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Report number **PROGRESS REPORT NO. 3**

MICROWAVE-VACUUM DRYING SYSTEM (MIVAC)*

PROGRESS REPORT NO. 3

ERDA CONTRACT NO. E(11-1)-2918

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1.0 INTRODUCTION

This progress report presents the results of activities performed in partial fulfillment of ERDA Contract No. E(11-1)-2918 during the period December 1976 through February 1977. There were two goals during this period:

- (1) Translate the test data into designs and specifications for the prototype 48 kilowatt drying system.
- (2) Make a preliminary economic analysis of a marketable MIVAC system.

The following paragraphs describe the design of the prototype dryer. The economic analysis is submitted in a separate report.

2.0 GENERAL DESCRIPTION

Two guidelines were used in designing the prototype dryer:

- (1) Make use of off-the-shelf equipment to minimize delivery time and cost, and to maximize reliability.
- (2) Design the unit for maximum flexibility in operating rates and for handling both corn and peanuts.

The basic dryer configuration is shown in McDonnell Aircraft Company drawing T-055678 (attached). The materials and dimensions for the basic configuration are defined. The remaining definitions will be finalized at the time fabrication drawings are produced. This allows flexibility in selection among alternatives and facilitates achievement of cost and delivery goals.

3.0 ELECTRICAL SCHEMATIC

The basic electrical schematic for the test unit is shown in Figure 1. All equipment used to operate the grain dryer is connected to the

precision wattmeter. By selectively operating various portions of the system, the contribution of each portion to the total power consumed for drying can be assessed. The power for the lights and incidental services unique to the test building would not be counted against the dryer. We have tentatively selected for the instrument wattmeter application, the Yokogawa (YEW) Model 2042-03 Wattmeter, with two YEW Model 2261 Potential Transformers and two YEW Model 2242 Current Transformers.

4.0 SYSTEM SCHEMATIC

Figure 2 is a simplified schematic of the complete MIVAC system. It consists of the pressure vessel, the microwave generation section and the condensing and pressure control section. The pressure vessel includes several hoppers. Three of these hoppers, labeled H1, H4, and H5, are identical carbon steel vessels used as lock chambers to transfer grain into and out of the main pressure vessel without changing the pressure in that compartment. The main pressure vessel is divided into three compartments. The three compartments are common in terms of pressure and gas flow but microwave energy is excluded from the upper and lower compartments. The upper compartment (H2) serves as a surge hopper to receive the grain periodically dumped into it by transfer hopper H-1. The product chute conducts the grain by gravity flow from hopper H2, through the microwave cavity (the center section) and then on into the lower hopper H3. The product chute will be fabricated of a fabric type material. It serves to hold the grain in a specific geometry for proper microwave penetration. It is of an open weave to allow free passage of the steam evolved from the grain. The maximum diameter chute that will be tested will be on the order

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of ten inches, but smaller diameter chutes will also be fabricated to test their effect on drying uniformity. Product chutes of various materials and weaves will be used during the course of the testing at Tifton for evaluation purposes. The walls of the center compartment serve as both the condensing surface and the microwave cavity. The upper surface of the lower hopper is configured to collect the condensate and channel it to the condensate collection tank. The lower hopper (H3) is used to increase the retention time of the grain in the vacuum cavity. This is provided primarily for corn.

The rotary product feeder located directly below the main pressure vessel, is provided to control the flow rate of grain through the dryer. The size of the unit (Sprout Waldron S-R-16 or equivalent) was selected in order to insure that it would handle peanuts without clogging. The vacuum pump is selected to allow evacuation of the main vessel and the inlet and outlet hoppers to 20 torr within 30 minutes or less. A three-horsepower motor will be required to permit the continuous gas-ballasting that is necessary to keep the pump oil relatively free of water.

The condensate collection tank permits periodic automatic dumping of the water condensed from the grain without interfering with the operation of the drier.

The valves are sequenced to permit filling the supply hopper (H-1) and emptying the outlet hopper (H5) without interfering with the continuous operation of the drier.

