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Spray Residue Information for the Orchardist and Fruit Packer

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TABLE OF CONTENTS

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INTRODUCTION

THE problem of spray residue is still an important one, and every orchardist and fruit packer should acquaint himself with the facts pertaining to its various phases. With the establishment of a lead tolerance and its progressive reduction each subsequent year, the margin of safety to the fruit is narrowed by more effective washing operations. Although improved fruit washing equipment is available in which may be used adequate solvents or combination solvents, the success of washing the residue below the prevailing tolerances depends upon the proper application of recommended sprays during the growing season. Neglect in this regard may prevent satisfactory cleaning of the fruit or cause losses from injury because of the severe washing treatment necessary.

The lead tolerance for the coming 1935 season has been set at .018 grain per pound. Federal health officials, upon whom rests the responsibility of preventing the sale of food unfit for human consumption, give no encouragement that there will not be a continued reduction in this tolerance. At present there is no satisfactory substitute for lead arsenate in codling-moth control. In many districts throughout the country, moreover, heavy infestations of the codling moth require so many applications of the spray that the residue load at harvest is very difficult to remove without causing injury to the fruit. In order to prepare for future lower tolerances, every orchardist in these districts should endeavor to reduce the codling-moth population by more thorough application of sprays, giving special attention to the tops and interiors of the trees, by timing the different spray applications, and by practicing general orchard sanitation. In a few fruit districts where the codling moth is controlled with comparative ease, calcium arsenate may be substituted for the lead. Wherever this is possible, calcium arsenate should be used.

With the lowering of the lead tolerance more growers now find it necessary to wash fruit, even though only one cover spray may have been applied. Furthermore, many small growers who market a few hundred boxes of fruit only, now request information on fruit-cleaning procedures. The purpose of this bulletin, then, is to acquaint these orchardists with procedures by which they may clean their fruit and also to report recent additional information pertaining to spray residue removal that may be of interest to the commercial fruit packer and others. Only a few of the numerous experimental and packing-house washing tests are reported. These are averaged results of several tests.

FACTORS THAT COMPLICATE THE REMOVAL OF SPRAY RESIDUE

It cannot be emphasized too often that the successful cleaning of fruit depends upon the orchardist, who should plan his spray program in accordance with recommendations available for each fruit district. Present recommendations for codling-moth control in Oregon do not include the use of fish oil, fluorine compounds, soaps, and many panaceas suggested by some salesmen. Soaps and their combinations with certain other materials may find a place in codling-moth control sprays, but the orchardist should not attempt their use until they have been tested and recommended by the Experiment Station. Soap reacts with lead arsenate, moreover, forming water-soluble arsenic that under favorable climatic conditions may cause severe injury.

Oil sprays are an important causative factor in preventing the removal of spray residues. Petroleum-oil sprays are necessary for red-spider control, and when applied at the proper time are good ovicides. In addition they function as stickers and, properly modified, as spreaders. When combined with the lead arsenate, oil increases the deposit. While oil sprays complicate the cleaning of fruit, yet if they are used properly their complicating effects should not prevent satisfactory cleaning of the fruit. In order to avoid difficulty, the orchardist should use the proper grade of oil, follow recommendations in regard to the amount and time of application, and avoid, if possible, use of oil in second-brood sprays.

Natural wax that forms on most varieties of apples complicates the removal of the residue in like manner to the oil. The lead-arsenate particles become imbedded in the wax and are thus protected from the action of the solvent. Some varieties of apples form appreciable amounts of wax before the optimum time of harvest. It is very important that these varieties be washed immediately after picking. All varieties will form natural wax in varying amounts when the fruit is left in the orchard or in common storage. Fruit should therefore be washed as soon as possible after picking in order to avoid complications caused by natural wax formation. Table 1 contains averaged results of tests where heavily sprayed apples and pears, washed immediately after harvest, were cleaned well below the lead tolerance.

The contributing factors that prevent the removal of spray residue and that should be avoided by the orchardist, may be summed up briefly as follows:

1. The application of a spray schedule not recommended for the district.

2. Too many sprays instead of the careful and thorough applications of properly timed sprays.

3. Permitting natural wax to form on the fruit by leaving it in the orchard several days after picking or keeping it in common storage before washing.

4. The improper use of oil sprays and their application too near harvest time.

5. Neglecting to harvest fruit at the proper time and to pick first those varieties that may wax up before harvest or very rapidly thereafter.

