743
Personnel		120,338
	Total Estimated Fly-Away Cost	$910,127

APPENDIX B

Production Costs of Field Bakery Systems

A summary of the costs of the several systems is shown in Table B–1. These estimates are based on our best judgement and costs incurred in contracts for ABS components already procured. It is certain that the M–1945 Bakery Plant could not be procured today without some redesign effort and some change in certain components, nor would it be desirable to reproduce it exactly as it is. The values shown also include an inflation factor.

Production costs based on amortization of the plant over 20 years and vehicles over five years, fuel costs, and personnel costs are strongly in favor of the ABS system. Even on a worst case basis for the ABS (22 men, 14,400 pounds bread production) the cost per pound of bread is over four cents less than under the other two systems.

On the basis of a production level of 18,000 pounds per 20 hour day – which is a distinct possibility with the ABS – the cost per pound of bread produced is only $0.049. When considered on the basis of supplying a 100,000 man force with 0.5 pounds of bread/man/day, there is a need for five M–1945's (4.45), four M–1945I's (3.44) and three ABS (2.77), the latter based on a production level of 18,000 pounds/day.

It is clear that personnel costs will always be significantly less for an automated system than a manual system. We did not cost out a comparable German system at this time, but from the limited information available, it appears as labor intensive as the M–1945 and its price was about $500,000 in 1978.

The fuel usage is shown only for the diesel generator required. An M–1945 using a VCM will require a 60 kW generator, which uses twice as much fuel as the 30 kW generator. The fuel required per hour for the ABS which uses three burners will be about the same as that used by the three ovens of the M–1945's. In any case, the cost of fuel per pound of bread baked is minor in comparison to personnel costs.

Table B–1

A Comparison of Production Costs for Several Field Bread Baking Systems
(Calculations are based on indicated line numbers)

		M–1945	M–1945 I	ABS
1	Vehicles (5 years)	$ 49,266.00	$ 49,266.00	$ 13,786.00
2	Cost/year (1)÷5	9,853.20	9,853.20	2,757.20
3	Equipment (20 years)	249,667.00	301,016.00	776,003.00
4	Cost/year (3)÷20	12,470.05	15,050.80	38,800.15
5	Equip. & Vehicles (cost/yr) (1)+(3)	22,323.25	24,904.00	41,557.35
6	Equip. & Vehicles (cost/yr) $\frac{(1)+(2)}{365}$	61.16	68.23	113.67
7	Production/day (pounds)	11,232.00	14,512.00	14,400.00
8	Cost/pound of bread (6)÷(7)	$0.00544	$0.00470	$0.00789
9	Fuel cost/day*	72.00	144.00	144.00
10	Cost/pound of bread (9)÷(7)	$0.00641	$0.01282	$0.01282
11	Personnel costs	393,066.00	464,068.00	228,281.02
12	Number of personnel	38	46	22
13	Cost/day** (11)÷365	1,076.89	1,271.39	625.42
14	Cost/pound of bread (13)÷(7)	$0.09587	$0.08760	$0.04343
15	Cost summary/pound of bread			
Summary of Costs				
	Equipment & Vehicles (8)	$0.00544	$0.00470	$0.00789
	Fuel (10)	0.00641	0.01282	0.01282
	Personnel (14)	0.09587	0.08760	0.04343
		$0.10772	$0.10512	$0.06414

*Based on fuel consumer per day by 30 kW Diesel generator for the M–1945 and 60 kW Diesel generator for the other two.

