from one-half to three-quarters of an hour longer in the gradually cooling bath. It is then wrung evenly, and dried without washing.

The acid dyestuffs are often used in the coloring of paper (vegetable fiber).

184. Dyeing of Woolen and Worsted Cloth Containing Cotton, with Acid Colors. Many two-color effects may be pro-

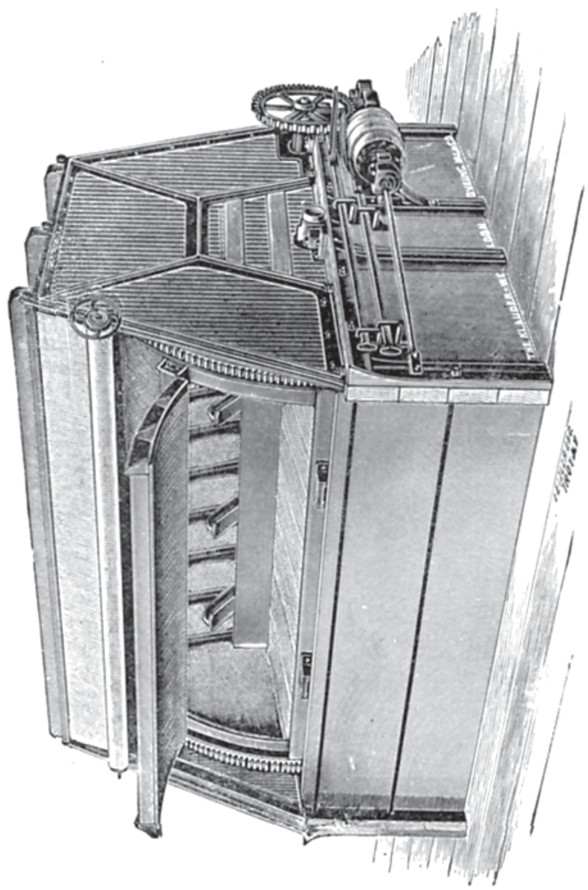


Fig. 60. Klauder-Weldon Dyeing Machine for Loose Stock.

duced upon woolen or worsted cloth containing cotton by the proper application of acid dyestuffs. Thus, if worsted cloth containing a white cotton thread is dyed with certain acid blacks, the cotton thread will not even be stained, whereas the wool will be dyed black. By working this same dyed cloth in a dye bath containing a direct cotton pink or red, the white cotton thread would be dyed pink or red, whereas the black would not be materially affected. Two-color effects, known as *shot effects* are thus produced, and the process is sometimes known as *cross dyeing*.

185. General Properties of the Acid Colors. The number of acid dyestuffs is so great and their properties so varied, that it is difficult to assign definite properties that will apply to all.

They are readily taken up by wool and silk in an acid bath, but for cotton and linen they have no affinity. Jute apparently has some direct affinity for certain acid dyestuffs.

Most of the acid colors are easily soluble in water, and dye the fiber evenly, and the dyestuff is as a rule entirely extracted or exhausted from the dye bath.

The acid colors include some very fast, and, at the same time, some very fugitive colors. Between these limits they include colors of all degrees of fastness.

186. List of Some of the Important Acid Colors:

REDS.

Acid Eosine.
Acid Magenta.
Anthracine Red.
Azo Bordeaux.
Azo Cardinal.
Azo Carmine.
Azo Coccine.
Azo Cochineal.
Azo Fuchsine.
Azo Eosine.
Bordeaux B.
Brilliant Bordeaux.
Brilliant Croceine.
Brilliant Cochineal.
Brilliant Ponceau.
The Chromotropes.
The Cloth Reds.
The Fast Reds.
Palatine Red.
The Ponceaus.
Scarlets G. R. and S.
Sorbine Red.
Wool Scarlet.

ORANGE.

Aniline Orange.
Aurantia.
Crocein Orange.
Milling Orange.
Orange I, II, III, etc.

BLUES.

Alizarine Blue S. A. P.
The Alkali Blues.
The Nicholson Blues.
Azo Acid Blue.
Basle Blue.
Bavarian Blue.
Coomassie Navy Blue.
Fast Navy Blue.
Fast Wool Blue.
Milling Blue.
Naphthalene Blue.
New Victoria Blue.
Patent Blue.
Pure Blue.
Silk Blue.
Soluble Blue.
Water Blue.
Wool Blue.

VIOLETS.

Acid Violet.
Alkali Violet.
Azo Acid Violet.
Formyl Violet.
Guinea Violet.
Lanacyl Violet.
Victoria Violet.
Wool Violet.

YELLOWS.

Acid Yellow.
Alkali Yellow.
Chrysoine.
Curcumeine.
Fast Yellow.
Indian Yellow.
Metanil Yellow.
Milling Yellow.
Naphthol Yellow
New Yellow.
Picric Acid.
Tartrazine.
Tropaeoline.
Uranine.

GREENS.

Acid Green.
Alkali Green.
Fast Green.
Guinea Green.
Milling Green.
Naphthalene Green.
Neptune Green.
New Acid Green.
Patent Green.
Wool Green.

DIRECT COTTON COLORS.

187. General Consideration. Great difficulty was at first experienced in the production of dyestuffs that would color cotton directly. The *basic*, *acid*, and *phthalic anhydride* colors all dyed wool and silk directly, but they had little if any direct affinity for

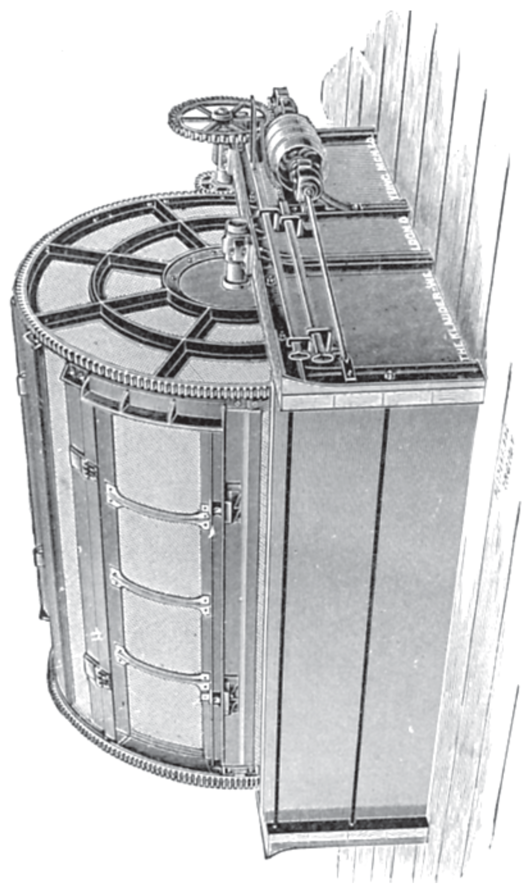


Fig. 61. Klauder-Weldon Dyeing Machine. Top Removed to Show Cylinder.

cotton, and even when mordants were used the acid colors could not be satisfactorily applied to that fiber. The production of a group of dyestuffs that would color cotton as easily as the acid colors dye wool, was therefore, the goal towards which color chemists were striving, and in 1884, Böttiger, a German chemist, discovered *Congo Red*, the first of the so-called *Direct Cotton*

Colors. The discovery of many others soon followed, and at the present time the direct cotton colors are more numerous than any other class, and are capable of producing nearly every color; although up to the present time no direct cotton blues or greens have been discovered, that are as brilliant as the basic blues and greens.

188. Application to Cotton. Cotton material may be readily dyed in a water solution of any direct cotton color, without any further addition to the dye bath. This method, however, is seldom if ever used practically, for it has been found that the addition of certain assisting substances such as sodium chloride (common salt), sodium sulphate (Glauber's salt), and sodium carbonate, brings about a far better extraction of the coloring matter from the dye bath, and more even dyeings.

The four dyeing methods which follow are most frequently used for cotton dyeing, but these are sometimes modified to suit special conditions.

FIRST METHOD.

This method may be considered the one of widest application and may be used with the majority of cotton colors and for nearly all shades. It consists in dyeing with soda ash and Glauber's salt, or soda ash and common salt.

Prepare the dye bath with:

	DARK SHADES.	MEDIUM SHADES.	LIGHT SHADES.
Direct Cotton Color.	3 % or more.	1 to 3 %.	1 % or less.
Glauber's Salt (Crystals).	20 to 30 %.	10 to 20 %.	5 to 10 %.
Soda Ash.	5%.	2 %.	1 %.

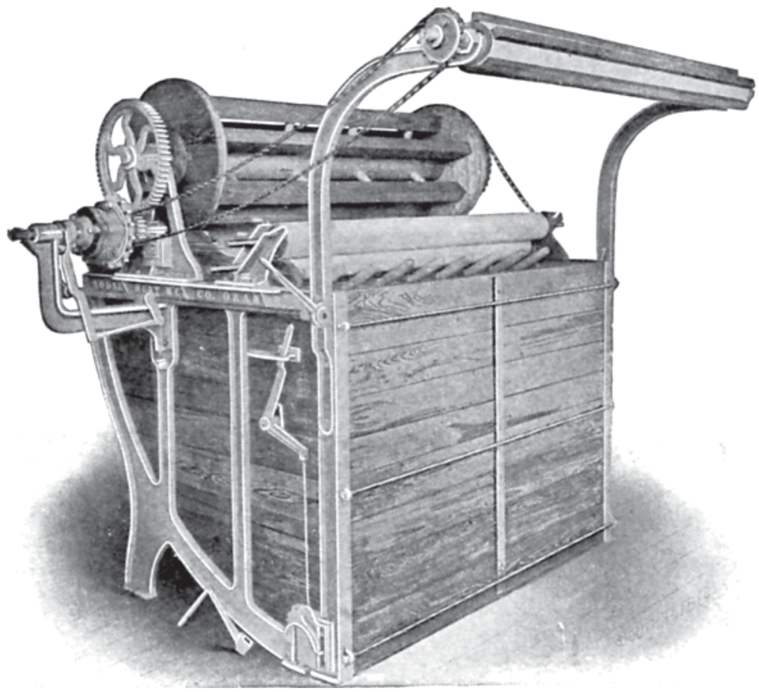
For dark shades enter the material into the dye bath at a temperature of from 120° to 170° F, and for light shades from 100° to 120° F. Bring the dye bath to a boil, and continue the dyeing at a boiling temperature for one hour. The material is then taken from the dye bath, rinsed once or twice in cold water to remove excess of salt, and then dried.

SECOND METHOD.

Dyeing with Glauber's salt or common salt, with no other addition.

Prepare the dye bath with:

	DARK SHADES.	LIGHT SHADES.
Direct Cotton Color.	3 % or more.	Less than 3 %.
Glauber's Salt (Crystals) or Common Salt.	20 to 30 %.	10 to 15 %.



IMPROVED DYEING MACHINE FOR CLOTH AND KNIT GOODS IN THE PIECE

Rodney Hunt Machine Co.

This method is used principally for dyestuffs which are extracted from the dye bath slowly, and for the production of deep shades. If the water used is calcareous a little soda ash (½ % of weight of goods usually enough) should be added. Dyeing directions are the same as for the first method.

THIRD METHOD.

This method should be used where slow dyeing is necessary, with goods that do not penetrate easily, and in the dyeing of delicate tints and compound shades, that are not easily matched.

Prepare the dye bath as follows:

	LIGHT SHADES AND TINTS.	MEDIUM.	DARK.
Direct Cotton Color	1 % or less	1 to 3 %	3 % or more
Common Salt	2 %	5 %	15 %
Soap	2 %	3 %	5 %

Enter the material at a temperature of 100° F or lower, into the dye bath containing the dyestuff and soap, and after working ¼-hour, add the proper quantity of common salt. Bring dye bath to a boil, and dye at a boil for one hour. Calcareous water should be corrected as in the second method before adding the soap.

FOURTH METHOD.

This method is the same as the third, except that sodium phosphate is used instead of common salt.

General Notes. When especially deep shades are desired it often is advisable to boil for ½-hour and then work in the gradually cooling bath for ½ to 1 hour, for by doing this the dyestuff is utilized to its fullest extent.

Some dyestuffs have been found to dye as well or better when entered into the boiling dye bath instead of at a lower temperature.

In some cases where a boiling dye bath is not desirable, the dyeing may be done at a lower temperature (160° to 180° F.), but this as a rule is not economical as regards the quantity of dyestuff used.

With colors that are very fugitive to washing, the rinsing after dyeing is sometimes dispensed with, but dyeings finished in this way will not stand even the mildest washing without running.

Notes on Dissolving Dyestuffs. It is far more convenient as well as safer to keep dyestuffs that are constantly used, in solution rather than in the dry powder state. In many works it is customary to keep large stock solutions on hand, generally so much color to the gallon, but for laboratory work the metric system is used, and a certain number of grams dissolved per litre. By using a certain volume of these solutions an exact weight of dyestuff may be had without the necessity of making a weighing before each dyeing.

It is essential that all the dyestuff be *completely dissolved* before its addition to the dye bath, for solid particles of the undissolved dyestuffs coming in contact with the goods, form spots which are removable with great difficulty, and sometimes not at all. For this reason it is well to strain the dyestuff solution through fine cotton cloth or flannel before adding it to the dye bath.

In the best regulated dye-houses no dyestuffs in the dry or powdered form are allowed in the dye-house proper, but are dissolved in a separate room. Much weighing is thus obviated, and the specks and unevenness upon the dyed goods, due either to the addition of the dry powder to the dye bath, or from small particles of the same settling from the air upon damp goods, is prevented.

Proportion of Water Used in Dye Stuffs. The degree of concentration of the dye bath is an important factor in the dyeing of cotton with the direct cotton colors, for the more concentrated the dye bath the more easily the coloring matter is absorbed by the material, and the more thoroughly extracted from the dye bath. The only advantage of using a dilute bath is in the production of light shades and tints. In general, the quantity of water added to the dye bath should be from 15 to 25 times the weight of material being dyed.

After Treatment with Metallic Salts. Cotton material dyed with certain of the direct cotton colors is rendered much faster to light and in many cases somewhat faster to washing by an after treatment with some metallic salt.

The after treating agent most frequently used is *copper sulphate* (*blue vitriol*), either alone or with *potassium bichromate*. The combination of the two seems to be most likely to increase the fastness to washing.

This after treatment has the disadvantage of dulling the original shade, but with some experience the dyer can usually satisfactorily allow for this change.

When copper sulphate and potassium bichromate are used the quantities are as follows for 100 lbs. of dye material, depending upon the depth of the shade.

1 to 2 lbs. Bichromate of Potash.
1 to 2 lbs. Copper Sulphate.
1 to 2 lbs. Acetic Acid.

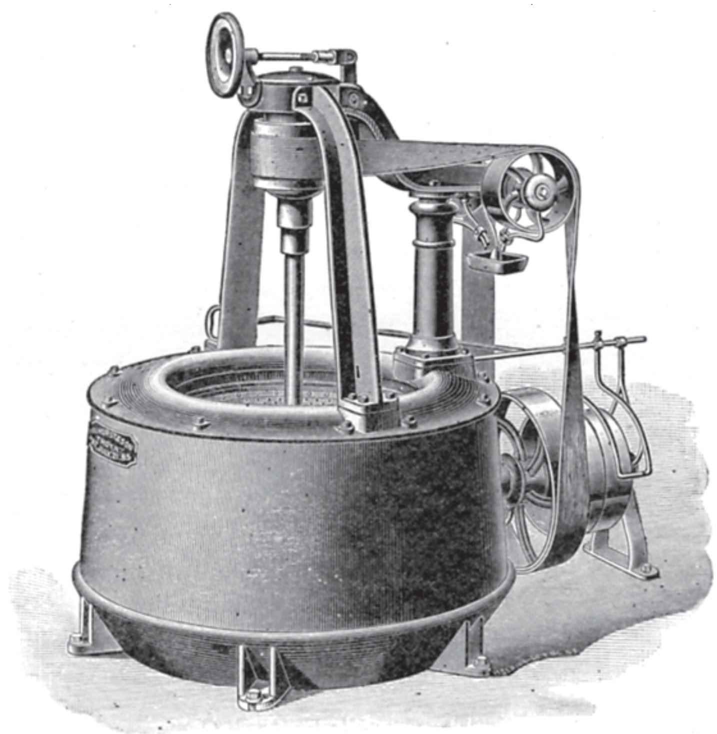


Fig. 62. Tolhurst's Hydro-Extractor.

The after treatment is carried on in a boiling bath for about ½-hour.

The bichromate of potash is often omitted when fastness to washing is of less importance than fastness of light.

Other copper and chromium salts, and salts of iron, aluminium, and nickel, are occasionally used.

Coupling or Diazotising and Developing. Cotton material dyed with direct cotton colors, particularly blacks, blues, and browns, may sometimes (depending upon their composition) be rendered much faster to washing and greatly increased in intensity by the process known as *coupling or diazotising and developing.*

The process is as follows:

The material which has already been dyed by one of the regular methods (already described), is rinsed in cold water and *diazotized* by working fifteen to twenty minutes in a cold bath made up as follows for 100 lbs., dyed material:

	DARK SHADES.	MEDIUM OR LIGHT SHADES.
Sodium Nitrite,	2½ lbs.	1½ lbs.
Hydrochloric Acid (32° Tw.)	7½ lbs.	5 lbs.

Then rinse in cold water containing a little hydrochloric acid and then *develop* or *couple* by working for ten to fifteen minutes in a cold bath containing the developer (usually ½ to 2 lbs.) dissolved in caustic soda solution. The material is then washed and dried.

NOTE—The developers most frequently used for this purpose are beta naphthol, alpha naphthol and phenylene diamine.

189. Application of Direct Cotton Colors to Wool. Wool may be dyed with nearly all the direct cotton colors in a neutral or weak soap bath, with or without the addition of Glauber's salt or common salt. In many cases the dye bath seems to work the best when slightly acidified with *acetic acid.* If the bath is made too strongly acid the wool absorbs the dyestuff too rapidly and uneven dyeing is likely to result, which unfortunately can not be improved by continued boiling, as is the case with the cotton material.

With material likely to dye unevenly it is best to start with a neutral bath, or with the addition of as little acid as possible, and when the color has been nearly all extracted add a little acid to assist in exhausting the color more completely.

The following is a general method for dyeing wool with direct cotton colors:

For light shades dye with the addition of 10 per cent Glauber's salt, or in case the material has a tendency to dye unevenly add 10 per cent Glauber's salt and 5 per cent ammonium acetate. Enter material at 180°F and dye at a boil for one hour. If the bath does not exhaust sufficiently add 1 to 2 per cent of acetic acid toward the end of the dyeing.

For dark shades, begin the dyeing with the addition of 10 to 20 per cent of Glauber's salt and 1 to 2 per cent of acetic acid. Enter at 180° F. and dye at a boil for one hour. If the dye bath does not exhaust sufficiently add 2 to 3 per cent of acetic acid toward the end of the dyeing.

NOTE—The ammonium acetate may be made by neutralizing ammonia with acetic acid.

After Treatment. In many cases an after treatment of the dyed material with certain metallic salts increases its fastness both to milling, washing, and light. In many cases this after treatment is of great importance.

The after treatment usually consists in adding to the dye bath at the end of the dyeing operation, one of the following:

1 to 4 per cent of Potassium Bichromate.
1 to 3 per cent of Chromium Fluoride.
1 to 5 per cent of Copper Sulphate.

and then continuing the boiling for ½ to 1 hour longer.

This after treatment is sometimes carried out in a separate bath.

190. Application of Direct Cotton Colors to Silk. The direct cotton colors are applied to silk in much the same manner as to wool. If boiled off liquor can be obtained, its use is advantageous.

The dye bath is best made up with

Dyestuff, necessary amount	(1 to 5 per cent).
Boiled-off Liquor	½ dye bath.
Glauber's salt	5 to 10 per cent.
Acetic Acid	1 to 3 per cent.

Enter at 140° F., raise very slowly to a boil, and dye at a boiling temperature.

Care must be taken not to make the bath too acid nor to commence the dyeing at too high a temperature, as these conditions cause too rapid absorption of the dyestuff, and consequently the production of uneven dyeings.

191. Application of Direct Cotton Colors to Cotton and Wool (Union Material.) The direct cotton colors having a direct affinity for both cotton and wool are extensively used in dyeing material composed of these fibres and commonly known as *union goods.*

By proper choice of dyestuffs, and regulation of the process such material may be dyed evenly, and almost any color, in one bath.

192. Properties of the Direct Cotton Colors. The direct cotton colors vary greatly in fastness. In general they are not extremely fast to light or washing, and some, particularly the reds, are very sensitive to acids. A few, however, possess very good fastness, which is often increased by an after treatment with metallic salts, or by the diazotising and developing process.

The property known as "*bleeding*" is one of the valuable, as well as one of the detrimental characteristics of the direct cotton colors.

This property is well illustrated by the following experiment: Take a beaker of water and introduce into it a skein of yarn dyed with a direct cotton color and a skein of un-dyed yarn. Boil the two for a hour, when it will be found, in many cases, difficult to distinguish one skein from the other. The color has run or "*bled*" from the dyed skein and been taken up by the un-dyed.

This property is valuable since it tends to produce very level dyeings, and also to correct unevenness. On the other hand it is detrimental as it prevents the use of the direct cotton colors for coloring of ginghams and in calico printing.

The direct cotton colors are much faster to washing when dyed upon wool than when on cotton.

The direct cotton colors are, as a rule, readily soluble in water.

193. List of Important Direct Cotton Colors. Under this head it will be unnecessary to give a list of the several hundred direct cotton colors, for the method adopted in naming them is more or less uniform.

The Casella Color Company, who are among the leaders in the manufacture of this class of colors, designate them as *Diamine* Colors, *e.g.*, *diamine red*, *blue*, *green*, *etc.*

The Farbenfabriken Co. designate them as *benzo* and *chloramine* colors.

The Meister, Lucius, and Brüning Co. (H. A. Metz) designate them as the *dianil* colors.

The Badische Aniline and Soda Fabrik (Kuttroff and Pickhardt) designate them as *pyramine* and *oxamine* colors.

The Berlin Aniline Works designate them as *Congo*, *Columbia*, and *Chicago* colors.

American Dyewood Co., as *Tetrazo* colors.

Levenstein and Co. (Thos. Leyland and Co.) as *Dianol* colors.

The terms direct and cotton, as direct blue, direct green, cotton blue, etc., are very extensively used.

THE SULPHUR OR SULPHIDE COLORS.

194. General Consideration. It was discovered as early as 1873, that by fusing sodium sulphide with sawdust, and extracting the fused mass with water, a dark brown coloring matter could be obtained which dyed cotton directly a brownish color. Further experimenting along this line led to the manufacture of a marketable coloring matter designated as *Cachou de Laval*, which was the first of the so-called *Sulphur Colors.*

Cachou de Laval was extensively used for many years after its discovery, for it could be applied to cotton easily, and the brown-

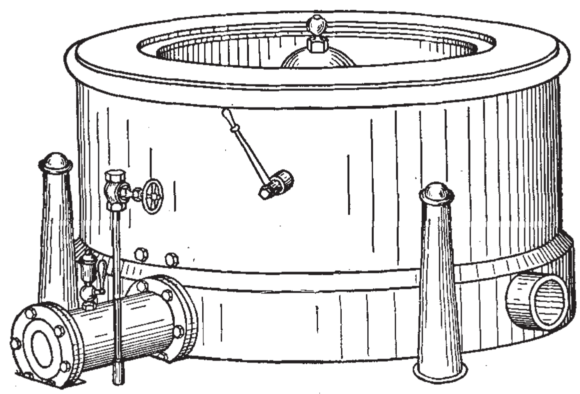


Fig. 63. Hydro-Extractor Underneath Driven.

ish shades which it produced possessed excellent fastness to light and washing. The process by which it is applied is somewhat different from that used for the more recent sulphur colors. It is as follows:

The coloring matter is dissolved in boiling water, and when solution is complete, sodium chloride, sulphate or bisulphate is added to the dye bath. The dyeing, which is done at just below a boiling temperature for from one-half to one hour, is followed by an after treatment at 180° F., in a bath containing one of the following reagents:

Sulphuric Acid, 2 to 3 ounces per gallon.
Hydrochloric Acid, 5 to 7 ounces per gallon.
Potassium Bichromate, ¼ ounce per gallon.
Copper Sulphate, ½ to ¾ ounces per gallon.

The shades produced vary somewhat with the after-treating agent used, mineral acids giving the yellowish shades.

Strange to say, twenty years elapsed before the second sulphur color made its appearance; for it was not until 1893 that Vidal produced the color which has since borne his name (Vidal Black). The success of this color caused color chemists and manufacturers to turn their attention to the study of possibilities along this line, and their labors have been rewarded, for we now have sulphur dyestuffs of almost every color except red; no sulphur red having yet been prepared.

The *sulphur* or *sulphide colors*, as they are often called, are in many respects similar to the direct cotton colors; but they differ so entirely in certain other respects that we place them in a group by themselves. In recent years they have become an important factor in cotton dyeing, on account of the fastness of the dyeings they produce, and they are now extensively used for the production of fast blacks, blues, browns, and compound shades upon cotton.

They are called sulphur colors for three reasons: In the first place, sulphur is a constituent of all of the dyestuffs of this class; sulphur and sodium sulphide are largely used in their manufacture; and finally, sodium sulphide is almost without exception a necessary constituent of the dye bath during their application.

195. **Application of the Sulphur Colors.** The sulphur colors are used only for the dyeing of vegetable fibers. The chief reason for this being the fact that they must be applied in an alkaline bath; a condition unfavorable to the dyeing of animal fibers. The application of the sulphur colors may be best discussed under the following heads:

Preparation of Dye Bath.
Dyeing Process.
After Treatment.
Machinery Used.

Preparation of Dye Bath. In general, the sulphur colors are applied in a dye bath made up as follows:

Dyestuff, 1 to 20 per cent, depending upon shade and character of dyestuff used.
Sodium Sulphide, 1 to 4 times the weight of dyestuff used.
Soda Ash, 5 to 10 per cent.
Caustic Soda (when necessary), $\frac{1}{10}$ weight of dyestuff.
Common Salt or Glauber's Salt, 20 to 50 per cent.

Most of the sulphur colors are either insoluble or only slightly soluble in water, but dissolve readily in a solution of *sodium sulphide*. It is, therefore, necessary to dissolve the dyestuff thoroughly in a solution of sodium sulphide before adding it to the dye bath. With some of the sulphur colors it is only necessary to use double their weight of sodium sulphide or even less; but as a rule, three times their weight is better. Where there is a constant agitation of the dye liquor in the presence of air, as is the case in gig dyeing, and many other formsof dyeing machinery, four times their weight is advisable.

The *soda ash* serves to keep the dye bath alkaline, which condition is necessary in order to prevent the decomposition of the sulphur compounds present. Decomposition, with the evolution of large quantities of hydrogen sulphide, readily takes place if the dye bath is in the least degree acid.

Caustic soda is sometimes used with dyestuffs which decompose readily, and this serves to react with the escaping hydrogen sulphide, thus forming sodium sulphide, which remains in the dye bath

The soda ash is commonly dissolved first of all in the dye bath at a boil, and the previously dissolved dyestuff then added.

The *salt* used, whether *common salt* or *Glauber's salt*, is added next, and the bath boiled for a few minutes and any scum removed. *These salts* act as *leveling agents*, and facilitate the exhaustion of the dye bath. As a rule the darker the shade desired, the greater the quantity used.

In special cases, other additions are sometimes made to the dye bath, such as dextrine, glucose, molasses, Turkey-red oil and petroleum.

The *quantity of dye liquor* and its *concentration* depends upon the depth of shade desired and form of apparatus used. In general the proportion may be given as follows:

For raw stock and yarn dyeing in any form of open kettle, twenty to twenty-five parts of liquor to one of material dyed.

For jig dyeing, five parts of liquor to one of material.

With various form of closed apparatus, the amounts vary between these limits.

Process. The material to be dyed is entered at, or just below, the boil. While a few sulphur colors may be dyed to advantage at a boil, it is customary to turn off the steam just after the dyeing commences, and occasionally turn it on during the dyeing in order to prevent the temperature from falling below 195° F. In most cases a continuous boiling is not recommended. With some dyes (Immedial sky blue, for instance) a lower temperature is desirable. The dyeing is usually continued for one hour, but this time may be reduced for light shades.

Although not absolutely necessary, with the majority of the sulphur colors, it is advisable to keep the material below the surface of the dye liquor as much as possible. A continued contact with the air causes a precipitation of the free coloring matter which may result in unevenness and bronzy dyeings.

Immediate wringing and rinsing is essential in most cases for the attainment of the best results, and in general the more thor-

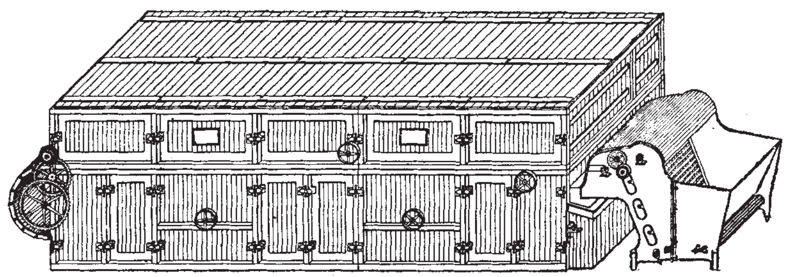


Fig. 64. Kitson Dryer.

oughly and evenly the material is wrung and rinsed after dyeing, the greater will be the fastness to rubbing, and the less the liability of unevenness. It is economical to return the first rinse water, which contains a relatively large amount of dyestuff, to the dye bath or to use it in dissolving the next lot of dyestuff. Should the shade produced be too deep, it may be partially stripped by working for a few minutes in a hot bath of sodium sulphide.

As with the direct cotton colors, the dye bath does not become exhausted, and a standing bath is used whenever possible. As a rule, the proportion of ingredients may be reduced as follows:

	FIRST BATH.	SECOND BATH.	THIRD AND FOLLOWING.
Dyestuff	10%	7½%	5 to 6%
Sodium Sulphide	30%	15%	10 to 12%
Sodium Carbonate	10%	4 to 5%	2 to 3%
Salt	50%	10 to 15%	3 to 5%

In general, the specific gravity of the standing bath should be kept above 10° Tw. for black and very heavy shades.

After Treatment. With many of the sulphur colors, no after treatment is necessary, but with others, an after treatment is beneficial, and in some cases it is necessary. The after treatment consists of one of the following:

(1) A treatment with some Metallic Salt. (Usually of chromium, copper or zinc.)

(2) A treatment with Acetate of Soda, or some Alkali.

(3) Oxidation or Ageing, by exposure to steam and air, or with Sodium Peroxide.

(1) Metallic Salts. A number of sulphur blacks and browns are rendered faster or the shade favorably modified by an after treatment with potassium bichromate copper sulphate or zinc sulphate. This after treatment follows the squeezing and washing of the dyed material and usually consists in treating for one half hour in a fresh bath at 160° F., which contains one of the following combinations:

(*a*) 1 to 3% potassium bichromate,
2 to 3% acetic acid.
(*b*) 1 to 3% copper sulphate,
2 to 3% acetic acid.
(*c*) 1 to 2% potassium bichromate,
1 to 2% copper sulphate,
2 to 3% acetic acid.
(*d*) 3% potassium bichromate,
5% caustic soda, solution 40° Beaumé.
(*e*) 2% chromium flouride,
2% acetic acid.
(*f*) 3 to 5% zinc sulphate,
3 to 5% sodium acetate.

(2) Acetate of Soda and Other Alkaline Reagents. An after treatment with sodium acetate,* or some alkaline reagent such as borax, ammonia, or soda, is advisable, particularly with sulphur blacks, and for union goods containing cotton warps dyed with sulphur colors which have been cross dyed with acid colors. Such treatment prevents, during storage, the deteriorating action of any acid that may remain upon the cotton.

* Note.—The application of acetate of soda for union material dyed with sulphur colors is patented by the Cassella Color Co., but may be used without restriction with their immedial colors.

(3) Oxidation or Ageing. A number of the sulphur blues require an after oxidation to fully develop their color. This is particularly true of such colors as *Immedial blue C and C R*, *Thiogene blue B*, which come from the dye bath a bluish gray color, but which develop into a dark blue when heated for an hour in a mixture of steam and air at a temperature of 180 to 200° F.

The apparatus used for this ageing should be so constructed that the air and steam will be well mixed as they enter, and will then thoroughly penetrate the dyed material. The steam should be admitted at the bottom so that the condensed water may easily run off, for if it comes in contact with the dyed material, spots will result. The hotter and drier the steam, the brighter and the more rapid the development of the color.

These blues may also be developed by the process called smothering, which consists in allowing the dyed material to lie in a pile several hours, or over night during which period the oxygen of the air should bring about the required oxidation. This should be done in a room at a temperature of 140 to 160° F.

When developed by either of the above oxidation processes, the dyed material should not be rinsed, but should be freed from dye liquor by hydro-extracting or squeezing.

This oxidation may also be brought about by the use of *sodium peroxide*, but this method is seldom used, as the steaming and smothering processes are so much cheaper.

Apparatus. The most essential requirement of apparatus used for dyeing sulphur colors is that it must have *no copper* or *brass* parts, as these are rapidly and seriously attacked by the sulphur compounds present in the dye bath, and the copper becomes converted into the black copper sulphide. For this reason the apparatus for dissolving the dyestuff as well as for the dyeing must be constructed of wood, iron or nickel. Lead-lined iron vessels have been found to be very durable.

Various forms of machines are largely used for the dyeing of *loose cotton* or *raw stock* as it is called, both with direct cotton colors and sulphur colors. Of these, the Klauder-Weldon, made by the Klauder-Weldon Co., at Amsterdam, N. Y.; the Delahunty; one made by the Vacuum Dyeing Machine Co., Chattanooga, Tenn.; and the Cohnen Dyeing Machine, A. Klipstein & Co., American Agents, are all worthy of mention.

The Klauder-Weldon Apparatus (Figs. 60 and 61) consists of a perforated drum, containing several compartments (made of iron for sulphur colors) which revolves in the dye bath. This machine is extensively used for all forms of loose cotton dyeing.

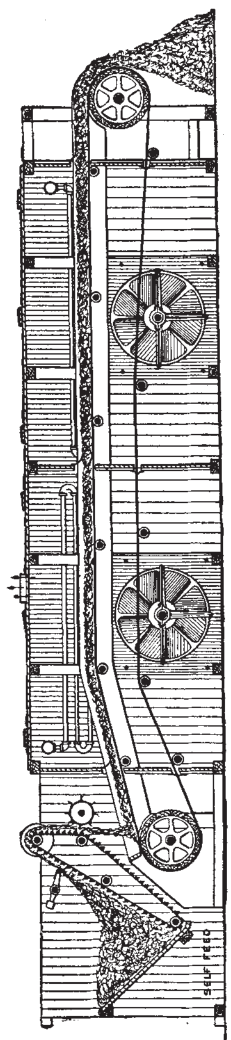


Fig. 65. Sectional Elevation of the Hurricane Dryer.

The Delahunty is similar in principle to the Klauder-Weldon, the chief difference being in the compartmental structure of the drum.

With the raw stock machines already described the washing of the material may be accomplished within the machine before its removal. After washing it is passed through a hydro-extractor, and then through some form of dryer.

A *hydro extractor* is a machine used for rapidly removing the excess of liquor from textile material. It consists of a cylindrical metal container with a perforated outer surface which revolves rapidly within an outer shell. As the container or *basket* revolves, any excess of water held by the material within is violently thrown through the perforations by centrifugal force. Hydro-extractors are of two general types, the overhead driven, illustrated in Fig. 62, and the underneath driven, in Fig. 63.