Table 1. FRUIT WASHED IN SINGLE-PROCESS FLOOD-TYPE MACHINE

Sprays applied	Percentage of acid	Time	Temperature	Lead per pound
	Per cent	*Seconds*	*Degrees F.*	*Grains*
Newtown apples				
1. Calyx, 6 covers, 3 pounds LA to 100 gallons	Unwashed	....	....	.228
2. Calyx, 6 covers, 3 pounds LA to 100 gallons	1.4	35	95	.007
3. Calyx, 6 covers, 3 pounds LA to 100 gallons with 1 gallon oil emulsion in 2d and 3d	1.4	35	95	.009
Nelis pears				
4. Calyx, 5 covers, 3 pounds LA to 100 gallons with 1 gallon oil emulsion in 5th cover (1 month before harvest)	Unwashed	....	....	.238
5. Calyx, 5 covers, 3 pounds LA to 100 gallons with 1 gallon oil emulsion in 5th cover (1 month before harvest)	1.4	35	83	.008

WASHING SOLVENTS AND THEIR COMBINATIONS

Investigations during the past few years have not disclosed any major solvents superior to hydrochloric acid and sodium silicate. From experimental tests and packing house observations, it is apparent that each of these solvents has its place and shows superiority for cleaning purposes depending upon the condition of the fruit and the kind and number of sprays that have been applied during the season. Neither solvent, however, even though used in the highly efficient dual-process washer, will clean the worst fruit effectively without causing injury. Some of the tests reported in Tables 2 and 3 exemplify the ineffectiveness of these solvents. Since the protective covering of wax or oil on heavily sprayed fruit prevents cleaning, the problem of spray-residue removal has resolved itself into discovering a supplementary solvent that, when mixed with either the acid or the alkali, will remove sufficient of this protective coating to enable the washing solution to dissolve the exposed lead-arsenate particles. Many combinations have been tested experimentally. Among them only the new wetting or degumming agents and petroleum oil have given results worthy of consideration. These combinations will be discussed later.

In order to avoid injury to fruit by the washing process, it is advisable to give it as light a cleaning treatment as possible. The many conditions under which fruit is grown, the varieties to be washed, the spray schedule applied, and other factors require variations in the solvent treatment in order to clean the fruit effectively and yet avoid injury. A general discussion of the action and effectiveness of the various solvents and combinations will serve to indicate the limitations of the different ones.

Hydrochloric acid. With the exception of the fruit districts east of the Cascade Mountains, such as the Milton-Freewater area, practically all of the apples and pears grown in Oregon have been washed to meet the prevailing tolerances by using hydrochloric acid as the solvent. Compared with sodium silicate, it is much more rapid as a solvent for lead arsenate. If the temperature of the acid is increased, its solvent action is accelerated, and more effective cleaning is accomplished. Higher temperature also softens the waxy coating of apples and exposes the residue particles.

The average concentration at which acid should be used is approximately 1.5 per cent or about 5 gallons of the commercial acid to 100 gallons of water. For cleaning heavily spotted fruit, a concentration of 1.7 to 2.0 per cent may be advantageous. Very little, if any, increased action will result at higher concentrations, especially when the acid is maintained at 80° to 100° F. This statement is based on the fact that, during the time the fruit is exposed to the solvent action of acid in concentration of 1.7 per cent, all lead-arsenate particles unprotected by wax or oil will dissolve. Higher concentrations of acid cannot penetrate the wax-covered particles any more effectively than the lower concentrations of approximately 1.5 per cent. When cleaning is not accomplished at prevailing water temperatures with acid in concentration of 1.7 to 2.0 per cent, heating of the solution is preferable to using a higher acid concentration.

Early apples, such as the Gravenstein, that have received three or four applications of spray, and late varieties, such as the Newtowns, that do not form very much excess wax by the proper time of harvest, may be cleaned effectively below the prevailing tolerance by using acid without the aid of heating. If one or more oil sprays, however, have been applied during the season, or the apples have been stored a week or more before washing, heating of the solution will be necessary.

Acid should always be used as the solvent when lime or bordeaux mixture has been added to the sprays during the season or where calcium arsenate has been used in place of lead arsenate. Sodium silicate will not dissolve these residues.

Hydrochloric acid and salt mixtures. It has been observed in experimental tests that when hydrochloric acid is fortified with salt, increased cleaning has been obtained. The principal advantage in using salt, however, is at the lower acid concentrations. Roughly, when about 15 pounds of salt are added to a 1.0 per cent solution of hydrochloric acid, the solvent effect of the mixture is about equivalent to that of a 1.5 per cent solution. As the maximum dissolving action of the acid is about 1.5 per cent, little benefit would be derived from adding salt to this strength acid. From the standpoint of injury to the fruit when high temperatures are maintained, it may be advisable to fortify 1.0 per cent acid with salt instead of using 1.5 per cent acid. Salt imparts no beneficial action to acid for cleaning residue protected by wax or oil.

Hydrochloric acid and wetting agent. A class of commercial compounds known as wetting or degumming agents, when combined with hydrochloric acid, have been found to aid materially the removal of spray residue. These compounds may be described as soap that can be used in acid solutions. They have detergent properties and foam profusely, like soap. In the acid solution they function principally by enabling the acid to come into close contact with arsenate particles. Then, by a detergent or emulsifying action they remove part of the wax or oily film and leave the residue particles exposed to the action of the acid. Many of these commercial wetting agents are available, but only a few of them have shown promise for aiding the removal of spray residue. Four have been tested, and the results given in Tables 2, 3, and 4 indicate their value. These are available under the trade names Vatsol, Hydralene, Areskap, and Lethalate. Limited funds for this work have not permitted making tests with other wetting agents doubtless equally effective.

