



INSTITUTE OF
PAPER CHEMISTRY
Appleton Wisconsin

**CONSTRUCTION OF A DEVICE FOR
STUDYING DRAINAGE AT ROLLS AND FOILS**

Project 2570

Report Three

A Progress Report

to

MEMBERS OF GROUP PROJECT 2570

May 11, 1967

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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MEMBERS OF GROUP PROJECT 2570:

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TABLE OF CONTENTS

	Page
SUMMARY	1
INTRODUCTION	2
CONSTRUCTION DETAILS	4
LITERATURE CITED	14
APPENDIX I. COMMERCIALY MANUFACTURED COMPONENTS OF THE HSHSD	15

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

CONSTRUCTION OF A DEVICE FOR STUDYING DRAINAGE AT ROLLS AND FOILS

SUMMARY

The high-speed hydrodynamic suction device (HSHSD) has been constructed and it has been demonstrated that reliable drainage data may be obtained on this unit. Artificial limitations imposed on the system have fixed the presently attainable maximum wire and water velocities.

Experimental results have shown that it is critical to define the drainage geometry and a series of tests have served to illustrate effects which some of the variables may have.

It is possible to evaluate the contributions of the following variables:

1. roll diameter
2. variable resistance
3. roll forming board geometry
4. foil design.

INTRODUCTION

The driving force causing drainage at the table roll nip has been studied by Taylor (1) and Burkhard and Wrist (2) who have shown the relationship between machine speed and suction profiles. Taylor developed an expression relating the drainage at a roll to table roll radius, wire speed, wire width, viscosity, density, and the resistance of the porous medium. Unfortunately, Taylor's equation has not been successfully applied without the introduction of empirical constants to adjust drainage properties as observed in the laboratory and on the machine.

Ingmanson (3) combined a simple material balance and Taylor's drainage equation to predict the basis weight increment at each roll of the table section. However, an empirical value equal to 1/20th of the maximum suction pressure developed was used to evaluate the resistance in his treatment. Inherent in the work of Ingmanson, Taylor, and others has been the assumption that the flow is laminar and no mixed mode of flow exists. Recent work has shown (4) that flow is probably of mixed mode; hence, the application of viscous resistance is not valid.

The failure of Taylor's equation to adequately describe the conditions encountered on commercial paper machines has led to an attempt to design a testing device which would yield reliable drainage data over a wide range of velocities and basis weights. The design of the equipment to generate the necessary data should satisfy the following criteria:

1. Wire and roll velocities should be continuously variable from 0 to 5000 f.p.m.
2. Wire width must be great enough to minimize edge effects.

3. Test zone for drainage must be well defined.
4. Rolls and foils must be tested in a fixed geometry.
5. The porous bed must be virtually incompressible but variable in resistance.

CONSTRUCTION DETAILS

Figure 1 is a photograph of the assembled unit as it has developed into a reliable test device. The features incorporated into the high-speed wet end have evolved with time and many are the result of numerous trials. The similarity to a foudrinier wet end with all its vagaries has caused some difficulties.

Figure 2 is a dimensional drawing which illustrates the most important constructional features of the high-speed hydrodynamic suction device (HSHSD). The drawing is intended to serve as a guide for the overall spacing of rolls and wire-carrying foils. It also serves to illustrate the form of the adjustable brackets and the slides for mounting of pillow blocks for tension adjusting. The frame members were designed to assure adequate rigidity to permit precise alignment of the wire-carrying rolls.

The framework was very carefully leveled with the adjustment screws in the pads and was then affixed in place by an epoxy cement to the concrete floor. Although there had been some heat distortion of the members during the welding, it was possible to position the frame as desired.

The positions of the carrying rolls (the 16-in. diameter rolls) were roughly indicated on the H beams. The drive motor and mounting assembly was then set in place and the spacing for wire clearance was checked. Once the drive and roll positions had been established, the drive roll on its pillow blocks was set in place and squared with the frame. This roll was then attached to the H beam in its fixed position.

The breast roll position was determined by taping from the journals of the drive roll. This technique gave good alignment and any slight error could be compensated for by the take-up roll.

