✓ (DEVELOPMENT AND DEMONSTRATION OF ENERGY-CONSERVING
DRYING MODIFICATIONS TO TEXTILE PROCESSES

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ENERGY CONSERVATION IN THE
TEXTILE INDUSTRY

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Summary of Effort

The first quarter of this project has been completed with success. The Machnozzle is fully operational and early experiments indicate that significant energy savings can be realized during drying. A visit to the University of Twente in Enschede, Holland was made to discuss the use of the Machnozzle in drying. This trip enabled Dr. David Brookstein to discuss the operation of the nozzle with Professor Van der Linden and Dr. Clemants Theusink. Their advice led to the development of a reel for transporting the fabric through the nozzle. They also provided further insight into the theory of operation for the Machnozzle. The concept of the Machnozzle as a device which imparts significant amounts of kinetic energy through the development of shock waves was dispelled. Instead the Machnozzle is viewed as a vacuum slot acting in reverse, that is a device in which a relatively large pressure differential across the fabric can be obtained.

The problem of steam condensation in the Machnozzle was discussed. This condensation, if allowed to occur, will reduce the effective flow resistance in the nozzle and will result in increased steam usage. The solution to this problem is to allow the nozzle to heat up before it is used and steam measurements are taken.

A mathematical simulation of steam can dryer has been initiated to continue the development of an optimization program for steam can dryers in industrial use. This simulation will lead to an automatic control program for minimizing steam use. Discussions with textile industry representatives indicate that there is an immediate need for this program. A new potential Ph.D. candidate has chosen this area for his thesis research under the supervision of Drs. Brookstein and Carr.

Machnozzle System Modifications

During the last three months there have been several modifications to the Machnozzle system. These include:

1. Development of a reel to store and deliver fabrics to the drying unit as needed. This reel eliminates the need for sophisticated fabric guiding equipment which is necessary when the system is operated with a continuous loop of fabric.
2. Development of a squeeze roll weighting system. This is necessary so that the fabric is conventionally dewatered to as low a level as possible prior to treatment by the Machnozzle.
3. Development of a fabric tensioning device - Experiments at the University of Twente in Enschede, Holland indicate that maximum fabric tensions result in maximum overpressures and subsequent drying.
4. Installation of a vacuum slot to reduce water content on fabric prior to Machnozzle treatment.

During the next quarter, a system for keeping the steam pressure within a tolerance of ± 1 psi will be installed on the Machnozzle system.

Experimental Results

Experiments conducted during the reporting period have been encouraging. A typical sheeting fabric (3.5 oz/yd² 65% polyester/35% cotton) was tested on the Machnozzle experimental system. Four test conditions were examined. These were:

Test Condition #1: 140 lbs nip pressure on squeeze rollers, no vacuum, full nozzle width 16 inches operating on 10 inch wide fabric, no additional fabric tension

Test Condition #2: 180 lbs nip pressure on squeeze rollers, squeeze twice, no vacuum 10 inch nozzle operating on 10 inch wide fabric, no additional tension.

Test Condition #3: Increased fabric tension, vacuum slot, 180 lbs nip pressure, 10 inch nozzle operating on 10 inch wide fabric

Test Condition #4: Increased fabric tension, vacuum slot off, 10 inch nozzle operating on 10 inch wide fabric 180 lbs nip pressure.

The average results of these experiments are given in Table I.

The results should be examined in view of the fact that typical thermal drying after conventional mechanical dewatering (squeeze rollers) uses about 2.5 lbs of steam per pound of water removed. For each test condition, the steam usage was independent of fabric speed. This finding is significant since higher fabric speeds result in greater amounts of wet fabric presented to the Machnozzle. However the moisture level after the nozzle increases with the increasing fabric speed.

Table I.

Test Condition	Steam Pressure, PSIG	Steam Usage, lbs/hour	Fabric Speed, meters/min.	Average Moisture Level, $\frac{\text{Weight of Water}}{\text{Weight of Dry Fabrics}} \times 100$			
				After Nozzle	After Vacuum Slot	After Rolls	Pounds of Steam Used per Pound of Water Removed
#1	85-90	82	20	59	-	96	3.81
			60	73	-	97	1.43
			80	76	-	98	1.17
#2	85-90	50	20	57	-	38	2.02
			60	67	-	37	1.05
			80	69	-	90	.75
#3	85-90	70	20	50	79	89	3.80
			60	67	84	90	1.72
			80	69	87	90	1.22
#4	85-90	65	20	57		89	2.62
			60	68		90	1.24
			80	71		92	.97

The energy use (lbs of steam per pound of water removed) is calculated in the following manner:

$$\text{Energy Use} = \frac{\text{Steam Use}}{(\text{Fabric Speed})(\text{Fabric Width})(\text{Weight of Fabric}) \times (\Delta \text{ Moisture Content})}$$

From the relationship it can be seen that if the fabric speed increases at a greater rate than the Δ moisture content decreases, the energy use will be reduced. This situation is present for all test conditions.

The results show that the minimum energy use occurs during Test Condition #2 at 80 meters/minute. The energy use here is .75 lbs of steam per pound of water removed.

The energy savings for Test Condition #2 at 80 meters/minute is determined in the following manner.

$$1 - \frac{(.90 - .69)(.75 \text{ lbs of steam}) + (.69)(2.5 \text{ lbs of steam})}{(.90)(2.5 \text{ lbs steam})} = 13\%$$

If the Machnozzle is isoenthalpic, as is expected, the energy savings is 23%.

Clearly, energy saved when using a Machnozzle in the drying process is substantial.

Optimization Program for Steam Can Dryers

The optimization program for steam can dryers has begun. The objective of the program is to determine values of the can dryer input parameters:

- 1.) Fabric weight, construction, and components
- 2.) Fabric throughput speed
- 3.) Can/medium temperature
- 4.) Fabric incoming moisture content

that will optimize:

- 1.) Fabric outgoing moisture content
- 2.) Energy consumption
- 3.) Productivity

Since the input parameters are numerous, a totally experimental approach to optimization would require extensive experimental testing.

Therefore, a mathematical model of the can dryer capable of predicting the effects of varying input variables on output variable is needed.

Thus, a thorough literature search was made to determine the state of the art in can drying. Although very little information on can drying in the textile industry is available, a considerable amount of work has been published concerning can drying in the pulp and paper industry.

However, the mathematical models used to simulate can drying of paper have been oversimplified and do not adequately describe the phenomena controlling drying. Since an adequate can dryer model was not found in the literature, the can drying process is currently being modeled. The governing equations, initial conditions, and boundary conditions have been written. The resulting equations are second order and nonlinear. Approaches for solving the equations are currently being considered.

Work on the can dryer model will continue next quarter.

Future Work

The Machnozzle system will be tested with different weights of fabric to determine its universality. Further, several different operating conditions will be investigated. These include effect of fabric tension, level of predrying and wrap angle on the slot. The steam exhaust from the nozzle will be mixed with fresh water to determine how much heat can be recovered for use in subsequent textile operations.

The installation of a Machnozzle on a commercial scale will be discussed with a large, textile finisher in Georgia. There will be no cost to DOE since this installation can be accomplished under the State of Georgia Industrial Energy Extension Service.

Further work on the simulation of the dryer can operation will be carried out. It is expected that the physics and mathematics of this simulation can be reported in full in the next monthly report.