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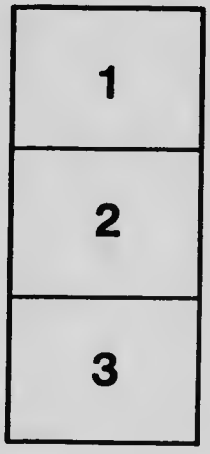

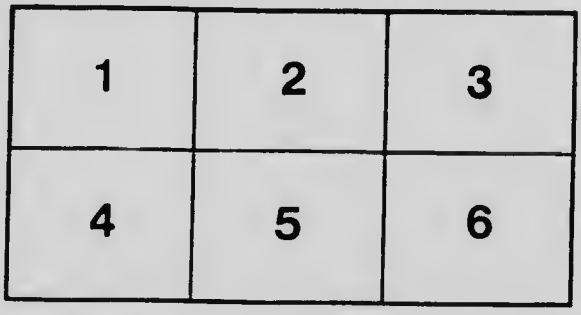

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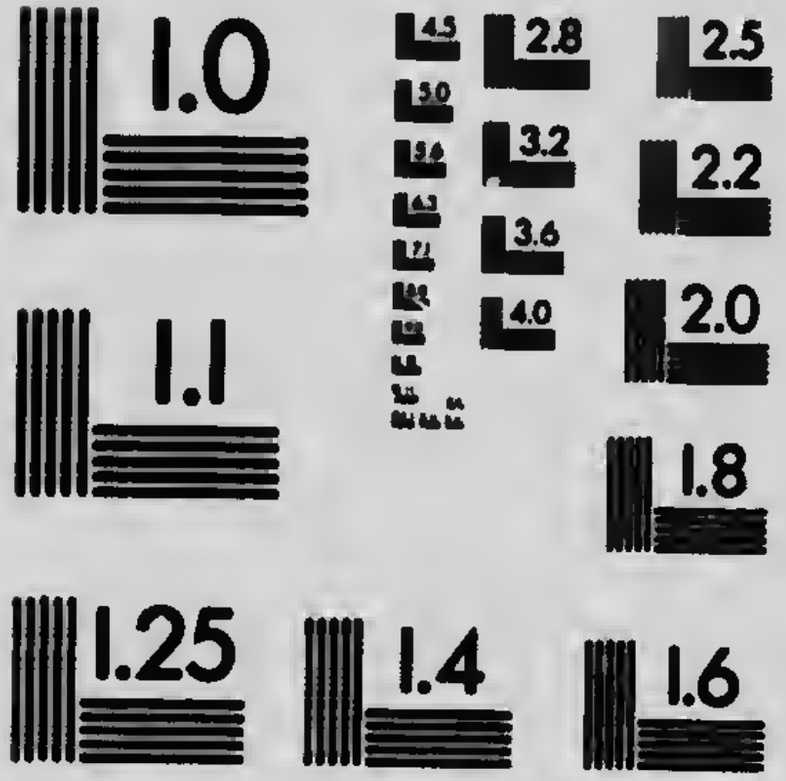

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BULLETIN NO. 177.] [DECEMBER, 1909

Ontario Department of Agriculture

ONTARIO AGRICULTURAL COLLEGE.

Lime-Sulphur Wash.

By H. L. Fulmer and Lawson Cæsar.

INTRODUCTION.

The Lime-sulphur wash has been used in Ontario for about twelve years, and, although it is a disagreeable material to work with, it has proven to be so useful that it has steadily gained in popularity, until to-day it is the standard remedy for the San José scale. The wash is also useful in destroying other scale insects, and, furthermore, it is recognized as a valuable and efficient fungicide. In fact it is without doubt one of the best all-round spraying materials at the disposal of the fruit grower at the present time.

This valuable spraying mixture was first used by the California fruit growers, who accidentally found that the Lime-sulphur sheep dip of Australia would destroy the San José scale. When the scale spread to the Eastern part of the Continent, the California remedy, or Lime-sulphur wash, quickly followed it. At first it was used entirely to control the ravages of the San José scale, but it was soon found to destroy the Oyster Shell Bark Louse and other forms of scale insects, and, quite accidentally, it was discovered that it controlled the Peach Leaf Curl. This suggested that the Lime-sulphur wash had fungicidal value. Up to this time the wash had always been used on trees in the winter or early spring, and was of a strength only suitable for use on the wood in the dormant condition. If, however, the mixture was to be useful as a fungicide for more than the Peach Leaf Curl, it must be sprayed on the trees during the growing season.

The commercial Lime-sulphur solutions next appeared on market. They are concentrated solutions, which do not crystallize the home-made article, consequently, they can be kept any length time and diluted as required for spraying purposes. These commerc washes were at first viewed with suspicion, but it was soon found t when properly diluted they gave excellent results both on dormant wo and on tender foliage. The foliage of the peach tree is an exception, it was found that even with what appeared extreme dilution the co mercial washes still burned the leaf. In the endeavour to get a fun cide to control the Brown Rot of the peach tree, the self-boiled Lim sulphur wash was introduced and has given excellent results. Th latter material and the diluted commercial solutions are now being su cessfully used as Summer sprays without russeting the fruit or othe wise injuring it or the foliage, as sometimes happens with the Bordea Mixture.

With regard to the composition of the Lime-sulphur wash, it h always been evident that there were wide variations. Salt was a co stituent of the original sheep dip and was retained, with the idea th it added to the caustic qualities, and particularly to the adhesive natu of the wash. In practical experience, however, the salt seems to ha been of little benefit, and is, therefore, omitted in all the formulæ no given. The formulæ have varied from time to time and in differe districts; in some instances very excessive quantities of lime have be used. but the nature of the compounds found did not vary with th different proportions of the ingredients. In all cases the mixture co tained the essential sulphides of Calcium and some thiosulphates an sulphites, with traces of sulphates. The amount of these latter com pounds was dependent upon the length of time the mixture was boile and the vigour with which the boiling was prosecuted. Indeed, it quite probable that the rate of boiling has been responsible for greate variations in the strength of the home-made wash than any other on factor, for, while 45 [illegible] to one hour's vigorous boiling has bee proven to be sufficie[illegible]r period of *slow* boiling will frequentl leave some of the s[illegible]combined or in the lower forms of th sulphides, and, hence [illegible]nferior wash.

The self-boiled washes in which caustic soda and sal soda wer used to aid the action, which were advocated at one time, gave fairl satisfactory washes, but so much depended on having a fresh quick slaking lime that the results obtained were not uniform and they ar seldom made now. The self-boiled washes now advocated contain muc smaller quantities of combined lime and sulphur and are purposel arranged to make weak washes for Summer spraying.

The commercial Lime-sulphur solutions which have been placed o the market during the last few years have some decided advantages ove

the home-made article. They are clear solutions containing a larger proportion of the sulphur in the form of the higher lime sulphides, and, because of the absence of large quantities of free lime, they do not crystallize. Consequently, they can be diluted to the required strength and applied at once, doing away with the rather disagreeable work of preparing the wash. However, it is very doubtful if these commercial articles will ever replace the home-made material for Winter spraying, unless they can be sold for less money.

The most recent advance in the preparation of the Lime-sulphur wash is the introduction of a method for making the home-made concentrated solution. The method is simple and consists essentially of boiling together lime and sulphur in the proportion of 1:2, allowing the residue to settle and drawing off the clear supernatant solution. A wash can easily be prepared in this way, that is 8 or 9 times as strong as that made from the old formula for home-boiled mixtures, and, as it does not crystallize, it can be made during the slack time in the Winter and stored ready for dilution when required.

The difficulty in handling both the commercial solution and the home-made concentrates is to know how much they should be diluted before applying. The solution prepared from the old formula, lime, 20 lbs., sulphur 15 lbs., water 40 gals. (Imperial), may be taken as a fair standard of strength for spraying dormant wood. But, so far as we know, no analyses of these washes have ever been published. To secure this data we collected and analyzed a large number of samples, and while, as was to be expected, there is a wide variation in the strength of the different samples, an average should give a fair standard. Knowing, then, the strength or density of the wash required it is a comparatively simple matter, by use of the hydrometer, to dilute any concentrated solution to the desired strength, either for a winter or summer spray. Thus a fruit grower may make his own concentrated solution or purchase the commercial article and dilute to a definite basis and apply a wash of a uniform strength, or, he may dilute to the strength desired for the different kinds of fruits he wishes to spray.

R. HARCOURT,
Prof. of Chemistry.

PART I.

CHEMICAL STUDY.

By H. L. Fulmer.

Need of a Study of the Composition of Lime-sulphur Was
The Lime-sulphur wash has now becom a popular spray, and
gradually becoming more and more a general spray for orchard con
work. But owing to the real lack of definite information and knowle
concerning the composition, preparation and application of this wa
farmers and fruit growers have many questions to ask regarding it wh
we are often unable to answer, except in a general way. This lack
our part has been doubly emphasized to us since the recent introduct
of what are known as the Commercial Lime-sulphur solutions. Farm
were using and knew the value of the home-made wash, but this n
thing was untried and was rightly regarded with doubt. They came
us with questions as to the value and genuineness of this new mater
but we had no figures of our own nor of others on the approximate co
position of either the home-made wash or the commercial bran
Therefore we could not make any statement as to the similarity of
two washes or, if similar, as to their comparative strength.

The need above indicated, then, led us to gather some data duri
the past year on the composition of the Lime-sulphur washes, bo
home-made and commercial. To get fair figures on these, our sampl
were obtained from as large a number of orchardists as possible a
from that district which is recognized as the leading fruit-producing o
of the Province. We endeavoured also, in collecting our samples of t
home-made wash, to draw them from all parts of the District as far
possible so that their analyses would present figures which would repr
average composition of these they are being made and applied

Besides the analysis of th nples of washes collected, we ha
also made a study of some other points in connection with the wash, ar
the results of and discussion on this work will be included along wi
those on the former.

Collection of Samples. Our samples of washes were all collecte
the Niagara fruit district, with the exception of a few representin
the commercial brands. This district was visited in April (19-23), an
then again in May (13-14), and the territory covered extends fro
Niagara-on-the-Lake and Queenston on the Niagara River front u
along Lake Ontario as far as Fruitland. Thus nearly all the fruit be
below the escarpement is represented in the samples which we obtaine
In all, twenty-eight samples of the washes were taken, and of thes

twenty-four were of the home-made variety, and the remainder represented commercial brands. Considering, in addition, the fact that six of the samples of home-made wash were taken from steam boiling plants that were supplying a large number of orchardists in their vicinity with the spray, namely, two at St. Catharines, and one each at St. Davids, Homer, Grimsby and Winona, it will be seen that we have secured samples which will give a thoroughly fair representation of the nature and composition of the home-made Lime-sulphur washes being used over the greater part of the Niagara fruit belt for Winter spraying.

When collecting the samples notes were kept regarding the methods of manufacture. This includes data as to whether steam or direct heat were used for boiling; kind and quality of *lime* and *sulphur* used; length of boiling period, etc., and these, where useful, will be introduced into the general discussion.

METHODS OF ANALYSIS.

The various determinations which we have made in our study of the composition of the Lime-sulphur washes include the following:

(a) Specific gravity (commercial washes),
(b) Sulphur in solution.
  (1) Total sulphur,
  (2) Sulphide sulphur,
  (3) Iodine sulphur,
  (4) Sulphur in other forms.
(c) Lime in solution.

Solutions Required:

(a) *Ammoniacal Zinc Chloride:* Made according to Sutton (Volumetric analysis, p. 323, 7th Ed.).

(b) *Bromine Solution.* Made by saturating a 20 per cent. solution of potassium bromide with bromine.

(c) *Barium Chloride:* A 20 per cent. solution.
(d) *Methyl Orange indicator.*
(e) *Nickel Sulphate indicator.*
(f) *Decinormal Iodine.*
(g) *Starch solution.*

SULPH[illegible]

Preparation of Sample:

(a) HOMEMADE WASHES: The [illegible] was thoroughly mixed. In cases where orange crystals had form[illegible] whole was first heated to 70° C. in a water bath until the crystals had dissolved. One hundred c.c. were then taken (when the wash was not at full dilution a proportionately less quantity was taken) and pas[illegible] through an asbestos filter with the aid of the pump. This removed [illegible] of the residue or "mud."

The residue was washed with cold water until free of sulphides cated by mixing a drop of filtrate with a drop of $NiSO_4$ indicat white plate. Filtrate and washings were then combined and m to a volume of 500 c.c.

(b) COMMERCIAL WASHES: A ten c.c. portion of the well wash was measured out. In the case of those brands from wh "mud" is not removed by the manufacturer, filtering of the samp carried on just as with the homemade washes. The whole wa made up to a volume of 500 c.c.

Determination:

(a) TOTAL SULPHUR: 50 c.c. of the bromine solution were to a 500 c.c. beaker containing about 200 c.c. of water, and then stirring, 25 c.c. of the sample were slowly run in from a pipette. of bromine was then removed by evaporation, 10 c.c of added, and the SO_4 precipitated and estimated in the way. $BaSO_4 \times .13732 = S$.

(b) SULPHIDE SULPHUR: The sulphides in 25 c.c. of the were precipitated with Ammoniacal Zinc Chloride, added in slight as indicated by Nickel Sulphate as an external indicator. Am was then removed by heating on the steam bath. The precipitate phides were next washed thoroughly by decantation and on the paper, dissolved in 25 c.c. of KOH (1:1), oxidized on the steam with 75 c.c. of hydrogen peroxide for 30 min., slightly acidified HCl and the resulting SO_4 precipitated with $BaCl_2$ and estimated usual way.

(c) IODINE SULPHUR: These forms of sulphur were deter in the filtrate and washings from the precipitated sulphides. The was made acid with HCl, using Methyl Orange as indicator, then line with solid Sodium bicarbonate, a little starch solution added then the reducing sulphur compounds titrated with decinormal solution. The reducing sulphur was figured as thiosulphate * sulph

(d) SULPHUR IN OTHER FORMS: Obtained by subtracting the of sulphide and iodine sulphur from the total sulphur.

LIME.

The total lime in solution was obtained from the same samp that prepared for the determination of the sulphur. A 25 c.c. a was oxidized with bromine in the same way as for total sulphur excess of bromine driven off by evaporation, 10 c.c. of HCl introd and the lime precipitated with solid ammonium oxalate and amm and estimated in the usual manner.

*This would not give an absolutely correct value for reducing sulphor on account of the presence sulphite, bot it has been found that this latter substance is present in such small quantity in lime- solution as to be negligible.

Valuation of a Lime-sulphur Wash.

Before an idea of the efficiency of a lime-sulphur wash can be gained from a table showing its composition, a knowledge regarding the value of the various compounds mentioned as occurring in it must be had. Value relates to the power which is possessed for killing insects or fungi, or preventing their attack, depredations or growth.

The value of the different compounds is in the main only comparative, and in practice is either high, medium, low or nil. Thus of two compounds A and B, both intended to be used for the same purpose, A may be stated to be more valuable than B for that purpose. Both may accomplish their work, A more quickly or thoroughly than B. Both may fail in their work, B more completely than A. A may accomplish its work, B may not, and yet it cannot be stated definitely just how valuable either one of them is when either be thought of apart from the other. All we can say is that the value of A is higher than that of B.