Table 2. WASHING TESTS IN SINGLE AND DUAL PROCESS FLOOD MACHINE SHOWING EFFECTS OF SUPPLEMENTARY SOLVENTS

Tests	Solvent used		Lead per pound
	In first unit	In second unit	
Spitzenberg			*Grains*
1....	Unwashed	....	.154
2....	Acid 1.0% 32 sec. at 100° F.	....	.038
3....	Acid 1.0% + oil 1.0% 32 sec. at 100° F.	....	.023
4....	Acid 1.6% + oil 1% 100, 32 sec. at 103° F.	....	.014
5....	Silicate 50 lb., 32 sec. at 120° F.	....	.031
6....	Silicate 50 lb., 32 sec. at 120° F.	Acid 1.0% + oil 1.0% 16 sec. at 100° F.	.012
7....	Silicate 50 lb., 32 sec. at 120° F.	Acid 1.0% + oil 1.0% 30 sec. at 100° F.	....
Winesaps			
8....	Unwashed	....	.165
9....	Acid 1.0% 32 sec. at 100° F.	....	.058
10....	Silicate 80 lb. to 100, 32 sec. at 120° F.	....	.018
11....	Silicate 80 lb. to 100, 32 sec. at 120° F.	Acid 1.0% 16 sec. at 100° F.	.025
12....	Silicate 80 lb. to 100, 32 sec. at 120° F.	Acid 1.0% + oil 1.0% 16 sec. at 100° F.	.008
13....	Silicate 80 lb. to 100, 32 sec. at 120° F.	Acid 1.0% + WA .05% 16 sec. 100° F.	.018
14....	Unwashed	....	.106
15....	Silicate 75 lb. to 100, 32 sec. at 110° F.	Acid 1.6% at 96° F.	.016*
16....	Acid 1.6% 32 sec. at 99° F.	....	.009†

*This washing treatment cleaned, but 10 per cent of apples showed small checks.
†No checking or other injury.

The wetting agents have been found most effective when used with acid in the flotation-type washers where the apples are retained in the solvent for one minute or more. Table 4 contains results that show the beneficial effect of the wetting agents (WA), when used in this type of washer. These are the averaged results of the four wetting agents mentioned above. Both groups of Winesap apples were very waxy and heavily sprayed. The apples of the first group were cleaned effectively when 4 pounds (.5 per cent) of the wetting agent were added to each hundred gallons of acid. The results for the second group were not so effective. These figures are reported to show that while the acid wetting agent combination is beneficial for most lots of apples, yet there are limitations to its effectiveness for cleaning bad lots of fruit.

The wetting agent in acid solution functions best at the higher temperatures. A material improvement, however, over acid alone will result even at prevailing water temperatures. Usually 2 to 4 pounds of the wetting agent to the 100 gallons of acid should be sufficient. If the orchardist has delayed picking or has allowed his fruit to stand in boxes several days before washing, 8 pounds of the wetting agent to 100 gallons of the acid or heating of the solution may be necessary. Further suggestions regarding the use of the wetting agent in the homemade flotation-type washer are given under washing procedures.

The wetting agents aid, but are not outstanding in their action when used in the commercial flood or spray type washers where the fruit is exposed to the acid from 20 to 40 seconds. In these machines, moreover, excessive foaming will occur if more than half a pound of the wetting agent per hundred gallons of the acid is used. Defoaming compounds may be used with the wetting agent to control the excessive foaming, but experimental tests indicate that these compounds counteract the beneficial action of the wetting agent. Tests numbers 15 and 16 in Table 3 exemplify this condition. These results are the averages of all wetting agents tested. Only enough of the wetting agents was added in test number 15 to create excellent foaming. This required less than half a pound to the hundred gallons of acid. Compared with test number 7 where acid was used alone, a slight yet positive increase in cleaning was obtained. When 4 pounds of the wetting agent to the hundred gallons of acid were used, however, and enough defoaming compound added to control the foam, as in test number 16, no improvement in cleaning occurred. Consequently, it is recommended that only enough of the wetting agent be used in the commercial flood and spray type machines to produce good but not excessive foaming.

Table 3. MISCELLANEOUS WASHING TESTS IN DUAL-TYPE FLOOD WASHER
Jonathan Apples

Tests	Solvent used		Lead per pound
	In first unit	In second unit	
			Grains
1	Unwashed	....	.678
2	SS	Acid	.035
3	Acid	SS	.040
4	SS (125°)	Acid	.027
5	Acid	SS (125°)	.036
6	SS	SS	.055
7	Acid	Acid	.033
8	SS	Acid + oil	.045
9	SS	Acid + Ker	.039
10	Acid + oil	Acid	.025
11	Acid + oil	Acid + oil	.009
12	Acid + oil + W	Acid + oil + W	.022
13	Acid + Ker	Acid + Ker	.009
14	Acid + Ker + W	Acid + Ker + W	.053
15	Acid + W	Acid + W	.028
16	Acid + WD	Acid + WD	.036

Legend:
Acid—1.5% HCl, 30 sec. at 110° F.
SS—Sod. silicate—90 lbs. to 100 gal., 30 sec. at 110° F.
W—Wetting agent (about .07%), just enough to produce foaming.
WD—Wetting agent, 1% + defoamer to control foam.
Ker—Kerosene, 1%.
Oil—56 viscosity white oil, 1%.