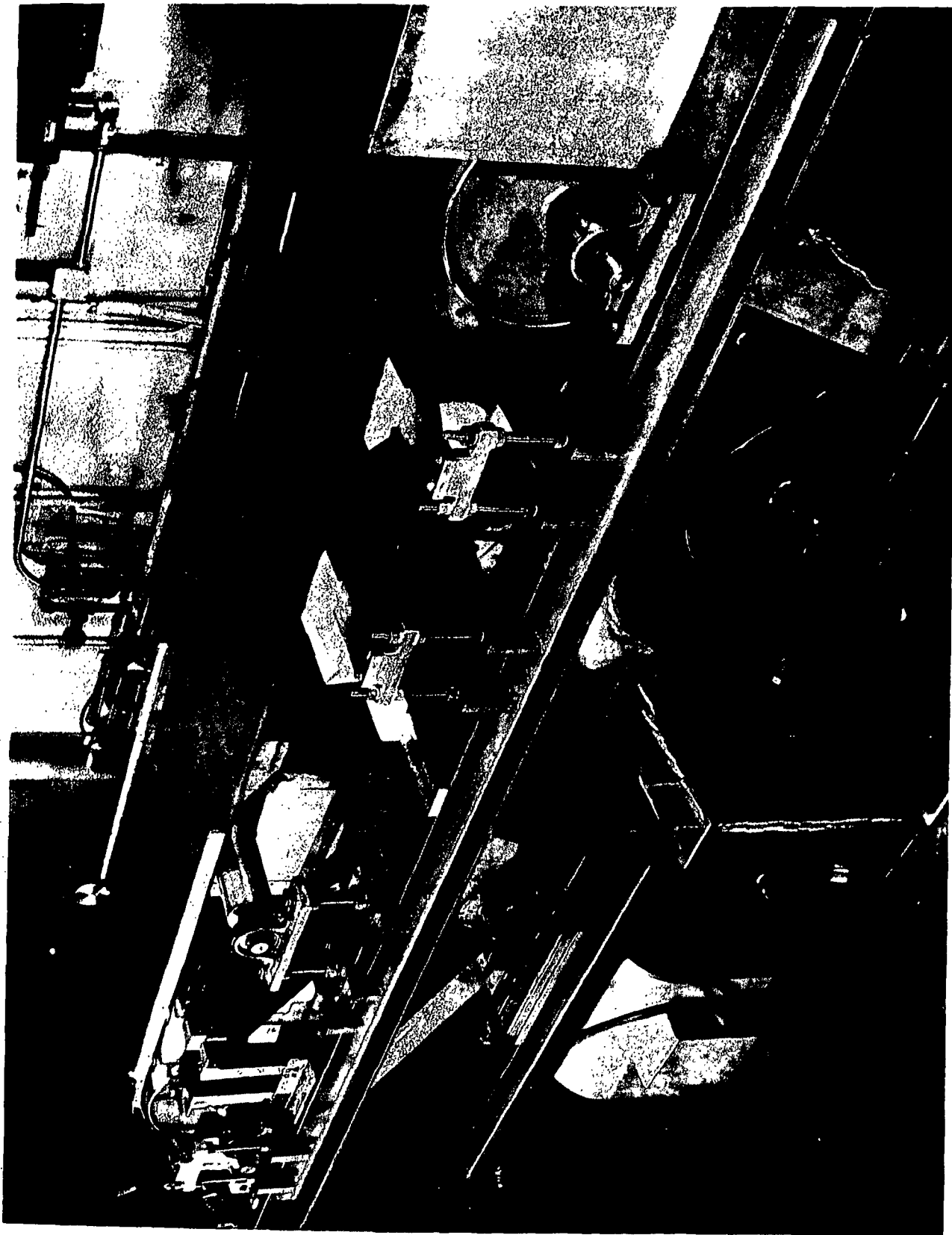
