A METHOD FOR SLIVER UNIFORMITY CONTROL IN THE TEXTILE DRAWING PROCESS

A THESIS

Presented to

the Faculty of the Division of Graduate Studies

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Textile Engineering

by

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June 1954

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Felix Bowden Montgomery, Jr.

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DRAWING PROCESS

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Date Approved by Chairman: June 3, 1954

ACKNOWLEDGEMENTS

I wish to express my sincere thanks to the following staff members of the Georgia Institute of Technology: Professor R. L. Hill, for his valuable guidance, patience, and understanding; and Dr. M. J. Goglia, for his advice and material assistance.

I would also like to thank the following companies for their aid and cooperation: Atlanta Textile Machinery Co.; Atlanta Textile Apron Co.; and Minneapolis Honeywell Regulator Company.

The opportunity to do this research was made possible by the T. Earle Stribling Memorial Fellowship Fund sponsored by the A. French Textile School.

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A METHOD FOR SLIVER UNIFORMITY CONTROL IN

THE TEXTILE DRAWING PROCESS

Felix Bowden Montgomery, Jr.

SUMMARY

A method of controlling the textile drawing process so that a sliver is produced of excellent short-length and over-all uniformity in one passage would eliminate the need for repeated passages through the drawing frame with its inherent creation of short-length irregularities, and would make available for the roving and spinning process a sliver from which it is possible to produce yarn of high quality. Production of a high quality product at minimum cost is economically sound. The purpose of this thesis is an attempt to accomplish this through design of an attachment to the drawing frame which utilizes the compressed air supply available in an average mill.

Previous solutions to the problem of automatic uniformity control in drafting processes have required a separate drive for each head of the machine in almost every case. The method of varying draft here utilizes tapered front drafting rollers driven at constant speed and a mechanism for positioning the drafting web relation to these rollers according to the weight of the sliver being drafted. Research done indicated that a sensitive linear relation existed between the density of a fiber bundle and the pressure drop of an air stream passing through the bundle. The sliver weight measuring device designed operates on this principle and

causes the position of the drafting web to be changed by signals to a pneumatic motor through a pressure relay system.

Tests were made of the mechanism response time and of the product of a drawing frame with this attachment compared to stock normally processed on an ordinary drawing frame. The tests indicated that a faster acting pressure motor than present commercial types would give better results through decreased response time and that the linear distance between the measuring device and the variable draft zone places a limit on the minimum length of an irregularity to affect a proper compensatory draft. Design of a non-drafting calendering action for use with this mechanism would improve its operation through elimination of tension draft which nullifies the compensatory action of the mechanism. The amount of short-length irregularities created in the stock being processed with use of the attachment exceeded the amount found in normally processed stock. Despite this, long-length non-uniformities were eliminated in one passage through the drawing frame with the attachment to the extent that the yarn ultimately produced had equal breaking strength to yarn normally produced with two passages through an ordinary drawing frame.

CHAPTER I

INTRODUCTION

The problem is to devise a method of automatically controlling the textile drawing process so as to produce an end product sliver of excellent uniformity in weight per unit length. The solution here is an attempt to design a mechanism by which the amount of draft placed on the stock being processed in a drawing frame will be automatically varied to compensate for irregularities in the weight per unit length of said stock. This will be accomplished by signals from a pneumatic sliver measuring device controlling through a pressure relay the lateral position of sliver guides in relation to a set of conical front drawing rolls whereby the draft is varied.

The characteristics which define a single ply yarn are its average weight per unit length, its average twist per unit length, the direction of the twist and the uniformity of the yarn. Short-length variations in weight of the yarn define the latter characteristic which effects short-length variations in twist. All these characteristics control the strength and elongation properties of the yarn. Irregularity in yarns are created by inherent operating characteristics of the processing machinery and by the necessary actions of the operators, such as repairing the stock when it breaks in process. Today there are widely used methods of gaining uniformity of stock in process. These are evener motions for the picker machine and the blending and averaging of stock on many of the various types of machines used in processing yarns. The main portion of averaging and blending the stock is carried out on the drawing frames where six or eight card slivers are combined into a single sliver and the operation repeated as many as three times, whereby the end product is an average of two hundred and sixteen to five hundred and twelve card slivers. Trouble occurs here, however, in the inherent operating characteristics of the drawing frame creating short-length irregularities in the produced sliver.

A method of controlling the drawing process so that a sliver is produced with excellent short-length and over-all uniformity would eliminate the need for repeated averaging on the drawing frame with the inherent creation of short-length irregularities and would make available for the roving and spinning processes a sliver from which it is possible to produce a yarn of the very highest quality. Thereby, this innovation would be based on sound economics through the creation of a high quality product at minimum cost. The purpose of this thesis is an attempt to accomplish this by arriving at a method which would be quite practical and easy to apply under standard mill conditions. This explains the choice of a pneumatically operated mechanism so as to make available a method which would utilize the compressed air supply of a mill and the experience of the average mill mechanic with compressed air.

Automatic textile process control has gained wide popularity in the fields of yarn preparation for weaving and dyeing and finishing where literature is available concerning the sound economics involved and the increased quality of the product gained. Instructions are available on the applications of control instruments to the processes with helpful details for design work. Various stop-motions and mechanisms to control the tension and the twisting of running yarns have been invented and patented which may be classified as automatic controls for yarn manufacturing processes. A device has been patented for the control of drafting roller pressure in yarn manufacturing machinery (1).

Automatic control of the uniformity of stock in process in yarn manufacturing has received attention from other sources. Practical methods to improve the evener motion on a picker machine have been patented. As in the ordinary picker evener motions in use today, these methods all vary the feed roll speed to gain uniformity of the stock in process by varying the draft. Only the methods of measuring the uniformity of the stock in process vary. One method passes Beta rays through the stock into an ionization chamber to detect irregularities (2). Measuring has also been accomplished by receiving supersonic waves transmitted through the stock (3). Passing the stock through the plates of a condenser and ascertaining the variations in capacitance has served as a measuring means (4). Automatic uniformity controllers for carding engines have been investigated. The Textile Research Department of the General Electric Corporation abandoned a study of this with the recommendation that research along this line would find a more profitable ground in later processes in yarn manufacturing (5). Other work, however, did lead to the design and patent of a mechanism which is said to result in a completely uniform sliver being produced on the carding engine (6).

Devices which could be applied to accomplish the same objective as the research done here have been patented. There is a textile drafting apparatus which varies the draft on the stock in process according to the density of the stock as it passes through a flow tube having openings corresponding to the normal sectional area of the sliver and which is connected to a source of fluid; fluid pressure variations control the draft regulating means (7). Another method treats the stock in process with an electrically conductive material and varies the draft according to the measure of electrical current which is passed through the stock (8). The primary fault with these methods is that they use a final control element which varies the drafting roller speeds, thereby creating a necessity for a separate drive for each head of the drafting mechanism. A mechanism is on the market today which varies draft on stock in process by changing feed roll diameter according to the pressure which thick and thin sections of the entering stock exert in passing between two evener rolls (9). This device may be questioned as to its sensitivity and as to a method for incorporating time lag so as to have the draft changed only when the section of the stock responsible for the desired change is in the drafting zone. No literature was found describing the operating characteristics or degree of acceptance of all these devices by industry.

CHAPTER II

EQUIPMENT

Original Research.—It was necessary, as a start on the problem, to select equipment to investigate the characteristics of air pressure drop across a fiber bundle in order to gather data for the design of the measuring device for the desired mechanism. The Sheffield Micronaire, Model 60602, made by the Sheffield Corporation, Dayton, Ohio, was used.

Stock Used.—The fibers used for original research with the Micronaire were Du Pont Dacron staple, 1.5 denier, 1-1/2 inch staple length, semi-dull; Carbon and Carbide Chemical Dynel staple, 2.0 denier, 1-1/2 inch staple length; and Celanese Corporation of America Acetate staple, 3.0 denier, 1-1/2 inch staple length. All testing and development work was done with American Viscose Corporation Viscose staple, 1.5 denier, 1-9/16 inch staple length, dull.

Textile Machinery.—The stock used for development and testing of the designed mechanism had been previously prepared as a 56.5 grain-per-yard card sliver using a Whitin, Model 1949, Rayon Picker with one beater section and a Saco Lowell Shops, Model 1948, 40 inch Roller Top Card. The drawing frame used for experimental work was a single head model manufactured by the Medley Co., Columbus, Georgia, for research work by this school. To have a basis for comparison of the product quality of the experimental drawing frame, stock was normally processed on a Whitin

Machine Works Drawing Frame L2 FS, Model 1949. The products from both the normal and experimental drawing frames were processed through spinning on Saco Lowell Shops 10 inch x 5 inch Standard Intermediate Fly Frame with Model FS-1 drafting and Standard Spinning Frame with Model S-Z-2 drafting.

Air Supply.—A Worthington Pump and Machinery Corporation 1-11/16 inch x 1-11/16 inch x 1-1/4 inch air compressor with a Fisher type 977Z pressure regulator was used to supply compressed air for all development and testing work.

Automatic Control Equipment.—Research and development work indicated the proper pneumatic control equipment for incorporation in the designed mechanism could all be obtained from Minneapolis Honeywell Regulator Company. The equipment required was a Pressure Controller PO 900A1, a Graduamotor MO 900B, a Brown Compressed Air Filter, two Model 352196-1 Brown Pressure Regulators, and two 1-30 pounds per-square-inch, J. P. Marsh Company Pressure Gauges.

Testing Equipment.—For indications of product uniformity during development work on the experimental frame a Saco Lowell Graphic Sliver Tester was used. Final testing of product uniformity from both the normal and experimental process was done on the Yarn Evenness Tester, Type GGP-B[4] manufactured by Zellweger Ltd., Uster, Switzerland. Yarn break tests were made on the Suter Vertical Single Strand Tester, oil plunger type, manufactured by Alfred Suter Company of New York.

Miscellaneous.—For roller speed checks, a Strobotac type 631-A made by General Radio Company of Cambridge, Mass., was used. Seederer-Kohl Busch, Inc. gram balances and Christian Becker, Inc. Model B30B61 grain balances were used for weighings.

CHAPTER III

RESEARCH AND DESIGN OF MECHANISM

Original Research.--A sensitive method of measuring the weight of a fiber bundle pneumatically is by passing a stream of air through the fiber and measuring the pressure drop caused. Very little data could be found on this subject. It was necessary therefore to investigate the characteristics of this operation. The Sheffield Micronaire is a testing machine for fiber fineness which measures air flow through a plug of fiber on a scale calibrated to read directly in weight per unit length of the individual fibers while the upstream static pressure of the air is held always at a fixed value. Readings from a particular type of scale called the "Causticaire" may be converted to cubic feet per minute of free air flow values by the relation

$$C.F.M. = (0.0236 \text{ Index}) - 0.20 \qquad (10).$$

By varying the density of the fiber plug for each of three different finenesses of fiber tested and calculating the resulting air flow, data given in Table 1 to be used in determining the characteristics of air pressure drop across a fiber bundle was obtained from the Micronaire. This data showed a linear relation, Fig., 1, existed between fiber plug density and air flow for each of the three fiber finenesses.

Values of line pressure drop in the Micronaire given in Table 2 were taken for the same range of air velocity obtained when testing fiber plug density by noting the upstream manifold pressure required to give various air flow values with no fiber in the measuring chamber. Line pressure drop in the Micronaire varies in curvelinear fashion with air flow as shown in Fig. 2.

Since the upstream manifold pressure was held at fixed value for the graph of fiber bundle density and air flow, the air pressure drop across the fiber bundle can be calculated by subtracting the line pressure drop for that particular air flow from the set upstream manifold pressure. Table 3 gives these values and the graph of this relation is shown in Fig. 3.

Design of Measuring Device.—The measuring device need be simply a box divided into two chambers with a slot between them for the slivers entering the drawing frame to pass; the upper chamber to serve as a manifold and to pass air through an orifice into the slivers in the slot with the lower chamber receiving the static pressure of this air stream impinged, after passing through the fiber, upon an orifice leading into the chamber. A sketch of the measuring device is shown in Fig. 8.

The measuring device should be designed to operate in the pressure drop and fiber density range investigated in order to be able to perform the necessary design calculations. If unforeseen operating characteristics of the measuring device caused later trouble then the fiber density and operating pressure range could be changed.

From the linear portion of the fiber density and pressure drop graph, Fig. 3, a fiber density was selected for an average fiber fineness. The air flow which resulted from this fiber density was taken from the fiber density and air flow graph, Fig. 1.

The slot or sliver passage-way must be designed to compress the sliver to a desired density of 4.25 grams-per-cubic-inch. The length of the measuring device was set at 1.5 inches to allow for the thickness of the walls and the length of the upper and lower orifices. In order to have a height that would not flatten the sliver too much a width of 3.0 inches was chosen for the slot. Based on a sliver weight of 50.0 grains-per-yard and feeding six slivers to the drawing frame, the height of the slot must be 0.23 inches. The entrance to the sliver passage-way must be rounded so as not to catch entering fibers. Figure 4 shows the final design.

Rectangular, sharp edged orifices should be satisfactory for the upper and lower orifice plates. Their width is set by the width of the sliver passage-way at 3.0 inches. The lower orifice should be more narrow than any fiber length used to prevent fibers being blown into the lower chamber. The lower orifice length was set at 0.50 inches. In order to have a large portion of the air stream strike the lower orifice dispite divergence, the upper orifice was made one half as long as the lower orifice or 0.25 inches. These orifice plates are shown in Fig. 5.

To determine the sturdiness of construction necessary for the measuring device, the expected manifold pressure was estimated at approximately five pounds per square inch. This value was calculated to have the fiber bundle pressure drop in exactly the same range as investigated on the Micronaire by totaling three separate pressure drops which must occur. The first pressure drop occurs across the upper orifice plate to give the desired air flow of 1.75 cubic feet per minute. The second pressure drop takes place through the fiber bundle of given density and of average fiber fineness and is taken from Fig. 3. The third pressure drop takes into account the pressure loss through the plug which is used for compression of a fiber bundle in the Micronaire. Standard equations of fluid mechanics are used for these calculations.