Hydrochloric acid and oil. As a supplemental solvent to hydrochloric acid, petroleum oil properly used has given outstanding results for the worse lots of apples. This combination was the only solvent mixture that cleaned effectively the bad lot of apples referred to in Table 3. Oils of high purity should be used that have a sulfonation test of not less than 85. Oils of lower purity may cause injury to the fruit. The viscosity of the oil may range between 40" and 55" Saybolt. During the past season, the oils used have had a viscosity between 55" and 60" Saybolt. Limited experimental tests, however, indicate that an oil of 45" viscosity is preferable to the heavier type as the latter leaves too much oil on the surface of the apple after washing. Kerosene, a very light oil of 25 viscosity, cleans equally well. The results in Table 3, under tests numbers 11 and 13, illustrate the cleaning results obtained with these two oils. Kerosene is not recommended, however, as when used at the higher temperatures loss by volatilization occurs rapidly.

Best results are obtained when the oil is used straight. This is practicable in the flood-type washers, where forced pumping of the acid keeps the oil well dispersed. When used in the spray-type machines and predipping tanks, the oil must be emulsified. Emulsification, however, ties up the oil and reduces its effectiveness. Consequently, a quick-breaking emulsion of the most unstable type should be used in those cases where emulsification is necessary. When an oil emulsion is used in the predipping tank setup, better results will be obtained if some kind of agitator is inserted in order to circulate the acid-oil combination as rapidly as possible.

Oil may be used at the rate of 1 gallon to 100 gallons of the acid solution. For fruit that cannot be cleaned otherwise, the rate may be increased to 2 gallons to the hundred. The temperature of the acid-oil combination should preferably be maintained between 90° and 105° F. It is questionable whether oil is of any value when used in the acid solution at prevailing water temperatures. When oil is used in the first unit of the dual-process washer, the rinse water between the two units should preferably be warm. If the rinse water between the two units is cold, the oil tends to congeal on the surface of the apple, and as the fruit passes into the second unit part of the time is utilized in rewarming the surface of the fruit to the point where the oil and acid may again function.

When sodium silicate is used in the first unit of the dual-process washer followed by acid in the second unit. a few experimental tests indicate that the oil does not benefit the cleaning action of the acid. This is exemplified in the results reported under tests numbers 8 and 9 in Table 3. Neither gave as good results as when either acid or silicate was used alone. These observations should be confirmed, however, under packing-house conditions.

Oils should not be used at random for cleaning any and all fruits that may be put through the washer. Apples that have formed appreciable amounts of wax, or that have received several applications of either fish oil or mineral oil, may be cleaned by the acid-oil combination. If little or no wax, however, has formed on the surface of the fruit, the oil may even retard the solvent action of the acid and poor results will be obtained. As there are optional solvents that may be used advantageously in the dual-process washers, this phase will be discussed more fully later.

Very little information is yet available on any injurious effects that the acid-oil combination may have on apples. The combination must not be used for cleaning pears. When a light oil of high purity is used for cleaning apples during the fall washing season and toward the latter part of the year, no injury occurs that throws them out of grade. A slight dehydration because of the removal of natural wax may occur, especially if the apples are allowed to stand after washing at common storage temperatures. On the other hand, if apples of any variety are washed after the period when they are in their prime, calyx injury may result. Both Winesap and Jonathan apples exhibited this type of injury when washed after the first of the year.

Sodium silicate. Sodium silicate is a solvent that is particularly effective for the removal of spray residues imbedded in natural wax or fish-oil residue. No chemical studies have been made to learn definitely how the silicate functions. Apparently, in addition to its solvent effects, it removes a large portion of the residue by its detergent action.

The sodium silicate ordinarily used has the following specifications:

Baumé, 58 to 60°
Sodium oxide (Na_2O), 19.5 per cent
Silicon oxide (SiO_2), 30.5 per cent
Water, 50.0 per cent

There is no reason why certain other sodium silicates may not be equally effective, although it is well to use the one stocked for the purpose.

Sodium silicate functions best at higher temperatures and under conditions of violent agitation. The temperature should never be below 90° F. Brushes in the machines also will aid the emulsifying action of the silicate. The amount of silicate to use under specified conditions has not yet been definitely determined. Usually, about 75 pounds per hundred gallons of water should be sufficient.

Sodium silicate will not clean bordeaux or lime deposits from fruit. When either Bordeaux mixture or lime has been used in combination with the lead arsenate during the season, the fruit should be washed in acid or first be put through a predip of acid in order to remove these deposits before it enters the silicate wash. If a dual-process washer is used, the acid should be added to the first unit and the silicate to the second.