The above outlines the position we are in when we come to treat of the value of the various compounds which occur in lime-sulphur washes. We know that when the wash is well made and thoroughly applied it forms a very effectual treatment for San José scale and many other small insect pests, and also for many fungus diseases; but we do not know the definite value of any of the compounds of which it is composed. The comparative value only of these substances is known. Thus, the most valuable of the constituents are the sulphur compounds; and of these the most valuable are the sulphides. Then, in order of merit, come the "thiosulphates, sulphites (both reported, combined, as Iodine sulphur in solution) and sulphates (reported as Sulphur in solution in other forms"). Outside of the sulphur compounds we have the "lime in solution," and the residue or "mud." These materials are practically inert and useless. It must not be overlooked, however, that the former is very important indirectly, in that the existence of the sulphur compounds depend on it; and that the residue is also useful in that it acts as a marker during the spraying operation, and that it also is claimed to increase the length of time that the wash is active on the tree, and, further, that it improves the sticking qualities of the wash.

Since the sulphur compounds are the most valuable constituents of the wash, we must use them as a basis for valuation. Sulphide sulphur is the most valuable sulphur compound present, therefore in placing value on two washes, we value that one the higher which has the greater quantity of sulphide sulphur per unit volume. This method does not take in the factor of economy. A wash may be so strong as to be applied at a great waste. The matter of *correct* strength is a problem by itself and depends on—purpose of application, time of spraying, degree of infestation, etc. In the present discussion we wish only to discuss the washes themselves, as the practical application of them has received no attention at our hands.

Home-made Washes.

Following is a table showing the composition of the twenty-fo samples of home-made washes which we collected in the Niagara fr district. Data regarding formulæ, kinds of lime and sulphur used, a methods of boiling are also included.

It will be seen that quite a variety of formulæ are used in maki the home-made wash. The lime varies in amount from 16 pounds to pounds, and the sulphur from 15 pounds to 19 pounds. The most pop lar formula is 20 pounds of lime and 15 pounds of sulphur.

No. 1 Sulphur, sometimes called A, which is Flour of Sulphur quality, is used by all; the kind of lime used varies with the locality.

One hour is the favourite boiling period, but some boil as little 40 to 45 minutes, and others as much as 1¼ to 1½ hours, and even to 2—3 hours. The common way of boiling is by means of steam. Th is because steam is much more convenient to use than direct heat.

The strength of the washes varies markedly. The total sulph runs from 8.51 pounds to 17.40 pounds per 40 gallons, and the sulphi sulphur is present in amounts varying from 6.29 pounds to 13.28 poun per 40 gallons. The average of all the washes gives 13.89 pounds total sulphur, and 10.41 pounds of sulphide sulphur per 40 gallons. A a rule about 75 per cent. of the total sulphur is in the form of th sulphide. This is shown in the last column. Therefore, when th quantity of either one of these forms is known, the quantity of the othe can be approximately calculated. A high total sulphur content indicate a correspondingly high sulphide sulphur content.

TABLE I.—SHOWING THE COMPOSITION OF HOME-MADE WASHES AS MADE BY DIFFERENT ORCHARDISTS.

Sample No.	Maker and Address.	Quantity of material: Lime, lbs.	Quantity of material: Sulphur, lbs.	Kind of lime.	Kind of sulphur.	Length of boiling period.	Method of boiling.	Total sulphur in solution, lbs. per 40 gals.	Sulphide sulphur in solution, lbs. per 40 gals	Iodine sulphur in solution, lbs. per 40 gals.	Sulphur in other forms in solution, lb. per 40 gal	Total lime in solution, lbs. per 40 gals.	Ratio of total lime to total sulphur.	Per ct. of total sulphur in form of sulphide.
126	Robt. Thompson, St. Catharines......	20	19	Pt. Colborne	No.1	1 hour	pan	17.31	13.00	4.20	0.11	10.72	1 : 1.61	75.1
127	Alfred Griffis, " "	22	18	"	"	"	steam	9.58	7.31	2.21	0.06	5.97	1 : 1.60	76.3
128	E. H. Hack, " "	16	16	"	"	1-1½ hrs	pan	13.58	9.61	3.74	0.23	8.69	1 : 1.56	70.8
129	— Wilson, " "	20	16 17	"	"	2-3 hrs	"	8.51	6.29	2.05	0.17	5.76	1 : 1.48	73.9
130	W. McCalla, " "	20	16	"	"	40 min	"	14.45	10.85	3.23	0.37	8.84	1 : 1.63	75.1
132	Wm. Pringle, Homer	20	16	"	"	1 hour	steam	11.55	8.46	2.72	0.37	6.86	1 : 1.68	73.2
133	F. A. Goring, "	20	15	"	"	"	"	13.30	9.08	2.46	1.76	7.09	1 : 1.87	68.3
134	Lowry Bros, St. Davids...............	24	15	Beachville	"	"	"	10.57	8.00	2.36	0.21	6.69	1 : 1.58	75.7
135	H. C. Fisher, Queenston..............	20	16	"	"	¾-1 hour	"	15.90	12.22	3.05	0.63	10.66	1 : 1.49	76.8
137	W. H. Bunting, St. Catharines......	20	15	"	"	1 hour	"	14.30	11.48	2.59	0.23	9.40	1 : 1.52	80.3
138	T. H. Griffis, " "	20	18	Pt. Colborne	"	"	pot	17.11	13.06	2.77	1.28	9.05	1 : 1.89	76.3
139	Sam. Shearer, Niagara-on-the-Lake..	20	15	"	"	1½ hours	"	14.12	10.54	3.33	0.25	8.52	1 : 1.65	74.7
140	A. Onslow, " " " ..	20	15	"	"	1 hour	steam	14.86	11.09	3.49	0.28	8.55	1 : 1.74	74.6
142	Thos. Crow, Grimsby.	20	17	....	....	45 min	"	14.13	9.97	3.23	0.93	9.14	1 : 1.55	70.6
143	J. E. Henry, Winona..	22	17½	Hamilton	No.1	1 hour	"	17.40	13.28	3.92	0.20	10.09	1 : 1.72	76.3
144	" " "	22	"	"	"	"	"	16.46	12.68	3.69	0.09	9.96	1 : 1.65	77.0
145	" " "	22	"	"	"	"	"	14.04	10.63	3.23	0.18	8.53	1 : 1.65	75.7
146	R. R. Smith "	20	15	"	"	"	"	10.49	7.82	2.56	0.11	7.41	1 : 1.41	74.6
152	Geo. Robertson, St. Catharines.......	22	18	Pt. Colborne	"	till green color develops	pot	17.40	13.14	3.90	0.36	10.25	1 : 1.69	75.5
149	J. W. Smith, Winona................	22½	17½	Hamilton	"	45 min	steam	14.88	11.14	3.49	0.25	8.73	1 : 1.70	74.8
150	G. D. Bell, Grimsby.................	22	16	"	"	1 hour	"	15.95	11.48	4.05	0.42	10 12	1 : 1.58	71.9
147	C. P. Carpenter & Son, Winona......	18	15	"	A	50 min	"	8.86	6.80	1.96	0.10	5.49	1 : 1.61	76.7
153a	" " " "	18	15	"	"	"	"	12.99	9.92	2.99	0.08	7.97	1 : 1.63	76.4
153b	" " " "	22	18	"	"	"	"	15.64	11.91	3.59	0.14	9.35	1 : 1.67	76.1

The Iodine Sulphur makes up quite a large proportion of the to sulphur. This material is made up of thiosulphate and a small quant of sulphite, and although not nearly so valuable as the sulphide sulph yet it imparts considerable efficiency to the wash.

The sulphur in other forms is mostly sulphate. It is of no val in the wash, but, except in three or four cases, it occurs in such sm quantity as to be negligible. The main point to be remembered in co nection with this substance is that it is present as the result of t breaking down of the more valuable sulphide and thiosulphate sulph during boiling. Prolonged or over-boiling increases its amount, ther fore the desirability of controlling the boiling process.

Total lime in solution is not important, except that it is an indic tion as to the amount of sulphur in solution. The greater the amou of lime, the greater the amount of sulphur. This is shown quite clear in the column, "Ratio of total lime to total sulphur," where it is see that the proportional amounts of lime and sulphur are fairly constan Thatcher states * that lime and sulphur dissolve in the proportion of part lime to 1.94 part sulphur; and that after allowing for the lime i solution (in the wash) as calcium hydroxide. the ratio of lime t sulphur is always about 1 : 2.24. The amount of lime in solution in thes washes varies from 5.76 pounds to 10.72 pounds per 40 gallons.

Commercial Washes.

Most of the commercial washes are made up of the clear liqui which is obtained when a wash is allowed to settle. The liquid in th case of these washes, however, is much more concentrated than is th liquid which would be obtained from the ordinary home-made wash a usually made. It is the high concentration of these washes which make them so feasible. By a dilution of 8 or 10 times, or more, with wate a wash can be obtained of as great strength as the average home-mad wash, with the elimination of the trouble of boiling, and other inconveni ences experienced in making the wash at home.

It will be noticed in the next table that the commercial washe contain the same constituents as do the home-made ones. The differenc lies in the quantity of these present; the concentration is much greater and a greater proportion of the total sulphur is in the sulphide form and less in the thiosulphate and sulphate form. The ratio between lime and sulphur is also somewhat greater.

Omitting No. 13, which contains a large amount of residue, or "mud," it will be seen that the strength of these washes corresponds very closely to the specific gravity reading, *i.e.*, the greater the amount of sulphur in solution, the greater is the specific gravity. For this reason the manufacturers of these washes use the hydrometer for con- trolling the strength of their product, knowing that when the solution attains a certain density it will closely approximate a certain strength.

* Jour. Amer. Chem. Society; Vol. 30, p. 64 and p. 65.

TABLE II.—SHOWING THE COMPOSITION OF DIFFERENT BRANDS OF COMMERCIAL LIME-SULPHUR WASHES.

Sample No.	Brand and Source.	Specific Gravity of Clear Liquid.	Total Sulphur in Solution. lbs. per gallon.	Sulphide Sulphur, in Solution. lbs. per gallon.	Iodine Sulphur in Solution. lbs. per gallon.	Other forms of Sulphur in Solution. lbs. per gallon.	Total Lime in Solution. lbs per gallon.	Ratio of total Lime to total Sulphur.	Per cent. of total Sulphur in Sulphide form.	One gallon will make.*	Remarks.
131	Grasselli, from Cold Storage, St. Catharines ...	1.2927	3.245	3.018	0.192	0.034	1.352	1 : 2.40	93.0	11.6 gals. of spray	No sediment.
136	Niagara, from T. H. Griffis, St. Catharines	1.2927	2.799	2.586	0.192	0.021	1.292	1 : 2.17	92.3	9.94 " "	Large amount of sediment.
148	Vanco, from C. P. Carpenter & Son, Winona.....	1.2946	3.176	2.991	0.167	0.018	1.525	1 : 2.08	94.1	11.49 " "	No sediment.
151	Vanco. from T. D. Jarvis, Grimsby	1.2325	2.371	2.123	0.231	0.017	1.068	1 : 2.22	89.5	8.15 " "	" "
154	Vanco, from Horticultural Department, O.A.C.....	1.3230	3.566	3.405	0.154	0.007	1.597	1 : 2.23	94.8	13.1 " "	" "
156	Rex, from Rex Company, Rochester, N.Y........	1.2946	3.268	2.990	0.192	0.086	1.310	1 : 2.49	91.5	11.48 " "	" "
157	Sherwin - Williams, from manufacturers.........	1.3000	3.225	3.019	0.179	0.027	1.430	1 : 2.25	93.6	11.6 " "	" "

* This column is figured on sulphide sulphur content, taking as a standard the sulphide content of the home-made wash, 10.41 lbs. per 40 gallons, which is the average for the 24 home-made washes analyzed.

Most makers aim at a density of about 1.2946 (33° Bé). When the m
is left in the wash, however, as in No. 13, the amount of combined s
phur per unit volume is greatly decreased. Consequently, this factor
only applicable in the case of the clear solution. In this connection,
might be stated that the hydrometer could be used to great advanta
in controlling the strength of the home-made wash. The instrument
cheap, and very easily manipulated, and its use would tend to reduce t
making of the wash to a system, and lead up to the making of a mo
uniform product, and to a greater intelligence in its application.

Home-made and Commercial Washes Compared.

There is no doubt but that the commercial lime-sulphur solutio
are nearly identical in every way with the home-made solutions in so f
as composition is concerned; and, therefore, it is quite reasonable
expect that when applied in the same strength as the home-made wa
they will be just as efficient. There are some differences in the tw
washes, however, which might affect the comparison, viz., the thiosu
phate would be present in greater quantity in the home-made wash, th
home-made wash is applied hot, and the commercial brand does not co
tain the residue or "mud." It is hard to judge just what would be th
extent of difference caused by these factors. Thiosulphate is a more
less active constituent in the spray, and therefore the home-made was
would be somewhat more valuable for that reason. By spraying hot
is likely that the spray will spread much better, and a very importa
factor in determining the results of spraying is the thoroughness wit
which the surface of a tree is covered. The presence of the "mud
adds to the life of the wash, causes it to adhere better, and in itself ha
an insecticidal value; and, further, it gives a means of controlling th
spraying by virtue of the whitewashing effect which it has on the tree
The absence of residue in commercial washes, which do not contain i
can, however, be controlled to a great extent by the addition of lime t
them.

Most of the manufacturers of commercial washes recommend thei
product to be diluted one to eleven. From the next to last column i
Table II., it will be seen that only one wash can be diluted to that exten
and still give a spray with a sulphide content equal to the average home
made wash. The most satisfactory way for an orchardist to dilut
these products, in order to get the proper strength, would be to contro
the dilution by means of an hydrometer. A commercial Lime-sulphu
solution, without any sediment, will, when diluted so that it will contai
.260 pounds of sulphide sulphur per gallon—the average of the home
made wash—have a specific gravity of about 1.028. Therefore, if in
diluting, water be added until this density be reached, the amount o
dilution which the sample can sustain will be determined.

Residue or "Mud."

When the home-made wash is allowed to stand quietly for a short time till it has had time to settle, a large quantity of material gathers at the bottom of the container. The amount and nature of this residue will vary. Under ordinary conditions it will consist largely of the excess of lime which has been used in making the wash, together with a certain amount of the impurities of that material. But in case of the use of large quantities of sulphur in the formula or in underboiled washes, due to either too short a time or too slow boiling, a great part of it may consist of free sulphur. Some decomposition products, such as calcium sulphate and calcium sulphite, may also be present.

To gain some idea as to the nature of this "mud" in a well-made wash, we analyzed a sample of it. The following are the figures:

Lime (CaO)	54.513 per cent.
Sulphur (S)	.793 per cent.
Carbon dioxide, etc. (by difference)	44.694 per cent.
	100.000 per cent.

Besides the Carbon dioxide, the 44.694 per cent. will consist of varying small quantities of iron, magnesium, etc., depending upon the nature of the lime which has been used.

It will be seen from the above figures that the residue from this particular wash will possess very little, if any, more virtue than ordinary lime when applied alone. Where much free sulphur is present, then the residue would be more valuable, since sulphur is quite an active fungicide. Outside of what has been said elsewhere, then, it will be noted that the liquid part of the wash is really the active part, the residue being merely an adjunct.

Crystals.

