AD NUMBER

AD213367

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 11 Feb 1959. Other requests shall be referred to the U.S. Naval Research Laboratory, Washington, DC, 20375.

AUTHORITY

NRL ltr, 3 May 2004

UNCLASSIFIED

AD 213367

Armed Services Technical Information Agency

ARLINGTON HALL STATION
ARLINGTON 12 VIRGINIA

Best Available Copy

FOR
MICRO-CARD
CONTROL ONLY

1 OF 1

UNCLASSIFIED

NRL Report 5265

AN IMPROVED DEVICE FOR THE FORMATION OF SUPERFINE, THERMOPLASTIC FIBERS

K. D. Lawrence, R. T. Lucas, and J. A. Young

Protective Chemistry Branch
Chemistry Division

February 11, 1959

U. S. NAVAL RESEARCH LABORATORY
Washington, D.C.

ABSTRACT

This report describes the modifications which have been made on the original NRL device for forming superfine, thermoplastic fibers. The modifications allow a more precise control of process variables. They include (a) a new nozzle which materially reduces shot formation, (b) an improved heating block and cooling system which reduces warmup time, and (c) an altered collection unit which markedly improves fiber laydown. The formation of reproducible lots of superfine, thermoplastic fibers of a given material is now possible.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

NRL Problem C08-10
Projects NS 097-001 and NR 478-000,
Task NR 478-005

Manuscript submitted December 17, 1958

AN IMPROVED DEVICE FOR THE FORMATION OF SUPERFINE, THERMOPLASTIC FIBERS

INTRODUCTION

For the past several years, this Laboratory has had in operation equipment which produces superfine fibers from a variety of thermoplastic materials. This equipment uses a melt extrusion process in which a hot, thermoplastic melt is forced through a row of fine orifices into two converging high-velocity streams of heated air. Fibers are attenuated within the air stream and are deposited on a moving screen as a random mesh. Submicron fibers have been produced successfully from such materials as polyamides, polyesters, and polypropylene.

MODIFICATIONS

Since the time of the first report,* a number of modifications have been made which include the improvement of original components and the use of additional control equipment. These changes have improved the control of the process variables so that extended runs yield spools of fiber with essentially identical characteristics. A definite improvement can be observed in the physical appearance of the fiber and its laydown.

Modifications on the fiber machine fall into four general classifications: nozzle redesign, electrical changes, redesign of the fiber collection unit, and addition or replacement of control equipment. Some changes were suggested in the above-mentioned report, while others became desirable after extended operation of the machine. A flow diagram of the essential apparatus is contained in Fig. 1, while an outline sketch of the extruder-heating blocks and nozzle array is shown in Figs. 2 and 3. Various views of the equipment are shown in Figs. 4, 5, and 6.

Nozzle

From the outset, the nozzle has proved to be the most critical feature of the entire apparatus and has given the most difficulty. After the original experimental designs were evaluated, the early runs were made with a nozzle containing 192 orifices arranged in four groups of 48, with each group occupying a width of one inch. However, some difficulty was experienced with the formation of nonfibrous material commonly called "shot." Shot formation was attributed in part to the small distance separating 48 orifices in a width of one inch. It was believed that a wider separation of the orifices would lead to a reduction of this objectionable material. Consequently, new nozzles were fabricated with 100, 68, and 36 openings, i.e., 25, 17, and 9 per linear inch.

*V.A. Wente, E.L. Boone, and C.D. Fluharty, "Manufacture of Superfine Organic Fibers," NRL Report 4364, May 1954

