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- [X] None
- [ ] Final Invoice or Final Fiscal Report (Already Submitted 3/30/84)
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Final Report

FEASIBILITY OF UTILIZING A MACHNOZZLE TO PREDRY NONWOVEN FABRIC

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Contracting Through

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ABSTRACT

The feasibility of using a Machnozzle to Predry Cerex® spunbonded, nylon 6,6 fabric has been investigated. The Machnozzle's moisture removing ability, energy efficiency, and impact on physical properties were studied. Tests were conducted with air and steam as the motive gas. The parameters varied during the tests were: fabric type, fabric weight, gas type, gas supply pressure, slot width of the Machnozzle and wrap angle on Machnozzle. The responses monitored were: gas flow rate, fabric regain (weight of water/weight of dry fabric) and physical properties of the fabric.

The tests were conducted in three phases. Information obtained from the earlier phases was used to establish optimal system parameters for testing in subsequent phases. Phase I was conducted to determine the effects of gas type, gas pressure and slot opening on the Machnozzle's moisture removing ability and on energy requirements. Phase II was conducted to establish the effects of wrap angle on moisture removal, energy requirements and fabric properties. The first two phases were conducted using 0.5 oz/yd^2, Type 23 Cerex® fabric. Phase III was carried out to determine the effects of fabric weight and fabric type on the Machnozzle's performance.

Tests results showed clearly that the Machnozzle can appreciably reduce (by as much as 121%) the regain of Cerex® fabric. Both steam and air were effective as the motive gas; however, lower fabric regains (9% versus 24%) were obtained with steam. Utilizing the Machnozzle to predry Cerex® fabric had no appreciable effect on the physical properties measured.

The moisture removed by the Machnozzle varied significantly with gas supply pressure, slot opening and wrap angles. Over the ranges of parameters tested, moisture removal increased as each of these parameters was increased. However, gas consumption also usually increased as these parameters were increased. Consequently, the energy cost of operating

the Machnozzle also increased. Thus a cost/benefit analysis was made to determine optimal parameter settings.

The effect of fabric weight on the fabric regain following processing with the Machnozzle was small; however, the economics of dewatering with the Machnozzle varied greatly with fabric weight. Energy cost savings associated with using the Machnozzle to predry 0.3 oz/yd^2 and 0.5 oz/yd^2 Cerex® nonwoven fabric were small (4% and 18%); however, use of the Machnozzle as a predrying device did appreciably reduce energy cost in drying of 2.0 oz/yd^2 Cerex® nonwoven fabric. Energy cost was reduced by approximately 67%.

The effect of fabric type (23 versus 24) on the Machnozzle's ability to remove water was small. Also, the economics of utilizing the Machnozzle were similar for the two types of fabrics.

1. INTRODUCTION

Extensive testing [1-3] has demonstrated the feasibility of using the Machnozzle to predry sheeting-weight, woven fabric. However, no information on the utilization of the Machnozzle to dewater nonwoven fabrics has been published. A brief study of the Machnozzle's ability to predry 2.0 oz/yd^2, Type 23 Cerex® was conducted to obtain an indication of the viability of using the Machnozzle to dewater light-weight nonwoven fabrics. The test results (see Table 1) indicated the Machnozzle can significantly reduce the regain (pounds of water per pound of dry fabric) of Cerex®. Following the favorable results of the preliminary test, a project has been conducted to evaluate the Machnozzle as a predrying device for Cerex® spunbonded, nonwoven nylon 6,6 fabric.

2. OBJECTIVE

The objective of the project was to determine the feasibility of predrying Cerex® spunbonded, nonwoven Nylon 6,6 fabric using a Machnozzle. The Machnozzle's moisture removing ability, energy efficiency, and impact on physical properties was investigated. Both steam and air were studied as the motive gas.

3. DESCRIPTION OF THE MACHNOZZLE

The Machnozzle is a mechanical method of predrying textiles. A cross section of a Machnozzle is shown in Figure 1. In this device, a high pressure gas, such as steam or compressed air, is accelerated to sonic velocity by passing it through a narrow, converging slit. Fabric is passed along the slit exit, where the high-speed gas flow effects water removal. Water and residual matter entrained in and around the fibers are literally blown out of the fabric.

4. TEST APPARATUS AND PROCEDURE

The test apparatus used to wet out, squeeze and transport fabric across the Machnozzle is shown schematically in Figure 2. A 400 mm

Table 1. Results of Machnozzle Test Performed on 2.0 oz/yd^2, Type 23 Cerex®

Sample Number (%)	R_B Regain Before Machnozzle (%)	R_A Regain After Machnozzle (%)	ΔR
1	141	17	124
2	154	13	141
3	156	14	142
4	171	12	159
5	173	13	160
AVG.	159	14	145

Regain $\equiv$ pounds of water per pound of dry fabric.

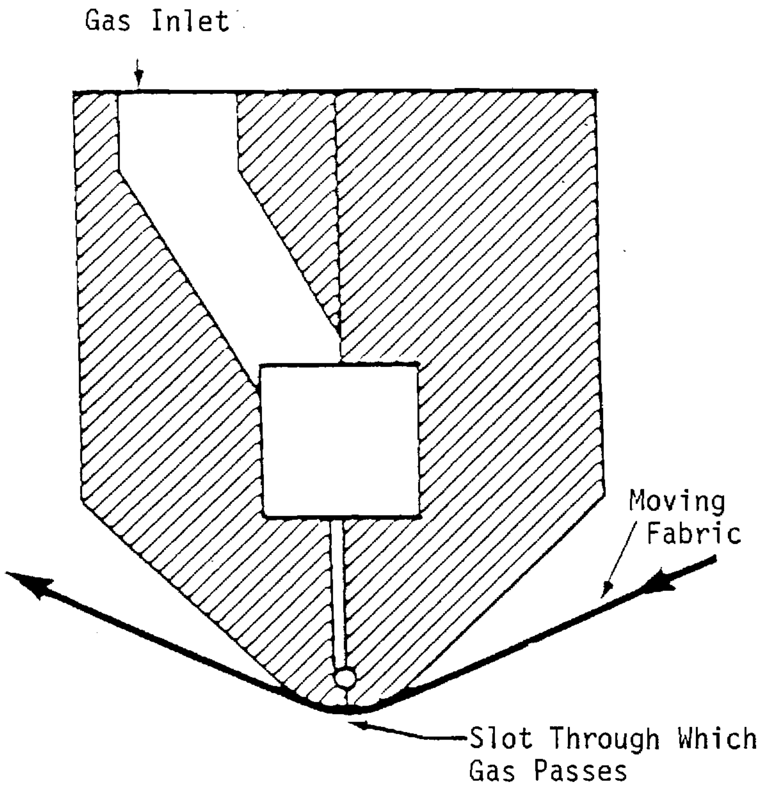


Figure 1. Cross Section of the Machnozzle.

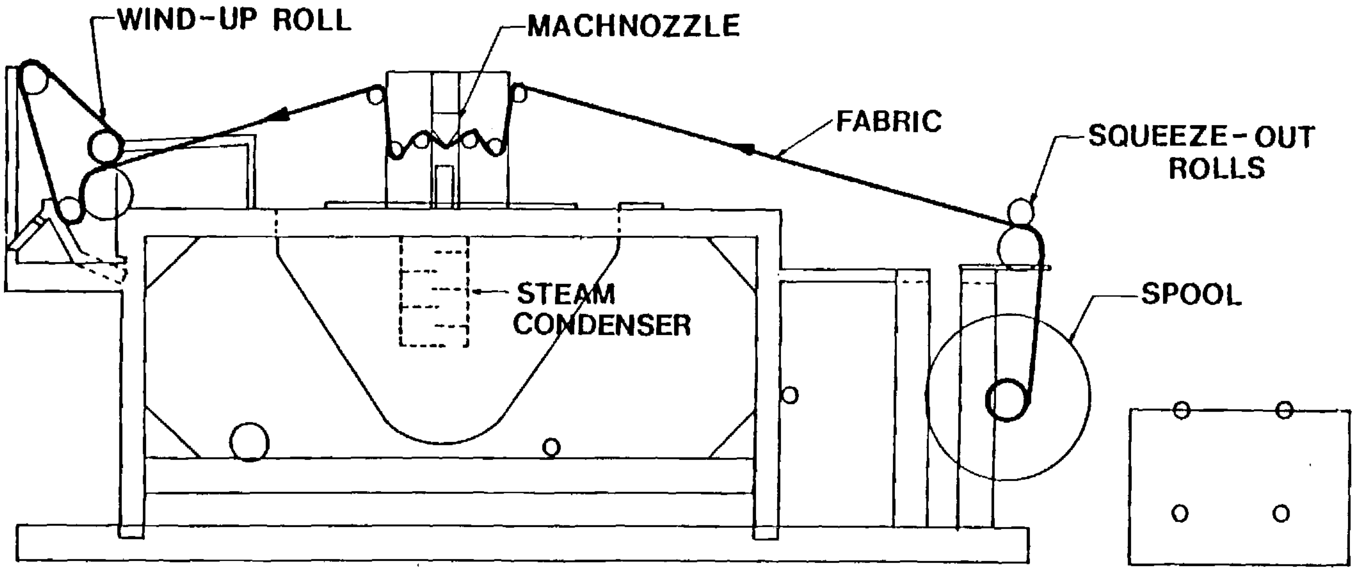


Figure 2. Test Set-Up

(approximately 16 inch) Machnozzle is mounted in a framework along with a series of guides. Variable speed gear motors allow fabric speed to be varied over a range of speeds from approximately 10 YPM to 90 YPM.

Either steam or air can be used as the motive gas for the Machnozzle. When steam is used, an electric resistance heated steam boiler is used to provide steam at various pressures up to approximately 90 psig. A 10-hp compressor is used to provide compressed air at pressures up to approximately 135 psig. Orifice plates are installed in the gas lines so flow rates can be measured.

The normal test procedure was as follows (see Figure 2):

- o Wet out the fabric and wind it onto the spool at the end of the machine.
- o Thread the fabric through the machine.
- o Set the boiler or compressor controller at the given gas supply pressure and wait for it to reach that pressure.
- o Turn on the gas line to the Machnozzle and allow the Machnozzle to heat up.
- o Set the drive roller variable speed gear motor for the given fabric speed.
- o Turn on the fabric drive and run fabric through the machine for the specified period.
- o Stop the machine and cut out fabric samples before and after the Machnozzle. Record relative humidity and gas flow rate. Sew the ends of the fabric together.
- o Weigh the fabric samples then dry the fabric samples overnight in an oven and reweigh them.

5. TEST PLAN

A series of tests was conducted to establish the Machnozzle's moisture removing ability, energy efficiency, and impact on physical properties. Tests were conducted with air and steam as the motive gas. The parameters varied during the tests were: fabric type, fabric weight, gas type, slot width of the Machnozzle, wrap angle on Machnozzle and gas supply pressure. The responses monitored were: gas flow rate, fabric regain and physical properties of the fabric.

The tests were carried out in three phases. Information obtained from the earlier phases was used to establish optimal system parameters for testing in subsequent phases. Phase I was conducted to determine the effects of gas type, gas pressure and slot opening on the Machnozzle's moisture removing ability and on energy requirements. Phase II was conducted to establish the effects of wrap angle (see Table 2 for definition) on moisture removal, energy requirements, and fabric properties. Previous studies [1-3] have shown that wrap angle is an important parameter affecting moisture removal with sheeting-weight, woven fabric. The first two phases were conducted using 0.5 oz/yd^2, Type 23 Cerex® fabric. Phase III was carried out to determine if similar results would be obtained for other fabric weights and for Type 24 Cerex® fabric.

The proposed tests (as appeared in the proposal) are summarized in Table 2. The results of tests performed are summarized in Appendix A.

The physical property tests conducted were selected and performed by Monsanto Fibers & Intermediates Company. The tests included: Taber abrasion, Mullen burst strength, air permeability, tear strength, and thickness. Samples representing optimal test conditions for each fabric were supplied to Monsanto Fibers & Intermediates Company. The test results were compiled and furnish to Georgia Tech for inclusion in the final report.

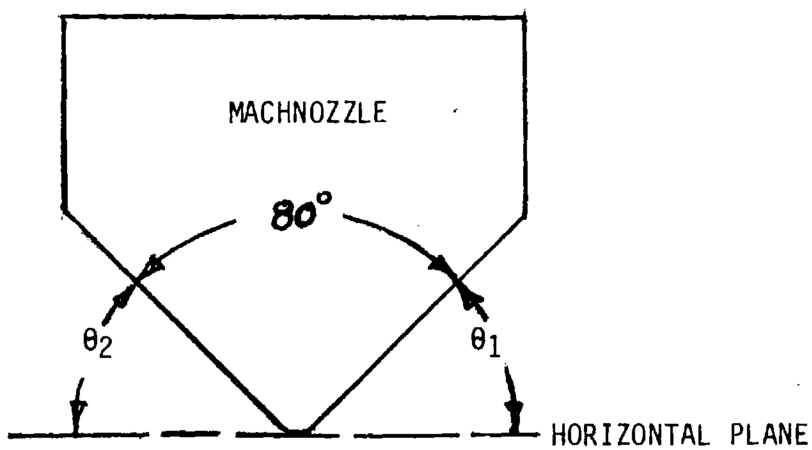
6. CALCULATIONS AND ASSUMPTIONS

The preliminary test results showed clearly that the Machnozzle can significantly reduce fabric regain of Cerex®. However if the Machnozzle is to be a viable way of predrying nonwovens, it must also be attractive economically. Thus an analysis comparing the energy costs associated

Table 2. Summary of Proposed Tests

Fabric Description	Fabric Speed (ft/min)	Gas Type: Air	Gas Type: Steam	Gas Pressure	Wrap Angle***	Number of Test
Phase I 0.5 oz/yd^2 Type 23	219	3 Slit Widths	1 Slit Width**	6 Pressures	$\theta_1=\theta_2=50^o$	24
Phase II 0.5 oz/yd^2 Type 23	219	Optimal Slit Width	1 Slit Width	Optimal	$\theta_1=\theta_2=30°$ $\theta_1=\theta_2=15°$ $\theta_1=\theta_2=0°$	6
Phase IIIa 0.3 oz/yd^2 Type 23	336*	Optimal Slit Width	1 Slit Width	3 Pressures	Optimal	6
Phase IIIb 2.0 oz/yd^2 Type 23	54	Optimal Slit Width	1 Slit Width	3 Pressures	Optimal	6
Phase IIIc 0.5 oz/yd^2 Type 24	219	Optimal Slit Width	1 Slit Width	3 Pressures	Optimal	6
					TOTAL	48

*Maximum speed obtainable up to 336 ft/min will be run.
*Minimal slit width will be used with steam.
***Wrap angle refers to θ_1 and θ_2.



with the Machnozzle with those of the currently used vacuum-drum thermal dryer was made for each test.