Table 4. WASHING TESTS IN FLOTATION-TYPE PADDLE WASHER

Washing treatment	Lead per pound
Winesap apples, Group 1.	*Grains*
Unwashed	.108
Acid 1.5% 2.5 min. at 90° F.	.038
Acid 1.5% 2.5 min. at 100° F.	.031
Acid 1.5% + WA .5% at 2.5 min. at 90° F.	.007
Acid 1.5% + WA 1.0% at 2.5 min. at 90° F.	.004
Winesap apples, Group 2.	
Unwashed	.306
Acid 1.5% 2.5 min. at 90° F.	.096
Acid 1.5% + WA .5%, 2.5 min. at 90° F.	.051
Acid 1.5% + WA 1.0%, 2.5 min. at 90° F.	.036
Acid 1.5% + WA .5%, 2.5 min. at 100° F.	.028
Acid 1.5% + WA 1.0%, 2.5 min. at 100° F.	.018

Sodium silicate and soap or wetting agent. Experience has shown that sodium silicate cleans best when sufficient soap is added to produce good foaming. The amount needed depends upon many factors, such as hardness of the water, waxiness of the apples to be washed, dirt and other debris in the tank, and the condition of the silicate used. A cocoanut-oil soap or other high-grade product is recommended for the purpose.

A wetting agent may be added to the silicate solution in place of soap. The amount needed to produce a good foam will depend upon the wetting agent and the amount of silicate used. Soap, however is recommended as preferable.

Sodium silicate and oil. Very little if any value may be expected from the use of oil in the sodium-silicate wash. The oil is soon emulsified by the alkali, especially when a little dirt has accumulated in the washing solution. A tight emulsion thus formed is inactive for cleaning purposes.

Sodium silicate and salt. A few experimental tests indicate that somewhat better cleaning is obtained when about 20 pounds of salt is added to the 100 gallons of sodium-silicate wash. Sodium chloride with silicate reacts more rapidly with lead arsenate than the silicate alone and hence may be beneficial. On the other hand, if the sodium silicate is used in sufficient amount that it will remove the lead arsenate during the period included in the wash, it would be superfluous to add the salt as a supplementary agent. If salt is used, a wetting agent instead of soap should be added to produce foaming as soap is ineffective in the presence of the salt.

WASHING EQUIPMENT

Fruit-washing machines vary greatly in efficiency. Each fruit packer or orchardist who processes fruit must select a machine that will remove the residue effectively below the prevailing tolerances without causing injury to the fruit. In districts where there is a heavy infestation of codling moth and the fruit produced is very hard to clean, care should be taken to choose the most efficient washer and one that will take care of future needs in the event of a lowering of the residue tolerance. The flood-type machines in which there is a heavy volume of the solvent passing over the fruit continually are, no doubt, the most efficient washers. Revolving brushes likewise add to their efficiency. At the other extreme may be placed the flotation-type paddle washer similar to the Oregon homemade washer, where the fruit is conveyed slowly through the solvent by means of dipping paddles. While these machines have their limitations, as indicated from the results in Table 4, yet in many districts they do the work satisfactorily, which is all that is required.

The outstanding recent development in fruit-washing equipment is the dual-process machine. This machine, which consists of two separate washing units, permits the simultaneous use of two different solvents. This increases the efficiency of the machine. The results given in Tables 2 and 3 indicate the superiority of the dual-process over the single-process machine.

SUGGESTED PROCEDURES FOR THE OPERATION OF WASHING EQUIPMENT

In order to know what solvent is most effective for cleaning fruit grown under prevailing conditions of each locality, it is necessary to correlate chemical analyses of the washed fruit with the solvent treatment given. The variety and condition of the apples or pears and the type of machine to be used must also be taken into consideration. When it is questionable whether a machine setup will clean a certain lot of fruit, a test or educational sample should first be put through the machine to learn whether the particular solvent will clean effectively below the prevailing tolerance without injury to the fruit. For this purpose a dozen samples showing heavy deposits in the stem and calyx ends should be selected from as many boxes of fruit and washed. If the analyses of the washed samples show that the fruit has been cleaned effectively, the solvent tested may be used.

Attention to details is necessary for the successful operation of a fruit-washing machine. The following important rules apply to all machines:

1. Keep a full tank of washing solution in order that the maximum amount of the solvent will be available for flooding the fruit. The flotation-type washers require replenishment every few hours.

2. Determine by titration the strength of the acid or alkaline wash at least twice a day. Follow methods outlined below. If the washing solution is warmed by live steam, titrations should be made at least four times a day.

3. An accurate thermometer conveniently placed should be used when the washing solutions are heated. Automatic thermal control is preferable.

4. A good supply of fresh rinse water should be available and turned on full force. The rinse water is most important to prevent acid injury, arsenic burn, and decay or mold-spore contamination.

5. Double layers of fruit or overloading of the machine should not be practiced. Double layers of heavily sprayed apples or pears cannot be cleaned.

6. The washing solvent should be drained from the machine at intervals, depending upon the amount of fruit washed and the dirt that accumulates over a period of time.

The observant machine operator soon learns how to control the acid strength, temperature, and other factors that contribute to the production of clean fruit. No longer can all lots of fruit received in the packing house be put through a machine blindly with the expectation of obtaining effective results. Consideration must be given to the condition of the fruit, the variety, and the apparent residue load that is best judged by visibility and experience. For those who are new each year at the business, a general outline of procedure may be of assistance. Beginning, then, with fruit easily cleaned and proceeding progressively to fruit difficult to wash, and finally to apples most difficult to clean below the tolerance, suggestions are made regarding solvents, time and condition of treatment, and other control factors, depending upon the condition of the fruit to be washed.