Operating Characteristics of Measuring Device.—Five samples of six slivers each three inches long were prepared ranging in weight from minus eight percent to plus eight percent in weight based on fifty grains-per-yard card sliver. Each of these samples were placed in turn in the measuring chamber and the static downstream pressure was read from a water manometer connected to the lower chamber. The upper manifold pressure had to be adjusted to 21.0 pounds per square inch before any downstream static pressures on the order of three centimeters of water were produced. No correlation existed between the values obtained. It was noticed that the air stream from the manifold air supply entrance failed to diverge in the manifold but passed through the orifice into the fiber as a stream. Aside from this, the lack of correlation was also attributed to the air escaping out the slots in the measuring device rather than passing through the fiber. Corrective action was taken by increasing the number of slivers to eight and placing a baffle in the air supply tube. The values given in Table 4 show excellent linear correlation was then obtained but the graph, Fig. 9, was inverse to the expected relation shown in Fig. 3. This can be attributed to the escape of air through the sliver out the passage-way slots.

Design of Tapered Rolls.—The amount of draft between two sets of drafting rollers depends on the difference in surface speed between the sets

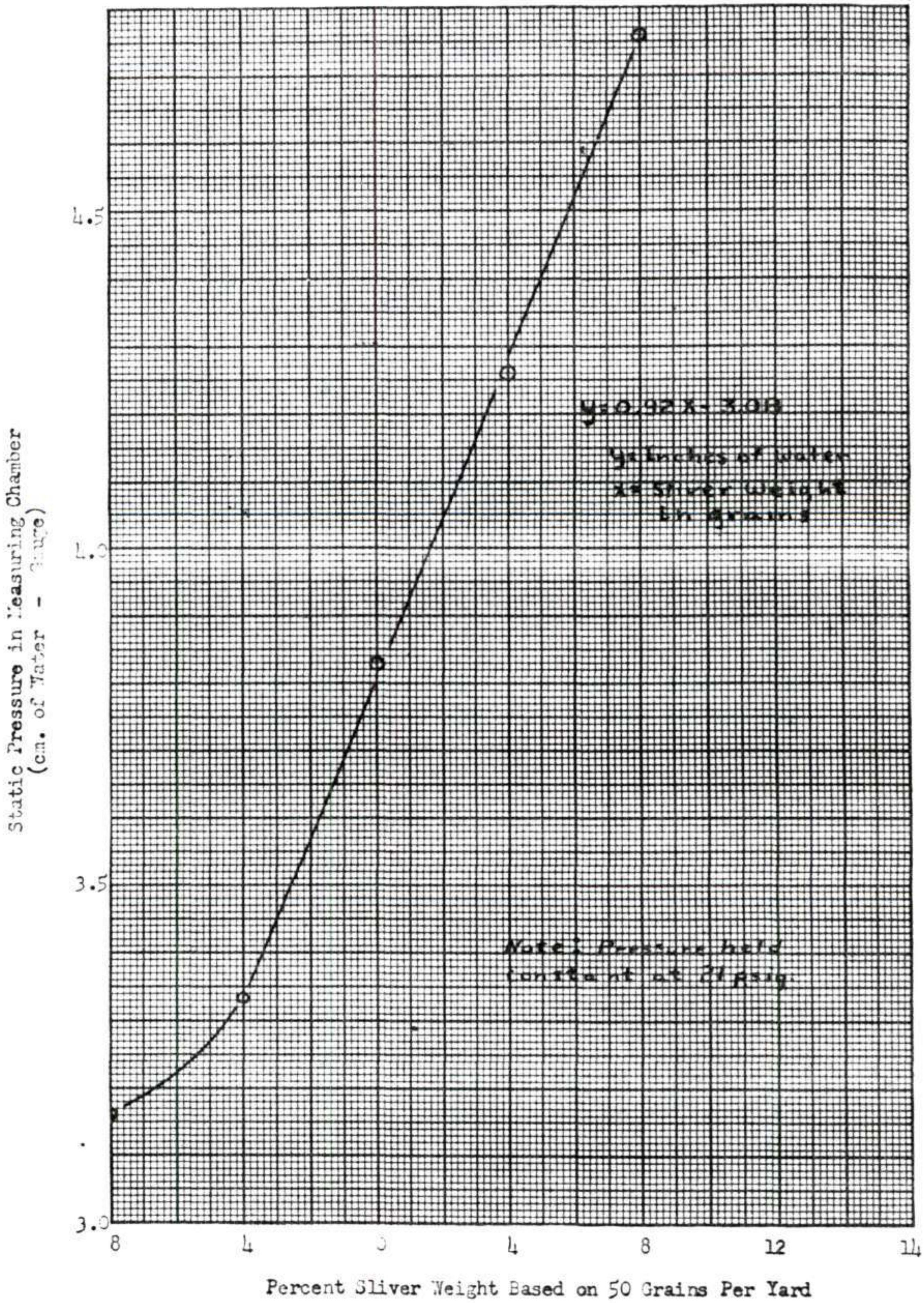


Figure 9. Measuring Device Characteristic

of rollers. The surface speed of a roller depends directly on its angular velocity and its radius. If each set of rollers is to run at a constant angular velocity the draft may be varied between the two sets by varying the roller diameter on one set. The tapered rollers were designed as shown in Fig. 10 to vary in diameter 15.0 percent greater and 15.0 percent less than the accepted front roll diameter of 1.25 inches. This results in a draft differential of 3.81 percent-per-inch with a total draft difference of 30.0 percent. Final product weight per unit length varies directly with the entering product weight per unit length and inversely with the draft. The weight of the final product varies from 13.0 percent less to 17.0 percent more than the product produced at the center of the roll with a gradient of 3.81 percent per inch. Roller fluting was designed for maximum grip on the fiber (11). A synthetic cot for the top roll was designed to compliment the taper of the bottom roller and to fit the steel core normally used on this drawing frame.

Movable Bracket Design.—The purpose of this bracket is to hold the measuring device, to act as a sliver condenser in the final two drafting zones, and to traverse over the entire length of the tapered drafting rolls, thereby positioning the sliver in relation to the desired drafting position. A composite sketch is shown in Fig. 8. As designed, the base, Fig. 6, of the bracket slides on two rails, Fig. 7, attached to supports, Fig. 7, bolted to the machine frame. One piece, Fig. 6, attached to the base carries a bracket, Fig. 6, for the measuring device; the other piece, Fig. 6, attached to the base acts as a slide for positioning the sliver guides, Fig. 7. V-shaped sliver guides were designed in an effort to compress the drafting web uniformly over its entire width.

CHAPTER IV

DEVELOPMENT

Selection of Automatic Controller.—This control system must be able to operate with a linear characteristic in the pressure range of one to five inches of water with a variable throttling range and a sensitivity on the order of twenty five thousandths inches of water pressure. To meet these specifications a bleed type pressure transmitter was chosen. As a means for positioning the movable bracket in relation to the tapered drafting rolls to compensate for a total irregularity of ten percent, a pressure motor was chosen which operated in the output range of the pressure transmitter. The air supply to these instruments required filtration and pressure regulation. To eliminate the adverse effects of machine vibration, these instruments, with the exception of the pressure motor, were mounted separately from the drawing frame. The lay out diagram is shown in Fig. 11. Two changes from the original design and operating specifications of the measuring devices had to be made in order to operate with this equipment. The addition of wooden blocks in the measuring chamber of the measuring device decreased the volume and increased the sensitivity. Manifold pressure of 1.0 pounds per square inch was required to give static pressures of 0.0 to 2.0 inches of water.

Drafting Characteristics of the Drawing Frame.—Individual control of each fiber throughout a drafting zone is required for ideal drafting conditions.

Increased weight of the stock being drafted and compression of this stock into a narrow web decreases fiber control and promotes irregularity (12). Extreme compression of the stock is necessary here, however, to minimize the draft differential across the width of the web in the variable draft zone.

For ease of lateral movement of the drafting web, an original effort was made to perfect the drafting operation with a common roll system. Failure to grip the fibers being drafted and hence allowing slippage causes inherent product irregularity from a common roll system. This slippage depends upon the friction between roller surfaces and the fiber, the drafting force required, and the draft distribution; and increased coefficient of friction of the roller surfaces and increased roller weightings would increase the grip on the fibers but greatly increased weighting has little additional effect (13). To reach a point of minimum irregularity roller weightings were increased stepwise to nearly three times the normal value without ever reaching an acceptable uniformity level of the product as shown in Table 5. Drafting force varies inversely with the distance between rollers and directly with the mass being drafted (14). In conjunction with increased roller weightings, roller settings were increased one sixteenth inch in the front and middle drafting zones and three sixteenths inch in the back drafting zone beyond those normally used (15). This decrease in the required drafting force showed little quality improvement. A draft organization shown in the gearing diagram, Fig. 12, based on maximum weight reduction on the fiber mass prior to maximum condensation in the variable draft zone gave better results than an organization giving constant weight reduction in each zone in common use today (16).

The addition of another sliver guide and reworking of the original guides in an effort to decrease the coefficient of friction and to lessen the angle placed in the selvage of the drafting web resulted in failure to improve the product uniformity to an acceptable level. Speed checks with a strobotac showed top roller speeds to be essentially constant and a check of the product without calendering indicated that major irregularities were not being created at the coiler head.

Maximum roller grip and little fiber slippage can be obtained with metallic rolls (17). The highly compressed and heavy drafting web here together with the failure of common rolls to produce an acceptable product indicated the use of metallic rolls. Despite the intermeshing action of the roller flutes gripping the fiber, weightings were increased stepwise to 84, 92, 84 and 92 pounds on the rollers back-to-front before the produced slivers reached an acceptable quality level with variations of .005 inches based on a sliver thickness of 0.30 inches. Inter-fiber kinetic friction of viscose rayon increases parabolically with increased relative velocity between fibers (18), thereby, inducing roller slip in a very high draft zone through an increase of the required drafting force. The positive fiber grip of metallic rolls indicates that acceptable drafting conditions will result despite high draft and comparatively short roller settings. Even single zone drafting from sliver to yarn is theoretically possible (19). To decrease the bulk of the fiber mass as much as possible prior to final condensation in the variable draft zone, high drafts were employed in the break and intermediate zones which resulted in better fiber grip and less guide interference. The final gearing diagram is shown in Fig. 12. Metallic rolls were adopted for the machine. The tension draft was set as near to 1.0 as possible at the center position of the tapered roll to have the produced web grow slack and tight with fluctuations in the variable draft. Tension draft which would nullify the compensatory action of the variable draft is not desired.

Installation and Calibration.—The pressure motor was mounted on a bracket on the machine frame with a single connecting link to the base of the movable bracket carrying the measuring device and sliver guides. Air supply and static pressure readings for the measuring device were carried in flexible rubber tubing. Higher pressures required for the pressure motor were carried in quarter inch copper tubing.

Total throw of the pressure motor selected was 2.69 inches which gave a total draft variation of 10.4 percent or 5.2 percent greater and less than the draft at the center position on the tapered rolls. The total compensation range for irregularities was therefore plus or minus 5.2 percent of the average weight of the incoming eight ends of card slivers. Calibration requires that two lots, each containing eight three-inch samples, of card slivers be prepared from the stock being run which weigh 5.2 percent less than average weight and 5.2 percent more than average weight.

The pressure transmitter used regulates the output pressure by adjusting the amount of bleed according to the positioning of a flapper above a nozzle by a spring loaded weight arm having two bells suspended in a bath of oil which measure reference atmospheric pressure and gauge static pressure. Prior to calibration the main air supply to the pressure transmitter and motor has to be set at fifteen pounds per-square-inch. A restriction in the air line must be set to allow the pressure to bleed to less than 1.0 pounds per-square-inch when the nozzle in the transmitter is wide open. With the bells level the nozzle is then positioned to the flapper to give one half throw of the pressure motor. With the minimum weight sliver sample in the measuring device the spring on the weight arm is set to give minimum throw of the pressure motor. With the maximum weight sliver in the measuring device the throttling range button on the fulcrum of the weight arm is adjusted to give maximum pressure motor throw. The function of the throttling range button is to vary the throw of the flapper resulting from movement of the weight arm. Therefore, the minimum throw position of the pressure motor must be checked again with the minimum weight sliver sample. The validity of this linear calibration procedure was checked to see if a straight line characteristic of static pressure and sliver weight occurred at higher sliver weights than those used in the original research. Fig. 13 shows this calibration procedure to be correct.

CHAPTER V

TESTING PROCEDURE AND DISCUSSION OF RESULTS

Procedure.—To evaluate the performance of this mechanism, three lots of 56.5 grain-per-yard card sliver were processed through spinning to produce approximately 15.0's yarn with a twist multiple of 3.25 giving 12.59 turns-per-inch. The roving operation was set to produce approximately 2.0 hank roving with a twist multiple of 1.06. Only the drawing operation was varied on the three lots. One lot was processed normally by two passages through a Whitin L2 F5 Drawing Frame. The second lot was processed through the experimental drawing frame holding the drafting position on the tapered rolls constant. The third lot was processed through the experimental drawing frame with the automatic uniformity control in operation. Processing data is given in Table 6. Approximately twenty four samples of five yards each of stock were initially tested for uniformity at each stage of processing for each lot run. Twenty single strand break tests were initially performed for each of the three lots of yarn produced. The standard deviations, sigma, of the uniformity and strength tests were calculated. That a statistical normal distribution occurs in the individual break and uniformity tests is a reasonable assumption. In a normal distribution, ninety five percent of all samples tested will fall inside two sigma limits of the average value. The number of sample tests necessary to have the two sigma limits fall within ten percent of the true average value may be computed by

$$n = 400 \left(\frac{\sigma'}{\bar{X}}\right)^2$$

where n is the required number of samples, σ' is the standard deviation, sigma, of the readings and $\bar{X}$ is the average. After the initial tests this check was made for each group of results and additional tests were made where necessary to have the averages of the uniformity and break tests be within ten percent of the true average.

For comparison of uniformity readings where the weight of two products being compared varies, a ratio may be formed with the counts of the yarn to indicate the better product as long as the products are made of identical fiber.

$$R = \frac{U\%}{\sqrt{\text{Hanks}}} \quad \text{or} \quad R = U\% \sqrt{\text{weight per unit length}} \ .$$

A small value for R indicates high uniformity and a large value for R indicates poorer yarn. This follows simply from the previous work of Enrick (20) as seen in Table 22. For slight variations in yarn counts the count strength product may be used as an indication of the stronger yarn (21).