Dryer. When large quantities of raw stock are dyed, the drying is usually accomplished in some form of a mechanical dryer. The Kitson Dryer, Fig. 64, made by the Kitson Machine Co., Lowell, and the Hurricane Dryer, Fig. 65, made by the Philadelphia Textile

Machinery Co. of Philadelphia, are good examples. They consist of a long continuous apron which carries the damp stock between coils of steam pipes. The whole apparatus is covered with a wooden structure which is well ventilated with fans.

The Vacuum Dyeing Machine (Fig. 66) consists of a circular iron tub T, with a loose perforated bottom upon which the cotton is packed. A perforated top is then placed upon the cotton, and the heavy cover C securely bolted on to the tub T. When in operation, the dye liquor is forced into the tub beneath the perforated

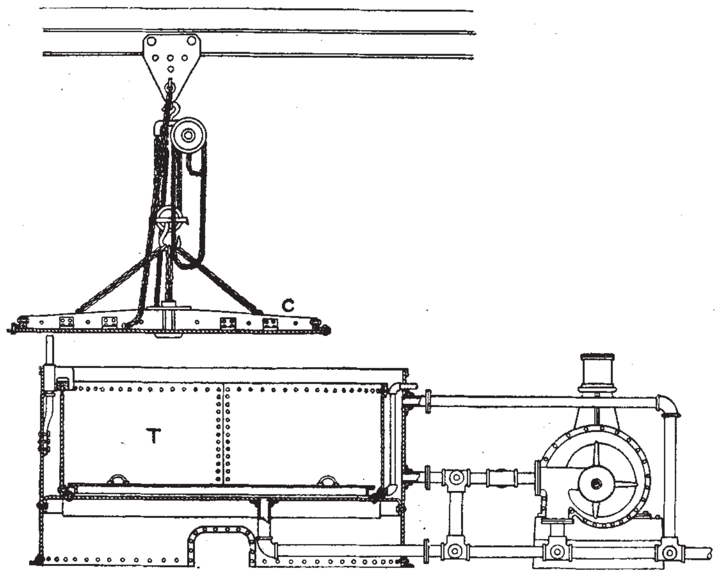


Fig. 66. Vacuum Dyeing Machine.

bottom, from whence it passes up through the cotton and finally returns to the pump through a pipe which leads from the top. In this way a positive circulation of the dye liquor is kept up as long as necessary. When the dyeing is completed the whole batch of compressed cotton (resembling in shape an enormous cheese) can be removed at one time by an overhead hoist. This apparatus gives very even dyeings, and reduces the cost of labor and dyestuff to a minimum.

The Cohnen Centrifugal Dyeing Machine (Fig. 67) is so constructed that the material can be boiled, dyed, washed and hydro-extracted without being removed from the machine. It consists of an upright drum, made up of separate compartments, into which the material is packed under pressure. These compartments all communicate with each other, and the liquor is forced into one, which we will call the first, and passes from the last compartment back to the pump. It is suitable for every kind of fiber that permits of being packed and pressed in boxes.

Inside the plain, unperforated centrifugal drum shown in Fig 68 is an inner chamber *a* into which the dye liquor is forced

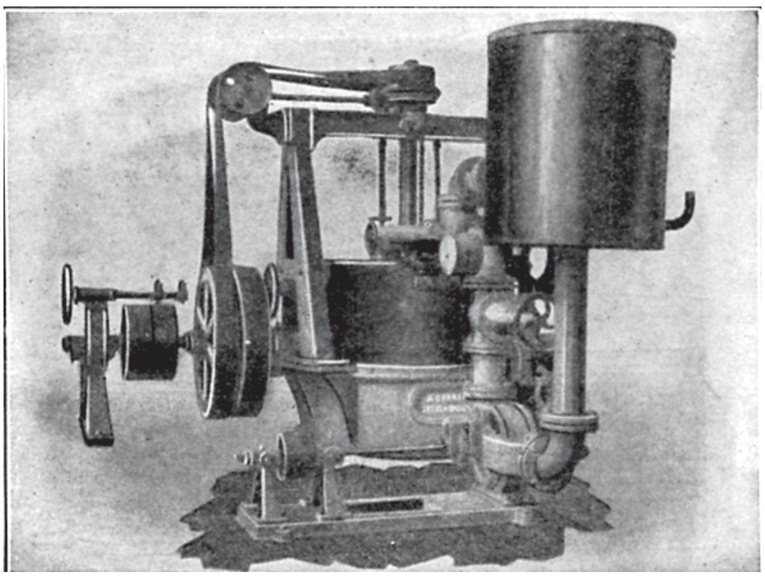
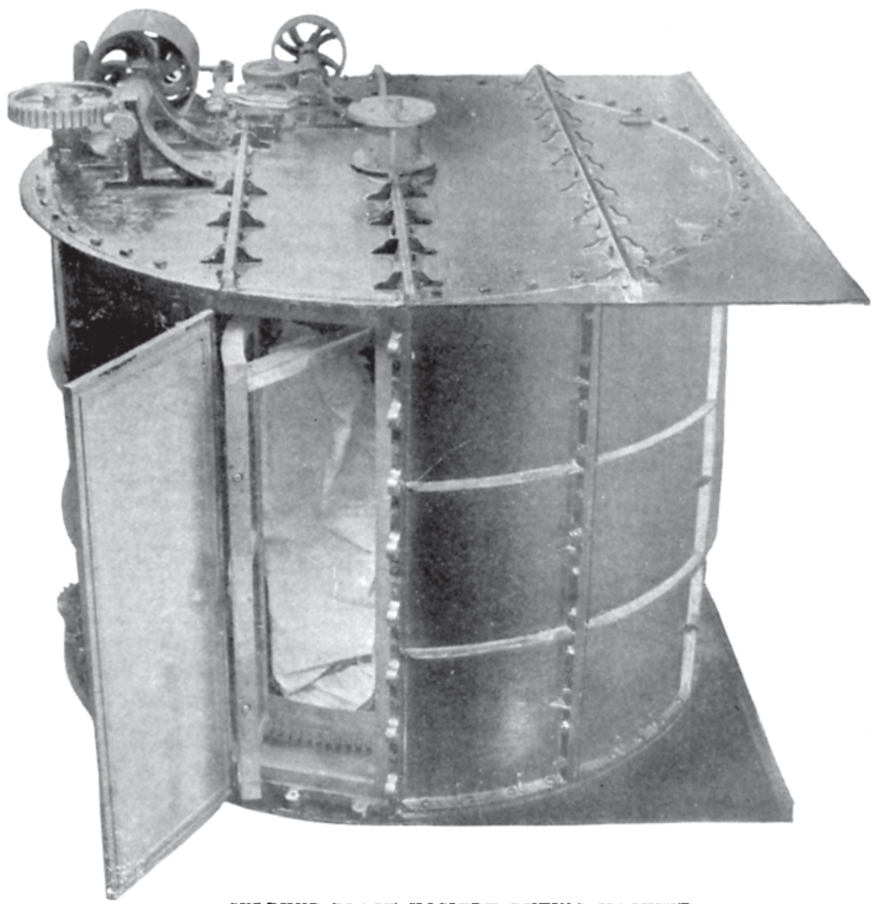


Fig. 67. Cohnen Centrifugal Dyeing Machine.

by means of a centrifugal pump *b* through either the pipe *d* or *g*. This inner chamber is in direct communication with a set of partially perforated boxes *c* into which the material to be dyed is packed. After the liquid has entered by the pipe *d*, it passes from the inner chamber *a* into the boxes, saturates the material, flows into and fills the collecting chamber *f*, then leaves the machine by the pipe *g*, returning thence to the pump to circulate again in the manner described. The conduit pipes *d* and *g* are so constructed that they can be easily disconnected from the drum, in which case



SULPHUR BLACK HOSIERY DYEING MACHINE

Klander-Weldon Dyeing Machine Co,

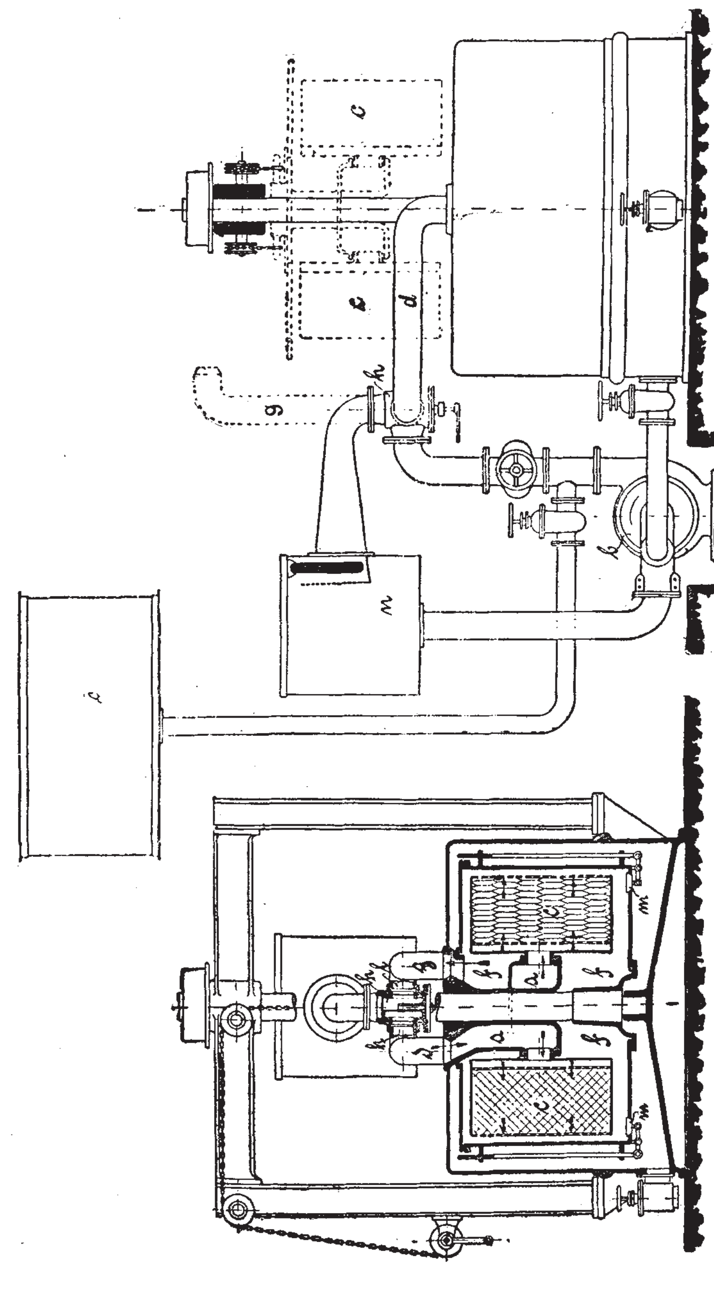


Fig. 68. Sectional View of Cohnen Centrifugal Dyeing Machine

they are swung up into the position indicated by the dotted lines after the dyeing, etc., have been completed, leaving the hydro-extractor free to rotate. These two pipes are connected by a three-way cock *h* which controls the direction of flow of the dye liquor and can be regulated at will — that is to say, the liquid entering first at *k* and leaving at *l* can, by simply turning this cock,

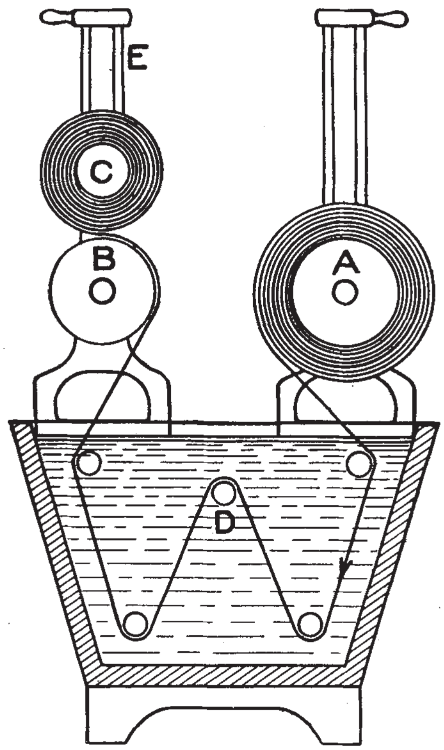


Fig. 69. Sectional View of Jig Dyeing Machine.

have its flow reversed, entering at *l* and leaving at *k*. The liquid then flows through the material from the outside. By this two-fold direction of flow more uniform results in the dyeing are obtained.

The dyeing being completed, the outlet valves *m* are opened and the hydro-extracting carried out in the usual manner.

Jig Dyeing Machines already referred to under the Basic Colors (See 170) are extensively used for dyeing cotton cloth in

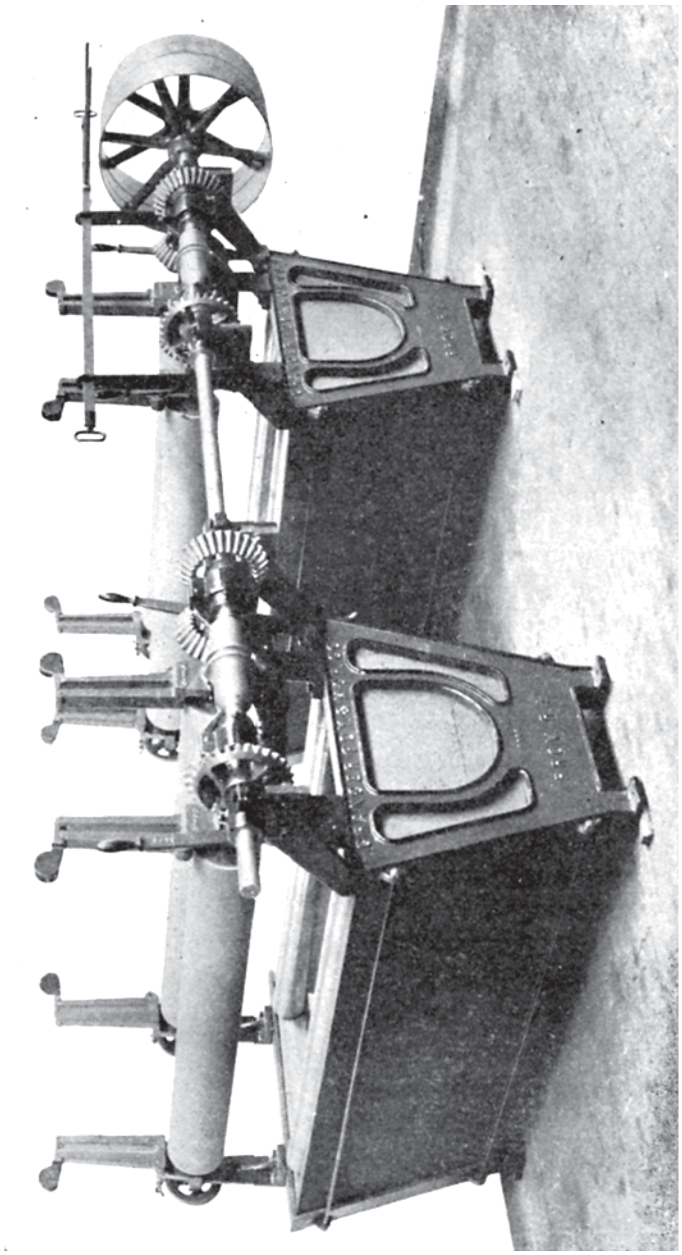


Fig. 70. Jig Dyeing Machines, Textile Finishing Machinery Co.

the open or full width with both the direct cotton and sulphur colors. A jig dyeing machine (See Figs. 69 and 70) consists of a dye vat D, and two fixed rollers A and B, worked by a series of gears. At the beginning of the operation the cloth to be dyed is smoothly wound upon one of the fixed rollers A, and then passed through the dye vat in the direction indicated by the arrowhead onto the second fixed roller B. The cloth is then passed through the dye liquor back on to A, and so on back and forth until the dyeing is completed. At the end of the operation the cloth is wound onto the movable roll C, which sets into the slotted upright E. Ten to fifteen pieces of cloth are sewn together in a continuous piece and passed through the dye liquor at the rate of about one minute per piece. The vat portion D should be as small as possible, and usually holds from thirty-five to forty-five gallons of liquor.

Cotton warps are uusually-dyed in a machine similar to that represented at Fig. 71. It consists of a dye vat provided with a series of rollers within the vat, about which the *chains of warp* (See 118, Part II.) pass several times, and a pair of squeeze rolls, between which the warp leaves the machine.

The single tub, Fig. 72, sometimes called a *Scotch dye tub*, is used largely for the dyeing of basic and direct cotton colors, but for sulphur colors, several tubs (two, three, and sometimes four) are combined together, as in Fig. 71. In a machine of this construction, eight or ten chains pass through, parallel to each other. Similar machines are used for washing the warp, and oftentimes the last compartment is used as a wash box. In this latter case, the warp goes directly to the drying cans (See Fig. 51, Part II.) upon leaving the apparatus. For sulphur colors the upper series of rolls should be kept below the surface of the liquor, as in Fig. 71.

196. Properties of the Sulphur Colors. The most valuable property of the sulphur colors is their fastness to light, washing and acids. Their fastness to chlorine and bleaching, however, is in most cases not good.

Nearly all the sulphur colors are insoluble in water, but dissolve readily in a solution of sodium sulphide, and as already explained, copper vessels must not be used for their solution.

Most of the sulphur colors contain more or less alkaline sulphide, and for this reason are more or less deliquescent. They must, therefore, be stored in closed containers, and in a dry room away from steam.

The shades produced by the sulphur colors are mostly of a dull character, and blacks, browns, dark blues, dark greens, and dull yellows; also various compound shades of these, such as drabs, slates, olive, and greys predominate. Sulphur yellows and greens as a rule do not equal the other sulphur colors in fastness. As yet no bright sulphur reds* have been prepared.

197. List of Principal Sulphur Colors. The list of sulphur colors is not larger, and the following includes the principal ones.

BLACKS.

Immedial Black V, FF, G, N B, N G, N R T, and N F
Sulphur Black T T G, T B, B B, and A.
Thiogene Black N A, N B, T, M, M R, M M, 2 B and 4 B.
Katigene Black T, S W, T G, 2 B, and S W R.
Tetrazo Sulphur Black 2 B, and R.

Thional Black	Buffalo Thiol Black G. B.	Melanogen Black
Vidal Black	Clayton Fast Black	Pyrogene Black
Kryogene Black	Cross Dye Black	St. Denis Black
Auronal Black	Direct Sulpho Black	Sufanil Black
Autogene Black	Eclipse Black	Mercaptol Black

BLUES.

Immedial Blue and C.	Thiogene Dark Blue	Katigene Indigo
Immedial Indone	Tetrazo Sulphur Indigo B.	Melanogen Blue
Immedial Sky Blue	Direct Cross Dye Blue	Katigene Chrome Blue
Sulphur Blue L.	Eclipse Blue	
Thiogene Blue B.	Vidaline Blue	Pyrogene Blue
Katigene Blue B.	Kryogene Blue	Sulphogene Blue

BROWNS.

Immedial Brown	Tetrazo Sulphur Brown	Katigene Brown
Immedial Bronze	Thiogene Brown	Katigene Khaki
Immedial Catechu	Thion Brown	Cachou de Laval S.
Sulphur Brown	Thional Bronze	Thio Catechine
Sulphur Bronze	Thional Brown	Thiogene Khaki
Sulphur Cutch	Vulcan Brown	Vidaline Brown

GREENS.

Immedial Green	Katigene Green	Sulphur Green
Immedial Olive	Katigene Olive	Thion Green
Alizarine Green K. O.	Kryogene Olive	Thional Green
Eclipse Green	Pyrogene Green	Vidaline Green
Eclipse Olive	Pyrogene Olive	

*Note—Thiogene Rubime O, recently introduced by the H. A. Metz Co., is the nearest approach to a sulphur red. It is, however, too much upon the violet to be called a red.

YELLOWS.

Immedial Yellow	Immedial Orange	Tetrazo Sulphur Yellow
Cross Dye Yellow	Kryogene Yellow	Thiogene Orange
Eclipse Phosphine	Katigene Yellow	Thiogene Gold Yellow
Eclipse Yellow	Pyrogene Yellow	

MISCELLANEOUS COLORS.

Cross Dye Drab	Eclipse	Pyrogene Gray
Eclipse Corinth (Reddish Brown)	Immedial Bordeaux	Thiogene Violet
Sulphur Corinth		

As with the direct cotton colors, dyestuff concerns have adopted certain trade names for the sulphur colors, some of which are as follows :

Immedial Colors,	Cassella Color Co.
Katigene Colors,	Farbenfabriken Co.
Sulphur Colors,	Berlin Aniline Works.
Thiogene Colors,	Meister Lucius and Bruning. (H. A. Metz.)
Kryogene Colors,	Badische Anilin & Soda Fabrik. (Kuttroff, Pickhardt & Co.)
Thional Colors,	Levinstein & Co., (Thos. Leyland & Co.)
Eclipse Colors,	Geigy Color Co.
Tetrazo Sulphur Colors,	American Dyewood Co.
Pyrogene Colors,	Klepstein.
Autogene Colors, Vidaline Colors, St. Denis Colors.	Sykes & Street.

THE ARTIFICIAL MORDANT COLORS.

198. General Consideration. Under this head we will include only those artificial coloring matters which cannot be applied without the use of some metallic mordant. The *Natural Mordant Colors* have already been described in Part III (Nos. 144 to 164) and the *Mordant Acid Colors*, sometimes included under this head, will be described later (See No. 204.)

The true metallic mordant colors cannot be permanently fixed upon cotton, wool and silk or in fact upon any textile fiber, except in conjunction with metals.* As a rule the metals are fixed upon the fiber as insoluble oxides or hydroxides (mordants) previous to the application of the dyestuff.

During the dyeing process the mordant dyestuffs, which con-

*The processes of applying mordants and their chemical nature are fully discussed in Part III, Nos. 128 to 132 inclusive.

tain either hydroxyl (–O H) or carboxyl (–C O O H) groups in their composition, react with the mordants in much the same manner as acids react with bases to form salts, the resulting salt-like compounds being insoluble color lakes, which become fixed upon and within the body of the fiber, which is thus permanently colored. During this reaction, which takes place between dyestuff and mordant, the hydrogen atoms of the hydroxyl and carboxyl groups are replaced by the metal of the mordant.

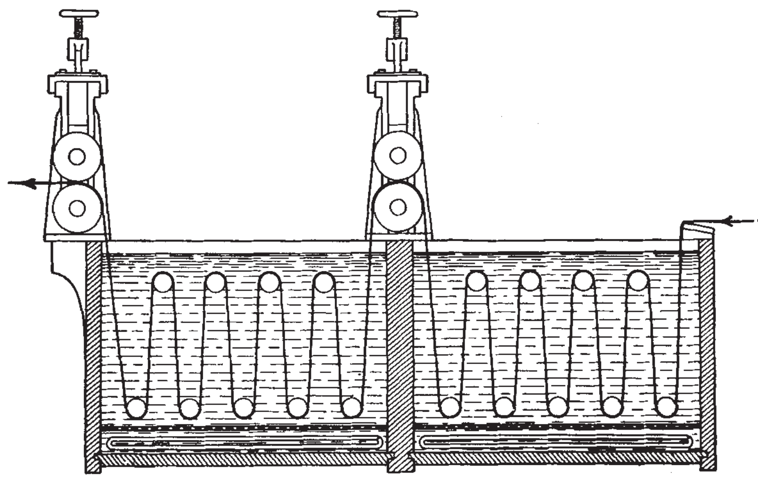


Fig. 71. Dye Tub for Chain Warps.

When classified according to composition there are four classes of Artificial Mordant Colors.

(1) Anthracene Derivatives (the Alizarines.)
(2) Naphthalene. "
(3) Pyrogallol "
(4) Nitroso Coloring Matters.

(1) THE ANTHRACENE DERIVATIVES are by far the most important group of metallic mordant colors. This group includes *alizarine* and its derivatives, and for this reason they are commonly called the alizarine colors.

Alizarine $C_{14} H_6 O_2 (OH)_2$ is produced as follows from anthracene, one of the solid hydrocarbons derived from coal tar.

Anthracene $C_{14} H_{10}$ is oxidized when the following reaction takes place.

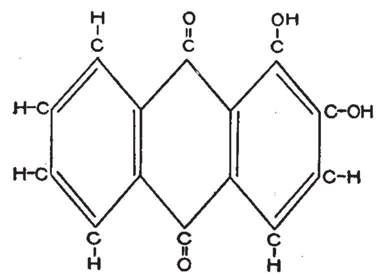
$$C_{14}H_{10} + 3\,O = C_{14}H_8O_2 + H_2O$$

The resulting compound anthraquinone $C_{14}H_8O_2$ is then sulphonated with concentrated sulphuric acid and the resulting sulphonate fused with caustic soda. The equations representing the reactions are as follows:

$$C_{14}H_8O_2 + H_2SO_4 = C_{14}H_7O_2\cdot\ HSO_3 + H_2O$$

$$C_{14}H_7O_2\cdot\ HSO_3 + 2NaOH = C_{14}H_6O_2(OH)_2 + Na_2SO_3 + H_2$$

The following represents the structural formula of alizarine.



Alizarine therefore contains two hydroxyl groups, and is known chemically as dihydroxy anthraquinone. It occurs naturally as the active coloring principle of madder and was first prepared artificially by Graebe and Liebermann in 1868.

Like many of the metallic mordant colors, alizarine is polygenetic * and gives different color lakes with different metals.

Thus alizarine gives

Red	with	Aluminium	Mordants.
Orange Reds	"	Tin	"
Wine Color	"	Chromium	"
Purplish Black	"	Iron	"
Yellowish Brown	"	Copper	"
Reddish Brown	"	Zinc & Nickel	"

Note. Coloring matters are sometimes classified as *monogenetic* and *polygenetic*.

Monogenetic colors are those capable of producing only one color, or at the most only varying hues of the same color, regardless of the manner of application, or the mordants used. Thus auramine always produces a yellow; methylene blue produces a blue and acid ponceau produces a red.

Polygenetic colors are those capable of producing entirely different colors depending upon the mordants used. Alizarine, cochineal and many of the mordant dyestuffs are polygenetic.

Alizarine is a stable compound and although mild oxidizing agents have no action upon it, powerful oxidizing agents like concentrated sulphuric and nitric acids react with it producing a number of valuable derivatives. Thus purpurin, anthrapurpurin, flavopurpurin, and anthracene brown are all trihydroxy anthraquinones.

The Alizarine Bordeauxs are tetra-hydroxy anthraquinones. Alizarine Cyanine R is a penta-hydroxy anthraquinone. In addition to these there are the *nitro sulphonic acid* and *amino derivatives*.

(2) NAPHTHALENE DERIVATIVES. The most important mordant color derived from *Naphthalene* is Alizarine Black S. In structure it bears the same relation to Naphthalene that Alizarine does to Anthracene. For this reason it is sometimes called Naphthazarin. Its formula is

$$C_{10} H_4 O_2 (OH)_2$$

(3) THE PYROGALLOL DERIVATIVES are more or less directly related to pyrogallol (pyrogallic acid) $C_6 H_3 (OH)_3$. They are fewer in number and of less importance than the anthracene derivatives.

(4) THE NITROSO COLORING MATTERS are produced by the action of nitrous acid upon various phenols, and contain the nitroso or (– NO) group.

199. Application of the Mordant Colors to Wool. The mordant colors are largely used in wool dyeing when it is desired to produce very fast colors. The colors produced (except with Alizarine and Alizarine Yellow upon aluminium or tin mordants) are of a dark and subdued character. Blacks, dark blues, dark greens, browns, garnets, dull reds and compound shades of these predominate.

In every case some metallic mordanting principle must be used in conjunction with the dyestuff. The mordant may be applied in three different ways.

I. Previous to the dyeing.

II. At the same time as the dyeing.

III. After the dyestuff has been applied.

The first method is by far the most important, the second being applicable only with some of the natural mordant colors and some alizarine reds and yellows. The third method is seldom if ever used for the true mordant colors, although extensively used with the mordant acid colors.

Chromium mordants are used almost entirely, except for reds, pinks, and bright yellows, aluminium and sometimes tin mordants being used for these. With some of the nitroso colors iron mordants are largely used.

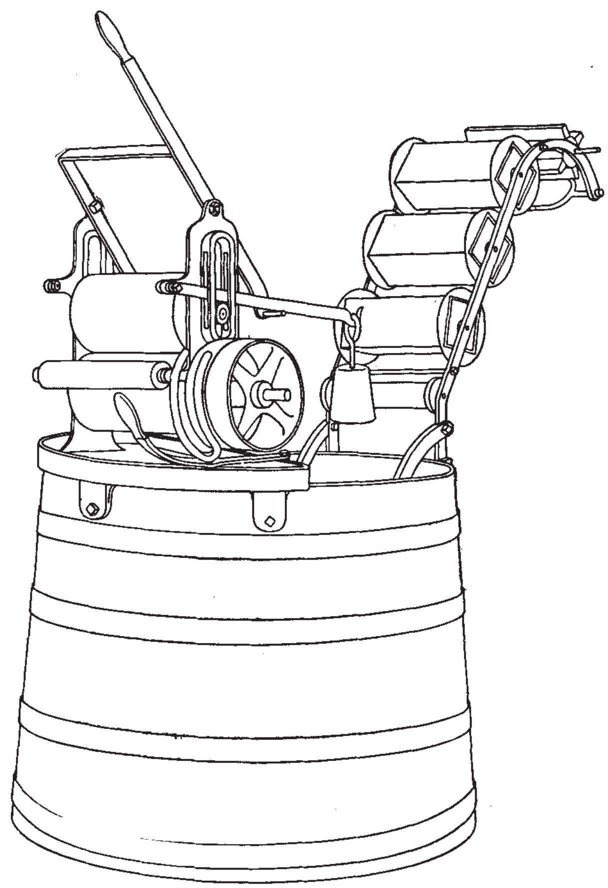


Fig. 72. Scotch Dye Tub.

The whole subject of mordants has been fully discussed, both as to principle and methods of application, and the student is referred at this time to Part III for details. The following general statement will therefore suffice.

Mordanting Process. The wool, which should be well scoured and washed, is mordanted by boiling from one to two hours, depending upon the nature of the material, in a bath containing the mordanting principle,* (usually potassium bichromate 1 to 4%) and some mordanting assistant, † (usually potassium bitartrate or lactic acid $1\frac{1}{2}$ to 3%) during which time there is a gradual dissociation of the mordanting principle and slow deposition of the mordant proper upon the fiber.

Dyeing Process. The chromium mordanted material (wool fiber) is thoroughly washed and then dyed in a fresh bath. When possible the mordanting material is not allowed to dry between the mordanting and dyeing. The dye bath is prepared with:

Mordant Color.	5 to 15% paste color or 1 to 5% dry powder color.
Acetic Acid.	A slight excess above the amount necessary to convert the calcium salts present in the water into calcium acetate.

The material is entered into the dye bath at ordinary temperature. The temperature is slowly raised to the boil, and the dyeing continued at a boil from $1\frac{1}{2}$ to, in some cases, $2\frac{1}{2}$ hours, this long boiling being necessary to bring about the complete reaction of mordant with dyestuff and ensure the thorough fixation of the color lake upon the fiber.

The *acetic acid* is added chiefly to convert alkaline calcium salts present in the water into calcium acetate, as the former react with most of the alizarine colors to form calcium color lakes, the presence of which is detrimental to the best results when chromium mordants are used. A slight excess of acetic acid not only prevents any reaction of the calcium acetate thus formed, with dyestuff, but seems to be beneficial to the formation of the chromium color lakes. For ordinary water 1 lb. of acetic acid (30% acid) per 100 gallons of dye liquor is usually sufficient, but if the hardness exceeds 5°, 3 oz. should be added for each additional degree.

When too great an excess of acetic acid is added at the beginning of the dyeing, the color is absorbed too rapidly, and uneven dyeings are likely to be produced. To prevent such unevenness the *Badische Anilin and Soda Fabrik*, extensive manufacturers of alizarines, recommend the addition of ammonium acetate (with a very slight excess of ammonia) to the dye bath at the beginning

* See No. 128.
† See No. 128-6.

of the dyeing. The slightly alkaline condition of the dye bath increases the solubility of the dyestuff, and prevents the rapid absorption of the color. As the temperature of the dye bath rises and it begins to boil, the excess of ammonia evaporates, the bath gradually becomes acid, and the union of dyestuff with mordant then takes place. Toward the end of the dyeing a slight excess of acetic acid is added to complete the absorption of the dyestuff and the fixation of the color lake.

When dyeing alizarine colors upon aluminum mordants the presence of calcium compounds is not as a rule detrimental, and in fact with alizarine red small amounts are necessary for the production of the best results. If the water is unduly hard, however, a small amount of acetic acid should be added.

The presence of iron compounds in the dye bath is very detrimental to the attainment of good results when dyeing alizarine reds upon aluminum mordants.

200. Application to Cotton. With the exception of alizarine upon an aluminum oil mordant for the production of the so-called "Turkey-reds", the alizarine colors are not extensively used in cotton dyeing, although largely used in cotton printing for the production of very fast colors.

Alizarine-red or Turkey-red. For many centuries cotton was dyed with madder (See No. 154) for the production of the so-called Turkey-reds, which possessed remarkable fastness to light, washing, dilute acids and dilute alkalies. Since the discovery of the method of manufacturing alizarine the artificial product has entirely replaced madder in the production of these reds.

The dyeing process which consists in fixing upon the fiber an alizarine – aluminium – calcium – oil color-lake has been experimented upon ever since the time of the ancients, and for this reason it is not at all strange that so many different processes exist for its application, but since the introduction of artificial alizarine the chemistry of these processes has been more thoroughly studied, with the result that they have been rendered simpler and fully as satisfactory, although as yet there is considerable variation in the detail of the methods used.

In general there are two different methods:

(1) The Emulsion or Old Process.

(2) The Turkey-red Oil or New Process.

The Emulsion process is by far the longer and consists of a great many tiresome operations, but when completed the reds produced possess greater fastness than those produced by the Turkey-red Oil process, although the latter claims greater brilliancy and can be completed in a much shorter time. These processes in outline are as follows.

Emulsion or Old Process

Operation 1. Boiling in 1° Tw. soda ash solution for 6 to 8 hours.

Operation 2. Treatment with rancid olive oil and soda ash solution, and is known as the *first greening*. The material is worked in this so-called *green liquor* at a temperature of 100° C, until thoroughly impregnated, and then dried at a temperature of 140° F.

Operation 3. *Second greening*. Repetition of Operation 2.

Operation 4. *Third greening*. Repetition of Operation 2.

Operation 5. *First white bath*. Consists in working the material in a 2° Tw. soda ash solution until thoroughly impregnated, then wringing and drying in the open air.

Operation 6. *Second white bath*. Repetition of Operation 5.

Operation 7. *Third white bath*. Repetition of Operation 5. The object of these white baths is to remove the excess of oil.

Operation 8. Steeping for twelve hours in a bath of clean water at 150° F., then wringing and drying. Sometimes a small quantity of soda ash is added to this bath.

Operation 9. *Mordanting and Aluming*. Consists in thoroughly working the material and then allowing it to steep for 24 hours in a bath made up with 4 parts of alum to 1 part of soda crystals, and standing at 8° Tw. Sometimes a small amount of stannous chloride (tin crystals) or aluminum acetate (red liquor) is added. After this operation the material is thoroughly washed.

Operation 11. *Dyeing*. This is carried out in a bath made up with

10 to 12 % Alizarine.
3 % Light Sumac Extract.
⅛ % Lime.

The material is entered cold, and worked until thoroughly saturated, when the temperature is raised slowly to a boil and the dyeing continued at a boil until the full shade is developed, which takes at least one hour.

Operation 12. *First Clearing*. Consists in boiling the material four hours with

3 % Soda Crystals.
3 % Soap.

Operation 13. *Second Clearing*. Consists in boiling two hours with

3 % Soap.
½ % Tin Crystals.