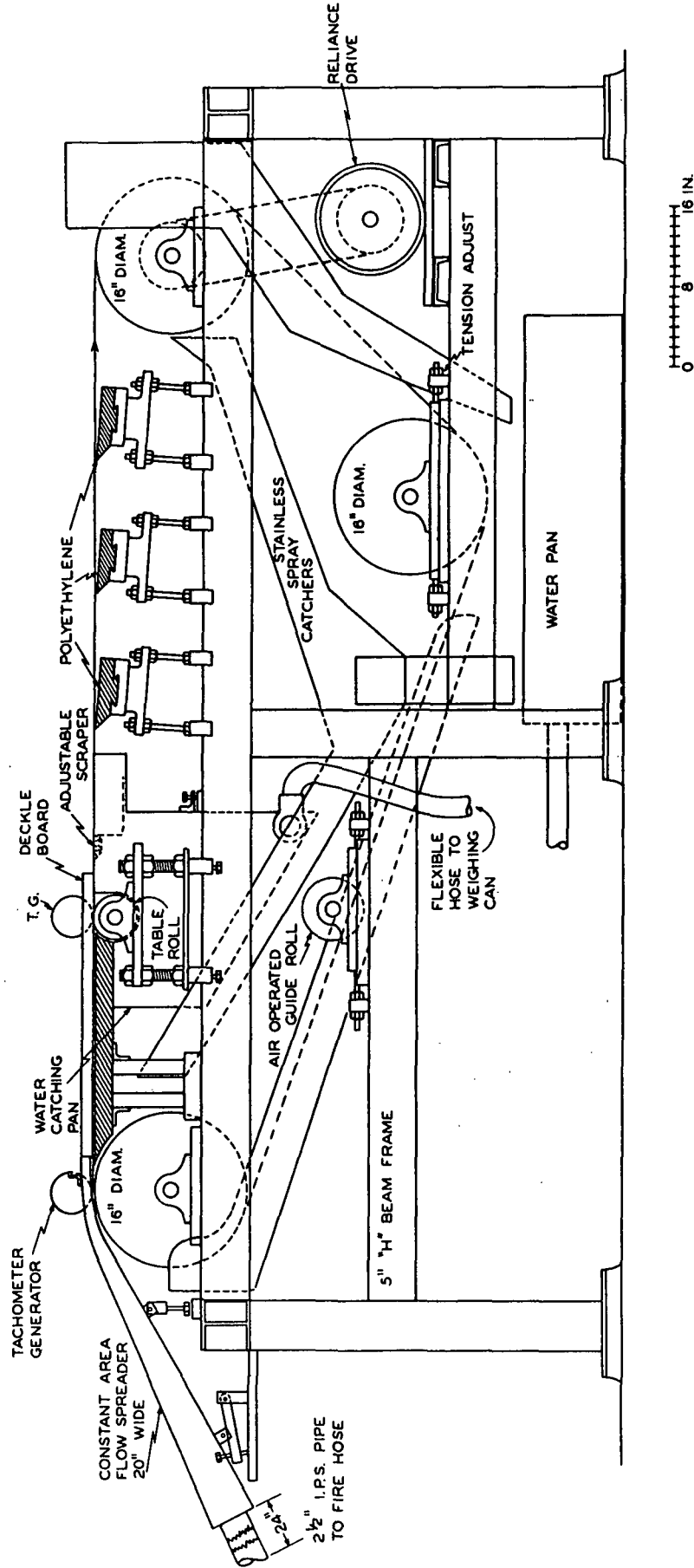