Calculations were based on process and energy cost data supplied by Monsanto (see Table 3). Fabric regain prior to the Machnozzle was higher than fabric regain just after squeezing in the Cerex® process. Calculations of moisture removal by the Machnozzle were made using the fabric regain ater squeezing in the Cerex® process since the Machnozzle would be located directly after squeezing in the plant situation.

The assumption was made that water left in the fabric after the Machnozzle would be removed thermally, requiring the same amount of energy on a weight basis as the currently used process. The total cost of drying with Machnozzle was obtained by adding the energy costs of the Machnozzle with the costs of removing the remaining water thermally. The current costs of thermally drying Cerex® nonwoven fabric was based on data provided by Monsanto, indicating that approximately 4.0 pounds of steam is used to remove one pound of water.

7. RESULTS AND DISCUSSION

7. 1 Phase I

Phase I was conducted to determine the effects of gas type, gas pressure, and slot opening on Machnozzle performance. The effects of these parameters on the Machnozzle's ability to remove water from Cerex® nonwoven fabric can be seen in Figure 3-6. Figure 3 shows that the Machnozzle can dewater Cerex® nonwoven fabric and that the amount of water removed depends on steam supply pressure. After squeezing in the 0.5oz/yd^2, Type 23 Cerex® process, fabric regain is approximately 69%, which can be used to judge the performance of the Machnozzle. As steam supply pressure was increased in 15 psi increments from 15 psig to 90 psig, regain of fabric passed over the Machnozzle decreased. At 90 psig, fabric regain was reduced to approximately 10%.

Table 3. Process and Energy Cost Data

Fabric Weight (oz/yd2)	Throughput (lb/hr)	Fabric Speed at Machnozzle (ft/min)	Fabric Regain Leaving Squeeze Rolls (lb water/lb dry fabric)
0.3	480	353	0.61
0.5	520	230	0.69
2.0	520	54	1.3

UTILITY DATA

Steam Cost : $8.16 per thousand pounds.
Compressed Air Cost: $0.30 per thousand per cubic foot.

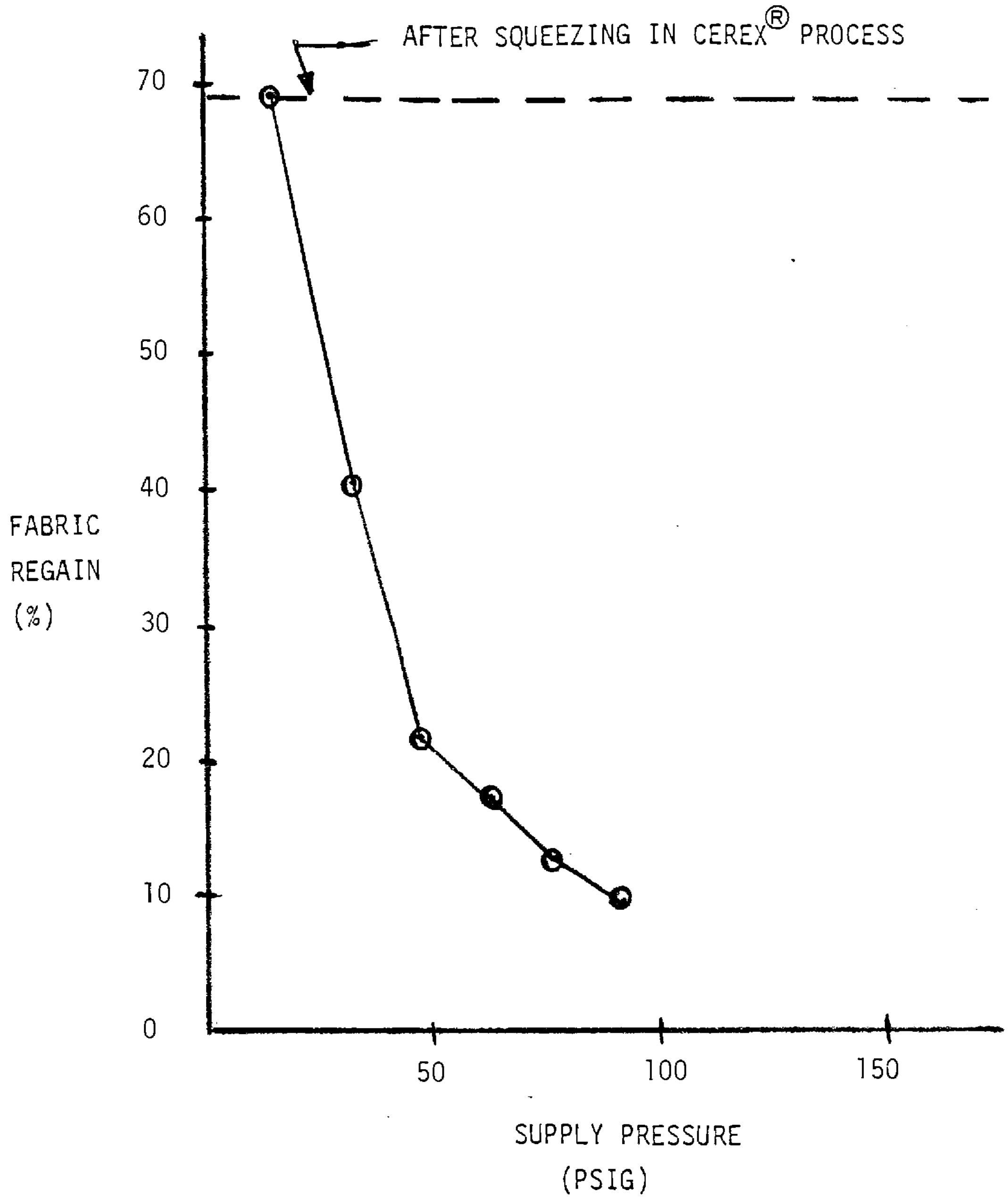


Figure 3. The Variation of Fabric Regain with Steam Supply Pressure - Phase I - No Shim.

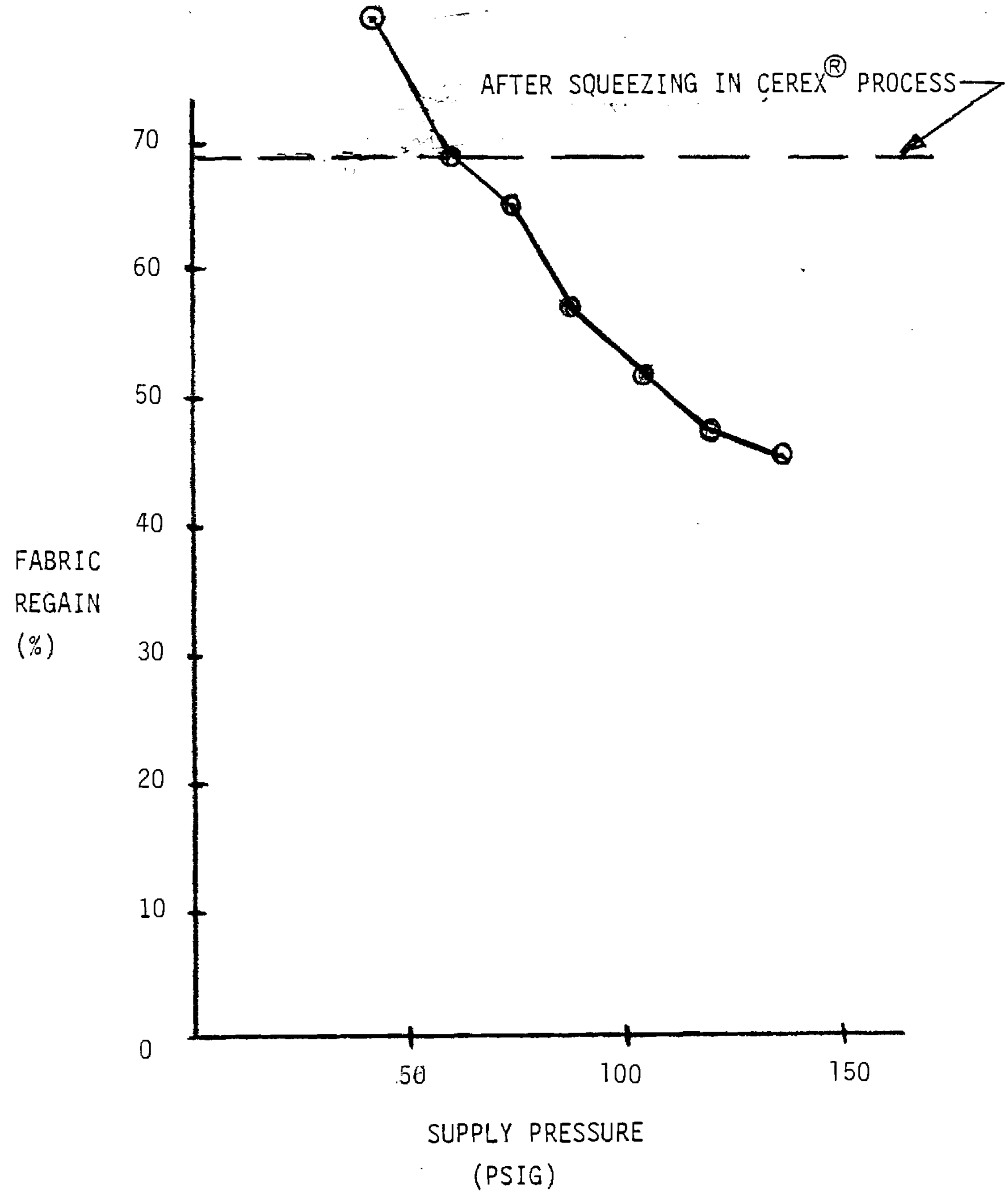


Figure 4. The Variation of Fabric Regain with Air Supply Pressure - Phase I - 2 Mil Shim.

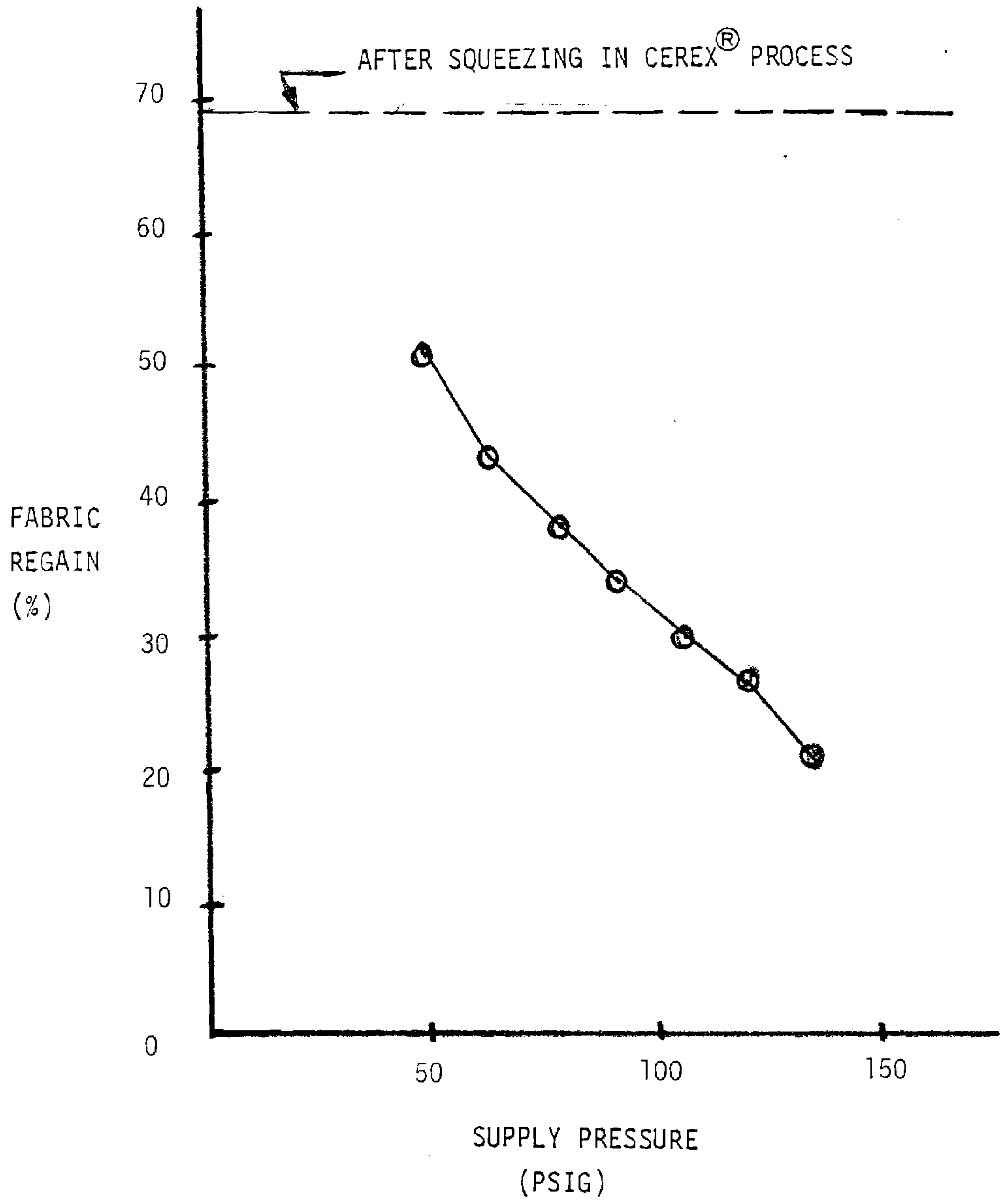


Figure 5. The Variation of Fabric Regain with Air Supply Pressure - Phase I - 3 Mil Shim.