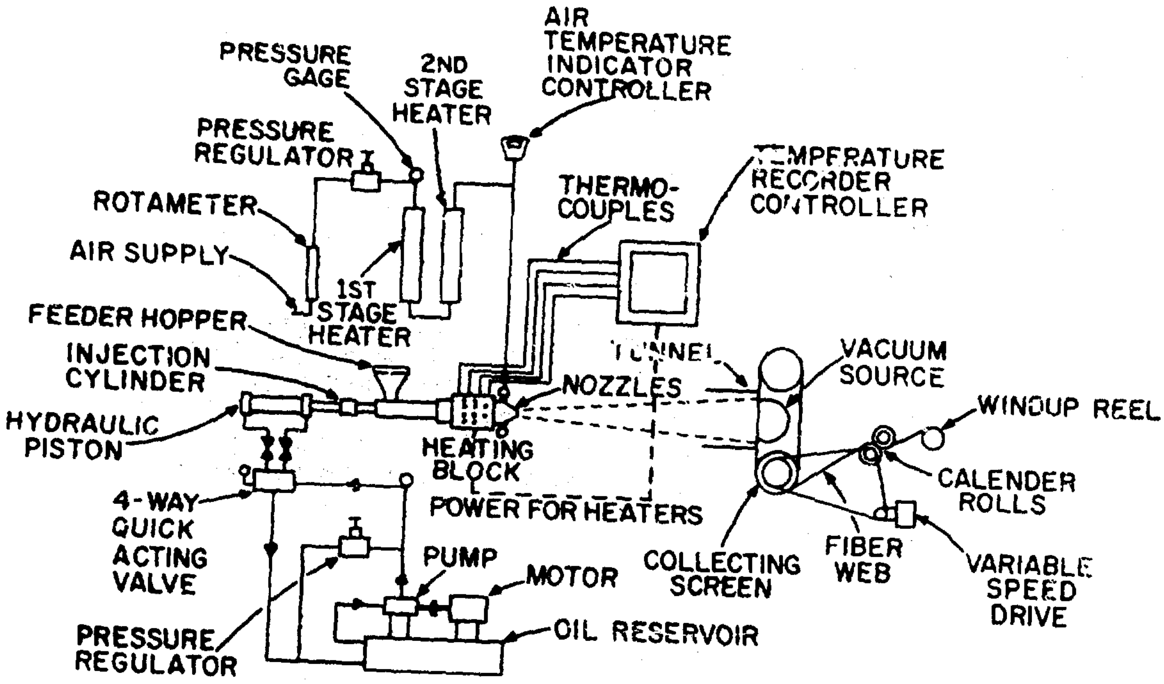

Fig. 1 - Equipment for fiber formation and collection

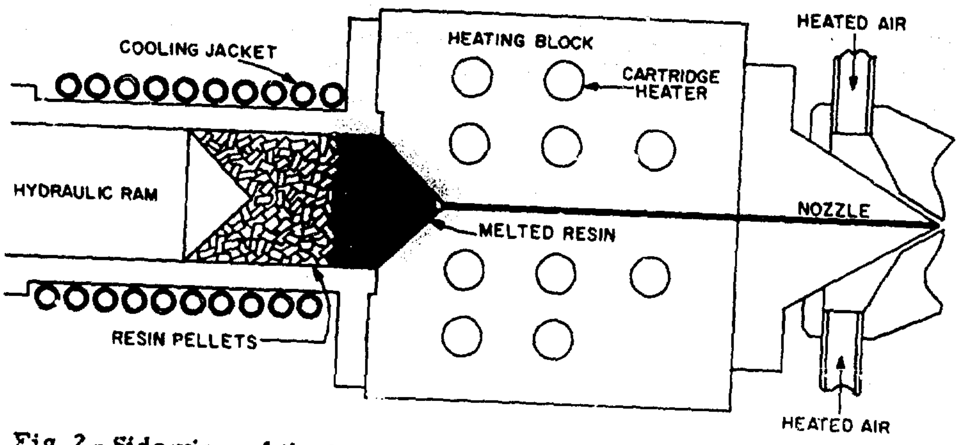

Fig. 2 - Side view of the heating block and nozzle arrangement. The cartridge heaters do not extend all the way through the block; there are 10 heaters extending into each side of the block, or 20 in all.

The 36-orifice nozzle has supplied the best results to date. It contains four groups of nine openings each, with orifices spaced one-eighth inch apart (Fig. 3). The increased spacing has very effectively reduced the formation of shot. Another feature of this nozzle is that the grooves are tapered at a one-half-degree angle from front to back. This reduces the ram pressure needed to force the melted resin through the nozzle. Recent runs have averaged about 150 grams of fiber per hour when using a commercially available polyamide and fiber diameters have been averaging about 0.8 micron. This diameter produces the most satisfactory laydown of the fiber mat, but is a slight increase over that obtained from the original nozzle.