**Cost/day based on 365 days.

Table B–2

A Comparison of Personnel Costs for Several Field Bakery Systems

Personnel costs	
Platoon, LT	$13,780.80
Platoon, SGT, E–6	$14,553.36
E–5	$12,277.44
E–4	$10,440.00
E–3	$9,312.48
E–2	$9,312.48

	M–1945	M–1945 I	ABS
Platoon Ldr. Lt	1	1	1
Platoon SGT, E–6	1	1	1
Shift Ldr, E–5	2	2	2
Bakers, E–4	18	18	8
Mechanic, E–4	1	1	1
Hv Truck Driver, E–4	1	1	1
Mixer Operators, E–4	2	2	
Oven Operators, E–4	2	2	
Baker's Helpers, E–3	4	4	4
Baker's Helpers, E–2	4	4	4
Lt Truck Driver, E–3	2	2	
Slicing, E–3		2	
Bagging		2	
Add'nl for VCM, E–2		2	
Add'nl for Pan Handling, E–2		2	
	38	46	22

Table B–3

Estimated Cost of Equipment Required by Field Bakery Systems

	M–1945	M–1945 I	ABS
Mixing and Makeup Trailer	$83,407	$83,407	
Ovens (3)	60,932	60,932	
Proof Cabinets (3)	11,276	11,276	
Sifting Machine	5,725		
Shelters (6)	6,622	6,622	$226,920
Ancillary Equipment	75,511	75,511	
Vehicles	49,266	49,266	13,786
Adm. and Personnel Equipment	5,928	5,928	3,743
Dough Developer			91,500
Proofer			91,500
Conveyor Oven			274,500
Depanning-Cooling			30,500
Slicing-Bagging		14,640	14,640
Power and Service Unit		42,700	42,700
	$298,667	$350,282	$789,789

APPENDIX C

Instruction Manual-Operation of Continuous Dough Making and Dough Depositing Machine with Pan Indexing

Sample Calculations For Ingredient Feed Rates

The continuous mix process requires that a steady stream of dough be supplied from the premixer to the developer. In order to keep the premixer filled to the proper level with dough, it is necessary to supply it with ingredients in the proper proportions and at the proper delivery rates. Therefore, prior to the start-up of the continuous mix operation, it is necessary to establish the dry mix and yeast brew formulas and to calculate the feed rates for the dry mix, yeast brew and shortening. Since all of these calculations depend upon conditions existing in the field, the conditions specified in the contract have been chosen for the following illustration:

Conditions:

1. Scaling weight: 18 ounces = 1.125 pounds
2. Rate of production = 12 loaves per minute, or 810 pounds per hour
3. Broth size: 30 minute bath

Dough formula:

	Percent
Flour	100.00
Water	64.00
Yeast	2.50
Sugar	5.00
Salt	2.00
Dried skim milk solid	3.00
Yeast Food	0.50
Mycoban	.25
Shortening	4.00
Bromate Tablet	(1)
Enrichment:	
Formula Weight	181.25
Less Fermentation Loss	.75
Total Dough for Scaling	180.50

It should be noted that the fermentation loss occurs in the brew due to loss of weight by fermentation and by evaporation. The value shown above represents about 1% of the initial weight of the brew.

Fermentation loss will vary with conditions; the more vigorous the fermentation action, the dryer the atmospheric conditions and the longer the fermentation time the greater the fermentation loss will be. A fermentation time of two to two and one half hours will result in a loss of about 2%. Shorter fermentation periods will result in proportionately smaller losses.

Dough Feed Rate

As previously mentioned, the dough must flow to the developer at a steady rate. In establishing this rate, the capacity of all bakery equipment must be considered. A small safety factor should be included to allow for the normal fluctuation in bakery conditions so that they will not cause unnecessary breaks in the continuous process. In this example, the dough feed rate will be 12 x 1.125 = 13.5 lb/minute; 60 x 13.5 lbs per minute = 810 lbs/hour.

A study of the representative formula reveals that 100 lbs of flour will produce 180.5 lbs of dough. Since only 13.5 lbs of dough are required per minute, then the flour needed is 100 x 13.5/180.5 = 7.48 lbs per minute. This will amount to 60 x 7.48 = 449 lbs of flour for each hour or 30 x 7.48 = 224.5 lbs of flour for each half hour or each brew batch.

For convenience in handling, etc., the dough formula is broken down into three ingredient blends.

1. Dry Mix (Pre-blended and packaged)
2. Yeast Brew (Prepared during operation)
3. Shortening Blend (Pre-blended and packaged)

These three ingredient blends contain all of the ingredients required in the dough. Each is introduced continuously by an ingredient feeder.

