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The Performance of a Laboratory Type Inclined Screen Washer

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THE PERFORMANCE OF A LABORATORY TYPE INCLINED SCREEN WASHER

Thesis

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SUMMARY:

This thesis is a study of pulp washing methods and factors influencing their operation. The literature survey is a discussion of diffusers, deckers, vacuum washers, screw presses, and inclined screen or side hill washers and methods of evaluation of washing systems.

Experimental work consisted of the analysis of the efficiency of a laboratory model inclined screen washer from the standpoint of suspended and dissolved solids removed and rate of flow. The experiments were run with deinked waste paper stock at four angles.

The results obtained indicated that an improved design of the inclined screen washer is necessary and suggestions along this line are offered.

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LITERATURE SURVEY

Pulp Washing

Introduction

The unit operation of pulp washing may be described as the removal of water soluble, and insoluble impurities from pulp at any stage of the papermaking operation. This includes brown stock washing, washing of deinked stock, and washing after bleaching.

Developments in this field have come about slowly and in no particular time sequence. The reasons are economic and developmental in nature. The investment needed for an operation is large, thereby delaying the acceptance of new methods. Also, the requirements of one mill differ so greatly with those of another, that universal developments are few.

The five types of washing operations to be discussed in this paper are; diffusers, deckers, vacuum washers, screw presses, and inclined screen or sidehill washers.

Theory

Of the three factors to consider in evaluation of a washing system namely economics, completeness of removal of undesirable material and water economy, this paper will be mainly concerned with the removal of undesirable material.

There are three recognized principles, one or more of which are found in all commercial washing equipment. They are: displacement with water, dilution followed by removal of the solution by decantation or otherwise, and the pressing

out or squeezing out of the solute. In the employment of the first principle the wash water passes downward through the pulp in a tank. The water acts as a piston driving the black liquor ahead of it through an opening in the bottom of the tank. The objective is to have the liquor removed without any dilution from the wash water. The ideal is never actually reached because of channeling effects, diffusion of the dissolved chemicals upward and the affinity of the black liquor for the fiber.

The second principle or method, dilution followed by removal of excess liquid, is wasteful of water. The potential of this method is low but percentage realization is high because, if eighty-five percent of the liquid can be decanted, then eighty-five percent of the soluble matter will be removed. This is the reason that this method continues in use along with other systems that are theoretically superior.

The third principle, squeezing liquor out of the pulp, has, in theory, the result of complete liquor removal without dilution. If the ideal were reached, the pressure would be high enough to ruin the fiber. Some fibers can be reduced to seventy percent dryness by this method while neutral sulfite semichemical pulp has been shown to resist pressure yielding dryness of only sixty percent. If the pulp had been blown at twenty percent fiber, a pressing to sixty percent will remove about eighty-three percent of the soluble material going into the press. (1)

Description

Diffusers

Diffusers are essentially tall tanks in which the pulp is placed and washed by introducing water at the top and draining the liquor off at the bottom. This type of equipment was developed early when water supply, stream polution and recovery of chemicals presented little or no problem.

In construction, the diffuser is about twice as high as its diameter and is provided with a false bottom which consists of a perforated plate. Under the false bottom is a drain for the removal of the liquor. At the top inlet is very often a cone shaped device for spreading the pulp evenly in the diffuser. Washing sprays are also located at the top. in the side of the diffuser at the level of the perforated plate is a hole for the removal of the pulp. After the washing has been completed the hole is opened and water from high pressure jets on the opposite side of the diffuser blow the pulp from the tank. (2)

The device is designed to operate under pressure (1) and the action is largely one of displacement of heavy black liquor by one of lower concentration. In alkaline pulping diffusers use about 0.8 to 1.0 gallons of water at 130 to 150 F for each pound of pulp. (3)

The use of hot water will speed the washing of the stock and increase the capacity of the operation. The application of hot water also means less work for the evaporators. (4)

For heat economy, very often it is the practice to use

only a small volume of hot water for washing. The hot water is then used as a continuation of the weak-liquor wash and is usually supplied from a special tank placed high enough to allow the water to flow in by gravity. After the hot water (of which a volume corresponding to two or three feet of the diffuser height is used) has settled in the stock, cold water is used to complete the wash. The hot water acts as a plunger, which produces increased washing efficiency and prevents any lowering of the temperature of the black liquor. (4)

The usual arrangement of a battery of diffusers is to place them in a circle and operate them in pairs. When the liquor falls below a certain test it is passed from a freshly charged diffuser to the top of the next one and there used as a primary wash as fast as it is obtained. (4)

Gothner and Robson (5) report that the washing capacity of diffusers may be increased as much as twenty-two percent by the installation of angle iron supports. The supports are placed crosswise in the tank at about six feet above the bottom. Increases in capacity as high as one hundred-eight percent were reported upon the installation of Markila-Brax strainers. These are a screen-cagelike device, with pointed ridges on top, which are placed crosswise in the bottom of the diffuser.