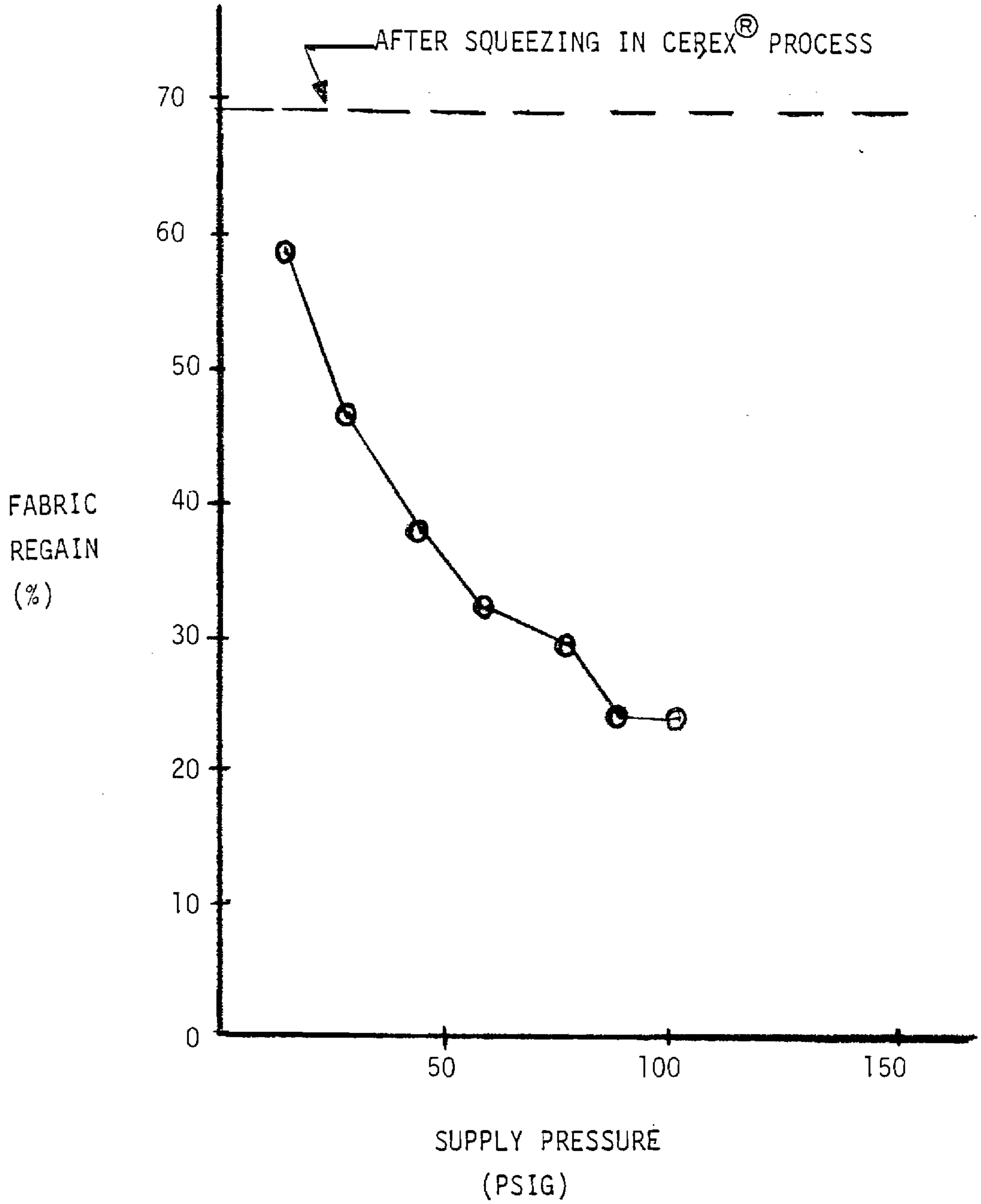


Figure 6. The Variation of Fabric Regain with Air Supply Pressure - Phase I - 5 Mil Shim.

When air was used as the motive gas for the Machnozzle, a wider slot opening was required. Wider slots were obtained by using shims in the Machnozzle. The slot opening is approximately equal to the shim thickness. Figures 4-6 show the results of tests for shim thicknesses of 2, 3, and 5 mils, respectively. Similar to the results for steam, fabric regain decreased as supply pressure was increased. The figures reveal that for the range of parameters tested, the Machnozzle's moisture ability with the 2-mil shim is not as good as its performance with the other two shims.

Fabric regain was lower for the 5 mil shim at the lower supply pressures. However, as supply pressure was increased, the difference in regains obtained with the 3-mil and 5-mil shims was small. At a given supply pressure, air flow rate was higher for the 5-mil shim than for the 3-mil shim. Since the capacity of the compressed air system was limited, the highest air supply pressures that could be tested with the 3-mil and 5-mil shims were different. The highest supply pressure used with the 3-mil shim was 135 psig while the highest supply pressure that could be tested with the 5-mil shim was 105 psig. The fabric regains obtained at these highest supply pressures for the two shims were comparable (22% and 24%).

The lowest regain obtained using air was higher (22% versus 10%) than that obtained using steam. The difference may be due to the evaporative effects associated with using steam versus room temperature air.

The energy cost associated with drying 0.5 oz/yd^2, Type 23, Cerex® nonwoven fabric using the Machonozzle in conjuction with the currently used thermal dryes were calculated and compared with the cost of drying using only the thermal dryer. The results are plotted in Figures 7-10. Total drying cost is plotted versus gas pressure supplied to the Machnozzle. As supply pressure is increased, fabric regain is reduced which decreases the quantity of water to be removed by the thermal dryer. However, as gas supply pressure is increased, gas flow rate through the Machnozzle is increased. As a result, energy cost for operating the

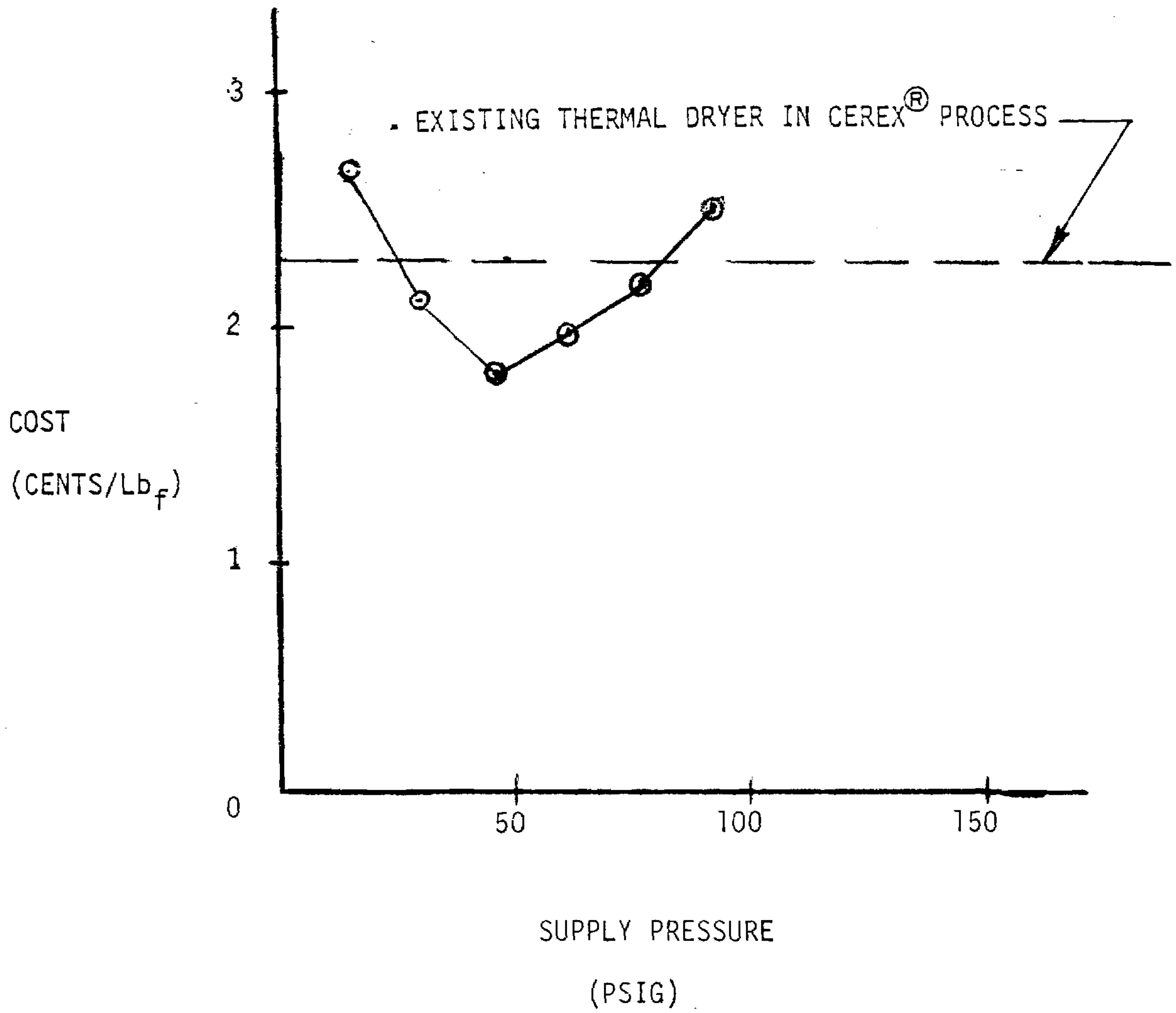


Figure 7. Total Drying Cost Using Machnozzle and Thermal Dryer Versus Steam Supply Pressure - No Shim.

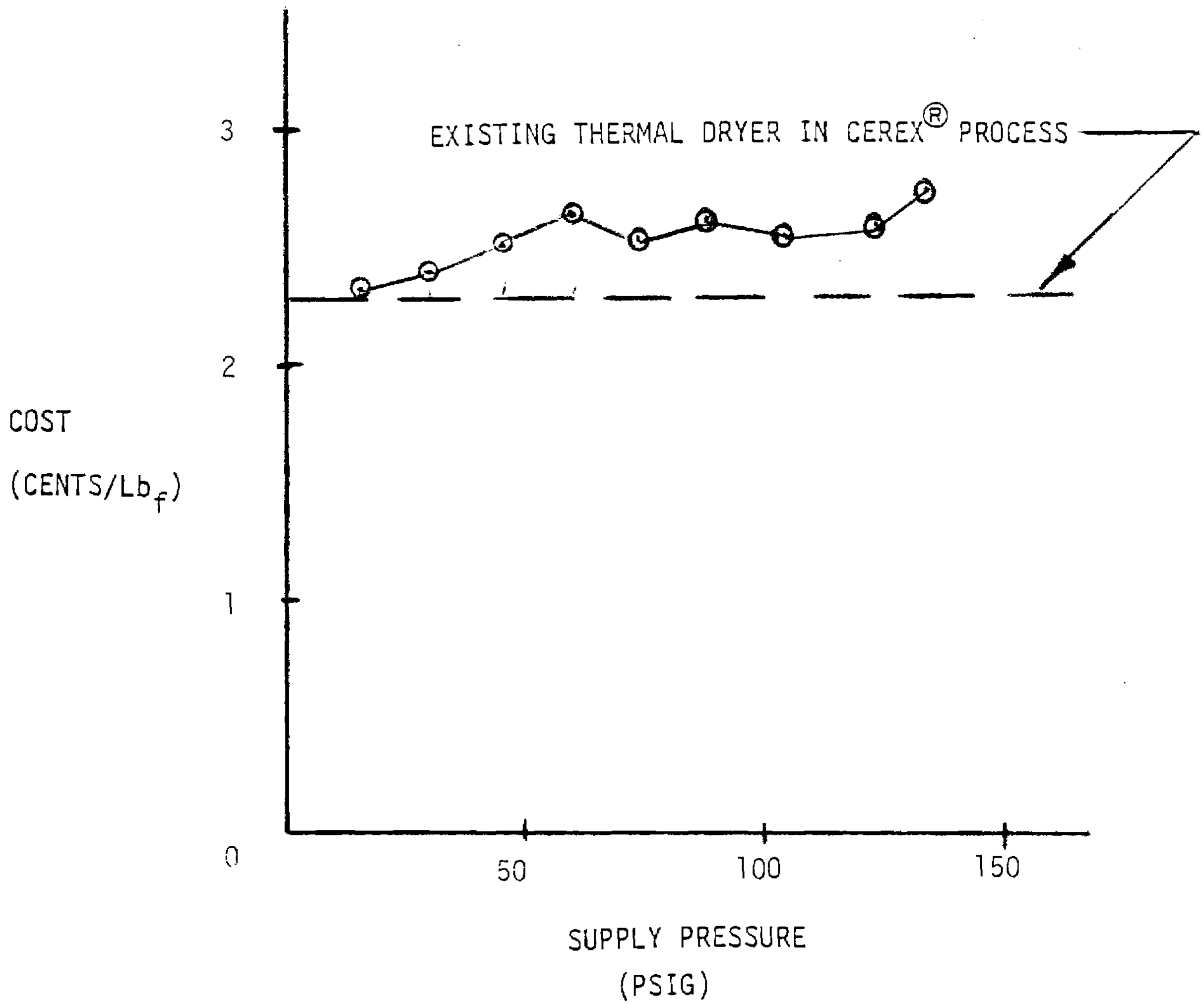


Figure 8. Total Drying Cost Using Machnozzle and Thermal Dryer Versus Air Supply Pressure - 2 Mil Shim.

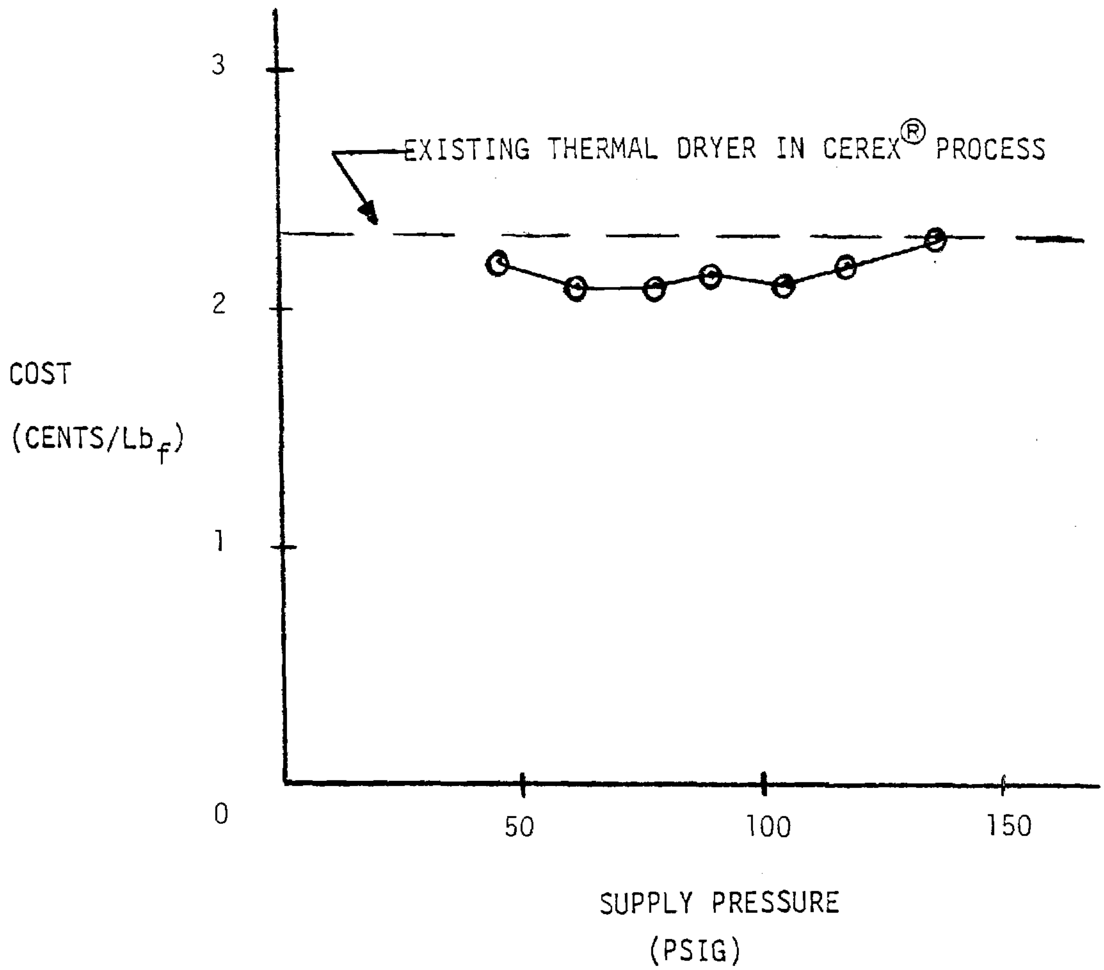


Figure 9. Total Drying Cost Using Machnozzle and Thermal Dryer Versus Air Supply Pressure - 3 Mil Shim.