Dry Mix Formula

	Bakers Percent	
Flour	100	
Sugar	5	
Salt	2	
Nonfat Dry Milk	3	
Mycoban	0.25	
Mineral Yeast Food	0.50	
Total	110.75	
10% Used in brew	11.075	
Fed as dry mix	99.675	99.675

Brew Formula

Water	64	
Yeast, Actively	2.50	
Bromate Tablet	(1)	
Enrichment Tablet	(1)	
10% dry mix	11.075	
	77.575	77.575
Shortening	4	4
Total Percent		181.25

Yeast Brew

The yeast brew includes all ingredients that contribute to fermentation. Each brew must be large enough to sustain production for a definite period (in this case 30 minutes). Each brew is set at about 85°F and after fermentation of 30 to 60 minutes should be at a temperature of 88 to 89°F. The yeast brew feed rate will be the final weight of the brew batch divided by the production period covered (in this case 30 minutes). The amount of each ingredient used in the brew will be the formula weight of the ingredient multiplied by the weight of the flour per brew and divided by 100. In the example, the weight of the flour used per brew is 225 lbs and, therefore, the amount of each ingredient used in the broth will be the formula weight multipled by 2.25.

Brew Formula Calculations:

Water (64 x 2.25) = 144

Yeast (2.5 x 2.25) = 5.625

Bromate Tablet (1 x 2.25) = 2.25

Dry Mix (11.075 x 2.25) = 24.91875

Dry Mix

The dry mix includes all of the ingredients not inquired for the fermentation that lend themselves to preblending and good stability in handling. The amount of each ingredient used in the dry mix will be the formula weight of the ingredient multiplied by the weight of the flour per half hour and divided by 100. In the example, the weight of the flour used per half hour is 225 lbs. Therefore, the amount of each dry mix ingredient required will be the formula weight multiplied by 2.25.

Dry Mix Formula Calculations:

	Pounds For 30 Minutes
Flour (100 x 2.25)	225.00
Sugar (5 x 2.25)	11.25
Salt (2 x 2.25)	4.50
Nonfat Dry Milk (3 x 2.25)	6.75
Mineral Yeast Food (0.5 x 2.25)	1.12
Mold Inhibitor (Mycoban) (0.25 x 2.25)	0.56

Setting Feeder Rates

The ingredient feed rates are adjusted by changing the speed of the feeders. The speed of the Brew and Shortening Feeders and the Dough Pump are adjusted by moving the motor base to adjust the drive pulley ratio. Before starting to operate the unit the feeders should all be pre-set at the desired feed rate.

The accompanying curves were prepared as a guide in achieving the desired setting. It should be remembered that these curves were prepared using available materials under conditions that existed at the time. The feed rate will vary with the density of the materials and the density will be affected by temperature, moisture, formulation, age of fermentation, etc.

From the curves select the speed that should produce the desired feed rate. Set the feeder at that rate and when the feeder has run long enough to insure that the rate has stabilized collect three (3) successive timed samples of one minute duration. Weigh the samples and deduct the tare weight to determine the net feed rate per minute. If the three (3) samples are similar their average is a pretty accurate determination of the feed rate at that setting.

If the feed rate is not close enough to the desired rate, make a proportional adjustment of the speed and repeat the check.

If the timed samples are not similar repeat the process until reliable series has been run. Make sure to use a technique that results in accurate timing.

