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The ABRICO controlled solar drying system for Barbados Agricultural Development Corporation

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A crop-dryer of 20-tonnes (or 10,000 FBM) capacity has been constructed for the Barbados Agricultural Development Corporation at their Spencer's Estate, based on the ABRICO Controlled Solar Drying concept. The project was a joint effort of BADC and the Canadian International Development Agency. The dryer will be used as a demonstration and production facility by BADC. Crops to be dried include peanuts, onions, cassava and cotton-seed. This paper describes the construction and operation of the dryer and includes a discussion of the economics of drying.

Keywords: Solar drying; vegetable crops

Introduction

In September 1985, at the Caribbean Food Crops Society meeting, held in Port-of-Spain, Trinidad, we introduced our concept of an agro-industrial scale crop dryer using mainly solar heat, specifically designed for use in tropical regions. Since that occasion, we have been encouraged by wide-spread interest in the concept, not only in the Caribbean, but in Africa and Asia, indicating that there is a place in the agro-economies of these countries for solar dryers of large capacity. However, the system was designed on the basis of surveys made in the Caribbean; and we have been pleased to be able to establish a dryer in Barbados as a proof-of-concept for this region.

In March of 1986 an agreement was signed between Barbados Agricultural Development Corporation (BADC), Redma Consultants Limited of Mississauga and ourselves to construct a solar crop dryer of 20-tonnes capacity at BADC's Spencer's Estate adjacent to Grantley Adams airport. BADC contracted with Nehaul Construction Limited of Barbados for the construction of the dryer. The preparation of the site and the construction of the foundation for the dryer were completed by Nehaul in November. After a recess during the month of December, assembly of the dryer itself was resumed in early January and completed in the first week of February. The dryer was immediately put into use to dry cotton-seed, as the ginning process and Spencer's was then in full swing.

BADC assumed financial responsibility for all local components of the project. The Canadian component was financed by the Canadian International Development Agency (CIDA). Redma Consultants Limited were prime consultants for the project and ABRICO was technical consultant, providing all designs and specifications and supervising construction and commissioning.

Design Features

The design of the dryer is exceptionally rugged. BADC stipulated that the structure should be high enough that their existing peanut trailers could be brought under cover for attachment to the drying system. At the same time, the structure was to meet Southern Building

Code standards, since the site is exposed and hurricane force winds are a possibility.

Aside from this characteristic of ruggedness, the design called for the simplest of construction techniques using standard materials of construction. This proved to be a wise decision, for during the construction of the dryer an accident resulted in the breakage of 59 panes of glass imported from Canada for glazing the air-heating solar collectors. Since the panes were of standard patio-door size, replacements were found immediately in Barbados. These replacements were installed without modification to the glazing support structures in any way. The quality of glass did not quite match the quality of the imported "Solatex" panes; however, the difference is slight and the collectors are performing more than adequately.

Division of Responsibilities

BADC assumed overall responsibility for the management of the contracts associated with the project. As client, BADC also undertook to provide the following:

a) A suitable site with unobstructed solar access
b) Access roads, fences, safe storage during construction.
c) A concrete foundation made to ABRICO specifications.
d) A concrete block drying chamber to ABRICO specifications.
e) Services: electrical power (typically 10 KW of 220V, 3-phase) and water (service, fire safety).
f) Staff to operate and maintain the system once it was commissioned.

BADC also paid all local fees, such as: entry-fees, handling and off-loading costs, duties and taxes, permits, insurance and inland transportation costs

ABRICO, as technical consultant, assumed responsibility for the following:

a) Solar Air Heating Array consisting of 36 panels of 5 m^2, each complete with T-175 steel absorber plates, Glasclad insulation and Solatex low-iron, tempered glazing, supported on extruded aluminum I-section beams with pressure plate and snap-cap protection. All metal surfaces coated to resist corrosion. 20 spare panes of glazing included.

b) Solar Array Support Structure consisting of Dricon treated wood trusses bolted to steel headers supported by H-section steel columns bolted in turn to headers and to anchor-bolts in the concrete foundation. This was designed to withstand 177 km/h wind pressures. All surfaces coated against salt corrosion.

c) Industrial Exhauster consisting of radial, standard duty fan rated at 2.4 m^3S^{-1} (5000 cfm) at 7.62 cm (3" W.G.), 10 HP, 220V 60 Hz, 3-phase motor, tropicalized for service in salt air environment. Spare motor belts and spare impeller included. All surfaces given paint finish suitable for tropical service.

d) Air Distribution System consisting of plenum down-comer, dampers, ductwork with adjustable vents, all of galvanized steel, and exhaust duct of 1.27 cm (1/2 in.) Wolmanised plywood.

e) Temperature and Humidity Sensors consisting of air actuated recording hygrometer with wet and dry bulb temperature sensors in the exit air flow; temperature sensors in both inlet and outlet air. Air flow measurement situated at the central control panel. Temperature ranges: 0 to 1000 °C.

f) Control Panel consisting of a hermetically sealed cabinet with power centre and controls supplying the fan motor and current meter registering current drawn by the motor. Also chart recorder for wet and dry bulb output. The dryer is operator controlled, i.e. the operator makes adjustments to obtain the required operating conditions. Once drying cycle parameters have been established, the process can be made automatic if BADC decides in favour of this step.

g) Roller Door: a rolling steel, overhead door for full opening access to drying chamber. Curved steel slats, galvanized finish, 9 cm deep track, wind-locks on alternate slats. Hand chain hoist with security lock.