After washing and drying the process is completed. The resulting red varies slightly with the brand of alizarine used. This process takes from two to three weeks for completion.

The Turkey-red Oil or New Process.

When it was discovered that by saponifying castor oil with alkali or by sulphonating it with concentrated sulphuric acid, products soluble in water were formed, which could be fixed upon cotton in a single operation, the process of producing Turkey-red became very much simplified.

The Turkey-red oil process is in outline as follows:

Operation 1. *Thorough Bleaching.*

Operation 2. *First Mordanting.* Consists in working the material in a bath of

Aluminium Acetate 9° Tw.
or
Basic Aluminium Sulphate 9° Tw.

until it is thoroughly and evenly penetrated, then squeezing and drying at 120° F. for 24 hours.

Operation 3. *First Oiling.* Consists in working the material until thoroughly penetrated in a bath made up with

1 part Turkey-red Oil
9 parts Water,

and then quickly and thoroughly squeezing, and then drying at a temperature of 140° to 150° F. for 12 hours.

Operation 4. *Second Mordanting* which is carried out the same as the first mordanting (Operation 2).

Operation 5. *Chalking.* Consists in working the dried mordanted material in a bath made up with

½ part Chalk (Calcium Carbonate)
100 parts Water

for ½ hour at a temperature of 85° to 105° F., and then washing in clean water.

Operation 6. *Dyeing.* The dye bath is made up with

6 to 15 % Alizarine Paste

and the necessary amount of water which should contain at least

5 parts Lime per 100,000 of Water.

The damp material is entered cold, and after working 20 minutes the temperature is slowly raised to 140 to 150° F. and the dyeing continued at that temperature for one hour, when it is washed, and then squeezed or hydro-extracted.

Operation 7. *Second Oiling.* This is carried out in the same manner as the first oiling (Operation 3.)

Operation 8. *Steaming.* This consists in steaming for two or three hours at a pressure of from 7 to 15 lbs. and then thoroughly washing.

Operation 9. *Brightening.* This, the last operation, consists in boiling the material for ½ to 1 hour in a soap solution made up with

1 part Soap
200 parts Water.

After the boiling the material is dried and finished.

To shorten the process Operations 7 and 8 are sometimes omitted.

In **Calico printing** the alizarine colors are largely used when it is desired to make very fast prints. They are applied by the process known as *steam printing*, which consists in mixing the dyestuff and mordanting principle together with some thickener, and printing the color paste thus formed upon the cloth in a printing machine. The cloth is then dried and passed through a steam chamber, where the high temperature and moist atmosphere cause a decomposition of the mordanting principle, and the mordant thus liberated reacts with the alizarine color to form a color lake. The cotton cloth should be previously bleached, and then prepared by working in a solution of Turkey-red oil, and then drying. Several recipes for such printing pastes will serve as examples of many others.

(A) 100 lbs. Alizarine Red Printing Color.

15 lbs. Alizarine Paste.
9½ lbs. Acetate of Calcium 15° Tw.
9 lbs. Sulphocyanide of Aluminium 32° Tw.
8½ lbs. Oxalate of Tin 25° Tw.
58 lbs. *Starch Thickener.

(B) 100 lbs. Claret Red Printing Paste.

10 lbs. Alizarine Paste.
4 lbs. Acetate of Calcium 15° Tw.
5 lbs. Acetic Acid 9° Tw. (30%).
9 lbs. Acetate of Chromium 32° Tw.
72 lbs. *Starch Thickener.

(C) 100 lbs. Violet Printing Color.

5 lbs. Alizarine Paste (Blue Shade.)
7½ lbs. Calcium Acetate.
25 lbs. Acetic Acid 9° Tw.
2½ lbs. Acetate of Iron 23° Tw.
60 lbs. *Starch Thickener.

(D) 100 lbs. Alizarine Blue Printing Color.

20 lbs. Alizarine Blue S Paste.
5 lbs. Acetate of Chromium 32° Tw.
75 lbs. *Starch Thickener.

(E) 100 lbs. Alizarine Green Printing Paste.

20 lbs. Alizarine Green S Paste.
5 lbs. Chromium Acetate 32° Tw.
75 lbs. *Starch Thickener.

*Note. The starch thickener referred to in the above recipes is made up as follows:

2 lbs. Wheat Starch.
5 lbs. Gum Tragacanth Paste (60 to 1000 water).
1¼ lbs. Olive Oil.
2 gallons water.

The mixture is stirred while cold, then boiled till a uniform paste is formed, and the mass kept stirred till cold, and finally passed through a fine sieve.

After printing with the above colors, the cloth is well dried and then steamed for one hour at 7½ lbs. pressure, or for two hours without pressure. After steaming the prints are washed and then soaped for ¼ hour at a temperature of about 120° F. With Alizarine red the cloth should be worked several minutes in a chalk bath before soaping.

201. Application to Silk. The mordant colors can be applied to silk, but are seldom used with this fiber, unless fastness to soap and washing are desired. Aluminium mordants are used for reds and bright shades of yellow and orange, iron mordants for blacks, and chromium mordants for other colors.

With *aluminium mordants* the process is as follows:

Prepare the mordanting bath with

175 parts water (Free from iron)
10 parts Alum
1 part Soda Crystals

and allow it to boil until it becomes perfectly clear.

Work the "boiled off" silk in this bath for one-quarter to one-half hour, then allow it to steep (completely under the surface of the liquor) for twelve hours. It is then wrung, or hydro-extracted, and without washing entered into a fixing bath of Silicate of Soda 1° Tw. It is worked in this for fifteen minutes, then thoroughly washed in running water and should then be dyed without drying in a bath made up with:

Dyestuff. Necessary amount to produce shade.
Water and "Boiled Off" liquor in proportion of 5 parts to 1.

In the production of alizarine reds, the dyebath is just neutralized with acetic acid, and, unless the water is very hard, a small amount of calcium acetate should be added. The silk is entered into the dyebath at 80° to 90° F., worked at this temperature for ¼-hour, brought very slowly to a boil and then dyed at a boil for about one hour. It is then washed, soaped at 140° F., and brightened by working in dilute acetic acid.

With *chromium mordants* the process is the same as for aluminium mordants, with the exception that chromium chloride solution 32° Tw. is used in place of alum and soda crystals.

202. Properties of the Mordant Dyestuffs. Most of the mordant dyestuffs are either insoluble or only slightly soluble in water, and are sold in the form of pastes which contain 20% of the coloring matter in an extremely finely-divided condition, and 80% water. A few of them are soluble in water, and are sold as dry powders. These powdered dyestuffs can be readily dissolved in water, except those that are bisulphite compounds, which should be dissolved in cold water, as hot water decomposes them. As a rule, the solubility of the mordant colors increases in alkaline solutions and diminishes in acid solutions.

Note. Great care must be taken when these pastes are removed from their containers, otherwise, one may draw nearly all water and the strength of the paste will increase rapidly as the bottom is reached. For this reason the head of the barrel should be removed, and the contents thoroughly stirred with a wooden stick before each removal of dyestuff.

As a class, the mordant dyestuffs are the fastest colors known, and their fastness to light, washing, soaping, alkalies, acids, perspiration, and in fact, nearly all of the color-destroying agencies, have given them an unquestioned standing, and have led many armies, navies and railroad companies to adopt them for the coloring of their uniforms. They are extensively used in the coloring of the best grades of suitings and overcoat cloths. Their properties are sufficiently alike in most cases to allow of their being used in the same dyebath, and, therefore, in the production of innumerable compound shades.

203. List of Important Mordant Colors. The following is a list of the most important mordant colors:

REDS.

Various brands of Alizarine, Purpurin, Anthra-Purpurin and Flavo-Purpurin, with aluminium mordant for bright reds, and with chromium mordants for dark reds, claret reds, and bordeaux reds.

YELLOWS.

Alizarine Yellows
Anthracene Yellows
Azo Chromine
Galloflavine
Mordant Yellow.

ORANGES.

Alizarine, with tin mordants
Alizarine Orange.

BLUES.

Alizarine Blues
Anthracene Blues
Alizarine Indigo Blue.

BLACKS.

Alizarine Blacks.

BROWNS.

Alizarine Browns
Anthracene Browns
Gambine.

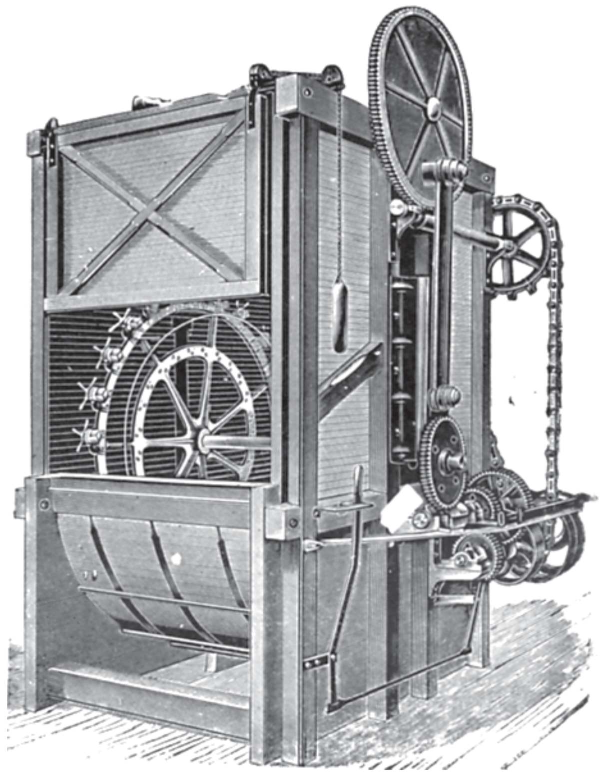
VIOLET.

Alizarine, with iron mordants
Chrome Violet
Alizarine Violet.

GREENS.

Alizarine Green
Alizarine Dark Green.

Note. Unfortunately, there has been such laxity displayed by certain dyestuff manufacturers and dealers in the naming of the mordant



SILK SKEIN DYEING MACHINE, SHOWING DYE-WHEEL IN WORKING POSITION

Klander-Weldon Dyeing Machine Co.

acid colors (See No. 204) that it is often impossible to tell by the name whether a dyestuff is a true mordant color or a mordant acid color. Again, the desirability of alizarine colors is so generally known that unscrupulous dealers sometimes use the term alizarine in connection with a color when it belongs to neither of the above classes, but is simply an acid color. The term has sometimes been applied to direct cotton colors.

THE MORDANT ACID COLORS.

204. General Consideration. The group of dyestuffs, known as the *mordant acid colors** is intermediate in character between the *acid colors* and the *mordant colors.* They resemble acid colors in that they may be dyed directly upon wool in an acid bath, and at the same time resemble the mordant colors in that they may be dyed upon metallic mordanted wool.

In chemical composition, these dyestuffs vary considerably, thus many of them are azo compounds combined with salicylic acid; the cloth reds are azo derivatives of benzene or toluene combined with naphthalene derivatives, while certain others are sulphonic acid compounds of anthracene derivatives. The most important chemical characteristic of composition is the presence of either hydroxyl or carboxyl groups, for it is these groups that render it possible for them to unite with mordants to form color lakes.

Of recent years, the number of mordant acid-colors has greatly increased, and at the present time they are receiving much attention in wool dyeing, having replaced the mordant colors to a certain extent. Their popularity lies in the ease with which they may be applied, and the fact that an after-treatment with some mordanting principle converts them into color lakes possessing excellent fastness to light, acids, washing and soaping.

205. Application of Mordant Acid-Colors to Wool. The first step in applying the mordant acid-colors is the same as the dyeing of acid colors upon wool, *i. e.*, in a bath containing

	Dyestuff	Necessary amount.
	Sodium Bisulphate	10%.
or	Glauber's Salt	10 to 15%.
	Sulphuric Acid	3 to 4%.

*Note. These dyestuffs are sometimes called the acid-mordant colors, but, as this name might imply that they were applied upon an acid mordant, the term mordant acid-colors is preferable, as it conveys the correct idea that they are acid colors of a mordant character

Enter the material at 140° F., bring gradually to the boil and dye at a boil until the color is exhausted from the dyebath. This should occur in from 45 minutes to 1 hour. In every case, there must be sufficient acid present to bring about as complete an exhaustion as possible, for any excess above this amount is detrimental, as it has a tendency to hold some of the dyestuff in solution.

After the dyeing, the material is raised from the dyebath and the mordanting principle (previously dissolved) added. After thoroughly stirring the bath, the material is re-entered and again boiled for ½ to 1½ hours, depending upon the nature of the dyestuff used. In case the dyebath is not exhausted of color, a new bath should be used for the after-treatment.

In nearly every case, the mordanting principle used is *potassium* or *sodium bichromate*, in the proportion ½ to 4%, depending upon the amount of dyestuff used and to some extent upon its character.

With some of these colors, *e. g.*, chromogen I, and the chromotropes, it is absolutely necessary that there shall be an oxidizing action during the after-treatment, in which case potassium or sodium bichromate must be used. With certain others an oxidizing action is detrimental, and with these either chromium floride, chromium chloride, chrome alum, or copper sulphate is used as the mordanting principle.

In some cases 1½ to 3% of *lactic*, or *formic acids*, may be added to advantage in addition to the mordanting principle, their action being the same as that of mordanting assistants during a regular mordanting process.

These dyestuffs may, in most cases, be applied equally well upon mordanted wool, but as this method is more expensive, and the results obtained are no better, it is seldom done.

As a rule, the color of the dyed material is greatly changed during the after-treatment. Thus the chromotropes give varying shades of red, which develop into navy blues and blacks, and certain of the browns and blues are of a yellow color before the after-treatment.

Many of the mordant acid-colors are useful as ordinary acid colors, but in nearly every case the fastness is greatly increased by the after-treatment.

206. List of Important Mordant Acid-Colors.

REDS.

Acid Alizarine Claret
Acid Alizarine Red
Alizarine Red, S, 2S & 3S
Anthracene Red
Anthracene Chrome Red
Anthracyl Red
Cloth Reds (All brands.)
Chrome Red
Chrome Bordeaux
Emin Red
Milling Reds (All brands.)
Palatine Chrome Red B
Salicine Red.

ORANGES and YELLOWS.

Alizarine Yellow GG., GW, R & RW
Alizarine Azo Yellow
Anthracene Yellow BN, C, & GG
Aurotine
Chrome Fast Yellow
Chrome Yellow D
Cloth Yellow
Cloth Orange
Crumpsall Yellow
Diamond Yellow
Diamond Flavine
Fast Mordant Yellow
Milling Yellow
Mordant Yellow GGR, R & 3R
Milling Orange
Resoflavin
Salicine Yellow.

BLUES.

Acid Alizarine Blues
Alizarine Sky Blue
Alizarine Saphirol
Alizarine Celestol
Anthracene Blues
Anthraquinine Blue
Anthracyl Blue
Brilliant Alizarine Blue
Chrome Blue
The Chromotropes
Cyananthrol
Gallanilic Indigo.

VIOLETS.

Alizarine Heliotrope 2B
Anthracene Chrome Violet B
Anthraquinine Violet
Fast Acid Violet
Gallanic Violet.

BROWNS.

Acid Alizarine Browns
Acid Chrome Browns
Anthracene Chrome Browns
Chrome Browns
Cloth Browns
Domingo Browns
Diamond Browns
Sulphamine Browns.

GREENS.

Acid Alizarine Green
Alizarine Dark Green
Alizarine Cyanine Green
Brilliant Milling Green
Chrome Green
Diamond Green
Domingo Green
Naphthol Green B.

BLACKS.

Acid Alizarine Blacks
Acid Chrome Blacks
Alizarine Black WR
Alizarine Chrome Blacks
Alizarine Fast Black T
Anthracene Acid Blacks
Anthracite Black B
Chrome Blacks
Crown Blacks
Diamond Blacks
Palatine Chrome Blacks.

THE INSOLUBLE AZO COLORS.

207. General Consideration. The insoluble azo colors, as the name implies, are a group of insoluble coloring matters of the azo type. Their insolubility in water renders them non-applicable by any of the methods already described, but fortunately the nature of the process of their formation is such that they may be produced directly upon the fiber.

Although many of these insoluble azo colors may be produced, only two are much used; the so-called *para nitraniline* and the *alpha naphthylamine reds.* These have been extensively applied in cotton dyeing during the past ten years, the former having replaced Turkey-red to a certain extent.

The colors of this class are sometimes known as *developed colors* because they are developed during the process of application; as *ingrain colors* because they are formed, as it were, within the grain of the fiber; and as *ice colors* because ice is often used to produce a low temperature during their application.

208. Chemistry of Process.* When an aromatic amine (substituted ammonia) is neutralized with one of the common mineral acids†, and then allowed to react with nitrous acid in a cold and slightly acid solution, it is converted into a diazo compound. Thus with para nitro aniline or para nitraniline, as it is called for short, the reaction is as follows:

$$C_6H_4\begin{array}{l}\diagup NO_2\\ \diagdown NH_2\end{array} + HCl = C_6H_4\begin{array}{l}\diagup NO_2\\ \diagdown NH_2\end{array}HCl$$

Para Nitraniline + Hydrochloric Acid = Para Nitraniline Hydrochloride.

$$C_6H_4\begin{array}{l}\diagup NO_2\\ \diagdown NH_2HCl\end{array} + HNO_2 = C_6H_4\begin{array}{l}\diagup NO_2\\ \diagdown N{=}N-Cl\end{array} + 2H_2O$$

Para Nitraniline + Nitrous Acid = Para Nitro Benzene Diazo Chloride.

When certain diazo compounds or salts react with certain phenols, naphthols, or their derivatives, chemical combination takes place with the formation of insoluble azo coloring matters.

*Note. The chemistry of the formation of the insoluble azo colors cannot be readily understood except by students of organic chemistry, the writer, however, has endeavored to make the process as clear as possible in the summary which follows the explanation of its chemistry.

†Note. The common mineral acids are sulphuric, nitric, and hydrochloric acids. The latter is most frequently used in this connection.

Thus when para nitro benzene diazo chloride reacts with sodium beta naphtholate, the compound formed is a bright red insoluble coloring matter or pigment, known as para red. The equation which represents the reaction is as follows:

$$C_6H_4{<}^{NO_2}_{N=N-Cl} + C_{10}H_7ONa = C_6H_4{<}^{NO_2}_{N=N-C_{10}H_6OH} + NaCl$$

Para Nitro Benzene Diazo Chloride + Sodium Beta Naphtholate = Para Red + Sodium Chloride.

If alpha naphthylamine, another aromatic amine, be neutralized and allowed to react with nitrous acid in the same manner and then combined with beta naphthol, the so-called alpha naphthylamine red is produced. The equations representing the reaction being as follows:

$$C_{10}H_7NH_2 + HCl = C_{10}H_7NH_2HCl$$

Alpha Naphthylamine + Hydrochloric Acid = Alpha Naphthylamine Hydrochloride.

$$C_{10}H_7NH_2HCl + HNO_2 = C_{10}H_7-N=N-Cl + 2H_2O$$

Alpha Naphthylamine Hydrochloride + Nitrous Acid = Alpha Naphthalene Diazo Chloride.

$$C_{10}H_7-N=N-Cl + C_{10}H_7ONa = C_{10}H_7-N=N-C_{10}H_6OH + NaCl$$

Alpha Naphthalene Diazo Chloride + Sodium Beta Naphtholate = Alpha Naphthylamine Red + Sodium Chloride.

Summary. In other words certain organic compounds known as substituted ammonias or amines when neutralized by acids are converted into salt-like compounds, which react with nitrous acid in cold acid solution to form diazo compounds or diazo salts. The carrying out of this reaction is known as the *diazotising process.*

These diazo salts are soluble in water and when their solution is brought together with the solutions of the sodium compounds of certain phenols and naphthols, chemical union takes place with the formation of insoluble azo coloring matters which are precipitated in a finely divided condition.

209. Application. The insoluble azo colors are extensively used for dyeing and printing cotton fabrics; to a less extent for dyeing cotton yarn; and to a very limited extent for dyeing raw or loose cotton. They cannot be applied satisfactorily to animal fibers, as one step in the process requires the use of a strongly alkaline solution.

Theory. The phenols and naphthols used readily dissolve in concentrated caustic soda solution, forming sodium salts which are soluble in water. When textile material is padded with one of these solutions, *e. g.*, with one of sodium beta naphtholate, it permeates the fiber, and when the material is dried the naphtholate remains upon the surface and within the body of the fiber.

When the material thus prepared is passed through a solution of the diazo salt, *e. g.*, para nitro benzene diazo chloride, this solution is rapidly absorbed by the fiber, and chemical union, as explained in Paragraph 208, takes place. The insoluble azo coloring matter, which in this case would be para nitraniline red, is formed wherever the naphtholate was deposited.

Practice. The process of application can be best considered under the three following heads, or steps:

(1) Preparation of the Diazo Bath.
(2) Preparation of the Cloth.
(3) Dyeing (Developing or Coupling).

PREPARATION OF THE DIAZO BATH.

This consists in converting the aromatic amine, or substituted ammonia, into one of its soluble diazo salts (usually the chloride), and then holding it in solution in a suitable bath until ready to be used in the third step of the process.

The compounds used in its preparation are the aromatic amine, sodium nitrite, hydrochloric acid, sodium acetate, ice, and water.

The *aromatic amine*, or *substituted ammonia*, is usually para nitraniline or alpha naphthylamine. These are for the production of reds, and should be used in sufficient quantity to give the desired depth of color.

The *sodium nitrite* is used in sufficient quantity to liberate enough nitrous acid to carry out the diazotising process and convert the amine used into the diazo salt.

The *hydrochloric acid* is used for three purposes: first, to neutralize the amine; second, to liberate nitrous acid from the sodium nitrite; and third, to keep the bath decidedly acid, for in this condition the bath will keep better. The hydrochloric acid should therefore be used in about three times the quantity necessary to neutralize the amine.

The *sodium acetate* is added to the diazo bath just before it is to be used, in order that it may react with the excess of hydrochloric acid present, to form sodium chloride and liberate free acetic acid, hydrochloric acid having been found to be detrimental to the best results if present during the dyeing. The sodium acetate should be added in slight excess of the amount necessary to react with the free hydrochloric acid present.

The *ice* is used to keep the bath at a low temperature as diazo salts are extremely unstable and many of them rapidly decompose even at ordinary temperature, while all of them are converted into entirely different compounds at still higher temperature. The use of ice is necessary in the Summer time, but in cold weather it may be omitted if the temperature of the diazo bath falls below 50° F. In general the colder the bath during the diazotising process the more stable the diazo compounds formed.

The preparation of the diazo solution requires considerable experience and great care, but strict adherence to the following directions should be followed by satisfactory results.

Preparation of Diazotised Para Nitraniline:

2½ lbs. Para Nitraniline
7 lbs. Hydrochloric Acid 36° Tw.

are boiled with

1½ gallons Water

until complete solution takes place, then the solution is poured slowly into

8½ gallons of Cold Water, (or enough to make up to 10 gallons)

and constantly stirred so that the yellow crystalline precipitate that forms will be as finely divided as possible. Then add

1 lb. 6 ozs. Sodium Nitrite

dissolved in

1 gallon Cold Water

as quickly as possible, stirring thoroughly. Allow the bath to stand 15 minutes, when the diazotisation will be complete.

Just before using, the excess of hydrochloric acid should be neutralized by adding

5½ lbs. of Sodium Acetate

dissolved in

1 gallon of Water.

Preparation of Diazotised Alpha Naphthylamine.

This may be prepared in the same manner as the diazotised para nitraniline with the exception that

2⅔ lbs. of Alpha Naphthylamine

should be taken and a little more water used in its solution.

PREPARATION OF MATERIAL.

Previous to the dyeing, the material, if cloth, is prepared with beta naphthol, by passing through a padding machine, and then dried by passage through a hot flue, upon a tentering frame, or by passing over drying cans well wrapped with cotton cloth; or if yarn, by working in the sodium beta naphtholate solution (using rubber gloves) then wringing, hydro-extracting and drying.

The padding liquor is prepared as follows:

2¼ lbs. Beta Naphthol
2 lbs. Caustic Soda, dissolved in a little water.
4½ gallons Hot Water
1 gallon Turkey-red oil

are dissolved together.

When solution is completely cool, make up to about 12 gallons with cold water.

No more padding liquor should be made than can be used the same day, for it does not keep well.

DYEING. ALSO KNOWN AS DEVELOPING AND COUPLING.

This consists in passing the material, prepared with beta naphthol, in a perfectly dry condition through the diazo solution, then giving it a short exposure to the air in order to bring about complete development, and then thoroughly washing.

This process may be carried out in an apparatus, a cross section of which is shown in Fig. 73. The beta naphthol prepared cloth is passed through the color box A, into which the cold diazo solution is constantly fed, then between a pair of squeeze rolls. After passing a short distance through the air in order that the color may fully develop, the cloth passes through the spray washer B, the soap bath C, and the final rinsing box D, when it is ready to be dried and finished.

210. Properties of Para Nitraniline and Alpha Naphthylamine Reds. Para Nitraniline Red on cotton is much faster than any of the direct cotton reds of similar character; and as regards fastness to light is excelled only by Turkey-red. Para red is much faster to the action of chlorine than Turkey-red, but not as fast to boiling alkaline solutions, or steaming. Para red is affected by boiling with acids, and the action of copper salts changes it to a tobacco brown. It has the advantage of being

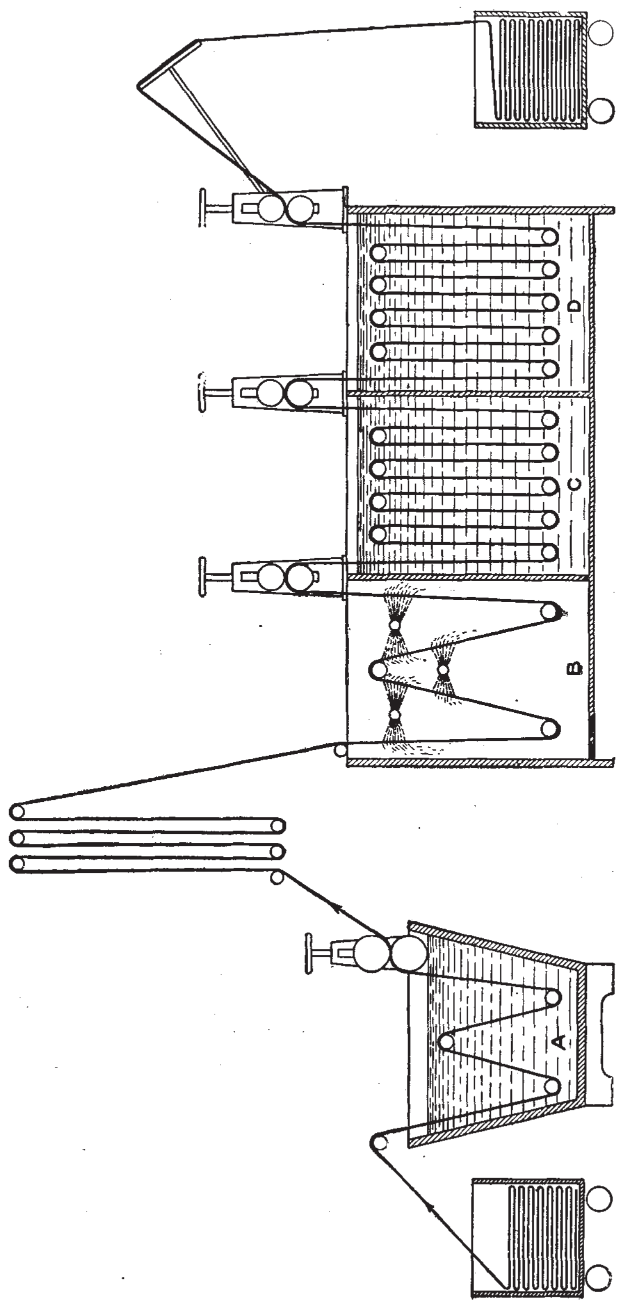


Fig. 73. Dyeing, Developing, and Washing Apparatus.

much cheaper to produce than Turkey-red and also of penetrating the material more thoroughly. Like Turkey-red, para red is not extremely fast to rubbing.

What has been said in regard to para red is in general true in regard to alpha naphthylamine red.

REDUCTION VAT COLORS.

211. General Consideration. Three dyestuffs of importance are included under this heading:

Indigo,
Indanthrene,
Flavanthrene.

These dyestuffs are all insoluble in water, but upon reduction in alkaline solutions are converted into soluble compounds, in which form they may be applied to cotton material. Upon exposure of the material to the air, oxidation takes place and the original insoluble compounds are formed, which become permanently fixed upon the fiber.

212. Indigo. This has already been considered in detail, under the head of Natural Coloring Matters (see No. 135) and need not be further discussed at this time.

213. Indanthrene. discovered in 1901, is made by fusing beta amino anthraquinone with caustic potash at a temperature of 250° C. It is insoluble in water, but when reduced by the action of hydrosulphite solution in a strongly alkaline bath, it passes into a soluble compound. In this respect, it resembles indigo and may be applied to cotton in a similar manner.

The dye bath should be made up as follows:

Indanthrene, Necessary amount to produce desired color.
Caustic soda, About 15%.
Sodium Hydrosulphite (10% solution) Five times the weight of Indanthrene.

Heat the bath to 140° F. and add the indanthrene mixed with 3 to 10 times its weight of water. Then add the caustic soda (previously dissolved) and finally the hydrosulphite solution. Stir constantly, keeping the temperature at 140° F. until complete solution of the indanthrene takes place.

The material is dyed in this bath for three-quarters of an hour at 140° F., but for light shades the temperature should be reduced and the period of dyeing increased.

The dyeing is followed by a short exposure to the air; then the material is washed, soured in dilute sulphuric acid, washed again, and finally soaped. Indanthrene differs from indigo in that it has a decided affinity for cotton when in the reduced condition, and is not washed out even if it passes directly from the dyebath into the wash water, whereas indigo must be oxidized before it is washed.

Indanthrene gives excellent shades of blue, which possess remarkable fastness to light, washing, soaping, alkalies, and acids. When first placed upon the market, indanthrene was not at all fast to chlorine, but later a product known as Indanthrene C was introduced which possesses excellent fastness to chlorine.

Flavanthrene is produced by the oxidation of beta amino anthracene. It may be applied in the same manner as indanthrene and gives yellow shades which possess the same degree of fastness.

By combining indanthrene with flavanthrene in varying proportions, it is possible to get shades of green which possess greater fastness than any other class of greens.

Indanthrene and flavanthrene are applied in calico printing, and the dyeing of yarn for ginghams, but their high cost has prevented their extensive use.

MISCELLANEOUS COLORS.

214. Aniline Black. In itself, aniline black is an insoluble black pigment of unknown composition produced by the oxidation of aniline. Probably a greater number of different methods have been tried for fixing this black pigment upon textile material than any other dyestuff or class of dyestuffs.

When *aniline is oxidized*, three consecutive products are formed: (1) Emeraldine, a greenish colored salt, insoluble in water; (2) Nigraniline, formed by the oxidation of emeraldine; (3) Aniline black proper, or ungreenable black as it is sometimes called, which is formed by the still further oxidation of nigraniline.

Aniline black is seldom applied to wool, but has been extensively used during the past forty years for the production of very fast blacks upon cotton cloth, hosiery, and to a much less extent upon cotton yarn and raw cotton. During recent years, the sulphur blacks have replaced aniline black to a considerable extent in dyeing, but not at all in calico printing.

In general, there are two methods of applying aniline black, the *Oxidation Method* and the *Single Bath Method*.

215. Oxidation Method. This consists in padding the material with a solution containing an aniline salt, usually the hydrochloride; some oxidizing agent, usually potassium or sodium chlorate; and certain metallic compounds, such as copper sulphide and vanadium salts which act as carriers of oxygen for the product of oxidized aniline black. Hundreds of recipes have been used and scarcely two dyers can be found using the same recipes and carrying out the process in the same manner. We will, therefore, only attempt to give general amounts in the preparation of the various baths.

For 100 parts of padding liquor:

Aniline Salt (Hydrochloride) 8 to 12 parts.
Sodium or Potassium Chlorate, 3½ to 4½ parts.
Copper Sulphide (30% paste) 1 part.
Thickener, enough to hold the copper sulphide in suspension.
Water, enough to make 100 parts.

In case vanadium compounds are used in place of copper sulphide, 40 to 65 mgs., ½ to 1 grain per gallon of padding liquor is sufficient.

In another oxidation method, 5 parts of *potassium ferrocyanide* are added to the padding solution in place of the oxygen carrier. The material is padded, dried in the air, passed through a steam chamber if cloth, or as is usually the case with hosiery, aged in an oxidizing chamber in the presence of air.

The ageing is followed by a treatment with *potassium* or *sodium bichromate* solution which carries the oxidation still further.

216. Single Bath Method. A single bath method is sometimes used for dyeing raw cotton, cotton yarn, and cotton warps with aniline black.

The dye bath is prepared with:

Aniline Salt (Quantity depending upon depth of shade desired).
Potassium Bichromate, 1½ times the quantity of aniline salt.
Hydrochloric Acid, equal to or less than quantity of aniline salt.

Dissolve the aniline salt and potassium bichromate separately, and mix in perfectly cooled condition just before the dyeing. Add the acid in several portions during the dyeing which should start cold and continue for two to three hours. The aniline will be better exhausted if the temperature is raised to 50° to 60° C. during the last half hour of the dyeing.

Aniline black is extremely fast to light, bleaching, and washing. The oxidation blacks are faster to rubbing than the single bath blacks, but the opposite is true in regard to fastness to acids.

WATER AND ITS APPLICATION IN THE TEXTILE INDUSTRY.

217. Important Data in Regard to Water.

Composition	By volume, 2 parts hydrogen	1 part oxygen.
	By weight, 1 part hydrogen	8 parts oxygen.

Boiling Point	212°	Fahrenheit Scale	100°	Centigrade	70°	Réamur.
Freezing Point	32°	" "	0°	"	0°	"

Maximum Density of water at 39.2° F. or 4° C.

Water expands $\frac{1}{10}$ of its volume upon freezing.

1 cu. ft. of water at 4° C. weighs 62.5 lbs.

Water at its maximum density is taken as the standard for specific gravity. See Part I. Page 39.

Raising the temperature above 4° C. or lowering it below 4° C. lowers the specific gravity of water. Thus,

Specific Gravity of water at	0° C.	.99987
" " " " "	4° C.	1.00000
" " " " "	15° C.	.99915
" " " " "	50° C.	.98817
" " " " "	100° C.	.95859

Latent heat of liquifaction of ice 79 heat units.

Latent heat of vaporization of water 537 heat units.

Boiling point of water increases under pressure and lowers under reduced pressure. Thus,

B. P. of water at normal atmospheric pressure	100° C.
" " " " 30 lbs. pressure approximately	120° C.
" " " " 90 " " "	160° C.
" " " " 120 " " "	170° C.

Boiling point of water is increased by the presence of soluble salts. Thus,

B. P. of distilled water	100.0° C.
" " 5% solution of common salt	101.5° "
" " 10% " " " "	103.0° "
" " 15% " " " "	104.6° "
" " 20% " " " "	106.3° "
" " 25% " " " "	107.9° "
" " 33% calcium chloride solution	128.0° "
" " 66% " " " "	156.0° "

218. Impurities of Water. If all water was pure, but little could be said in regard to it other than has been given in the above table. As a matter of fact, however, absolutely pure water may be looked upon as a curiosity. Distilled water is the nearest approach to pure water, and even when this is prepared very carefully under the most favorable conditions and with many precautions, it is never entirely free from traces of gaseous impurities. Assuming that absolutely pure water could be prepared, it would remain so but a few seconds when exposed to the air.

Normal water is therefore a water of impurities, and it is these impurities that will engage our attention in its study.

Two Classes of Impurities. The impurities present in water may be divided into two entirely different classes.