All manufacturing and testing was carried out under conditions of controlled 70.0 degree Fahrenheit temperature and 65.0 percent relative humidity approximately. Samples for testing were selected throughout the lot of stock to guarantee representative results.

To check the response of the automatic uniformity control system, the lag involved in transmission of a pressure signal from the measuring device to the pressure motor and the speed of traverse of the movable bracket with stock being processed in the machine was timed. The inertia of the system excluding the pressure motor was checked with stock in process by observing average pressure variations at the pressure motor with a mercury manometer.

Discussion of Results.—Table 7 gives the response times measured. The response of a pneumatic control system may be considered to be logarithmic (22). The lag time involved in this system is very small as shown in Fig. 14. The main part of the response time shown in Fig. 15 is taken up in movement of the pneumatic motor. A time interval of 4.0 second elapses in movement of an irregularity from the measuring device to the variable draft zone. During this time if the pressure motor is in continuous movement, the weight of the product just ahead of the irregularity has suffered a maximum of 2.0 percent weight variation due to the change in draft. The incoming product passes through the measuring device at 2.18 inches-per-second which places a limit on the length of an irregularity to receive maximum compensation or even any compensation at all. Fig. 16 indicates these lengths. Observation of the machine in operation shows that the position of the produced web does not continually vary about the center of the tapered roll and hence eliminate tension draft by simply taking up and letting out slack in the web. Long-length thin places in the incoming sliver cause the tension draft to come into play which nullifies the corrective action.

Table 8 summarizes the product testing data listed in Tables 9 through 21. Two passages of the card sliver through an ordinary drawing frame and drafting it to a very light sliver causes a definite increase

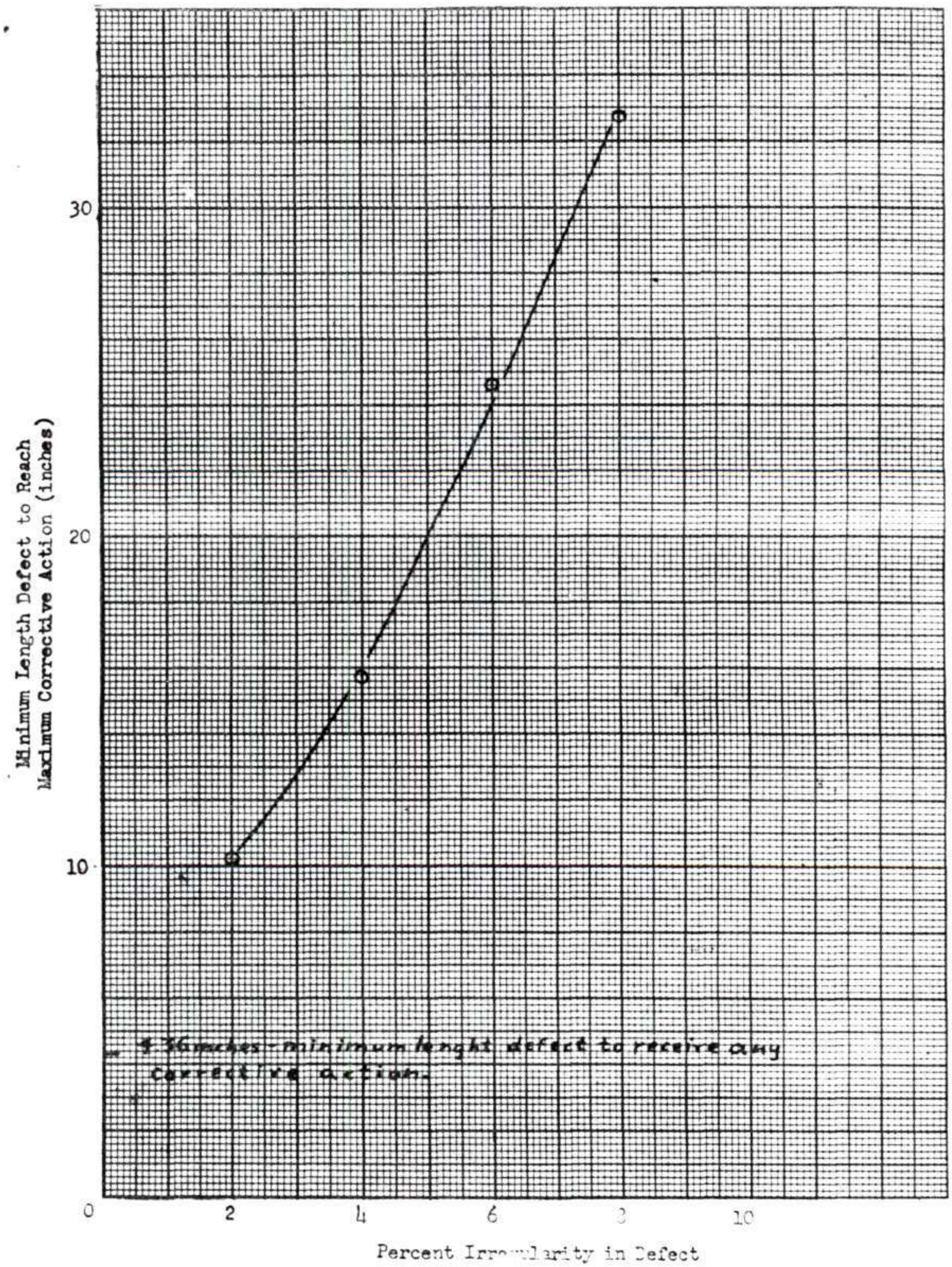


Figure 16. Required Lengths of Defects for Compensatory Action

Table 8. Comparison of Test Results

	Normal Process	Experimental Process Without Uniformity Control	Uniformity Controlled Process
Uniformity Ratio			
Card Sliver	24.45	24.45	24.45
Drawing Sliver	33.40	26.60	34.80
Roving	4.94	7.44	8.15
Yarn	2.76	3.34	3.44
Count Strength Product	17.78	15.89	17.13

in short-length irregularity but doubling at the roving frame decreases this to an acceptable level again. The effect of this doubling here should not effect these results. The Uster Tester compares variations in the volume of the material being tested from one three-inch section to another (23). The order of uniformity of the roving and yarn indicates that the normally processed stock is best and the uniformity controlled stock is the worst. The uniformity variation between the experimental process without control and the normal process shows that short-length variations are created inherently by the drafting of a compressed web. The slight difference in uniformity in the experimental process with and without control are within ten percent of each other for the final yarn and may therefore have the same true average. Any slightly higher irregularity in the yarn from the controlled process may be contributed to the shifting of the web in process.

Logic dictates that the strength of a yarn depends not only on its overall weight but also on the short-length variations based on that weight, therefore, if long-length variations in weight were removed, the chance of getting low strength values caused by short-length variations in a long thin spot would be removed. By this reasoning a higher strength would be obtained with the same degree of short-length variation from a yarn of fairly good long-length weight uniformity than from one in which long thin places out-number long lengths of greater thickness. The count strength products of the normally processed stock and the uniformity controlled stock are quite close. These two processes produced yarn equal in strength in the light of the statistical ten percent band set up around the averages in the testing procedure.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

During the interval of time required for the passage of an irregularity from the measuring device to the variable draft zone, a variation in weight is created in otherwise even sliver just preceding this irregularity. Short-length irregularities are not compensated for and long-length irregularities are partially removed. Tension draft prior to calendering nullifies compensatory action of the automatic uniformity control in the event of a long thin portion of incoming sliver.

The shifting of a web during drafting creates short-length irregularities. Drafting of a highly compressed web creates additional irregularities. Long-length weight variations in yarn play a large part in its strength value along with short-length variations. Despite increased short-length yarn irregularities, stock processed once through a drawing frame equipped with the automatic uniformity control produced a yarn of equal strength to stock given two processes on an ordinary drawing frame under the conditions of this experiment.

It is recommended that further work be done with this equipment by placing the measuring device in the drafting zone prior to the variable draft zone, designing a faster acting pressure motor and designing a non-drafting unit for calendering purposes.

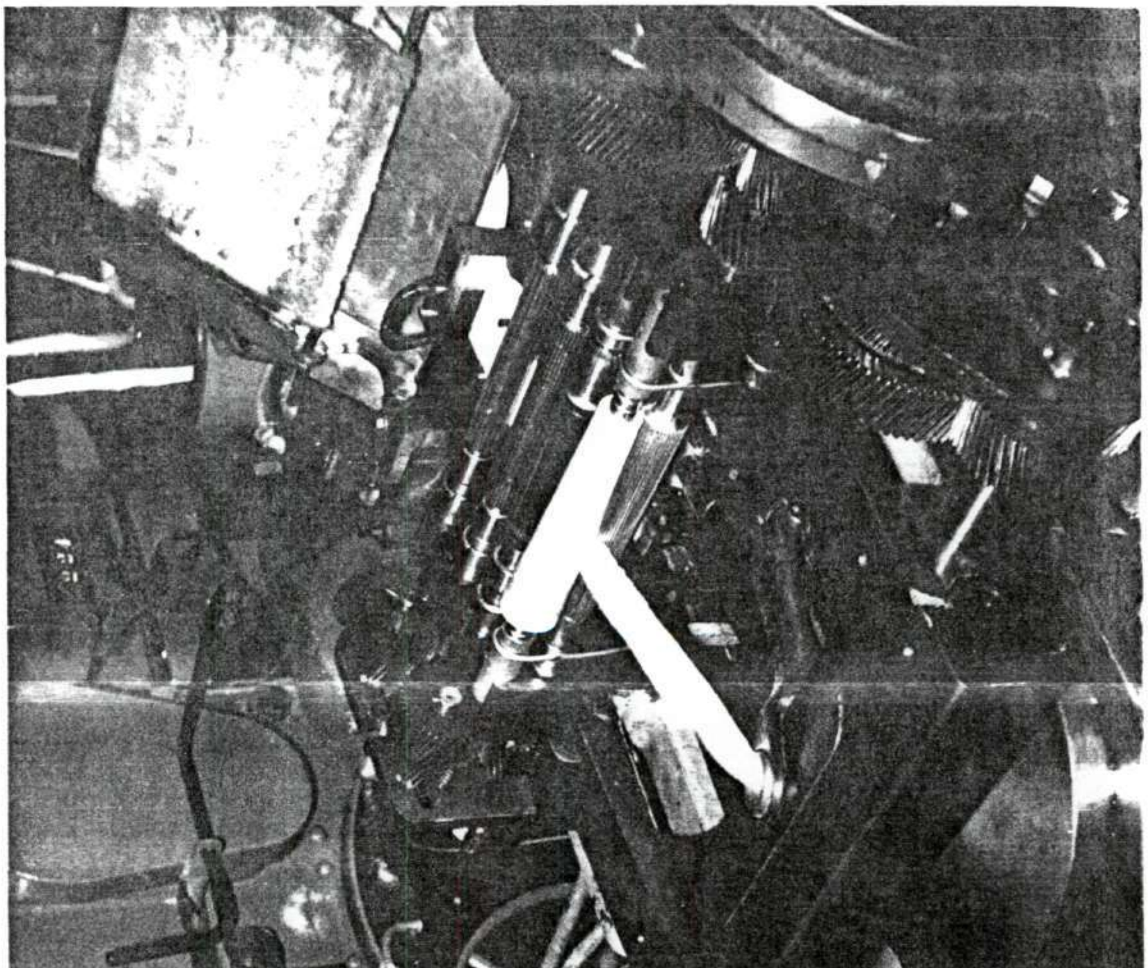


Figure 17. Drawing Frame with Uniformity Controller

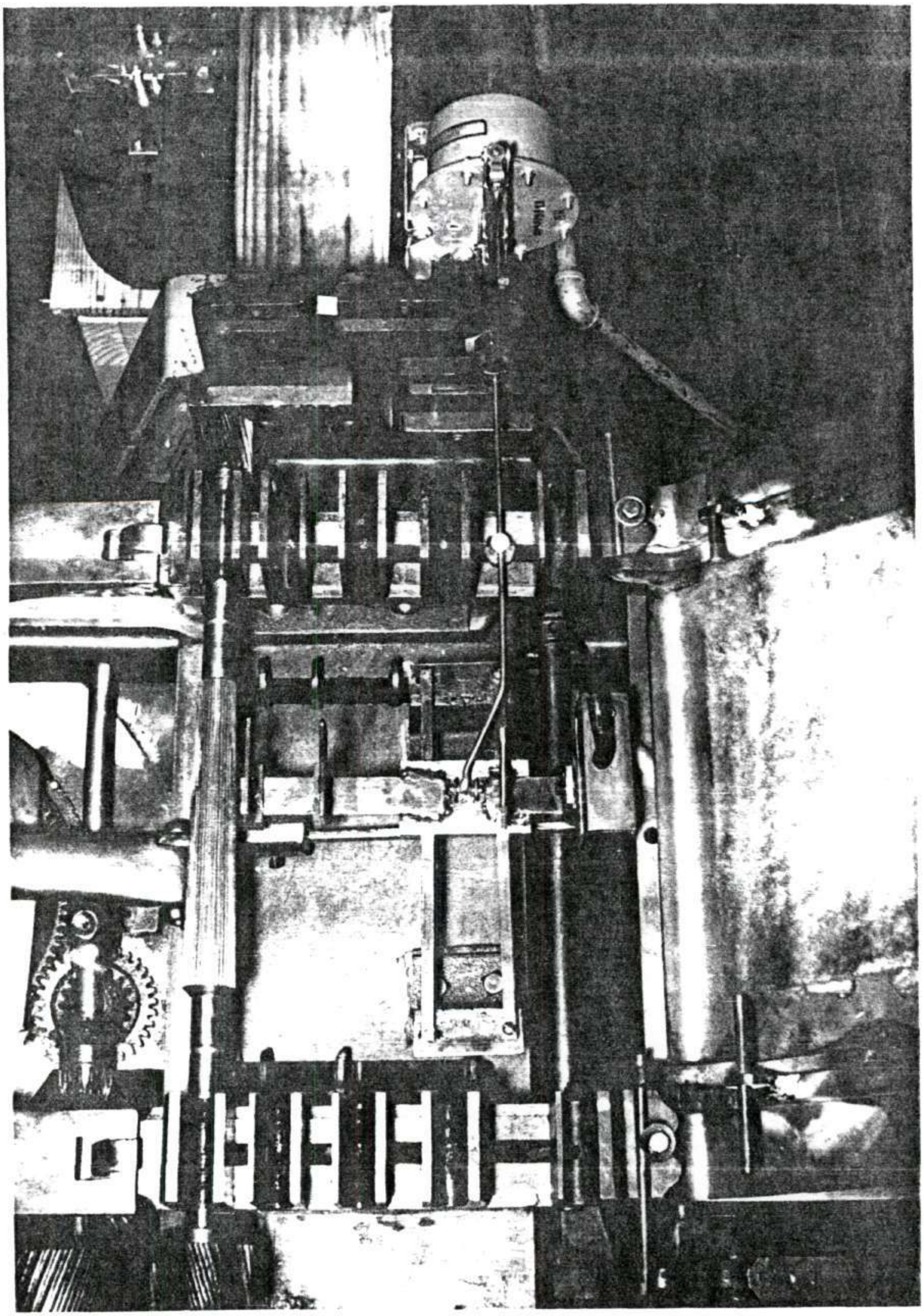


Figure 18. Top View of Movable Bracket and Pressure Motor Mounting

APPENDIX

Table 1. Air Velocity, Denier and Density Relation on Micronaire

Deniers Relative to Specific Gravity - 1.38
Manifold Pressure - 6 p.s.i.
Measuring Chamber Volume - .781 Cubic Inches