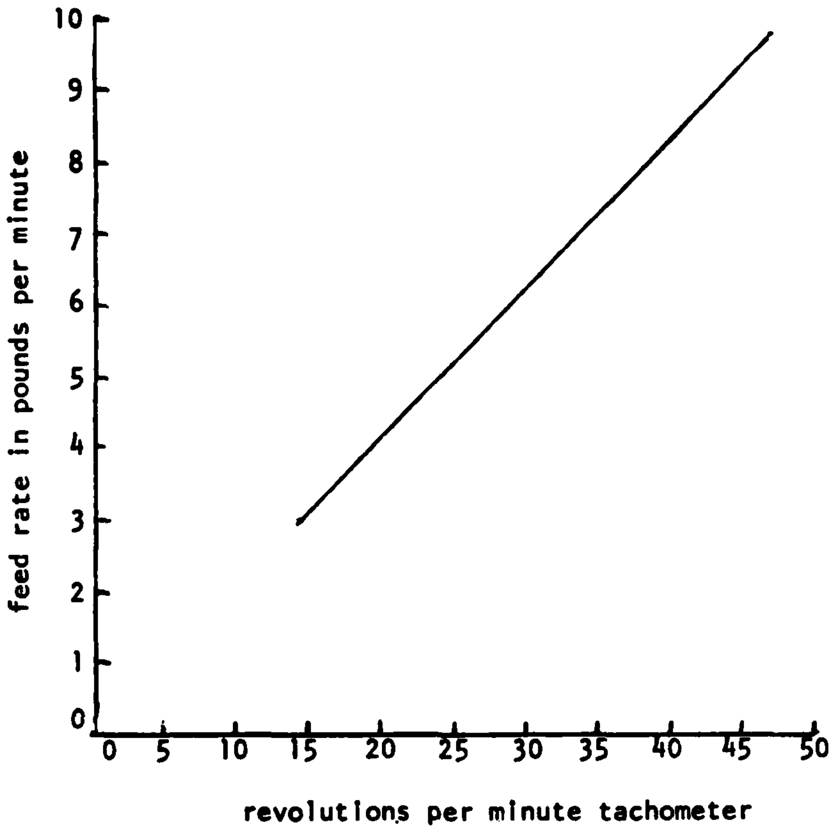

Figure C—1. Dry mix feeder rate

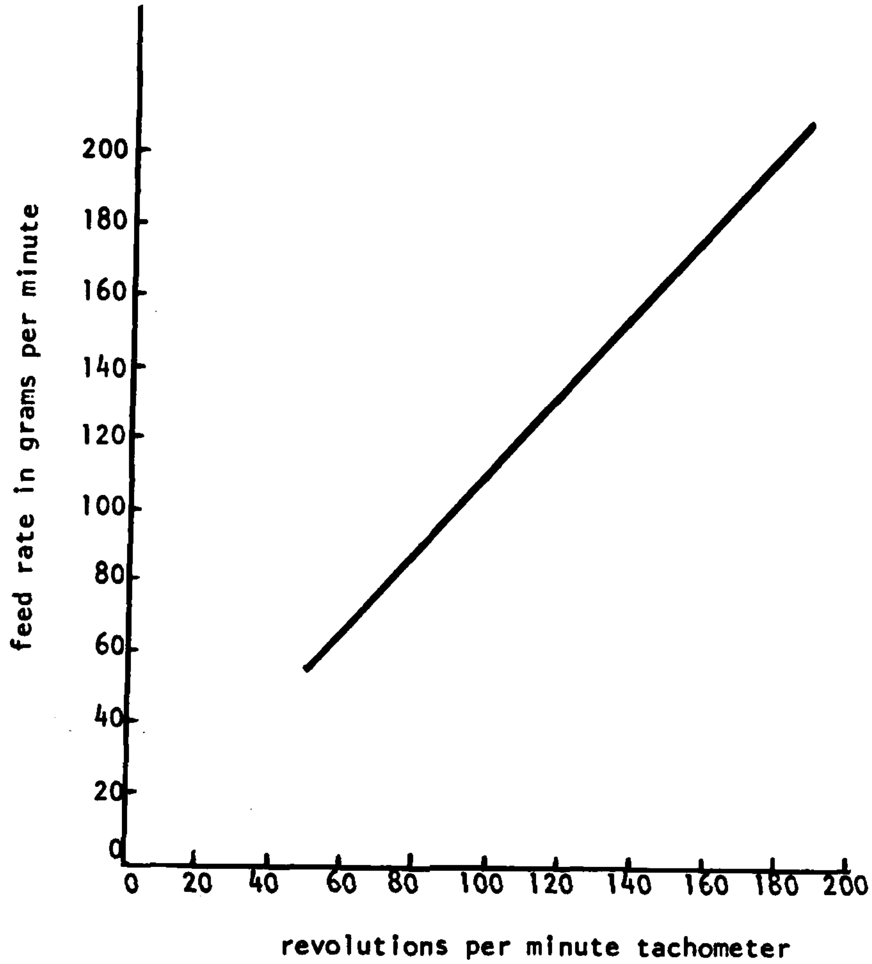

Figure C—2. Shortening feeder rate

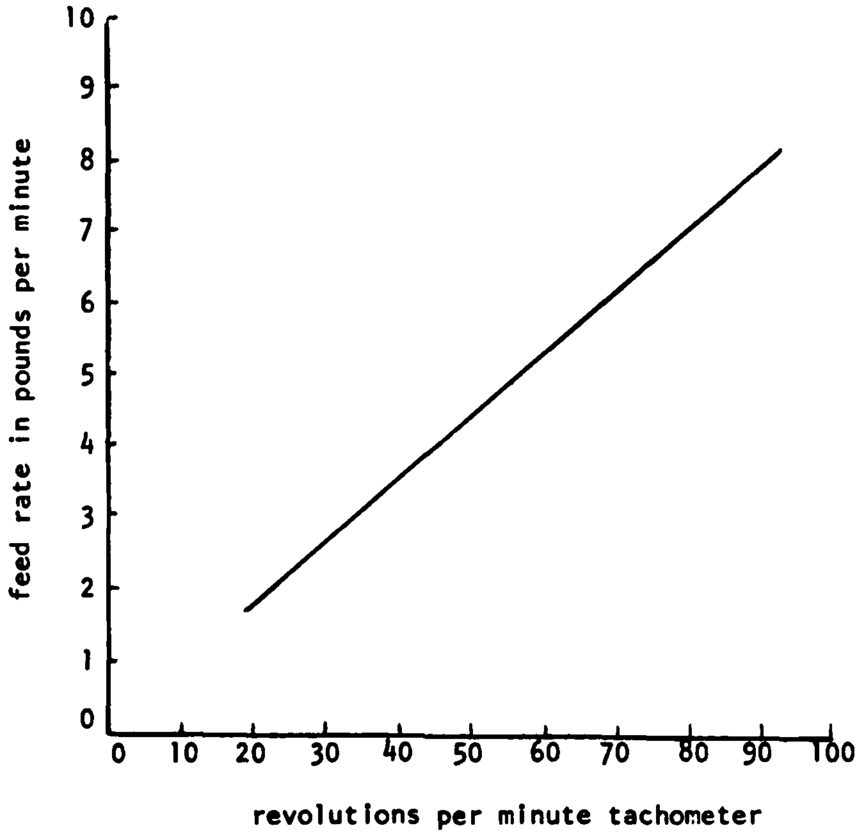

Figure C-3. Yeast brew feeder rate

Preparation of Brew: Step Procedure

The fermentation period is the time that elapses between the setting of the broth and the entry of broth into the premixer. Therefore, if a one-hour fermentation period is to be used, the operator arrives approximately two hours before the mixer is to be started. He should check to see that there is an adequate supply of hot water and should then proceed to set the first brew.

1. Accurately scale off all dry ingredients needed for one batch.

2. Check the tank inlet and outlet valves to be sure they are closed.

3. Check cleanliness of tanks.

4. Open water inlet valve of tank to be filled. While water is running into the tank, the water temperature should be adjusted if necessary. Water temperature requirements vary with condition including ambient and ingredient storage temperature. Select the water temperature that will produce a final temperature of approximately 89° to 91° at the end of the fermentation period. Using sucrose, the water temperature should be approximately 86°F.

5. When the water level covers the agitator blade, turn on the agitator and introduce all dry ingredients **except the yeast.**

6. At the proper time, add the yeast. The fermentation period starts when the yeast is added and is generally about one hour.