When the wash cools it slowly deposits beautiful orange red needle-shaped crystals. These will be found mixed throughout the residue. They probably consist of a combination of one of the sulphides of calcium with lime. According to some authorities,* they have the following formula: $3CaO\ CaS_4\ .12H_2O$. The formation of these crystals goes on at the expense of the strength of the wash, and this is one reason why it is advisable to spray while hot, or at least before cooling has continued long enough, usually about 12 to 24 hours, to allow crystallization to take place. Free lime is essential to their deposition, and thus it is that we do not find them to any extent in commercial solutions, where the only free lime present is that which may be held in solution in the liquid. It is also said† that air is necessary to their

* Watts' Dictionary of Chemistry, Vol I., p. 667.
† Bull. No. 92, Penn. Experiment Station.

formation, and that if air be excluded, as by completely filling the c tainer with the wash and then sealing, or by covering the exposed s face with oil, no crystallization will take place.

These crystals will dissolve readily in water heated to 60° or 70° leaving a white residue. Thus, if a wash which has cooled to crystalli tion be heated up again before spraying, most of the sulphur deposi will again be brought into solution.

A sample of these crystals was analyzed by us, and the followi table shows their approximate composition:

Total Sulphur (S) in soluble part	18.622 per cent.
Total Lime (CaO) in soluble part	16.390 "
Total Sulphur (S) in insoluble part	0.000 "
Total Lime (CaO) in insoluble part	25.341 "
	59.353 "

or,

Total Sulphur	18.622 per cent.
Total Lime	41.731 "
Water of crystallization	39.647 "
	100.000

According to the formula $3CaO\ CaS_4\ .12H_2O$, the compositio would be as follows:

Sulphur (S)	23.19	per cent.
Lime (CaO)	40.58	"
Water of crystallization	39.10	"
	102.87	"
Subtracting	2.87	" of oxyge
	100.00	

The main thing to be inferred from the above composition is tha any considerable amount of crystallization will remove from solution great deal of sulphur, and sulphur in its most valuable form.

Chemistry of the Sulphur Compounds in Lime-sulphur Wash

The following are the reactions which the sulphur undergoes dur ing the preparation of the wash and after the wash is on the tree*:—

Manufacture:

(1) $3Ca(OH)_2$ (Slaked lime.) + $12S$ (Sulphur) = CaS_2O_3 (Calcium thiosulphate) + $2CaS_5$ (Calcium pentasulphide) + $3H_2O$ (Water.)

This reaction illustrates the main chemical change which goes on during the boiling of the wash, showing the formation of the pentasul

* Haywood Journal Amer. Chemical Soc., Vol. 27, pp. 244-255. Thatcher Journal Amer. Chemica Soc., Vol. 30, pp. 63-68.

plhide and . ' iosulphate. The following secondary reactions will also proceed:

(2)	CaS_5 Calcium pentasulphide	+	3O oxygen	=	CaS_2O_3 Calcium thiosulphate	+	3S. sulphur.
(3)	CaS_2O_3 Calcium thiosulphate			=	$CaSO_3$ Calcium sulphite	+	S sulphur.
(4)	$CaSO_3$ Calcium sulphite	+	O oxygen	=	$CaSO_4$ Calcium sulphate.		

showing the further formation of thiosulphate, and also the formation of sulphite and sulphate. The free sulphur liberated in (2) and (3) again takes part in reaction (1). Thus a sort of cycle is maintained, during which a gradual increase in the amount of thiosulphate, sulphite and sulphate takes place. When all the original sulphur added has taken part in reaction (1), then the valuable pentasulphide begins to suffer rapidly, and thus it is that undue prolonged boiling when making the wash is objectionable.

On the Tree:

The reactions given in (2), (3) and (4) represent what takes place after the wash is on the tree. Thus, it will be seen, the final products of the wash are free sulphur and calcium sulphate (gypsum).

The residue will also be present, and will now consist largely of calcium carbonate.

Theories Regarding the Action of the Wash.

Nothing definite is known regarding the action of the Lime-sulphur wash which causes it to be so effective in destroying the San José scale and the various other insects, and fungi; but some knowledge of the properties and actions of some of the constituents help us to formulate some theories as to the probable cause of its effectiveness.

(1) Caustic Action. All who have ever had anything to do with the manufacture or application of the wash know how very disagreeable it is to handle, on account of its very corrosive or caustic action. The exposed part of the person must be protected from the wash, as well as horses, harness, and other perishable parts of the spraying outfit. It is reasonable to expect then that if the tender body of an insect or the mycelium or spore of a fungus, be exposed to this sort of dosage, destruction or at least a very considerable check in growth and increase will be effected. To this action of the wash a great deal of its effect must be attributed, and it is to the sulphide that this caustic property of the wash is due. The sulphides are aided to a considerable degree in their work by the free lime which is present, by the somewhat appreciable caustic action of this material also, but more by reason of the fact that lime will tend to loosen the protecting scale of the scale insects

from the bark, and expose the unprotected body of the inmate to t sulphide. This action of lime is the secret of its value in combating t Oyster Shell bark louse.

(2) FREE SULPHUR. Sulphur has long been known to be valuab for combating fungus and insect pests. Years ago it was used wi great success for controlling the powdery mildew of the grape France, where that pest was the great scourge of the wine industry. F this purpose the sulphur was merely dusted over the leaves. Accor ing to reactions 2 to 3 under "Chemistry of the Sulphur Compounds sulphur is deposited from the Lime-sulphur wash. This occurs throug the decomposition of the sulphides and the thiosulphates, and this sulphu will have a marked advantage over sulphur that would be dusted on i the original form in that it is in a very much more finely divided cond tion, and, further, that the surface of the tree would be more perfectl covered with it.

Just how this fine sulphur acts is not known. It has been suggested by some that its action is due to the fact that it becomes changed to sul phur dioxide through the heat of the sun and the oxygen of the air, an that it is this compound or the sulphurous acid into which it woul readily change in the presence of the moisture of the air, which effect the benefits. Haywood,† however, partly disproves this, for he found i his experiments that total and free sulphur on the tree did not decreas in amount even after the end of four weeks, which could not possibly happen if the sulphur became oxidized, for under these conditions a great deal of it would volatilize. As Haywood states, however, it is not disproven that the sulphur dioxide does not form in quantity appreciable enough to be of great value, but only that this compound is not account- able for the major action of the wash.

(3) SULPHITES. These compounds are quite active as antiseptics, and would therefore by virtue of this property act as fungicides or insecticides, to a greater or less degree. During the decomposition of the wash Calcium sulphite is formed in quite large quantity, the thiosul- phate finally all changing to this compound. Such a theory as this would explain why the action of the wash extends over such a long period, for it takes several weeks for the decomposition into sulphite to become complete. The sulphite in its turn becomes changed to the more stable but inactive Calcium sulphate; still, as long as thiosulphate is present, its continued decomposition will present considerable quantity of the sulphite.

From what has gone before, then, it would appear that the caustic action of the sulphides, aided by the free lime, and free sulphur and sulphite from the decomposition of the sulphides and the thiosulphates, impart to the Lime-sulphur washes their efficacy for insect and fungus control work. A drenching rain right after spraying would greatly lessen or perhaps destroy the effects of a wash, for the sulphides and

* Journal Amer. Chemical Society, Vol. 27, p. 254.
† Ibid p. 255.

thiosulphates, the mother substances of the sulphites, and free sulphur, are readily soluble, and therefore would soon be washed off the tree. And frequent showers throughout the life of the wash would also be quite harmful, because of the constant removal of the thiosulphate. A period free from heavy showers during the spraying season would be ideal for obtaining the maximum effect of Lime-sulphur washes.

Manufacture of Home-made Washes.

A great variety of methods are in vogue for the manufacture of the home-made wash. The appliances used, especially for boiling with direct heat, are often very ingenious, and a visit to a fruit district where spraying is quite general shows the length to which orchardists will go in order to get the spray when they have once wakened up to the fact that spraying must be practised if orchards are to be maintained on a paying basis.

Judging from the great variety of practices followed and opinions held in regard to the making of the wash, there seems to be a great lack of definite knowledge as to the principles underlying the manufacture of the mixture. Some of these differences relate to the kind and quantity of materials to be used, others to the method of boiling and the length of time necessary for complete boiling, and others to various minor details in the process of making and applying.

In view of the above, we have carried out a few experiments on the manufacture of the wash, in order to obtain some figures bearing on these points. The nature and discussion of these experiments follow:

Experiment I.—Different Kinds of Lime for making Lime-sulphur Wash.

In this experiment we aimed to find what influence limes of various degrees of purity would have upon the strength of the wash. Four limes were tested which in composition are representative of all lines that will be found on the market in Ontario. They include the pure lime of Beachville and the dolomite of Guelph, and also the limes of Port Colborne and Caledon, which latter are depressed in purity on account of the presence of such substances as iron, aluminum, silica, etc.

The following figures will show the purity of these limes:

Beachville	99.4 per cent.	CaO
Port Colborne	86.4 "	"
Caledon	91.6 "	"
Guelph (dolomite limestone)	48.8 "	"
	37.2 "	MgO

Washes were made from each of these lines, and analyzed. Fo lowing is a table showing their composition. Formula: Lime 20 pound sulphur 15 pounds, water 40 gallons. Method of Bo ling: By steam.

Lime.	Time boiled. min.	Sulphur as sulphides. lbs.	Sulphur as thiosulphates and sulphites. lbs.	Amount o sulphur i solution. lbs.
Beachville	60	12.19	1.76	18.95
Port Colborne	60	12.77	1.	14.60
Caledon	60	12.89	1.76	14.65
Guelph	60	13.10	1.65	14.75

Here we have the rather unexpected phenomenon of obtaining th strongest wash with the weakest lime. There is a difference of pounds of total sulphur in solution between Beachville and Guelph lim in favour of the Guelph; and further, Beachville, the purest lime, ha given the weakest wash all through. All these washes are good, how ever, and none of them but would give satisfactory results in spraying leaving out of consideratic . the amount and composition of the residu

An interesting point brought out in this experiment is the fact tha twenty pounds of lime in the case of those of a high purity gave a grea excess of CaO over that required to bring fifteen pounds of sulphur int solution. Twenty pounds of Guelph lime will furnish 9.77 pounds o CaO, while the same amount of Beachville lime will contain 19.88 pound of CaO; still, Guelph lime furnishes enough of the oxide of Calcium t bring into solution a maximum amount of the 15 pounds of sulphur Arguing from this, 20 pounds of Beachville lime must furnish at leas 10.11 pounds of CaO in excess of that required. In other words, 2 pounds of Beachville lime are sufficient to dissolve over 30 pounds o sulphur.

From the relation which exists between lime and sulphur in solu tion, in Lime-sulphur wash, 1 part of CaO will combine with 1.94 part of S. It appears then that 15 pounds of sulphur actually require abou 7.73 pounds of CaO to bring it into solution. From this even 20 pound of *Guelph* lime, with its 48.8 per cent. purity, will furnish 2.04 pound of CaO in excess of the necessary amount.

In view of the foregoing facts, it can be safely argued that th formula 20-15 will in all cases furnish sufficient lime for making a satis factory wash; and further, that judging from the table of analysis, dolo mite limestone, such as is found in the Guelph formation, produces lim suitable for the manufacture of the Lime-sulphur wash.

EXPERIMENT II.—TO COMPARE FLOUR OF SULPHUR, AND FLOWERS OF SULPHUR FOR MAKING LIME-SULPHUR WASH.

Lime used: Beachville.

Formula: Same as in Expt. I.

Method of boiling: By steam.

Kind of Sulphur.	Time boiled. min.	Sulphur as sulphide. lbs.	Sulphur as thiosulphate and sulphite. lbs.	Amount of sulphur in solution. lbs.
Flowers of Sulphur	20	9.67	1.06	10.73
" "	40	11.33	1.83	13.16
" "	60	11.62	1.83	13.45
Flour of Sulphur	20	10.94	1.48	12.42
" " "	40	12.37	1.62	13.99
" " "	60	12.19	1.76	13.95

The above results show that Flour of Sulphur combines more rapidly and more completely with lime than do the Flowers of Sulphur. The difference between the two, however, is not so great but that the matter of choice between the two forms would rest rather on cost than on form. From Table I. it is seen that Flour of Sulphur (called No. 1 or A) is used altogether in the Niagara district, due to the fact that it is cheaper, and also that it is found to be just as satisfactory.

The completeness and rapidity with which sulphur will enter into combination with lime depends on its fineness. Haywood cites an experiment which he performed with a sample of coarse, dark coloured brimstone sulphur in making lime-sulphur wash. He found that no treatment would cause this sulphur to combine with lime rapidly, or anywhere near completely, until it was powdered finely, after which it was almost as satisfactory as Flour or Flowers of Sulphur.

Given several varieties of sulphur, then, the finest and purest one should be chosen as the most suitable for making the Lime-sulphur Wash.

EXPERIMENT III.—LENGTH OF TIME NECESSARY TO BOIL IN ORD
OBTAIN THE MAXIMUM COMBI TION OF LIME AND SULPHU

Formula: Same as in Expt. I.
Method of boiling: By steam.

Lime.	Time boiled. min.	Sulphur as sulphide. lbs.	Sulphur as thiosulphate and sulphite. lbs.	Amou sulph solu lb
Beachville	20	10.94	1.48	12
"	40	12.87	1.62	18
"	60	12.19	1.76	13
Pt. Colborne	20	11.04	1.27	12
"	40	12.77	1.54	14
"	60	12.77	1.88	14
Caledon	20	11.29	1.48	12
"	40	11 97	1.69	13
"	60	12.89	1.76	14
Guelph	20	9.41	1.06	10
"	40	11.40	1.41	12
"	60	13.10	1.65	14

Maximum combination has taken place practically in every ca the expiration of one hour; and in case of the Beachville and Pt. borne l.. es we have indeed a maximum sulphide content after ..rty minutes of boiling.

From the figures shown, it is clear that one hour's boiling is suffi for preparing the wash, regardless of the kind of lime used; and fur that some limes unite more readily with sulphur than do others. I boiling period be pushed past that time necessary for maximum bination, the cost of manufacture increases; and further, the effec ness of the wash decreases, because of the breaking down of the able sulphur compounds into less valuable ones: viz., sulphides into sulphates and sulphites, and also sulphites into sulphates. In fact, ..onged boiling will actually reduce the amount of total sulphur in bination, as is shown by the Beachville lime in the above table. last would happen more readily when direct heat is used for boiling in the pot or pan method.

It must be borne in mind, however, that the *rate of boiling* determine the length of time necessary for maximum combination. the above experiment *vigorous boiling* was maintained throughout boiling period. Although the strength of the wash will vary in r to the amount of lime and sulphur used, no quantity of materials give a wash of maximum strength if the boiling is not properly d *Weak, slow boiling* on account of a small fire or low steam pressure never give a good wash even after prolonged boiling. If Table I.

examined, some interesting points will be noticed regarding the strength of the various washes. Although the formulæ vary considerably, yet we do not find that we always get the greater quantity of sulphur in solution where we have the larger quantities of materials used (compare Nos. 127 and 128 or 132 and 133, Table I.), nor the same amount where we have the same quantities of materials (compare Nos. 129, 130 and 132, or 140-146, Table I.). There is not a formula there indicated but would give a splendid wash if the boiling be properly done, yet there are some of them that are remarkably low in combined sulphur and show a great waste in uncombined sulphur. All such have been underboiled because of a slow fire or low steam pressure. Sulphur left uncombined will probably be no more effective than sulphur that is merely mixed with water and then applied.