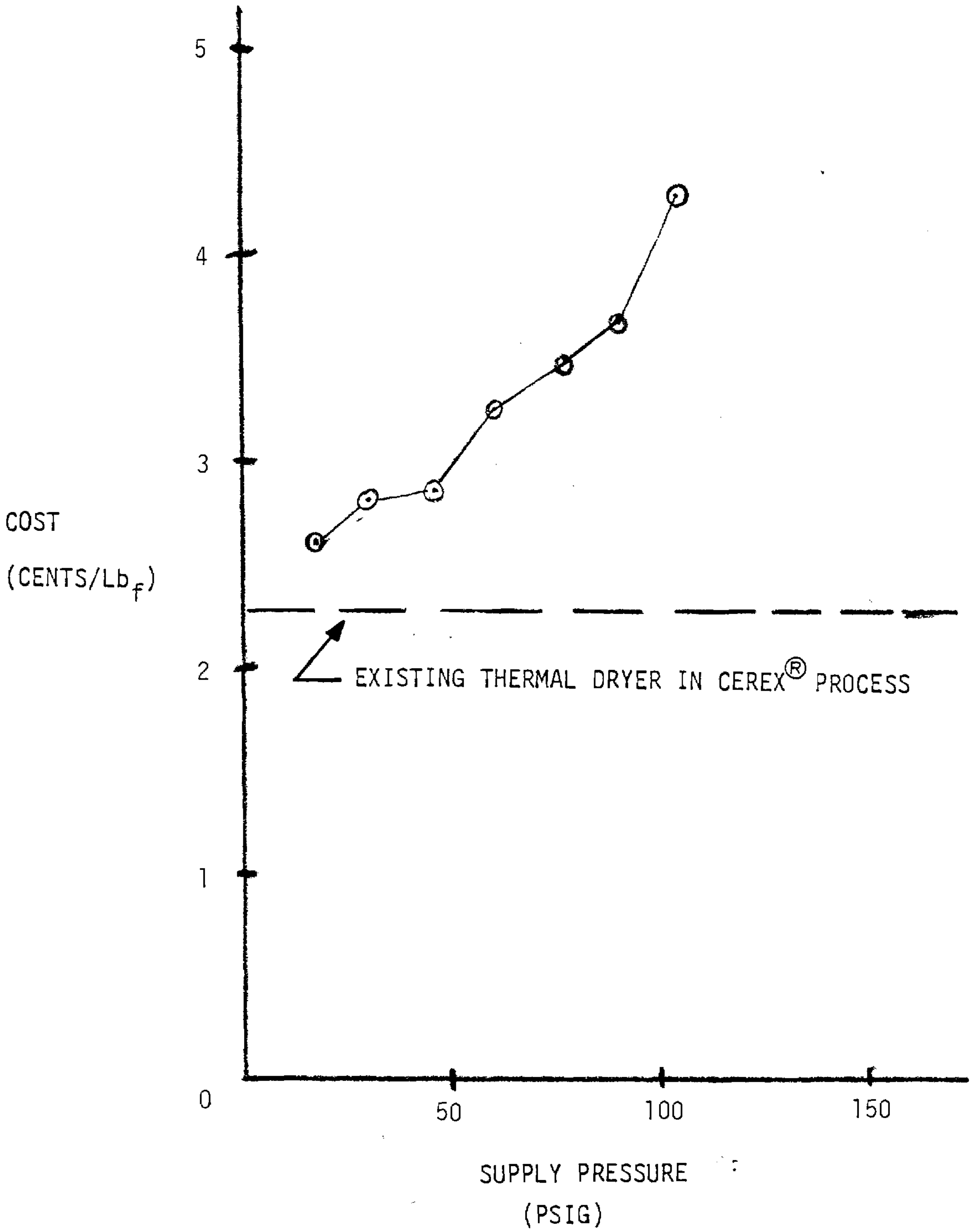


Figure 10. Total Drying Cost Using Machnozzle and Thermal Dryer Versus Air Supply Pressure - 5 Mil Shim.

Machnozzle increases as supply pressure is increased. Thus, cost/benefit of increasing gas supply pressure was evaluated. The plot in Figure 7 indicates that when steam is used as the motive gas, the cost of drying is minimal for a steam supply pressure of approximately 45 psig. Thus, a steam supply pressure of 45 psig was selected as the pressure to be used in Phase II tests.

In Figures 8-10, total drying cost is plotted versus air supply pressure for shim thicknesses of 2, 3 and 5 mils, respectively. The total drying cost for 2 mil and 5 mil shims, at all pressures tested, exceeded the cost of using only the thermal dryer. When the 3 mil shim was used, total drying cost was lower than the cost of using only the thermal dryer. The minimal total drying cost appears to be between 60 and 75 psig. An air supply pressures of 75 psig and a shim thickness of 3 mils were selected for the Phase II tests.

The energy cost of drying 0.5 oz/yd^2, Type 23, Cerex® nonwoven fabric is not greatly reduced by using the Machnozzle. The fairly high energy requirement per mass of water removed is associated with the fairly low water mass flow rate per unit width of fabric passing over the Machnozzle. Previous tests [1-3] have indicated that the Machnozzle's dewatering ability changes little as process speeds (and mass flow rate) is increased. Also, the gas consumption of the Machnozzle is insignificantly affected as process speed (and mass flow rate) is increased. Consequently, the Machnozzle's energy-efficiency tends to be better at higher water mass flow rates per unit width of fabric passing over the Machnozzle. In the 0.5 oz/yd^2, Type 23 Cerex® fabric process, the fabric mass flow rate per unit width of Machnozzle is low (4.33 pounds per hour per inch). Also, the squeeze rolls reduce fabric regain to 69%. Consequently, the quantity of water "seen" by the Machnozzle is low. With heavier weight Cerex® fabric (2.0 oz/yd^2, Type 23), the squeeze rolls are less effective in lowering fabric regain. As a result, a larger water mass flow rate per unit width of fabric passes across the Machnozzle, and total drying cost can be significantly reduced (see Phase III).

7.2 Phase II

Phase II was conducted to determine the effects of wrap angle (see Table 2 for definition) on Machnozzle performance. Contact angles of 0°, 15°, 30°, and 50° were selected for testing. When tests using steam as the motive gas were conducted, very little moisture removal was obtained at contact angles less than 50°. The tests were performed using a steam supply pressure of 45 psig. Supply pressure was increased to 90 psig, but steam flow rate was extremely low and little dewatering occurred at contact angles below 50° (see Figure 11).

The large effect of contact angles on the Machnozzle's dewatering performance is related to the wet fabric's not touching the face of the Machnozzle at contact angles less than 50° (see schematic in Table 2). Steam flow rate through the Machnozzle depends greatly on whether fabric is touching the inlet face of the Machnozzle and whether the fabric is moving or stationary. Apparently, when wet, cold fabric passes across the upstream face of the hot machnozzle, thermal stresses build up in the machnozzle, causing the slot opening to increase. As a result, steam flow rate increases greatly when wet fabric is in contact with and passes over the upstream face of the Machnozzle.

One set of tests with slot opening increased by using a 3 mil shim was conducted to determine if dewatering with steam could be achieved at lower contact angles. By increasing the slot opening, steam flow rate was increased and fabric regain was reduced at the lower contact angles (see Figure 12). Even with the 3 mil shim in the Machnozzle, steam flow rate increased (approximately doubled) when the contact angles were increased to 50°. Best results (minimal total drying cost) were obtained at contact angles of 30° and a supply pressure of 45 psig. The results were slightly inferior to the previous results obtained using no shim. Since testing of slot opening with steam as the motive gas was beyond the scope of this project, most of the steam tests in Phase III were conducted using 45 psig steam supply pressure, 50° contact angles and no shim.

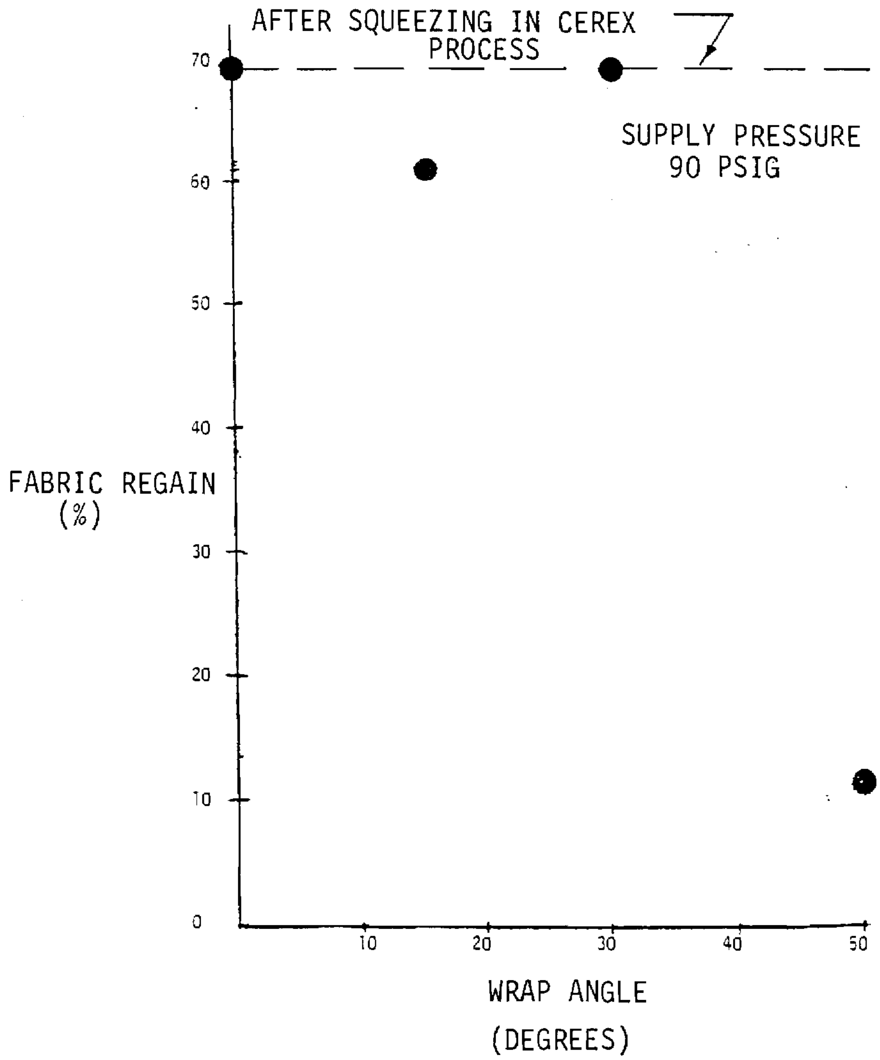


Figure 11. The Effect of Wrap Angle on Fabric Regain, Phase II - Steam and No. Shim.

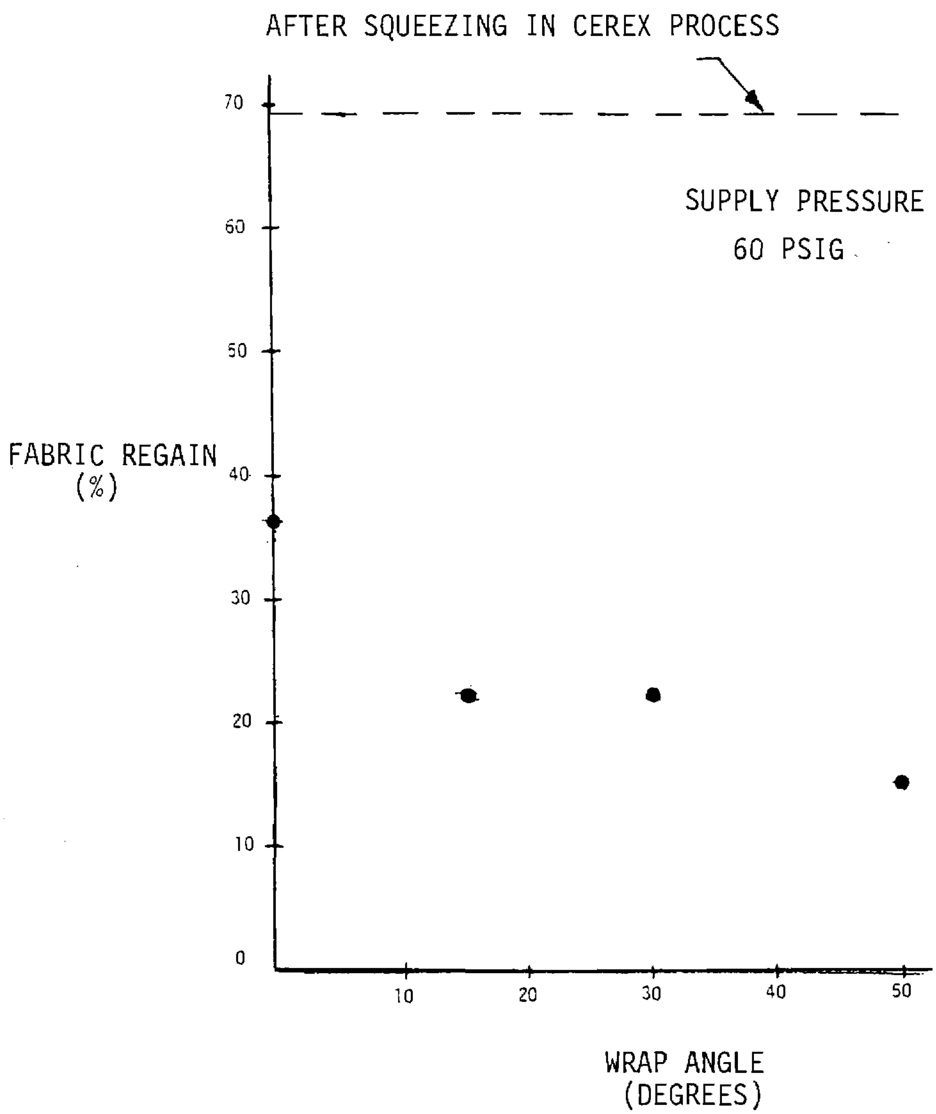


Figure 12. The Effect of Wrap Angle on Fabric Regain, Phase II- Steam with a 3 mil Shim.