(1) Those of importance from a physiological or *sanitary* point of view.

(2) Those of importance from a technical or *industrial* point of view.

It is the latter class that will naturally engage our attention at this time.

219. Classification of Waters. We have already said that in the study of water it is the impurities contained therein that engage our attention. The nature of these impurities depends upon the substances with which the water has come in contact previous to the time of use or examination, and it is therefore advisable, especially for technical purposes, to classify various waters according to their sources.

Adopting this method we have

(1) Distilled Water.
(2) Rain Water.
(3) Surface Water.
(4) Subsoil or Ground Water.
(5) Deep Well or Artesian Well Water.
(6) Sea Water.
(7) Mineral Water.

220. Distilled Water. On account of its freedom from mineral matter and other impurities, distilled water would obviously be the best form of water to use for textile and other industrial purposes, but the expense of its production is so great as to make its use impossible for anything but special purposes. In chemical laboratories, however, it is indispensable for analytical and many experimental purposes, and consequently small stills producing anywhere from one to five gallons per hour are usually installed.

These stills may be heated by direct gas flame or what is better, by a steam coil inserted within the still, or by a steam jacket. Fig. 74 represents a cross section of such a still. The water in the still A is constantly kept at the level of the water in the condenser B by means of the cross connection C. Steam is introduced into the jacket J through the valve D and escapes through valve E, and by properly regulating these valves, the water in A may be boiled steadily for hours. The vapor passes over through the neck G, condenses in the worm B, which is surrounded by cold water, and

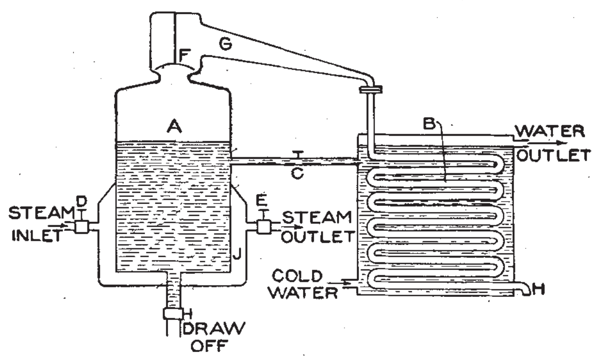
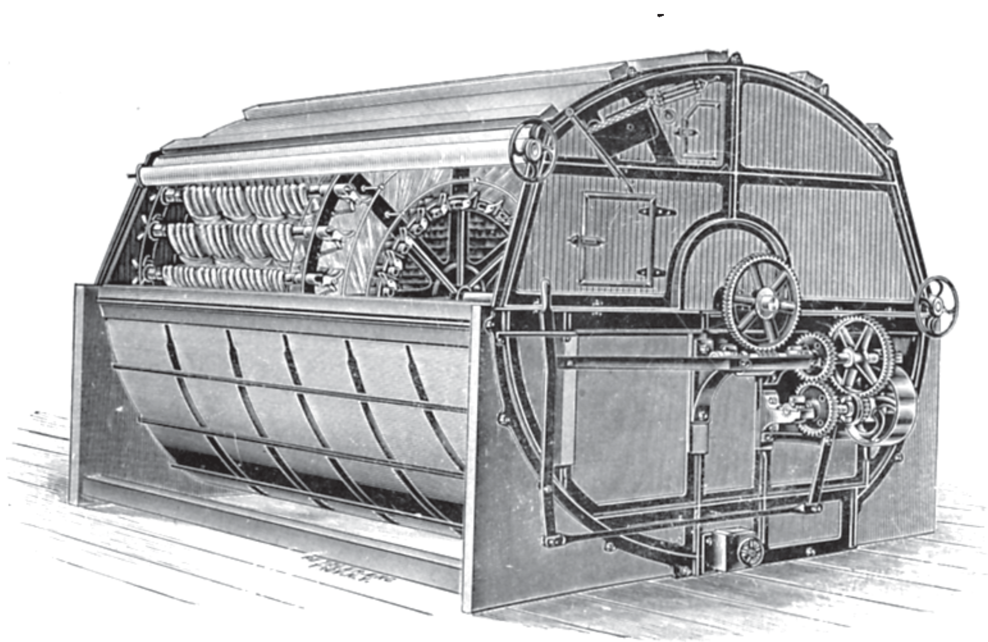


Fig. 74. Steam Heated Still.

finally issues at H as distilled. A baffle plate F may be located in the head of the still to prevent any water from being carried over mechanically in case the water in A should boil too violently.

In works where only a limited amount of pure water is required, it is sometimes the practice to condense direct steam from the boilers, or indirect steam that has already been used for heating purposes or otherwise. In this way a comparatively pure water is obtained, but its purity cannot always be depended upon, as oil, which is volatile with steam, is likely to get into it in various ways, and iron rust from steam pipes occasionally causes trouble.

221. Rain Water. Rain water may be considered a naturally distilled water. Evaporation is constantly going on at the



SKEIN AND SLUBBING MACHINE, CAPACITY FROM 250 TO 700 POUNDS PER BATCH

Klander-Weldon Dyeing Machine Co.

surface of all bodies of water exposed to the atmosphere, and the water vapor thus formed, being lighter than the air, rises. The amount of evaporation varies, being but little upon a cold damp day but very great upon a warm and dry day. As the warm air, partially saturated with moisture, rises, it eventually becomes cooled to a point where a large proportion of the moisture it holds condenses out as clouds, which, being carried about by the various currents of air, constantly increase in density until they become so heavy that the water falls to the earth as rain.

Rain water, however, is never absolutely pure, for it always contains a certain amount of foreign matter, usually of a volatile character.

The degree of purity of rain water depends chiefly upon two conditions, *i. e.:* the locality and the period of the storm during which the rain fell. In a large city where many industrial establishments, such as gas works, bleacheries, chemical works, etc., are located, large quantities of gaseous impurities, such as ammonia, various oxides of nitrogen and chlorine, escape into the air, and in addition to these, sulphur compounds from the burning of enormous quantities of soft coal.

During the first few hours of a rain storm, these impurities, which in a dry season may have been collecting for several weeks, are readily absorbed by the rain, and the rain water falling at this time is likely to be more or less contaminated by impurities. After the rain has fallen for some time, these impurities are well extracted from the atmosphere, particularly in country districts, and rain water then becomes almost as pure as distilled water.

Rain water as actually collected, however, always contains additional impurities, owing to dust, dirt, etc., which collect upon roofs or other surfaces from which it is drained. In many works where only very hard water is obtainable, the collection of rain water may be made more of an item than is generally realized.

222. Surface Water. Under this head is included all surface bodies of fresh water, such as brooks, rivers, ponds and lakes. Sea water is a surface water, but being so rich in inorganic matter is classified separately.

When rain water strikes the earth a considerable portion is immediately absorbed, especially if the soil is of a dry and porous character. It percolates through the soil to various depths and contributes to the fourth and fifth classes of water known as subsoil and deep well waters. After it has rained some time, the soil becomes more or less saturated, or perhaps the soil is already wet as is the case in a swampy region, and then that portion which is in excess of the amount absorbed, flows in the direction of the incline of the earth and soon contributes to brooks, rivers, lakes, and constitutes one of the two sources of surface water.

The second source of surface water is from springs consisting of subsoil water, which having passed through the earth has had an opportunity to dissolve various forms of mineral matter. As a rule, water from the second source contains more matter in solution than water from the first.

It can readily be seen, from its origin, that surface water will vary greatly in the nature and amount of impurities that it contains, these depending chiefly upon the locality and the conditions through which it has passed previous to the time of its examination. If surface water comes originally from a locality consisting of a hard and non-porous soil, and then passes over a river-bed composed of insoluble rocks, it will contain but few impurities and be nearly as pure as rain water. On the other hand, if it comes largely from spring water, and then passes over river-beds composed of limestone, dolomite, and gypsum, and finally through several cities or towns, it may contain a great variety of impurities, both organic and inorganic, and be unfit for either industrial or drinking purposes until purified.

223. Subsoil Water. This includes for the most part spring and shallow well water. The rain absorbed by the earth percolates through the soil to various depths until it reaches a strata of rock or soil, which is partially or wholly impervious to water. If this strata of impervious material slopes in either direction, the water will flow in the direction of the incline. A shaft sunk into the ground until it penetrates such an impervious layer, constitutes a shallow well. Oftentimes such an impervious strata of rock outcrops at the surface of the earth, usually upon the side of a hill, and constitutes a spring. The impurities contained in such a water depend almost entirely upon local conditions, that is, the nature of the soil through which it has passed and any artificial sources of contamination that it may have met. The former impurities are of great importance from a technical standpoint, whereas the latter are of the utmost importance from a sanitary point of view.

224. Deep Well or Artesian Well Water. In some localities the formation of the crust of the earth is such that fissures or crevices extend into the earth to great depths. Their upper terminations may be in direct communication with lakes or rivers, but more often with subsoil water. The water from these sources has, during the course of time, completely filled all of the subterranean

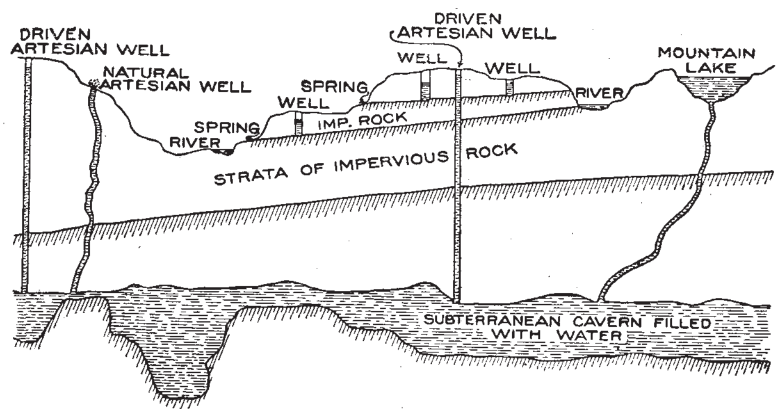


Fig. 75. Diagram Showing Sources of Water.

cavities with which the lower terminations of such fissures connect. Here it collects and, undoubtedly in many instances, forms large subterranean bodies of water, which are found located at a depth of many hundred feet below the surface of the earth. An artificial shaft sunk into the earth until it reaches such a subterranean body of water constitutes an artesian well. In some cases there is enough pressure behind the water to bring it to the surface without pumping.

Artesian well waters vary greatly in composition. Some are comparatively pure, while others are so rich in inorganic matter as to be classed as mineral waters.

225. Sea Water. Sea water contains between three and four per cent of soluble mineral matter which consists chiefly of sodium chloride and smaller quantities of the chlorides and sulphates of calcium and magnesium. Sea water cannot be used for ordinary purposes unless previously distilled.

226. Mineral Waters. In various localities, spring waters are found which are heavily charged with soluble inorganic compounds which have been dissolved by the passage of the water through various deposits in the earth. The mineral matter present is in such large quantities as to usually render them as unfit for industrial purposes as is sea water.

IMPURITIES EXISTING IN WATER AND THEIR CHEMISTRY.

227. Classification of the Impurities in Water. Impurities existing in water naturally divide themselves into two classes; first, those *not in solution*, which we will designate as mechanical or suspended impurities; secondly, those *in solution*, designated as dissolved impurities. As a rule, river water contains the least amount of dissolved impurities and the largest amount of suspended matter and inorganic impurities, while the opposite is true of the subsoil and well water.

228. Mechanical or Suspended Impurities. These impurities are more noticeable in river water than in any other variety. The rapidly flowing stream has an opportunity to take along with it finely powdered particles of matter, both mineral and organic, which are insoluble in water. A river flowing rapidly through a locality where the soil is of a light and pulverized nature, especially during the spring months, will contain large quantities of mechanical impurities. On the other hand a river with a slow current which passes through lakes, where there is an opportunity for suspended matter to settle out, may contain but little of this form of impurities.

229. Soluble Impurities. Under this head are classed all impurities which, under the conditions through which a water has passed, have been taken into solution. The solvent action of water is so great that surface and subsoil water always contain a certain amount of soluble matter, both of inorganic and organic origin, the nature of which depends entirely upon the character of the rock or soil over or through which the water has passed, and also to a certain extent, upon artificial contamination.

Waters whose origin is in a district composed of such insoluble rocks as granite or gneiss remain comparatively free from inorganic impurities and are termed *soft waters.* On the other hand, waters passing through or over formations of limestone, dolomite, magnesite, red sandstone or gypsum, dissolve varying quantities of inorganic compounds and are known as *hard waters.*

230. Classification of Soluble Impurities. For convenience the soluble impurities will be discussed according to the following classification:

(*a*) 1. Calcium or magnesium impurities.
2. Iron impurities.
3. Alkaline impurities.
4. Acid impurities.
5. Organic impurities.

(*b*) 6. Sea water and mineral water.

231. Calcium or Magnesium Impurities. Under this head are included all compounds of calcium and magnesium occurring in different forms of natural water.

From an industrial or technical point of view, these are of the utmost importance, as they occur more frequently than any of the other impurities, and if present in any quantity, may cause serious trouble in many industrial operations. They are most frequently present as the acid or bicarbonates and less often as sulphates and chlorides.

Calcium carbonate $CaCO_3$ and magnesium carbonate $MgCO_3$ are practically insoluble in water, but water which contains in solution carbon dioxide gradually dissolves these normal carbonates, converting them into acid or bicarbonates, according to the following equations:

$$CaCO_3 + H_2O + CO_2 = Ca\ H_2\,(CO_3)_2$$
$$MgCO_3 + H_2O + CO_2 = Mg\ H_2(CO_3)_2$$

Carbon dioxide (CO_2) is often formed by the decomposition of organic matter and, as is frequently the case, rain water while psssing through the earth comes in contact with the carbon dioxide thus formed. As the water passes through the earth the conditions of pressure and low temperature are favorable for the solution of the carbon dioxide and it is readily dissolved. Later in its course, this water, which is nothing more nor less than a solution of carbonic acid, may pass over limestone $CaCO_3$, magnesite $MgCO_3$, or dolomite $CaMg\,(CO_3)_2$, and a certain amount of the calcium or magnesium become dissolved in the form of their bicarbonates.

Calcium and magnesium sulphates and chlorides are all more or less soluble in water, and if water comes in contact with any of these substances, they will be taken into solution. In some localities the mineral gypsum $CaSO_4 + 2H_2O$ occurs in large quantities and is therefore not an uncommon impurity in water.

HARDNESS OF WATER.

232. General Consideration. In order to understand the exact nature of a hard water, one must be familiar with the composition of soaps, and their chemical nature. Soaps are the metallic salts of certain of the so-called fatty acids, the common soaps being the potassium and sodium salts of such acids as *stearic*, *palmitic*, *margaric*, *etc*. These potassium and sodium soaps or salts are for the most part readily soluble in water. There are other metallic salts such as those of calcium, magnesium, iron, lead, etc., with these same acids, and these are from a chemical point of view as truly soaps as the potassium and sodium compounds, but they are for the most part extremely insoluble in water.

The soaps in general use are those first mentioned, that is, the potassium and sodium soaps which are soluble in water If these soaps are added to water free from mineral matter and acid, they readily dissolve and it takes but little to form a lather. Such a water is said to be *soft* and is particularly desirable in most industrial operations.

If, on the other hand, a water contains soluble salts of *calcium*, *magnesium*, *iron*, or in fact of any metal which forms an insoluble soap, and we add to such water one of the common potassium or sodium soaps, double decomposition takes place with the formation of an insoluble soap which is precipitated, and the formation of a potassium or sodium salt of the inorganic acid liberated. In this case no lather will be formed and the soap will have no action until all of the calcium, magnesium, iron, etc., has been precipitated as an insoluble soap. Such a water is said to be *hard* and is very objectionable in most industrial operations as it wastes large quantities of soap, and the insoluble soaps formed are very disastrous in many cases.

In general it may therefore be said that a hard water is one containing in solution any metal capable of forming an insoluble soap.

233. Temporary and Permanent Hardness. Hardness of water may exist either as temporary or permanent hardness, or both combined.

TEMPORARY HARDNESS.

From previous definition it will be understood that a water containing the soluble acid or bicarbonates of calcium, magnesium, and iron, are hard. By boiling such a water, however, these bicarbonates decompose according to the following equations:

$$Ca\ H_2\ (CO_3)_2 + \Delta^* = Ca\ CO_3 + CO_2 + H_2\ O$$
$$Mg\ H_2\ (CO_3)_2 + \Delta = Ca\ CO_3 + CO_2 + H_2\ O$$

into the normal carbonates of calcium, magnesium and iron, which are insoluble in water. These metals would therefore be precipitated out, and being no longer in solution, they would not affect soap. The water is therefore rendered soft. This form of hardness is known as temporary hardness, and any water which loses its hardness upon boiling is said to be temporarily hard.

PERMANENT HARDNESS.

For the reasons previously mentioned, a water containing the chlorides of calcium or magnesium, or the sulphates of calcium and magnesium, or, in fact, any soluble sulphate, chloride or nitrate of a metal forming an insoluble soap, is hard. If such a water should be boiled under ordinary conditions, these salts would still remain unchanged, and the evaporation of the water would consequently, by concentration, increase the degree of hardness. Such a water is said to be permanently hard.

SCALES OF HARDNESS.

It is customary to express the hardness of water in degrees, two scales being extensively used for this purpose. First, Clark's scale, in which one degree of hardness corresponds to one grain of calcium carbonate, or its molecular equivalent of some other compound forming a hard water, per gallon of water. In other words

*Note. Δ is the symbol commonly used as representative of heat.

one part in seventy thousand. Secondly, Frankland's scale, in which one degree of hardness corresponds to one gram of calcium carbonate, or its molecular equivalent in some other compound. per one hundred thousand grams of water. In other words one part in every one hundred thousand.

Frankland's scale may be easily converted into Clark's by multiplying the number of degrees in the former scale by $\frac{7}{10}$, or *vice versa*, by multiplying Clark's scale by $\frac{10}{7}$.

234. Iron Impurities. Iron impurities include all compounds of iron which may occur in natural water. Similar compounds of manganese, which occur less frequently than iron, are often included under this same head. They occur principally in the neighborhood of coal mines, iron mines, and in localities where minerals containing iron abound. Iron occurs so abundantly and is so widely distributed in nature that water containing this metal may be found in almost any locality. It is usually present as the bicarbonate, having been dissolved by an excess of carbon dioxide.

As a rule the bicarbonate of iron decomposes quite readily into the normal carbonate. Simple exposure to the air and sunlight is often sufficient to purify the water by causing this precipitation to take place.

The *iron rust or oxide* which frequently collects in iron water pipes should not be confused with iron that is present in solution. Its presence is due wholly to local conditions which may easily be corrected, and is not detrimental to the purity of the water in its original form. Iron may also occur as the sulphate. Manganese acts similar to iron, but is not as frequently found in water.

235. Alkaline and Saline Impurities. In certain localities deep well water may contain an appreciable amount of sodium carbonate. This is particularly true in coal regions. Water that has received waste from a wool scouring plant, especially if it be a small river, may contain sufficient potassium salts to render the water slightly alkaline. In some localities, particularly in certain parts of New York state, deep well water is charged with comparatively large amounts of saline or salty impurities. Occasionally there is enough present to render the water similar in composition to sea water.

236. **Acid Impurities.** Water that has drained through marshy or boggy districts may dissolve small amounts of organic acids, sometimes termed peaty acids. They easily attack iron and in some cases may be present in sufficient quantity to cause trouble.

When water is contaminated with ferrous sulphate, this compound may decompose upon exposure to the air and sunlight, forming ferric oxide with the liberation of free sulphuric acid.

Hydrogen sulphide, present in the so-called sulphur waters, may also be included as an acid impurity. It generally arises from the decomposition of calcium sulphate.

237. **Organic Impurities.** From a technical point of view organic impurities, unless present in large amounts, are not usually serious. In a drinking water, however, they are of the utmost importance. Organic impurities may be present in water that has passed through a marshy or swampy district, by the introduction of sewerage from cities and towns, by vegetable growth in the water, or by the introduction of waste liquors from various industrial establishments.

238. **Artificial Impurities.** Under this head may be classified all impurities which have been introduced into water by other than natural means. For this reason, they exist for the most part only in surface water. They vary greatly in quantity and character, depending wholly upon local conditions. Near the source of a stream there is little if any danger from such impurities, but great trouble is often experienced by manufacturers whose works are located near the mouth of a large stream that has passed through numerous towns and cities, receiving contributions from paper works, chemical works, bleacheries, dye houses and other industrial establishments.

In most cases strict laws exist in regard to the pollution of streams, but the expense and trouble in complying with these laws often leads a manufacturer to overlook the state laws, as well as the rights of other manufacturers located farther down the stream.

EFFECTS OF IMPURE WATER IN THE DIFFERENT BRANCHES OF THE TEXTILE INDUSTRY.

239. General Consideration. The injurious effects of the impurities present in water are probably more numerous and varied in the textile industry than in any other. In bleaching, wool scouring, textile printing, and various dyeing processes, to say nothing of the action of impure water in boilers, the textile manufacturer is often confronted with serious problems. In order to overcome these difficulties, he may be obliged to change his water supply or install an extensive filtration or water softening plant.

For convenience in their consideration, we will study the effects of impurities in the same order that we have already discussed the impurities themselves, and finally consider the various methods that may be used for correcting and overcoming the various injurious actions of these impurities.

240. Effect of Calcium and Magnesium Impurities. More trouble arises from the presence of calcium and magnesium compounds in water than from any others. In wool scouring, or in fact in any operation where soap is to be used, the insoluble calcium and magnesium soaps are at first formed. Consequently the soap has no effect and no lather will be formed until a quantity of soap has been added sufficient to precipitate all the calcium and magnesium as insoluble soaps. The great waste of soap thus involved is not the only disadvantage, for the calcium and magnesium soaps are of a sticky nature and become attached to the fiber in such a manner that they cannot be removed by washing, and their presence often causes disastrous effects in subsequent dyeing and finishing operations.

With some dyestuffs these insoluble soaps act as *resists*, thus preventing the proper fixation of the color and resulting in light spots and streaks upon the dyed material. For other dyestuffs these insoluble soaps have a certain affinity thus causing a more perfect fixation of the color and consequently dark spots or streaks upon the dyed material. With certain basic colors the acid portion of the insoluble soap acts as a mordant, producing similar effects.

If a hard water is used for washing material after it has been soaped, an insoluble soap is often formed upon the fiber. In certain mordanting operations the presence of calcium and magnesium compounds tends to cause a premature precipitation of the mordanting principle, which condition is not only wasteful, but is likely to result in a superficial fixation of the mordant and consequently dye shades which are not fast to rubbing.

The presence of calcium and magnesium impurities is also injurious in water used for the solution of dyestuffs, many colors, particularly those of the basic group, being precipitated as insoluble compounds.

In the dyeing of alizarine reds, a small amount of calcium in the dye bath may be an advantage, and in fact chalk is commonly added in small quantities, but even in this case, it is far better to use pure water and add the necessary amount of calcium compounds in such forms as are most beneficial during the dyeing process.

In *dyeing with the alizarine colors*, the presence of calcium and magnesium in the form of bicarbonates is very objectionable, as is the case with most of the mordant dyestuffs.

The absence of calcium and magnesium impurities is also of the utmost importance in waters used for boiler purposes, their presence resulting in formation of boiler scale. This, however, will be considered later in a special number.

241. Action of Iron Impurities. In their action towards soaps, compounds of iron are similar to those of calcium and magnesium, precipitating insoluble soaps. When the iron is present as the bicarbonate, it decomposes easily with the formation of the insoluble normal carbonate, which may become deposited upon the fiber and interfere seriously in bleaching, scouring, and dyeing operations.

Even the smallest quantities of iron are very injurious in the production of alizarine or Turkey-red, for with alizarine, iron acts as a mordant producing purplish black instead of red color lakes. Minute quantities of this darker color lake materially dulls the resulting red.

In bleaching processes, particularly of cotton, iron compounds, if present in the final wash water, are liable to become deposited upon the cloth. If locally deposited, brownish spots will be formed, but if the deposit is general it will slightly yellow the material and detract from its final whiteness.

Iron present mechanically in the water as an oxide must be guarded against as well as iron compounds in solution. In bleaching with sodium peroxide, even small quantities of iron in the water detract decidedly from the resulting white. Manganese impurities, if present, produce effects similar to those produced by iron.

242. Alkaline Impurities. In wool scouring, or in fact in any operation where sodium carbonate or any other alkali is a normal constituent of the bath, alkaline impurities may be overlooked. In mordanting operations their presence may cause a premature decomposition of the mordanting principle, but in the application of acid dyestuffs they cause no particular trouble other than the necessity of adding a larger amount of acid in the dye bath.

243. Effect of Acid Impurities. Acid water is unsuitable for scouring purposes since it wastes the soap, not by the formation of an insoluble soap, but by the liberation of the insoluble fatty acid of which the soap is a salt. In certain dyeing operations acid impurities may prove injurious.

244. Action of Organic Impurities. Organic impurities, unless present in large quantities, are in most cases without action. There are times, however, when organic impurities may be present in sufficient quantity to discolor the water. If present in the final wash water they may detract from the whiteness of bleached cloth and from the production of delicate tints.

245. Action of Mechanical Impurities. Mechanical impurities may be present in sufficient quantity to cause trouble in various textile operations, particularly in bleaching and scouring. A water containing mechanical impurities, as, for instance, mud, is bound to detract from the whiteness of bleached cloth if used in the final washing.

246. Action of Impure Waters in Boilers (Boiler Scale). At this time it is unnecessary to enter into a discussion of the various types of boilers in use, suffice to say that in all boilers a certain condition exists, namely, plates or tubes of iron of varying thickness heated by direct flame upon one side and in contact with water upon the other.

If the water used in a boiler contains soluble bicarbonates of *calcium*, *magnesium*, and *iron*, these will be precipitated as the normal carbonates, which, if no other compound is present, will usually deposit in a finely divided condition upon the bottom and exposed surfaces of the boiler in the form of a mud, which may be blown out of the boiler from time to time and thus cause no serious trouble.

If a boiler water contains, in addition to the bicarbonates, calcium and magnesium sulphates or chlorides, an entirely different condition exists, for as evaporation takes place, the water eventually becomes saturated with these compounds, and as they crystallize out, form a hard crystalline deposit which tends to cement the loose particles of the normal carbonate together thus forming a hard and difficultly soluble crust upon the bottom and exposed surfaces of the boiler. This crust is commonly known as *boiler scale.*

The presence of this boiler scale increases with great rapidity the amount of coal necessary to evaporate a given weight of water, for it is a poor conductor of heat and it is with difficulty that the heat is conveyed through it from the fire to the water. Furthermore, it lessens the capacity of the boiler by diminishing its cubical contents.

The most serious result, however, comes when this deposit increases to such a thickness that the heat cannot be conducted through it sufficiently fast to prevent the iron plates or tubes from becoming overheated. This condition results in the warping and eventually cracking of the plates or tubes, thus allowing water to flow into the fire-box and suddenly generating an enormous quantity of steam, which has resulted in some of the most disastrous of boiler explosions. The necessity of pure water for boiler purposes is therefore obvious.

247. Prevention of Boiler Scale. Boiler scale may be prevented by one of three methods:

First, by adding to the boiler some substances or combination of substances that will cause the mineral matter present in the water to deposit in a loosely divided condition that may be easily blown out of the boiler from time to time.

Second, by heating the water in an auxiliary boiler before it enters the boiler proper, thus depositing the scale in the first boiler, which is so constructed that it may be removed from time to time without serious inconvenience.

Third, by chemically treating the water with some chemical compound or mixture of chemical compound which will precipitate the objectionable mineral matter, and then removing this

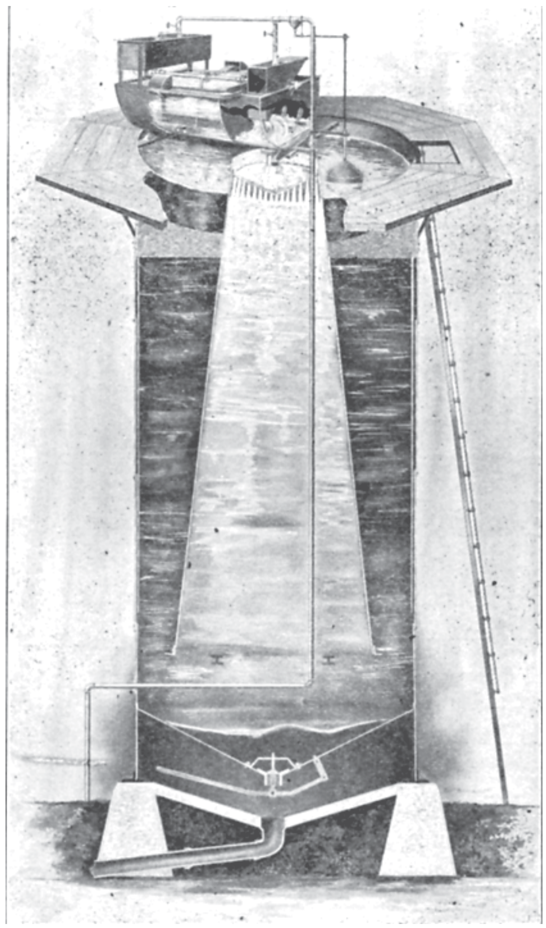


Fig. 76. Kennicott Water Softener.

from the water by filtration or decantation before the water enters the boiler.

The first method is used with varying success. It may work well with a temporarily hard water, but cannot be depended upon unless based upon a chemical analysis of the water and prepared with chemical exactness. Substances which are purely mechanical in action are often added to boilers to prevent boiler scale. Among these may be mentioned various forms of *oil*, *bran*, *sawdust*, *sugar*, *molasses*, and innumerable other substances.

In the case of oils, they have a tendency to form a thin film about each particle of precipitated matter, thus preventing the particles from becoming cemented together. In the case of bran, sawdust and like substances, the particles of these, becoming mixed with the depositing particles of mineral matter, form a mud or sludge rather than a scale.

Other of the so-called boiler compounds are chemical in their action, various alkaline chromates and barium compounds being used, which tend to precipitate the objectionable substances in the water in a finely divided condition, as these substances have little tendency to crust or cake together. These boiler compounds, however, cannot be depended upon unless their use is based upon the analysis of the water and then prepared quantitatively with chemical exactness.

The second method of preventing boiler scale is not practical unless an enormous quantity of waste heat is available. It is therefore seldom used.

The third method, that is, purification of the water before it enters the boiler, is by far the best and will be discussed later under the headings Water Softening, and Filtration.

PURIFICATION OF WATER

248. General Consideration. From what has already been stated in the preceding pages, it is obvious that for many purposes, particularly in connection with the textile industry, it is essential that an impure water be purified before being used. If such a water is extremely hard, chemical means must be resorted to and the process usually comes under the general head of water softening.

If only mechanical impurities and organic matter are present in the water, various forms of filtration may be sufficient, but it must be remembered that ordinarily filtration does not remove the hardness of a water. We will therefore consider the purification of water under two heads, *i. e.*, Water Softening, and Filtration.

249. Water Softening. The various processes of water

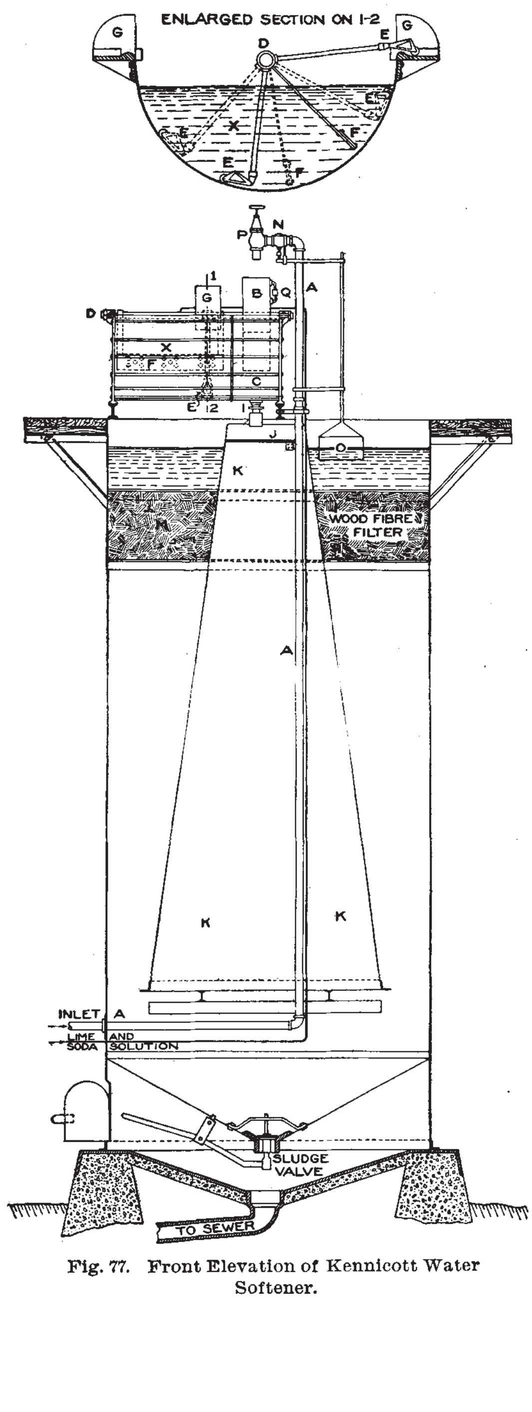
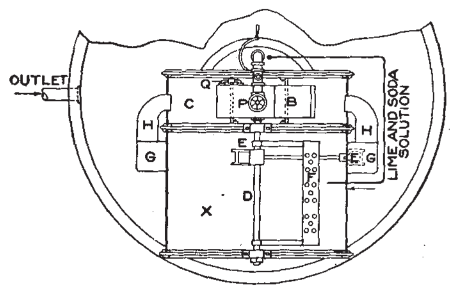


Fig. 77. Front Elevation of Kennicott Water Softener.

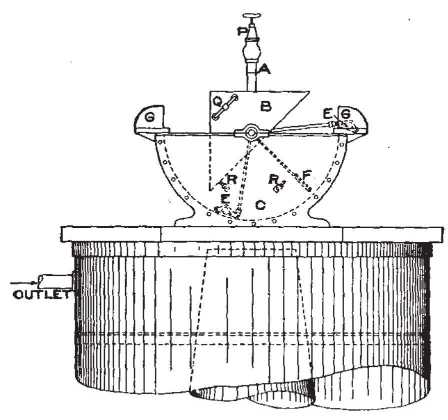
softening consist essentially of two steps; first, the chemical precipitation of the objectionable mineral matter in an insoluble state, and secondly, the subsequent removable of this precipitate by mechanical means. The chemistry of the precipitation is com-



Plan of Fig. 77.

paratively simple, but the various forms of apparatus for removing this precipitate from the water are more or less complicated.