Boil vigorously and then any of the average formulæ will give a good wash, without the boiling period being longer than from forty-five minutes to one hour.

Experiment IV.—The Effect of Increasing the Proportion of Sulphur to Lime.

Lime used: Beachville.
Water: Forty gallons.
Method of boiling: By steam.

Amount of lime. lbs.	Amount of sulphur. lbs.	Time of boiling. min.	Sulphur as sulphides. lbs.	Sulphur as thiosulphate. lbs.	Amount of sulphur in solution. lbs.
20	15	60	12.89	1.76	14.65
20	20	60	16.00	2.54	18.54
20	20	120	16.18	2.68	18.86

The main effect observable in the above table, caused by increasing the proportion of sulphur to lime, is that the amount of total sulphur in solution is increased. This is what we would expect to happen so long as the lime is present in sufficient quantity as to be in excess. Since, as stated elsewhere, 1 pound of lime (CaO) is a sufficient quantity to dissolve 2 pounds of sulphur, then 20 pounds of Beachville lime (99.4% CaO) will be sufficient to cause about 40 pounds of sulphur to go into solution.

The amount of sulphur which goes into solution, however, does not bear a direct ratio to the amount which is used. According to the figures, 15 pounds of sulphur with 20 pounds of lime furnish 14.65 pounds

of combined sulphur; and 20 pounds of sulphur with 20 pounds of furnish 18.54 pounds of combined sulphur. The increase in the am of sulphur used is equal to 33 per cent., whereas the increase in bined sulphur is only 27 per cent. Longer boiling up to 2 hours incr the amount to 29 per cent., but even then it is 4 per cent. below. T would be a slight increase in the waste of sulphur, then, where larger proportion is used, but the increase in the amount of wash tained would amount to 10.8 gallons, the value of which would e cover the cost of the 5 pounds extra sulphur used, the only additi expense. Figuring sulphur at $1.50 per cwt., the extra wash prep would cost .69c. per gallon; whereas the cost of preparing one gallo home-made wash averages about 1c. Therefore increasing the am of sulphur in our formulæ up to a certain limit appreciably decreases cost of production, and more so is this true when we allow that the creased amount of wash is produced without entailing any additional in time, labor and fuel.

The main point to be noticed where the proportion of sulphu lime is increased is that the amount of sulphur in solution is corresp ingly increased, although not in direct proportion. This fact is ta advantage of in the manufacture of the factory-made solutions, wh are from 8 to 10 times or more stronger than the average home-bo wash. The same fact can be taken advantage of also for making ho made concentrates, a matter which will be dealt with later on.

EXPERIMENT V.—TO COMPARE STEAM AND DIRECT HEAT METHODS BOILING.

Lime used: Beachville.

Formula: Same as Experiment I.

Method of boiling.	Time boiled. min.	Sulphur as sulphide. lbs.	Sulphur as thiosulphate and sulphite. lbs.	Amount sulphur solution lbs.
Direct Heat.....	20	10.94	1.48	12.42
" "	40	12.37	1.62	13.99
" "	60	12.19	1.76	13.95
Steam Heat....	20	10.94	1.13	12.07
" "	40	11.86	1.69	13.55
" "	60	12.52	1.69	14.21

From the above results it is seen that direct heat induces a mo rapid combination of the lime and sulphur than does the steam heat, b gives a wash of slightly lower value. The difference shown, howeve does not give any decided choice of method. Considering the greate

convenience of boiling by steam, it is perhaps the most desirable way to prepare the wash; still there are many small orchardists who have not the facilities at hand to boil by steam, in which case its preparation by direct heat may be conveniently and cheaply employed.

A point which has been mentioned before and which can here again be emphasized is that the results of boiling and the strength of the wash depend more largely on the *vigour* with which the boiling is carried on than on any other one factor, other conditions being equal. *Slow boiling*, no matter what the source of heat be, will always give weak, unsatisfactory washes.

In view of the more rapid combination of the lime and sulphur, and also of the tendency to decomposition after a certain point is reached, it is recommended that the boiling period be confined within the limits of 45 to 50 minutes when direct heat is used.

Experiment VI.—On the Development of a Green Colour in the Wash During Boiling.

It is thought by some who make and use the Lime-sulphur wash that the development of a green colour is a good indication as to when boiling is complete. We found this colour formation to be due largely to the presence of iron in the lime, or to that derived from the vessel in which the boiling is carried on, or from the pipes conveying the steam. The fact remains, at least, that in the absence of iron or some other similar metal, such as copper, lead, nickel, etc., this colour does not develop, even after prolonged periods of boiling. Hence the colour change cannot be used as an indicator. The length of time it takes for the colour to develop depends upon the amount of iron, etc., which is present. With some limes with which we have worked the colour appeared about the time that the maximum amount of sulphur is in combination, viz., one hour, and therefore in such cases serves as an indicator; but with other limes it did not develop until long after that period; while with others it developed within 20 minutes, at which time only about three-quarters of the sulphur is in combination. Plainly, then, the colour change is an indication of the completeness of boiling only in cases where those limes are used which contain a certain amount of iron or other like metal.

Port Colborne lime, which is used extensively in the St. Catharines district, always produces the green colour, and at the end of about one hour; but Beachville and Hamilton limes do not produce it.

Experiment VII.—On the Depreciation of the Wash if Allowed to Cool.

When the Lime-sulphur wash is allowed to stand for some time a large quantity of orange red crystals form in the residue at the bottom

of the container. This happens at the end of 12 to 24 hours. crystals are made up largely of sulphide sulphur, and their form results in a lowering of the strength of the solution. They c readily be sprayed, as they tend to clog the nozzle, and even if they be applied to the tree they would not be very effective. By heatin spray up to 60° to 70° C. (140° to 158° Fah.) these crystals can be readily dissolved, however, and their value regained to a great exte

The following figures show the difference in composition of washes, one of which has been allowed to cool for 24 hours and heated up again, the other conditions being maintained alike:—

Lime used: Beachville.
Formula: Same as used in Experiment I.
Method of boiling: By steam.

Treatment.	Sulphur as sulphide.	Sulphur as thiosulphate and sulphite.	Amoun sulphu soluti
Boiled 60′ and analyzed at once	12.19	1.76	13.9
Boiled 60′, cooled 24 hrs., brought to a boil and analyzed at once	11.91	2.01	13.9

These figures show that the wash becomes slightly less valu when allowed to cool before being applied, the sulphide and total sulp having both decreased in amount. The difference in these two was is so small, nevertheless, as to be negligible, and if at any time a ba of wash be allowed to cool and crystallize before it is sprayed, it sho not by any means be discarded. If it be heated up and boiled for a minutes it will be almost as valuable as before.

Home-made Concentrates.

One of the greatest inconveniences connected with the use of home-made wash is the amount of time and bother which is required boiling it; and this at a time when, as a rule, labour could be used mu more profitably in some other direction. For this reason the comm cial brands of Lime-sulphur appeal to some orchardists, although t spray in this form is a little more expensive. This is especially true no since Lime-sulphur has begun to take the place of Bordeaux mixture a summer spray, for at this season of the year it seems almost out place to boil, and it is much more congenial and a great deal handier dilute from a stock solution. In view of the fact that the results o tained from these purchased materials are as satisfactory as those pr duced by the home-boiled stuff, it is quite safe to predict that man orchardists will soon come to use them altogether. When these materia were first introduced fruit growers were a little dubious as to the

value, and were rather conservative in their use of them, but in the light of experimental work that has been carried on with them, both by practical men and Experiment Station workers here in Canada and also in the United States, their usefulness and similarity in composition and source with the home boiled article are now apparent.

These factory boiled Lime-sulphur solutions, for obvious reasons, could not compete successfully with home-made washes if the latter could be stored for any length of time without deteriorating considerably in quality. The home-made wash could be made in quantity during the less busy times of the winter, and be ready for use as soon as the spraying season opened up in the spring. But its crystallizing property and, what is more important, the fact that it would require an immense amount of storage space, puts such a procedure out of the question.

Recently, however, it has been demonstrated that it is quite possible to make a home-made concentrated Lime-sulphur solution that will compare very favourably with the concentrated commercial solutions.* If this can be done, then the main difficulty in the way of preparing the season's wash during the winter, viz., the lack of storage facilities, will be largely overcome. The principle on which the concentrate is made does away with the excessive crystallizing tendency, *i.e.*, as elsewhere stated the use of a large quantity of sulphur in proportion to the lime, so that very little uncombined or free lime is left at the end of the boiling period.

If the maximum quantity of sulphur to lime be used, *i.e.*, with a lime like Beachville 99.4 per cent. pure, 40 pounds of sulphur, to 20 pounds of lime (or 2 to 1), and the quantity of water used be kept within minimum limits, a very strong Lime-sulphur solution can be manufactured, and a solution which on cooling will not deposit crystals. This is the basis on which a home-made concentrate can be made, suitable for storage.

A formula for preparing the concentrate and directions of procedure are given by Professor Stewart,‡ of Pennsylvania Experiment Station, which is very suitable for making about 40 gallons of mixture at a time, an amount which will give from 32 to 35 gallons of clear liquid concentrate similar to the clear commercial brands.

His formula and directions are as follows:†

50 lbs. best stone lime (not over 5% impurities).
100 lbs. sulphur (flour or flowers).
40 to 45 gallons of water, *at finish.*

"Put 8 gallons of water in kettle and start fire. Place lime in kettle. After slaking is well started, add the dry sulphur and mix thoroughly, adding enough water to maintain a thin paste, which requires about 5 gallons. After the slaking and mixing is completed, add water

* Penn. Bulletin No. 92.
‡ Penn. Bull. No. 92, p. 12.
† The author's figures for volume have been changed to Imperial measure.

to the height of 40 gallons on the measuring stick, bring to a
stir until the sulphury scum practically disappears. Then add
(preferably, but not necessarily, hot) to the 55 gallon height a
again to 50 gallons, if storage space is limited. If it is not lim
little more water should be added the third time and boiling sto
about 45 gallons. The material should be kept well stirred, es
during the early stages of the process, and any lumps of sulphur
should be thoroughly broken up.

"The total time of actual boiling should be about one hour,
a ten-minute variation either way is not objectionable providi
sulphur is evidently dissolved. This fact is best determined by
and slowly pouring some of the material. The amounts of wate
cated above are ample for one hour's fairly vigorous boiling, wi
finishing volumes as indicated. If it is not at the desired height
close, it may be made so by more water or more boiling, and eith
amount of water in the third addition or the vigour of boiling can
modified in later trials as to enable the total to be brought to the
height approximately at the end of the hour.

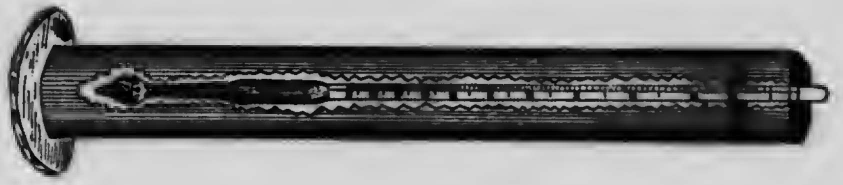
"The finished product may be immediately poured or strained
barrel or settling tank or into the spray tank. The straining is me
safeguard to prevent any possible clogging because of imperfect
rials or failure to break lumps in the sulphur. When properly ma
amount of sediment left in the strainer is insignificant, being less
1%, as shown in Table I., and may be thrown away. To avoid any
siderable loss of materials, however, the sediment in the strainer c
washed with part of the water used in making the next lot, simply
ing the water through the strainer into the kettle, and any lum
sulphur discovered may be broken up and used again.

"If the straining is not done, the whole product may be put i
settling tank or barrel, and the clear liquid drawn off later as requ
This process, however, is likely to lose efficient liquids in the sludg
well as the fine sludge itself, which may be of value in several ways
is of no apparent hindrance in the spraying.

"The crust which forms on the finished material is prevente
immediately covering the solution with a layer of oil about an eight
an inch thick, and avoiding unnecessary exposure to air in the tra
from kettle to storage tank. An ordinary paraffin oil was very sati
tory in our work, but there is reason to believe that any other oil,
injurious to trees nor likely to take fire at boiling temperatures, ma
used with equal success.

"The crust may also be prevented by immediate storage in ti
closed vessels, filling them completely. But partially filled vessels
likely to develop some crust upon continued exposure."

Washes were made, using the above formula and directions, f
two of the common limes, Beachville and Port Colborne, and analy
The results are shown in Table III.



An hydrometer, a form of specific gravity spindle, very useful in testing the strength of lime-sulphur solutions. It is here shown suspended in a cylinder of water in the same way that it would be suspended in a vessel containing lime-sulphur solution.

TABLE III.—SHOWING THE COMPOSITION OF SOME HOME-MADE LIME-SULPHUR CONCENTRATES.

Sample No.	FORMULA.			Specific Gravity of Clear Liquid.	Kind of Lime.	Length of Boiling Period.	Total Sulphur in Solution. lbs. per gallon.	Sulphide Sulphur in Solution. lbs. per gallon.	Iodine and other forms of Sulphur in Solution. lbs. per gallon.	Per cent. of total Sulphur in Sulphide form.	Amount of Clear Liquid obtained. Gallons.
	Lime. lbs.	Sulphur lbs.	Water. gals.								
158	50	100	40	1.232	Beachville	1 hour.	2.393	2.192	.202	91.6	35.5
159	50	100	40	1.232	Pt. Colborne	"	2.371	2.228	.143	93.1	32.2
160	50	100	35	1.245	Beachville	"	2.670	2.646	.023	99.1	30.7

If this table be compared with Table II., it will be seen th
is not much difference in composition between the commercial
trated Lime-sulphur solution and the home-made solution. T
mercial articles are stronger and denser than the home-made,
latter could easily be made as high in these respects by merely r
the quantity of water used. This tendency is shown in No. III.
the quantity of water was reduced by 5 gallons, thereby raisi
specific gravity by .013 points and increasing the amount of the
compounds per unit volume to quite an extent.

To control the manufacture of the strong solution, it will b
tically necessary to use a specific gravity spindle (hydro
Especially would the use of this instrument be essential in the
mental stages of making the wash, for it is the only ready means
hand of the practical man for determining the strength. The ma
tions in using the spindle are very simple. All one has to do in
the density of his wash by this means, is to allow the wash to stan
enough to settle and cool to about 60° F., and then to suspen
instrument in the clear supernatant liquid. The density of the liq
that reading on the graduated scale just at the surface. The furth
spindle sinks into the liquid the less is the density, and *vice versa*

The specific gravity of a wash also gives the only ready bas
the dilution of the concentrated washes, or for that matter, of any
It is pretty well established that unless other substances such as
soda, etc., have been used in the manufacture of the Lime-sulphur
that the specific gravity varies in nearly direct proportion to
strength, *i.e.*, the denser a wash is the greater the dilution necessa
reduce it to a standard strength. The only exact basis of dilutio
course, is on the sulphur content, especially the sulphide sulphur
tent, but such a factor can only be determined by chemical analysis.