The effect of contact angles on the Machnozzle's dewatering performance was small when air was used as the motive gas (see Figure 13). The Machnozzle does not heat up when air is used, and the cold, wet fabric's touching the upstream face of the machnozzle has little effect on gas flow rate. However, fabric regain was lowest at contact angles of 50°, and total drying cost was also minimal at 50°

7.3 Phase III

Phase III was conducted to determine the effect of fabric weight and type on Machnozzle performance. The effect of fabric weight is illustrated in Figure 14 and 15, where fabric regain following the Machnozzle is plotted versus gas supply pressure. Figure 14 shows that at a given gas supply pressure, fabric regain following the Machnozzle is slightly higher for the 0.3 oz/yd^2 fabric than for the other two weight fabric. The steam flow rate through the Machnozzle at a given supply pressure was slightly lower for the 0.3 oz/yd^2 fabric, which may be the reason for the higher fabric regains. Since the 0.3 oz/yd^2 fabric carries less water across the upstream full of the Machnozzle, the slot may not open up as much with the 0.3 oz/yd^2 fabric as it does with the heavier fabrics. As a result, a lower steam flow rate would result. Figure 15 shows that when air is the motive gas, fabric regain following the Machnozzle ws similar for the three weights of fabric tested.

Although fabric regains following the Machnozzle are similar for the three fabric weights, the economics of dewatering are quite different for the three fabric weights, mainly due to differences in fabric regain following squeezing (61%, 69%, and 131% for fabric weights of 0.3 oz/yd^2, 0.5 oz/yd^2, and 2.0 oz/yd^2, respectively). Figures 16 and 17 show that for 0.3 oz/yd^2 fabric, the total cost of drying using the Machnozzle in conjunction with the existing thermal drying system is close to the cost of using only the thermal dryer. On the other hand, when the Machnozzle is used to dewater 2.0 oz/yd^2 fabric, the total cost of drying is considerably reduced (see Figures 18 and 19).

The effect of fabric type on the Machnozzle's dewatering performance was studied by running tests using Type 24, 0.5 oz/yd^2 Cerex® nonwoven

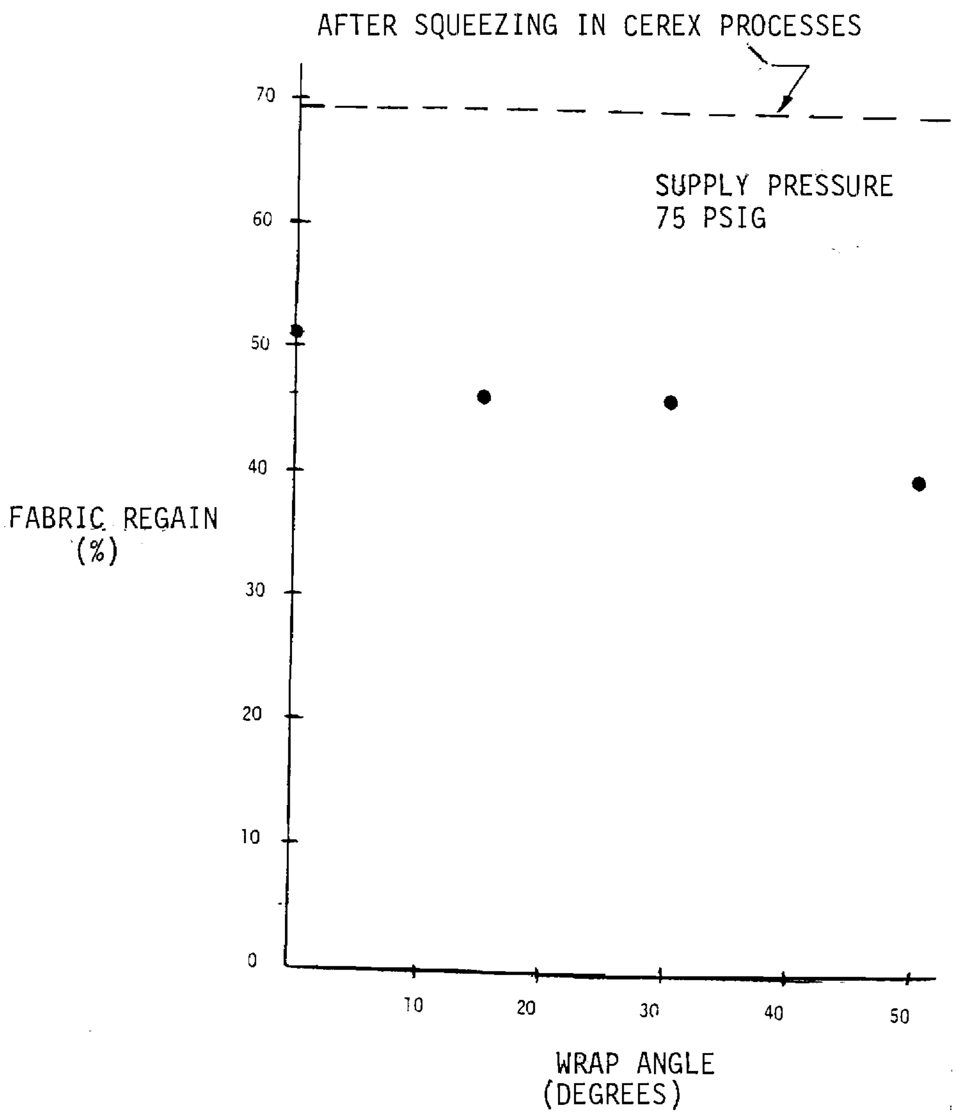


Figure 13. The Effect of Wrap Angle and Fabric Regain Phase II - Air with 3 Mil Shim.

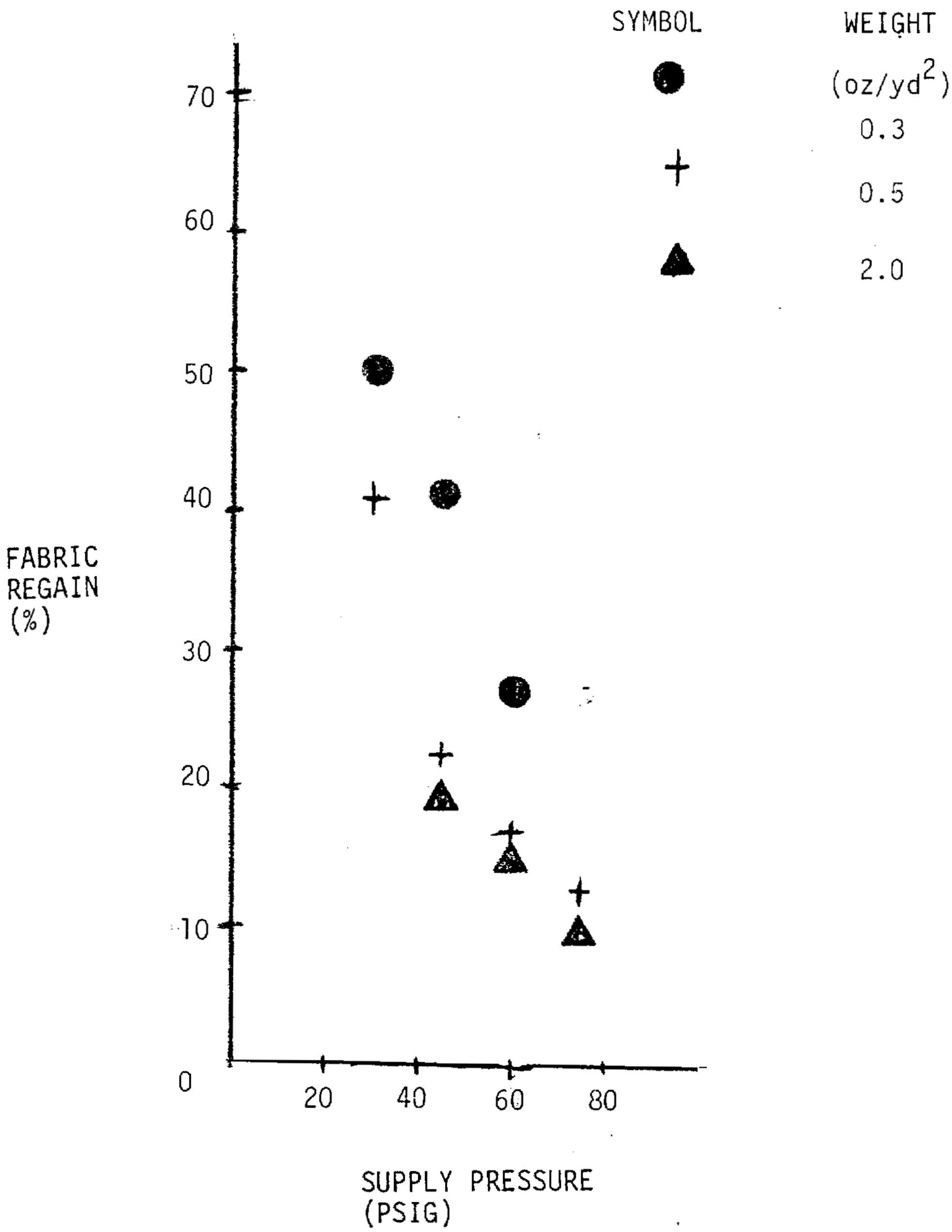


Figure 14. The Effect of Fabric Weight on Machnozzle Performance Type 23 Fabric - No Shim - Steam.

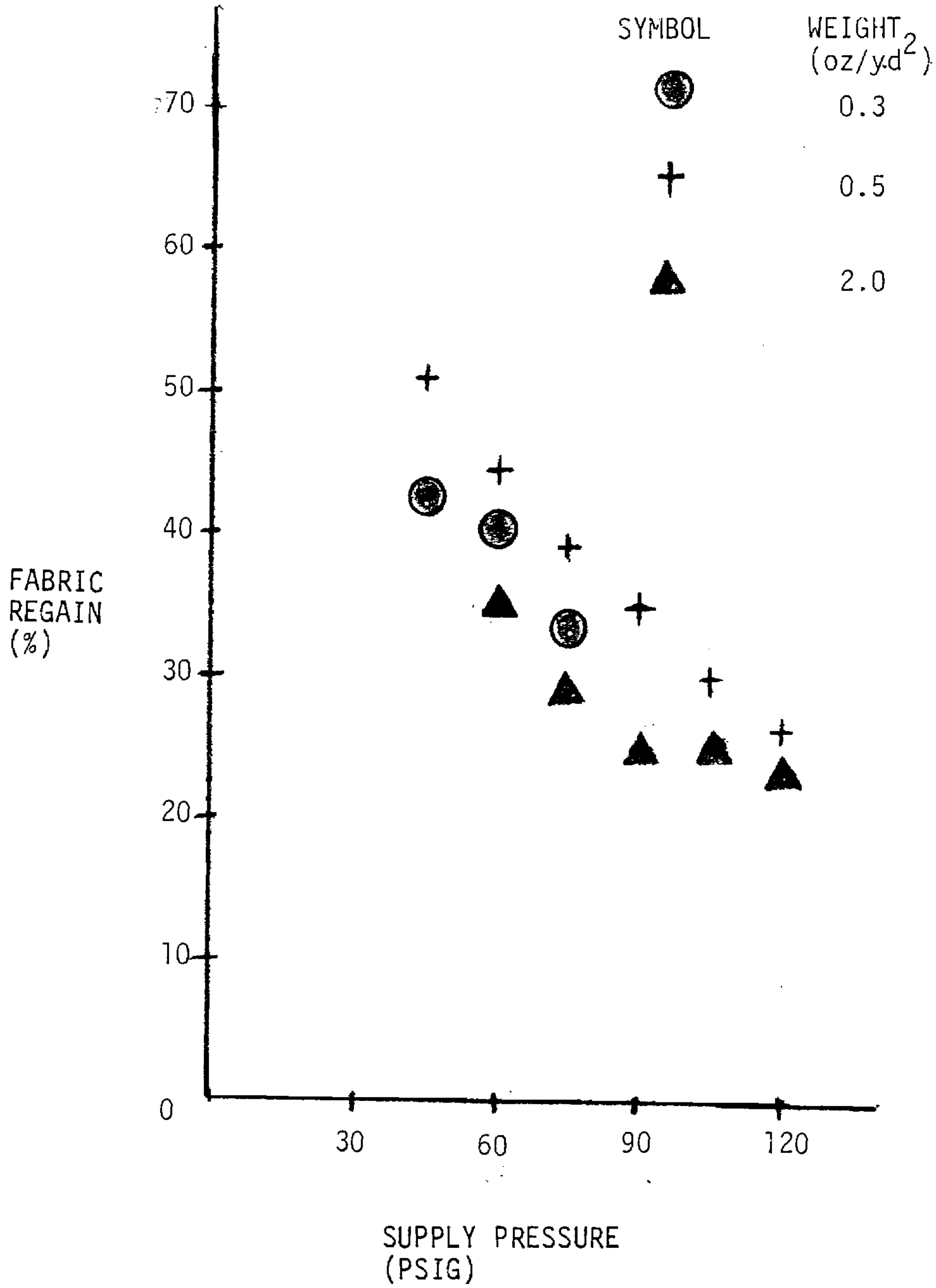


Figure 15. The Effect of Fabric Weight on Machnozzle Performance Type 23 Fabric - 3 Mil Shim - Air.