The commonest re-agents used as precipitants are *sodium carbonate* and *calcium hydroxide*. These are added to the water



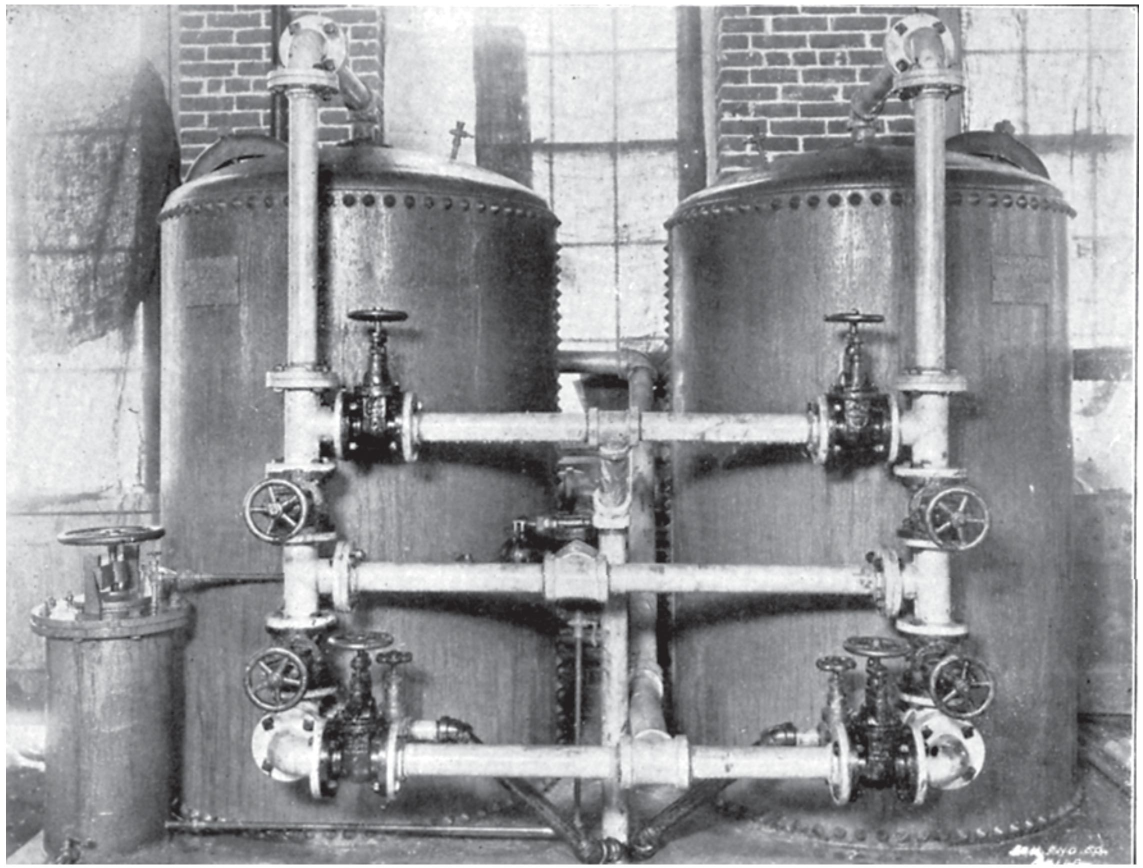
Side Elevation of Top of Fig. 77.

in just the right proportion to react with the mineral matter present according to the following equations:

First, assuming that the water is only temporarily hard:

$$CaH_2(CO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O.$$

By this method it will be seen that if lime water is added



FILTER PLANT INSTALLED AT NICETOWN DYE WORKS, PHILADELPHIA

The Philadelphia Water Purification Co.

in just the right amount, the water will be rendered soft without the permanent introduction of any chemical compound.

Second, assuming that the water is permanently hard:

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4.$$

In this case sodium sulphate will remain dissolved in the water, but this is no serious objection as its presence causes no great trouble in boilers.

Third, assuming that the water is both permanently and temporarily hard:

$$\left\{\begin{matrix} CaSO_4 \\ CaH_2\,(CO_3)_2 \end{matrix}\right. + 2Na_2CO_3 = 2CaCO_3 + Na_2SO_4 + 2NaHCO_3$$

With *magnesium compounds* the equations would be similar to those above substituting magnesium for calcium. Iron, if present, would act in a similar manner.

The precipitated carbonates may be removed by filtration, but more commonly by decantation in some form of a softening tower.

Figures 76 and 77 illustrate the Kennicott apparatus made by the Kennicott Water Softener Co., of Chicago. The water mixes with the softening reagents as it enters the apparatus; which is so constructed that the insoluble carbonates will settle out completely before the water leaves it, providing that the circulation is not too rapid.

The water for treatment enters the apparatus from the pumps or other source of supply through A (Fig. 77), and after passing through the automatic regulating valve N, which is controlled by float O, it enters the oscillating receptacle B, from which it is discharged into compartment C. A rocking motion through an arc of about 90° is given to the shaft D by the movement of the oscillating vessel B. Firmly attached to the shaft D are arms which carry cups E. These cups moving in unison with the oscillating vessel B follow the curved sides of the solution tank X, which contains the lime and soda, and are so designed as to scoop up and discharge the requisite amount of these chemicals. The milk of lime and soda solution is kept thoroughly agitated by means of the agitator F. The cups discharge into the hoods G and the mixture of lime and soda is conducted through troughs H into the water as it is discharged from the oscillating vessel B.

The valve I is a simple slide valve, set so that the water does not all flow into the settling tank as quickly as it is dumped from the receptacle B, but the space C will always contain at least a small amount of water, so that, as previously stated, there is practically a steady stream of water mixed with chemicals going into the settling tank. An exceptionally thorough mixture of the chemicals and water is obtained in the apparatus owing to the peculiar bonnet or spout placed over the discharge bar of the tilting receptacle, which, as it dumps, discharges a powerful stream of water into the space C, thus thoroughly mixing the water and

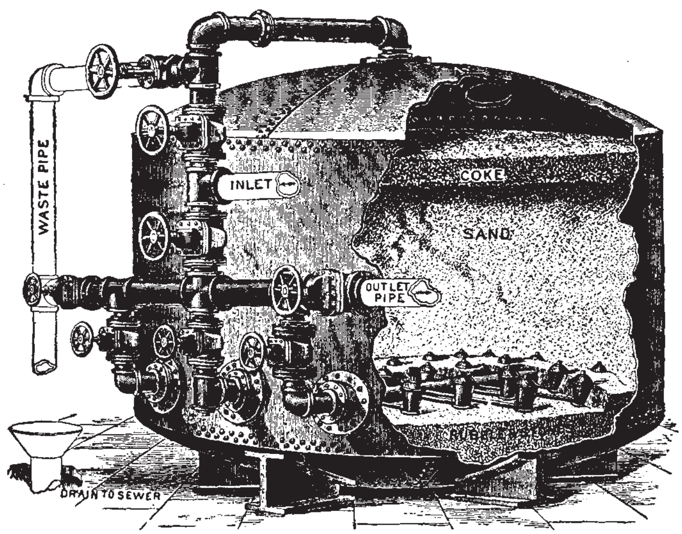


Fig. 78. Water Filter.

chemicals. The water, after passing valve I, falls upon the distributing plate J, then slowly passing through the conical downtake K, turns and rises, finally passing through the wood fiber filter M and emerges from the softener at the outlet soft and ready for use.

250. Filtration of Water. Two different methods of filtration are in practical use, *i. e.*, the so-called European and American systems.

In the *European system*, a large filter bed is prepared five or six feet in thickness and constructed of coarse gravel at the bottom, gradually growing finer as it approaches the top, where there are several inches of sand. The water to be filtered is allowed to flow over this filter bed and gradually percolates through it. After the filter bed has been in use for some time, a thin deposit of silt and organic matter deposits upon the upper surface and gradually coats each individual grain of sand in the upper layer. This upper layer filters out all mechanical impurities present in the water and reduces the number of bacteria present in the water to a marked degree.

With the European system a filter bed of large area is necessary, and it is not very efficient until it has been in operation for

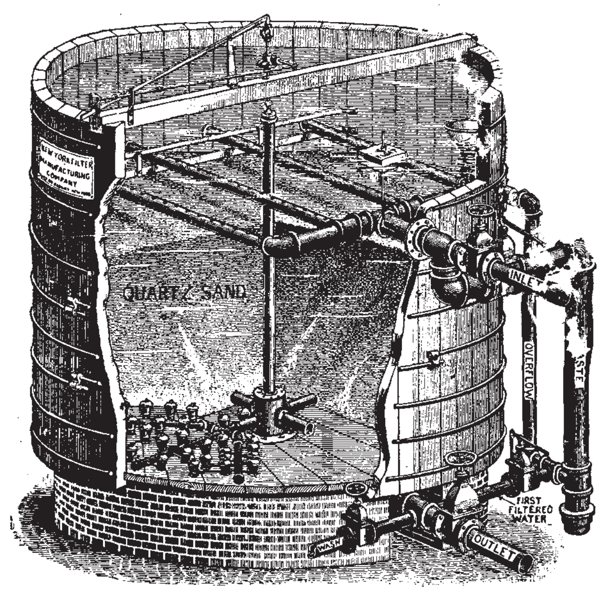


Fig. 79. Water Filter.

several weeks, but with proper care it can then be used for a long time. This method of filtration is extensively used for the purification of drinking water in large cities, but less frequently in industrial establishments.

The *American system* aims to produce, by artificial means, a condition similar to the European system. Cylindrical filters are constructed and filled with broken quartz, coke, and sand, as illustrated in Figs. 78 and 79.

Before the water enters this filter a small amount of aluminium sulphate is added, which reacts with impurities present in the water and forms minute particles of aluminium hydroxide, which are of a gelatinous nature. This gelatinous precipitate collects upon the individual particles of sand in the upper layer of the filter bed, and when water is forced through the filter under pressure, and in some cases by gravity, it retains through its adhesive character the minutest particles of suspended matter and bacteria.

At the end of the day water is forced through the filter in the opposite direction in order to thoroughly scour it out. This system is not only used for drinking waters but is very extensively used in industrial plants.

251. Correction of Water by Simple Additions. In many operations the injurious action of the water may be corrected by simple chemical additions without resorting to filtration or the use of extensive softening plants. In many dyeing operations the addition of acetic acid converts the bicarbonates of calcium and magnesium into the acetates which are not objectionable.

An alkaline water may be neutralized by the addition of a small amount of acid, and an acid water may be corrected by the addition of a small amount of some alkali.

The injurious action of iron in alizarine dyeing is sometimes corrected by the addition of ammonium sulpho-cyanate.

The addition of sodium carbonate, sodium chromate and bichromate, and barium chloride in the right proportion to a hard water that is to be used for boiler purposes will often cause the precipitation of the injurious mineral matter in a finely divided non-incrusting condition, and if blown out of the boiler at regular intervals, the introduction of a softening plant may sometimes be avoided.

If a hard water is to be used for scouring purposes, sufficient sodium carbonate should be added to precipitate the calcium and magnesium before it enters the scouring bath.

DISCOVERY OF ARTIFICIAL DYESTUFFS

The present year (1906) marks the fiftieth anniversary of the discovery of the first artificial dyestuff by William Henry Perkin. The celebration of no event has ever brought forth more general

13. Describe the common silk cocoon and the process of treatment previous to reeling.

14. (*a*) What is a conditioning establishment? (*b*) To what extent is silk hygroscopic?

15. What are the principal natural impurities of cotton?

16. Give the properties of artificial silk and describe its process of manufacture.

17. Describe the microscopic appearance of cotton.

18. Describe the structural and microscopic appearance of wool.

19. Describe the microscopic appearance of linen.

20. In general, how do solutions of metallic salts and dyestuffs act toward cotton?

21. (*a*) Describe the microscopic appearance of silk. (*b*) How does it differ in this respect from wool and the vegetable fibres?

22. (*a*) What is the approximate composition of raw cotton? (*b*) Give name, properties and composition of the principal constituent.

23. What can you say about the action of cotton towards atmospheric changes?

24. (*a*) What is Ramie Fibre? (*b*) Make a list of all the vegetable fibres mentioned in the instruction paper.

25. (*a*) What takes place when wool is boiled in solutions of various metallic salts? (*b*) Illustrate with the case of Aluminum Sulphate Solution.

26. Give composition of raw silk.

27. How does linen differ from cotton in composition?

28. Compare the average length of cotton, linen, wool and silk fibres.

29. (*a*) Describe the ordinary hydrometer. (*b*) Upon what fact is its utility based?

30. Give the object of the Hackling Process and its products.

31. (*a*) Define wool. (*b*) How are the different grades separated and what is the process called?

32. (*a*) How does jute differ from linen and cotton in composition? (*b*) How does jute act toward certain dyestuffs?

interest among men of science and chemical industry and been more fittingly observed both in America and abroad, than this discovery. Perkin made his discovery when but a youth of eighteen, and no doubt the interest in this celebration is greatly enhanced by the fact that Perkin is still alive, actively engaged in chemical research, and is the central figure of the various exercises and festivities.

In presenting an account of Perkin's early investigations, we can do no better than quote, directly, his own words abstracted from a lecture on Hofmann, delivered by Dr. Perkin and published in the Journal of the Chemical Society of June, 1896.

"As a young chemist I was ambitious enough to wish to work on the subject of the artificial formation of natural organic compounds. Probably from reading some remarks on the importance of forming quinine, I began to think how it might be accomplished, and was led by the then popular additive and subtractive method to the idea that it might be formed from toluidine by first adding to its composition C_3H_4- by substituting allyl for hydrogen, thus forming allytoluidine, and then removing two hydrogen atoms and adding two atoms of oxygen, thus

$$\underset{\text{Allytoluidine}}{2(C_{10}H_{13}N)} + 3O = \underset{\text{Quinine}}{C_{20}H_{24}N_2O_2} + H_2O$$

"The allytoluidine having been prepared by the action of allyl iodide on toluidine, was converted into a salt and treated with potassium dichromate; no quinine was formed, but only a dirty reddish-brown precipitate. Unpromising though this result was, I was interested in the action, and thought it desirable to treat a more simple base in the same manner. Aniline was selected, and its sulphate was treated with potassium dichromate; in this instance a black precipitate was obtained, and, on examination, this precipitate was found to contain the colouring matter since so well known as Aniline Purple or Mauve, and by a number of other names. All these experiments were made during the Easter vacation of 1856 in my rough laboratory at home. Very soon after the discovery of this colouring matter I found that it had the properties of a dye, and that it resisted the action of light remarkably well.

"After the vacation, experiments were continued in the evening when I had returned from the Royal College of Chemistry, and combustions were made of the coloring matter. I showed it to my friend Church, with whom I had been working, on his visiting my laboratory, and who, from his artistic tastes, had a great interest in colouring matters, and he thought it might be valuable, and encouraged me to continue to work upon it; but its evident costliness and the difficulties of preparing aniline on the large scale, made the probability of its proving of practical value appear very doubtful. Through a friend, I then got an introduction to Messrs. Pullar, of Perth, and sent them some specimens of dyed silk. On June 12th, 1856 I received the following reply:

"'If your discovery does not make the goods too expensive, it is decidedly one of the most valuable that has come out for a very long time. This colour is one which has been very much wanted in all classes of goods, and could not be obtained fast on silks, and only at great expense on cotton yarns. I enclose you pattern of the best lilac we have on cotton—it is dyed only by one house in the United Kingdom, but even this is not quite fast, and does not stand the tests that yours does, and fades by exposure to air. On silk the colour has always been fugitive; it is done with cudbear or archil, and then blued to the shade.'

"This somewhat lengthy extract is quoted because it gives a glimpse at the state of the dyeing trade in reference to this shade of colour at that period.

"This first report was very satisfactory; the "if" with which it commenced was, however, a doubtful point.

"During the summer vacation, however, the preparation of the colouring matter on a very small technical scale was undertaken, my brother (the late T. D. Perkin) assisting me in the operations, and, after preparing a few ounces of the product, the results were thought sufficiently promising to make it desirable to patent the process for the preparation of this colouring matter. This was done on August 26, 1856. (Patent No. 1984.)

"A visit was then made to Messrs. Pullar's and experiments on cotton dyeing were made, but as no suitable mordants were known for this colouring matter, only the pale shades of colour, produced by the natural affinity of the dye for the vegetable fibre, were obtained; these, however, were admired. Experiments on calico printing were also made at some print works, but fears were entertained that it would be too dear, and, although it proved to be one of the most serviceable colours as regards fastness, yet the printers were not satisfied with it because it would not resist the action of chloride of lime like madder purple.

"Although the results were not so encouraging as could be wished, I was persuaded of the importance of the colouring matter, and the result was that, in October, I sought an interview with my old master, Hofmann, and told him of the discovery of this dye, showing him patterns dyed with it, at the same time saying that I was going to undertake its manufacture, and was sorry that I should have to leave the Royal College of Chemistry. At this he appeared much annoyed, and spoke in a very discouraging manner, making me feel that perhaps I might be taking a false step which might ruin my future prospects. I have sometimes thought that, appreciating the difficulties of producing such compounds as aniline and this colouring matter on a large scale, Hofmann perhaps anticipated that the undertaking would be a failure, and was sorry to think that I should be so foolish as to leave my scientific work for such an object, especially as I was then but a lad of eighteen years of age; and I must confess that one of my great fears on entering into technical work was that it might prevent my continuing research work, but I determined that, as far as possible, this should not be the case.

"Still, having faith in the results I had obtained, I left the College of Chemistry and continued my experiments, and found that not only aniline, but also toluidine, xylidine, and cumidine gave a purple colouring matter when oxidized.

"The following is a copy of the principal part of the complete specification of the patent I took out at that time:

DYEING FABRICS

"'The nature of my invention consists in producing a new colouring matter for dyeing with a lilac or purple colour stuffs or silk, cotton, wool, and other materials in the manner following:

"'I take a cold solution of sulphate of aniline, or a cold solution of sulphate of toluidine, or a cold solution of sulphate of xylidine, or a cold solution of sulphate of cumidine, or a mixture of any of such solutions with any others or other of them, and as much of a cold solution of a soluble bichromate as contains base enough to convert the sulphuric acid in any of the above-mentioned solutions into a neutral sulphate. I then mix the solutions and allow them to stand for 10 to 12 hours, when the mixture will consist of a black powder and a solution of a neutral sulphate. I then throw this mixture upon a fine filter, and wash it with water till free from the neutral sulphate. I then dry the substance thus obtained at a temperature of 100° C., or 212° F., and digest it repeatedly with coal-tar naphtha, until it is free from a brown substance which is extracted by the naphtha. Any other substance than coal-tar naphtha may be used in which the brown substance is soluble and the colouring matter is not soluble. I then free the residue from the naphtha by evaporation, and digest it with methylated spirit, or any other liquid in which the colouring matter is soluble, which dissolves out the new colouring matter. I then separate the methylated spirit from the colouring matter by distillation, at a temperature of 100° C. or 212° F.'"

As stated above, this coal-tar colouring matter, known as Mauve was patented the 26th of August, 1856, and after a number of obstacles and defects had been overcome, the actual manufacture of this dyestuff began at Greenford Green, near Harrow, England, in December of 1857. From this small beginning, the artificial dyestuff industry has grown so as to have become one of the most, if not the most extensive of the chemical industries, and to-day there are at least fifty concerns actively engaged in the manufacture of coal-tar coloring matters. Of this number more than half are located in Germany, and among these are some of enormous magnitude, as for instance, The Badische Anilin und Sodafabrik, Ludwigshafen am Rhein; The Farbenfabriken Company, of Elberfeld, Germany; Leopold Cassella and Co., Frankfort-am-Main; The Hoechst Farbwerke; and the Berlin Aniline Works.

The five concerns, just mentioned, probably manufacture 75% of all of the artificial dyestuffs made, and the following statistics in regard to the Hoechst Farbwerke, collected in 1904,* will give an excellent idea as to the extent to which the industry has developed.

* From "Year Book for Colorists and Dyers." Vol. VII, 1904.

THE HOECHST FARBWERKE IN 1904

Workmen	5000
Overseers	200
Chemists	185
Technical Officials	60
The commercial department, excluding salesmen	340

The total ground covered by the works including dwellings for workmen is 341.28 acres.

Corporation buildings under cover, excluding dwellings, 59.82 acres.

Railway Track	26.09 miles
Locomotives	18
Steam Cranes	4
Wagons	1060
Steam boilers	118
With heating surface of	116,389 sq. ft.
Steam engines	210
Capacity	12,200 h. p.
Electric motors	130
Capacity	2800 h. p.

The works are lighted with 370 arc lights and 6000 incandescent lights.

The daily consumption of coal is	662 tons
The daily water consumption is	145,49350 gallons
The daily gas consumption is	529,717 cu. ft.
The daily ice consumption is	750,000 lbs.

OUTPUT

The total movement in and out by rail is 268,963 tons.

The total movement in and out by water is 319,670 tons.

The various beneficial organizations of the Farbwerke have grown so that now the statistics are as follows:

The Kaiser Wilhelm and Augusta funds amount to	1,688,000 marks
The Overseers' Pension Fund	332,000 marks
Pension fund of executive and clerical force	1,653,000 marks
The reserve of the department sick relief fund is now	142,000 marks
The savings bank deposits amount to	668,000 marks

The improvements contemplated have been finished during the past year and the dwellings for workmen and overseers number now 670, besides 50 residences for the official staff.

The pension and relief system of this concern is worthy of special notice, for all sick and injured workmen, as well as those who have reached a certain age, receive sufficient money to comfortably provide for them. Extensive libraries, dormitories, restaurants, bath houses, and a savings bank are also provided by this progressive concern for its employes.

CHRONOLOGY OF IMPORTANT DISCOVERIES IN THE COAL-TAR DYESTUFF INDUSTRIES

The following chronology of some of the important discoveries in regard to the coal-tar industry will give some idea of its development.

1856 Perkin's Mauve. First artificial dyestuff prepared on a commercial scale.
1858 Hofmann's Aniline Red or Magenta. Discovered and manufactured the following year by Verguin.
1863 Aniline Black. Patented by Lightfoot.
1864 Bismark Brown. (First important azo dyestuff prepared.)
1864 Martius Yellow. (First important nitro dyestuff prepared.)
1868 Artificial Alizarine. Prepared by Grabe and Liebermann.
1874 Eosine, the first of the phthalic anhydride colors prepared.
1876 Discovery of the Griess reaction, which lead to the manufacture of Chrysoidine and the many azo dyestuffs which followed.
1877 Introduction of the process of sulphonating basic colors.
1880 Artificial preparation of indigo by Baeyer.
1884 Congo Red, first of the Direct Cotton Colors, prepared by Boettiger,
1890-1896 Introduction of the insoluble azo colors and the development of the sulphur colors and mordant acid colors.

NUMBER OF ARTIFICIAL DYESTUFFS

The latest edition (1902) of Schultz and Julius, "Tabellarische Uebersich der Kunstlichen Organischen Farbstoffen" (Tabular View of the Artificial Organic Dyestuffs), which is the standard dictionary of the coal-tar colors, describes 681 dyestuffs of different chemical composition.

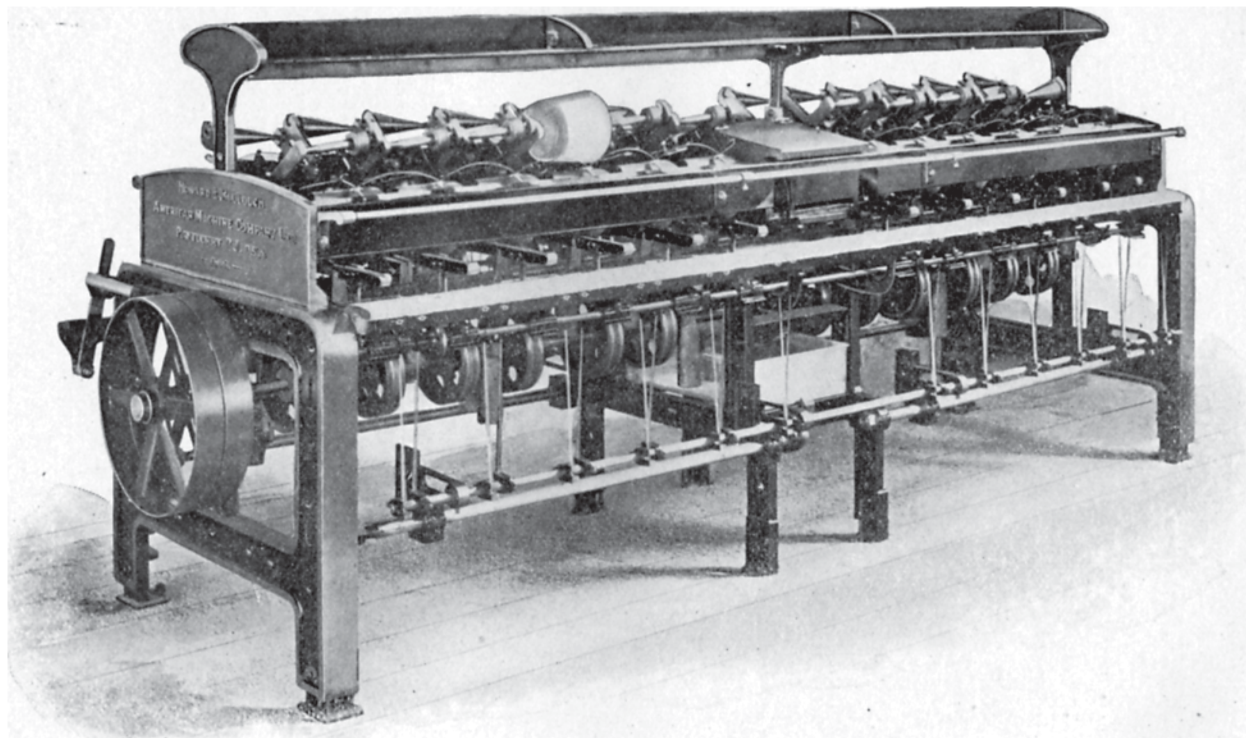
NOTE: The development of the artificial dyestuff industry is well illustrated by the following table which gives the period of introduction of these 681 dyestuffs.

16	Previous to	1860
39	Between	1860-1870
125	"	1870-1880
261	"	1880-1890
240	"	1890-1902

This number by no means represents all the artificial dyestuffs. Thousands are upon the market, but examination will show that many, though sold under entirely different names, are identical. Malachite Green, for instance, has no less than fifteen different names assigned to it by different manufacturers. Many others will be found to be mixtures of two or more distinct colors.

Many dyestuffs have been rendered obsolete by the introduction of newer ones of the same class which are either cheaper or faster and often both. Many others are discovered but, for some reason, are never put upon the market.

Although the number is constantly increasing, and every monthly report publishes many new patents, we may safely say that, at the present time, there are upon the market not more than fifteen hundred dyestuffs that are of different composition.



IMPROVED CONE WINDER

Howard & Bullough American Machine Co. (Ltd.)

TEXTILE CALCULATIONS.

SIZES OF YARNS — NUMBERING.

The sizes of yarns are designated by the terms *cut*, *run*, *hank*, *count*, *skein*, *dram*, *grain*, *etc.*, all of which are based upon two elementary principles, *i.e.*, weight and length. Each term represents a certain length of yarn for a fixed weight, or *vice versa;* but unfortunately there are different standards of weights and measures, which results in a great deal of confusion. The largest variety of terms is found in the woolen industry. In the United States we have woolen cut, run, grain, etc., when all may be reduced to a common basis. There is no doubt that the adoption of an international standard would benefit the textile industry, but which standard to adopt is a question on which manufacturers disagree.

A simple method would be 1,000 metres as the unit of length, to be called count or number, and the number of units which weigh one kilogram to represent the counts or number of yarn. By this method the counts of the yarn would always show at a glance the number of metres per gram, as

No. 1— 1,000 metres = 1 kg.
No. 2— 2,000 metres = 1 kg.
No. 2½—2,500 metres = 1 kg.

WOOLEN COUNTS.

The simplest method in use at present is the one used in the New England States, in which No. 1 woolen yarn represents 100 yards to the ounce, or 1,600 yards to the pound, as a standard. The number of the yarn is the number of yards contained in one ounce, divided by 100. The yarn is spoken of as so many hundred yards to the ounce. Thus,

No. 4 = 400 yards to 1 ounce.
No. 4½ = 450 yards to 1 ounce.
No. 5 = 500 yards to 1 ounce.
No. 5⅛ = 512.5 yards to 1 ounce.

A comparison of Troy and Avoirdupois weights may be made by the following tables. The Avoirdupois table should be committed to memory, as it is used very extensively in Textile Calculations.

AVOIRDUPOIS WEIGHT.

437.5	grains (gr.)	= 1 ounce (oz.)
16	drams (dr.)	= 1 ounce.
7,000	grains	= 1 pound (lb.)
16	ounces	= 1 pound.
100	pounds	= 1 hundredweight (cwt.)
20	hundredweight	= 1 ton (t.)

NOTE.—25 pounds are sometimes called a quarter.

TROY WEIGHT.

24 grains (gr.)	= 1 pennyweight (pwt.)
20 pennyweights	= 1 ounce (oz.)
5,760 grains	= 1 pound (lb.)
12 ounces	= 1 pound.

It is necessary to familiarize one's self with the standard numbers of the various yarns; also, as in the case of woolen yarns, where different standard numbers are used for the various terms, it is well to be familiar with the standard number of each term, as by this means a great deal of confusion will be avoided.

TABLE OF RELATIVE COUNTS OF YARN.

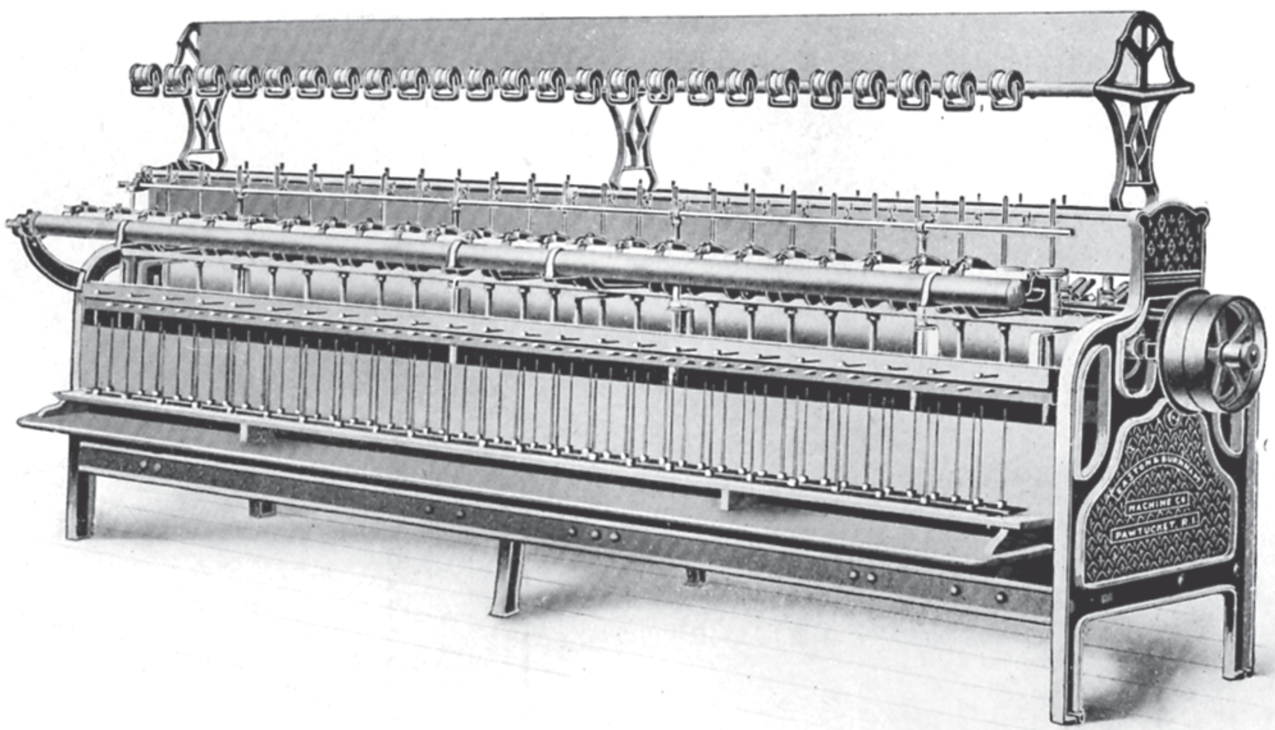
Yarn.	Size.	Standard Number.
Woolen	No. 1 run	= 1,600 yards per lb.
"	No. 1 cut	= 300 " " "
"	No. 1 skein	= 256 " " "
Worsted	No. 1 count	= 560 " " "
Cotton	No. 1 count	= 840 " " "
Linen	No. 1 lea	= 300 " " "
Spun silk	No. 1 count	= 840 " " "

Such fibres as linen, jute, hemp and ramie fibre are usually figured by the lea of 300 yards to the pound. In the grain system the weight in grains of 20 yards designates the counts. Thus, if 20 yards weigh 20, 25, or 30 grains the counts would be No. 20, No. 25 or No. 30 grain yarn respectively.

SILK COUNTS.

Spun Silk is based upon the same system as cotton, *i.e.*, hank of 840 yards, and the number of such hanks which weigh one pound denotes the counts.

NOTE.—Silk that has been re-manufactured or re-spun is called spun silk.



DOUBLING SPOOLER EQUIPPED WITH STOP-MOTION

Easton & Burnham Machine Co.

and $150 \times 2.25 \div 5.5 = 61\frac{4}{11}$ of 8's worsted.
$150 \times 2.25 \div 5.5 = 61\frac{4}{11}$ of 8's "
$150 \times 1 \div 5.5 = 27\frac{3}{11}$ of 12's "
150 pounds of loop yarn.

To Find the Weight of a Given Yarn to be Twisted With a Yarn, the Weight and Counts Being Known. The problem may now be put in a different way. There may be a given quantity of one of the yarns, and it is required to find what weight will be necessary to twist with it and just use it up. This is obviously the reverse of the above proceeding, and at once resolves itself into a simple proportion, being dependent only upon the relative counts; thus 20's and 30's are to each other as 2 is to 3, and, as the higher number is the lighter yarn, the proportion must be inverse.

Supposing then, that there are 400 pounds of 30's yarn and it is required to find how much 20's would be necessary to twist with it. The problem would be as $20 : 30 :: 400 : \times = 600$. Proof: 600 pounds of 20's would contain $600 \times 20 = 12{,}000$ hanks, and 400 pounds of 30's would contain 12,000 hanks, so that the length of each would be equal.

Rule 21. Multiply the given weight by its counts and divide by the counts of the required weight and the quotient will be the weight required.

Example. If you have 480 pounds of 30's cotton, what weight of 26's cotton would be required to twist with it to work it all up, and what will be the counts of the resulting twist?

$$480 \times 30 \div 26 = 553\tfrac{11}{13} \text{ pounds.}$$

$$\frac{26 \times 30}{26 + 30} = 13\tfrac{13}{14} \text{ counts.}$$

Proof.

$$480 \times 30 = 14{,}400 \text{ hanks.}$$

$$553\tfrac{11}{13} \times 26 = 14{,}400 \text{ hanks.}$$

AVERAGE COUNTS.

When average counts are required, it is assumed that the threads are contiguous in the woven fabric and retain their respective individualities, *e.g.*, when two or more threads of various sizes are used side by side in a fabric. It is frequently necessary to determine the average counts of these threads, that is, the counts which will represent the same weight and length for the combination of several yarns employed in the woven fabric. Suppose a cloth is woven with the pattern as follows: 2 threads of 60's cotton, and 1 thread of 20's cotton. What is the average counts?

Rule 22. Multiply the high count by the number of threads of each count in one repeat of the pattern.

$$60 \times 2 = 120 \text{ hanks.}$$
$$60 \times 1 = 60 \text{ "}$$

Divide each product separately by the given counts.

$$120 \div 60 = 2 \text{ pounds.}$$
$$60 \div 20 = 3 \text{ "}$$
$$180 \qquad 5 \text{ pounds.}$$

Divide the total number of hanks by the sum of these quotients.

$$180 \div 5 = 36 \text{ average counts.}$$

Rule 23. To find the average counts when any number of threads of different counts are used in the same cloth. Divide the product of the counts by the sum of the unequal counts, then multiply by the number of threads in one repeat of the pattern. The answer is the average counts.

A sample is composed of 1 thread of black 16's cotton, and 1 thread of white 40's cotton. Find the average counts.

$$\frac{40 \times 16 = 640}{16 + 40 = 56} = 11.45 \times 2 = 22.86 \text{ average counts.}$$

The threads are laid side by side in the pattern, and each one retains its individuality, therefore, the average weight of the threads is half that of the compound thread, or the average counts is double the counts of the compound thread.