Specimen	1.50 Denier SCFM	2.11 Denier SCFM	3.14 Denier SCFM	Density gm/in^3
1	1.88	1.88	—	3.693
2	1.85	1.83	—	3.696
3	1.85	2.00	2.28	3.698
4	1.85	1.85	2.23	3.705
5	1.92	1.90	2.21	3.743
6	1.85	1.85	2.18	3.781
7	1.69	1.74	2.09	3.825
8	1.66	1.71	2.07	3.864
9	1.64	1.69	2.04	3.905
10	—	1.66	—	3.915
11	—	1.64	—	3.933
12	—	1.62	—	3.940
13	1.77	1.79	2.14	4.070
14	1.61	1.63	1.77	4.450
15	1.42	1.51	—	4.830
16	1.29	—	1.51	5.055
17	1.22	—	1.52	5.080
18	1.19	1.22	1.50	5.090
19	.97	1.09	1.35	6.000

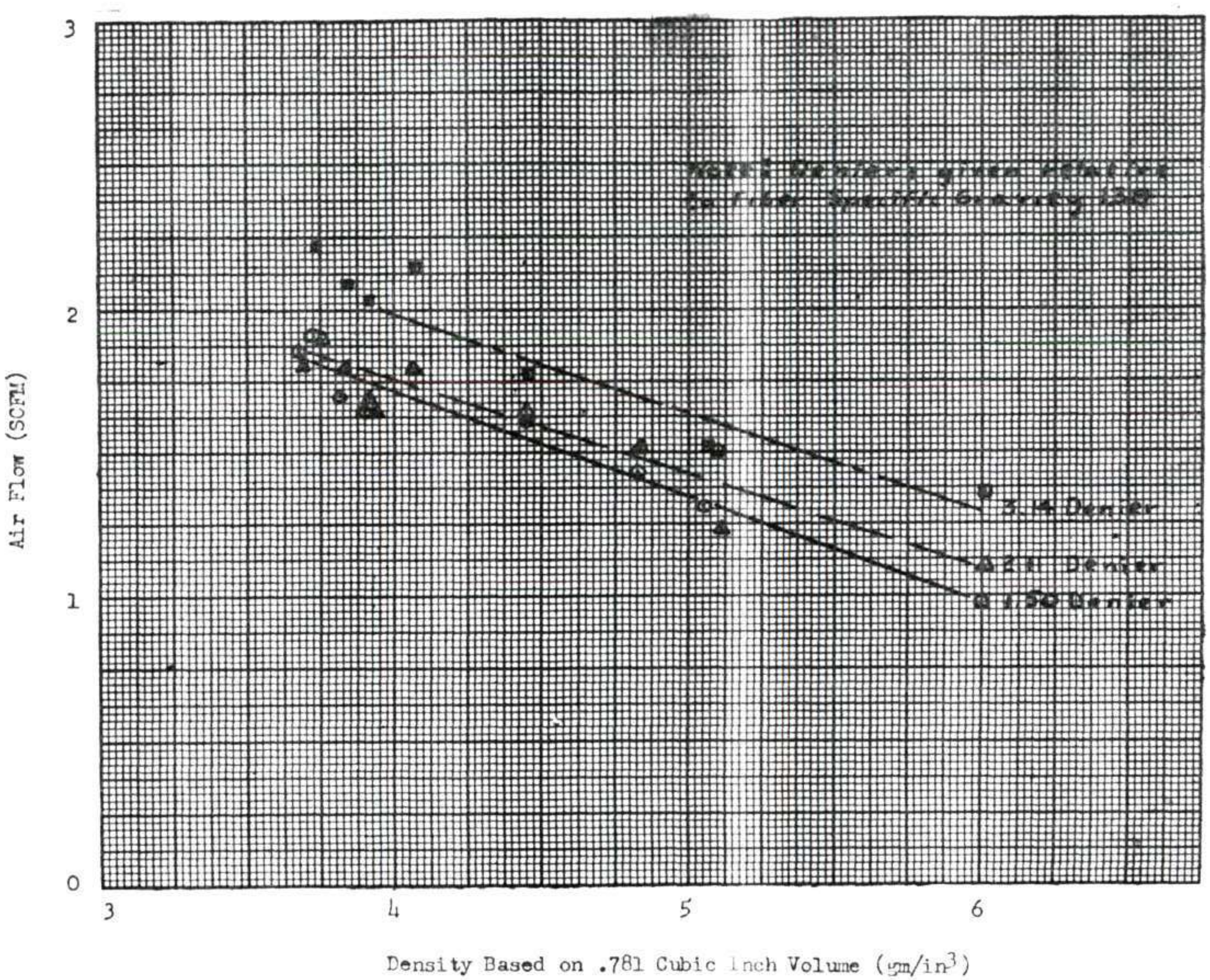

3
2
1
0
Air Flow (SCFM)
3
4
5
6
Density Based on .781 Cubic Inch Volume (gm/in^3)
3.4 Denier
1.50 Denier

Table 2. Micronaire Line Pressure Drop for
Given Velocity Range

Reading	Scale Value	Manifold Pressure psi	Velocity SCFM
1	105	2.870	2.278
2	100	2.640	2.160
3	95	2.550	2.040
4	90	2.305	1.925
5	85	2.150	1.805
6	80	1.975	1.685
7	75	1.830	1.570
8	70	1.630	1.450
9	65	1.500	1.334
10	60	1.325	1.215
11	55	1.190	1.098
12	50	1.075	.980
13	45	.990	.861
14	40	.825	.745

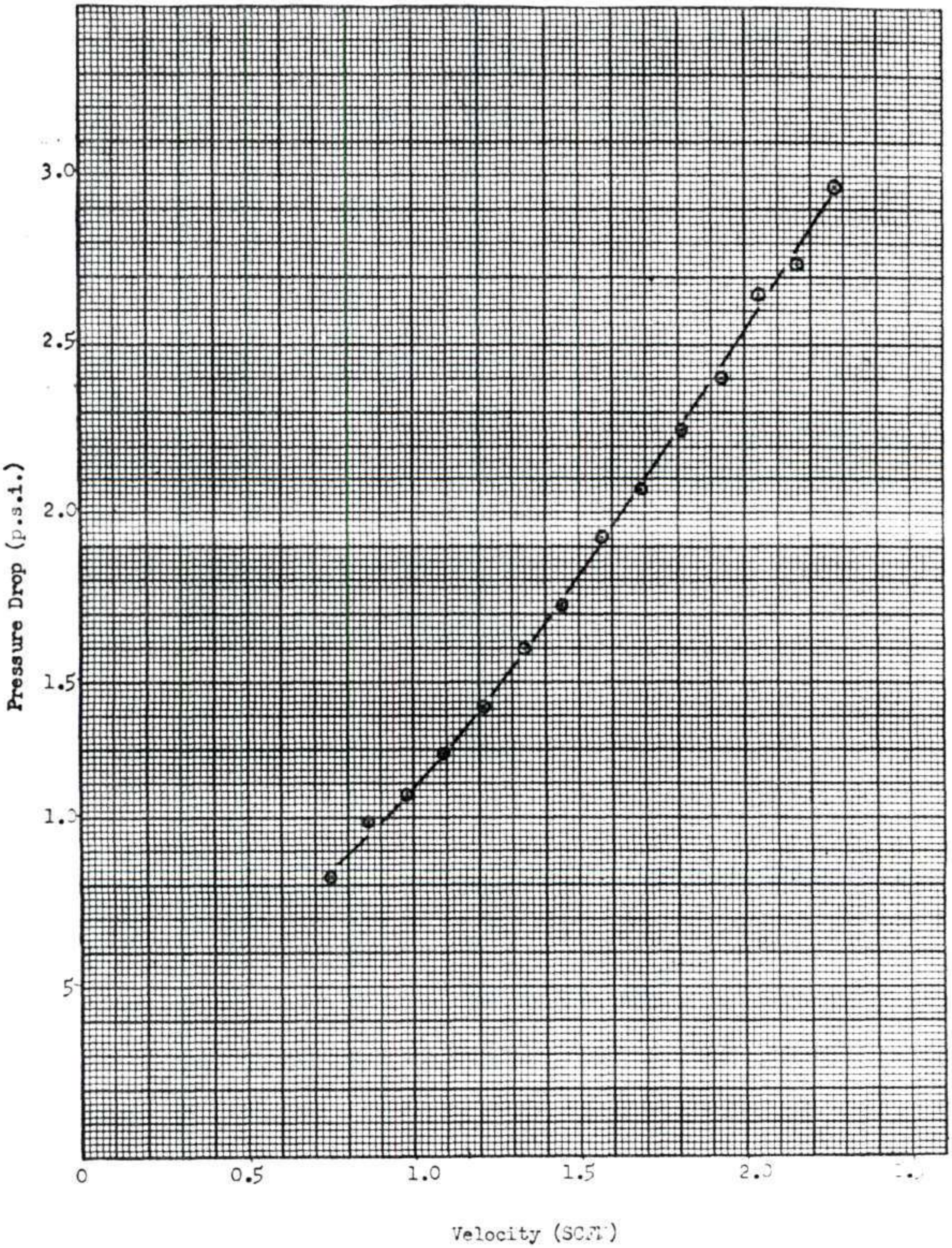


Figure 2. Micronaire Line Pressure Drop for Given Air Velocity Range

Table 3. Pressure Drop Across Fiber Bundle

Denier Relative to Specific Gravity 1.38

Density gm/in^3	Fiber Denier	Velocity SCFM	Line Pressure Drop	Fiber Bundle Pressure Drop
4.00	1.50	1.700	1.96	4.04
4.00	2.11	1.750	2.04	3.96
4.00	3.14	1.975	2.38	3.62
4.25	1.50	1.625	1.84	4.16
4.25	2.11	1.675	1.92	4.08
4.25	3.14	1.700	2.27	3.73
4.50	1.50	1.525	1.70	4.30
4.50	2.11	1.575	1.76	4.24
4.50	3.14	1.800	2.12	3.88
4.75	1.50	1.425	1.58	4.42
4.75	2.11	1.500	1.68	4.32
4.75	3.14	1.725	2.00	4.00
5.00	1.50	1.325	1.42	4.58
5.00	2.11	1.425	1.58	4.42
5.00	3.14	1.625	1.85	4.15
5.25	1.50	1.250	1.35	4.65
5.25	2.11	1.325	1.42	4.58
5.25	3.14	1.550	1.74	4.26
5.50	1.50	1.150	1.24	4.76
5.50	2.11	1.250	1.35	4.65
5.50	3.14	1.450	1.62	4.38