The specific gravity of the liquid of a well made home-made
of the 20-15-40 formula will run about 1.028. Therefore, since
wash is very satisfactory, although not by any means an establi
standard, the foregoing factor can be used as a basis for dilution
winter spray. Suppose a wash on hand has a specific gravity of 1.
The amount of dilution which it can stand can be approximately d
mined by dividing the decimal part of the reading by the decimal
of the reading of the standard. Thus:

$$\frac{.200}{.028} = 7.14.$$

That is, one gallon of the wash when diluted to
proper strength will have a volume of 7.14 gallons, or, in other wo
for each gallon of the wash approximately 6.0 gallons of water must
added in order to get a wash of the correct strength.

For the summer spray, dilution would have to be carried to a m
greater degree. It is quite possible, however, that the self-boiled Li
sulphur wash as recommended by Mr. W. M. Scott, of the United Sta
Department of Agriculture, will become the popular summer spray.

Hydrometers for heavy liquids, ranging from 1.000—1.400, can be obtained from any chemical supply house in Toronto or elsewhere for 75 cents to one dollar. They can be had showing both the Baumé and Specific Gravity scales, but if an instrument is obtained showing only one of the scales, the latter is to be preferred as it gives the most ready means for dilution unless a conversion table for the two standards be at hand.

Amount of Spray Supplied by the Home-made Concentrates as Given in Table III.

When the home-made concentrates—as given in the table—are diluted to winter spray strength, the following amounts of spray will be obtained.

Sample No.	Diluted on sulphide basis—10.41 lbs. to 40 gallons.	Diluted on specific gravity basis —1.028 for average spray.
158	299 gallons	294 gallons
159	276 "	267 "
160	313 "	269 "

One hundred pounds of sulphur, as in the ordinary home-made wash, of the formula 20-15-40, will make about 266 gallons of spray.

The dilutions in above table are all figured on the volume of clear liquid which would be furnished as indicated in Table III. This amount would vary for different limes and different concentrations, but would be fairly constant when these factors are constant.

If all the concentrate be used, both mud and liquid, then the amount of water added to each gallon would have to be lessened in proportion. The retention of the mud in the spray might be advisable. It does not disturb the keeping qualities of the concentrate, and further, it possesses considerable merit, as elsewhere mentioned.

Quality of Lime Useful for Making the Concentrate.

Lime of good quality should be used in making the home-made concentrate. Beachville lime (0.6% impurities) is of ideal quality, but Port Colborne (13.6% impurities) is also suitable according to Table III. The purer the lime the greater will be the quantity of strong liquid obtained. Beachville gives 2.8 gallons more than Port Colborne per 40 gallons. Caledon lime with its 8.6 per cent. of impurities would also be suitable. Guelph lime which has 51.2 per cent. of impurities, is quite unsuitable. With it a wash ranging only from 1.100 to 1.126 sp. gravity could be obtained by using the proportion of 1 : 2.

Freshly burnt lime should also be used, because air-slaked combines with sulphur very slowly. It is very good for makin ordinary home-boiled wash where the proportion used is usually g than the sulphur, but for the manufacture of the concentrate it is v unsuitable. Air-slaked Beachville lime gave a wash ranging only 1.140 to 1.153 sp. gravity after one hour boiling. Longer boiling ... case this but such a procedure would be undesirable.

From the conclusions of Professor Stewart, and from the resu our own work, it seems altogether likely that the home-made co trated Lime-sulphur solution will take an important place in ord control work. After the initial expense for barrels and storage has been once covered, the concentrate can be prepared more ch than the commercial article can be purchased unless the price of latter be reduced. It can also be prepared more cheaply than can ordinary home-boiled wash, as more economy both in lime and fu accomplished; it can be made at slack times; and it is ready for spra at a moment's notice.

The Use of Arsenicals with Lime-sulphur Washes.

In view of the fact that Lime-sulphur solutions are beginning take the place of Bordeaux Mixture for summer spraying for fur diseases, it is important to know whether arsenicals can with safety added to them for controlling codling moth larvæ, etc. If they then a second spraying operation, which would otherwise be necessa will be obviated.

The main points to consider in this connection are: (1) Will wash be decomposed or lessened in strength and activity by the addi of arsenicals, and (2) will the arsenicals be lessened in efficiency changed in such a way that they would induce foliage injury.

As to the second point, there is little doubt as to the efficiency of arsenicals being left unchanged, since no arsenic is withdrawn from field of action. But there is a danger regarding foliage injury. found that considerable quantities of soluble arsenic, the injurious su stance, were present in the spray where arsenicals were used. On tend foliage, such as peach, marked damage might result, but this is a po which can only be settled by actual spraying experiments. Plenty free lime in the spray will overcome the danger to a great extent, b would not altogether prevent damage on susceptible foliage.

The first point, the effect which the addition of arsenicals will pr duce upon the strength of the wash, we studied quantitatively. Th effect on activity can only be studied by spraying experiments, exce in so far as it might be indicated by effect on strength. For obviou reasons the strength of a wash could not possibly be markedly change —for the amount of an arsenical which would be added would be com paratively so small in amount that the extent of decomposition which

could bring about would be practically insignificant; but some quantitative estimations were made in order to gain some information on this point. A wash was prepared and divided into several portions. To a separate portion one each of the more common arsenicals was added and then each portion was analyzed for total sulphur in solution. The plan was as follows:

To portion No. I. was added Lead Arsenate, at the rate of 3 pounds per 40 gallons.

To portion No. II. was added Paris Green at the rate of 1 pound per 40 gallons.

To portion No. III. was added Calcium Arsenite at the rate of ½ lb. of As_2O_3 per 40 gallons.

To portion No. IV. nothing was added.

After the arsenicals were added the mixtures were agitated every few minutes for an hour and then at the end of that time analyzed. The following figures show the results:

No.	Arsenical added.	Total sulphur in solution. Lbs. per 40 gallons.	Amount of sulphur removed from solution. Lbs. per 40 gallons.
I.....	Lead Arsenate....	12.587	.067
II.....	Paris Green.....	12.149	.505
III.....	Calcium Arsenite..	12.653	.001
IV.....	Check.....	12.654	....

It will be seen that the amount of sulphur removed from solution is very small when Lead Arsenate or Calcium Arsenite are used—it is removed in insignificant amounts by the latter. But Paris Green causes considerable destruction, slightly over one-half pound of sulphur being destroyed, an amount which would represent from 10 to 40 per cent. of the sulphur which would be present in summer sprays.

There is no reason why arsenicals such as Lead Arsenate and Calcium Arsenite should not be used along with Lime-sulphur washes, should no foliage injury result. Calcium Arsenite would be preferable as it is cheap and effective and can readily be made at home.

Summary.

Data secured in regard to the home-made washes reveal a large number of different formulæ and decided differences in the strength of the wash as applied. Sulphur in the formulæ varies from 15 to 19 pounds, and lime from 16 to 24 pounds to 40 gallons of water. The popular formula is the old 20-15-40 one, and the favor[illegible] boiling period is one hour.

Analyses show that the liquid part of the wash consists of a solution of calcium sulphide, calcium thiosulphate and sulphite, and calcium sulphate. The average amount of sulphur in these different forms is 10.41, 3.11 and .37 pounds, respectively, per 40 gallons. The residue or "mud" is composed of lime and very small amounts of free and combined sulphur, together with such substances as iron, aluminium, silica and magnesia, and other impurities in the lime used.

The strength of the wash does not depend upon the formula entirely, but more largely on the *thoroughness* and *rate* of the boiling. Weak, slow boiling will produce a weak wash no matter how much sulphur or lime be used. It is this fact which is accountable for the many conflicting opinions held regarding formulæ and methods of preparation, etc.

Commercial Lime-sulphur solutions contain the same constituents as the home-made washes, except that they lack the "mud," (one exception, see No. 136, Table II). They are therefore of similar origin and value. They are 8 to 10 times or more stronger than the home-made washes, and must be diluted accordingly.

The strength of the commercial Lime-sulphur solutions is controlled by means of the specific gravity, for it has been found that strength and density of the clear solution of lime and sulphur vary in nearly direct proportion. Specific gravity can readily be determined by means of an hydrometer, an instrument which costs but little, and which can be utilized by any one after a little experience.

Further, the hydrometer can be used for controlling the strength of *any* genuine Lime-sulphur solution, *i.e.*, any solution which has been made by boiling together lime and sulphur in water without the addition, either before or after, of any other material such as soda, salt, etc.

The valuable constituent of the Lime-sulphur wash is the Calcium sulphide (sulphide sulphur), but its effect is ably complemented by the other constituents present. The greatest aid, however, is obtained from the decomposition products—free sulphur and calcium sulphite.

Dry weather during and following the spraying season allows the wash to exert its maximum effect. A heavy rain right after spraying or intermittent showers following every few days will greatly lessen or destroy the benefits of the wash.

From the results of our experiments on the preparation of the home-made wash, we arrive at the following:

(1) Normal limes, ranging from 48 pounds and upwards of pure CaO per 100 pounds, are suitable for making Lime-sulphur wash with a formula of 20 pounds lime and 15 pounds sulphur (or any formula having the proportions, 4 lbs. lime to 3 lbs. sulphur).

(2) *Flour* and *flowers* of sulphur are of equal value for making the wash, provided they possess an equal degree of fineness and purity.

(3) Forty-five minutes to one hour is a sufficient length of time to boil the wash, provided the boiling is *vigorous*.

(4) Increasing the proportion of sulphur to lime up to 1 : 1, or even higher in case of the use of a pure lime such as Beachville, will increase the strength of the wash and decrease the cost of production.

(5) Steam and open fire are of nearly equal value as sources of heat energy for boiling the wash.

(6) The development of a green colour during boiling cannot be taken as an indication of the completeness of boiling with all limes.

(7) If a wash cools and crystallizes before it is applied it is not valueless. Heating up to 60° or 70° C. (140° to 158° F.) and stirring to break up the sediment and crystals at the bottom till the crystals dissolve will render the wash practically as efficient as before.

Experiments carried on in regard to other points show the following:

(a) Home-made concentrated Lime-sulphur solutions comparing favourably with the commercial solutions can be made on the farm and at less expense.

(b) Lead arsenate and calcium arsenite can be added to Lime-sulphur washes without causing any appreciable depreciation in the strength of the latter.

(c) The formation of crystals in Lime-sulphur washes is mainly due to an excess of free lime, but contact with air will also cause concentrated Lime-sulphur solutions to crystallize. If lime be added to concentrated Lime-sulphur solutions, they will suffer extensive crystallization at once. Lime added to diluted concentrates will soon cause appreciable crystallization. Concentrated Lime-sulphur solutions should be diluted first and then the lime added just immediately before spraying.

Recommendation.

It is very desirable that extensive orchard experiments be carried on, in connection with chemical analytical work, in order that some standard formula for making and preparing a Lime-sulphur wash could be settled on which would at various dilutions cover all cases in question. At the present time there is a great lack of unity and definiteness concerning everything in this connection. Formulæ vary, directions for preparation vary, and even closest neighbors are at variance over the question. There is no doubt but that a standard formula, with specific directions attached, can always be made to produce a wash of constant strength. The flagrant latitudes which are now so general are only producible of constant misunderstandings and controversies which are hard to explain away.

Acknowledgments.

Credit is due to all the available sources of information which have been used in carrying on this work in connection with the Lime-sulphur washes, and especial thanks are due to Professor Harcourt for the many valuable aids and suggestions given, and for laying the plans of the investigations herein reported.

PART II.

PRACTICAL AND POPULAR TREATMENT.

By L. Caesar.

In discussing the lime-sulphur wash from the practical and popular standpoint attention will be given first to the different forms in which the wash may be used, the proper method of preparing each of these, the use of arsenicals with the wash, proper spraying outfits, and hints on spraying. After these subjects have been discussed the remaining space will be devoted to an account of the different insects and fungus diseases which experience has shown may be controlled by the wash, and to specific directions for the proper treatment of each.

The Different Forms of the Wash.

1. Home-boiled lime-sulphur.
2. Self-boiled lime-sulphur.
3. Home-made concentrated lime-sulphur.
4. Factory-made or commercial lime-sulphur.

Of these forms Nos. 1 and 4 are at present by far the most commonly used in Ontario. No. 2 is beginning to be used a good deal, but No. 3 is still in the experimental stage. It promises, however, to become the most popular of all in a few years when further study and experiments will have shown the best method of preparing it, and of determining the proper strength to use in each particular case.

Home-boiled Lime-sulphur.

This form of lime-sulphur is meant to be used on the trees only when they are dormant or before the buds have actually burst. It is often, however, used without injury when the tiny leaflets have protruded nearly half an inch beyond the bud scales, but it is not safe to use it later than this as it will usually burn the leaves after they are once unfolded. For years this wash has been very popular in the Niagara district and in nearly all the states across the border.

The Proper Formula. There have been many different formulæ for making it, some much stronger than others. The one most popular to-day is 20 lbs. fresh stone lime, 15 lbs. sulphur and 40 gals. water. If a few trees very badly infested with San José scale are to be treated the proportions are sometimes changed to 25 lbs. lime and from 18 to 20 lbs. sulphur to 40 gals. water. For all ordinary purposes the former

strength is sufficient. In very dry climates still weaker formulæ may be used satisfactorily but it is not advisable to use them in Ontario.

DEVICES FOR BOILING. Many different devices are used for boiling the mixture. It is not at all necessary to have an expensive outfit. A cheap simple one will give as good results. A kettle holding from 20 to 25 gals. water will serve the purpose.

Fig. 1. Kettle used for boiling the lime-sulphur wash.

Fig. 1 shows a kettle that was used by a successful fruit-grower last spring and that gave satisfaction. A more economical device is shown in Fig. 2.

Fig. 2. Wooden box with sheet-iron bottom used for boiling the lime-sulphur wash.

This consists of a stout, close-fitting box with wooden sides and ends and sheet-iron bottom. This box is usually made large enough to boil sufficient of the mixture at one time for two barrels of diluted spray. Each box is about 6 feet long, 3 feet wide and from 14 to 18 inches deep. The sides and ends are made of 2 inch planks closely fitted together at the corners. The sheet-iron bottom should extend slightly beyond the planks to protect them from the fire. It is nailed to them by ordinary wire nails. The box thus constructed is placed on iron bars stretched across a roughly made brick or stone foundation from 14 to 20 inches high with one end open for throwing in fuel, and the other provided with a couple of lengths of stovepipe to create a draught and carry off the smoke. It is found very convenient to place a

Fig. 3. A small steam-generator used for boiling the lime-sulphur wash.

" molasses gate " or faucet with a good sized aperture near one corner to enable the operator to draw off the wash when ready. If this faucet is situated about one-half inch or so above the sheet-iron bottom it will prevent any coarse sediment from passing out, and will thus make the mixture easier to strain. Before using the box it should be filled with water, and let soak a few hours. It is found that the mixture can be made very rapidly in these boxes because of the large amount of surface exposed to the flames. To prevent unnecessary loss of heat there should be a wooden covering made of three or four boards running lengthwise and fastened together by crosspieces near the ends. An opening must be left between the two middle boards wide enough for a hoe handle to run through easily to permit the necessary stirring.

Instead of boiling by direct heat from the fire many prefer to use steam. This is the most pleasant method and the most convenient, especially where a large quantity has to be prepared each day.