A pattern is composed of 2 threads of 40's black cotton, and 1 thread of 16's red cotton. Find the average counts.

A sample is composed of 1 thread of black 16's cotton, and 1 thread of white 40's cotton. Find the average counts.

$$\frac{40 \times 16 = 640}{16 + 40 = \ \ 56} = 11.43 \times 2 = 22.86 \text{ average counts.}$$

The threads are laid side by side in the pattern, and each one retains its individuality, therefore, the average weight of the threads is half that of the compound thread, or the average counts is double the counts of the compound thread.

A pattern is composed of 2 threads 40's black cotton, and 1 thread 16's red cotton. Find the average counts.

$$\begin{array}{rl} 40 \times 2 = & 80 \\ 40 \times 1 = & 40 \\ \hline & 120 \end{array} \qquad \begin{array}{rl} 80 \div 40 = & 2 \\ 40 \div 16 = & 2.5 \\ \hline & 4.5 \end{array}$$

$120 \div 4.5 = 26.66$ average counts.

$$\begin{array}{rl} 40 \div 40 = & 1 \\ 40 \div 40 = & 1 \\ 40 \div 16 = & 2.5 \\ \hline & 4.5 \end{array}$$

$40 \div 4.5 = 8.88 \qquad 8.88 \times 3 = 26.64$ average counts.

A pattern is composed of 4 threads of 80's white cotton, 2 threads of 40's black cotton, and 1 thread of 16's red cotton. Find the average counts.

$$\begin{array}{lll} 80 \div 80 = 1 \times & 4 \text{ threads} = & 4 \\ 80 \div 40 = 2 \times & 2 \text{ threads} = & 4 \\ 80 \div 16 = 5 \times & 1 \text{ thread} = & 5 \\ \hline & 7 & 13 \end{array}$$

$$\frac{80 \times 7}{13} = 43\tfrac{1}{3} \text{ average counts.}$$

Proof. Obtain the weight of one hank of each count given, then the weight of an average hank with the threads of the proportion given, and find what would be the counts of that weight.

1 hank of 80's = 7,000 ÷ 80 = 87.5 grains.
1 hank of 40's = 7,000 ÷ 40 = 175. grains.
1 hank of 16's = 7,000 ÷ 16 = 437.5 grains.

$$\begin{array}{lll} 80 = 87.5 & \times 4 = & 350 \\ 40 = 175. & \times 2 = & 350 \\ 16 = 437.5 & \times 1 = & 437.5 \\ \hline & 7 & 1137.5 \text{ grains.} \end{array}$$

$1137.5 \div 7 = 162.5$ grains average.

$7{,}000$ grains $\div\ 162.5 = 43\frac{1}{3}$ average counts.

UNKNOWN COUNT IN A COMPOUND OR TWIST THREAD.

Occasionally, it happens that a manufacturer or spinner has given to him the counts of a novelty or fancy twist yarn, also the counts of one or more of the threads of which it is composed. It then becomes necessary to find the size of the unknown thread which, together with the known counts, makes the compound twist yarn.

Rule 24. To find the required counts of a single yarn to be twisted with another, the counts of which is already known, to produce a compound or twist thread of a known count. Multiply the counts of the known single thread by the counts of the compound or twist thread, and divide the product by the known counts of the single thread minus the known counts of the compound thread. The quotient will be the counts of the required single thread.

Example. Having some yarn in stock, the counts of which is 1-30's cotton, it is desired to produce a compound or twist thread equal to 1-12's cotton. Find the count of the required thread.

$$\frac{30 \times 12}{30 - 12} = \frac{360}{18} = 20\text{'s required thread.}$$

Proof.
$$\frac{30 \times 20}{30 + 20} = \frac{600}{50} = 12\text{'s twist or compound thread.}$$

In the cotton trade, worsted and silk threads are twisted with cotton. In the worsted trade, cotton and silk threads are twisted with worsted. In the woolen trade, cotton, silk, and worsted threads are twisted with woolen.

For the cotton trade, transfer the worsted and silk to cotton counts. For the worsted trade, transfer the cotton and silk to worsted counts. For the woolen trade, transfer the cotton, silk, and worsted to woolen numbers.

Rule 25. Two known single thread, a third thread required to produce a known compound thread. First find the size of the two known threads twisted together, then proceed as in previous examples.

Find the counts of the third thread to twist with a 1-30's cotton thread, and 1-60's cotton thread, to produce a three-ply thread equal to a 12's cotton.

$$\frac{60 \times 30 = 1{,}800}{60 + 30 = \quad 90} = 20\text{'s cotton.}$$

$$\frac{20 \times 12 = 240}{20 - 12 = \quad 8} = 30\text{'s required.}$$

Proof. Three-ply twist, 60's, 30's and 30's.

$60 \div 60 = 1$
$60 \div 30 = 2 \quad 60 \div 5 = 12$'s 3-ply thread.
$60 \div 30 = 2$
$\overline{\quad 5}$

Find the size of a worsted thread to twist with a 1-30's cotton. to produce a two-ply thread equal to a 2-30's cotton.

2-30's = 1-15's cotton.

$$\frac{30 \times 15 = 450}{30 - 15 = \quad 15} = 30\text{'s cotton.}$$

$$840 \times 30 = 25{,}200$$

$$\frac{25{,}200}{560} = 45\text{'s required worsted thread.}$$

EXAMPLES FOR PRACTICE.

1. A pattern is composed of 4 threads of 80's black worsted, 3 threads of 60's white worsted, and 1 thread of 16's blue worsted. Find the average counts.

2. Find the counts of the required thread to twist with a 40's cotton to produce a compound thread equal to a 24's.

3. Find what counts twisted with 24's cotton would produce a compound thread equal to a 9's cotton.

4. Required the counts of a spun silk thread to twist with a 20's cotton and a 30's worsted to produce a 3-ply thread equal to a $3\frac{1}{2}$-run woolen.

5. Find the counts of a third thread to twist with a 30's cotton, and a 20's cotton to produce a 3-ply thread equal to a 12's cotton.

CONSTANTS.

In figuring textiles there are many numbers which are constantly repeated, thus making it desirable to dispense with some of them by cancelling one into the other, for instance: 7,000 ÷ 840 7,000 ÷ 1,600. 7,000 ÷ 560, etc.

These numbers are also used in reverse order, one being multiplied by, or divided into, the other very frequently. To simplify these calculations, the following constants have been worked out and will prove a valuable reference table:

Long Method		First Constant	Second Constant.
Woolen	7,000 ÷ 1,600 =	4.375 ÷ 36 =	.1215
Worsted	7,000 ÷ 560 =	12.5 ÷ 36 =	.3472
Cotton	7,000 ÷ 840 =	8.33 ÷ 36 =	.2314
Linen	7,000 ÷ 300 =	23.33 ÷ 36 =	.648

Woolen	1,600 ÷ 7,000 = .228
Worsted	560 ÷ 7,000 = .08
Cotton	840 ÷ 7,000 = .12
Linen	300 ÷ 7,000 = .043

Frequently the counts of a very small amount of yarn is required, and to obtain the necessary data, a pair of fine grain scales is one of the most necessary pieces of apparatus required in a manufacturer's or designer's office.

Suppose a sample of woolen cloth contains 40 threads per inch and the sample is 2 inches long, then there would be $40 \times 2 = 80$ inches of yarn, and these threads weigh 2.5 grains. What is the run of the yarn ?

Rule 26. Multiply the number of inches of yarn by 7,000 (the number of grains in 1 lb.), and divide by the weight (in grains) of the yarn, multiplied by the standard number, and by 36. The answer will be the run of the yarn.

$$\frac{80 \times 7,000}{2.5 \times 1,600 \times 36} = 3.88 \text{ run.}$$

Example. If a sample of cotton cloth 1 inch long has 40 warp threads in 1 inch, and the yarn weighs 2.5 grains, what is the count?

$$\frac{40 \times 7,000}{2.5 \times 840 \times 36} = \text{No. } 3.7037.$$

Explanation. As there are 7,000 grains in 1 lb. and 840 yards of number 1 yarn in 1 lb. 7,000 ÷ 840 gives the number of grains in one yard of number 1 yarn, or $8\frac{1}{3}$ grains. The constants, as we have 40 warp threads per inch, $8\frac{1}{3}$ grains, multiplied by 40 gives us the weight in grains of one running yard of number 1 warp one inch in width, or $333\frac{1}{3}$ grains.

As one square inch of warp weighs 2.5 grains, one running yard one inch wide would weigh $2.5 \times 36 = 90$ grains. Now, as 90 grains is the actual weight of the yarn, and $333\frac{1}{3}$ grains the weight of an equal quantity of number 1 yarn, the number of our warp yarn is the number of times the weight of number 1 yarn is greater than the given yarn, or

$$333.33 \div 90 = 3.7037 \text{ cotton counts.}$$

Example. Supposing 12 threads worsted were obtained, each 36 inches long with a total weight of 1 grain, what is the counts? *

$$\frac{7{,}000}{560} = 12.5 \text{ grains, the weight of 1 yard of number 1 worsted.}$$

Therefore, if 1 yard of yarn weighs $12\frac{1}{2}$ grains, the counts are 1's, or if 2, 3, 4, or 5 yards weigh $12\frac{1}{2}$ grains, the counts are 2's, 3's, 4's, or 5's respectively, or the number of yards of yarn which weigh $12\frac{1}{2}$ grains is equivalent to the counts in worsted.

Then the counts in the above example would be number $12\frac{1}{2}$, because $12\frac{1}{2}$ yards would be required to weigh $12\frac{1}{2}$ grains.

If 48 inches of woolen yarn weigh 2 grains, what is the run?

Long method. $$\frac{48 \times 7{,}000}{2 \times 1{,}600 \times 36} = 2.916, \text{ say } 2.9 \text{ run.}$$

First constant. $$\frac{48 \times 4.375}{2 \times 36} = 2.916 \text{ run.}$$

Second constant. $$\frac{48 \times .1215}{2} = 2.916 \text{ run.}$$

If 96 inches of cotton yarn weigh 2 grains, what is the counts?

Long method. $$\frac{96 \times 7{,}000}{2 \times 840 \times 36} = 11.10 \text{ counts.}$$

First constant. $$\frac{96 \times 8.33}{2 \times 36} = 11.10 \text{ counts.}$$

Second constant. $$\frac{96 \times .2314}{2} = 11.10 \text{ counts.}$$

If 75 inches of worsted yarn weigh 2.5 grains, what is the count?

Long method. $$\frac{75 \times 7{,}000}{2.5 \times 560 \times 36} = 10.416 \text{ counts.}$$

*NOTE—This subject is again taken up in Yarn Testing.

First constant. $\frac{75 \times 12.5}{2.5 \times 36} = 10.416$ counts.

Second constant. $\frac{75 \times .3472}{2.5} = 10.416$ counts.

YARN TESTING.

The term "Yarn Testing" means a great deal more than the casual observer in a mill supposes. Failure to test yarn, or imperfect testing may cause serious trouble. It is often necessary to test yarns in a variety of ways, and for different purposes. The most common test, and it may be safely said the only test which is applied in a large number of mills, is to ascertain the counts, but there are instances when the yarn should be tested for *strength, elasticity, evenness, and for quality.*

This latter test in some cases is a difficult one, and the question often arises as to what is meant by quality. As applied to yarns, the term quality is difficult to define briefly and accurately, in fact, it may almost be said that it cannot be defined, because as applied to different classes of yarn it has altogether different meanings. Without attempting to give definitions, an effort will be made to show what the different qualities or characteristics of yarn comprise, and so ascertain what tests are necessary to decide their suitability for the purpose to which they are to be applied.

The first step in yarn testing is to test the counts, which means to find the weight and size of the yarn. As previously explained, there must be some standard measurement or weight, and some means of determining the bulk or quantity of yarn. In this case the determination is based upon the length of yarn in a given weight, as, for instance, the number of yards per pound, ounce, or grain; but in different yarns and different sections of the country, this is a variable quantity. For example, the counts of cotton are figured by hanks per lb., and the hank contains 840 yards. Worsted is also figured by the hank, but the length of yarn is 560 yards. The basis of linen calculations is the lea, which is practically equivalent to the hank, but contains 300 yards. Woolen is reckoned in a variety of ways, but chiefly by 1,600 yards to the pound.

There appears then to be only one way of dealing with this subject so as to meet the requirements of students of different districts, and that is, to deal with it on general lines, and illustrate with examples from the best known and generally recognized system of counting yarns, and in such a manner that the student can readily adapt himself to any other system.

Testing for Counts. The process of testing for counts in the cotton and worsted systems, in which the method of indicating the count is general, may now be explained. In testing these yarns in the mill, there are two systems in use; one by what is known as the "quadrant", which is a balance with a graduated scale and upon which a certain number of yards is placed, when a pointer indicates the counts; the other system is by weighing with an ordinary fine balance and grain weights. The latter test is frequently done in a careless manner and very inferior balances employed, with the result that the tests are very unsatisfactory.

The "*quadrant*" arrangement is very useful because the indicator shows the counts the moment the yarn is put on the hook. The arrangement is very simple in principle, being in fact nothing more than an adjusted balance or lever. If it is arranged for cotton or worsted, the two arms of the lever, that is, the hook end and the indicator respectively are so balanced that one is, say, seven times the weight of the other, or more properly speaking that their relation to each other and to the scale is as 7 to 1. Then, if $\frac{1}{7}$ of a hank is placed upon the hook, the indicator is at once brought to the point on the scale which shows the number of hanks per pound. When cotton is to be tested, 120 yards are measured off and placed upon the balance, and the pointer at once indicates the counts; if worsted, 80 yards are measured off and balanced with a similar result.

It must be clearly understood that the "quadrant" balance is always made for a given class of work, and to weigh a given number of yards; it is not usually made so that it can be applied to every purpose, but, like most special machines, must be applied to the testing of a specified class of yarn, and a specified number of yards weighed. Of course, the operator may vary this with a little ingenuity, but this would involve calculations, and consequently the machine would lose its advantages.

Reeling. By this system any length of yarn may be reeled off and weighed and the exact counts found by calculation.

This operation is carried on by means of a reel; one of the best examples of which is shown at Fig. 1. A sufficient length of yarn can be readily measured on this machine to test the counts to the greatest degree of accuracy.

The reel is 54 inches, or one and one-half yards, in circumference, and the dial is graduated into 120 parts to indicate the number of yards reeled from each spindle. While feeding yarn upon the reel, the yarn guides and the spindles are kept in line with each other, this being very desirable, in fact, necessary when reeling fine yarns. The extra length of the yarn guides is useful in increasing the friction upon the yarn by taking a half turn or more around them. The automatic feed motion lays the yarn flat upon the reel, thus securing accurate and uniform measurement, and consequently correct results as to stretch, strength, and numbering. When the skein is taken off the reel, it is weighed and the counts calculated from the weight.

It is a common practice to reel yarn upon a machine of very inferior construction, and in a very rough manner, which of course produces doubtful results. For example, in reeling worsted yarns, it is a common practice to use a reel with a circumference of one yard, and which does not distribute the yarn in the manner indicated. The number of yards which will correspond to the intended counts of the yarn is measured off by counting the turns of the reel, then this yarn is weighed in a common apothecaries' balance against a weight of $12\frac{1}{2}$ grains, and if it balances or approximately balances the $12\frac{1}{2}$ grains, it is said to be of the counts indicated by the number of yards weighed. Similar systems are sometimes used in the cotton and woolen industries, and, in some cases, the methods are, if possible, even more crude. But, although this is the common practice, it is not sufficient for good work, therefore, we must have more complete systems.

The first question which suggests itself is, how is the $12\frac{1}{2}$ grains found to be the constant weight, and what weight would be employed for other yarns? The grain weight, being the lowest of the recognized standard weights, is made use of, and as there are 7,000 grains in one pound (Avoirdupois), this is divided by 560 (the number of yards in one hank) which gives $12\frac{1}{2}$. For cotton $8\frac{1}{3}$ grains would be the constant; for woolen, $4\frac{3}{8}$ grains.

How to ascertain the number of cotton yarn. Reel, or measure off, and weigh 9, 18, 30, 90, or any number of yards of the yarn, observing that the greater the number the more accurate the result will be.

Rule 27. Multiply the number of yards by $8\frac{1}{3}$ and divide the product by the weight of the sample in grains; the quotient will be the number of the yarn, *i.e.*, the number of hanks in a pound.

Example. Suppose 9 yards weigh 5 grains; then $9 \times 8\frac{1}{3} =$

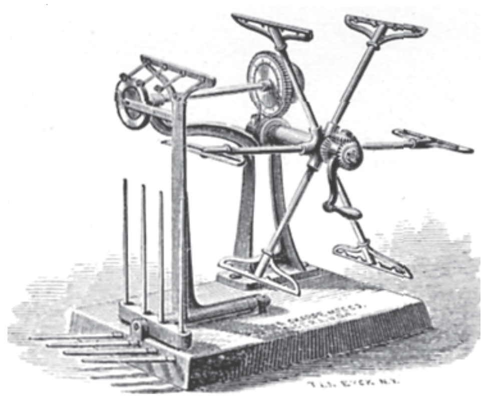


Fig. 1. Brown & Sharpe Yarn Reel.

75. $75 \div 5 =$ 15's, the number of yarn, *i.e.*, the number of hanks to a pound.

Rule 28. *To ascertain the number of linen yarn.* Reel, or measure off, and weigh 9, 18, 30, 90, or any number of yards, the greater the number the more accurate the result will be. Multiply the number of yards by $23\frac{1}{3}$ and divide the product by the weight of the sample in grains; the quotient will be the number of the yarn.

Examples. Suppose 12 yards weigh $17\frac{1}{2}$ grains; then $12 \times 23\frac{1}{3} = 280$. $280 \div 17\frac{1}{2} = 16$, the number of counts per pound. Suppose 9 yards weigh 5 grains; then $9 \times 23\frac{1}{3} = 210$. $210 \div 5 = 42$, the count of the yarn.

Rule 29. *To find the number of worsted yarn.* Reel, or measure off, and weigh 9, 18, 30, 90, or any number of yards, the greater the number the more accurate the result will be.

Multiply the yards by $12\frac{1}{2}$ and divide the product by the weight of the sample in grains; the quotient will be the number of the yarn, *i.e.*, the number of hanks or skeins to the pound.

Example. Suppose 9 yards weigh 5 grains; then $9 \times 12\frac{1}{2} = 112.5$. $112.5 \div 5 = 22\frac{1}{2}$, the number of the yarn.

Rule 30. *To find the run or number of woolen yarn.* Reel, or measure off, and weigh any number of yards of the yarn, observing that the greater the number the more accurate the result will be. Multiply the number of yards by $4\frac{3}{8}$ and divide the product

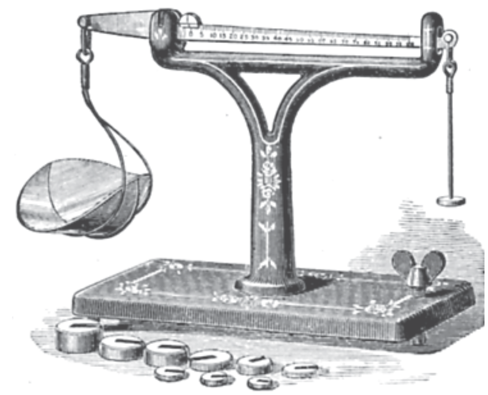


Fig. 2. Sample Scales.

by the weight of the sample in grains; the quotient will be the number of hanks per pound.

Examples. Suppose 90 yards weigh 45 grains; then $90 \times 4\frac{3}{8} = 393.75$. $393.75 \div 45 = 8\frac{3}{4}$, the number of run of the yarn. Suppose 9 yards weigh 5 grains; then $9 \times 4.375 = 39.375$. $39.375 \div 5 = 7.875$ or $7\frac{7}{8}$, the number of the yarn.

The common practice in testing yarns is what might be termed a rough and ready one, yet it is often considered sufficient in ordinary practical work, but for good analysis a more perfect and delicate system must be used.

Suppose, for instance, that it is required to reproduce a cloth, or for any purpose to make a complete analysis of it. The operation ought to be conducted with as much care and nicety as a chemist makes a quantitative analysis; in fact, it must be a quantitative analysis. The counts of the yarn must be ascertained with the greatest degree of exactitude, as well as the different quantities of the material employed, threads and picks per inch, etc., and if only a small piece of cloth is available, there must be careful work. Of course, by long experience and careful observation, a manufacturer may guess, or, as he terms it, "judge" with a degree of accuracy what the yarn is, but this is not accurate enough. He may have to try many experiments, some of them costly, before he arrives at the result desired, whereas a system of analysis, carefully carried out, will give him results at once. This applies at present to testing yarns for counts, and ascertaining the number of threads per inch in a sample, but it will apply to other systems which will come under notice in due time. Then as to the requisites for this work.

Scales. The first and most important is a good balance. Of these there are many styles which weigh to different degrees of accuracy. Small balances or scales may be had for a few dollars, and for a student who cannot give more for his own private use, they are better than nothing, certainly better than trying to guess the counts of yarn. A good balance, and one which may come within the students' reach is shown at Fig. 2. These balances are made to work with the utmost degree of accuracy, and will weigh one pound by ten thousandths of a pound.

The scales illustrated at Fig. 3 are still better, however, as they weigh by the grain system. These scales will weigh one pound by tenths of grains, or one seventy thousandth part of one pound Avoirdupois, which makes them especially well adapted for use in connection with yarn reels, for the numbering of yarn from weight of hank, giving the weight in tenths of grains to compare with tables.

These scales can be had to weigh by the metric system to $\frac{1}{100}$ gram, being supplied with weights of 1, 2, 5, 10, 20, 40, 60, 100, and 200 grams.

When the testing is merely for percentages, the gram weights are the most convenient, as they are based upon the decimal system, but where it is a question of ascertaining the counts of yarn or the weight of cloth, the grain weights are the best to use. With the above series of scales and weights, tests can be carried out to almost perfect accuracy.

When a very small quantity of yarn is available, say one or two yards, it must be weighed with great care. Of course, when a large quantity is available, find now many yards will weigh $12\frac{1}{2}$ grains, if the yarn is worsted; $8\frac{1}{3}$ grains if cotton; and so on for other yarns, according to the system of counting. Suppose, for instance, that it is required to test the yarn in a cloth, and only a small piece can be obtained, say two or three square inches. This

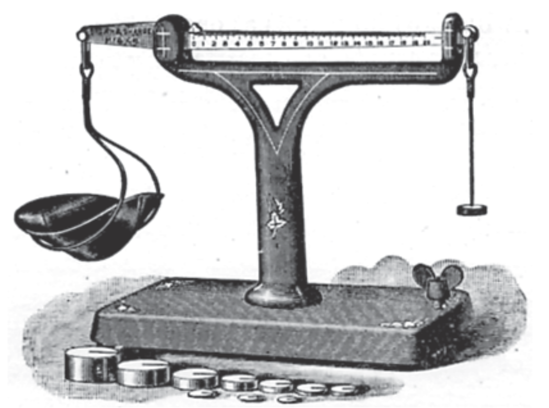


Fig. 3. Brown & Sharpe Scales.

must be measured carefully, and as many threads taken out as will make one yard, two yards, or as much as possible. For example, let it be two yards of worsted weighing $1\frac{39}{100}$ grains. Find the counts. If two yards weigh $1\frac{39}{100}$ grains, how many yards will weigh 7,000 grains? Putting it in the usual form of a proportion as $1\frac{39}{100} : 7{,}000 :: 2 : 10{,}072$ yards, or there are that number of yards in one pound. As there are 560 yards per hank in worsted, and the counts are indicated by the number of hanks per pound, the 10,072 must be divided by 560, thus $10{,}072 \div 560 = 18$ hanks nearly, then the counts would be called 18's, as it is near that number. If it were cotton, the same rule would apply, but instead of dividing by 560, the yards would have to be divided by 840 thus, $10{,}072 \div 840 = 12$ hanks, or equal to 12's counts. If it were woolen on the run system, it would be divided by 1,600, and so on for other varieties of yarn. In such small quantities as this, there is always some slight liability to error, but with careful work this should not exceed 2 per cent.

The problem may be simplified by putting it in the form of an equation. Let Y represent the number of yards or length weighed, and W the weight in grains found. There are 7,000 grains in one pound and a fixed number of yards per hank in the system upon which the yarn is counted, then

$$\frac{7{,}000 \times Y}{560 \times W} = \text{counts in worsted,}$$

$$\frac{7{,}000 \times Y}{840 \times W} = \text{counts in cotton, etc.}$$

This may be further simplified as the 7,000 grains and the yards per hank are constant numbers. Let the grains be divided by the yards per hank and find one constant number, thus for worsted

$$\frac{7{,}000}{560} = 12\tfrac{1}{2} \text{ as the constant; for cotton}$$

$$\frac{7{,}000 \times Y}{840 \times W} = 8\tfrac{1}{3} \text{ for constant.}$$

Now let C represent the constant, and the formula will stand

$$\frac{C \times Y}{W} = \text{counts.}$$

TESTING BY COMPARISON.

As we have said that in some mills yarns are tested by comparison, this lesson would not be complete without giving an idea as to the method employed.

It consists in taking a few threads from the fabric, and these are crossed and folded over the same number of threads of some known count, the two ends of each respective group of threads being held between the fingers, the group of the unknown in one hand and the known in the other. The two groups are then twisted simultaneously so as to compare their relative diameters.

Fig. 4 illustrates this method of comparing known with unknown counts. A represents the known and B the unknown counts. Take one, two or more threads of each kind of yarn and placing them together, as shown in the illustration, twist them, making, as it were, one continuous thread. By this simple act of twisting it is natural to make a comparison of the area and solidity of the threads. It is advisable to wet the yarns at the point where they are crossed, previous to twisting. During comparison, threads are added or taken from one or the other of the sets and again twisted as directed and compared until the two sets appear to make a similar thickness of thread.

It follows that when the number of threads of a known count are of equal thickness to some other number of threads of unknown counts, these numbers bear a simple and direct proportion to each other.

Fig. 4. Testing by Comparison.

Example. 6 threads of 2-30's worsted are found by twisting and comparison to equal 8 threads of some unknown count. What is the count of the unknown threads? 2-30's = 15. Then as 6 : 8 :: 15 : $\times$ = 20's, or 2-40's worsted *i.e.*, 8 threads twisted together of 2-40's are equal in thickness to 6 threads 2-30's worsted twisted together.

This method of testing is used practically, because a mill-man usually uses the nearest counts he has in stock to the counts of yarn in the sample to duplicate. Others do not trust to the eye when comparing yarns, but prefer to use a magnifying glass or microscope.

Constants for Testing Yarns for Counts by Weighing Short Lengths of Cotton.

1. 1,000 divided by weight in grains of 1 lea = counts.

2. The number of inches that weigh 1 grain $\times$ .2314 = counts.

3. Number of yards weighed $\div$ .12 $\times$ weight in grains = counts

4. The number of strands of yarn, each $4\frac{5}{16}$ inches or 4.32 inches long that weigh 1 grain = counts.

5. The number of yards weighed $\times$ $8\frac{1}{3}$ $\div$ weight in grains = counts.

STRUCTURE OF CLOTH.

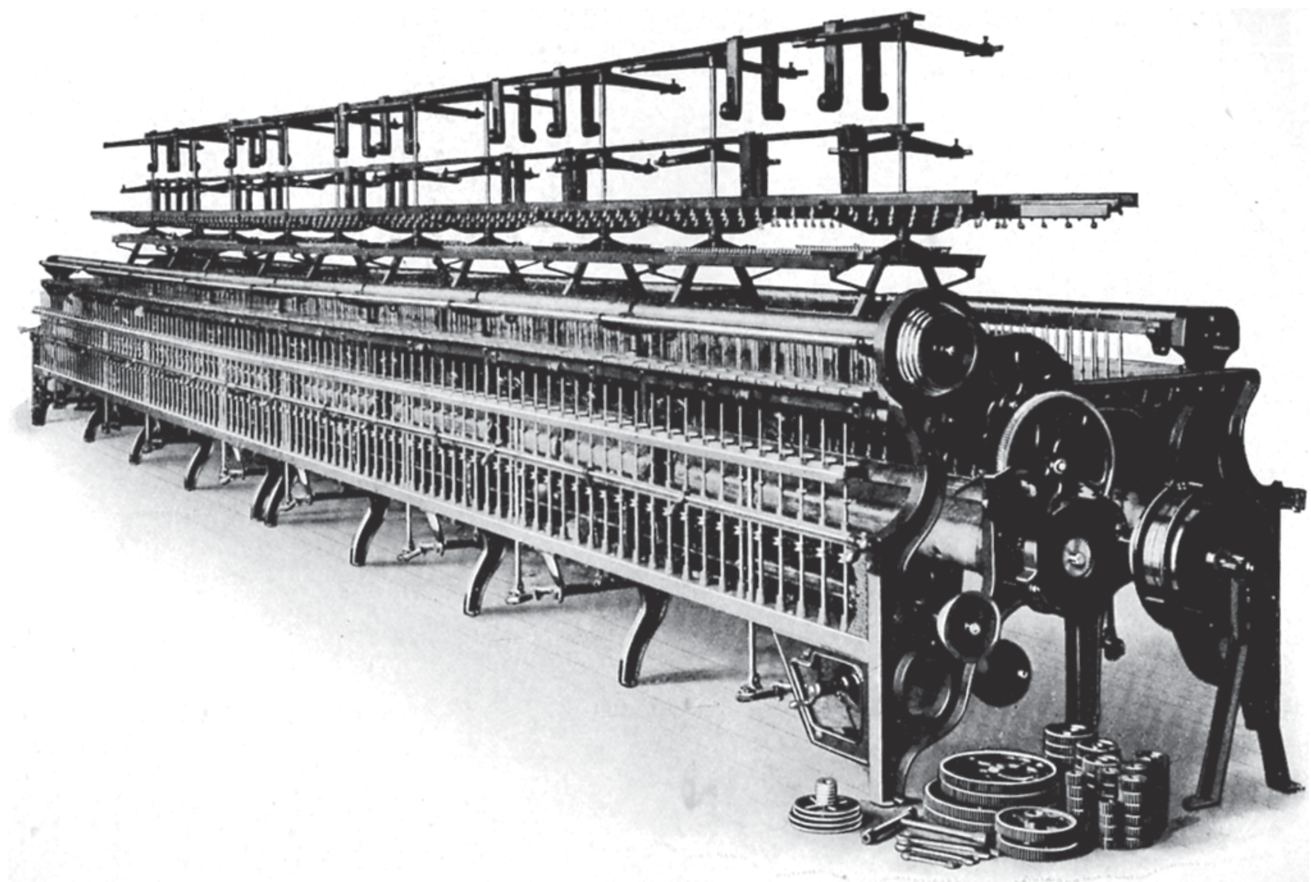
Structure of cloth does not mean the fabric, nor the yarns from which the fabric is constructed, but it designates the materials from which the fabric is made, together with the system of interweaving. It has been explained that no woven fabric can be produced without crossing, or interweaving at right angles, two distinct sets of threads. In the Instruction Papers on Textile Design several systems of interweaving are given and the meaning of plain or cotton weave, prunella twill, cassimere twill, basket or hopsack weave, five-harness sateen, etc., are explained. Now, the object is to find the *quantity and kind of yarn*, which, when used with certain weaves will produce a fabric of good structure.

The *plain weave* is the simplest texture, requiring only two threads of warp and two picks of filling to complete the full weave. Not only is it the simplest, but it is the most limited in size. If two threads are drawn in on the same harness side by side, or two picks are placed in the same opening or shed, it is not a plain weave, and if one thread is taken away, the fabric is left without any means of binding or interweaving.

Adding to the plain structure and only admitting of one additional thread and pick, we enter on the first lesson of figure and twill weaving, and the weave is designated as the *three-harness twill or prunella twill*. This is the first form of diagonal or rib effect at an angle of 45 degrees, and with the variations of this weave we can work out designs on a figured basis by twilling to the right for a number of threads and then reversing the twill, using either the warp-flush or the filling-flush weaves or combining the two.

The addition of one more thread forms the *swansdown weave*, which is a regular four-harness filling-flush twill, advancing one thread and one pick in regular consecutive order, forming a twill or diagonal at an angle of 45 degrees. We may say that with this number of threads, or this weave, the field for new combinations is unlimited, for with four harnesses, an endless variety of fabrics are constructed, such as dress goods, men's wear, etc. Weaves which repeat on four harnesses are very useful in cotton, woolen, and worsted manufacture.

Adding one more thread and one more pick gives five threads



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in the warp, and five picks in the filling; the smallest number on which a *sateen weave* may be constructed. There is in use a weave of four harnesses called the crowfoot weave, which is sometimes called a sateen or doeskin, but as the first and second threads run consecutively to the right, and the third and fourth run consecutively to the left, it cannot be a sateen. A true sateen must in no instance have two threads running consecutively either to the left or to the right.

Sateens generally have a warp-flush surface, which gives a soft and full appearance to the fabric and are used more or less in the construction of fancy figured goods and piece-dyed fabrics, such as damasks and table linen, covert coatings, beavers, etc. As the weave is either a warp-flush or a filling-flush face, the character of the cloth is always of a limited nature.

The derivatives of the sateen are very diversified in character, but more perfect in structure than those obtained from other weaves or modes of interweaving.

So far, we have been considering simple weaves or cloths constructed on a one-weave basis, but the method of constructing fabrics from a combination of several weaves, is a most comprehensive one and the effects produced cover a wide range of fabrics.

Combination of Weaves. In all cases when a fancy figured effect is required in cloth made from the same shade of yarn, this principle is invariably adopted, as every plan of interweaving, whether twill, basket, diamond, herring-bone, spotted or all-over effects, can be produced by a combination of weaves.

The essential points to be noticed in combining or amalgamating two, three, or more weaves are (*a*) class of fabrics to be constructed, (*b*) the capabilities of each weave intended to be combined with other weaves.

Some weaves are specially adapted for cotton effects, others for silk, woolen, or worsted. To combine weaves without due consideration as to their utility is a useless toil. To amalgamate weaves for fulled-woolen goods is a waste of time, as weaves for woolen goods should be of a regular and uniform character, and those nearly approaching each other are preferable. In cotton and worsted goods the opposite characteristics are desired, and the manner of interlacing is of the utmost importance; the principal feature of a worsted fabric being its decided and clearly defined weaves.

Our considerations have thus far been the structure of a fabric as affected by the weave. For our next consideration we will take the structure of a fabric as affected by its relation to warp and filling.

The *strength*, *utility*, and the *purpose of the structure* must be considered. Generally speaking, the smaller the yarns, the larger the flushes in weaves which may be employed. A cloth constructed with yarn 2,560 yards to the pound, 24 threads to the inch using the plain weave would be firm and regular in construction, but if it were woven in an 8-harness twill, 4 up and 4 down, it would be very loose, coarse and open in construction. This clearly shows that weaves that are useful for one class of yarn, are not suitable for all, so we must have in mind the quality of texture required, when laying out or constructing a cloth.

When combining weaves the importance of the filling capacity must not be lost sight of, and when several weaves are combined, the complete design must possess a similar capacity for the admission of the filling.

The construction of a cloth in its broadest sense is, to consider the weave, size of yarns and materials of which they are made, and also to enter into the details and calculations required in connection with the correct method of building a perfect structure. *The following points should be noted when constructing a fabric:*

Weave, or combination of weaves.

Judgment in selecting weaves for combination.

The class of fabric intended to be produced, whether wool, worsted, cotton, or silk.

The weaving capabilities of the separate weaves to be combined.

Weaves combined to have an equal filling capacity.

The purpose and utility of the fabric.

Nature of the raw material to be used.

The size of the yarns for warp and filling.

The number of turns of twist to be put in warp and filling yarns.

The number of threads in the warp per inch.

The number of picks of filling per inch.

The take-up in weaving.