5.0 MICROWAVE POWER SUPPLIES

The microwave power supply units selected are Cober model S6F. This unit has an output adjustable from 0.6 to 6 kilowatts. The energy is emitted at a

nominal 2450 megahertz. Each power supply requires a 480 volt source of 3-phase 60-hertz A.C. Power. The unit is approximately 47% efficient at full output so the installed input power requirement is approximately 13 kW per unit. A central operating console will be provided. The system will be displayed schematically upon this console with switches, power adjustment dials, status lights and power meters logically arranged to facilitate operation of the system.

At the location of the power supply itself, provisions are made for attaching a portable forward/reflected power meter for the purposes of tuning the waveguide for minimum reflected power. Slide-screw tuners are provided in the waveguide to effect this adjustment. An on-off switch is provided on each power supply that permits it to be turned off or turned on to the power level pre-set at the central control console. The enclosures are dust-tight and are continuously purged to prevent the possibility of a dust explosion. Each power supply incorporates a ferrite circulator that protects the magnetron from reflected power.

System interlocks are provided to prevent operation of the microwave power supplies without cooling water and when the chamber pressure is above 50 torr. This is done to protect both the equipment and operating personnel.

6.0 COOLING WATER SYSTEMS

There are two separate cooling water systems, the magnetron cooling water system and the condenser cooling water system. The magnetron cooling water uses demineralized, deionized water circulating through the magnetrons to remove their waste heat. This prevents the possible accumulation of minerals on the heat transfer surfaces of the magnetrons and thereby maximizes

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their useful life. This high purity water cooling loop transfers its heat into facility cooling water via a heat exchanger in the system.

The condenser cooling water system sprays cooling water directly on the outside of the pressure shell. It runs down the outside of the pressure shell and is collected for discharge at the bottom. A shroud around the pressure shell prevents mist, droplets or other carryover from going anywhere except to the drain.

Approximately 70 gallons per minute of cooling water at a temperature no greater than 80°F will be needed for condensing and magnetron cooling.

7.0 PRODUCT FEEDER

The product feeder selected is a Sprout-Waldron Model S-R-16. This has a side-entry design to minimize damage to products such as peanuts and pecans, as well as operating more satisfactorily with corn. The size of the inlet section was also chosen with flexibility of use for various products in mind. The drive motor control will have a speed ratio range of at least three to one. It shall be sized to feed corn at rates as high as 50 bushels/hr (for full capacity dry-down of corn requiring 5 points of moisture removal), down to 17 bushels per hour. If further reductions in feed rate are desired, these can be accommodated by inserting volume reducing sectors into the feeder segments. This will permit great flexibility in the watt-density of the power dissipated in the product. Watt-density in the product is expected to be the most important factor in maintaining product quality.

8.0 PRODUCT FLOW VALVES

The product flow valve selected is a nominal 10-inch diameter DeZurik knife-gate valve. Samples of this valve and others were tested in the laboratory. The knife-gate feature permits the valve to close through a solid column of grain and seal leak tight. Any kernels that are encountered as the blade nears the sealing surface are sheared off. Leak tests demonstrated that many cycles of operation (with grain in the valve) could be performed with no detectable increase in the leak rate. The size selected (10 inches) was based on tests in which Virginia peanuts were fed through a simulated valve. Free flow was obtained with an 8-inch opening. The nominal 10-inch valve has a clear opening larger than 9 inches; an 8-inch valve has a clear opening of less than eight inches diameter. These valves will have a pneumatically-powered remote operator to permit actuation of the valve by a control switch on the central console.

9.0 VACUUM PUMP

The volume of the main chamber is approximately 286 cubic feet. The air volume of each of the lock vessels is approximately 16 cubic feet, when empty, and 7 cubic feet when filled with corn. The pump selected for use is the Beach-Russ Model RP-30 WS. This pump has features that permit it to purge itself of the water that will inevitably get into it when pumping a chamber full of wet grain. It has a nominal volumetric capacity of 50 cubic feet per minute. The theoretical pump-down curves for the main chamber and for a single lock compartment is shown in Figure 3. The actual pump-down is expected to be very near the theoretical down to about 40 torr. Below that

pressure it is probable that the evacuation rate may decrease due to evolution of water vapor from the grain. The system actual operating pressure will be primarily dependent upon the condenser cooling water temperature once the pump has removed the air down to the 30-40 torr level. The pump is water cooled but can utilize warm condenser cooling water; therefore, no water source beyond those previously described will be needed.