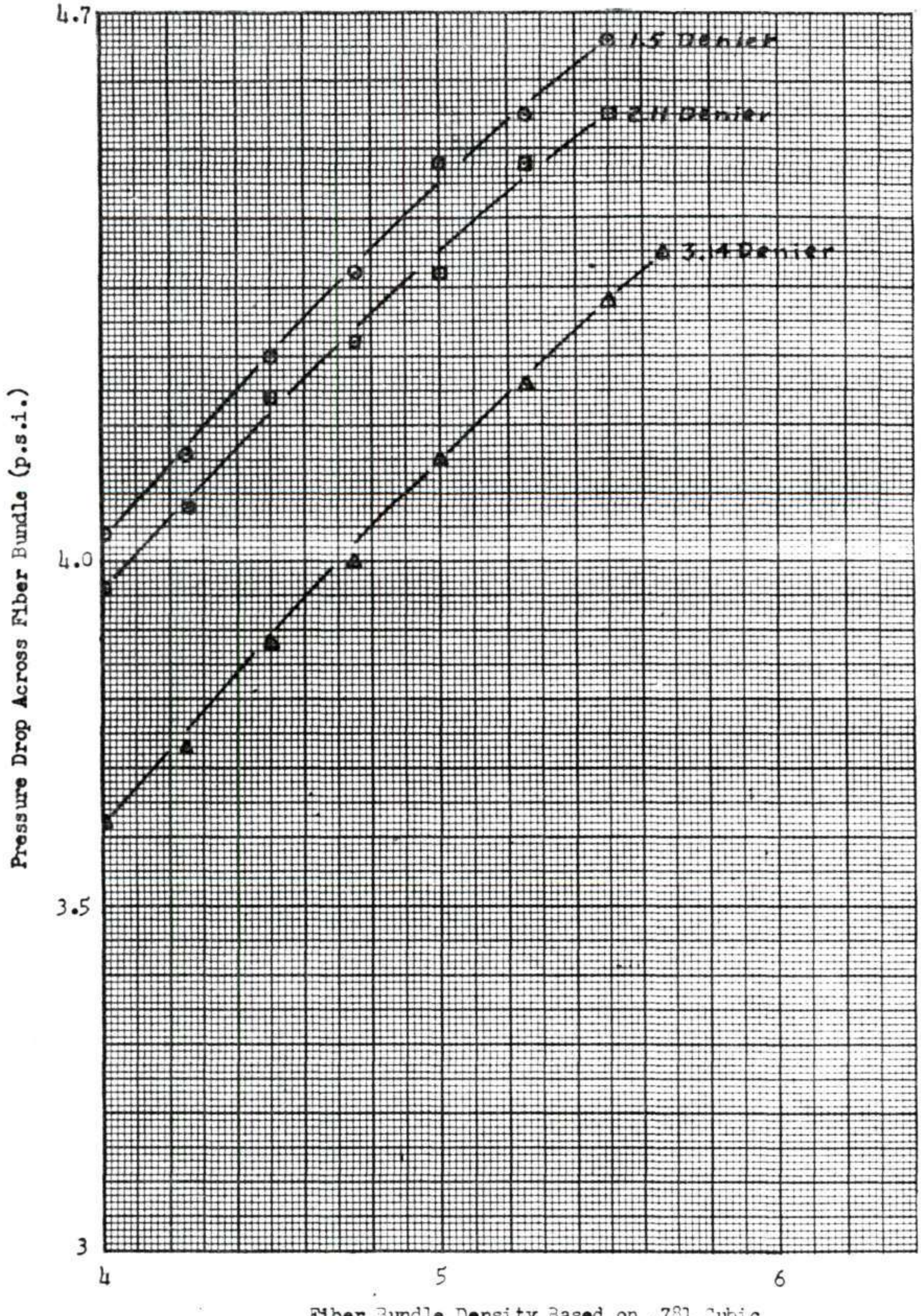


Figure 3. Fiber Bundle Density and Pressure Drop Graph

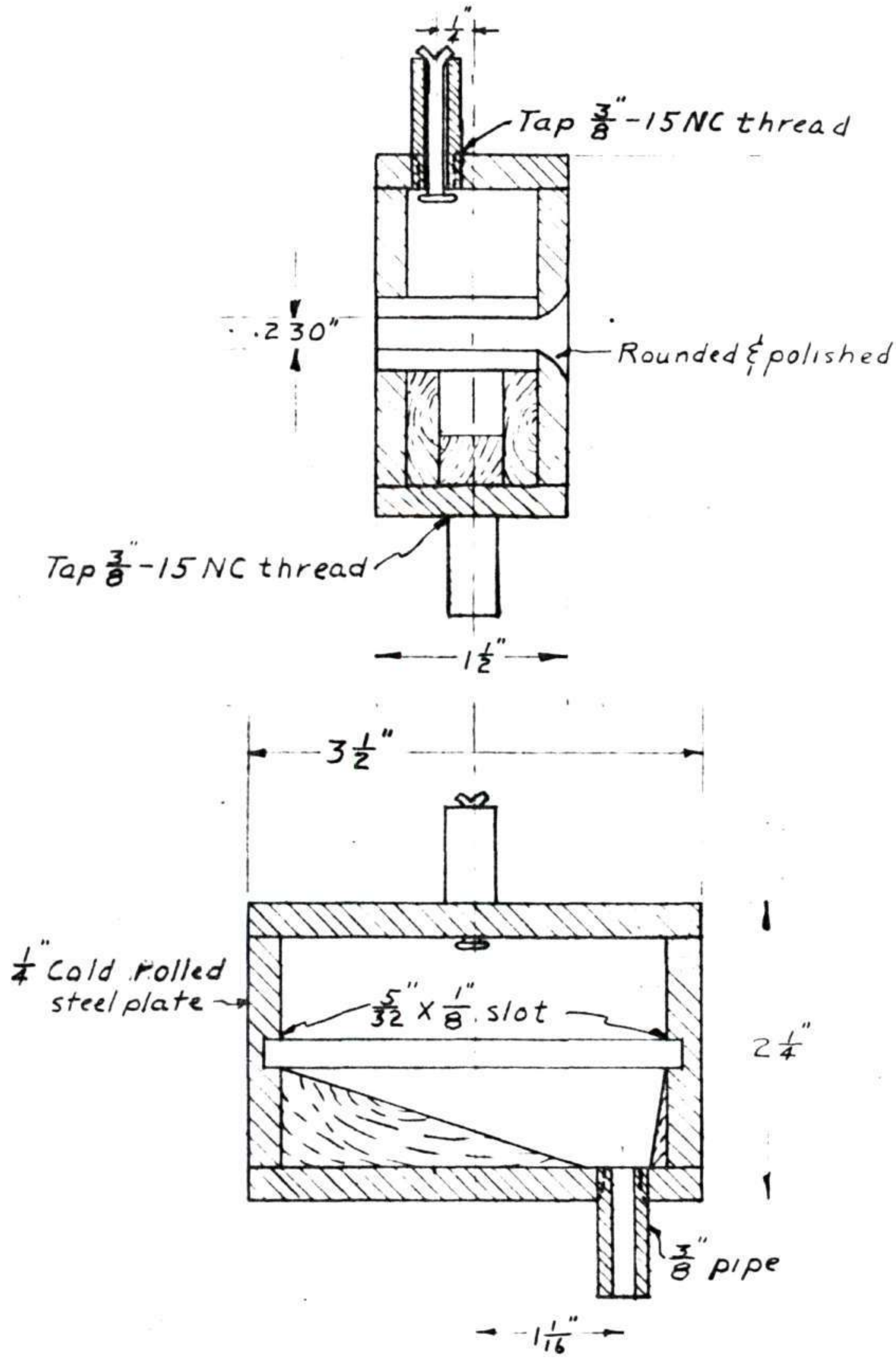
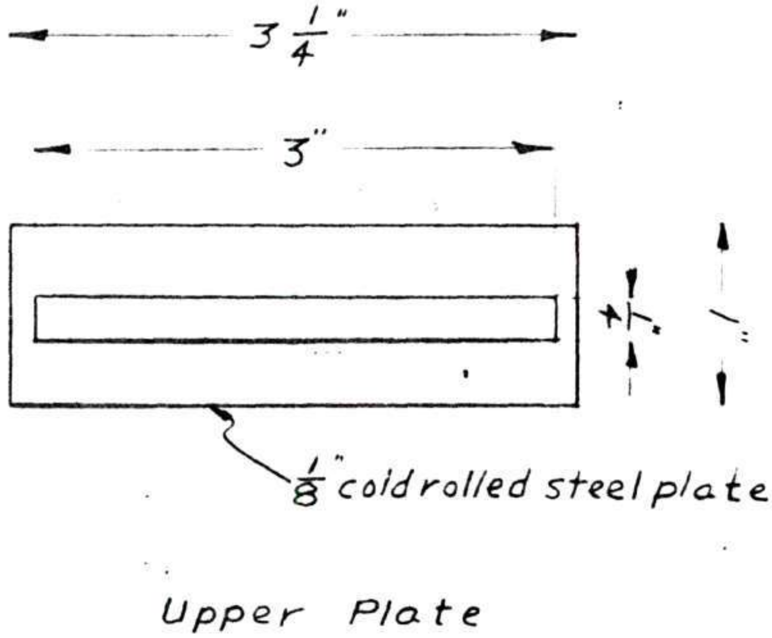


Figure 4. Measuring Device



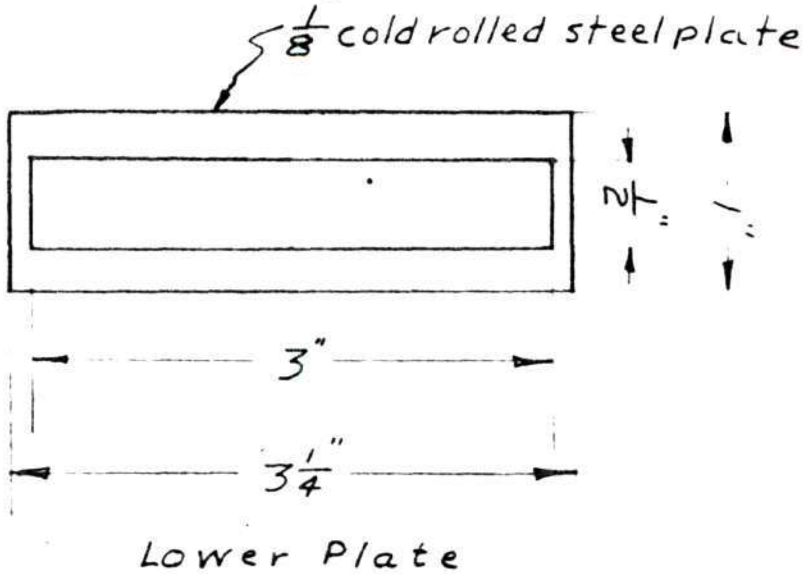
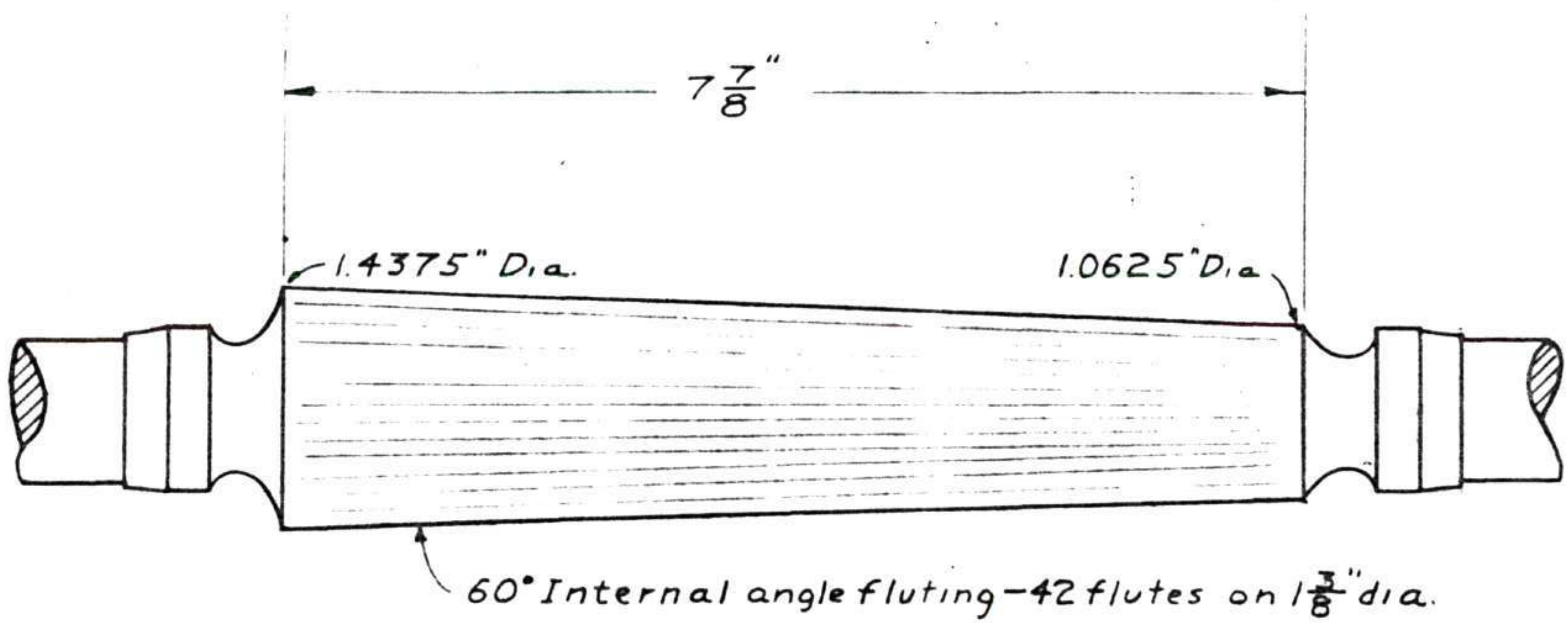


Figure 5. Orifice Plates

Table 4. Operating Characteristics of Measuring Device

Manifold Pressure - 21 p.s.i.
Weights Based on 50 grain Sliver

Reading	-8 Percent Cm.of Water	-4 Percent Cm.of Water	0 Percent Cm.of Water	+ 4 Percent Cm.of Water	+ 8 Percent Cm.of Water
1	4.9	4.4	3.9	3.3	3.3
2	4.8	4.2	3.9	3.4	2.9
3	4.6	4.2	3.7	3.3	3.3
Total	14.3	12.8	11.5	10.0	9.5
Average	4.76	4.26	3.83	3.33	3.16



NOTE: To be made of polished roller steel to normal dimensions for Medley front drawing roll.