1. Fruit easily cleaned.

Apples: Early apples, such as the Gravenstein, that are normally harvested before September 1 and have received a maximum of three cover sprays, may be washed effectively in any machine, including the home-made flotation paddle washer. Hydrochloric acid is the preferable solvent, and may be used at a strength of about 1.0 per cent. No artificial heating of the washing solution is necessary. Exposure to the solvent for 30 or 35 seconds should be sufficient in commercial machines, such as the Cutler, Bean, or Ideal washers, where thorough agitation of the solution occurs. Treatment in flotation-type machines must be longer; viz., about 90 seconds. If the fruit is washed in a dual-process machine, only one unit need be charged with acid. The acid should be used in the first unit, while water may be added to the second unit as well as in the rinse section.

In addition to the early apples that are harvested before September 1, the first pickings of the later varieties are easily cleaned. Acid is still the preferable solvent for cleaning Oregon-grown fruits. It may be necessary, however, to increase its strength to 1.5 per cent or a little more. If very little wax has yet developed on the apples and if oils of medium grade have been applied in the first two cover sprays only, no difficulty should be encountered until about half the crop has been harvested. By that time wax begins to form on some varieties and cleaning becomes more difficult. The analyses of the washed apples should then be watched carefully, and if the results approach the tolerance, the washing treatment must be modified accordingly.

Pears: Pears come in the category of fruits easily cleaned unless complicated by extra-heavy applications of lead arsenate or by the careless use of oil sprays. In most pear districts red-spider infestations necessitate one or two applications of oil sprays. If five weeks or more have intervened between the date of the last oil spray and harvest and the proper grade of oil has been used, no difficulty should be encountered in the cleaning process. Pears sprayed according to Experiment Station recommendations, including two oil applications, using the medium grade or lighter, can be washed in 1.5 per cent acid solution without artificial heat. Table 1 reports an experimental test where two oil sprays were applied in July in combination with lead arsenate and then one month before harvest another oil spray in combination with the fifth lead arsenate cover application was made. This was cleaned without difficulty in acid of 1.4 per cent concentration at 83° F.

2. Fruit difficult to clean.

Apples: As the season progresses, wax forms on some varieties of apples, such as the Spitzenberg, even before harvest. It will then be impossible to clean fruit below the prevailing tolerances without heating the washing solvent. Consequently, when the chemical analyses of test samples show that the fruit cannot be cleaned at prevailing water temperature, the acid solvent should be heated, preferably to about 90° F. As the need demands, it may be increased to 105° F., but never higher.

If the apples carry a heavy residue load or have received several applications of oil sprays during the season but have not yet developed much wax, acid should be used as the solvent. For cleaning apples in this condition, it is advisable to use only enough wetting agent in the acid to create good foaming. For the flood-type machines, a little less than half a pound to the hundred gallons will be sufficient. The spray-type machines, such as the Bean, may cause trouble, as a very small trace tends to foam excessively. Four ounces of the wetting agent to 100 gallons is enough. If a flotation-type machine is being used, sufficient quantities may be added to produce effective cleaning. Two to eight pounds will be required.

If the apples are obviously waxy or if the orchardist has applied fish oil, though contrary to Oregon recommendations, sodium silicate may be used as the solvent. Fifty to seventy-five pounds of the silicate to one hundred gallons of water, depending upon the condition of the apples, may be used. Also, enough soap should be added to the silicate to produce good foaming. Subsequently soap should be added at intervals to maintain a good foam. The temperature of the silicate should be held about 105° F. If necessary this temperature may be increased to 115° or 120° F., provided the fruit is not exposed to the solvent for more than 35 seconds.

As stated previously, if a dual-process machine is used at the beginning of the harvest season, acid is necessary in the first unit only. For cleaning apples in the condition now under discussion, acid will be required in both units of the machine. It will be advisable to use a little wetting agent in the acid in both units. As this machine is very efficient, it may not be necessary to heat the acid much over 80° F. In the event that a very waxy lot of fruit is encountered, such as the Spitzenberg or Arkansas Black apples, it may be advisable to empty the acid from the first unit and replace it with sodium silicate. The temperature of the sodium silicate should be maintained about 110° F. and sufficient soap should be added to create good foaming.

Pears: While pears ordinarily fall in the category of fruit easily cleaned, yet another condition must be recognized. In spite of spray recommendations, many growers modify their spray mixtures by the addition of soap, oil spreaders, and other materials that may increase the residue load. As a consequence, a mixed deposit is left on the pears that is difficult to remove. In order to clean such fruit, it is necessary to heat the acid solution. Temperatures between 90° and 100° F. should be the upper limit. Higher temperatures have been used, but acid burn is sure to occur if the length of treatment is much more than 35 seconds in the flood or spray type machines. For very bad lots of pears, a wetting agent in small proportion (.5 pound or less to 100 gallons) may be added to the acid to produce a good foam. It may be necessary to rig up a predipping tank in which is used warm acid and wetting agents. One per cent acid to which are added wetting agents at the rate of about 2 pounds to the hundred gallons should suffice. Enough salt likewise must be added in order to float the pears. Care must be exercised in the use of the acid and wetting agent combination to clean pears. Experimental observations have indicated that injury may result to the first picking of most varieties. When, therefore, wetting agents are to be used in the acid solvent, a test sample should be run and put aside for twenty-four hours to learn whether any injury has occurred from the treatment. It is also very important that all the traces of the wetting agent be thoroughly rinsed off of the fruit, otherwise injury may occur.