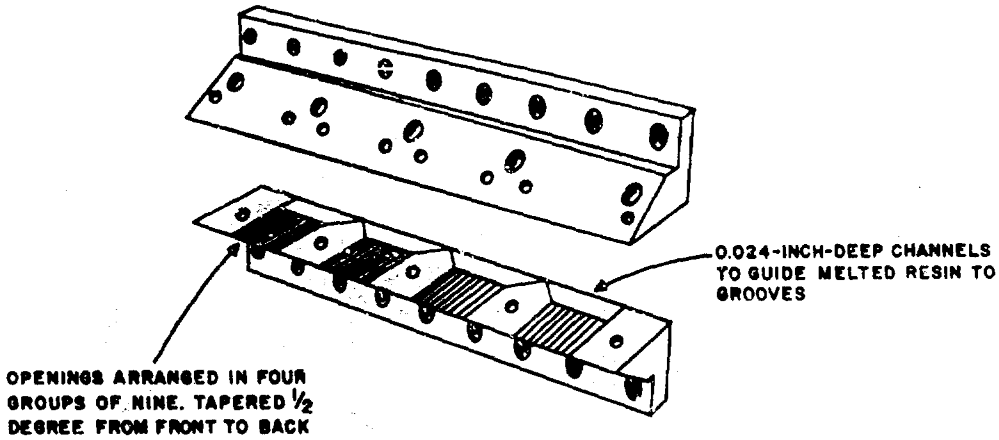

Fig. 3 - The 36-orifice nozzle. The grooves are 0.007-inch-deep 90-degree V cuts in both the top and bottom halves so as to fit together to form diamond-shaped orifices.

Electrical

In the original design of the fiber machine, a one-section heater control was used to regulate the temperature of the heating block. All heaters on one side of the block were wired to one autotransformer and those on the other side were wired to another. Since 20 heaters were involved, it was decided that the addition of two 110-volt autotransformers to the system would give a closer adjustment and control of the nozzle temperature. These have been mounted on a new convenient instrument panel. At the same time, the wiring of the system has been changed to provide a three-section control of this process variable (Fig. 7). The heaters at the rear of the block now operate constantly. This is necessary since the solid resin pellets enter at that point, and the water jacket, which prevents resin from melting in the injection cylinder, removes a considerable amount of heat. Heaters at the center of the block now operate intermittently through a temperature controller, while those at the front can be shut off after the nozzles reach operating temperature.

The above electrical changes have resulted in a much more uniform block temperature. Thermocouples are imbedded in the block at four different points, front, rear, and the sides. In a recent typical run, the temperature at the rear of the heating block averaged 620°F, the front, 665°F, and the sides, 700°F, all readings constant to ±10 degrees.

Future plans call for use of ten 250-watt heaters instead of the twenty 100-watt units. Heaters will extend all the way through the heating block, giving a more uniform heat distribution. Besides providing an increase in total wattage, closer control of the block temperature will be expected from this arrangement.

Fiber Collection

The fiber stream is separated from the air blast by use of a 16-mesh collecting screen moving across a suction chamber. The original suction chamber could not handle the required volume of heated air at high rates of flow. Hence, a new suction chamber was fabricated in which the two four-inch-diameter exhaust ducts were replaced with six-inch ducts. Six-inch-diameter flexible hoses were added to connect the new ducts with the exhaust trunks. Measurements taken in the exhaust trunk show that air flow is more uniform and has increased nearly 10 percent to 890 cubic feet per minute.