Figure 1. High-Speed Hydrodynamic Suction Device



HIGH SPEED HYDRAULIC SUCTION DEVICE

Figure 2. Detail Drawing of Drainage Device

The pillow blocks of the take-up roll were mounted in a brass slide which allowed a total travel of the block of six inches. The movement of the take-up roll is controlled by the opposing lead screws which also lock it firmly in position while the unit is being operated.

The welded frame does not make provisions for wire installation or changing. Since wire life is not a factor in the operation, it was felt that the wire could be seamed in position and that this would not limit the application of the device.

Contrary to normal practice, the guide roll was placed inside the wire. The possibility that the numerous layers of fabric could interfere with guiding could not be ignored. It would have been desirable to move the guide roll parallel with the wire rather than at a considerable angle to it to prevent stretching. Space limitations dictated both the position and direction of travel of the roll.

The drive that has been used in the early phases of the program is underpowered to meet full load requirements of the top velocity of 5000 f.p.m. It has served very adequately up to 2000 f.p.m. and is virtually continuously adjustable within this range. The motor is a Reliance "Super T" 3-h.p. d.c. unit. The speed control is an external 10-turn potentiometer mounted on a swinging bracket with the start-stop switch.

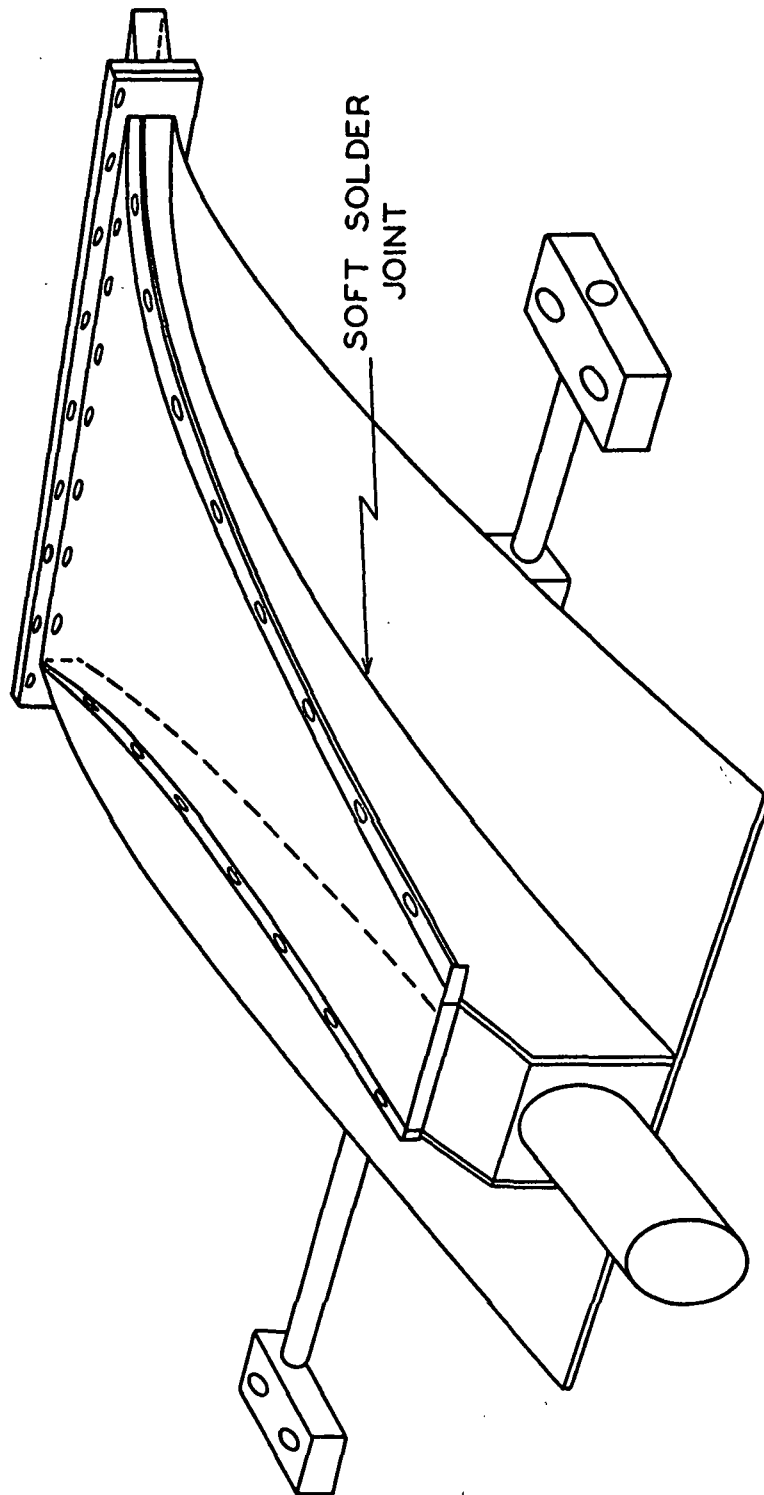
The constant-area flow spreader is patterned after the spreader installed on the IPC Web Former. Flexural rigidity was improved by the addition of threaded pins alternately top-bottom spaced 1 in. apart across the width of the spreader at the point where the variable slice is attached. The velocity distribution of this inlet has been checked with small-bore impact tubes and was

found to be quite flat. Unfortunately, the fluid pressures at the high flow rate are great enough to cause some distortions and unusual disturbances result. The mechanical strength of the soft solder and mastic seals is not great enough to withstand appreciable increases in the loading. The very high drainage ranges will have to be covered by a different type of inlet. Figure 3 is an isometric sketch of the spreader configuration.