A prediction of results obtainable by installation of Markila-Brax strainers is impossible to make, as the shape of the diffuser into which they are placed is apparently critical; the washing pressure and the permanganate number of the pulp

seem to have considerable effect.

As the pulp in the top half of the diffuser may be practically thoroughly washed while that in the bottom half may contain fairly strong black liquor, the wash water must travel down through the washed pulp so as to push the liquor out of the stock in the bottom of the diffuser. An attempt has been made to remove the thoroughly washed stock from the top half of the vessel, then refill the diffuser by pumping unwashed stock into it just above the false bottom and resume normal washing. The attempt, so far, has been unsuccessful. (1)

Deckers

Another type of equipment for washing of pulp is the decker. This consists of a wire screen covered cylinder which revolves slowly in a vat of stock. A sheet or mat of fiber is formed on the wire wcreen as the water passes through the screen. The ends of the cylinder are open allowing the water to drain from the machine. This drainage brings about a difference in the heads of the water in the vat and inside the roll. The difference in level causes the water to flow through the screen.

As the roll revolves, the mat emerges from the water and passes under a press roll driven by the cylinder mold. Excess water is pressed from the mat and the sheet is transferred from the cylinder mold to the press roll. The mat goes over the top of the press roll and is doctored off on the other side.

There is very little fiber loss on deckers, except for a small amount of fines lost before a mat has completely formed on the mold.

Vacuum Washers

Vacuum washers are, in some respects, similar to deckers. They consist of a cylinder mold revolving in a vat of fiber suspension. The interior of the cylinder mold is divided into a series of radial, stationary compartments which are under vacuum. There are several alternate lateral rows of showers that spray water and weak liquor on the fibrous mat a short distance from where it emerges from the vat.

All material removed from the fiber mat is forced by pressure to the center of the mold and is removed through a pipe in the axis of the cylinder. The difference in pressure is created by a barometric leg of the liquid removed and the ends of the mold are made air tight.

In a typical washer of twenty-eight sections, (4) six are used for sheet formation. The outer perimeter of these are at the bottom of the mold or in the submerged area. Four sections are for drainage before wash. The next twelve compartments of the cylinder are used for washing. The strong liquor is removed from the fibers by displacement with week liquor and water from the showers. The last five of the washing compartments are sometimes attached to a separate high vacuum. The remaining six compartments of the mold are blocked off for sheet discharge which may be accomplished by doctoring or by transfer to another roll.

The washing operation is frequently combined with thickening of the stock. Sometimes several thickeners are arranged for counter-current operation.

It has been said (4) that a continuous vacuum filter operating under the proper conditions on mechanical stock will discharge water containing from 0.8 to 1.25 pounds of fiber per one thousand gallons effluent. With chemical pulps, the effluent is nearly free from fibers.

There are many modifications of the typical washer described above. As an example, one type employs pressure by placing the cylinder mold very close to the edge of the vat where it emerges from the suspension. The mat is pressed between the cylinder and the wall, thereby squeezing the liquid from the fiber. (4)

In the vacuum washer the results are due partly to diffusion and partly to dilution with only limited time for diffusion. By removing knots and rejects with a pre-knotter, channeling of wash water can be prevented.

The effectiveness of the washing operation depends on the amount and temperature of the water and the depth of the stock on the filter mat of the vacuum washer.

The content of electrolytes and pH of the wash water has a bearing on the ash content of the pulp. The calcium and magnesium ions found in hard waters coagulate the resins on the fiber, thus making them hard to remove.