The process in dry finishing.

Scouring, fulling, shearing.
Finishing shrinkage.

DIAMETER OF THREADS.

The square root of the yards per lb. will give the diameter of the yarn, or the number of threads which will lie side by side in one inch without being interlaced with another set of threads.

Example. Suppose a cloth is to be made from 80's cotton, and it is desired to ascertain the number of threads that will lie side by side in one inch of space.

80 × 840 = 67,200 yards of 80's cotton in 1 lb. Extracting the square root of 67,200

$$\sqrt{67{,}200} = 259.22.$$

Allow 7 per cent for shrinkage of yarn from first spin.

$$259.22 - 7\% = 241.07.$$

NOTE.—When the tension, which is put on yarn in spinning, is removed, cotton shrinks 7 per cent; worsted 10 per cent; woolen 14 per cent; and silk 4 per cent.

As a fraction, it will give the diameter of the thread, as $\frac{1}{241}$ of an inch, therefore, 241 threads of 80's cotton would lie side by side in one-inch space. The same rule will apply to woolen and worsted yarns, where the basis of the calculations is of a similar character.

Example. Suppose a cloth is wanted from 40's worsted.

$$40 \times 560 = 22{,}400 \text{ yards per lb.}$$

$$\sqrt{22{,}400} = 149.66 - 10\% = 134.70 \text{ (approximately 135.)}$$

Therefore 135 threads of 40's worsted will lie side by side in 1 inch.

Rule 31. To find the diameter of any yarn use the square root of 1 counts in yarn required, as a constant number, and multiply the square root of the counts of the required diameter by the constant. Thus the square root of 1's worsted is $\sqrt{560} = 23.66$.

$$23.66 - 10\% = 21.30$$

What is the diameter of 16's worsted yarn?

$$\sqrt{16} = 4. \quad 21.30 \times 4 = 85.20.$$

Proof. $560 \times 16 = 8{,}960.$ $\sqrt{8{,}960} = 94.65 - 10\% = 85.19.$

BALANCE OF CLOTH.

There are no definite rules to determine what is perfection in a textile fabric The term "Balance of Cloth" is capable of wide interpretation, but the generally accepted meaning is the proportion in which the warp and filling stand to each other. A second interpretation is the distance the threads are set from each other according to their weight and diameter. This would be correct if all cloths were made on the same principles, but as all classes of fabrics are not made for the same purpose, either as to wear or general utility, no definite nor systematic rules can be given that will apply to every variety of textiles.

Suppose a concern is making dress goods, and has found that the layout or construction of this fabric, on a plain weave basis, is all that can be desired. The warp and the filling threads are made of the same material, and the warp is so set in the reed that the *diameter of the threads* and the *spaces between the threads* are *equal;* the filling threads are equal in counts or diameter to the warp threads, and there are the same number of threads and spaces in the same area as there are in the warp. This layout may be considered as representing an equally balanced fabric, and it does not matter what the material may be, whether cotton, linen, woolen, or silk, the construction of such a cloth is perfect and is made on the truest principles.

Taking the plain cloth as here laid out as the foundation for a reliable basis, we have something on which to commence our further studies on cloth construction.

It very frequently happens that to produce special effects, this principle must be departed from. We may wish to make a cord or rib running in the direction of the warp, or we may wish the cord to run across the cloth in the direction of the filling. These two fabrics are made on two distinct principles, and although the variation in texture is due to alterations and modifications in the weave, the foundation of both is the plain weave. In the plain weave the threads are equal, both warp and filling being deflected, but in a corded effect, one set of threads is heavier than the other, which results in the light thread being bent and the heavy thread retaining its straightness.

In such instances, there is no space between the warp threads for they may be in *actual contact*, and the number of threads per inch determined by the diameter of the threads, without any allowance for space between them. Poplins are a good illustration of this construction. In this class of goods the cords run across the cloth, and instead of the warp threads having a space between them equal to the diameter of the threads, they must be set very closely together, and the filling threads some distance apart, otherwise the clear cord will not be produced. Care must also be taken that the filling threads are not too far apart, or the corded effect will be destroyed. When producing a cord parallel to the length of the cloth the procedure is exactly the reverse.

From these two examples we come to another conclusion, *i.e.*, on the warp cord, the warp is present in larger quantities than the filling, while on the filling cord, the filling is the larger quantity. It has been stated that as the warp or filling preponderates, it must be *increased in quantity*, and that which is least seen must be *decreased*. This rule holds good for nearly all makes of cloth.

Twilled Cloths differ very much from plain fabrics. By the construction of the weave the threads must be closer together, for the same counts of warp and filling, to produce a cloth of equal firmness. A plain cloth is interwoven at every thread and pick whereas in a twill cloth, the picks pass over a number of threads before they are interwoven, therefore, weaves which produce long floats require heavier yarn or a closer set to produce an approximate firmness of texture. The number of threads and picks per inch must be increased in proportion to the length of the floats.

In twilled cloths, the warp or filling may be made to preponderate on the face of the fabric in two ways, (*a*) as in plain cloth by having more threads of one set than of the other, at the same time decreasing the diameter of one set of threads, and increasing the diameter of the other, or (*b*) by weaving the desired set of threads on the face.

To Change From One Weave to Another and Retain the Same Perfection of Structure. As has been explained in regard to the plain fabric, when it was desired to change from the plain weave to a fancy twill or diagonal, it may occur that one of these fancy twills may be desired in some other effect, and at the same time be necessary that no alteration of the structure of the fabric take place.

A heavier or bolder twill may be desired, or it may be that the twill is too deep or prominent, or that a still lighter fabric is in demand. The layout or texture of the original fabric is known and it is required to construct a new fabric of exactly the same character, and also to use the same size and quality of yarns as in the first cloth, thus saving the expense of making new yarns. For example, we have a cloth woven with the 4-harness cassimere twill, 80 threads per inch, warp and filling being equal. We now desire the same build of cloth, made from a design that will give a bolder twill, so the 6-harness common twill $\frac{3}{3}$ is used. How many threads and picks per inch must be used in the new fabric?

(*a*) Obtain the number of threads and units in known weave.
(*b*) Obtain the number of threads and units in required weave.
(*c*) Obtain the number of threads and picks per inch in known fabric. (Threads and picks per inch is known as texture.)

Rule 32. Multiply the number of known threads or texture by the units of the known weave, and by the threads of the required weave, and divide the product by threads of known weave, multiplied by the units of required weave.

The term unit is given to the threads and intersections of a weave. For example, the plain weave has one thread up one thread down, expressed $\frac{x \mid \quad \mid}{\mid x \mid}$. Each pick of filling passes over threads 1, 3, 5, 7, etc., and under threads 2, 4, 6, 8, etc., or *vice versa*, thus forming a space between every thread and those on either side. To find the number of units, the weave should be expressed $\frac{x \mid \quad \mid}{\mid x \mid}$ the crosses representing threads, and the vertical lines representing intersections. It will be seen that the plain weave contains two threads and two intersections, or four units.

The cassimere twill would be two threads up and two threads down, expressed $\frac{xx \mid \quad \mid}{\mid xx \mid}$ which shows four threads and two intersections, or six units.

The three up and three down twill would be $\frac{xxx \mid \quad \mid}{\mid xxx \mid}$ or six threads and two intersections, or eight units.

Proceeding with the problem given above

$$\frac{\text{Texture (80)} \times \text{known weave units (6)} \times \text{threads of required weave (6)}}{\text{Threads of known weave (4)} \times \text{required weave units (8)}} = 90$$

Thus 90 threads and picks per inch on a 6-harness twill will give the same texture as 80 threads and picks per inch on a cassimere twill with the same counts of yarn.

It is required to change from the weave, 2 up, 1 down, 1 up, 2 down; to the weave 2 up, 1 down, 1 up, 1 down, 1 up, 4 down. The texture is 72 threads and 72 picks per inch.

First weave has 6 threads and 4 intersections = 10 units.

Second weave has 10 threads and 6 intersections = 16 units.

$$\frac{72 \times 10 \times 10}{6 \times 16} = 75 \text{ threads and picks per inch.}$$

If it is necessary to make the cloth lighter and maintain the structure of the heavier cloth, and to use the same yarn, a firmer weave must be used to reduce the number of threads per inch. Proceed in the following manner:

(*a*) Obtain the number of threads and units in known weave.

(*b*) Obtain the number of threads and units in the required weave.

(*c*) Obtain the texture of known weave by finding threads and picks per inch.

Rule 33. Multiply the known texture by the threads of the required weave and by the units of the known weave, and divide the product by the units of the required weave multiplied by the threads of known weave.

If a fabric woven with the weave 3 up, 1 down, 1 up, 3 down, 3 up, 1 down, 1 up, 3 down, has 80 threads per inch, and we wish to use the weave 2 up, 1 down, 1 up, 2 down, 2 up, 1 down, 1 up, 2 down, how many threads will be required to maintain the exact structure of the original cloth?

First weave has 16 threads and 8 intersections = 24 units.

Second weave has 12 threads and 8 intersections = 20 units.

$$\frac{\text{Texture (80)} \times \text{threads required weave (12)} \times \text{units of known weave (24)}}{\text{Units of required weave (20)} \times \text{threads of known weave (16.)}} = 72$$

Thus 72 threads per inch will give the same texture on the second weave that is produced by 80 threads per inch on the first weave; using same counts of yarn.

In all these examples it is assumed that the warp and filling are equal in size, quality, and texture of the fabric, and the fabric is built on the principle of what is generally understood as a square cloth.

Having determined that a truly balanced cloth is where the number of threads and picks are equal and of the same diameter, and having determined what sett of reed will give the best result for a given number of yarn, it is easy to find what sett will suit any other count of yarn to produce a similar result. For example, we will take four threads of a plain cloth.

x		x		4 threads	= 4 units.
	x		x	4 intersections	= 4 units.
					8 units.

In a fixed rule, we assume that the proportions of size of yarn warp and filling, and spaces are equal, therefore we will take the diameter or size of yarn as the unit of measurement. Supposing our sample of plain cloth to have 60 threads per inch, and we wish to change the weave to the 4-harness cassimere twill.

xx		4 threads	= 4 units.
	xx	2 intersections	= 2 units.
			6 units.

Four threads of plain cloth equal 8 units, while the same number of threads of the cassimere twill equals 6 units, therefore the twill weave will require a greater number of threads to make as perfect a fabric as the plain weave, and the increase is in proportion as 6 is to 8. Our example supposed the plain cloth to have 60 threads per inch, then to have an equal fabric with the twill weave, the problem will be $6 : 8 :: 60 : \times$ or 80 threads per inch.

As the cloth is built square, what has been said of the warp applies equally to the filling. The 4-harness cassimere twill interweaves regularly, the twill moving from end to end consecutively. Warp and filling flushes are equal, as in the plain weave, and the quantities of warp and filling on the face are equal.

Take another example—5-harness twill, 3 up and 2 down.

xxx		5 threads	= 5 units.
	xx	2 intersections	= 2 units.
			7 units.

Two repeats of the weave would equal 14 units. Ten threads of the plain weave would equal 20 units, therefore the 5-harness twill requires a *greater number of threads.*

The increase is in proportion as 14 : 20 :: 60: × or 85 $\frac{71}{100}$.

We will take a final example on the 6-harness common twill basis, three threads up and three threads down, the filling passing over and under three threads alternately, therefore there will be only 2 intersections; xxx | ooo | = 6 threads and 2 intersections equals 8 units. In a plain weave, there would be 6 threads and 6 intersections, equaling 12 units, so this weave would require an *increase* as 8 : 12 :: 60 : × which equals 90 threads.

It must be thoroughly understood that the examples given herewith are all supposed to be made from the same material, same kind of yarn in weight and diameter, and the structure of the fabrics is exactly the same as far as the build is concerned, but as the 4, 5, and 6-harness weaves require more threads per inch to form as perfect a structure as the plain weave, the fabric when woven must necessarily be heavier. This is one of the important considerations when laying out a new fabric. The weight per yard has to be taken into account, therefore the size of yarn and weave are two very important factors.

In order to make proper use of previous calculations, and to put them into practice, it is necessary that the actual size of threads should be known, that is, the size, counts, and diameter to produce a perfect structure. Threads composed of different substances vary greatly in proportion to their weight. The specific gravity of cotton and linen is about $1\frac{1}{2}$ times the weight of water. Animal fibers, silk and wool, have a specific gravity of 1 $\frac{30}{100}$ or nearly $1\frac{1}{3}$.

The *diameters* of linen threads are similar to cotton. Woolen yarns present a thicker thread for the same weight. Spun silk has about the same diameter as cotton.

We must now consider the diameter of yarns. Threads vary as to the square root of their counts. After finding the diameter of a thread, find how many threads will lie side by side in one inch. For any counts of yarn, find the number of yards per pound and extract the square root. The square root of number 1 cotton would be $\sqrt{840} = 28.98$. This is without any allowance for shrinkage, and without any allowance for space.

Rule 34. To change a plain weave into a fancy twill or diagonal and retain the same perfection of structure:

(*a*) Obtain the number of threads in required weave.

(*b*) Obtain the number of intersections in required weave.

(*c*) Add threads and intersections together and call them units.

(*d*) Obtain the units there would be in the number of threads of the plain weave that are occupied by the required weave.

Example. If a plain fabric has 80 threads per inch, what number of threads will it require for the weave 3 up, 3 down, 2 up, 1 down?

Multiply the units of the known weave by the threads per inch, and divide by the units of the required weave.

Explanation. In two patterns of the above weave, there would be 18 threads and 8 intersections = 26 units, a plain weave on 18 threads would have 18 intersections = 36 units.

$$26 : 36 :: 80 : \times = 110\tfrac{77}{100}.$$

Thus 110 threads will be required to produce a fabric on the required weave, which is equal in texture to 80 threads on a plain weave; the same yarn being used in each case.

DISSECTING AND ANALYZING.

In the manufacture of textile fabrics, there are at least two important divisions of a designer's work: (*a*) *designing*, (*b*) *dissecting and analyzing*.

Designing consists in the building of a fabric from designs, more or less original, and the weaves, texture of the fabric, and colors used in its manufacture are limited only by the looms and yarns under the designer's control.

Dissecting and Analyzing differs widely from designing and is the most important work in a design office. In this case the designer must reproduce or imitate a fabric; which is a difficult problem if not worked in the right way. A thorough knowledge of designing in all its branches, and a theory of the many calculations necessary, together with the most expedient manner in which the theory may be put into practical use are essential for a successful analysis.

Many designers perform their work without any special method, which causes great inconvenience to themselves, and results in a useless waste of time and material. A methodical designer can perform his work in a comparatively short time with far better results, saving the manufacturer considerable time and expense. The first principle of a designer should be *method*, for method leads to economy, which is one of the foundations of a mill-man's success. Too much stress cannot be laid upon this point, and if the beginner is methodical and continues so, dissecting and analyzing will prove comparatively easy to him.

When analyzing a fabric, many important facts must be considered, especially when it is desired to reproduce the fabric. The nature of the fiber from which the yarn is spun, the quality and twist of the yarn, colors, and weaves used to produce the desired effect, and the character of the finishing processes should all be carefully studied, in order that the reproduction may be perfect in every detail.

The first thing to determine is the *class and nature of the fabric*. Double, triple, and backed cloths may be easily determined by a close inspection of the sample, one side usually being woven with coarser yarn than the other. Heavily napped fabrics should first be singed, care being taken to singe the nap without injuring the yarn in any way; while single cloths need but a glance to classify them as such.

The next step is to decide upon the face and the back of the fabric. Double and triple cloths usually are woven with a heavier yarn on the *back* to add weight and strength to the material. This is especially true of the so-called "two and one" system. Frequently "one and one" cloths are woven with yarn of equal counts, and the face is determined only by one or more of the several tests described later. The conditions which apply to double cloths also apply to backed cloths.

Worsted dress goods and similar fabrics often prove confusing, but in many cases a close examination will show that one side is smoother to the touch than the other, and the "draw" is very noticeable. By passing the fingers one way of the cloth a smooth feeling is noticeable and this is termed the "draw". Passing the fingers the other way of the cloth a slight resistance is felt, which is termed the "bite". These conditions are caused by shearing, and are undoubtedly the best test for the determination of face and back. Union goods are usually woven with the animal fibres more prominent on the *face*.

The next thing to consider is the scheme of warp and filling, and the texture of the fabric, and is practically the first step in dissecting.

Every woven fabric is composed of two sets of threads or yarns. Those running lengthwise in the fabric or in the direction of the warp are commonly termed threads, while those running across the fabric, or in the direction of the filling or weft, are termed the picks. From now on, the terms threads and picks will be used to denote warp and filling respectively.

We are now confronted by the problem of determining which is warp and which is filling. If the sample contains a portion of the selvedge there is no difficulty, for the selvedge always runs in the direction of the warp. If, however, the sample is cut so that no portion of the selvedge is present the warp may be determined by any of the following tests:

(*a*) If the yarn is double and twisted one way and single the other, the double and twisted yarn will indicate the warp.

(*b*) If the yarn is harder twisted one way than the other, the yarn with the harder twist is the warp.

(*c*) If one set of yarn is finer than the other, it is safe to say that the finer yarn forms the warp. Usually yarn used for warp is finer than that used for filling.

(*d*) If the yarn one way appears straight and regular, and the other way loose, rough, and displaced, or not strictly regular, the straight yarn is assumed to be the warp.

(*e*) Reed marks of any kind will show which is the warp.

(*f*) If the yarn one way is single or double cotton, and the other way is single woolen, the cotton is invariably the warp.

(*g*) If the yarn one way is starched or sized, and the other is not, the starched yarn is the warp. Warps are sized or starched to add strength or weight to the yarn.

(*h*) The test for nap has been previously stated and is valuable to denote the warp, for the nap lies in the direction of the warp.

(*i*) Stripes are generally formed by the warp.

(*j*) A fabric may be woven with the yarn right twist one way and yarn left twist the other way. The former is invariably the warp.

Exceptions to these tests seldom occur. In many fabrics, varying conditions prevail, but the reasons for such variations are so pronounced, especially with yarn, that little examination is required to distinguish the warp from the filling.

Warp yarn is usually stronger and finer than filling yarn, with a harder twist, and made from the best and strongest material on hand.

Texture. The density of a fabric is controlled by the texture, and its required weight and thickness. The sample should be cut to a certain size, usually 1 inch square, and each thread drawn out of the fabric separately and laid aside in its proper order. Each thread should be examined in turn, and the *twist*, *nature*, and *color* determined as it is drawn out of the sample. This will save a repetition of the work later on. When only a small sample is available the texture and color scheme must necessarily be determined at the same time.

Having drawn out each set of yarn, warp, and filling, the texture may be ascertained by counting the number of threads in each lot. If in the sample on hand there are 56 threads in the warp and 48 threads in the filling, the texture will be 56 threads and 48 picks per inch. It is not always convenient to cut the sample 1 inch square, and the threads and picks per inch may be determined by accurately measuring the length and width of the sample, and dividing the picks and threads respectively by these measurements. A sample may be $\frac{3}{4}$-inch long and $1\frac{1}{2}$ inches wide and contain 36 and 84 threads respectively. The calculations would be

$$36 \div \tfrac{3}{4} = 48 \text{ picks per inch.}$$
$$84 \div 1\tfrac{1}{2} = 56 \text{ threads per inch.}$$

NOTE.—This is not a reliable method and, if possible, should be avoided.

As the threads are drawn out, care should be taken to find the number of each variety and color of yarn, and in their exact order. When a repeat has been found by adding the number of threads of each color and variety, the threads in a pattern are determined. Suppose the threads in a sample are as follows:

Twist cotton	2		2	= 4
White worsted		2		= 2
Green worsted			2	= 2
				8

Thus there are 8 threads in a pattern, 4 twist cotton, 2 white worsted, 2 green worsted.

Fabrics, such as plaids, frequently have a fancy arrangement of warp and filling, and the threads in a pattern exceed in number the threads and picks per inch. Determine the extent of the repeat in the sample and measure it accurately. By dividing the number of threads in a pattern by the number of inches the pattern occupies, the texture may be found. Thus, a pattern $2\frac{1}{2}$ inches wide contains

Red cotton	18						= 18
Blue cotton		36					= 36
Yellow cotton			4				= 4
Dark tan				54			= 54
White					48		= 48
Light tan						80	= 80
							240

$240 \div 2.5 = 96$ threads per inch.

The easiest way to ascertain the woven construction of a fabric, is to take it from the face or from the figure presented on the surface of the fabric; but this requires experience and familiarity with the many kinds of weaves. Constant practice in constructing cloths from designs, and noticing the woven effects of each particular "*sign*", "*riser*", or "*sinker*" used on the point or design paper is the best way to become familiar with weaves. But sometimes, the sinkers and risers are so intermingled, several individualities being contorted and merged into one eccentric combination, that even experts find it necessary to resort to unravelling or "*picking-out*" each warp and filling thread, in order to find the true character of the weave.

The picking out of samples presents no difficulties except those of concentrated sight and steady application. This only refers, however, to fast-woven and much felted cloths, in which all the crossings have become nearly, if not totally, obliterated. If the texture were as open as mosquito netting, there would be no difficulty, because every crossing of the threads, warp, and filling could be distinctly seen and marked.

Of course there are gradations from the most openly constructed to the finest setted fabrics, and from the least to the most heavily felted cloths; still the principle of dissection is the same in all.

There are other particulars to be obtained from a sample, besides the weave or figure, and upon which the figure depends for its appearance. These are the relative fineness of the warp and filling, and the number of threads per inch, and also the amount and kind of finish to be given to the fabric to gain solidity and handle, as well as effect. We say nothing here of the materials of which the threads are composed.

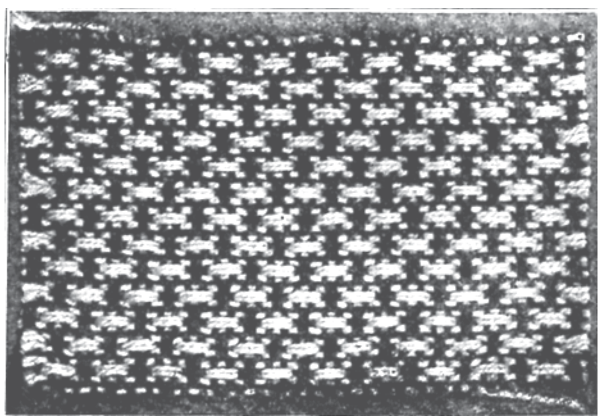


Fig. 5.

Now, suppose a sample of finished cloth exactly 1 inch square is to be analyzed. The first procedure is to weigh it in very fine (grain) scales, and record the weight. Assuming that the weight of one square inch is 5 grains and that the finished cloth is 56 inches wide, we proceed to find the weight of one yard of cloth.

Rule 35. To find the weight of 1 yard of cloth, weight of 1 square inch and width being known. Multiply the grains per inch by the given width of cloth $\times$ 36, and divide by 437.5 grains. The answer will be weight in ounces per yard.

$$\frac{5 \times 56 \times 36}{437.5} = 23.04 \text{ ozs. per yard.}$$

Or the constant found by dividing 437.5 by 36 may be used as follows:

$$5 \times 56 \div 12.153 = 23.04 \text{ ozs. per yard.}$$

NOTE.—The weight of woven fabrics is usually expressed in ounces, and as there are 7,000 grains in one pound Avoirdupois, 7,000 ÷ 16 = 437.5 grains per ounce.

Rule 36. To find the weight of one yard of cloth when the weight of any number of square inches is known; weight in grains of sample × width × length, divided by square inches × 437.5 grains.

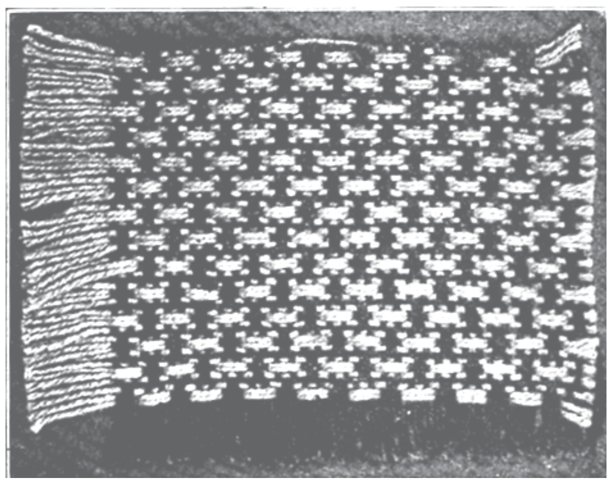


Fig. 6.

Assuming that a sample which contains 4 square inches weighs 20 grains and the cloth is 56 inches wide the process would be as follows:

$$\frac{20 \times 56 \times 36}{4 \times 437.5} = 25.04 \text{ ounces per yard.}$$

The above explains the general principles which underlie the method of obtaining the weight per yard of any fabric, woolen, worsted, cotton, linen, or silk, of any given width, and should be thoroughly understood by all who are employed in the designing room, weave rooms, or in the superintendent's or manager's office.

This simple formula with explanations will apply to all fabrics.

$$\frac{\text{Grains} \times \text{width} \times 36''}{\text{sq. inches} \times 437.5} = \text{ounces per yard.}$$

PICKING-OUT.

(*a*) Trim the edges of the sample perfectly square with the warp and filling threads. (See Fig. 5.)

(*b*) Unravel, by taking out about one-quarter of an inch of warp threads from the left side of the sample and about one-quarter of an inch of filling threads from the bottom part of the sample. (See Figs. 6 and 7.)

(*c*) Take the sample in the left hand between the finger and the thumb, placing the warp threads in a vertical position, that is, the first thread of weave on the left and first pick of weave nearest your body.

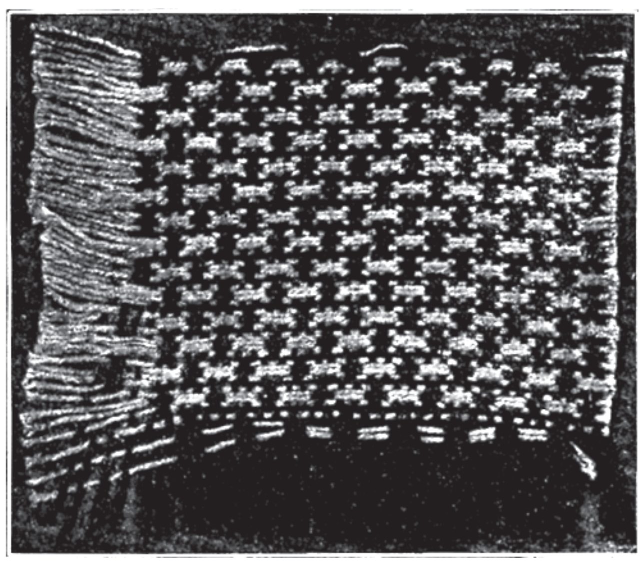


Fig. 7.

A piece of design paper must be at hand to mark down the result of the pick-out, as shown in the diagrams. With a small pointed instrument, say a needle, commence at the *left hand bottom corner* and lift the first thread away from the body of the cloth so that the filling crossing can be seen.

Now notice which filling threads this first thread is over and under, and mark on the design paper (commencing at the left hand bottom corner) those picks which are down; the up picks, of course, will be represented by the blanks or vacant squares. For instance, the first warp thread is over the first and second picks, under the third pick, over the fourth pick, under the fifth pick and sixth pick, over the seventh pick, and under the eighth pick: that is, over two, under one, over one, under two, over one and under one. The ninth and tenth are like the first and second, the eleventh is like the third and so on; so the first eight picks represent one repeat of the weave on the first thread, and is represented on the design paper by the black filled-in squares on thread A, Fig. 8.

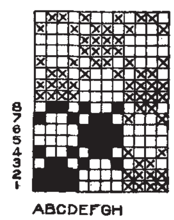


Fig. 8.

Now remove the first thread, lift the second thread to the front, and proceed as before. The second thread is over the first 3 picks under 4, over 4 and so on as shown at the thread marked B. Each succeeding thread is treated in the same manner until the weave or design repeats.

When the pattern is found to be repeating in either direction, the pick-out need not be continued, yet for safety it is advisable to go far enough both ways and then fill in the design at the repeats and disregard the other crosses. This design is complete on 8 threads and 8 picks, as shown at Fig. 9.

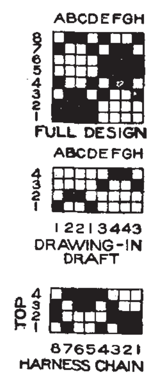


Fig. 9.

Fig. 9 also shows the drawing-in draft and harness chain. The design is reduced to four harnesses to work it easily. The letters above the drawing-in draft correspond with those in Fig. 8 and denote the order of the threads and the order of their drawing-in upon the harness, and the figures under the draft the number of the harness upon which each thread must be drawn, according to the design, while those on the left hand side show the number of harnesses employed. The numbers on the left of the reduced chain show the condensation of the design and draft. Fig. 10 shows the interweaving of the threads.

However intricate the sample or design may be in its woven construction, this method will simplify it. Sometimes the design will not repeat on so small a number as 8 × 8, and if the sample is not large enough to obtain one-half repeat, a larger sample must be obtained if possible, unless it is seen that the design runs in regular order, when a few threads taken out are sufficient to show the principle of construction without going further.

With constant practice in the analysis or picking-out of samples, the character of the figure or weave may be ascertained almost as well as in its production in the loom, as in both cases one becomes familiar with signs, sinkers, and risers and their effects.

The preceding remarks have had reference to comparatively easy and simple textures for analysis, such as worsted or cotton goods, but with the more heavily felted woolen fabrics a little preparation is necessary before proceeding with the above method. Any fibers which obstruct the clearness of the design and prevent the interweaving of the threads from being clearly seen must be removed by singeing or shaving the surface; care being taken that the threads are not destroyed, or damaged so that they cannot be removed, or followed in their regular course.

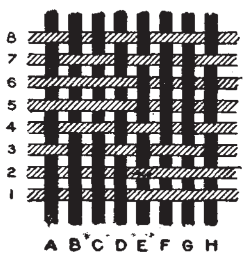


Fig. 10.

Pattern. Having found the construction of the weave, so far as figure or design is concerned, the next procedure is to note the number of threads which complete the pattern in each direction.

Referring to Fig. 11, the analysis of which is given on the analysis sheet, it will be noticed that the scheme or pattern of warp is, 2 threads of light, 1 thread of dark, 2 threads of light and 2 threads of dark, or

Light 2 2 = 4
Dark 1 3 = 3
7 threads in pattern, or scheme of warp.

The pattern or scheme of the filling is 3 picks of dark and 2 picks of light, or

Dark 3 = 3
Light 2 = 2
5 picks in pattern, or scheme of filling.

Referring again to the analysis sheet for data the analysis is as follows:

1. Weight of 1 yard, given width.

NOTE.—Pattern refers to color only, design or figure refers to weave. In the first example the warp is dark and the filling light, which is termed solid colors. Pattern is the arrangement of colors as they lie side by side in the warp and filling.

$$\frac{\text{Grains} \times \text{width} \times 36}{437.5} = 5.03 \text{ ozs. weight per yard.}$$

2 and 3. Pick-out, drawing-in draft and chain (see Fig. 12.)

4. System or pattern of warp according as the colors lie side by side in the fabric. (See Page 56.)

5. System or pattern of filling, according as the colors lie side by side in the fabric. (See Page 56.)

6. Threads in warp. Width (36) × threads per inch (56) = 2,016.

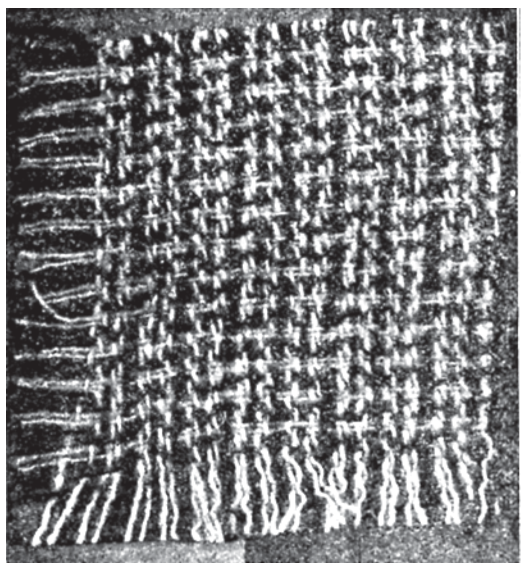


Fig. 11.

7. See No. 4 for warp and No. 5 for filling.

8. Patterns in warp. Threads in warp (2,016) ÷ threads in pattern (7) = patterns (288).

9. Size (counts or run) of warp in finished cloth 21.6.

NOTE.—See rules for the various ways of obtaining counts from small quantities or short lengths of yarn.

10. Size (counts or run) of filling in finished cloth 21.7.

11. Weight of warp yarn in one yard of finished cloth. Width of goods (36″) multiplied by threads of warp per inch (56) gives the total number of yards of warp yarn in one yard of goods, or

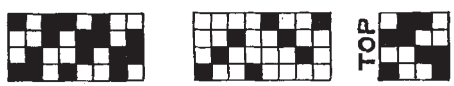
2,016 yards. As the warp yarn is numbered 21.6, or as it takes 21.6 times 560 yards to equal 1 pound of yarn, the weight of above 2,016 yards would be $\frac{2,016}{21.6 \times 560}$ = lbs., or multiplied by 16 = 2.66 oz. of warp yarn in one yard of cloth.

12. Weight of filling yarn in one yard of cloth. The picks of filling per inch (50) times width of cloth (36) gives the length in inches of filling in one running inch of the cloth or 1,800 inches. Multiplying this amount by 36 inches gives the number of inches of filling in one running yard of cloth. Again dividing by 36 inches, reduces it to yards.

$$\frac{1,800 \times 36}{36} = 1,800 \text{ running yards of filling in one yard of cloth.}$$

NOTE.—As multiplying and dividing by 36 would be superfluous, it is omitted from the formula.

Following our reasoning in the explanation given in a previous



Pick-out Drawing-in Draft Chain

Fig. 12.

paragraph, counts of filling × 560 yards gives the number of yards in 1 pound of filling, therefore,

$\frac{1,800}{21.7 \times 560}$ = lbs., or multiplied by 16 = 2.37 ounces, filling yarn in one yard of cloth.

Weight of warp yarn in one yard	= 2.66
Weight of filling yarn in one yard	= 2.37
Weight of yarn in one yard	5.03 ozs.

The weight of yarn in one yard should equal the weight of finished cloth per yard.

Take-up. So far the analysis has been simply as the yarn stood in the cloth. Yarn in a finished piece of cloth must have more or less crimps or corrugations in it according to the weave or design used.

The plain weave which interlaces at every thread and pick will require a longer warp than the 4-harness swansdown weave, to produce a fabric of equal length, provided all other things are equal.

This is a very important point in the analysis of any fabric. It must be remembered that a *yard of yarn will not weave a yard of cloth*, so cloth is always shorter than the original length of warp from which it was woven, which is due to the take-up by its being bent around the filling.

The *cloth is always narrower than the width the warp was spread in the reed* previous to being woven, which is due to the filling pulling in the edges of the cloth and to the filling bending around the warp threads. It is a well-known fact, that cloth from two looms working side by side may vary in width and length, and each loom working apparently under same conditions.

The material of which yarn is made and the manner in which it is spun, dressed, and manipulated in the loom, has much to do with the take-up in the weaving and finishing processes. The finer the quality of the filling and the softer it is spun, as compared with the warp, the greater take-up there will be in the width. Increased tension on the warp increases the length of the cloth, and makes the width narrower, up to a certain limit. If the filling is hard twisted and of a coarse nature, or coarser than the warp, the cloth will not take up much in the width.

The warp for plain stripes and sateen stripes should not be placed on the same beam nor reeded in the same manner, as the plain weave will take up much faster than the sateen portion. Care should be taken in reeding weaves of variable intersections.