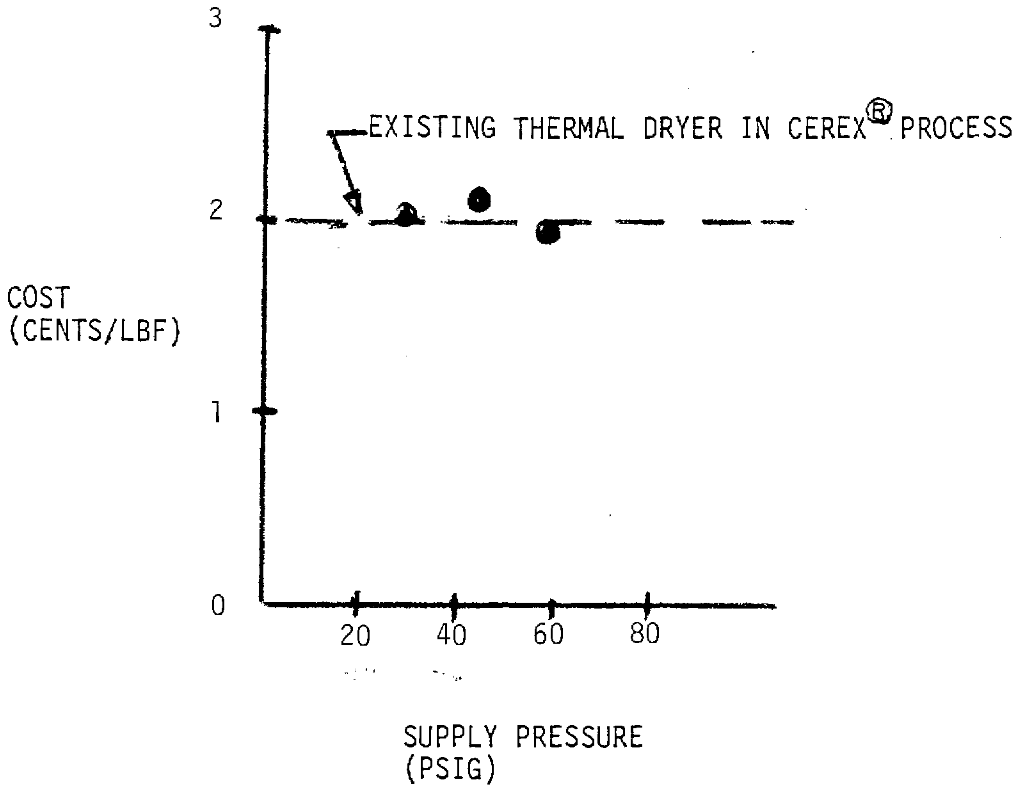


Figure 16. Total Drying Cost Versus Steam Supply Pressure 0.3 oz/yd^2, Type 23 Fabric - No Shim.

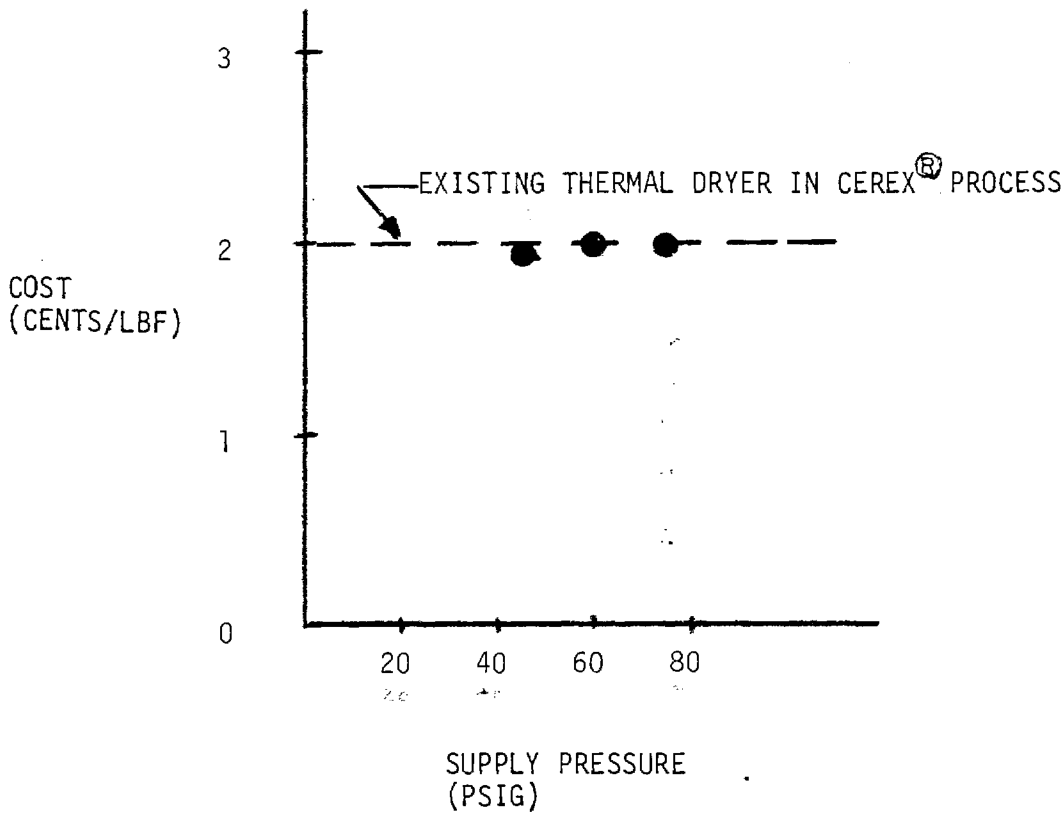


Figure 17. Total Drying Cost Versus Air Supply Pressure 0.3 oz/yd^2, Type 23 Fabric - 3 Mil Shim.

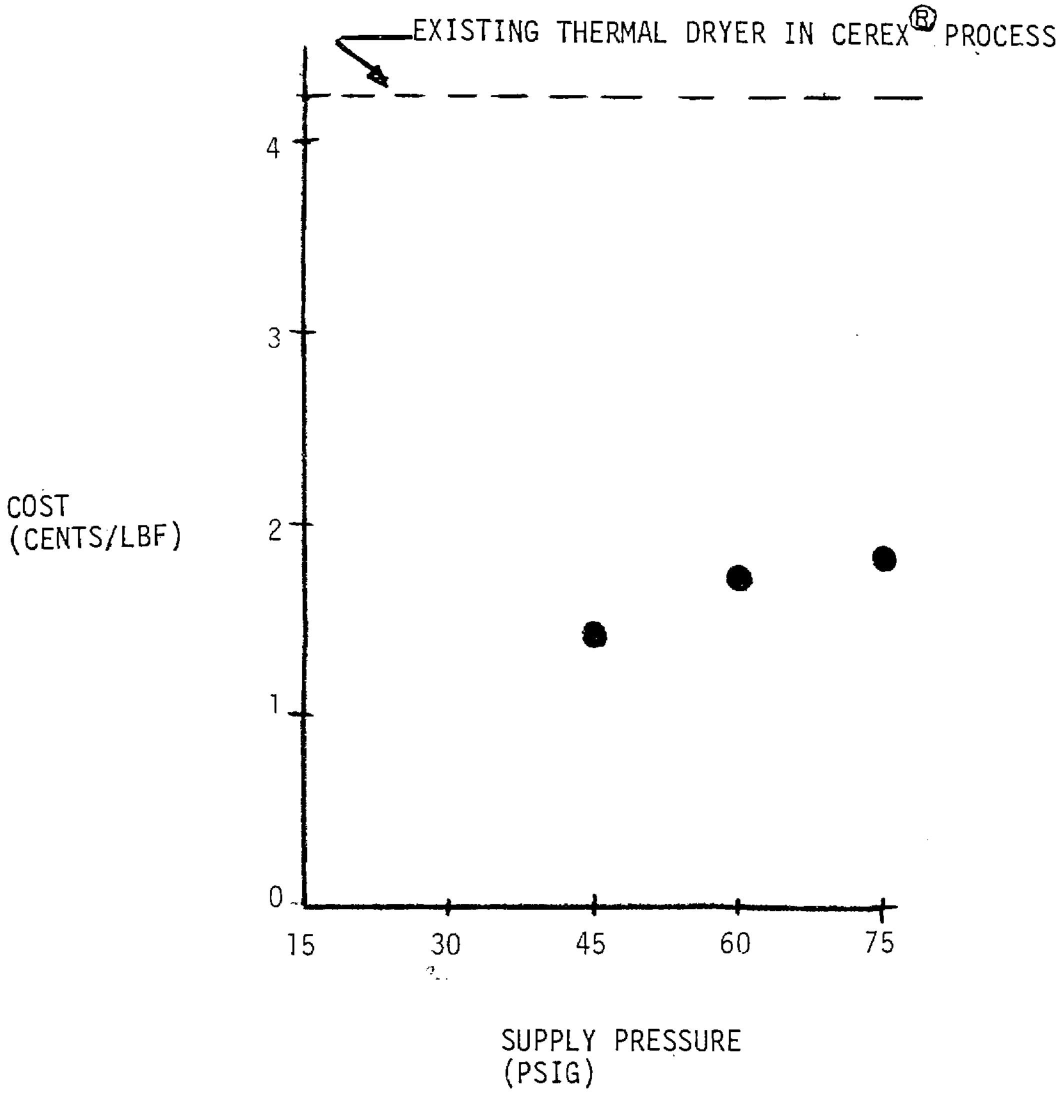


Figure 18. Total Drying Cost Versus Steam Supply Pressure 2.0 oz/yd^2, Type 23 Fabric - No Shim.

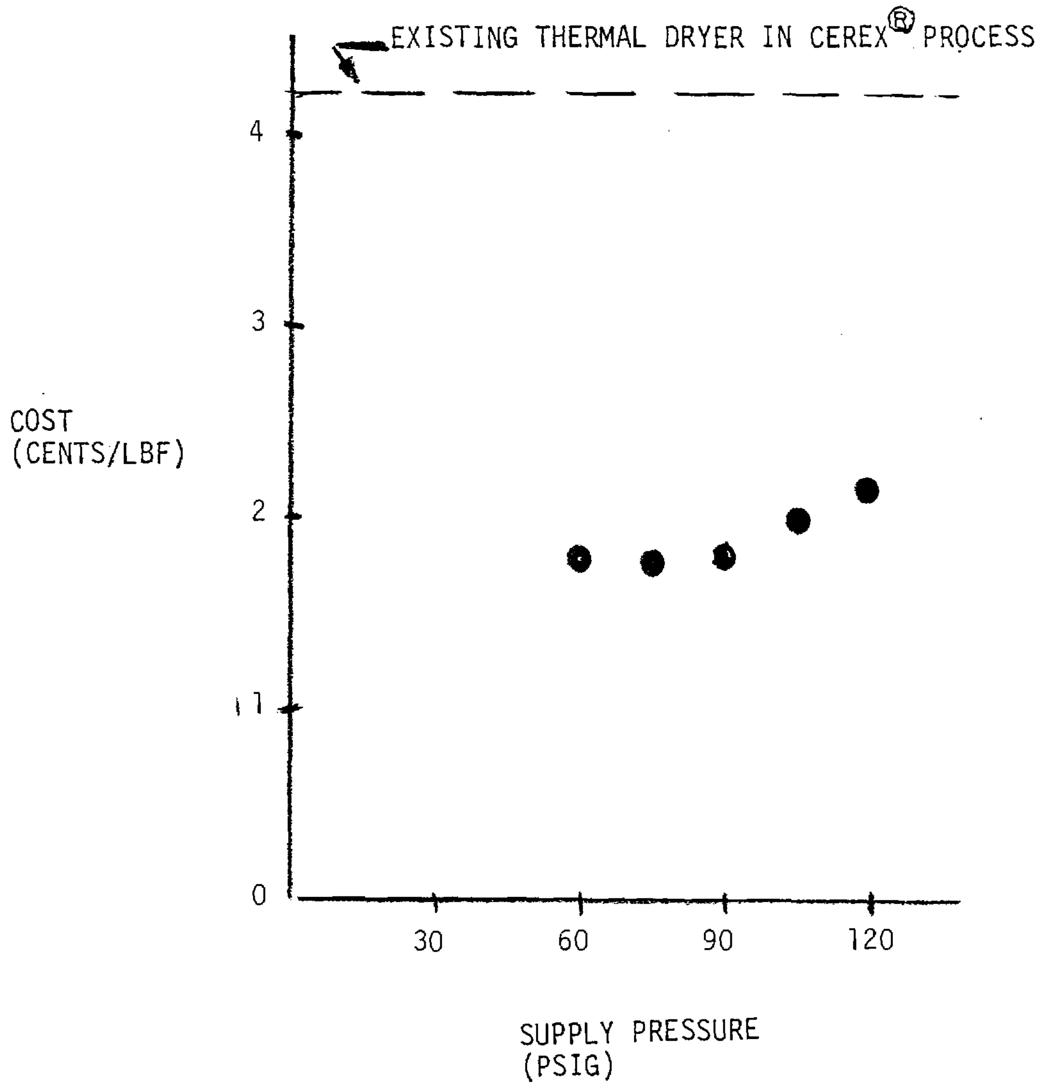


Figure 19. Total Drying Cost Versus Air Supply Pressure $2.0\ oz/yd^2$, Type 23 Fabric - 3 Mil Shim.

fabric and company the results with those from Phase I and II where Type 23, 0.5 oz/yd^2, Cerex® nonwoven fabric was used. Fabric type had little (if any) effect on moisture removal by the Machnozzle (see Figure 20). Since gas consumption was not affected by fabric type, the economics of dewatering using the Machnozzle should be the same for Types 23 and 24 fabric.

7.4 Physical Property Tests

Physical property tests on selected samples were conducted by Monsanto Textile and Intermediates Company. Results of the tests (Taber Abrasion, tear strength, thickness, Mullin burst strength, and air permeability) are summarized in Tables 4-6.

Samples were taken before and after the Machnozzle to determine if the Machnozzle had any effects on fabric properties. The results indicate that the effects were small in all of the tests. Taber abrasion values for samples taken after the Machnozzle were slightly lower than those for samples taken before the Machnozzle; however, the effect was small. All but one of the samples had Taber Abrasion values in the A-grade category.

Tear strength was evaluated in both the transverse and machine directions. The Machnozzle had little effect on tear strength in either direction. In some cases tear strength increased, while in other case it decreased. With one exception, tear strength of the samples fill in the A-Grade category. The Machnozzle had no obvious effects on thickness, burst strength or air permeability.