Armstrong (6) states that the temperature of wash water should be as high as possible: 130 to 150 F for alkaline cooked

pulps and 160 F for unbleached sulphite pulp. Too high a temperature and vacuum cause excess foaming. (3)

Calhoun (7) has found that in washing kraft brown stock a dilution ratio of three pounds of water per air dry pound of pulp on a three-stage system of proper design should give a salt cake loss of no more than thirty pounds per air dry ton on soft wood liner grade pulp, and twenty-five pounds or less per air dry ton on an easy bleaching grade of softwood. These figures are based on the number of pounds of chemicals calculated as sodium sulphate in each air dry ton of washed pulp when a given quantity of water has been introduced into the filtrate system, expressed as pounds of water per air dry pounds of pulp.

The greatest factor in preventing color from reverting after bleaching is the removal of all the reaction products. Thorough washing of bleached chemical pulps may require as much as ten thousand gallons for washing, or about sixty thousand to seventy thousand gallons per ton of pulp in a six to seven stage bleaching process. Because of shortage of water in many areas, frequently no more than twenty thousand to forty thousand gallons are used in the multistage bleaching of sulphate pulp. Counter-current washing from stage to stage is practised with the wash water being used as much as possible. (3)

When washing deinked stock, Morrison (8) has found that a vacuum washer preceeded by a Vortrap or Dirtec and followed by a second vacuum washer will insure well cleaned

pulp. The effluent will carry fifteen to twenty pounds of insolubles per one thousand gallons.

According to Morrison (8) the best conditions in the vacuum washer when working with deinked stock are:

(A) Feed temperature not less than 150 F.

(B) Feed consistency not over 0.75 percent a. d.

(C) Washer cylinder at three to rour r. p. m.

(D) Washer cylinder cover 30 x 30 mesh wire cloth.

He also notes that a better formed and freer sheet may be obtained by adding some long fiber stock to the stream of old paper stock. This will increase the permeability of the sheet making the operation more efficient and reducing the quantity of wash water needed.

Screw Press

The screw press, as a method of removing undesirable material from pulp, has been in service since 1930. It is the outcome of development in the vegetable oil field where it was first used for extraction. The first models were simply a continuous helix on a shaft turning in a tube. Many modifications have been made but today the principle is still the same.

The modern press consists of two stages; a vertical press section with its own transmission and a horizontal with its transmission and motor. (9)

There are several problems to be overcome in designing this type of equipment, among which are case friction and

inability of certain materials to withstand the torque and pressures developed. (9)

Dedbert (10) says the removal of liquor works on the principle of diffusion and cappillary action in combination with each other. About eighty-three percent efficiency is realized without dilution. (1)

The screw press offers many advantages for producers of high yield pulps. Natwick (11) states that in pressure washing you press the liquor out of the inside of the fiber. The cooking liquor is expressed at digester concentration and Ginaver and Adams (12) note that the fibers so handled exhibit improved strength at relatively high freeness, greater freedom from shives, and faster drying.

From a quality standpoint, the intense pressure and rubbing action which takes place in at least one commercial model (12) results in a superior preliminary fiberizing action. The heat in combination with the natural or added moisture in the chips provides a steaming action that produces desirable properties in fibers processed for insulating board, and hard-board and mechanical pulp made with presses and disk refiners.

The pressing operation is usually carried out in several stages with dilution in between. Doyier (13) points out that the most favorable time for dilution is as the pulp is expelled from the press. While the pressure is being released the pulp immediately absorbs the water or the wash loquor.

Von Hildebrandt (14) describes a multistage system of removing cooking liquor and washing of chemical pulp employing

the screw press. The blow tank is perforated and surrounded by an outer shell. This permits the extraction of liquor and channeling for collection. The pulp then moves through a tapered and perforated screw conveyor with inlet for steam, to a distributor and on to a defiberizer and grooved press rolls. At this stage the undercooked pulp and knots are fiberized and the liquor is removed to the extent of ninty-five percent.

The pulp proceeds to a horizontal, tapered, and perforated screw conveyor and continues through a vertical screw conveyor. It then enters the bottom conveyor under pressure, is washed, and passes through a preheater tank before being pumped into the next conveyor.

The four stages of the counter-current system require about 700 gallons of water per ton of pulp, with a salt cake loss of less than twenty pounds per ton of pulp in the kraft process.

The resulting fiber is stronger and cleaner than that processed by the conventional method, with a saving of water, power, space, steam and man hours. Because there is no contact with the atmosphere the foam problem is eliminated.