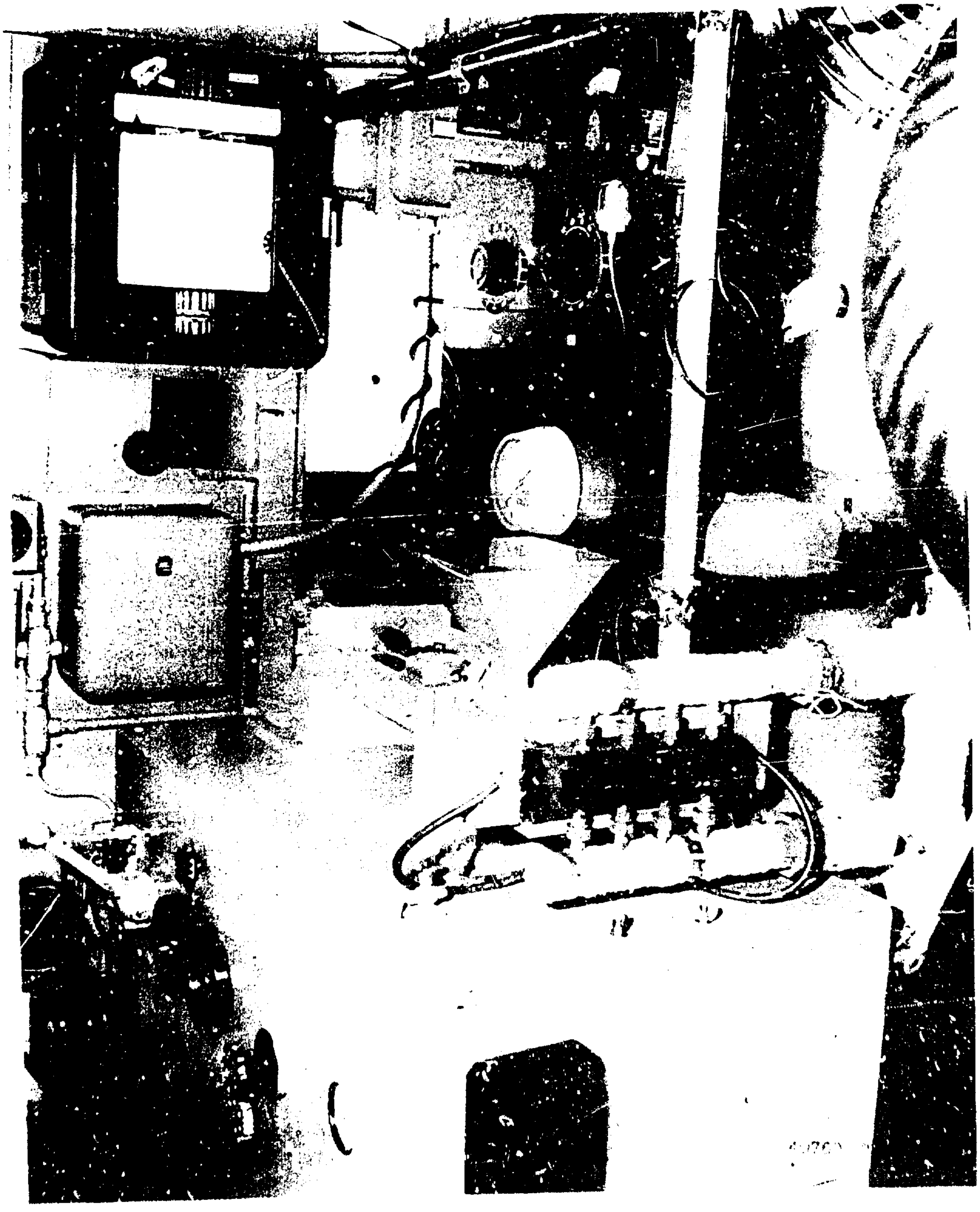

Fig. 4 - View of the nozzles, the jacketed air supply to stream the fibers away from the nozzles, the feed hopper, and control equipment

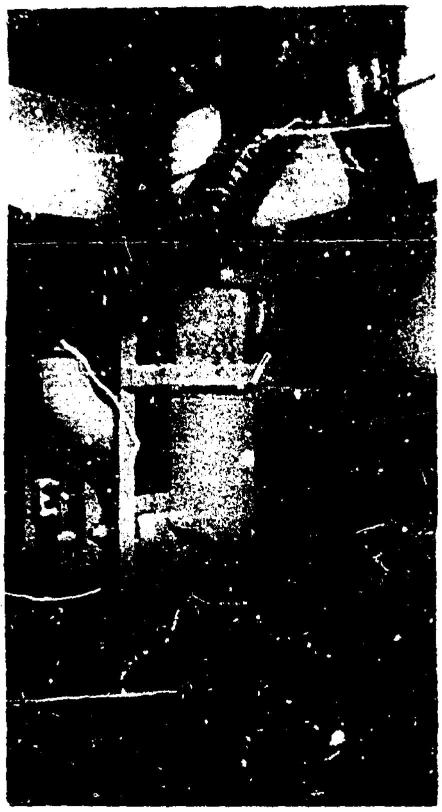

Fig. 5 - View of the collection unit showing the exhaust ducts from the vacuum source behind the collecting screen and the rectangular tunnel to maintain smoother air flow through the screen