3. Apples most difficult to clean.

In this category may be included apples that carry a heavy load of lead arsenate that has become imbedded in a thick coating of wax because the particular variety has been harvested too late or has been allowed to stand around in common storage before washing. In general, apples that have received five or more cover sprays of lead arsenate and that have not been washed by November 1 are very difficult to clean. At this late date, sufficient time has elapsed since harvest to permit enough wax to form on most varieties to make cleaning uncertain without causing some injury. The spray schedule used during the season may further complicate the washing problem. The worst lots of apples are those that have received six or more cover sprays, of which three or more have been in combination with fish oil, petroleum oil, or soap.

For cleaning apples in the category described above, one of the most efficient machines available is required. Some of the lots may be washed satisfactorily in a single-process machine provided one of the most efficient types of washer is used. A machine of the flood type that may be slowed down to allow the fruit not less than 45 seconds exposure is recommended. Either of two solvent combinations may be used in the machine: one in which sodium silicate is used at the rate of 75 to 100 pounds to the hundred gallons of water; the other in which acid at 1.8 per cent plus oil, 1 gallon to the hundred, is used. If fish oil has been applied during the season and in addition the apples are very waxy, the sodium silicate maintained at about 115° F. may clean most effectively. On the other hand, if the fruit has been kept in cold storage since harvest and petroleum oil has been applied several times during the season, the acid-oil combination maintained at about 105° F. will probably prove most effective. Under such harsh treatment just described, either heat injury or calyx injury may be caused. A test sample should therefore be run through the machine and set aside for at least twenty-four hours to note whether injury to the fruit has resulted from the washing treatment. When washing fruit under these conditions, the margin of safety from injury is exceedingly narrow and each different lot put through the machine must be watched carefully. Past experiences and good judgment will serve best to decide regarding the safest procedure to follow.

While some of the bad lots of apples may be washed in the single-process machine, the double-process machine is recommended and may be necessary for cleaning most of the heavily sprayed fruits complicated with wax and oil as described above. The double-process machine used, moreover, should be the most efficient flood type available. The less effective double-process flotation machines cannot clean this fruit without causing too much injury. While a comparatively small percentage of the apples grown in Oregon fall in this catagory, yet districts such as the Milton-Freewater section will require the more efficient machines if the lead tolerance is lowered further.

The solvent for use in the double-process fruit washer should also be selected according to the condition of the fruit. If the apples are very waxy or have received several applications of fish oil in combination with lead arsenate during the season, sodium silicate in the first unit, followed by acid in the second unit, is recommended. If oil sprays have been used in combination with lead arsenate throughout most of the season and very little wax has accumulated either because the fruit has been kept in cold storage prior to washing or because of the particular variety, the acid-oil combination should be used in both units. Attention is called to the results reported in Table 3. These Jonathan apples had received nine cover sprays of lead arsenate, five of which contained oil. As a consequence, the lead-arsenate load was exceedingly heavy at the time of washing. No soft natural wax was apparent, and the residue was imbedded in a hard, oily deposit that presented a glazed appearance. None of the sodium silicate combinations cleaned these apples effectively. Furthermore, they could not be washed satisfactorily in a single-process machine. As indicated in the table, the acid-oil combination used under the conditions specified was the only solvent mixture that removed the lead effectively below the tolerance. Altogether about forty different combinations were tried, but none cleaned effectively except the acid-oil mixture. This does not mean, however, that the acid-oil combination will be found most effective for cleaning all hard lots of fruit, as the solvent to use in a double-process machine will depend upon the spray schedule used, the condition of the fruit at the time of washing, and possibly the variety. The machine operator should have data pertaining to the condition of the fruit and the spray schedule, together with the chemical analyses of the washed apples, in order to know best what solvent should be used for cleaning each lot of fruit.

INFORMATION ON THE OPERATION OF THE HOMEMADE FLOTATION WASHER BY THE SMALL ORCHARDIST

The revision downward of the lead tolerance for the 1935 season and for subsequent years will necessitate the washing of fruits grown in the localities where heretofore cleaning has not been necessary. Accordingly directions are given for cleaning this fruit, together with other general information that may be of special help to the small orchardist.

Chemical analyses of apples that have received only one cover spray during the growing season indicate that the amounts of lead remaining on the fruit at harvest time may exceed the tolerance. Table 5 reports a few of these analyses.