Figure 10. Tapered Drafting Roll

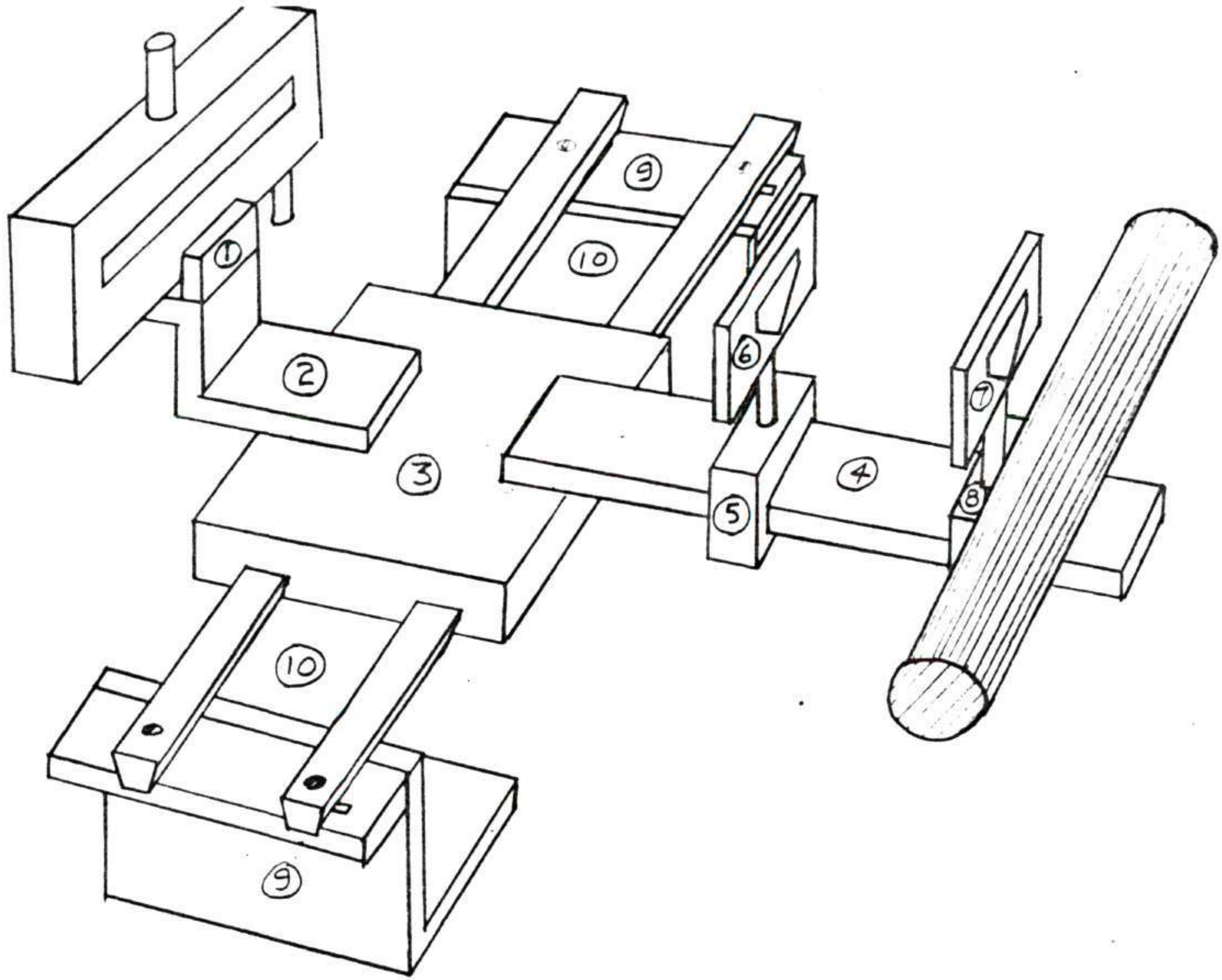


Figure 8. Movable Bracket and Measuring Device

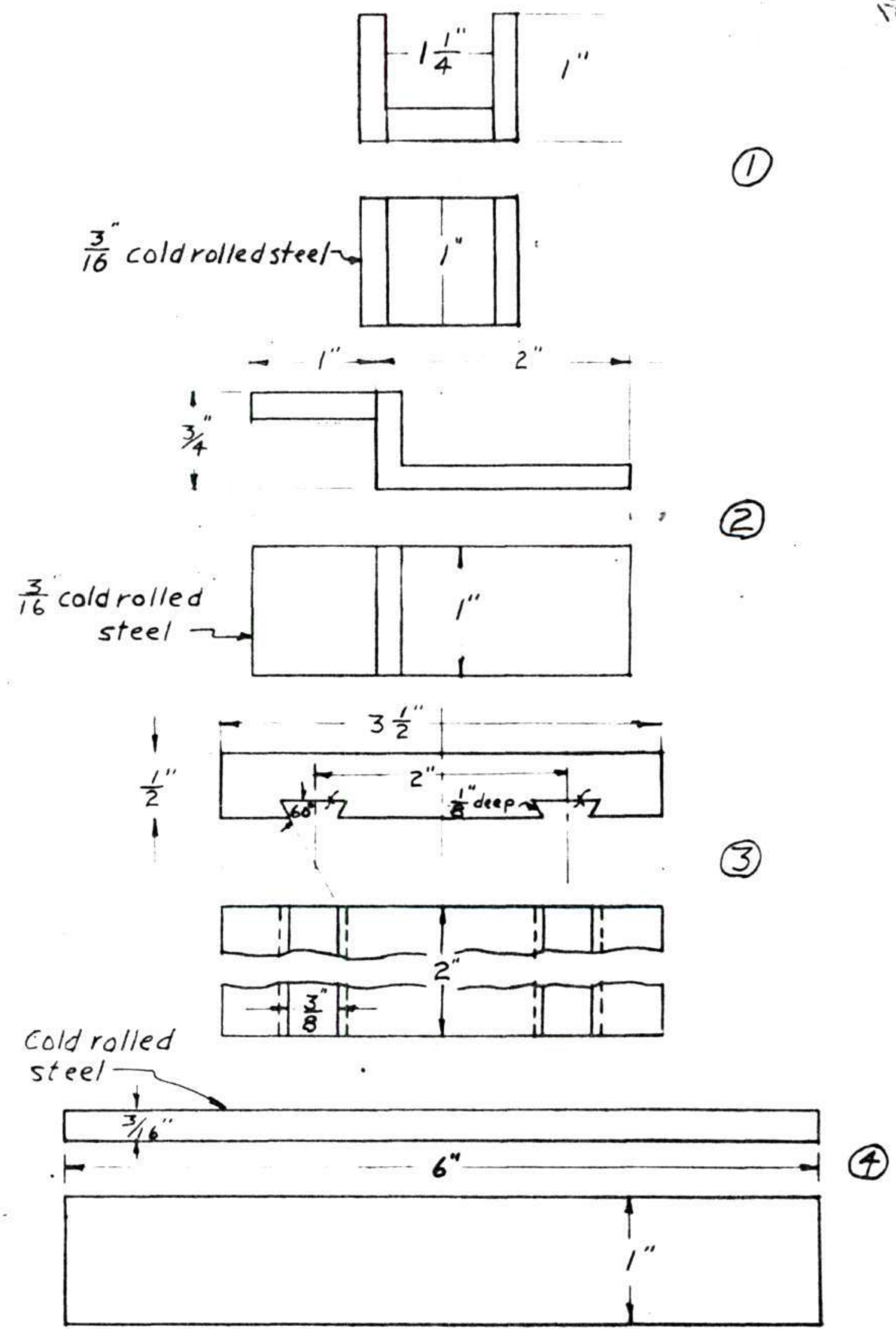


Figure 6. Components of Movable Bracket

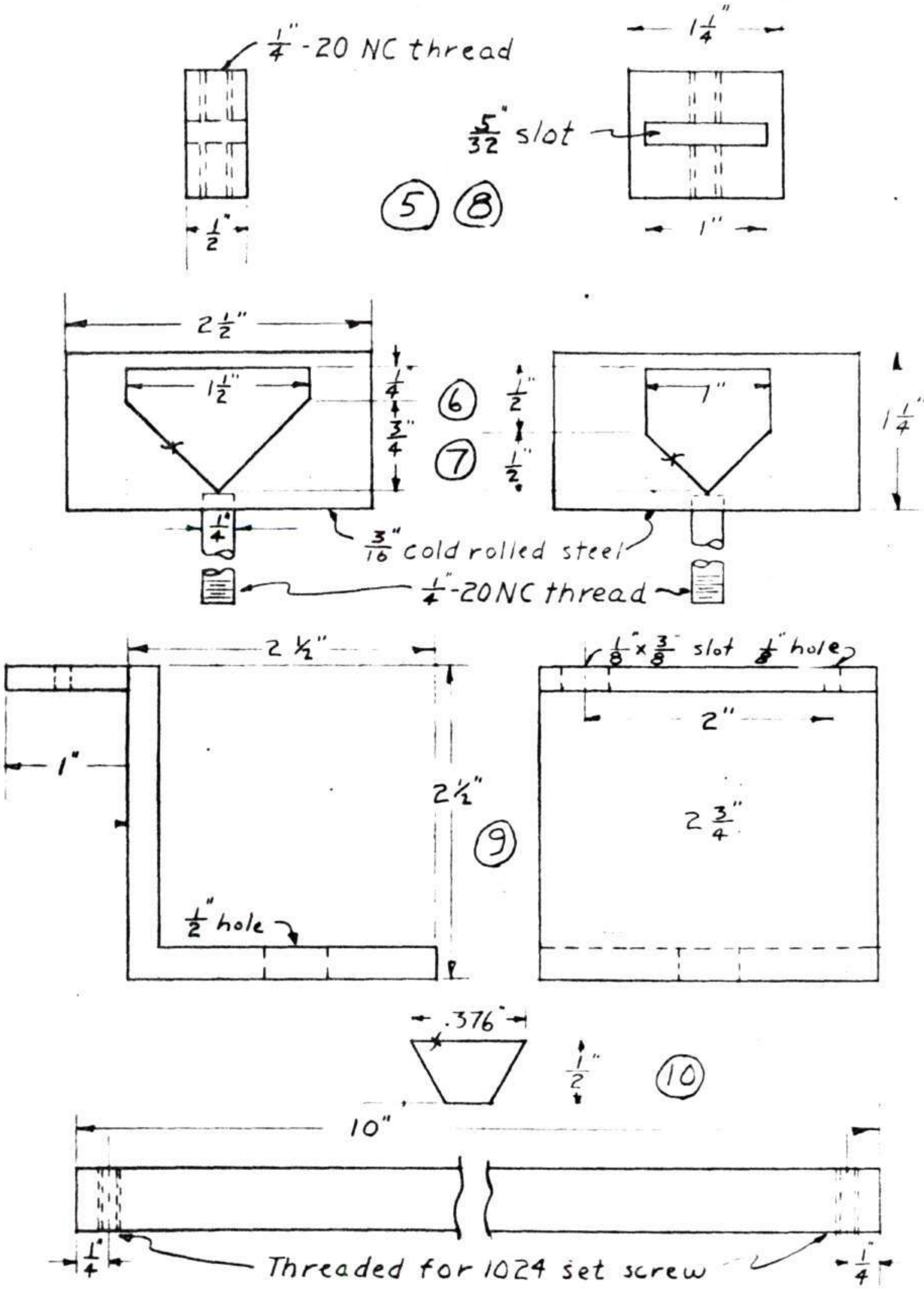


Figure 7. Components of Movable Bracket

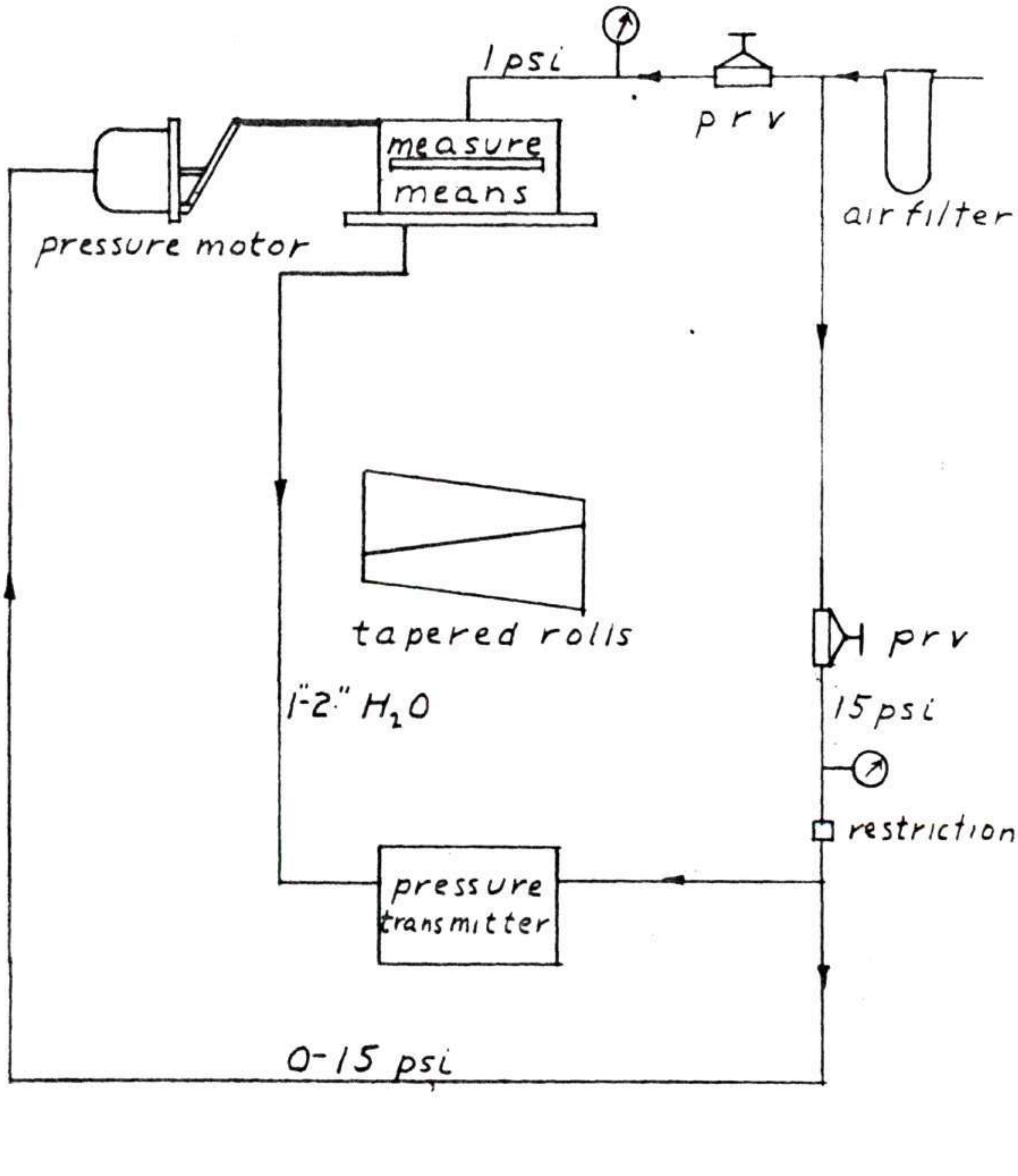


Figure 11. Control System Layout Diagram

Table 5. Evenness of Sliver Produced at Various Roller Weightings with Smooth Rolls

Arrangement No.	Roller Weighting Back To Front Roll Pounds	Evenness
1	48 - 48 - 44 - 44	Thick lumps of cockled sliver produced.
2	48 - 48 - 48 - 48	Cockled sliver produced.
3	48 - 48 - 48 - 84	Prominent drafting waves produced.
4	48 - 48 - 76 - 84	Prominent waves produced in selvage.
5	48 - 80 - 76 - 84	.020 in. variations on .030 in. sliver indicated.
6	70 - 30 - 84 - 84	.012 in. variations on .030 in. sliver indicated.
7	84 - 84 - 92 - 92	Slightly visible drafting waves remain in selvage.