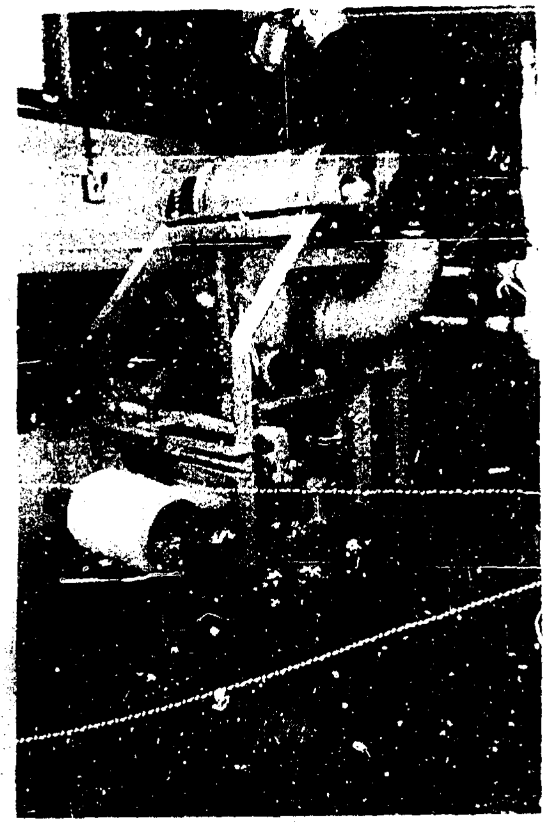

Fig. 6 - View of the collecting unit showing the windup reel and the revolving cleaning brush.

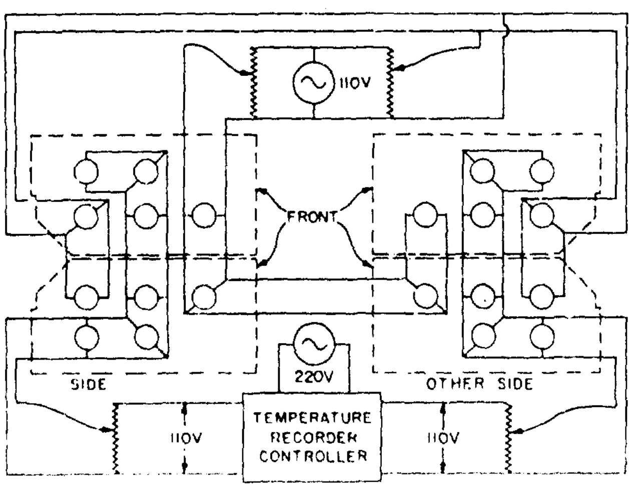

Fig. 7 - Wiring diagram of the heating block. Each of the 20 cartridge heaters supplies 100 watts at 110 volts.

The fiber stream is now directed through a short rectangular tunnel about 14 inches long. This tunnel is made of 14-gage aluminum and measures about 10 inches by 15 inches in cross section. Its purpose is to reduce turbulence of the air stream. It has been shown that by providing smoother air flow, the number of strings or parallel fibers deposited as loosely coiled bundles is greatly reduced.

The original windup reel has been replaced by one that is a plastic cylinder. Cardboard sleeves are made to slide over the cylinder, and the fiber is rolled onto them from the moving screen. When the desired amount of fiber has been wrapped, the cardboard sleeve is slipped from the cylinder and replaced with another.

A revolving wire brush has been mounted along the return section of the screen. This brush cleans all loose fiber from the screen before its next pass across the face of the suction chamber.

Miscellaneous

Several years of operation have taken their toll on certain units of the fiber machine. One of the affected items was the cooling jacket surrounding the injection cylinder. A new cooling system of soft copper tubing, coiled around and soldered to the injection cylinder, was installed. A thermometer was inserted into the exit line to determine the temperature of the waste water. The water is allowed to run as high as 80° to 90°C, sufficient to keep the resin in the injection cylinder from melting prematurely without excessive heat loss from the heating block. This procedure reduces the warmup period (the period before acceptable fiber is obtained) by nearly 25 percent. Initial warmup is presently about 90 minutes.