10.0 LOCK CHAMBER

The three lock chambers are identical in design and construction. They are fabricated of low-carbon commercial steel. The calculated volume of the chamber is 15.31 ft³. The calculated corn capacity, assuming a 30° natural angle of repose, is approximately 12.5 bushels. For continuous operation, this implies that the lock must be cycled at 30 minute intervals when the unit is operating at 25 bushels per hour.

11.0 MAIN VESSEL

The main vessel is fabricated of 5454 aluminum alloy. Aluminum was chosen because it has low magnetic and resistance losses; this maximizes the efficiency of the microwave coupling into the product. Also, this specific alloy was chosen because it has good formability, weldability and corrosion resistance. It is commonly used for ASME code pressure vessels. The strength of the alloy is only a minor consideration because the design of the vessel is dictated by elastic stability criteria which is a function of the modulus of elasticity and not of the strength.

The aluminum will be brush-alodined and then painted in those areas where it contacts steel supports or other dissimilar metals. There are

non-metallic pipe sections between the aluminum flanges on the vessel and the steel-bodied valves. This is done to minimize the possibility of electrolytic corrosion between the dissimilar metals.

12.0 PRODUCT CHUTE

The product chute consists of three sections. The upper section is the conical hopper located in the upper part of the main vessel. This is essentially a surge hopper that accepts the contents of the upper lock hopper and then dispenses it to the processing section while the lock hopper is cycling another load into the dryer. The conical portion is removable for cleaning the dryer and for installation of new fabric portions if needed.

The fabric portion of the product chute will maintain the grain in a ten-inch cylindrical geometry down the center of the chamber. A close-weave, polyester fabric having good abrasion resistance will be fashioned into the cylindrical sleeve. The sleeve will be attached at the top and bottom with band clamps.

The lower portion of the product chute (see zone E-6 of T-055678) incorporates a unique cushion-box design that cushions the impact of the grain falling down the tube upon initial filling. Also, the baffle design in the lower compartment exposes a maximum amount of irradiated grain to the chamber vacuum for additional drying before it passes through the rotary product feeder and out of the dryer.

Condensate water drains down the inside of the pressure shell and drains to the condensate collection system from the annular space between the lower compartment of the product chute and the conical portion of the pressure shell.

13.0 MICROWAVE INJECTION PORT

The microwave injection port will utilize the proven dome window developed in the earlier testing. The design is further improved by providing cooling air for the dome. Holes will be drilled in the clamping flange (-63 flange, T-055678) around the inner periphery of the dome. Cooling air from a fan inside each microwave power supply is blown into the dome through the waveguide, flows over the inner surface of the dome and exits through the holes in the flange. The holes will be sized to preclude leakage of microwave energy to the external environment.

The eight microwave injection ports are arranged in a spiral fashion around the length of the microwave cavity. The purpose of this is to minimize the possibility of nonuniformities in the application of the microwave energy. The waveguide does not point directly at the product chute. Microwaves emerging from the waveguide into the cavity must disperse or rebound off the cavity wall prior to encountering the grain in the product chute. This is designed to disperse the energy and improve the drying uniformity.

FIGURE 1 - A.C. POWER DIAGRAM

Figure 2. Simplified Schematic of MIVAC Drying System.

H = Hopper, KGV = Knife-gate valve, MW = Microwave power supply,
PC = Product chute, SV = solenoid valve.

FIGURE 3- THEORETICAL PUMP-DOWN CURVES
FOR MIVAC CHAMBER COMPARTMENTS

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[illegible]

-101 FLANGE

REV	REV	CODE	PART OR	QUANTITY	DATE	DESCRIPTION	STOCK	MATERIAL	ENGINEER	DATE	NOTE
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<p>McDONNELL AIRCRAFT COMPANY McDONNELL DOUGLAS CORPORATION</p> <p>MICRO-WAVE GRAIN DRYER</p> <p>REV. 1 76301</p> <p>SCALE 1/4" = 1"</p> <p>18 SHEETS OF 22</p> <p>WAC 100000-100 10 SEP 71</p>											