8. CONFIDENTIALLY AND PUBLICATIONS

The project was conducted in accordance with the Non-Disclosure Agreement between Georgia Tech and the Monsanto Fibers and Intermediates Company which was agree on as of April 22, 1983. The Georgia Tech researchers are free to publish the information generated by the project

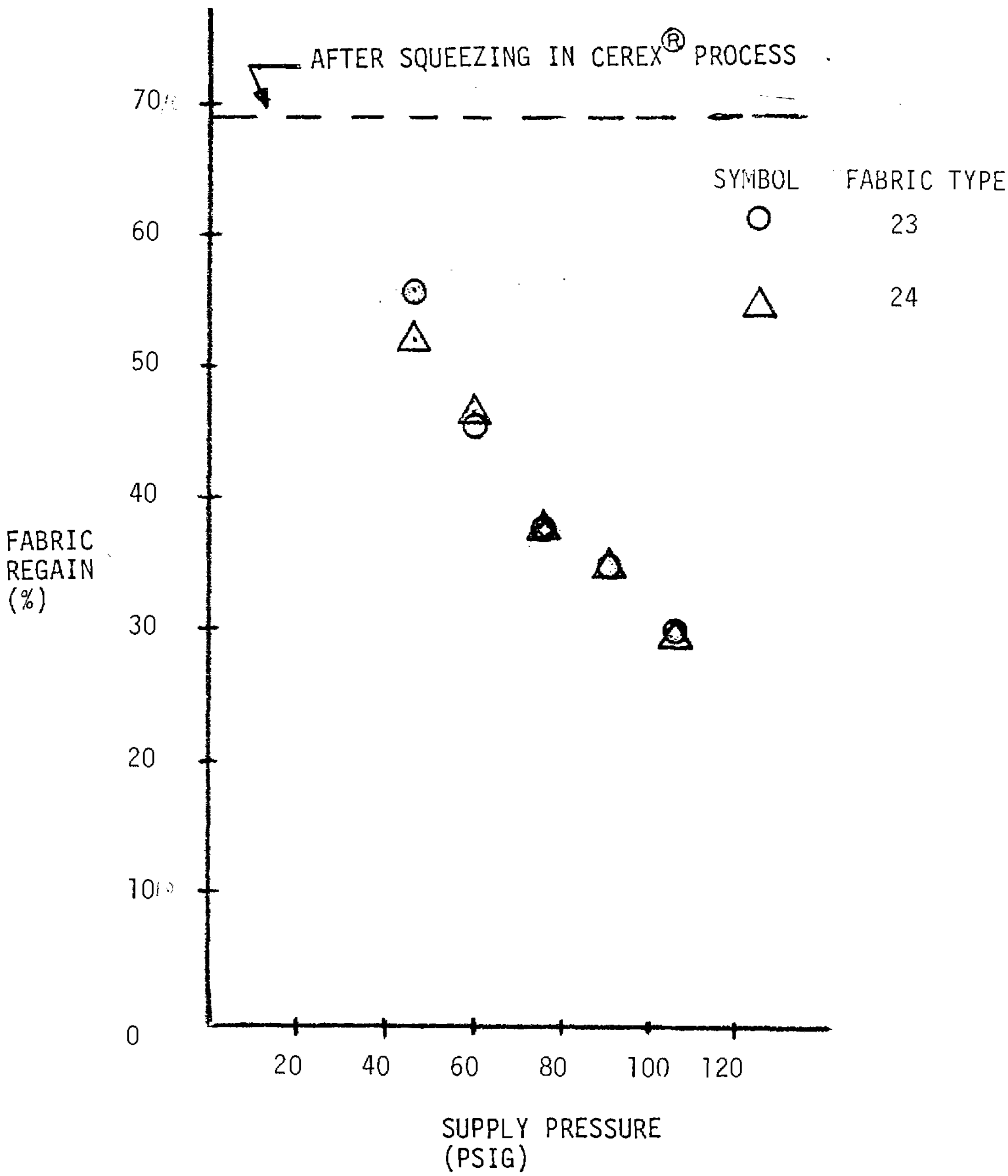


Figure 20. The Effect of Fabric Type on Machnozzle Performance 0.5 oz/yd^2 - 3 Mil Shim - Air.

Table 4. Fabric Property Test Results.

"Fabric Sample Summary"

Fabric Type	Weight	Sample I. D.
T-23	.5 osy	1 thru 22
T-23	.3 osy	23, 24, 43, 44
T-23	2.0 osy	25 thru 30
T-24	0.5 osy	31 thru 42

Lab Test Results

I. Type 23 Products

Sample Number	Taber Abrasion	Tear Strength Transverse	Tear Strength Machine	Thickness	Burst Strength	Air Permeability
1	4.7	---	---	---	---	960
2	4.9	4.7	---	---	---	1056
3	4.5	5.4	7.1	3.2	33	859
4	4.5	4.9	6.0	3.5	32	874
5	5.3	5.6	9.4	3.7	32	949
6	4.9	4.3	5.0	3.3	34	869
7	5.6	6.3	6.0	3.7	31	911
8	5.2	5.3	6.0	3.1	32	965
9	5.6	5.5	6.6	3.7	29	822
10	5.2	4.7	5.8	3.2	32	914
11	5.2	4.2	7.7	3.1	32	923
12	5.3	5.2	6.7	3.5	31	897
13	5.4	4.4	4.7	3.0	31	876
14	4.8	4.8	4.7	3.7	33	920
15	4.7	4.3	4.7	3.3	35	869
16	4.4	4.5	5.5	4.6	38	816
17	5.8	4.5	5.8	3.6	28	1019
18	4.4	4.3	5.4	3.5	33	901
19	5.5	4.8	5.5	3.3	33	981
20	5.5	5.1	4.9	3.4	30	1078
21	6.0	5.1	---	3.1	30	961
22	4.5	---	---	3.1	30	1023
23	4.8	2.6	4.4	2.6	24	1202
24	5.2	2.2	4.6	3.4	24	1349
25	4.0	11.0	16.6	7.0	87	142
26	2.0	13.4	16.8	8.0	87	174
27	3.6	11.5	17.6	7.2	83	156
28	3.3	11.7	20.1	8.3	92	135

Table 4. Fabric Property Test Results (Cont'd.)

I. Type 23 Products (cont'd)

Sample Number	Taber Abrasion	Tear Strength Transverse	Tear Strength Machine	Thickness	Burst Strength	Air Permeability
29	4.0	11.6	17.7	7.7	90	143
30	3.8	9.5	21.5	7.1	84	138
43	4.5	3.2	5.1	3.2	25	1214
44	4.8	3.1	5.5	2.3	26	1191

II. Type 24 Products

Sample Number	Taber Abrasion	Tear Strength Transverse	Tear Strength Machine	Thickness
31	1.0	1.0	3.8	3.4
32	1.0	1.2	3.9	3.8
33	1.0	1.2	4.1	3.8
34	1.1	1.5	5.2	4.0
35	1.0	1.5	4.7	3.6
36	1.2	1.0	4.0	3.9
37	1.3	1.2	4.3	3.7
38	1.0	1.2	4.6	3.5
39	1.2	1.0	3.7	3.9
40	1.4	0.9	3.5	3.7
41	1.0	1.5	4.6	3.7
42	1.0	1.2	3.6	4.2

Table 5. Cerex® Physical Property Specifications

I. Type 23 Products

A. 0.3 oz/yd²

Property	Typical	Min	Max	Target
Abrasion Resistance, Taber Cycles				
A-Grade Avg.	5.0	4.0		4.7
A-Grade Individual		3.0		
B-Grade Avg.		2.5		
Tear Strength, Pounds				
Transverse Direction	2.7	1.8		
Machine Direction	4.0	2.0		
Thickness, mils.	2.51			
Average Burst Strength, psi	25.0	14.0		
Air Permeability, CFM/ft²	1359			

B. 0.5 oz/yd²

Property	Typical	Min	Max	Target
Abrasion Resistance, Taber Cycles				
A-Grade Avg.	5.0	4.0		4.7
A-Grade Individual		3.0		
B-Grade Avg.		2.5		
Tear Strength, Pounds				
Transverse Direction	4.1	2.4		
Machine Direction	4.7	2.8		
Thickness, mils.	3.4			
Average Burst Strength, psi	33.5	18.0		
Air Permeability, CFM/ft²	933			

Table 5. Cerex® Physical Property Specifications (Cont'd.)

I. Type 23 Products (cont'd)

C. 2.0 oz/yd²

Property	Typical	Min	Max	Target
Abrasion Resistance, Taber Cycles				
A-Grade Avg.	5.0	4.0		4.7
A-Grade Individual		3.0		
B-Grade Avg.		2.5		
Tear Strength, Pounds				
Transverse Direction	11.75	11.0		
Machine Direction	14.5	13.0		
Thickness, mils.	7.3			
Average Burst Strength, psi	92	55		
Air Permeability, CFM/ft²	153			

II. Type 24 Products

0.5 oz/yd² only

Abrasion Resistance Taber Cycles	1.0
Strip Tensile Strength, lbs/in	
Transverse Direction	2.4
Machine Direction	4.9
Thickness, mils.	3.8

Table 6. Fabric Property Sample Identification.

Sample Number	Gas Type	Gas Supply Pressure (psig)	Contact Wrap Angle (degree)	Fabric Speed (ft/min)	Location of Sampling Machnozzle Before	After
Type 23, 0.5 oz/yd^2						
1	Steam	90	0	219	B	
2	Steam	90	0	219		A
3	Steam	45	0	219	B	
4	Steam	45	0	219		A
5	Steam	45	15	219	B	
6	Steam	45	15	219		A
7	Steam	45	30	219	B	
8	Steam	45	30	219		A
9	Steam	60	30	219	B	
10	Steam	60	30	219		A
11	Steam	75	30	219	B	
12	Steam	75	30	219		A
13	Air	75	0	219	B	
14	Air	75	0	219		A
15	Air	75	15	219	B	
16	Air	75	15	219		A
17	Air	75	30	219	B	
18	Air	75	30	219		A
19	Air	75	50	219	B	
20	Air	75	50	219		A
21	Air	135	50	219	B	
22	Air	135	50	219		A
Type 23, 0.3 oz/yd^2						
23	Air	60	15	265	B	
24	Air	60	15	265		A
43	Control					
44	Control					

Table 6. Fabric Property Sample Identification (Continued).

Sample Number	Gas Type	Gas Supply Pressure (psig)	Contact Wrap Angle (degree)	Fabric Speed (ft/min)	Location of Sampling Machnozzle Before	After
Type 23, 2.0 oz/yd^2						
25	Steam	60	50	65	B	
26	Steam	60	50	65		A
27	Air	75	50	65	B	
28	Air	75	50	65		A
29	Air	75	50	219	B	
30	Aira	75	50	219		A
Type 24, 0.5 oz/yd^2						
31	Steam	45	0	219	B	
32	Steam	45	0	219		A
33	Steam	45	15	299	B	
34	Steam	45	15	219		A
35	Steam	45	30	219	B	
36	Steam	45	30	219		A
37	Air	90	30	219	B	
38	Air	90	50	219		A
39	Air	90	50	219	B	
40	Air	90	50	219		A
41	Air	60	50	219	B	
42	Air	60	50	219		A

pertaining to the use of the Machnozzle to dewater nonwoven fabrics. In accordance with the Non-Disclosure Agreement, any publication of the results will not disclose information concerning Monsanto Fibers and Intermediates Company's Nonwoven Fabric Manufacture.

9. CONCLUSIONS

The results of the study show that the Machnozzle can appreciably lower the regain of Cerex® spunbonded, nonwoven nylon 6,6. Both steam and air were effective as the motive gas; however, lower fabric regains were obtained with steam. Passing the fabric across the Machnozzle had no appreciable effect on the physical properties measured.

Gas supply pressure, slot opening, and wrap angle are important system parameters that affect water removal and energy efficiency of the Machnozzle. Over the ranges of parameters tested, moisture removal by the Machnozzle increased as each of these parameters increased. However, when gas supply pressure and slot width (also, wrap angle when steam is the motive gas) are increased, gas consumption is increased, and conseqntly, energy cost of operating the Machnozzle is increased. Thus a cost/benefit analysis is necessary to establish optimal parameter settings. When steam was used with no shim in the Machnozzle, the optimal system parameters were: supply pressure of 45 psig and contact angles of 50°. When air was the motive gas, optimal system parameters were: supply pressure of 75 psig, contact angles of 50° and shim thickness of 3 mils.

The effect of fabric weight on the Machnozzle's ability to remove water is small; however, the economics of dewatering are quite different for the three fabric weight tested. The difference is due to the variation of fabric regain following squeezing with fabric weight. Energy cost savings associated with using the Machnozzle to dewater 0.3 oz/yd^2 and 0.5 oz/yd^2 Cerex® nonwoven fabrics were small (4 and 18%). On the other hand, use of the Machnozzle appreciably reduced the energy cost of drying 2.0 oz/yd^2 Cerex® nonwoven fabric. Energy cost was reduced by approximately 67%.

The effect of fabric type (23 versus 24) on the Machnozzle's ability to remove water was small. Also, the economies of utilizing the Machnozzle were similar for the two types of fabric.