If it is desired to boil only two barrels at a time Fig. 3 shows a very convenient little steam generator costing about sixty-five dollars.

Fig. 4 shows an ordinary steam engine of about 12 horse-power which is used to boil from eight to ten barrels at a time.

Fig. 5 shows a still larger outfit where the mixture is boiled in large tanks, each having a capacity of several barrels. The tanks, it will be observed, are placed on a platform, which is a few feet higher than the spray tank, and the wash when ready can flow through a tap and large hose into the screen and be strained directly into the tank, thus avoiding the rather unpleasant task of dipping it out with pails.

Fig. 4. A threshing engine used for boiling lime-sulphur.

It is perhaps necessary to repeat that, although boiling by steam is a very convenient and satisfactory way, it makes no better wash than can be made in the kettle or box or some other cheap device.

Whatever style of boiling plant is used it should be situated in some place that will be dry, easily drained, and yet very close to an abundant water supply. Many persons select some suitable spot near a large ditch or pond where there is usually plenty of water in spring, the time when the boiling is done.

How to Make the Wash. Having decided upon a satisfactory formula and outfit for boiling, the next thing to consider is how to perform the task itself. Let us first suppose that we are boiling a barrel by steam from an engine or other steam generator. First fill the barrel about one-third with either hot or cold water, as is most convenient, and

then turn on the steam to be heating this while the lime and sulphur are being got ready. Place the 15 lbs. sulphur in a large pail or similar vessel and add enough water to make a thick, not sloppy, paste. Stir well to have all the sulphur moistened and the lumps so far as possible broken up. Then weigh out 20 lbs. good fresh lime. Drop this into the boiling water in the barrel, and when it has begun to slake vigorously add the sulphur paste. During the slaking the steam from the engine should be turned off for a few minutes until the very violent boiling ceases sufficiently to allow its being turned on again without causing too much of the liquid to splash out of the barrel. The boiling must be continuous and very vigorous throughout. Frequent stirring is necessary to help the sulphur to combine with the lime and to prevent

Fig. 5. An outfit for boiling the lime-sulphur in large quantities.

sediment being left over. If the boiling is vigorous forty-five minutes will be long enough; it is wiser, however, in most cases to boil for one hour. Too much emphasis can scarcely be placed upon the necessity for vigorous boiling. So vigorous should it be that the liquid will splash up to the top of the barrel. To prevent its splashing out an old sack or a couple of boards should be placed over the barrel. This will also help to keep the heat in. Many writers have said that boiling must be continued until the liquid reached a certain color. This is not at all a safe rule; for colour depends almost entirely upon the kind of lime used, different kinds of lime often producing different colours.

Where the boiling is done in a kettle or box practically the same method of procedure is followed. It is impossible to give specific directions for the exact amount of water to use, but the principle on which

to go is, that the smaller the amount of water the sooner the boiling will be done. There should always, however, be at least 12 gals. water for each 40 gal. barrel of diluted spray. In the box, on account of the large amount of surface covered, a considerably larger quantity will be found necessary. The very rapid evaporation from the kettle or box will require the addition of a little extra water from time to time. If the mixture threatens to boil over add cold water.

As soon as the wash has been boiled sufficiently long it should be diluted to the full 40 gals., or whatever multiple of this is required. This may be done with either hot or cold water. If cold water is used it is better to pour it directly into the vessel in which the boiling is being done, so that the heat of the vessel itself may be utilized in maintaining a higher temperature. A hot or fairly hot spray passes through the nozzles better than a cold one and seems in a number of cases to have given considerably better results.

As soon as the proper amount of dilution has been made the liquid should be strained through a wire screen of not less than 20 meshes to the inch. The wash should then be applied to the trees at once.

If for any reason it is necessary to allow a barrel to stand over until the next day it should be re-boiled for a few minutes until all the little orange crystals are dissolved. These crystals form as soon as the wash gets cold, and if not brought into solution they would by clogging the nozzles make spraying almost impossible and would weaken the wash by separating some valuable substances from it.

THE COST. The cost of a 40 gal. barrel of this wash is not very great. If a number of men in a district club together and buy their lime and sulphur in large quantities they will get the lime for about 25 cents a bushel and the sulphur for about $1.50 per cwt. or 1½ cents per lb. At these prices the cost per barrel apart from the labour and fuel would be about 9 cents for lime and 23 cents for sulphur, a total of 32 cents.

SELF-BOILED LIME SULPHUR.

This wash has been brought into prominence lately by Prof. W. Scott of the Department of Agriculture, Washington, D.C., who has used it chiefly on peach trees to control the Brown Rot and Scab. He advises using the formula 10 lbs. good fresh lime, 10 lbs. sulphur and 40 gals. water. His directions for making the wash are as follows: "The mixture can best be prepared in rather large quantities—say 20 lbs. or even 40 lbs. at a time—so as to get enough heat to produce a violent boiling for a few minutes. Place the lime in a barrel and pour enough water (about 3 gals. per 20 lbs.) to start it slaking and to keep the sulphur off the bottom of the barrel. Then add the sulphur which should first be worked through a sieve to break up the lumps, and finally enough water to slake the lime into a paste. Considerable stirring is necessary to prevent caking on the bottom. After the violent boiling which accompanies the slaking of the lime is over the mixture should be

diluted ready for spraying, or at least enough cold water added to stop the cooking. Five to fifteen minutes are required for the process according to whether the lime is quick acting or sluggish Only a small percentage of the sulphur—enough to improve the adhesiveness of the mixture—goes into solution, but if the hot mass is allowed to stand as a thick paste the sulphur continues to unite with the lime, and at the end of thirty or forty minutes enough of the reddish liquid is produced to burn peach foliage and even apple foliage in some cases. Hence the necessity for cooling the mixture as soon as the lime is well slaked."

The writer has used a good many barrels of this wash this summer and found it very easy to prepare. For use on apple foliage he used boiling water to slake the lime instead of cold water. To stir the mixture while boiling, a hoe was found satisfactory. With it the lime should be raised merely a little way from the bottom to let the water down and so prevent caking. It should not be brought to the top as that tends to check the boiling. The stirring must not begin until slaking has got well started. For peach trees 8 lbs. lime and 8 lbs. sulphur are reported to be equally as satisfactory as 10 lbs. of each.

As there is a great deal of sediment in this wash it can be strained much more easily if first diluted to almost the total amount. The same sort of screen may be used as for home-boiled wash.

When applying the wash to the trees extra precautions should be taken to see that it is kept well agitated.

The cost per barrel at the prices of the materials given is very low: lime 5 cents, sulphur 15 cents, total 20 cents.

Home-made Concentrated Lime-sulphur.

If any attempt is made to store the ordinary home-boiled lime-sulphur, either in a somewhat concentrated or a dilute condition, orange crystals form in large numbers and make it necessary to re-boil the mixture to dissolve them before it can be applied to the trees with the best results. That a concentrated wash can be made and stored without crystallization and that it may have practically the same high insecticidal and fungicidal value as the home-boiled, has been shown by the lime-sulphur sprays put on the market by several commercial companies. These commercial washes are, however, costly, especially for spring work; consequently efforts have been made by experiment stations to discover a satisfactory formula for making a home-made concentrated wash that will be of as high merit as those sold by the different companies, and very much cheaper. Several formulæ have from time to time been proposed. Prof. J. P. Stewart, of Pennsylvania, took up the problem last year and tested many formulæ until he discovered one that seemed to be quite satisfactory. The formula recommended by him is 25 lbs. lime, 50 lbs. sulphur and 20 gals. water boiled one hour. Only lime with a high percentage of calcium must be used. Such lime can be obtained from either the Beachville or Port Colborne lime dealers. Any

of the devices for boiling mentioned in describing the Home-boiled Lime-sulphur may be used. The general method of procedure indicated there may also be followed. Care should be taken to stir very frequently, and to see that whatever water has evaporated during the hour's boiling is replaced by the addition of fresh water. A measuring stick is a convenient guide. As soon as the wash is boiled, it should be strained through a screen of 30 meshes to the inch and stored in barrels which should either be completely filled and tightly covered or have oil poured over the surface of the liquid to the depth of one-eighth of an inch to keep it from exposure to the atmosphere; otherwise it gradually deteriorates. The barrels must of course be stored in some place where there is no danger of freezing.

For use on trees before the buds burst, it is claimed that a wash of this strength may be diluted about seven times; that is, to every gallon of the wash seven gallons of water may be added. Of course it may be used stronger than this, and in the case of trees badly infested with scale it will be better to dilute it only five times. For use on foliage it must be diluted much more than this. Apple and pear foliage will probably stand a strength of 1 gal. of the mixture to 24 gals. water; other kinds of foliage, especially the peach, are tenderer. These rules for dilution are not to be relied upon implicitly, but rather taken as suggestions. Each fruit grower is advised to test different strengths and find out for himself the ones that are safe and give good results. Prof. Stewart strongly advises that instead of determining the strength by any such rules as those given, an instrument called the *hydrometer* should be used. This gives the specific gravity of the wash and thus enables one to be sure in each case of the exact strength of every barrel that is being made ready for spraying. Directions for using the hydrometer will be given in the Chemistry part of this bulletin. There is very little doubt that before long it will be considered almost indispensable, and will be a great boon to the fruit growers in helping them to obtain uniform results.

Note. As the writer has not had an opportunity to test for himself the home-made concentrated wash, and as it has been very little tested by anyone in Ontario, he will, when describing later how to treat the different insects and diseases, confine his attention to the washes that have been fairly well tested. He hopes, however, that many persons making use of the information given above will co-operate with him in testing the wash, and send in reports of the degree of success which they may have, so that in a year or two the joint information gained will make it possible to give reliable directions for the use of the concentrated mixture to the fruit growers of the Province.

Commercial or Factory-Boiled Lime-sulphur.

Very little need be said about the commercial or factory-boiled lime-sulphur at this stage. It will be referred to frequently later. When first the different brands of this wash were put on the market it was doubted

whether they would give satisfactory results, but numerous tests have shown that many well-known brands are washes of genuine merit. They are gaining popularity very rapidly. No wash could be in a much more convenient form for use than these, as all that is required is to dilute them with water to the proper strength. Directions for dilution are given on each barrel. When applying the wash before the buds burst it is often necessary to use it considerably stronger than the directions state, especially if the pest aimed at is a very serious one, like the San José Scale. The addition of from 10 to 20 lbs. of fresh lime to every barrel of the diluted wash is an advantage in many cases, particularly when any kind of scale insect is being treated, as the lime itself has considerable merit as an insecticide and helps to show clearly whether the trees have been thoroughly covered with the spray. The lime should always be slaked before putting it into the diluted wash and the latter must then be applied at once or orange crystals will form. The one real objection to the commercial washes is the cost. If home-made concentrated lime-sulphur fulfils our expectations there is little doubt that it will be used by many in preference to the commercial as very much more economical.

The Use of Arsenicals with Lime-sulphur.

Every fruit grower will aim at spraying his trees just as few times as are necessary to keep them healthy and the fruit free from injury by insects or fungus diseases. When using Bordeaux mixture to control the diseases he knows that he may safely combine with it arsenate of lead, Paris green, or arsenite of lime, and thus control at the same time a number of injurious biting insects, such as Canker Worms and the Codling Moth larvæ. This combination of an insecticide and fungicide lessens the total amount of spraying by nearly one-half. Consequently it is a very important matter to know whether any or all of the poisons mentioned above may be combined with the same degree of safety with the different kinds of lime-sulphur washes. With the self-boiled wash numerous tests prove that any one of the three poisons referred to may be safely used. With the home-boiled wash, which is only to be used before the foliage appears, there will seldom be any need of adding a poison, and if need for it should arise what is said about commercial lime-sulphur will apply to it also. The main question then is—what poisons, if any, may be combined with the commercial lime-sulphur? It does not seem desirable to use Paris green, because, while a few have done so and caused no injury to fruit or foliage, others have suffered considerably. Arsenate of lead seems to be much safer. It has been used in numerous instances and nearly always without any sign of damage. In the few cases where it has burned the foliage the injury was so insignificant as to be almost negligible. Possibly the addition of a few pounds of lime to each diluted barrel just before spraying would lessen the danger. If arsenate of lead is used it should be at the strength of from 2 to 3 lbs. to every 40 gals. of the diluted mixture.

Our chemists, however, tell us that the chemical reactions that take place when arsenate of lead is added to lime-sulphur in all probability make its sticking qualities no better than those of arsenite of lime. In this case it is wise to use the latter, especially as it is only about one-quarter as expensive. In limited trials made with it at Guelph on apples and pears it showed no signs of burning the foliage and controlled Codling Worms very satisfactorily. Prof. tSewart strongly urges that it be used in preference to arsenate of lead as equally effective and also cheaper and safer. The following is the substance of his improved method of making it.

How to Make Arsenite of Lime:

White arsenic, 2 lbs.
Sal soda crystals, 2 lbs.
Water, 1 to 1½ gals.

Add the white arsenic and sal soda to the water and boil with frequent stirring until all the arsenic is dissolved. This usually requires about 15 minutes. Then add three or four pounds of good fresh lime and boil a few minutes, letting the lime slake in the boiling liquid. After this remove the vessel from the fire and add enough water to bring the total up to 2 gals. Each quart of this mixture, if thoroughly stirred, will then contain one-fourth pound of the white arsenic or one-eighth of the original 2 lbs. This amount is ample for 40 gals. spray for Codling Moth and other biting insects, in fact where drenching sprays are used it would be better to use a little less than one quart. As much of this arsenite of lime as is likely to be required for the summer's work may be made up at one time and stored away. Care must of course be taken to label the barrel "POISON," and to see that the white arsenic itself is not left where it may be mistaken for some other substance. Serious accidents have occurred from carelessness of this kind. The barrel should be kept tightly covered, lest the stored liquid evaporate and thus render it impossible to determine the proper strength to use. Always stir thoroughly before measuring out the quantity desired.

Hints on Spraying Outfits.

Before discussing the different insects and diseases that may be controlled by lime-sulphur it seems advisable to devote some attention to spraying outfits and spraying itself.

The first requisite for good spraying is a satisfactory spray machine. Experience has shown that for large trees, or even for medium sized trees, if at all close together, traction machines which furnish the power by means of the wheels are not satisfactory. The reason is simply that they do not keep up sufficient pressure to permit a thorough job to be done in every case. No machine should be purchased which will not allow the operator to remain as long as he desires at any tree and which

will not enable him to maintain a uniform pressure all this time. The conditions are satisfactorily met where the pressure is generated either by a hand pump or gasoline engine, or by one of the new styles of compressed air sprayers which have recently been introduced into a few districts in the United States and are said by good authorities to be likely to become very popular in a few years.

Among the best known manufacturers of spraying machinery are the following:

The Spramotor Co., London, Ont.

The Goulds Manufacturing Co., 91 Fall St., Seneca Falls, N.Y.

The Friend Manufacturing Co., Gasport, Niagara Co., N.Y.

For a small orchard of not more than five or six acres the simple barrel outfit with the best quality of hand pump that goes with it gives fairly good satisfaction. Such outfits should not cost more than $20.00 if a number of farmers club together and purchase them at the same time.

For larger orchards tanks holding 120 to 200 gallons and equipped with powerful double acting pumps or with gasoline engines are required. A good gasoline engine in a large orchard will pay for itself in a couple of years by the amount of hand labour it saves.