Inclined Screen Washers

Besides the three principles of washing mentioned above which have resulted in the development of the diffuser, vacuum washer, and the screw press, there is a fourth principle; classification or fractionation. By employing this principle

large desirable particles may be separated from smaller undesirable particles as in the removal of ray cells in brown stock or ink particles in deinked stock. This fourth principle is employed in the inclined screen or side hill washer and to a small degree in the decker.

When used as a saveall the best angle for the screen is said to be thirty-eight degrees with the headbox so arranged as to give a smooth even flow onto the wire. (15) (16)

An analysis was made in two mills of the waste water from an inclined screen washer in one case and a Lancaster washer side by side in the other. (17) The study was made by the Kalamazoo River Improvement Company's Laboratory located at Western Michigan University. Following is a table showing the results obtained.

Table I

Analysis of Waste Water

	Mill A	Mill B	
	Side Hill Washers	Side Hill Washers	Lancaster Washers
	%	%	%
Total Solids	0.597%	0.791%	0.496%
Ash to Total Solids	52.0%	52.8%	58.9%

A particle size distribution analysis of the total solids showed that very little papermaking fiber, fiber that would be retained on a 65 mesh screen, is lost on the side hill washer.

Concerning the capacity of this type of equipment in one installation (18) four brown stock washers, two nine by fifteen feet and two ten by nine feet have been used to wash eight to ten tons per hour. After the fourth step the stock is pumped to the bleach towers. The incoming consistency is 1%, output 2.35%, and sometimes as high as 7.5% is obtained.

In as much as there is very little information in the literature on inclined screen washers it was decided to evaluate a laboratory model for (a) removal of suspended solids from deinked stock and (b) removal of soluble undesirable chemicals from bleached kraft pulp, and to offer suggestions for improvement in design that may become evident during operation.

Evaluation of Washing Systems

Very little information was found in the literature concerning the analysis of a washing system. From the few articles that are available, it appeared that this is a field of very recent endeavor.

Most of the literature available concentrated on brown stock washing although some of the mechanics of analysis were applicable to the problems presented in this paper.

Dedert and Waters (19), in a review of methods used to measure brown stock washer effectiveness, spoke of the dilution solids concentration from mill to mill and different grades of Pulp within a mill.

They presented a simplified formula, along with examples, for the calculation of the dilution factor.

Perkins, Welsh and Mappus (20) and Armstrong (21) wrote of a method using the displacement ratio and expressing the washing accomplished in terms of the reduction in soluble solids. The formulas developed from this theory made possible the analysis of a system in part, that is, each stage separately, and as a whole by considering the sum of the parts.

One series of tests showed that the empirical displacement ratio-dilution factor relationship can be expressed as a constant (K) multiplied by the theoretical equivalent of the displacement ratio. (20) The empirical expression would then take a form where K is the empirical displacement factor. To measure the dilution, the amount of water used by the brown stock washing system which joined the black liquor solids must be determined. The values obtained from this method should not be used as a comparison unless the method of obtaining the data is stated.

One method considers only g.p.m. of water being put on the showers of the last drum. This is usually expressed as g.p.m. wash water used per air dry ton of pulp. This totally disregards the amount of water leaving the system with the clean pulp and not entering the black liquor recovery cycle.

Dilution may be also expressed as the difference between the concentration of black liquor solids produced in the digester and the concentration of the black liquor solids sent to the evaporator. The disadvantage in this is the difference in black liquor constant and a function of the independent variables of the system. With empirical K values estab-

lished for a wide range of pulps, the solids reduction ratios may be used to eliminate the tedious stepwise calculations for any specific washing system.

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EXPERIMENTAL WORK AND RESULTS

Experimental Design I

As stated in the literature survey, it was decided to analyze the efficiency of a laboratory model inclined screen pulp washer for the removal of soluble and insoluble solids. The washer was used at four different angles with a 50-42 mesh screen.

The inclined screen washer, made by the Kalamazoo Tank and Silo Co., is of wooden construction throughout except for fittings, most of which are brass. It consists of a filtrate box with inside dimensions of 36" x 21". The box has a sloping bottom with a depth on the back of 12¼", and on the front 13½". At the front end there is a drain to the outside by means of a spigot. Two bubble levels, arranged in ninety degree position to each other, aid in leveling. The tank is leveled and supported by three casters with solid rubber tires; the two on the back may be adjusted by hand screws for leveling.

