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MICROWAVE-VACUUM DRYING SYSTEM (MIVAC) *

PROGRESS REPORT NO.1

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MASTER

* Patent Applied For

? No invention here

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1.0 INTRODUCTION

This initial progress report describes the activities performed and the results accomplished in partial fulfillment of ERDA Contract No. E(11-1)-2918 during the period June through August 1976. Generally, the order of priorities was as follows:

- (1) Select and procure microwave power supplies for evaluation.
- (2) Initiate a subcontract with the Aeroglaze Corporation and develop a baseline system definition to coordinate work efforts.
- (3) Devise and fabricate equipment for use in testing system components and concepts.
- (4) Develop a more thorough understanding of the phenomena involved in transferring the microwave energy into the product.

The following paragraphs describe the progress that has been achieved in each of these areas.

2.0 MICROWAVE POWER SUPPLY SELECTION AND PROCUREMENT

A key element in the scale-up of this system is the microwave power supply. Consequently, considerable effort was expended in locating and selecting a supplier for this equipment.

We contacted nine of the prominent suppliers of microwave equipment. After reviewing the literature and information supplied, it was decided that only two of these vendors, Cober Electronics and Gerling-Moore Incorporated, had off-the-shelf equipment that was fully compatible with this application.

It was judged that the goals of the project would be best served by procuring one unit from each company for a thorough evaluation. This serves two purposes: it allows in-depth comparison of the two best units, and it allows

simultaneous operation of two sources into a common cavity to determine if there are any interference effects between them. Pursuant to this decision, we purchased a 2.5-kilowatt, 2450-megahertz power supply from Gerling-Moore and a 6-kilowatt, 2450-megahertz power supply from Cober Electronics. These units are currently being used in the development tests.

The 2.5-kilowatt system is composed of four modules coupled together: a variable power source, a power source control unit, a ferrite circulator, and a dual power monitor. It operates from a 208-volt, 60 hertz, single phase AC source. It produces a 2450-megahertz output pulsed at 120 hertz. The output is continuously variable from 200 to 2500 watts. It has a Litton magnetron with a specified nominal life of up to 8000 hours. The circulator is a protection device to prevent experimental use from damaging the magnetron. The power output is controlled by operational amplifier circuitry.

In the 6-kilowatt system, the source, control, circulator and power monitor are integrated into a single cabinet. It operates from a 480-volt, 60-hertz, three-phase AC source. It produces a constant 2450-megahertz output with a small ripple at 360 hertz. The output is continuously variable from 600 to 6000 watts. It has an Amperex magnetron having a specified nominal life of up to 8000 hours. The power output in this unit is controlled with magnetic amplifiers.

3.0 SUPPORT SUBCONTRACT AND BASELINE SYSTEM DEFINITION

A subcontract for support work by the Aeroglide Corporation of Raleigh, North Carolina, has been initiated. Aeroglide management personnel and the engineers that will be involved have received in-depth orientation on the program. Aeroglide has provided a design engineer who is currently working at

MCAIR's facilities in St. Louis. He works directly with MCAIR engineers on the MIVAC program. He supplies expertise on crop handling equipment, crop characteristics, and the fabrication capabilities of Aeroglides. He is doing groundwork in helping to select materials and manufacturing methods. He is an integral part of the team that is developing the conceptual design of the drying system.

In order to coordinate MCAIR/Aeroglide efforts and to develop a design for the drying system that can be integrated readily into a facility, we have developed a conceptual design for the completed facility. Dr. James L. Butler of the USDA-ARS in Tifton, Georgia, provided information about the site upon which the system will be installed. Aeroglide provided proposed designs for the building, the grain-storage bins, the bucket elevators and the transfer conveyors.

The arrangement evolved for the site installation is shown in Figure 1. The system will occupy a site approximately 35 feet square at the northeast corner of the USDA-ARS Coastal Plains Station in Tifton. An installed capacity of approximately 100 kilowatts of 480-volt, 3-phase, 60-hertz electrical power will be required. Approximately 40 gallons per minute of cooling water at a maximum temperature of 75°F will also be required, for condensing the steam evolved from the grain and for cooling the microwave power supplies.