Appendix A

COMPILATION OF TEST RESULTS

Table A1. Phase I

0.5 oz/yd^2, TYPE 23 CEREX® NONWOVEN FABRIC

Gas Type	Gas Supply Pressure (psig)	Gas Consumption (lb/hr-in)	Shim Thick-ness (Mils)	Wrap Angle (Degrees)	Fabric Speed (ft/min)	Fabric Regain After Squeezing in Cerex® Process (%)	Fabric Regain After Machnozzle (%)	Reduc-tion in Fabric Regain (%)	Drying Cost (cents/pounds of fabric) Machnozzle	Drying Cost (cents/pounds of fabric) Thermal Dryer	Drying Cost (cents/pounds of fabric) Total
CONTROL	-	-	-	-	230	69	-	-	0	2.25	2.25
STEAM	15	2.2	0	50	230	69	69	-	0.42	2.25	2.67
	30	4.1	0	50	230	69	41	28	0.77	1.33	2.10
	45	5.9	0	50	230	69	22	47	1.11	0.72	1.83
	60	7.8	0	50	230	69	17	52	1.47	0.54	2.01
	75	9.7	0	50	230	69	12	57	1.81	0.41	2.22
	90	11.5	0	50	230	69	10	59	2.17	0.32	2.40
AIR	15	0.4	2	50	230	69	69	0	0.03	2.25	2.29
	30	1.3	2	50	230	69	69	0	0.12	2.25	2.37
	45	3.0	2	50	230	69	69	0	0.28	2.25	2.54
	60	4.5	2	50	230	69	69	0	0.28	2.25	2.67
	75	5.8	2	50	230	69	66	3	0.55	2.16	2.70
	90	7.5	2	50	230	69	57	12	0.71	1.87	2.58
	105	9.2	2	50	230	69	52	17	0.87	1.68	2.55
	120	10.9	2	50	230	69	48	21	1.03	1.57	2.60
	135	13.0	2	50	230	69	46	23	1.22	1.50	2.71

Table A1. Phase I (Continued)

0.5 oz/yd^2, TYPE 23 CEREX® NONWOVEN FABRIC

Gas Type	Gas Supply Pressure (psig)	Gas Consumption (lb/hr-in)	Shim Thickness (Mils)	Wrap Angle (Degrees)	Fabric Speed (ft/min)	Fabric Regain After Squeezing in Cerex® Process (%)	Fabric Regain After Machnozzle (%)	Reduction in Fabric Regain (%)	Drying Cost (cents/pounds of fabric)		
									Machnozzle	Thermal Dryer	Total
AIR	45	5.4	3	50	230	69	52	17	0.51	1.69	2.20
	60	6.8	3	50	230	69	44	25	0.64	1.44	2.08
	75	8.9	3	50	230	69	39	30	0.83	1.27	2.11
	90	10.8	3	50	230	69	35	34	1.00	1.14	2.14
	105	12.3	3	50	230	69	30	39	1.15	0.98	2.13
	120	14.1	3	50	230	69	27	42	1.32	0.88	2.19
	135	16.1	3	50	230	69	22	47	1.50	0.73	2.23
AIR	15	8.0	5	50	230	69	58	11	0.75	1.89	2.64
	30	13.8	5	50	230	69	46	23	1.29	1.51	2.80
	45	17.0	5	50	230	69	38	31	1.60	1.25	2.85
	60	23.2	5	50	230	69	33	36	2.17	1.08	3.26
	75	26.5	5	50	230	69	30	39	2.49	0.98	3.47
	90	30.6	5	50	230	69	25	45	2.86	0.80	3.66
	105	36.7	5	50	230	69	25	45	3.44	0.81	4.25

Table A2. Phase II

0.5 oz/yd^2, TYPE 23 CEREX® NONWOVEN FABRIC

Gas Type	Gas Supply Pressure (psig)	Gas Consumption (lb/hr-in)	Shim Thickness (Mils)	Wrap Angle (Degrees)	Fabric Speed (ft/min)	Fabric Regain After Squeezing in Cerex® Process (%)	Fabric Regain After Machnozzle (%)	Reduction in Fabric Regain (%)	Drying Cost (cents/pounds of fabric): Machnozzle	Drying Cost (cents/pounds of fabric): Thermal Dryer	Drying Cost (cents/pounds of fabric): Total
CONTROL	-	-	-	-	230	69	-	-	0	2.25	2.25
STEAM	90	-	0	0	230	69	69	0	-	-	2.25
	90	5.1	0	15	230	69	61	8	0.97	1.99	2.96
	90	-	0	30	230	69	69	0	-	-	2.25
	90	14.8	0	50	230	69	12	57	2.169	0.32	2.49
STEAM	45	6.6	3	0	230	69	38	31	1.25	1.22	2.48
	45	6.2	3	15	230	69	32	37	1.17	1.04	2.22
	45	6.4	3	30	230	69	27	42	1.21	0.89	2.10
	45	11.0	3	50	230	69	16	53	2.08	0.54	2.62
STEAM	60	8.0	3	0	230	69	36	33	1.51	1.18	2.69
	60	8.0	3	15	230	69	22	47	1.51	0.71	2.22
	60	8.0	3	30	230	69	22	47	1.51	0.72	2.23
	60	14.4	3	50	230	69	15	54	2.72	0.48	3.20
AIR	75	8.9	3	0	230	69	51	18	0.83	1.66	2.49
	75	8.9	3	15	230	69	46	23	0.83	1.51	2.34
	75	8.9	3	30	230	69	46	23	0.83	1.33	2.16
	75	8.9	3	50	230	69	41	28	0.83	1.27	2.10

Table A3. Phase III

0.3 oz/yd^2, TYPE 23 CEREX® NONWOVEN FABRIC

Gas Type	Gas Supply Pressure (psig)	Gas Consumption (lb/hr-in)	Shim Thick-ness (Mils)	Wrap Angle (Degrees)	Fabric Speed (ft/min)	Fabric Regain After Squeezing in Cerex® Process (%)	Fabric Regain After Machnozzle (%)	Reduction in Fabric Regain (%)	Drying Cost (cents/pounds of fabric) Machnozzle	Drying Cost (cents/pounds of fabric) Thermal Dryer	Drying Cost (cents/pounds of fabric) Total
CONTROL	-	-	-	-	331	61	-	-	0	1.99	1.99
STEAM	30	2.0	0	50	265*	61	50	11	0.41	1.64	2.05
	45	3.9	0	50	265	61	43	18	0.81	1.39	2.20
	65	5.1	0	50	265	61	27	34	1.03	0.89	1.92
AIR	45	5.4	3	50	265	61	42	19	0.55	1.38	1.93
	60	6.8	3	50	265	61	41	21	0.69	1.32	2.01
	75	8.9	3	50	265	61	34	27	0.90	1.10	2.00

* Maximum Speed Obtainable on Test Apparatus.

Table A4. Phase III

2.0 oz/yd^2, TYPE 23 CEREX® NONWOVEN FABRIC

Gas Type	Gas Supply Pressure (psig)	Gas Consumption (lb/hr-in)	Shim Thick-ness (Mils)	Wrap Angle (Degrees)	Fabric Speed (ft/min)	Fabric Regain After Squeezing in Cerex® Process (%)	Fabric Regain After Machnozzle (%)	Reduc-tion in Fabric Regain (%)	Drying Cost (cents/pounds of fabric)		
									Machnozzle	Thermal Dryer	Total
CONTROL	-	-	-	-	65	130	-	-	4.24	4.24	4.24
STEAM	45	4.3	0	50	65	130	18	112	0.80	0.60	1.40
	60	6.7	0	50	65	130	15	115	1.25	0.50	1.75
	75	8.3	0	50	65	130	9	121	1.56	0.30	1.86
AIR	60	6.8	3	50	65	130	35	95	0.64	1.14	1.78
	75	8.9	3	50	65	130	29	101	0.83	0.96	1.79
	90	10.8	3	50	65	130	26	104	1.00	0.84	1.84
	105	12.4	3	50	65	130	26	104	1.16	0.85	2.01
	120	14.2	3	50	65	130	24	106	1.32	0.78	2.10

Table A5. Phase III

0.5 oz/yd^2, TYPE 24 CEREX® NONWOVEN FABRIC

Gas Type	Gas Supply Pressure (psig)	Gas Consumption (lb/hr-in)	Shim Thick-ness (Mils)	Wrap Angle (Degrees)	Fabric Speed (ft/min)	Fabric Regain After Squeezing in Cerex® Process (%)	Fabric Regain After Machnozzle (%)	Reduc-tion in Fabric Regain (%)	Drying Cost (cents/pounds of fabric) Machnozzle	Drying Cost (cents/pounds of fabric) Thermal Dryer	Drying Cost (cents/pounds of fabric) Total
CONTROL	-	-	-	-	230	69	-	-	-	2.25	2.25
STEAM	45	5.3	3	0	230	69	41	28	1.01	1.35	2.36
	45	6.2	3	15	230	69	30	39	1.18	0.99	2.17
	45	6.5	3	30	230	69	31	38	1.23	1.03	2.26
AIR	45	5.4	3	50	230	69	56	13	0.51	1.82	2.32
	60	6.8	3	50	230	69	47	22	0.60	1.52	2.12
	75	8.9	3	50	230	69	38	31	0.83	1.24	2.07
	90	10.8	3	50	230	69	36	33	1.01	1.17	2.18
	105	12.3	3	50	230	69	29	40	1.16	0.96	2.12

Appendix B

GAS CONSUMPTION VERSUS GAS SUPPLY PRESSURE

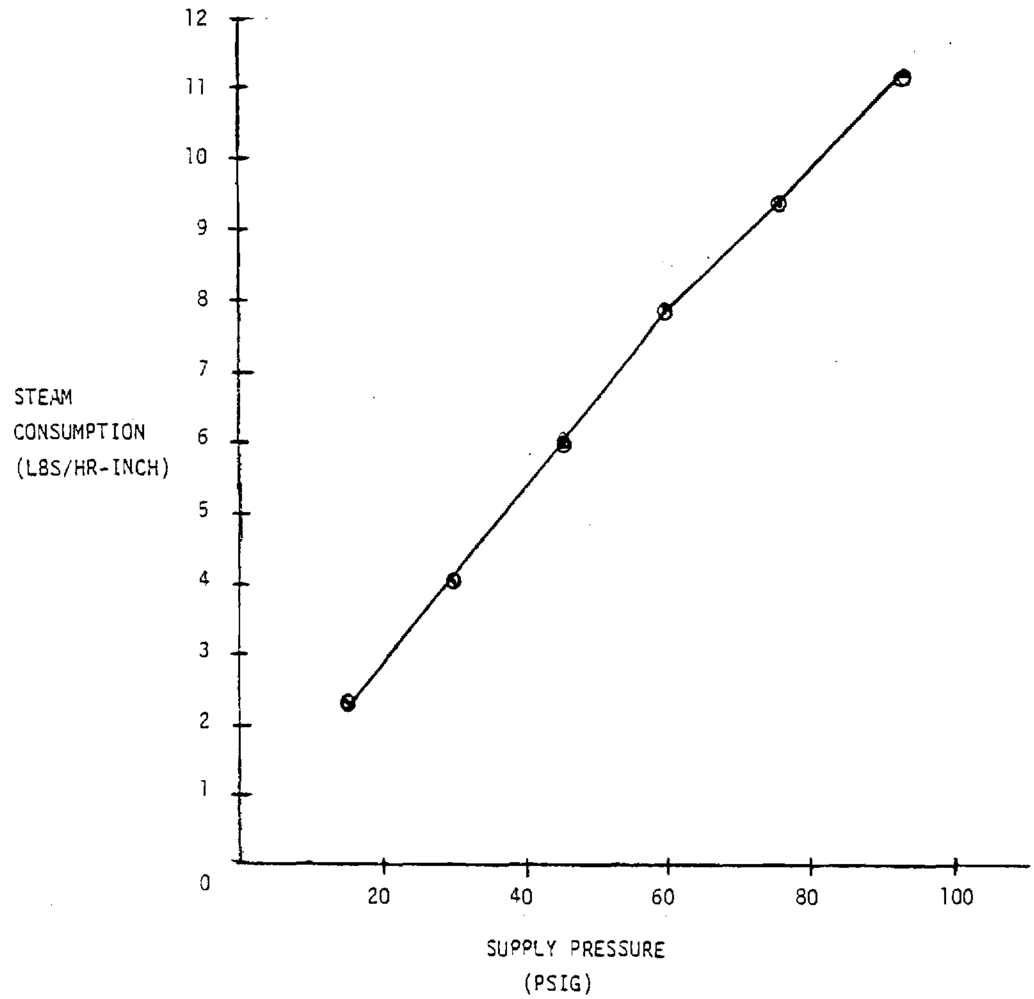


Figure B1. Steam Flow Rate Versus Supply Pressure - No Shim.

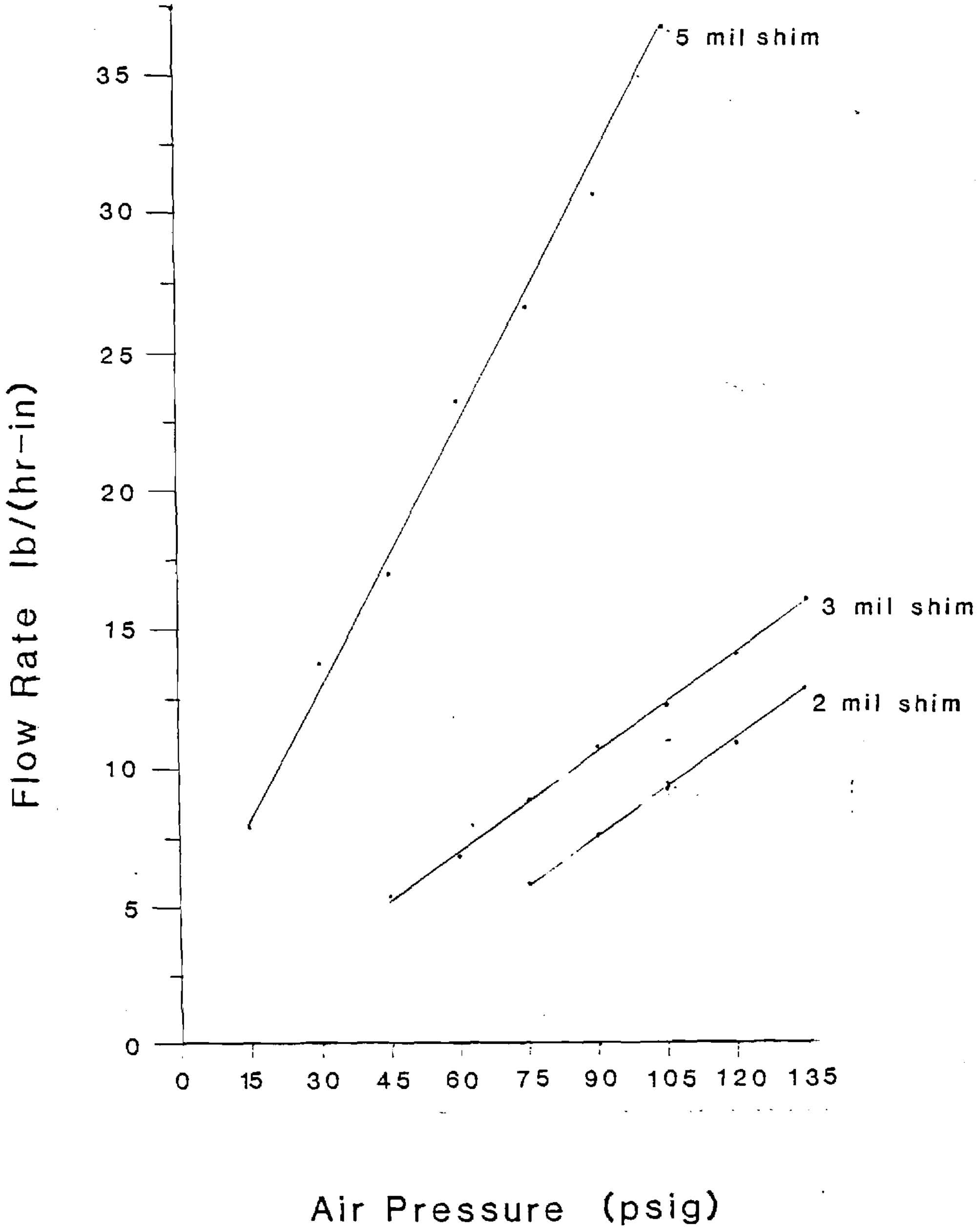


Figure B2. Air Flow Rate Versus Supply Pressure

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