In almost every case a spray machine should be provided with two lines of hose and two extension rods with their complement of nozzles. The one line of hose is used by a man on the ground, the other by a man on a tower for large trees, or on the tank itself for medium sized trees. It is not always necessary to use both lines of hose but they should be available whenever needed. The hose should be of good quality, capable of standing a pressure of 200 lbs. The one for the tower should be from 10 to 12 feet long, the other from 20 to 25 feet.

Bamboo extension rods are the most common kind. It is desirable to have them of different lengths, one from 6 to 8 feet, the other 8 to 10 feet. Occasionally, where an attempt is made to do without a tower, rods of from 12 to 14 feet in length are purchased.

The selection of the nozzles is a very important matter. The most popular kind of nozzle is probably one of the Friend type. Plates with different sizes of holes may be got for use in these nozzles and thus a coarse or fine spray can be secured at will. Each nozzle of this kind costs $1.00. Often it is advisable to use two nozzles on a V at the end of the extension rod.

Another good kind of nozzle is the ring cluster with either 4 or 8 nozzles to the ring. These give a beautiful mist spray, but are too much inclined to clog if there is any appreciable amount of sediment in the wash.

A cluster of Vermorel nozzles also gives a good mist spray but is somewhat heavier than the ring cluster and is inclined to get entangled among the branches to the annoyance of the sprayer. It also is inclined to clog with thick washes.

In most cases it is a great benefit to have the nozzles set at an angle of about 45° to the extension rod. This enables the operator to control the direction of the spray, and is especially important when spraying for the Codling Moth as it makes it possible to send the spray directly into the open calyx, thus coating every part of it with the poison. The Spramotor Co., London, manufactures a small brass elbow (Fig. 6), costing 20 cents, which is very light and convenient and can be inserted in a minute or two between the extension rod and any kind of nozzle. Ring cluster nozzles are already set at an angle, and so do not require an elbow.

A good strainer is another important part of the outfit. This is usually made of brass wire, but a cheaper kind will do as well for lime-

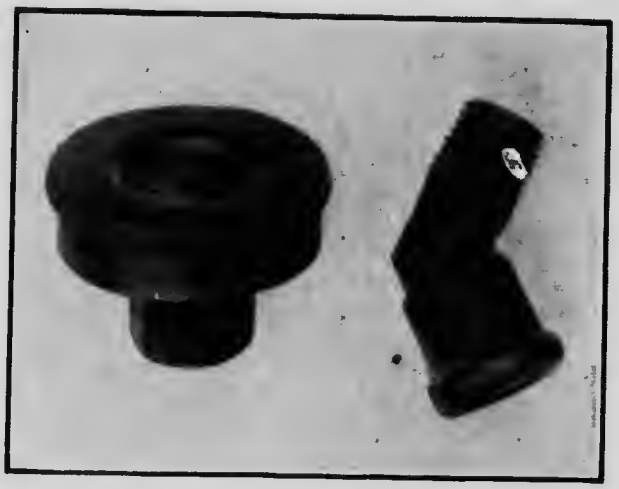


Fig. 6. Friend type of nozzle, and a small elbow found very desirable in spraying. Both natural size.

sulphur though not for Bordeaux. Usually a strainer is purchased with the spray machine. They are of various shapes, some having the wire in the form of a cone in an ordinary galvanized-iron pail with a large funnel fixed in the bottom for the liquid to pass through into the spray tank; others have a sheet of wire fastened obliquely across the lower part of a nearly rectangular vessel of at least a pail's capacity, the liquid passing out through a funnel; others are made by merely attaching the wire close to the bottom of a small hopper with sloping sides that fits tightly into the opening in the spray tank. The sieve should have at least 20 meshes to the inch, and if the liquid is fairly free from sediment 40 meshes or even 50 may be used. Wire-cloth of any required number of meshes to the inch may be purchased from the Wire Goods Co.,

King William Street, Hamilton, Ont., or from other manufacturers. The screen should always be washed after it is used, and it is well to leave it in the water between loads.

Those who intend purchasing a spray outfit should write for catalogues to any of the companies mentioned above, or to others, and in these they will see good illustrations of all the different parts referred to above, and of others that it would require too much space to discuss here.

The best pressure to use is a disputed point. No one advocates less than 100 lbs. and a few advocate as high as 200 lbs. With most spray pumps it is found fairly difficult to maintain a steady pressure of 100 lbs., but whenever it is possible without excessively hard labour to secure a higher pressure the spraying can be done more thoroughly and

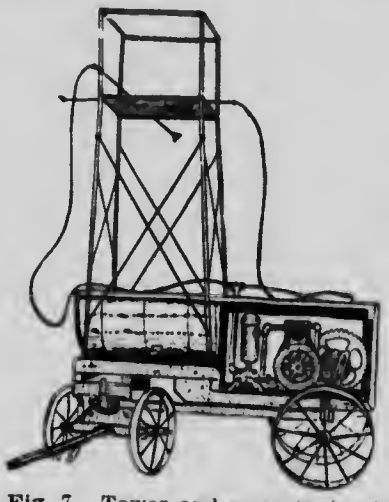


Fig. 7. Tower and spray-tank with gasoline engine.

rapidly, especially on large trees after the foliage has appeared. In purchasing a gasoline engine it is well to stipulate that it shall be able to furnish 200 lbs. pressure if desired. Of course high pressure requires a good strong hose but this can be obtained. The writer used 200 lbs. pressure for several days this summer without any sign of the hose giving way.

Hints on Spraying.

If spraying is to pay well it must be done with the right mixture properly prepared, at the right time, and thoroughly. In the pages that follow the different insects and diseases for which lime-sulphur is a fairly satisfactory remedy will be mentioned. The proper time and form of the wash to use for each of these will also be stated, so that we shall confine our attention here to the thoroughness of the work.

It should scarcely be necessary to say that unless the farmer has a very intelligent and reliable assistant he should himself oversee the spraying and make sure that the work is being well done.

There are certain occasions when it is unwise to spray: Lime-sulphur should not be applied when the temperature is below freezing point, or while the trees are wet with rain or dew. Moreover, if a rain follows in a few minutes after spraying and before the mixture has time to dry it will wash the spray off and the operation will have to be repeated. Ordinarily the wash dries in about an hour so that it is seldom necessary to respray because of rain. Long continued and frequent rains, of course, gradually wash the spray off, and are sometimes the cause of poor results.

Spraying should in nearly every case be done with the wind. Hence, one side of the trees will be sprayed first and as soon as the wind changes, the other side. A wind is often of decided benefit in applying the wash, especially to large trees. A very strong wind will doubtless waste a little of the mixture, but it is very seldom that there is any need of stopping operations because of its violence.

When spraying the first side of large trees stop the waggon just as it comes within a few feet of the tree and do the nearest side as far in as the spray can be driven; then drive directly opposite and spray all the central part thoroughly; again move until just past the tree, and now spray this last part as far in as possible before leaving. In this way nearly two-thirds of the tree will have been covered, and when the wind changes it will be easy to make a good job of the rest. A tower is always necessary to do the topmost parts of these large trees.

As it is very important to cover every twig and branch many fruit growers take some of the wash a couple of days after the orchard has been done, and go up and down the rows touching up places that have been missed. This is a most desirable practice in the spring application and serves also to show whether the work has been thoroughly done.

In spraying after the foliage has appeared many are misled by the advice that is often given to stop spraying just before the leaves begin to drip. It is impossible to spray a large or even medium sized tree thoroughly without a considerable amount of dripping. Hence the first rule to follow is, *Make sure that every leaf and fruit is covered*, and second, *Try to do this with as little material as possible*. We cannot expect the spray to keep scab off our apples unless the apples are first covered with the spray.

As spraying apparatus is costly and easily gets out of order, if neglected, it will be wise to wash the tank out each night with clean water and also to pump some of this through the nozzles. Unless washed out in this way lime-sulphur corrodes the brass. Many make a practice of unscrewing the nozzles each night and putting them into kerosene or some other oil to keep them from getting set so firmly that they can only be moved with a wrench.

Another matter requiring attention is the packing of the pump. Frequently this gets worn and then the power cannot be kept up, or only with extra labour. In such cases new packing must be put in. This every fruit grower should learn how to do, and if possible should require the company from which he buys the outfit to send a man to teach him the proper way before he begins to use the pump at all.

As lime-sulphur is quite caustic and will soon make one's hands sore it is important to see that all connections are tight so that there may be no leakage to cause the hands to become wet with the liquid. The ordinary clamps often fail to give as tight a connection between the pump and hose, or hose and extension rod, as can be got by using tough wire about half the size of fence wire and tightening it up with nippers. If the wire is of good quality, and two or three separate bands are put on a very secure connection may be made. Vaseline is used by some to keep the hands from being injured; leather gloves are used by others. A few use rubber gloves but they are too expensive. The horse and harness may be protected by a light cover.

INSECTS THAT CAN BE CONTROLLED BY LIME-SULPHUR.

Having discussed the different forms of lime-sulphur, the methods of making each, the use of arsenicals with the wash, and a few points about spraying outfits and spraying itself, let us now turn our attention to the wash as an insecticide and fungicide, taking up its insecticidal value first.

San José Scale.

(*Aspidiotus perniciosus,* Comst.)

Although the San José scale is a very tiny insect, not nearly so large as the head of a pin, it is capable, if not kept under control, of completely destroying whole orchards in a very few years. Fortunately many of our best fruit growers in districts where this scale has been for many years have learned how to keep it so thoroughly in check that they do not fear it at all, and even think it a blessing in disguise, because has forced them to use a wash which has greatly helped their trees in other ways than merely by destroying the scale. Of the many spray mixtures which have been tried against the scale none has given so uniformly good results as lime-sulphur; so that it is to-day almost the only wash used to any extent for combatting this pest.

Treatment: Spray very thoroughly in spring, as late as time permits before the buds burst, with either home-boiled lime-sulphur or with commercial lime-sulphur. If the latter is used it is often necessary to make it considerably stronger than the directions state, and it is wise to add about 20 lbs. of fresh lime to each 40 gal. barrel of the diluted mixture. The lime should be slaked, preferably with hot water, before adding it to the wash. Of the two forms of the wash the preference

should still be given to the home-boiled, although in many cases the commercial wash has given very good results. It has, however, two defects, first, it cannot be applied hot, and second in a wet spring it washes off the trees much more quickly. It is believed, and apparently with very good reason, that the persistence with which the home-boiled remains on the trees is no small factor in the control of the scale.

Very badly infested trees should receive two applications. These may both be made in the spring with an interval of a couple of days or more, or one may be made in autumn, as soon as the leaves have nearly all fallen, and the other in spring. Very large apple trees are hard to

Fig. 8. San José scale on Pear, showing full-grown and immature scales. Natural size.

keep free from the scale, much harder than smaller or medium-sized ones. To make it easier to treat them thoroughly fruit growers in infested districts are heading the trees back severely. In doing this care should be taken to make a sloping cut in large upright branches, so that the rain will run off, and to see that the wound is thoroughly painted over to prevent disease getting in and destroying the trees. It need scarcely be said that all the pruning of trees should be done before spraying, and that all prunings should be burned, not thrown into brush-heaps and allowed to remain there. If the loose bark be scraped off with a hoe early in the season it will allow the spray to reach scales that otherwise

might escape. Careful cultivation and a liberal use of manure will assist the spray in giving renewed vigour to badly infested trees.

There is no insect, in Ontario at least, that requires more careful and thorough work on the part of the sprayer if he is to get good results, because, if even a few infested twigs are left unsprayed, there will frequently be enough scale on them to produce great numbers by autumn. Hence, after spraying both sides of the trees carefully, it is always advisable to take an extra tankful of the mixture in a day or two

Fig. 9. Oyster-shell scale. Natural size.

and go up and down the rows touching up any poorly sprayed places and seeing that every part of the tree above ground is white with the wash.

Oyster-shell Scale or Apple Bark-louse.

(*Lepidosaphes ulmi, L.*)

Though not nearly so destructive an insect as the San José, the Oyster-shell scale is doing nearly as much damage to the province as a whole, because it is found in almost every orchard, whereas the San José scale is still almost entirely confined to a few south-western counties.

Treatment: Spray in spring, as late as convenient, before the buds have actually burst, with home-boiled lime-sulphur. This wash has given the writer very much better results than the commercial lime-sulphur applied at the same date, though a number of persons claim very good results from a spring application of the latter. If it is used do not dilute to the full amount, and add lime as recommended for San José scale.

A second spraying early in June when the eggs are seen to have hatched and the young creamy white insects are observed running about on the twigs, branches and trunk will destroy great numbers of these. For this purpose use commercial lime-sulphur about 1 gal. to 30 of water, or as strong as experience shows the foliage will safely stand. Lime may be added or not.

Though lime-sulphur is an excellent wash for the Oyster-shell scale it is seldom that any one application will kill more than about 80 or 85% of the eggs, but orchards that are sprayed two or three years in succession with the home-boiled mixture become at the end of that time almost entirely free from this insect.

The commercial wash applied just as the young had all hatched gave unexpectedly good results in the writer's experiments this summer. This treatment would, however, often mean making an extra spraying soon after the regular one for the Codling Moth, and so the spring application with home-boiled lime-sulphur should be relied upon in most cases.

It ought to be kept in mind that this scale is usually much more abundant on trees that are not thrifty; consequently by fertilizing and cultivating orchards the trees will become more vigorous and better able to resist attack.

Other Scale Insects.

There are a number of other scale insects that attack orchard trees, such as the New York Plum scale (*Eulecanium cerasifex*, Fitch.), Curtis Scale (*Aspidiotus ostreaeformis*, Curt.), Putnam Scale (*Aspidiotus ancylus*, Putn.), and Scurfy Scale (*Chionaspis furfura*, Fitch.). The same treatment as for San José or Oyster-shell scales will keep these in check. Hence, it is clear that lime-sulphur is a good remedy for almost all kinds of scale insects.

Leaf Blister Mite.

(*Eriophyes pyri*, Scht.)

The Leaf-blister Mite is a very tiny insect, so small that unless a number are clustered together they are invisible to the naked eye. In spite of their diminutive size they make their presence very noticeable on both apple and pear trees by causing numerous spots on the leaves. These spots are ofen confused with fungus diseases, but can easily be distinguished by their being slightly raised beyond the lower surface of

the leaf. As the name indicates they are blisters or swellings in which the mites live and reproduce. Affected leaves are quite conspicuous in the fall of the year. On the apple leaves at this time the blisters are reddish brown in colour and visible on both the upper and lower surface. On the pear leaves they are usually more clustered along the mid-rib than on the apple and become nearly black, often disfiguring the foliage very greatly and being visible several rods away.

The Blister Mite has gradually been spreading all through the province, and is now found in numerous orchards. It does not, so far as

Fig. 10. Work of Blister Mite on leaves of apple and pear. Natural size.

we know, cause the tree to die but weakens it greatly by interfering with the power of the leaves to perform their proper function of manufacturing food for the rest of the tree.