The arrangement of the drier and its support equipment is shown conceptually in Figure 2. To be consistent with conventional grain handling facilities, the MIVAC system will incorporate accepted material handling procedures. Incoming (wet) grain will be placed in a receiving hopper to be fed to the "wet" side of the MIVAC drier (i.e., the "wet" bucket elevator leg and the "wet" storage tank). Parallel "dry" equipment and a series of spouts and conveyors interconnect with the system and provide flexibility of operation.

The facility is planned to receive up to 400 bushels per hour and store up to 1000 bushels each of wet and dry grain. Quantities of about 300 bushels, which is the capacity of a typical farm truck, will be used for preliminary testing.

4.0 TEST ACTIVITIES

To simplify the design of the scaled-up drier, we have developed a concept in which a single shell serves as the pressure vessel, the condenser, and the microwave cavity. Figure 3 is a photograph of a segment of a microwave cavity which has been fabricated for testing our design concepts. This cavity, a 48-inch diameter aluminum cylinder with flat circular ends, represents a segment of the prototype microwave cavity. This segment is the same diameter as the baseline prototype vessel but is only 39 inches long, to allow it to be inserted into an existing 5.5-foot diameter chamber for reduced pressure tests. Tests with this unit have shown that steam will condense on the cavity walls. Future tests will determine if this imposes any efficiency penalties.

The figure shows the cavity connected to the 6-kilowatt power unit. Provisions are made for connecting the 2.5 kilowatt unit at the same time.

The cavity is currently being used to test various configurations of the product chute. The geometry of the chute is one factor that governs the heating uniformity that is achievable in the microwave field.

Efficient energy transfer is achieved by "tuning" the electrical characteristics of the cavity to those of the generator. Various tuning devices are commonly used. We have performed preliminary evaluations with a slide-screw tuner, a triple-stub tuner, and an inductive iris tuner. Each has been found to function satisfactorily, but each behaves differently, and all of them have disadvantages as well as advantages.

We performed tests in the chamber used for the pre-proposal work and found that at power levels above one kilowatt, there was arcing and glow discharge at the existing window when the chamber pressure was reduced to the desired operational pressure. We have devised and fabricated a window that should reduce the field strength of a 6-kilowatt microwave beam before it emerges into the evacuated region. No tests of the window have been performed as yet.

5.0 SUMMARY

The results of the first quarter of work are summarized as follows:

- (1) We identified potential suppliers of microwave supplies and bought two off-the-shelf units for evaluation.
- (2) We initiated a contract with Aeroglides. An Aeroglides design engineer is at MCAIR facilities in St. Louis contributing his expertise and working on the design of the drier and its installation interface requirements.
- (3) We (including Aeroglides) developed a baseline configuration for the completed facility in order to achieve a coordinated design and to permit price estimates for follow-on phases of the program.
- (4) We identified areas where tests are needed and began fabricating and assembling the test equipment necessary to acquire the data.

6.0 PROJECTED ACTIVITIES FOR NEXT QUARTER

In the next quarter we plan to continue tests of the product chute configuration, the window configuration, and tuning methods. Once a satisfactory configuration for each of these elements has been defined, we will begin tests to see what levels of conversion efficiency can be expected. This

latter data is required for the economic analysis that will be done in the third quarter of work.

In addition to the test work projected, we will begin design calculations and sketches pursuant to providing Aeroglide with a firm design of the microwave applicator and its attendant vacuum and cooling water systems.

**FIGURE 1 - CONCEPT SKETCH OF SITE INSTALLATION OF USDA-ARS
COASTAL PLAINS STATION, TIFTON, GEORGIA**

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FIGURE 1

FIGURE 2

FIGURE 2 - DRYING SYSTEM BASELINE CONFIGURATION

FIGURE 3 - SIX KILOWATT MICROWAVE UNIT AND
FOUR FOOT DIAMETER CAVITY SECTION

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FIGURE 3