At the rear of the washer is an upright frame assembly with a hand screw elevating mechanism. Placed in a cradle in the top of the assembly is a stainless steel pan holding the stock before it passes over the wire. Attached at this point is the upper end of the wire, which is 24 3/4" long and 17 7/8" wide. The lower end of the wire frame rests on horizontal slides installed along the inside of the tank slightly below the top. Here also rests the pan which receives the stock after its pass over the wire. Both pans are identical in

dimensions and design.

The lower end of the wire and the receiving pan slide back and forth as the angle of the screen is changed by raising or lowering the elevating mechanism, to which the upper end of the wire is attached. On the elevating assembly is an indicator from which the angle of the wire from the horizontal may be read directly.

Experimental Work I

The stock formula used was 40 per cent colored ledger, 40 per cent Life magazine stock, and 20 per cent tabulation cards. This mixture was deinked with four per cent caustic soda at 180 F. and five per cent consistency for 45 minutes.

The consistency at the start of each run on the wire was one per cent, and the quantity eight liters. Each run consisted of four passes over the wire all at a temperature of 20 plus or minus 2 C. Runs were made at 49, 45, 38 and 33 degree angles.

The stock was placed in the upper pan which was then tipped so that the stock would flow at a realistic rate over the wire. The suspension that passed through the wire was drained from the tank, measured and a liter sample taken. This sample was then filtered through analytical paper on a Buechner funnel to determine the amount of suspended solids removed. After weighing, the solids were ashed to determine the quantity of volatile and mineral matter.

The filtrate from the Buechner funnel was evaporated

in glass beakers and finally in tared porcelain casserols. The amount of dissolved solids was thus obtained and corrected for a typical low solids content analysis of Kalamazoo city water.

The dissolved solids obtained above were ashed at 700-800 C, and the weight of ash was obtained and corrected for the mineral portion of a typical low solids content analysis of Kalamazoo city water.

The results obtained from the procedure above were converted to pounds per ton of oven dry deinked waste paper and may be seen in table II.

Discussion of Results I

The experimental work performed above and the results presented in table II indicate that there is no significant difference in the volume passes through the wire or solids removed for each of the four angles. The quantity of suspended and dissolved solids passing through the wire was, as expected, highest for the first pass and decreased progressively with each further pass.

It was found that the amount of solids removed per unit folume at all angles was about the same, and that any difference in total solids removed was dependent upon the volume passing through the wire. The total volume passed through the wire fell within a narrow range and the small differences observed indicated no definite pattern.

Table II

Quantities of Solids in Effluent From Washer

Identification		Suspended Solids lbs/Ton	Suspended Solids Ash lbs Per Ton		Dissolved Solids lbs/Ton	Dissolved Solids Correct lbs/Ton	Dissolved Solids Ash lbs Per Ton	Dissolved Solids Correct Ash/Ton
45° Angle								
R 1 P 1		285	155		158.7	117.0	57.7	34.5
R 1 P 2		147	64		78.0	32.2	41.2	15.7
R 1 P 3		56	17		50.2	3.4	32.6	6.7
R 1 P 4		49	12		48.3	1.3	30.3	4.2
	Total	537	248		335.2	153.9	161.8	71.1
38° Angle								
R 2 P 1		273.5	158.2		138.0	112.4	46.7	24.1
R 2 P 2		137.0	60.5		72.2	29.2	34.9	11.0
R 2 P 3		73.5	25.8		53.7	7.9	32.5	7.1
R 2 P 4		40.4	10.1		59.6	1.7	27.2	3.9
	Total	524.4	254.6		323.5	151.2	141.3	46.1
33° Angle								
R 3 P 1		263.2	152.0		156.9	116.7	94.7	68.3
R 3 P 2		126.5	54.7		73.4	31.4	51.6	28.3
R 3 P 3		86.0	24.0		62.5	23.4	14.9	-----
R 3 P 4		48.1	12.1		45.2	2.7	27.8	4.2
	Total	522.8	242.8		338.0	174.2	189.0	----
49° Angle								
R 4 P 1		311.4	174.7		161.5	119.4	87.4	64.1
R 4 P 2		115.8	46.6		60.9	17.4	37.6	13.5
R 4 P 3		85.9	27.7		56.0	12.5	34.3	10.2
R 4 P 4		58.3	11.4		44.9	1.9	27.7	3.8
	Total	571.4	260.4		323.3	151.2	187.0	91.6

1. Pounds per ton denotes pounds of solids per ton of oven dry deinked waste paper.

2. Correct figures for dissolved solids denote values corrected for typical low solids content Kalamazoo city water.

Experimental Design and Work II

Since the observations in experimental part I failed to produce significant results, it was decided to determine rates of flow through the wire at 49, 44, 39 and 34 degrees, with time as a variable. These angles were chosen as they almost covered the total range of the machine and there was a difference of five degrees between each one.