The installation of the so-called "forming board" has proven to be a necessary feature of the design. For the case of this testing device flow must be nearly inhibited before the wire-water resistance system contacts the test item. Any water drained by gravity will tend to cling to the underside of the wire and will be subsequently forced back into the system in passing over the roll crown. This water, plus any drained by whatever action prior to the test section, would be construed as part of the measured drainage.

Various types of scrapers were installed between the end of the forming board and the test roll and evaluated. Such scrapers tended to complicate the analysis as they acted as foils or forced an additional amount of water into the wire system.

Two materials were examined for the forming board--polyethylene and aluminum. Both materials were obtained in sheet form with the poly being about 1-11/16-in. and the aluminum 5/8-in. thick. The dimensional stability of the poly sheet gave severe distortion problems. The water contacting the upper surface was about 3°C., and although the board was scored to relieve the stresses, considerable curvature could be observed. The conductivity of polyethylene is very low and hence it takes a long time to adjust the temperature of this rather considerable mass.



MATERIAL OF CONSTRUCTION
MUNTZ METAL

Figure 3. Isometric Sketch of Flow Spreader

Although the thermal expansivity of the aluminum is sufficient to produce nonplanar surfaces, the high thermal conductivity quickly brings the entire board to an equilibrium temperature. The aluminum was coated with a thin Teflon coating to reduce friction and to minimize corrosion effects in the water-brass-aluminum cell.

The test roll or foil is installed on adjustable brackets so that the geometry of the breast roll, forming board, roll or foil, and trailing scraper are fixed and reproducible. It has been found desirable to operate with the top of these four items all in the same plane, and although this reduces wire wrap at the roll, the improved definition of the drainage conditions justifies this position.

The test zone is defined in its drainage dimensions by a catch pan designed to surround the roll or foil and to catch all the drained water. In the case of the roll, provision has been made for a scraper to remove the water clinging to the surface of the roll. The level of water in the container may be observed through a Lucite window, and a flexible hose leads to a tared drainage container.

The velocities of the breast roll and test roll are checked by means of a tachometer generator and an impulse counter. The drive wheel of the generator was machined to give a 12-inch circumference which gives a calibration factor of $1/6$ for the impulse counter. By using two tachometer generators, one may obtain either roll speed independently or the ratio of the two speeds to three significant decimal places. The impulse counter has been wall mounted to permit the operator instantaneous viewing of the digital read-out.

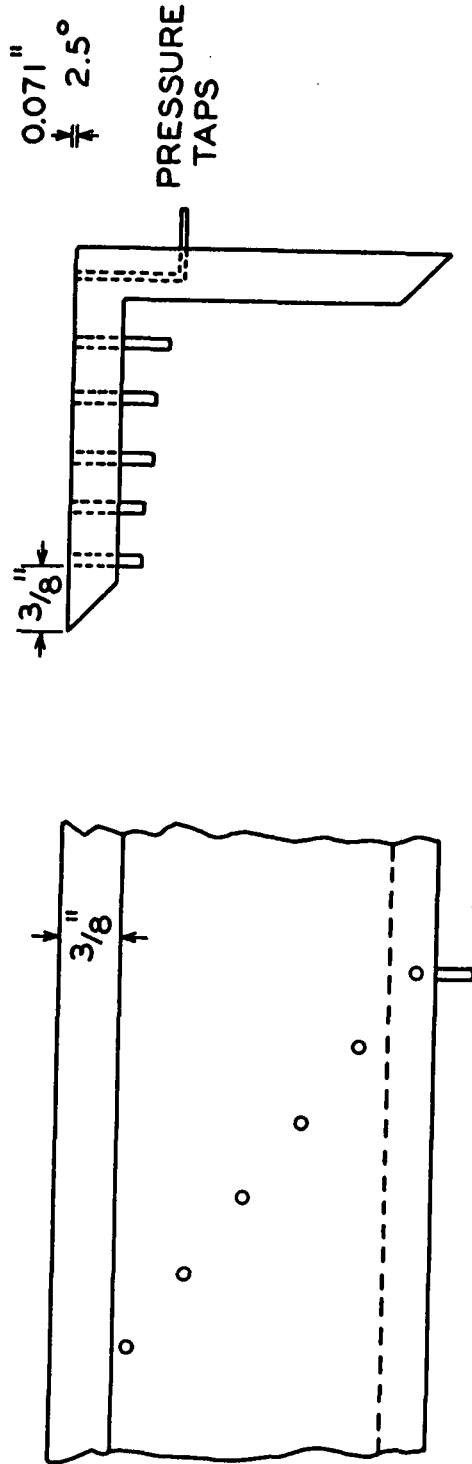
It was anticipated that frictional losses in the bearings and the drag contribution of the roll could possibly result in a test roll speed significantly below that of the wire. A small air motor coupled to the test roll permits this roll to be driven at any desired ratio within the control limits of the system.