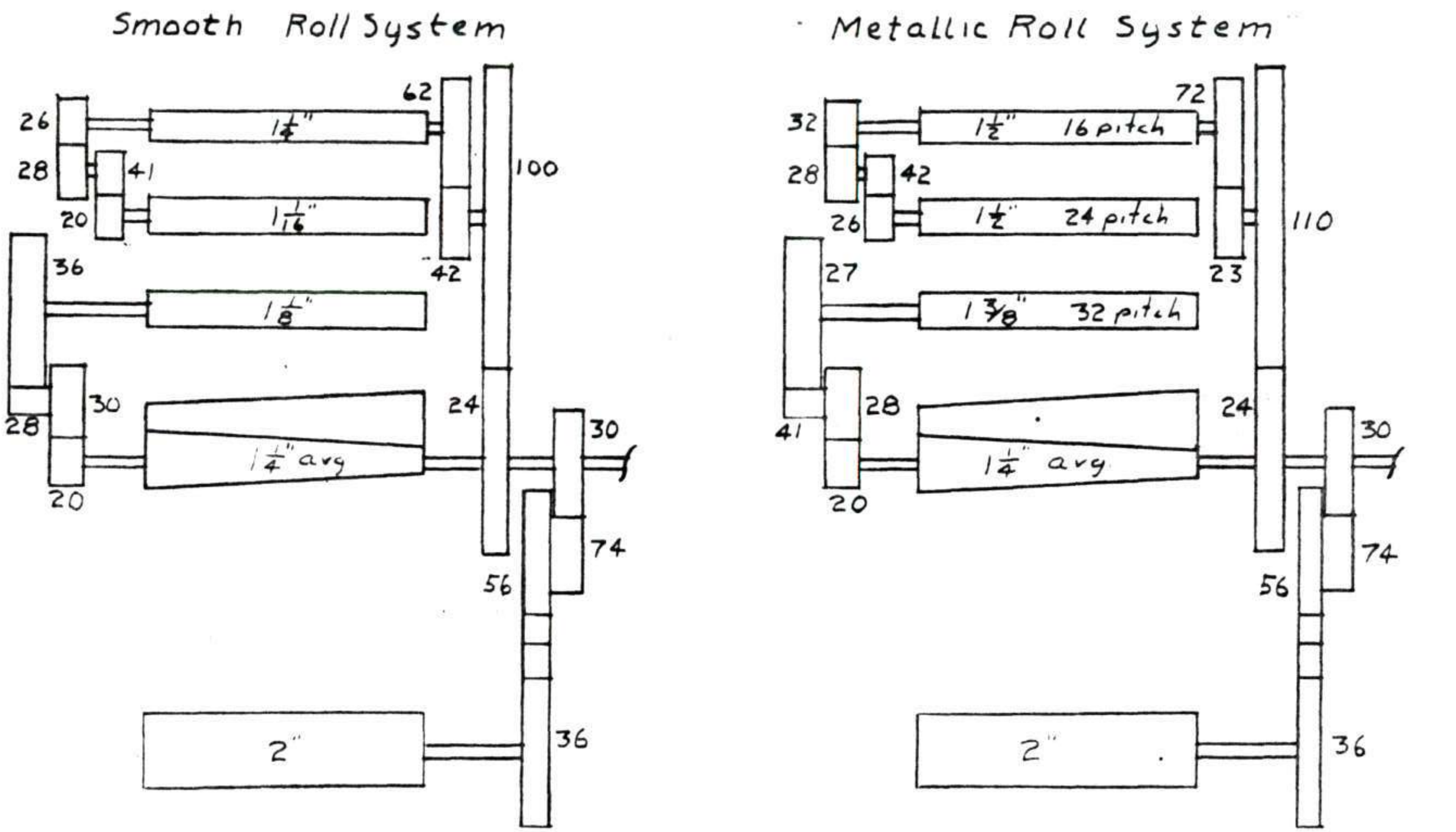


Figure 12. Final Gearing Diagram of Smooth and Metallic Roll Systems

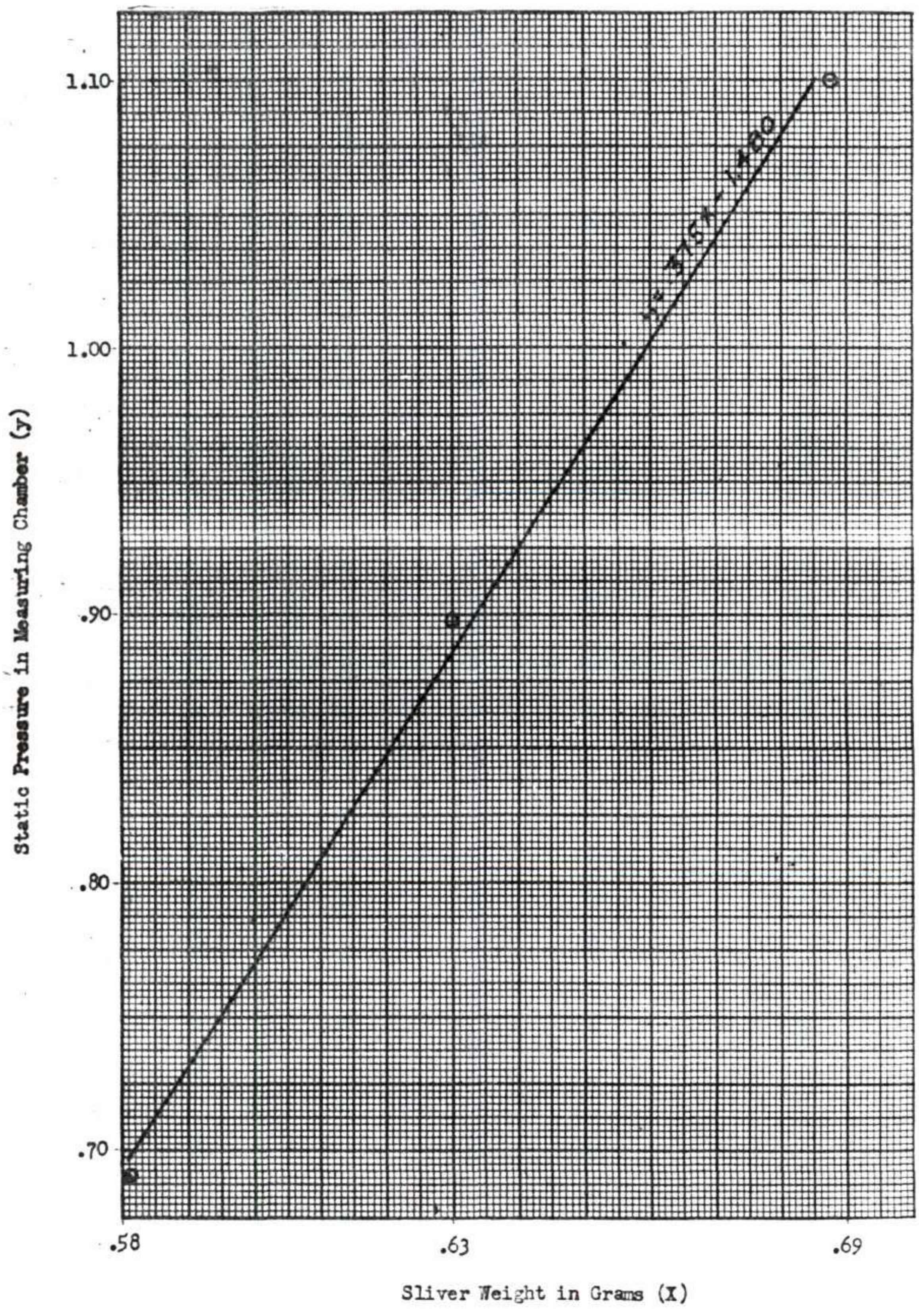


Figure 13. Measuring Device Characteristic

Table 6. Processing Data for Machinery

	Normal Process	Experimental Process Without Uniformity Control	Experimental Process with Uniformity Control
Card Sliver Weight in Grains-per-yard	56.5	56.5	56.5
Drawing			
Ends up	6	8	8
Draft	6.17	9.04	9.33
Front Roll Speed	111 ft.per min.	90 ft. per min.	90 ft. per min.
Roll Settings	1-21/32"-2"-1-31/32"	1-7/8"-2"-2-3/16"	1-7/8"-2"-2-3/16"
Type Rolls	Metallic	Metallic	Metallic
Back	1-1/2"-16 pitch	1-1/2"-16 pitch	1-1/2"-16 pitch
Third	1-1/2"-24 pitch	1-1/2"-24 pitch	1-1/2"-24 pitch
Second	1-1/2"-32 pitch	1-3/8"-32 pitch	1-3/8"-32 pitch
Front	1-1/2"-32 pitch	1-1/4"avg.common	1-1/4"avg.common
Passages	2	1	1
Final Sliver Weight in Grains-per-yard	28.5	50.0	48.5
Roving			
Ends up	2	1	1
Draft	12.0	12.2	13.0
Roll Settings	2-1/4"-1-13/16"	2-1/4"-1-13/16"	2-1/4"-1-13/16"
Twist-per-in.	1.49	1.49	1.49
Hank Roving	1.75	2.03	1.92
Spinning			
Ends up	2	2	2
Draft	21.0	15.59	15.52
Twist-per-in.	12.5	12.50	12.50
Counts	17.60	15.80	14.90

Table 7. Sensitivity and Response Measurements of System

1. Indicated Lag Time of Pneumatic System	.20 seconds
2. Total Throw of Pressure Motor	2.69 inches
3. Average Speed of Pressure Motor	7.10 inches-per-second
4. Speed of Material Through Measuring Means	2.18 inches-per-second
5. Average Pressure Fluctuation at Pressure Motor	0.3 p.s.i.
6. Time Interval Between Measuring Means and Variable Draft Zone	4.00 seconds