The stock was prepared and washed as in Experiment I, and the volume passed through the wire, and the time for each pass recorded. From this data a rate of flow for each pass was calculated and may be seen in Table III.

Discussion of Results II

The data presented in table III indicated that at three out of four angles the rate of flow was the greatest at the first pass. It was thought that this might be caused by the soaps, produced during deinking, acting as wetting agents. According to this hypothesis, most of the soap should be washed out on the first pass, and the rate of flow in succeeding passes should be less than during the first pass. This seemed to be in accord with the results obtained.

Experimental Design and Work III

The results obtained in Experiment II looked promising and it was decided to investigate further. The procedure was repeated as in Experiment II at 39 and 44 degrees; but in addition, eight grams of Nacconol, an anionic wetting agent, were added to the suspension before each pass. If the addition

of an excess of a soap-like substance before each pass would equalize the rates of flow, the hypothesis deduced from the results obtained in Experiment II could be considered valid. The results obtained are presented in Table IV.

Discussion of Results III

The data obtained and presented in Table IV indicated that the hypothesis formed in Discussion of Results, Experiment II, was not correct and another approach had to be made to the problem.

Experimental Design and Work IV

In order to make sure that the results obtained in operating the inclined screen washer were reproducible, the procedure in Experimental Design and Work II, were repeated. The results obtained are shown in Table V.

Discussion of Results IV

As seen from Table V the rate of flow values could not be reproduced. The reason for lack of reproducability was determined. The variability was caused by the changing degree of contact between the wire and the wooden supports under the wire. Suggestions for improved design of the washer were offered.

CONCLUSIONS

The results of this thesis indicate that the amount of suspended and dissolved solids removed from deinked stock on an inclined screen washer was dependent upon the amount of

Table III

Determination of Rates of Flow

in Milliliters / Second

Experimental Work II

Angle	49	44	39	34
Pass 1	116.4	202.6	111.1	33.3
Pass 2	78.4	86.3	82.9	27.6
Pass 3	89.6	86.9	74.2	33.4
Pass 4	90.8	151.2	67.1	39.4

Table IV

Determination of Rates of Flow

in Milliliters / Second

With Eight Grams of Nacconol

Added Before Each Pass

Angle	39	44
Pass 1	41.7	55.9
Pass 2	34.9	93.2
Pass 3	44.5	100.5
Pass 4	45.8	86.0

Experimental Work III

Table V

Determination of Rates of Flow

in Milliliters / Second

Experimental Work IV

Angle	49	44	39	34
Pass 1	132.8	79.0	150.6	158.2
Pass 2	162.8	106.1	164.1	168.4
Pass 3	160.0	118.1	174.6	113.8
Pass 4	138.5	138.1	195.6	198.3

water removed from the suspension. Under the conditions of the experiment, the angle of the screen had no effect upon the amount of solids, per unit volume, contained in the filtrate. Hence, the extent of washing was dependent upon the quantity of water removed and efficiency upon the rate of flow.

It was found that the rate of flow of water through the wire was influenced significantly by the extent of contact between the wire itself and the wooden wedges over which it was stretched. Therefore, to obtain optimum results, there must be contact at all times across the width of the wire. This condition would cause the water to pass through the wire and be deflected into the tank below rather than to follow the wire over its total length and to drain into the receiving pan.

SUGGESTION FOR IMPROVEMENT OF WASHER

During the operation of the washer it became obvious that several improvements could be made in its design. These would facilitate ease of operation, make results more reproducible and simplify maintenance of the instrument. Since the rate of flow through the wire is affected by the contact between the wire and its deflectors, it is recommended to develop a mechanism for keeping the wire stretched. In the future the bottom of the wire should be attached to a bronze bar which would be adjustable by means of wing nuts and screws attached to the frame.

Other suggestions are; avoiding the use of dissimilar metals and thereby preventing corrosion, fastening of the

fillets along both sides of the screen with bronze screws instead of tacks, installing of corrosion resistant leveling devices on the casters to prevent them from binding, and using resin impregnated plywood as much as possible to avoid swelling.

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