7. The brew should be checked periodically for foaming, which can be reduced by adding a small amount of shortening.

8. During fermentation the brew should be checked periodically for a normal temperature rise.

9. Repeat above procedure in setting subsequent batches.

One of the two tanks supplied is required every 30 minutes or so depending on the size of the batch. Therefore, if it takes 10 minutes to prepare a brew it will be only 20 minutes old when ready for use and 50 minutes old at the end of use (average age 35 minutes). Larger tanks and more tanks are recommended for longer fermentation time and longer production periods.

Pre-Start-Up Check List

Approximately 15 minutes before starting up the unit, checks should be made to ensure that:

1. Shortening holding tank outlet, supply is available and heater is turned on, if required, and set at the desired temperature.

2. Handles of the three-way brew valves are properly positioned.

3. Dry mix supply bin is full.

4. Developer by-pass valve is open, and bowl cover is secure.

5. Divider shaping block and cover are in place and secure.

6. Divider blades are opened approximately 1/8 of an inch.

7. Dough pot is under divider, and bucket is under by-pass pipe.

8. Panner belts and indexing fingers move freely.

9. Dough scale is set for 18 ounces.

10. All equipment operates and panel meters are at correct settings.

11. All fittings are secure.

12. Divider oil, dusting flour, thermometer, and scraper are available.

13. All equipment meets standards for clenliness.

Start-Up: Step Procedure

1. Open valve from the No. 1 fermentation tank to the brew feeder pump.

2. Turn control panel main switch on "ON" position.

3. Turn brew selector switch to "ON" position.

4. Turn shortening selector switch to "ON" position.

5. After shortening blend and brew are flowing uniformly from the nozzles, turn feeder selector switches to "OFF" position.

6. Turn on premixer and check visually for operation.

7. Turn on developer motor. Turn on developer clutch.

8. Set developer speed control dial to run developer impellers at approximately 20 rpm.

9. Turn on shortening and brew feeders. With brew now entering the premixer, turn on the dry mix feeder.

10. Visually check consistency of dough in premixer.
Visually check the feeder tachometer meters.

11. When the dough in the premixer reaches its proper level, turn on the dough pump.

12. When dough begins to flow out of the developer by-pass valve, turn the valve for flow to the developer.

13. Turn up developer speed to maximum.

14. Start divider when dough extrudes in a steady stream and is showing signs of some development.

15. Check dough for development. When signs of optimum development are observed, reduce developer impeller speed to correct rpm.

16. Take a doughpiece sample and check it for correct scaling weight.

17. When dough development and scaling weight are satisfactory, turn on divider panner control and guide the first strap of pans to the depositing point.

18. Check dough weights until conditions have stabilized and thereafter as required.

19. Check all ingredient streams periodically for flow and temperature.

20. Record operating conditions accurately on daily record sheet at regular intervals.

Start-Up Procedure

In time the operator of this system will develop his or her own techniques. The following is offered as a guide to help in the initial production efforts.

When starting up the unit, allow some of the liquid ingredients to run in to the premixer for a few seconds before starting the dry mix feeder. When it is sure that the liquid ingredients are flowing, start the dry mix feeder. This will help prevent raw dry mix from entering the dough pump. The dough pump cannot pump dry mix and could be damaged. Allow the premixer to fill, then start the dough pump.

Allow some of the dough to bypass the developer, to purge that initial portion of premixed dough which may not be properly mixed or blended. As soon as the dough becomes uniform, close the bypass valve and fill the developer. Running the developer at low speed during filling helps prevent short circuiting to the developer outlet.

It takes about 2 minutes to fill the premixer and about 30 to 40 seconds to fill the developer. During the preliminary trials, the timing of the starting sequence was found to be as follows:

Time Min:Sec	Function
0:00	Start Yeast Brew and Shortening Feeders
0:10	Start Dry Mix Feeder and Allow Premixer to fill to operating level
2:00	Start the Dough Pump with Bypass Valve open
2:30	Close the Bypass Valve and Fill the Developer
3:20	Turn the Developer to full speed
4:00	Start the Divider Reduce the Developer speed to normal
4:15	Start to Pan dough