One limitation in the original system was the capacity of the air-flow meter. Maximum air flow was limited by the flowrator to approximately 30 cubic feet per minute. A new flow meter was installed in the line with a capacity of 200 cubic feet per minute.

A pointer has been added to the hydraulic ram and a scale attached to the supporting framework of the injection cylinder. It is now possible to measure the rate of travel of the ram in inches per minute. Subdivisions on the scale are marked for each 0.050 inch.

An additional hydraulic gage (0 to 200 psig) has been added to the instrument panel in parallel with the existing gage (0 to 1500 psig). Pressures may now be read and controlled to ±2 psig in contrast to the ±20 psig of the original design.

EXPERIMENTAL RESULTS

The results of a typical fiber run using a polyamide are contained in Table 1. Spools of fiber were removed from the machine at one-hour intervals. From each spool, a 30-layer mat 14 inches in length was unwrapped. Two six-inch-diameter pads were then cut from each mat and marked A and B. Air resistance was measured in millimeters of water at a standard air flow of 85 liters per minute through 100 square centimeters of fiber pad. Penetration tests were made on the NRL E-3 light-scattering meter.*

*H.W. Knudson and L. White, "Development of Smoke Penetration Meters," NRL Report 2642, Sep. 1945

Table 1
Typical Fiber Run Using Zytel 31

Spool	Pad	Weight (grams)	Resistance (mm H_2O)	R per gram (mm/g)	Penetration (%)	Eff.
1	A	6.30	55.0	11.7	0.52	4.1
	B	6.65	58.0	11.7	0.40	4.1
2	A	6.55	49.5	10.2	1.00	4.0
	B	6.65	51.0	10.3	0.84	4.1
3	A	7.25	59.5	10.1	0.44	4.0
	B	7.55	62.0	10.1	0.37	3.9
4	A	6.50	50.5	10.5	0.66	4.3
	B	6.68	51.5	10.4	0.65	4.2

Resistance per gram of fiber was calculated on the weight of the 100-square-centimeter area. Efficiencies of the pads were calculated from the formula

$$E = \frac{-\log P}{R}$$

where E is the efficiency of the pad, P is the smoke penetration in percent, and R is the resistance in millimeters of water. As seen from the table, the characteristics of the fiber were essentially constant over the four-hour period.

CONCLUSIONS

The modifications made on the NRL superfine-fiber machine have greatly simplified its operation and improved appearance and uniformity of the fiber. These changes have allowed a more precise control of the process variables; the nozzle has been modified to reduce appreciably the presence of shot; the heating block and cooling system have been altered to give a substantial reduction in the warmup period; and redesign of the collection unit has brought about a smoother laydown of fiber with excellent edge definition.

ROUTE SHEET
NDW-NRL-5216/2030 (Rev 2-82)

CODE	DATE	INITIALS	*PURPOSE	REMARKS
5227	5/8/97	MT		
6100	5/12	J		DR MURDAY PLEASE REVIEW NRL REPORT 5265 TO SEE IF THE DISTRIBUTION STATEMENT IS PUBLIC RELEASE. J
1221.1	5/14	Q		CHUCK ROGERS
5227				MARY TEMPLEMAN (767-3425)

INSTRUCTIONS

Prepare 2 copies of this route sheet and forward ALL copies together with necessary correspondence and other documents.

*PURPOSES
1. FOR INFORMATION
2. FOR APPROVAL
3. PREPARE REPLY
4. PREPARE ENDORSEMENT
5. FOR NECESSARY ACTION
6. FOR SIGNATURE
7. RETAIN ENCLOSURES
8. RETAIN COPY

GPO 888-793

FROM: 5227

DATE OF MATERIAL: 05/08/97

BRANCH IDENT. SYMBOL: 5227/MT

ORIG. IDENT. SYMBOL (Mail Room Fill in): 13 MAY 1997

DIVISIONS DO NOT FILL IN

DATE MAILED

FILE NO.

SUBJECT: FORWARDING OF:
NRL REPORT 5265 TO SEE IF THE DIST STATEMENT IS PUBLIC RELEASE.

THE CONOCO INC IS REQUESTING A COPY

R/S NO. (Mail Rm. Fill in)

AD213367