The difference in temperature, weather, system of sizing, kind of loom used, tension of warp, tension of filling, also number of reed and picks per inch as compared with each other will affect the amount of take-up.

The yarns in weaves of the rib and cord type, where three, four, or more threads or picks work together, act like heavy yarns and tend to retain a straight line, the finer yarns bending around them, consequently the fine yarns have the greater take-up.

Rules may be given which will give good results and which have been proved to be practical, to some extent, for finding the various items necessary for the reproduction of a fabric, yet they are only approximately so, the best results being obtained by experience and using the records of other fabrics.

NOTE.—Take-up will be further explained under the heading "Take-up and Shrinkage".

SETTS AND REEDS.

Having found the weave, draft, chain and counts of yarn as they appear in the finished fabric, the next important step is to find the "sett" in loom, which includes reed, dents per inch, threads per dent, approximate counts of the warp and filling yarns previous to being woven, and finally the picks per inch in loom.

The density of the warp threads in the process of weaving and subsequently in the woven fabric, is represented by the relative number of heddles on the harness shafts, and the dents in the reed distributed over a fixed unit of space, which will include the number of warp threads passed through each dent in the reed.

The system of numbering reeds now almost universal in all the textile industries (perhaps with the exception of silk) is known as the "*threads per inch*" system. The number of dents per inch in the reed with two threads in each dent is the basis of the sett. If the reed has 40 dents per inch it is called a 40's reed or 80's sett.

40 reed × 2 threads = 80 threads per inch.

Obviously, the "dents per inch" is the simplest basis for a sett system and should be adopted where English measurements are used.

For all reed calculations in this work, one inch is given as the unit of measurement, and the number of warp threads contained in that space, forms the basis of the sett. When the threads per inch are of an equal number, the reed for the divisions is easily found, that is for ordinary requirements. For instance, if 40 threads per inch are required, a 20's reed 2, 10's reed 4, or 8's reed 5 may be employed, that is, a reed having 20 dents, 10 dents, or 5 dents per inch, each dent containing 2, 4, or 5 threads respectively.

By this method the number of threads for the whole warp is easily ascertained as follows: A warp is required to be 70 inches wide, with 40 threads per inch, then 70 × 40 = 2,800 threads are required for the warp.

A cloth has to be woven in a 100's sett, 4 threads in each dent. How many dents per inch must the reed contain?

Sett ÷ threads in dent = Reed.
100 ÷ 4 = 25

A cotton fabric is woven 3 threads in a dent, 42 inches wide, and warp contains 2,520 threads. What is the sett and what is the reed?

Warp threads (2,520) ÷ width (42) = sett (60)
Sett (60) ÷ threads (3) = reed (20)

A reed contains 1,320 dents in 33 inches, 2 threads in each dent. What is the reed?

$$\frac{\text{Dents } (1{,}320)}{\text{Inches } (33) \times \text{Threads } (2)} = 20 \text{ reed.}$$

Given 120 threads per inch, to be laid 72 inches wide in loom. How many threads in warp? Threads per inch (120) × width (72) = threads in warp (8,640).

Unevenly Reeded Fabrics. The requirements of design and the construction of the cloth are so various as to sizes of yarn, and the number of threads per inch employed in the warp, that the number of dents per inch in the reed is dependent upon it. But the number of threads in each division of the reed is not always uniform, that is, not always the same number in each dent throughout the whole width of the warp, this depending upon the pattern to be woven. For example, in the production of a fancy sateen stripe while 2 threads in each dent may be required, say for $\frac{3}{4}$-inch space, the following dents may require 3, 4, 5, or 6 threads in them, and then repeat with 2's and so on through the width of the reed. This will show that no hard and fast rule can be laid down which will cover every requirement.

Example. A worsted stripe is made in which the warp contains 1,920 threads; it is laid 40 inches wide in the reed, and reeded as given below. Find the average number of threads per inch, and the number of reed.

Pattern 1 dent = 4 threads black.	1,920 ÷ 24 =	80 patterns.
1 " = 4 " white.	80 × 6 =	480 dents.
1 " = 6 " black.	480 ÷ 40 =	12 reed.
1 " = 4 " white.	1,920 ÷ 40″=	48 average.
1 " = 4 " black.	48 ÷ 12 =	4 average
1 " = 2 " white.		in each dent.
6 dents 24 " in pattern.		

Rule 37. To find average threads per dent, and reed for cloth, number of threads per dent varying. First find the number of threads in one pattern and the number of dents which they occupy,

then divide the total number of threads in the warp (1,920) by the number of threads in the pattern (24) which gives the number of patterns in the warp (80), this multiplied by the dents in a pattern (6) gives the total number of dents required to reed the warp (inside selvedges). The number of dents (480) divided by the width of the cloth (40) gives the number of reed (12). Dividing the threads in the warp (1,920) by the width of the cloth (40) gives the average threads per inch (48), and dividing this by the reed (12) gives the average threads in each dent. Dividing the number of threads in a pattern (24) by the dents in a pattern (6) will also give the average number of threads in each dent.

A fabric is made with 3,264 threads in the warp; set 40 inches wide in the reed, and is reeded as given below. Find the number of dents per inch in the reed.

30 threads	2 in a dent	=	15	dents
20 "	1 " " "	=	20	"
12 "	2 " " "	=	6	"
Miss one dent	0 " " "	=	1	"
12 threads	2 " " "	=	6	"
Miss one dent	0 " " "	=	1	"
12 threads	2 " " "	=	6	"
20 "	1 " " "	=	20	"
30 "	2 " " "	=	15	"
136 threads in 1 pattern.			90	dents in 1 pattern.

3,264 ÷ 136 = 24 patterns.
24 × 90 = 2,160 dents.
2,160 ÷ 40 = 54 reed.

A cotton sateen stripe fabric has 3,520 threads in the warp and is reeded in a 40's reed as given below. What is the width in reed?

22 threads	white	2 in dent.
6 "	lt. blue	
6 "	" pink	
6 "	" blue	
12 "	white	6 in dent.
12 "	lt. blue	
12 "	" straw	
12 "	" blue	
12 "	white	

4	"	pink	2 in dent.
4	"	blue	
4	"	pink	
4	"	blue	
4	"	pink	
12	"	white	6 in dent.
12	"	lt. blue	
12	"	" straw	
12	"	" blue	
12	"	white	
6	"	lt. blue	2 in dent.
6	"	" pink	
6	"	" blue	
22	"	white	

TAKE-UP AND SHRINKAGE.

Cotton Cloth. In cotton cloth, the take-up depends chiefly upon the character of the weave, and quality and counts of yarn used. The term "sley" is used to denote the number of threads per inch in the cloth.

Suppose we have analyzed a cotton sample, and there are 100 threads per inch, or 100 sley. Find the number of dents per inch in the reed to give this texture, using 2 threads in 1 dent.

Deduct 1 from the given sley and divide by 2.1.

$$100 - 1 = 99. \quad 99 \div 2.1 = 47.14 \text{ reed.}$$

As an illustration of how cotton cloths will vary in the amount of take-up according to the construction in weaving, the following examples are given:

1. A fabric made with 48's warp and 2-15's filling, 34 inches in reed, 88 threads per inch, 50 picks per inch, 5 harness sateen weave, gives $33\frac{1}{2}$ inches of cloth. Showing a take-up of about $1\frac{1}{2}$ per cent. $34 - 33.5 = .5$. $.5 \div 33.5 = .0148$ or 1.48%.

2. 48's warp and 15's filling. 33 inches in loom, 64 threads by 40 picks. 5-harness $\frac{4}{\quad 1}$ weave, gives 32 inches of cloth, showing a take-up of $3\frac{1}{8}$ per cent or $33 - 32 = 1$. $1 \div 32 = .03125$ or $3\frac{1}{8}$ per cent.

3. 2-26's warp and 48's filling. $31\frac{1}{8}$ inches in loom. 48 threads by 128 picks. 6-harness broken twill, filling face, gives

28 inches of cloth. Showing a take-up of 11.16 per cent. $31\frac{1}{8} - 28 = 3\frac{1}{8}$. $3\frac{1}{8} \div 28 = .1116$ or 11.16 per cent.

These examples could be multiplied, showing the various take-ups by using weaves of various intersections and yarns of different counts, also by varying the number of threads per inch.

The following rules are on a basis of 5 per cent, and are given as approximately correct.

Rule 38. For cotton cloth. To find the number of dents per inch in reed to produce a given "sley".

Deduct 1 from the given sley and divide by one of the following numbers:

For 1	thread	in	dent	divide	by	1.05
" 2	threads	"	"	"	"	2.1
" 3	"	"	"	"	"	3.15
" 4	"	"	"	"	"	4.2

Rule 39. To find sley of cloth woven with a reed, the number of dents per inch being given.

Multiply the number of dents per inch by one of the following numbers and add 1:

For 1	thread	in	dent	multiply	by	1.05
" 2	"	"	"	"	"	2.10
" 3	"	"	"	"	"	3.15
" 4	"	"	"	"	"	4.2

Examples. Find the number of dents per inch in reed, to give a 120 sley drawing 4 threads in each dent. $120 - 1 = 119$. $119 \div 4.2 = 28\frac{1}{3}$ dents per inch.

What sley cloth would be woven with a reed containing 50 dents per inch, with 3 threads in each dent? 50 dents $\times$ $3.15 = 157.5$. $157.5 + 1 = 158.5$ sley cloth, or threads per inch.

Rule 40. To find sley reed to produce unequally reeded patterns such as lenos, cords, dimities, etc. Multiply the threads in the pattern by patterns per inch, which will give the average sley: then multiply the average sley by the number of dents per pattern and by 2, and divide by the number of threads per pattern.

In a sample of cloth, the pattern is found to be reeded 2, 4, 4, 4, and there are 9 patterns per inch. What reed will produce it?

$2 + 4 + 4 + 4 = 14$ threads in pattern. $14 \times 9 = 126$ average sley.

$$\frac{126 \times 4 \times 2}{14} = 72 \text{ sley reed.}$$

$$72 \div 2 = 36 \text{ actual reed.}$$

When figuring cotton fabrics, allowances must be made for quantity of size, starch, and other substances used.

Worsted Cloth. In the analysis and construction of worsted fabrics, that is, those composed of worsted warp and worsted filling, the same principles are to be observed as in cotton cloths.

Piece dyed worsted goods sometimes gain as much in weight in the dyeing operation as they lose in the process of scouring, so the weight of the cloth from the loom may be taken as net, and the calculations based accordingly.

The width of the warp in the reed depends upon the class of goods to be made, the required width of the finished piece, and the structure of the design. In ordinary worsted textures, the shrinkage of the cloth from the loom to the finished state, varies from 8 to 12 per cent.

A sample of finished cloth contains 80 threads and 80 picks per inch. Allow 10 per cent for shrinkage in the width and length. Find the width of the warp in the reed, and the number of threads and picks per inch with which it must be woven. The cloth is 56 inches wide finished.

$100\% - 10 = 90\%$ $\frac{80 \times 90}{100} = 72$ threads and picks per inch in loom.

$$\frac{\text{Threads (80)} \times \text{width (56)}}{\text{threads per inch (72)}} = \frac{\text{threads in loom (4,480)}}{72} = 62\tfrac{2}{9}$$
inches.

The original length and width represented 100%. The shrinkage was 10%, so the finished cloth is 90% of the original length and width. As there are 80 threads and picks per inch in the finished cloth, there must have been a smaller number per inch when the length and the width were greater. Therefore, multiply the number of threads and picks by the finished width and length and divide the product by the original length and width.

To find the width in reed: First find the number of ends in the warp by multiplying the finished width by number of threads per inch in the finished cloth; then divide the product by the threads per inch in the loom.

Example. A worsted cloth contains 64 warp and filling threads. Shrinkage 9%. Finished width 55 inches. Find the reed width, and the number of threads and picks with which it should be woven.

Fancy worsted cloths are made from yarns dyed in the hank, or from yarns where the material has been dyed in the raw state or in the worsted top, therefore, the loss in scouring and finishing must be considered.

Fulled Woolen Goods. Fabrics which come under this head may have a finishing shrinkage of 20% to 35%, and in some cases even more. Such goods are said to be "made" in finishing, for the cloth as produced by the loom would not be recognized in the finished condition.

When analyzing a small sample of woolen goods, it is very important that the shrinkage be accurately found, or the reproduction will not be a success.

Method of finding picks in loom.

$$\frac{\text{Picks in finished cloth} \times \text{finished length}}{\text{length out of loom}} = \text{picks in loom.}$$

A finished woolen coating has 71 picks per inch. 63 yards of cloth out of loom gives 57 yards finished.

$$\frac{71 \times 57}{63} = 64 \text{ picks in loom.}$$

Or, a finished woolen suiting has 80 picks per inch, and it has had a shrinkage in length in the warp, or number of picks, of 20%. What was the number of picks in the loom?

$100 - 20 = 80\%$. $80 \times 80\% = 64$ picks in loom.

There is a large number of fabrics for heavy clothing, that are made with a back stitched to the original or face fabric in order to gain weight and warmth. When analyzing such fabrics the counts and weight of the back cloth yarns are calculated as a separate cloth.

CONSTANTS.

Constants for the customary width of any fabric, whereby the weight per yard may be easily obtained from a small sample.

Formula.

$$\frac{\text{Width} \times \text{inches in 1 yard} \times \text{ounces in 1 lb.}}{\text{Grains in 1 lb. (Avoirdupois)}} = \text{constant.}$$

$54 \times 36 \times 16 \div 7{,}000 = 4.44$ constant.

Rule 41. Weight of sample × the constant ÷ sq. in. of sample = weight of yard, given width (54″).

Sample. 3×2 inches = 24 grains.

$$\frac{24 \times 4.44}{6} = 17 \text{ oz. per yard.}$$

TABLE OF CONSTANTS.

Inches wide.		Inches wide.	
12	.98	42	3.45
14	1.15	44	3.62
16	1.31	46	3.78
18	1.48	48	3.95
20	1.65	50	4.12
24	1.97	52	4.27
27	2.22	54	4.44
28	2.30	55	4.52
30	2.47	56	4.60
32	2.63	58	4.77
34	2.79	60	4.94
36	2.96	62	5.10
38	3.13	64	5.26
40	3.30	66	5.42

Example. A small sample 1 square inch = 5 grains. What is the weight of a yard of cloth 56 inches wide?

Constant $4.6 \times 5 = 23$ ozs.

The utility of this rule is at once apparent when applied to the solution of the above example, or to the following: A given sample is 3×3 inches and weighs 27 grains. What is the weight if the fabric is 28 inches wide?

$$3 \times 3 = 9. \qquad \frac{27 \times 2.3}{9} = 6.9 \text{ ozs.}$$

EXAMPLES FOR PRACTICE.

1. A sample is 4×1.5 inches and weighs 18.5 grains. What will one yard of the fabric weigh, 54 inches wide?

2. What will one yard of cloth, 36 inches wide, weigh, if a small sample $2\frac{1}{2} \times 2$ inches weighs 6.7 grains?

3. A yard of cloth 40 inches wide weighs 10.3 ozs. What will be the weight of a sample $4 \times 2\frac{3}{4}$ inches?

4. What will one yard of cloth, 72 inches wide, weigh, if a $4 \times 2\frac{1}{3}$-inch sample weighs 30 grains?

ANALYSIS OF PATTERN.

Cloths composed of one-color warp and one-color filling are said to be of solid color, but when there are two or more colors in the warp or in the filling, the arrangement of the colors is termed the pattern. Where several shades of colors of yarn are used in fancy fabrics, to produce certain effects, the order of the threads must be carefully noted to make a correct reproduction. Of course the order of arrangement of these threads may be ascertained during the process of dissection.

One thing to be attended to is, that the leading thread in the pattern should be found, with reference to the style of the design or weave employed. Sometimes particular threads are intended to show either prominently or the reverse and a special arrangement in the weave is made to produce this result. In such cases the *relation of the thread to its working arrangement* must be strictly observed, or the attempt at reproduction will be a failure. If the style of weave is all one kind, as in an ordinary twill or sateen weave, the above may be disregarded.

An additional consideration, with regard to these differently colored threads in the warp, and one which must receive attention is that, whatever number of threads there may be in the pattern, it must be repeated an even number of times in the width of the warp, so that if the edges of the cloth, minus the selvedges, were brought together so as to form a tube, the pattern would be continuous all around.

Suppose that it is necessary to produce a fabric which contains 16 threads in one repeat of the pattern, as follows: 4 threads black, 2 threads drab, 2 threads slate, 4 threads black, 2 threads slate, 2 threads drab. This arrangement must be repeated as many times as is made necessary by the required width. A few extra threads may be disposed of by casting out, or a few may be added to make up even patterns.

Suppose a warp contains 1,920 threads and the pattern is composed of 16 threads.

Threads divided by number of threads in pattern equals number of patterns. $1{,}920 \div 16 = 120$ patterns.

Suppose a warp fabric is measured and found to be $32\frac{1}{4}$ inches wide and there are 48 threads per inch and 16 threads in the pattern.

$$48 \times 32\frac{1}{4} = 1{,}548 \text{ threads.}$$

$$1{,}548 \div 16 = 96 \text{ patterns} + 12 \text{ threads.}$$

The 12 extra threads must be cast out.

A fabric 35 inches wide contains 2,380 threads in the warp and is dressed 2 black, 2 white, 2 black, 1 red. (*a*) How many patterns are there in the warp? (*b*) How many threads per inch?

Relative Weights of Warp and Filling. There is yet another essential consideration in reference to these varied threads, for, in addition to finding the number of each kind, their weight also must be obtained, for the purpose of warping and dressing, as well as in making out the cost of the fabric. To the designer, spinner, and manufacturer calculations of this kind are very useful.

Find the weight of a warp 64 yards long, made of 2–32's worsted, and woven in a 16's reed, 4 threads in a dent, 66 inches wide in reed.

$$16 \times 4 = 64 \text{ threads per inch.} \quad 2\text{–}32\text{'s} = 16\text{'s.}$$

$$\frac{64'' \times 66'' \times 64 \text{ (threads per inch)}}{16 \times 560} = 30.1 \text{ lbs.}$$

or

$$\frac{\overset{4{,}224}{\text{threads in the warp}} \times \overset{64}{\text{the length}}}{\underset{16}{\text{counts}} \times \underset{560}{\text{standard}}} = 30.1 \text{ lbs.}$$

Example. Find the weight of filling required to weave a piece 64 yards long, 64 inches wide in the reed, 80 picks per inch of 1-18's worsted. Add 5 per cent to cover the waste in weaving.

$$\frac{80 \times 64'' \times 64 \text{ (yds)} \times (100 + 5\%)}{18 \times 560 \times 100} = 34.1 \text{ lbs. of filling yarn.}$$

It must be remembered that a yard of warp will not weave a yard of cloth, and in making calculations, sometimes the length of the warp is taken instead of the loom length, the difference in length being considered sufficient to cover extra cost of waste of filling during the weaving.

EXAMPLES FOR PRACTICE.

1. Find the weight of warp and filling required to weave a piece 63 yards long, 64 inches in the reed, made from 70 yards of warp and containing 84 picks per inch, plus 5% for extra filling to cover the waste in weaving. Yarn is all 16's worsted.

2. A fabric 72 yards long is 56 inches wide in the reed, and contains 80 picks per inch. Waste in weaving 5%. 80 yards of warp are used in the fabric. Find the weight of warp and filling if both are 2-40's worsted.

3. 64 yards of warp are woven into a fabric 56 yards long. In the loom the cloth is 64 inches wide, and contains 50 picks per inch. 5% waste in weaving in filling. Find the weight of warp and filling if both are 14's cotton.

4. A woolen fabric is set 56 inches wide in the reed, and is woven with 40 picks per inch; 72 yards of warp finish to 64 yards of cloth. 5% waste in filling. What is the weight of warp and filling if both are 3-run woolen?

5. A 2-48's worsted warp 65 yards long is warped to the following pattern: Woven in a 12 reed, 4 threads in a dent, 60 inches wide.

2 black 2 dk brown	} × 4
2 dk. brown 2 dk. drab	} × 2
24 threads in pattern.	

$12 \times 4 = 48$. $48 \times 60 = 2{,}880$ ends in warp.

$2{,}880 \div 24 = 120$ patterns.

Find the weight of each color of yarn.

The following is the most convenient form to write out the scheme of warp and filling, as the summary of the threads can be obtained more easily. It is very essential to ascertain he weight, of each color and sort of material used, especially in the warp where the number of threads of each color and sort must be known, so that the several calculations can be made for spooling and warping.

Black	2		2		2		2			= 8	threads.
Dk. brown		2		2		2		4	2	= 12	"
Dk. drab								2	2	= 4	"
										24	" in pattern.

120 patterns	× 8	threads	=	960 Black.
120 "	× 12	"	=	1,440 Dk. brown.
120 "	× 4	"	=	480 Dk. drab.
				2,880

The weight of each kind can now be obtained by the regular method.

$$\frac{960 \times 65}{24 \times 560} = 4.64 \text{ lbs.}$$

$$\frac{1{,}440 \times 65}{24 \times 560} = 6.96 \text{ lbs.}$$

$$\frac{480 \times 65}{24 \times 560} = 2.32 \text{ lbs.}$$

13.92 total weight of warp.

There is another method of obtaining the number of threads of each color.

$$\frac{\text{Total number of warp threads} \times \text{threads of any color in one repeat}}{\text{Number of threads in pattern.}}$$

$$\frac{2{,}880 \times 12}{24} = 1{,}440.$$

In patterns where there is a large number of threads of one color, as may be the case in a Scotch or Tartan plaid, it is advisable to commence the color scheme by *dividing the largest number of threads*, commencing with one-half and ending with the other.

A plaid is made from 2-24's worsted warp and filling, 12's reed, 4 in one dent, 44 picks per inch, width within selvedges 36 inches, plus 24 threads on each side for selvedges. The warp take-up is 15% during weaving, 60 yds. of warp before weaving. Selvedges, white 2-24's worsted.

Black	24			6		20		20		6		24	= 100
White		12			6		68		6		12		= 104
Red			6							6			= 12
													216

This pattern has purposely been started with 24 threads of black (note the selvedges are white), and finished with the same number and color. If the selvedges had been ordered black, the pattern would have commenced with 34 white.

48 × 36 = 1,728. 1,728 ÷ 216 = 8 repeats.

Black	100 × 8 = 800	× 60 ÷ (12 × 560) =	7.14 lbs.
White	104 × 8 = 832	× 60 ÷ (12 × 560) =	7.43 lbs.
Red	12 × 8 = 96	× 60 ÷ (12 × 560) =	.86 lbs.
	1,728		15.43 lbs.

Selvedges white 48 × 60 ÷ (12 × 560) = .43 lbs.

15.86

Note.—The selvedge may be added to white in body of warp.

The weight of each color of filling is obtained by the use of a similar formula, but the width includes the selvedges.

$$36 + 1 = 37'' \times 44 \text{ pks.} = 1{,}628.$$

$$1{,}628 \div 216 = 7.54.$$

Black	7.54 × 100 =	754
White	7.54 × 104 =	784
Red	7.54 × 12 =	90
		1,628

$$\frac{37 \times 44 \times 60}{12 \times 560} = 14.5 \text{ lbs., total weight of filling.}$$

$$\frac{14.5 \times 100}{216} = 6.72 \text{ lbs. of black filling.}$$

$$\frac{14.5 \times 104}{216} = 6.98 \text{ lbs. of white filling.}$$

$$\frac{14.5 \times 104}{216} = .80 \text{ lbs. of red filling.}$$

14.5 total weight of filling.

The total weight can first be obtained, and then the proportions of weight of each color may be determined by the ratio of picks of each color to the total number of picks in each repeat, or multiply the number of picks per inch by 36, to find the number of picks in one yard, then multiply the result by the length of the warp, which will give the total number of picks in the whole piece. Divide the total number of picks by the number of picks in the pattern, to find the number of repeats. Multiply the repeats by the number of picks of each kind of filling, and again multiply these products by the width of the warp in the reed in the loom, which will give the total number of inches of filling of each kind. Divide the results by 36 to reduce to yards and by the counts of the yarn multiplied by the standard number to obtain the weight.

Lay a warp 72 inches wide in loom, 60 yards long, 4-run yarn. (40 picks per inch.)

Pattern of filling.	20	picks	black
	1	"	brown
	6	"	black
	1	"	brown
	20	"	black
	48		

There are 46 picks of black and 2 picks of brown in the pattern. Find the amount of yarn required of each color.

$$\begin{array}{rl} 36'' & \\ 40 & \text{picks per inch} \\ \hline 1{,}440 & \text{" " yard} \\ 60 & \\ \hline 86{,}400 & \text{picks in 60 yards} \end{array}$$

$$\frac{\text{Total number of picks (86,400)}}{\text{Picks in pattern (48)}} = 1{,}800 \text{ repeats.}$$

Brown $\frac{1{,}800 \times 2 \times 72}{36} = 7{,}200$ yards.

$$\frac{7{,}200}{400} = 18 \text{ ounces.}$$

Black $\frac{1{,}800 \times 46 \times 72}{36} = 165{,}600$ yards.

$$\frac{165{,}600}{400} = 414 \text{ ounces.}$$

The same rule applies to the picks of worsted and cotton by using their respective counts and standard numbers.

REVIEW QUESTIONS.

PRACTICAL TEST QUESTIONS.

In the foregoing sections of this Cyclopedia numerous illustrative examples are worked out in detail in order to show the application of the various methods and principles. Accompanying these are examples for practice which will aid the reader in fixing the principles in mind.

In the following pages are given a large number of test questions and problems which afford a valuable means of testing the reader's knowledge of the subjects treated. They will be found excellent practice for those preparing for Civil Service Examinations. In some cases numerical answers are given as a further aid in this work.

REVIEW QUESTIONS

ON THE SUBJECT OF

TEXTILE CHEMISTRY AND DYEING

PART I

---

1. Explain what is meant by hygroscopic moisture.

2. (*a*) In general, how do acids act towards cotton? (*b*) Give the special features in regard to the action of Sulphuric and Nitric acids on cotton. (*c*) What are Gun Cotton, Celluloid and Collodion?

3. What is chlorinated wool? What advantages may be derived by chlorinating wool?

4. (*a*) How is a silk fibre characterized? (*b*) Define "Scroop."

5. In general, how do acids act toward wool?

6. What are wild silks?

7. Of what value is cotton seed, and what is the process of separating the seed from the fibre called?

8. (*a*) In general, how do alkalies act toward cotton? (*b*) What special action does caustic soda have on cotton? (*c*) What practical applications are made of this action, and what general name is applied to the process?

9. (*a*) What are motes, dead cotton fibres, and kemps? (*b*) How do they act toward dyestuffs?

10. Compare the action of acids and alkalies upon cotton and wool, and give two methods of separating these fibres, based upon their difference.

11. What is the felting process and upon what principle does it depend?

12. In general, how do alkalies act toward wool?

13. Describe the common silk cocoon and the process of treatment previous to reeling.

14. (*a*) What is a conditioning establishment? (*b*) To what extent is silk hygroscopic?

15. What are the principal natural impurities of cotton?

16. Give the properties of artificial silk and describe its process of manufacture.

17. Describe the microscopic appearance of cotton.

18. Describe the structural and microscopic appearance of wool.

19. Describe the microscopic appearance of linen.

20. In general, how do solutions of metallic salts and dyestuffs act toward cotton?

21. (*a*) Describe the microscopic appearance of silk. (*b*) How does it differ in this respect from wool and the vegetable fibres?

22. (*a*) What is the approximate composition of raw cotton? (*b*) Give name, properties and composition of the principal constituent.

23. What can you say about the action of cotton towards atmospheric changes?

24. (*a*) What is Ramie Fibre? (*b*) Make a list of all the vegetable fibres mentioned in the instruction paper.

25. (*a*) What takes place when wool is boiled in solutions of various metallic salts? (*b*) Illustrate with the case of Aluminum Sulphate Solution.

26. Give composition of raw silk.

27. How does linen differ from cotton in composition?

28. Compare the average length of cotton, linen, wool and silk fibres.

29. (*a*) Describe the ordinary hydrometer. (*b*) Upon what fact is its utility based?

30. Give the object of the Hackling Process and its products.

31. (*a*) Define wool. (*b*) How are the different grades separated and what is the process called?

32. (*a*) How does jute differ from linen and cotton in composition? (*b*) How does jute act toward certain dyestuffs?

REVIEW QUESTIONS

ON THE SUBJECT OF

TEXTILE CHEMISTRY AND DYEING

PART II

1. (a) Why is it necessary to give textile material a preliminary treatment before it is in a suitable condition for the processes of textile coloring and finishing?

(b) At what stages of the manufacturing process may this treatment be given?

2. (a) What is the object of cotton bleaching?

(b) What general principles are commonly involved in the process?

3. (a) What is the object of singeing cotton cloth?

(b) Describe the methods of carrying out the process.

4. (a) Give the approximate composition of raw cotton and explain the difference between the natural and foreign occurring impurities of cotton material.

(b) What is a back cloth?

5. (a) For what purposes is the madder bleach used, and how did it get its name?

(b) Give outline of the steps of the madder bleach.

6. (a) How is shearing accomplished?

(b) If you had to remove napp or fuzz from cloth after bleaching, would you singe or shear it? Explain your answer.

7. (a) What is a kier? (b) What are the common types, and how do they differ?

8. (a) Describe the brown sour. (b) Give the chemistry of the brown sour.

9. Explain fully the chemistry and object of the lime boil.

10. (a) What are the common difficulties and irregularities met with in the working of a kier ?

(b) What precautions may be taken to overcome these ?

11. (a) Describe the process known as the resin or rosin soap boil. (b) Explain the chemistry of the lye boil.

12. Explain the action of kiers illustrated in Figures 34 and 44.

13. Explain fully the theory of bleaching with chlorine and give reasons for the belief that this theory is true.

14. (a) Under what conditions is raw cotton bleached ? (b) How does the handling of raw or loose cotton in bleaching differ from that of yarn or cloth, and what precautions should be taken ?

15. (a) How does the Mather Steamer Kier Process differ from the Madder Bleach ? (b) Give outline of process and mention any advantages claimed for it.

16. (a) What is the object of the white sour ? (b) What can you say as to the relative values of hydrochloric and sulphuric acids for the souring process ?

(c) Why is a wash given just before the white sour ?

17. Why is it necessary that the goods should be thoroughly washed at the end of the bleaching process ?

18. (a) Under what conditions should cotton yarn be bleached ? (b) Give outline of typical yarn bleaching process.

19. (a) What is bleaching powder ? (b) How is it made and what are its two possible formulæ ?

20. (a) Describe the method of preparing the bleaching bath when sodium peroxide is used.

(b) Explain the chemistry of the process.

21. Describe briefly the common grades of bleaching other than the madder ?

22. (a) What is the object of chemicking ? (b) How is it accomplished ?

REVIEW QUESTIONS

ON THE SUBJECT OF

TEXTILE CHEMISTRY AND DYEING

PART III

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1. (*a*) Give general classification of dyestuffs.
   (*b*) Explain terms adjective, substantive, monogenetic, and polygenetic dyestuffs.
2. (*a*) Explain fully what is meant by a mordant.
   (*b*) What is the difference between a mordant and a mordanting principle?
3. (*a*) Explain the terms textile coloring, textile printing, and dyeing.
   (*b*) Explain the terms fixing agent and mordanting assistant.
4. (*a*) Give general method of applying mordants to wool.
   (*b*) Give general methods of applying mordants to cotton.
   (*c*) Why does the mordanting of wool differ from the mordanting of cotton?
5. (*a*) What metals act as mordants under certain conditions?
   (*b*) What particular compounds of these metals are usually the actual mordants?
6. (*a*) What are the common chromium mordanting principles?
   (*b*) Explain the use of potassium bichromate in wool mordanting.

7. Give as many methods as you can for applying chromium mordants to wool.
8. (*a*) How may the natural dyestuffs be classified?
   (*b*) Give names of important dyestuffs of each class.
9. (*a*) What is indigo?
   (*b*) How is it obtained?
   (*c*) What are its sources?
10. (*a*) Explain the chemistry and principle of vat indigo dyeing, with equations.
   (*b*) How is the dyeing carried out?
11. (*a*) How is the woad vat set?
   (*b*) How is the hyposulphite vat set?
12. How does the dyeing of cotton with indigo differ from the dyeing of wool?
13. (*a*) What are indigo extracts?
   (*b*) How and for what are they used?
14. (*a*) What is logwood?
   (*b*) For what is it used?
15. (*a*) Explain three stages in development of coloring matter of logwood.
   (*b*) What connection is there between the above and logwood ageing?
16. How may logwood be applied to wool?
17. How may logwood be applied to cotton?
18. (*a*) What are the principal red natural dyestuffs?
   (*b*) What is madder, and why has it gone out of use?
   (*c*) How is cochineal applied to wool?
19. (*a*) What are the principal yellow natural dyestuffs?
   (*b*) For what is fustic used?
20. (*a*) For what is cutch used?
   (*b*) Give process of applying cutch to cotton.

REVIEW QUESTIONS

ON THE SUBJECT OF

TEXTILE CHEMISTRY AND DYEING

PART IV

---

1. (*a*) How did the coloring materials of the older dyers differ from those used at the present time?

(*b*) Give an important classification of the artificial dyestuffs.

(*c*) Upon what is this classification based?

2. (*a*) Why are the basic colors so called?

(*b*) Why do the basic colors dye wool directly but not cotton?

(*c*) How can this lack of affinity between the basic colors and cotton be overcome?

3. (*a*) Give the essential difference between the process of dyeing wool and silk with basic colors, as compared with the application of the same dyestuffs to cotton.

(*b*) Give the characteristic properties of the basic colors.

(*c*) Name ten important basic colors.

4. What are the janus colors and why so called?

5. (*a*) What are the general characteristics of the phthalic anhydride colors and why are they so called?

(*b*) For what are the phthalic anhydride colors used and how are they applied to silk?

(*c*) Name some of the most important phthalic anhydride colors.

6. (*a*) Why are the acid colors so called?

(*b*) Into what three classes may the acid dyestuffs be divided, and upon what differences in composition is this classification based?

REVIEW QUESTIONS

ON THE SUBJECT OF

TEXTILE CALCULATIONS

---

1. Find the worsted counts of the following yarns: 10,080 yards weigh 1 lb.; 9,240 yards weigh 12 ozs; 17,500 yards weigh $1\frac{1}{4}$ lbs.

2. Find the woolen runs of the following yarns: 6,400 yards weigh 1 lb.; 2,100 yards weigh 4 ounces; 8,400 yards weigh $5\frac{1}{4}$ lbs.

3. Find the cotton counts of the following yarns: 33,600 yards weigh 1 lb.; 20,160 yards weigh $\frac{1}{2}$-lb.; 100,800 yards weigh $1\frac{1}{2}$ lbs.

4. What is the weight of 21,840 yards of 13's worsted yarn? 31,500 yards of 15's cotton yarn? 4,800 yards of 6-run woolen yarn? and 134,400 yards of 20's spun silk?

5. Change the following yarns to cotton counts: 60's worsted; 10-run woolen; and 14-lea linen.

6. Change the following yarns to worsted counts: 16's cotton; 7-run woolen; and 24's spun silk.

7. Give the metric counts of the following yarns: 28's worsted; 5-run woolen; and 32's cotton.

8. Give the counts of the compound threads when the following yarns are twisted together: 36's and 30's worsted; 120's and 60's cotton; 30's and 60's spun silk.

9. Find the counts of a 3-ply thread composed of 60's, 30's, and 15's worsted; 72's, 36's, and 24's cotton; 12-run, 6-run, and 4-run woolen.

10. What is the counts of a novelty yarn composed of one thread each of 60's, 48's, and 36's cotton? The relative lengths of yarn used are 5, 4, and 2 inches. The 36's thread of which 2 inches are used is straight or 100%.

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