Commissioning and performance

Commissioning was completed without difficulty in late February and the drying chamber was used almost immediately to dry cotton-seed preparatory to storage, although the formal opening was not until 1st April. It was at once apparent that, with the insolation being received, temperatures could not be reduced below 40 °C in the drying chamber by controlling the air-flow through collectors, even at the maximum flow of 2.4 m^3 S^{-1} (5000 cfm.). A simple modification was made to the fan intake which allowed ambient air to be mixed with the solar heated air in any proportion desired. This permitted a range of temperatures between ambient and 50°C to be obtained. Tests have yet to be made to determine the maximum upper temperature which can be obtained with solar heating alone.

Sensors for temperature (RTD) and humidity (capacitance) measurements originally installed were electronic. Although the temperature measurements were reliable, difficulty was experienced with the humidity readings and it was finally concluded that the capacitative sensors were becoming contaminated with salt from the sea air being drawn into the dryer. These sensors have now been replaced by recording wet and dry-bulb thermometers with stainless steel bulbs containing pressurised gas to actuate the recording pens. Ambient, inlet and outlet temperatures are also monitored with thermisters connected to a Cole/Parmer electronic thermometer.

The drying chamber is a simple concrete block room of 60 m^3 capacity. An air distribution duct was supplied with the installation to direct the air-flows in the chamber laterally against the walls. This duct is also provided with an attachment for connection with the peanut trailers. However, it is expected that the duct will not be used for crops such as onions or cassava, since special supports will be developed for these crops to maximise effectiveness of air flows. Timber may also be dried on an experimental basis; and this will require still another drying configuration in the chamber.

Despite considerable research, a complete understanding of the mechanism of drying has yet to be fully developed (Anon., 1985). The system at Spencer's will be used as a development and production facility to establish drying technology for a variety of crops and materials. Users will include the following:

Barbados Agricultural Development Corporation
Barbados Sugar Industries Limited (cotton, onions)
Caribbean Agricultural Research and Development Institute (onions)
Barbados Industrial Development Corporation (timber)

It is also hoped that other organisations will participate in the drying program; e.g. the St. Vincent Organisation for Rural Development, the St. Lucia Banana Growers Association, and the Grenada Cooperative Nutmeg Association.

System Economics

The appropriateness of the drying system for the Caribbean region seems assured in the sense that drying is a major post-harvest requirement, sunshine for heating is "super-abundant' for a good part of the year and, in most countries of the region, conventional heating fuels, if available, place a strain on foreign exchange reserves. However, the final arbiter of appropriateness is the farmer/grower and his market. We have been much influenced by the work of Baynes (1988), in our assessment of our system. The drying system is semi-industrial; that is, it is not suitable for the individual farmer/grower unless he is producing on an agro-industrial scale, but is suitable for cooperatives or organisations collecting the output of a number of individual farmers/growers.

The initial investment is of the order of \$ 100,000 Cdn. In the Caribbean, this corresponds to energy costs of about Cdn\$ 50 per annual GJ of heat energy collected, a figure which is competitive with conventional energy costs in the Caribbean. However, the cost per unit of energy is only one aspect of a solar installation. The owner is, by definition, insulated against further changes in conventional energy costs. Since the system uses standard building materials, a system life of 20 years is the minimum of expectation and even a 10 year pay-back time gives a period of productivity of another ten years at practically no cost other than the cost of operating the drying fans. As shown below, the pay-back period is considerably shorter than ten years.

The economic performance of the BADC dryer has yet to be determined. However, it has been shown that drying air at temperatures ranging from 35 - 50^{o}C is produced at rates up to 2.4 m^3S^{-1} (5000 cfm). Starting with air at 28^{o}C and 80% relative humidity (normal at Spencer's) and drying at 50^{o}C (20% R.H.) using full fan power of 6 KW. to send 5000 cfm through the drying chamber, it can be shown that - with a reasonable "pick-up efficiency" (Anon.,1985), approximately 10 hours of operation are required to remove a tonne of water . This means an expenditure of 60 KWh of electrical energy. At the current rate of B\$ 0.26/KWh this works out to:

60 KWh x B\$ 0.26/KWh = B\$ 15.6/tonne water

Meanwhile, a tonne of water requires at least 2.26 GJ of heat energy to vaporize it for removal by the air stream. At an energy cost in Barbados of B\$ 70/GJ, this represents a minimum cost of B\$ 158. However, the air stream is only about 50% effective (pick-up efficiency = 0.5) hence the cost will be at least B\$ 300, or Cdn\$ 215. To achieve a simple pay-back of Cdn\$ 100,000 would, at this rate, require the removal of 390 tonnes of water or operation for 3900 hours. Since the dryer is multi-purpose, this might be achieved over a period of 3 - 5 years. Thus the installation would pay for itself in this time.

As noted by Baynes (1985), the appropriateness of the technology for the farmer/grower will depend not only on such things as the simple pay-back time calculated above, but upon whether the out-put from the dryer results in financial gain for him or herself. This can only occur if the increased production made possible by the dryer can be sold on the market at a price bringing a reasonable profit. Where such a market exists, or has been identified, or where the drying process is essential for other reasons (such as in the drying of timber for furniture manufacture) the ABRICO Controlled Solar Dryer System would appear to be a technology whose time has come.

References

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