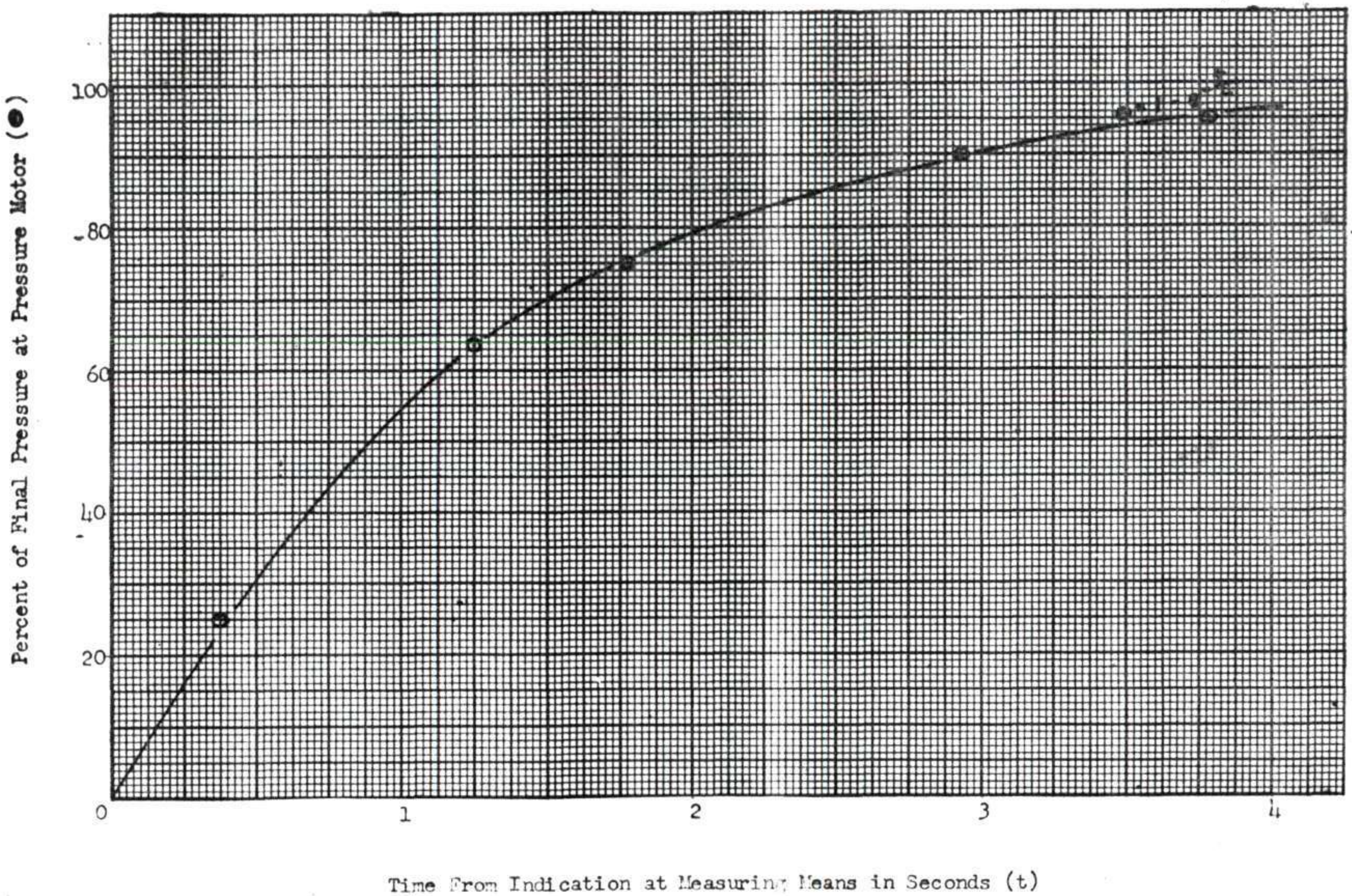


Figure 14. Response Curve for System Without Pressure Motor

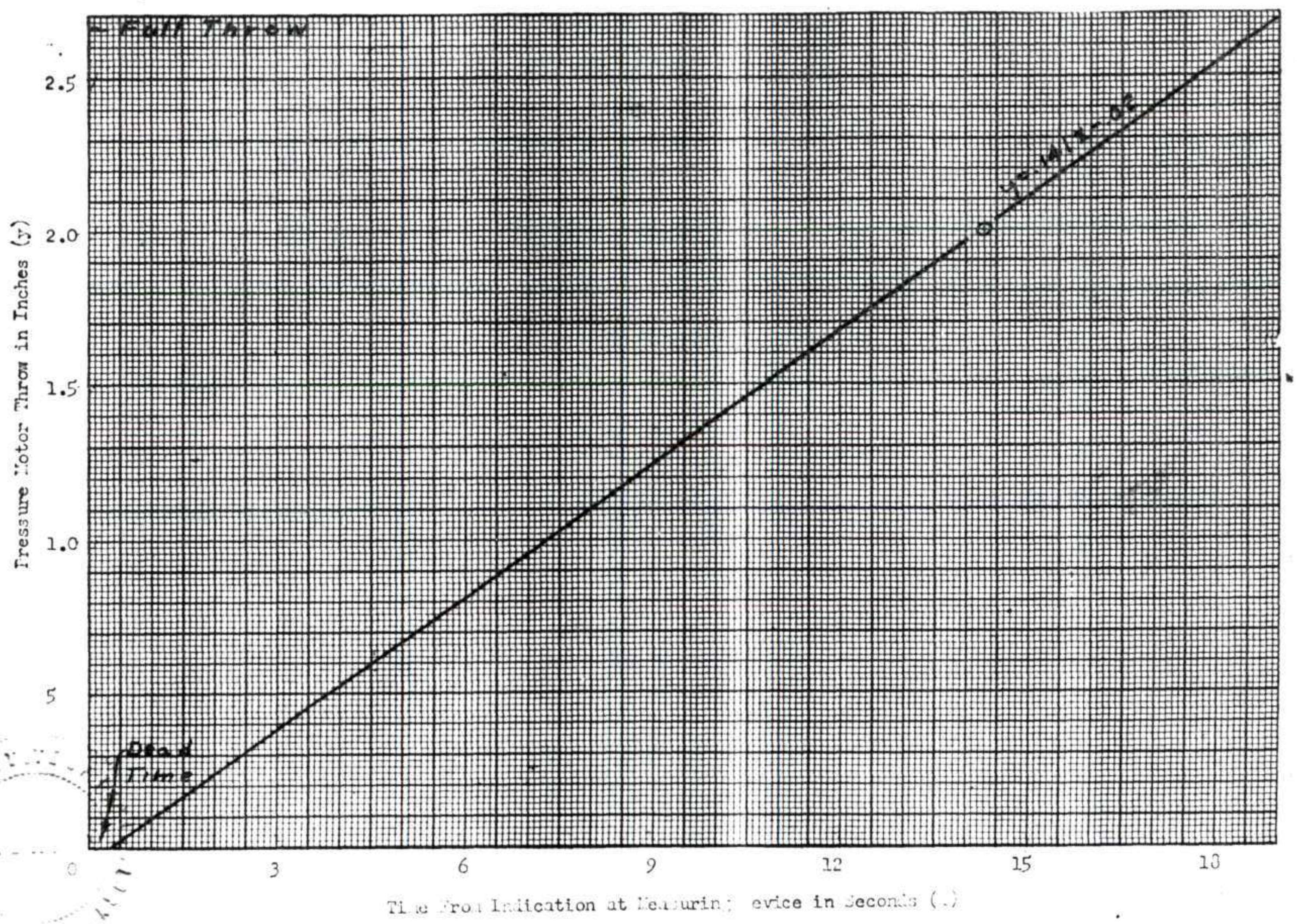


Figure 15. Response Curve for System

Table 9. Uniformity of Card Sliver

Weight - 56.5 Grains-per-Yard

Specimen No.	Uster Value	Specimen No.	Uster Value
1	2.5	25	3.7
2	2.8	26	2.6
3	2.6	27	2.0
4	3.4	28	3.4
5	2.9	29	4.7
6	4.0	30	3.7
7	3.5	31	2.1
8	4.9	32	2.6
9	4.7	33	3.2
10	2.2	34	2.5
11	2.5	35	2.4
12	2.2	36	1.7
13	4.2	37	2.4
14	2.2	38	2.4
15	1.7	39	2.6
16	3.1	40	3.0
17	2.8	41	2.3
18	3.0	42	3.6
19	5.2	43	4.3
20	3.7	44	3.0
21	4.4	45	3.5
22	6.1	46	3.9
23	4.6	47	3.7
24	4.2	48	3.1
		Total	155.8
		Average	3.25

Standard Deviation - 1.22

Samples Required to be Ten
Percent from True Average - 48.0

Table 10. Uniformity of Normally Processed Drawing Frame Sliver

Weight - 28.5 Grains-per-Yard

Specimen No.	Uster Value	Specimen No.	Uster Value
1	6.0	13	6.4
2	6.4	14	6.1
3	6.0	15	6.2
4	5.3	16	6.2
5	6.0	17	5.3
6	5.5	18	4.9
7	5.2	19	5.3
8	7.0	20	5.5
9	6.0	21	5.5
10	8.7	22	6.2
11	9.7	23	6.4
12	8.8	24	5.1
		Total	149.3
		Average	6.22

Standard Deviation - 1.24

Samples Required to be Ten
Percent from True Average - 16.0

Table 11. Uniformity of Experimental Drawing Frame Sliver Without Uniformity Control

Weight - 50 Grains-per-Yard

Specimen No.	Uster Value	Specimen No.	Uster Value
1	4.0	9	3.5
2	3.8	10	3.6
3	3.6	11	3.7
4	3.7	12	3.7
5	4.1	13	3.7
6	3.7	14	3.5
7	3.5	15	4.6
8	3.6	16	3.8
		Total	60.1
		Average	3.76

Standard Deviation - .32

Samples Required to be Ten Percent from True Average - 2.9

Table 12. Uniformity of Experimental Drawing Frame Sliver With Uniformity Control

Weight - 48.5 Grains-per-Yard

Specimen No.	Uster Value	Specimen No.	Uster Value
1	3.6	13	4.7
2	4.2	14	4.8
3	4.3	15	5.0
4	5.5	16	5.0
5	5.0	17	5.3
6	5.0	18	5.5
7	5.4	19	5.7
8	5.3	20	4.8
9	4.8	21	5.5
10	5.1	22	5.0
11	5.0	23	4.7
12	5.3	24	5.3
		Total	119.8
		Average	5.00

Standard Deviation - .48

Samples Required to be Ten Percent from True Average - 3.5

Table 13. Uniformity of Normally Processed Roving

Hank Roving - 1.75
Twist-per-Inch - 1.49

Specimen No.	Uster Value	Specimen No.	Uster Value
1	6.2	13	7.8
2	8.3	14	7.5
3	5.3	15	7.0
4	5.5	16	6.8
5	5.7	17	9.0
6	4.6	18	5.5
7	5.8	19	5.6
8	6.5	20	6.5
9	6.0	21	5.7
10	5.6	22	6.8
11	6.5	23	6.8
12	5.5	24	10.4
		Total	156.9
		Average	6.54

Standard Deviation - 1.34

Samples Required to be Ten
Percent from True Average - 16.3

Table 14. Uniformity of Experimental Roving Without Uniformity Control

Hank Roving - 2.03
Twist-per-Inch - 1.49

Specimen No.	Uster Value	Specimen No.	Uster Value
1	10.2	13	10.7
2	10.8	14	12.3
3	12.1	15	10.1
4	11.9	16	10.6
5	10.4	17	11.3
6	9.6	18	11.4
7	10.2	19	10.9
8	12.5	20	10.6
9	9.7	21	9.8
10	10.6	22	10.4
11	12.5	23	8.6
12	9.3	24	11.0
		Total	255.5
		Average	10.60

Standard Deviation - 1.98

Samples Required to be Ten
Percent from True Average - 14.0

Table 15. Uniformity of Experimental Roving With Uniformity Control

Hank Roving - 1.92
Twist-per-Inch - 1.49

Specimen No.	Uster Value	Specimen No.		Uster Value
1	10.5	13		10.9
2	13.7	14		11.4
3	10.9	15		13.9
4	11.5	16		13.2
5	10.0	17		9.9
6	9.6	18		11.1
7	10.5	19		11.2
8	11.6	20		16.0
9	10.7	21		12.5
10	9.5	22		11.3
11	9.9	23		10.6
12	9.9	24		10.6
			Total	270.9
			Average	11.30

Standard Deviation - 1.50

Samples Required to be Ten
Percent from True Average - 7.0

Table 16. Uniformity of Normally Processed Yarn

Counts - 17.60's
Twist-per-Inch - 12.50

Specimen No.	Uster Value	Specimen No.	Uster Value
1	10.4	13	11.3
2	12.0	14	11.5
3	12.0	15	11.7
4	11.9	16	10.7
5	11.4	17	11.5
6	12.9	18	12.4
7	10.9	19	11.1
8	11.5	20	12.1
9	13.4	21	9.5
10	10.9	22	10.0
11	10.9	23	10.6
12	13.3	24	13.8
		Total	277.7
		Average	11.60

Standard Deviation - .66

Samples Required to be Ten
Percent from True Average - 1.3

Table 17. Uniformity of Experimental Yarn Without Uniformity Control

Counts - 15.80's
Twist-per-Inch - 12.50

Specimen No.	Uster Value	Specimen No.	Uster Value
1	14.2	13	12.2
2	13.4	14	14.0
3	13.4	15	14.2
4	14.9	16	14.8
5	12.5	17	14.6
6	12.1	18	13.1
7	12.9	19	12.1
8	14.5	20	12.2
9	13.3	21	11.7
10	14.5	22	12.9
11	12.2	23	13.0
12	12.0	24	15.3
		Total	177.1
		Average	13.30

Standard Deviation - .47

Samples Required to be Ten
Percent from True Average - .49

Table 18. Uniformity of Experimental Yarn With Uniformity Control

Counts - 14.90's
Twist-per-Inch - 12.50

Specimen No.	Uster Value	Specimen No.	Uster Value
1	16.3	13	11.9
2	13.9	14	12.6
3	14.1	15	14.3
4	14.3	16	14.5
5	13.0	17	14.1
6	12.7	18	13.5
7	11.5	19	14.9
8	15.7	20	11.8
9	13.1	21	11.5
10	12.5	22	13.9
11	12.6	23	13.8
12	12.1	24	11.5
		Total	319.7
		Average	13.30

Standard Deviation - 1.65

Samples Required to be Ten Percent from True Average - 6.2

Table 19. Single Strand Breaking Strength and Elongation of Normally Processed Yarn

Counts - 17.60's
Twist-per-Inch - 12.5

Specimen No.	Break Strength Pounds	Elongation Percent	Specimen No.	Break Strength Pounds	Elongation Percent
1	.88	12.5	11	.96	13.6
2	1.00	14.8	12	1.24	15.0
3	.96	15.8	13	1.12	14.5
4	.79	10.8	14	1.18	14.7
5	.67	9.9	15	1.04	13.3
6	.84	12.0	16	1.02	13.7
7	.93	12.7	17	1.23	16.0
8	.96	14.0	18	1.10	15.5
9	1.06	15.0	19	1.14	13.5
10	1.06	15.8	20	1.10	14.5
			Total	20.82	277.6
			Average	1.01	13.88

Strength Standard Deviation - .18

Strength Samples Required to be Ten Percent from True Average - 12.8

Table 20. Single Strand Breaking Strength and Elongation of Experimental Process Yarn Without Uniformity Control

Counts - 15.80's
Twist-per-Inch - 12.50

Specimen No.	Break Strength Pounds	Elongation Percent	Specimen No.	Break Strength Pounds	Elongation Percent
1	1.17	14.3	11	1.04	12.0
2	1.00	12.0	12	1.20	14.4
3	1.00	12.8	13	.92	12.0
4	1.03	12.4	14	1.12	12.7
5	.86	10.5	15	1.06	12.2
6	.92	12.3	16	1.12	13.8
7	.92	12.3	17	1.00	12.0
8	.80	10.0	18	1.06	12.8
9	.96	12.3	19	.82	11.0
10	1.12	14.0	20	.92	12.0
			Total	20.04	247.0
			Average	1.00	12.4

Strength Standard Deviation - .10

Strength Samples Required to be Ten Percent from True Average - 4.24

Table 21. Single Strand Breaking Strength and Elongation of Experimental Process Yarn With Uniformity Control

Counts - 14.90's
Twist-per-Inch - 12.50

Specimen No.	Break Strength Pounds	Elongation Percent	Specimen No.	Break Strength	Elongation Percent
1	1.02	13.0	17	1.32	13.0
2	1.10	13.8	18	1.45	15.2
3	1.05	12.5	19	1.19	12.5
4	1.16	14.0	20	1.08	12.8
5	.96	13.0	21	1.28	15.0
6	1.10	14.0	22	1.01	12.1
7	1.17	15.0	23	.93	11.5
8	1.02	14.0	24	.88	11.8
9	1.04	13.8	25	1.07	12.9
10	1.16	13.0	26	1.26	13.3
11	1.08	13.5	27	1.15	12.6
12	1.12	13.2	28	1.42	14.5
13	1.34	14.5	29	1.11	13.5
14	1.25	15.0	30	1.00	13.6
15	1.50	15.4	31	1.17	12.5
16	1.20	13.5	32	1.19	13.7
			Total	36.95	431.1
			Average	1.15	13.5

Strength Standard Deviation - .33

Strength Samples Required to be Ten Percent from True Average - 32.0

Table 22. Uniformity Ratio Derivation

Enrick states that inherent yarn irregularity, CV, is

$$CV = 0.82 \sqrt{\text{counts (Fiber Fineness Index)}}.$$

With this as a basis a ratio may be formed to evaluate relative uniformity in products of identical fiber.

$$\frac{CV}{0.82 \sqrt{\text{counts (Fiber Fineness Index)}}} = \text{constant}$$

$$\frac{CV}{\sqrt{\text{counts}}} = \text{constant} .$$

With substitution of the Uster reading for the irregularity

$$\frac{U\%}{\sqrt{\text{counts}}} = \text{constant}$$

or

$$U\% \sqrt{\text{weight per unit length}} = \text{constant}.$$

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