The test roll diameter may be varied from 2 to 8 inches in 2-inch increments. The current program has been limited to the smaller diameter rolls because of other limitations of the system.

The foil design has been standardized as shown in Fig. 4. Since the drainage is controlled by the foil angle, a number of constructions will be evaluated. It was necessary to machine the foil from a material which will not change in its critical dimensions. The spacing of the pressure taps is arbitrary and they have been installed only to develop the suction profile as a function of machine variables.

A comprehensive listing of conventional papermaking wire weaves were evaluated for their flow resistance for possible application to this unit. The 80 x 80 flat warp wire supplied by Appleton Wire Works was found to have the desired characteristics. This weave has a resistance comparable to the 100-mesh but has sufficient rigidity to reduce guiding problems at high speeds.

The web resistance has been approximated by using synthetic fiber cloth of various meshes and weight combinations. Static permeation tests have demonstrated, for example, that two layers of a 200-mesh nylon cloth is roughly equal to the resistance of a 10-g./m.² sheet of a classified, unbeaten sulfite pulp. By various combinations of mesh sizes up to a 400 mesh it is possible to model various basis weight webs. The 100-g./m.² case may be evaluated by a single layer of a dacron sailcloth.



FOIL

MATERIAL: $2" \times 2" \times 1/4"$ 304 SS ANGLE

Figure 4. Detail of Foil Construction

The primary disadvantage of using nylon is the hydroexpansivity of the material. Once the nylon is on the wire it is imperative that the nylon be wetted at all times.

The cloth has been attached to the wire by sewing it into position (while wet) using 0.006-in. stainless steel wire. The wire is damaged by this technique, but it is possible to reuse the needle holes each time a new layer is added.

The nylon has exhibited only a mild decay in permeability during the course of its usage. Particulate matter contamination has effected essentially a 10% increase in the effective resistance of the material. Periodic measurements of the permeability can easily check this condition of any number of layers of the material.

The complete specifications and suppliers of the various components of the unit are listed in the Appendix. This list is intended as a guideline and should not be construed as a recommendation of any one particular manufactured product.

LITERATURE CITED

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2. Burkhard, G., and Wrist, P. E., Pulp Paper Mag. Can. 57, no. 4:100(1956).
3. Ingmanson, W. L., Tappi 42, no. 6:449-51(1959).
4. Han, S. T. The status of the sheet-forming process: A critical review. Appleton, Wis., The Institute of Paper Chemistry, Dec. 31, 1965.

THE INSTITUTE OF PAPER CHEMISTRY

Bruce D. Andrews, Jr.

Bruce D. Andrews
Research Fellow
Mechanical Processes Group
Technology Section

APPENDIX I

COMMERCIALY MANUFACTURED COMPONENTS OF THE HSHSD

Drive: Reliance Electric and Engineering Company
Cleveland, Ohio

Reliance d.c. motor
3 h.p.
150 volts, 17.4 amp.
Electronic drive style "ES"

Guide: Bailey Meter Co.
Wickliffe, Ohio

Pilot valve assembly - 0.003-in. port sleeve
Part no. 581030-3

Short-radius valve stem for 1/16-in. radius
Part no. 58880-1

(Above from drawing no. P99-15)

Air cylinder - Bellows Power Dome
4-inch diameter cylinder
2-inch travel

Wire: Appleton Wire Works Corp.

80 x 80 flat warp semitwill weave

Fabric: Tobler, Ernst & Traber, Inc.
71 Murray Street, New York, N.Y.

Nitex nylon monofilament screen cloth

200-74
230-62
270-57
325-44
400-37

Hardware: Local supplier constructed framework and rolls.