Treatment: The mites cannot be killed while in the leaves, but fortunately they desert these late in autumn and pass the winter under the bud scales. Here they may be destroyed by either home-boiled or commercial lime-sulphur applied in the spring perferably just as the buds are almost ready to burst. The writer sprayed very badly infested pear trees last spring after the buds had burst, but before the leaflets had

opened up. Every mite was destroyed by the one application. It is seldom possible to get so good results as this, especially on apple trees, but thorough work will give excellent results.

Pear Psylla.

(*Psylla pyricola*, Forst.)

The Pear Psylla is also a tiny insect but larger than any yet mentioned. The adult is about one-quarter of an inch long, measuring from the head to the end of the folded wings. It is reddish crimson in colour and has clear wings. The eggs are orange yellow, and are laid on the twigs in spring before the leaves appear. It is the little nymphs which hatch from these that do most of the injury by sucking the juices from the leaf-stems and leaves. As they work they exude an enormous amount of honey dew.

A few years ago this insect threatened to cause much damage to pear trees in the Niagara district, but since the use of lime-sulphur has become common it has ceased to give any trouble in sprayed orchards.

Treatment: Use either home-boiled or commercial lime-sulphur in spring, at the same time as for the San José scale.

Aphids.

Most kinds of fruit trees in the early part of the season are subject to attacks of Aphids. Apple trees were severely attacked this summer by one or more species of green Aphids. These and many other kinds of Aphids deposit eggs late in the autumn on the twigs and smaller branches. It is from these eggs that the next season's insects come. Hence, if the eggs, which are very tiny and usually glossy black, can be destroyed we may hope to be very little troubled by the Aphids the succeeding season.

Treatment: The writer has not yet entirely satisfied himself that the eggs can nearly all be destroyed by lime-sulphur, but other entomologists who have experimented much more extensively assure us that the lime-sulphur is a reliable method of control. Weak washes, however, are not reliable. Home-boiled of the strength of 25 lbs. lime and 18 or 20 lbs. sulphur to 40 gals. of water is preferable to the ordinary 20, 15, 40 formula. If the commercial wash is used it will require to be proportionately strong. The spraying should be done shortly before the eggs hatch. This takes place usually about a week before the buds burst.

In cases of severe infestation the lime-sulphur should be supplemented by a spray of kerosene emulsion of the ordinary strength applied just as the buds are about to burst. Some fruit growers claim that if the watersprouts and suckers are sprayed with kerosene emulsion

about the end of September it will destroy the Aphids before they can lay their eggs, and so will secure their control for the following season.

Spruce Gall-louse.

(*Chermes abietis*, Linn.)

So many enquiries have come to the department of Entomology for the best remedy for the Spruce Gall-louse that it seems desirable to mention here that contrary to the writer's expectation one thorough application of the home-boiled wash applied the first week in May exterminated these insects on Mr. J. W. Smith's beautiful spruce hedge at Winona. The date above given or the last week in April is the proper time to do the spraying.

Red Spiders.

(*Tetranychus sp.*)

In dry seasons Red Spiders by working on the underside of the leaves and sucking the juices from them cause much injury to plants of various kinds. We have not tested lime-sulphur for this insect but have good reason to believe we are safe in recommending that a weak wash of commercial lime-sulphur be tried. Probably 1 gal. to 80 of water would be strong enough in most cases. This wash should also be tested in poultry houses for the destruction of chicken mites. Drench the roosts and every part of the interior, keeping in mind that the mites only attack the birds at night and hide in crevices on the roosts and in various other places nearby during the daytime. A strength of 1 to 25 may be used in this case.

FUNGUS DISEASES THAT CAN BE CONTROLLED BY LIME-SULPHUR.

For most fungus diseases of plants Bordeaux is probably the best spray mixture that is known to-day but in a number of cases lime-sulphur is giving just about as good results and in a few perhaps even better. It can moreover be used with safety in certain forms on trees with very tender foliage like the peach where Bordeaux mixture, even when greatly diluted, often causes serious damage. Furthermore, in some seasons Bordeaux causes a good deal of russeting of fruit which detracts from its appearance and occasionally lessens its selling value. This russeting can be avoided by the use of lime-sulphur. We do not however, advise those who have been getting good results from Bordeaux to change to lime-sulphur.

Fig. 11. Peach Leaf-curl.

Fig. 12. Peach tree almost defoliated by the Leaf-curl disease.

Peach Leaf Curl.

(*Exoascus deformans,* (Berk.) Fckl.)

All peach growers are familiar with this fungus disease which causes a thickening and curling of the leaves in the early part of the season. In cold wet springs the leaf-curl is very severe and does a great deal of damage.

Treatment: Spray with lime-sulphur, either home-boiled or commercial, but preferably home-boiled, when the buds are just beginning to swell, or earlier. If the spraying is left off until the buds are almost ready to burst the disease sometimes gets a start and unsatisfactory results follow.

Bordeaux applied at the same time of year also gives good results, but, of course, has no insecticidal value.

Brown Rot of Peach.

(*Sclerotinia fructigena,* (Pers.) Schrot.)

The Brown Rot of the Peach is the same disease as causes the rotting of plums and cherries. It is so familiar to every peach grower that it requires no description. The disease is apparently not so severe in Ontario peach orchards as in some parts of the United States, but it often causes the loss of a great many peaches in the province. Professor Scott's experiments have shown that it can be controlled.

Treatment: (1) If the Plum Curculio is abundant use for its destruction arsenate of lead, 2 lbs. to 40 gallons of water, and apply as soon as the fruit is set. It is very important to control the curculio as the Brown Rot spores often get into the fruit through the punctures it makes.

(2) Spray three times with self-boiled lime-sulphur, 8, 8, 40 formula. The first application should be about four weeks after the blossoms fall, the last about the same length of time before the fruit ripens, and the middle application about half way between these two.

(3) The destruction of the mummied peaches (Fig. 13.) in late fall or winter will help considerably to make the control of the disease easier, as these are always sources of infection.

Before commercial lime-sulphur can be recommended for this disease or Peach Scab a good many more tests will have to be made. If used it must be very much diluted, at least as much as 1 gal. to 100 gals. of water. Even this strength has been known to do considerable damage.

Fig. 13. Mummied fruit on plum and peach due to the Brown Rot. About one-half natural size.

Fig. 14. Apple Scab.

Peach Scab.

(*Cladosporium carpophilum*, Thüm.)

The Peach Scab disease causes little black spots on the fruit; sometimes when it is very severe the fruit is cracked.

Treatment: By using the self-boiled lime-sulphur for the Brown Rot the Scab is also controlled. If it is desired to spray for it alone a single application of this wash applied about four weeks after the blossoms fall will be sufficient.

Apple Scab.

(*Venturia inaequalis*, (Cke.) Aderh.)

Apple Scab is the main disease in Ontario attacking the fruit of the apple. It also attacks the leaves. The disease begins to appear on the leaves about the time of the earliest blossoms, hence to control it we must spray once a little earlier than this date.

Treatment: Use either commercial lime-sulphur 1 gal. to 30 or even to 40 of water, or self-boiled lime sulphur (10, 10, 40), or Bordeaux (4, 4, 40). Spray three times, first a little after the leaf buds have opened but before the blossoms appear, second when most but not all of the blossoms have fallen, and third about three weeks later. A poison should be used with at least the first and second applications, especially with the second as this is the proper time to spray for the Codling Moth. For what poison to use see discussion under "The Use of Arsenicals with Lime-sulphur."

Pear Scab.

(*Venturia pirina*, Aderh.)

The Pear Scab is very severe on some varieties, especially Flemish Beauty. (Fig. 15.) It produces dark blotches here and there over the surface of the fruit, often causing it to crack and become quite unfit for market. The leaves are also attacked. It is more difficult to control than Apple Scab.

Treatment: Spray four times as follows: first, before the leaf buds burst; second, just after these have burst but before the flower buds have quite done so; third, as soon as most of the blossoms have fallen; and fourth, two weeks later. The application before the buds burst seems to be necessary for the control of the disease. Either home-boiled or commercial lime-sulphur may be used for the first application and commercial for the other three at about the same strength as for apple foliage. This method of treatment gave absolutely scab-free Flemish Beauty pears at Guelph this year in the writer's experiments.

Fig. 15. Pear Scab.

Bordeaux 4, 4, 40 used at the same dates has frequently given good results.

A poison should be combined as in the case of Apple Scab with the second and third applications.

Black Rot Canker of Apple Trees.

(*Sphæropsis malorum*, Pk.)

Much of the dying of branches and trees usually attributed to winter killing is really due to a very destructive fungus disease known as Black Rot. This disease attacks the leaves, fruit, trunk and branches of apple trees, and less frequently of pears. On the leaves it causes small circular spots about one-eighth of an inch in diameter and usually with a purplish border; on the fruit it causes a firm, not a soft, brown rot which turns black late in the season; on the trunk and branches it causes dead areas, called cankers, some of these often of large size. The disease on the leaves and fruit is seldom serious, but the cankers produced on the trunk and branches often do very great damage. The disease is worst in the counties east of Toronto, where it is a very common sight to find numerous branches or even whole trees killed by it. The fungus usually finds an entrance through some wound, such as those made by boots when climbing trees or by whiffle-trees when cultivating the orchard. It often, however, follows sunscald, and on the branches frequently begins in the cracks caused by the bursting of the bark due to the very rapid growth in spring.

As a rule the disease does not die out in these cankers at the end of the season but continues to extend in every direction year after year until at last it completely girdles the trunk or branches and kills all above the girdled area. Small superficial cankers, however, do often die out before doing much damage.

There is no disease in Eastern Ontario that requires more careful attention than this Black Rot Canker since it threatens, not the quality of the fruit, but the very life of the tree. Experiments in New York State in previous years and by several persons in our own Province this season show that we may hope for complete control by following the methods outlined below.

Fig. 16. Black Rot Canker on apple branch. About two-thirds natural size.

Treatment: Spray thoroughly with home-boiled lime-sulphur or Bordeaux mixture in spring before the buds begin to burst, taking special pains to cover the bark of the tree and branches. This is to destroy the spores which begin to spread early in the spring.

Mr. Frank Dempsey, of Albury, and Mr. Charles Dakin, of Rednersville, both in Prince Edward county, have been testing the home-boiled lime-sulphur wash this year for the control of canker, which is specially severe in that county. They report excellent results and predict that the wash will be used very extensively throughout their district next year.

The second, third and fourth spraying should be at the times indicated above for controlling Apple Scab. In these sprayings one man should always remain on the ground with a rather short extension rod, and have as his chief duty the spraying of the lower branches and trunk. Either Bordeaux mixture (4, 4, 40) or commercial lime-sulphur, about 1 to 30 or 40, may be used for these sprayings.

Whenever the cankers on the trunk or main branches can be cut out this should be done early in spring and the wound thus made disinfected with corrosive sublimate of the strength of 1 part by weight to 1000 parts of water, and then thoroughly painted over with white lead free from turpentine. The corrosive sublimate is very cheap and can be procured in the form of tablets, one of which is sufficient to use with a pint of water.

Caution: Corrosive sublimate is deadly poison if taken internally. It corrodes iron, so should be carried in a wooden or glass vessel and applied with a sponge or swab on the end of a stick. See that the vessel is thoroughly washed before using it for any other purpose.

In cutting out the canker the writer has found a drawknife very satisfactory. Care must be taken to cut back to the perfectly healthy bark on every side. Some have failed to do this, and consequently did not get good results.

This cutting out should be done before the spraying begins. Branches with far advanced cankers should be sawed off and burned. Scions from desirable trees may then be grafted on to take their place.

It is found that some kinds of trees are much less subject to canker than others. Pewaukee, Tolman Sweet, and McMahon White seem to be the least subject; consequently if these are planted and then top-grafted with other more desirable but less resistant varieties an excellent hardy stand of trees should be the result.

Note: Anything that tends to make trees more thrifty helps to ward off canker, hence orchards should be fertilized and cultivated up to July.

Brown Rot of Cherry and Plum.

(*Schlerotinia fructigena* (Pers.), Schröt.)

As mentioned above this is the same disease as attacks the peach and is so well known that it needs no description.

Treatment: As the disease often attacks the blossoms the first spraying should be shortly before the buds burst with either home-boiled or commercial lime-sulphur (spring strength) or Bordeaux (4, 4, 40). The second spraying should be very soon after the blossoms fall. The third spraying should be about three weeks later. Plums may be given a fourth spraying two or three weeks after the third. For the second, third and fourth spraying use either commercial lime-sulphur 1 to 40 (if there is any sign of burning dilute still more) or self-boiled lime-sulphur (10, 10, 40) or Bordeaux mixture (2, 2, 40). With the second and third applications from 2 to 3 lbs. arsenate of lead or 1 quart of the stock solution of arsenite of lime should be used to every 40 gallon barrel of the mixture. This is to keep the Curculio in check.

In dealing with Brown Rot it is alw[illegible]elp to prune the trees sufficiently to let in plenty of sunlight [illegible] to destroy any mummied fruit that may l[illegible]

Cherry Leaf-spot or Shot-hole Fungus.

(*Cylindrosporium padi*, Karst.)

This disease attacks the leaves of the plum as well as cherry but is more severe on the latter. Several reports of cherry orchards almost defoliated with it have been sent to the writer from different parts of the province.

Fig. 17. Cherry Leaf-spot or Shot-hole Fungus.

Treatment: Use commercial lime-sulphur 1 to 40 or 50 or self-boiled lime-sulphur (10, 10, 40), or Bordeaux mixture (2, 2, 40) and spray first about four weeks after the blossoms fall, and second immediately after the fruit is picked; occasionally a third spraying about two weeks later may be necessary.

Powdery Mildew of the Gooseberry.

(*Sphaerotheca mors-uvae* (Schw.) B. & C.)

Imported or English gooseberries are usually so severely attacked by the Powdery Mildew that it is seldom profitable to grow them. The disease attacks the shoots, leaves and fruit. Currants are also attacked but not so frequently nor severely. At first the disease appears as a whitish powdery covering of the affected parts but later on this develops into a thick felty brown coat that is especially noticeable on the fruit.

Treatment: Spray about the time the buds are ready to burst with home-boiled lime-sulphur, covering every part thoroughly with the wash. Commercial lime-sulphur does not seem to have been tested but would probably give the same good results. Mr. Joseph Tweddle, of Stoney Creek, Mr. E. D. Smith, of Winona, and several other fruit growers have informed the writer that the above treatment has given them excellent results, and that they highly recommend it. It is probable that a second treatment just after the fruit has set with either self-boiled or weak commercial lime-sulphur would assist in the control of the disease.

Other Kinds of Powdery Mildew.

There are many kinds of Powdery Mildew besides the one mentioned; for instance, one kind attacks the foliage and twigs of the cherry, another attacks in a similar way the peach, another the grape. As sulphur is the standard remedy for all of these it is almost certain that lime-sulphur would be equally efficient and probably more so.

Treatment: As soon as the first sign of the disease appears spray with self-boiled lime-sulphur or the commercial wash diluted to the strength the foliage will endure. On peaches the self-boiled should be used.

The above are all the important insects and fungus diseases of Ontario for which the writer feels it safe at present to recommend lime-sulphur as a means of control. He has tested to a limited extent both the commercial and self-boiled washes on potatoes, but found Bordeaux mixture superior to either. On grapes he has been unable to test any form of lime-sulphur, but Washington reports seem to indicate that for the Black Rot of Grapes, the worst grape disease in Ontario, Bordeaux mixture is still to be preferred.

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