Table 5. ANALYSES SHOWING NUMBER OF SPRAYS THAT MAY EXCEED THE LEAD TOLERANCE

Variety	Number of sprays	Lead arsenate per hundred	Lead per pound
		Pounds	*Grains*
Jonathan	Calyx and one cover	2-100	.012
Jonathan	Calyx and one cover	3-100	.021
Spitzenberg	Calyx and one cover	4-100	.028
Ortley	Calyx and one cover	2-100	.017
Newtown	Calyx and one cover	2-100	.016
Ortley	Calyx and two covers	2-100	.031

These results show that where one cover spray of lead arsenate was applied at the rate of 4 pounds to 100 gallons, the amount of lead remaining at harvest time was far in excess of the present .018 tolerance. When two pounds to 100 were used, there is less chance for exceeding the tolerance, although in most cases the lead will be slightly above. Any visible trace of the spray on the surface of the fruit or around either the calyx or stem cavity will be sufficient to exceed the tolerance. As a consequence, washing of the fruit will be necessary.

Calcium arsenate is recommended for control of the codling moth in the Willamette Valley. If only the calyx spray and one cover spray are applied the residue will not exceed the .01 grain arsenic tolerance at harvest time. If two or more applications of the calcium arsenate are necessary, the arsenic tolerance may be exceeded and washing of the fruit may be necessary. Only chemical analyses can determine definitely the need for washing.

Fruit can not be cleaned by wiping. Even though fruit may have received only one or two cover sprays, wiping for the removal of the residue is useless. At the time the first and second cover sprays are applied the fruit is very small and consequently most of the residue is in the stem cavity or around the calyx. These parts are inaccessible by mechanical wiping and washing therefore is necessary to clean the fruit.

The Oregon flotation-type fruit washer. The many small growers who produce from 100 to 1,000 boxes of apples ordinarily can not afford to purchase a commercial fruit washer. Furthermore, they are not grouped in districts that would permit several of them to use one machine. As a substitute, the Oregon flotation washer, designed and introduced several years ago by the Oregon Agricultural Experiment Station, will be found satisfactory for them. Specifications and detailed drawings for making this homemade washer may be obtained by sending for Experiment Station Circular 92, *The Oregon Apple Washer* by Henry Hartman. The machine is of simple construction and can be built by any one who has a little mechanical ability. As a further aid, the machine may be inspected at any time in Agriculture Hall, Oregon State College, Corvallis.

PROCEDURE FOR OPERATION OF THE FLOTATION MACHINE

After the flotation washer has been set up, its operation is simple, but care must be exercised to carry out the procedure properly. Commercial hydrochloric acid, commonly called muriatic acid, is the only solvent that should be used in this machine. The acid may be obtained from commercial fruit packers or from one of the larger dealers in spray materials. The concentrated acid is about 30.0 per cent actual acid and is shipped in ten-gallon glass carboys marked 20° Baumé.

Amount of acid to use. The amount of acid necessary for cleaning apples depends upon the number of cover sprays applied and whether the fruit is washed immediately after picking. It is very important that fruit be harvested at the proper time of maturity and then put through the washer as soon as it is picked. When not more than three cover sprays have been applied during the season, the fruit can be cleaned in 1.0 per cent hydrochloric acid. To obtain this percentage, three gallons of the commercial acid is added to 100 gallons of water. If more than three cover sprays have been applied, the acid should be used at the rate of 1.5 per cent, or 5 gallons to 100 gallons of water. No matter how difficult the apples are to clean, there is not much gained by using acid of higher concentration and injury to the fruit might result.

Washing procedure. After the required amount of acid has been added to the tank and a good flow of fresh water has been turned into the rinse section of the machine, all is ready for dumping the apples into the acid. If the fruit is washed immediately after picking, two minutes in the acid will suffice for effective cleaning. One box of apples, therefore, should be fed into the machine every two minutes. It is most important that a good flow of rinse water shall flood the apples as they leave the machine. This reduces chances for acid injury and infections from decay organisms.

Treatment of fruit difficult to clean. When more than three cover sprays of lead or calcium arsenate have been applied during the season, or when an oil spray has been used in one or two of them, the apples are more difficult to clean. Also, some varieties become waxy before harvest which adds to the difficulty of cleaning. Under these conditions, it is necessary to modify the solvent in order to obtain satisfactory results. For this purpose, one of several available wetting agents may be added to the washing solution in order to aid cleaning. Either Vatsol, Hydralene, or Areskap wetting agent may be available in the local feed store. Otherwise, write to the Chemistry Department of the Agricultural Experiment Station for sources of supply. Depending upon the need, from 2 to 6 pounds of the wetting agent to 100 gallons of the acid should be used. A chemical analysis of the washed fruit will be necessary in order to know whether the particular cleaning treatment has been effective.

When apples are so waxy that they can not be cleaned by means of the hydrochloric acid and wetting agent combination at prevailing water temperatures, it will be necessary to heat the solution to about 90° F. In the event that this is necessary, heating may be accomplished by either one of two methods: (1) by live steam, or (2) by circulating the acid solution through a stove containing heating coils. The preferable method is by live steam although it will be necessary to have available a small boiler to supply a sufficient head of steam. The live steam may be conveyed by rubber hose, the end of which dips into the acid solution. It is then turned on sufficiently to maintain the temperature desired. An accurate Fahrenheit thermometer should be available for testing the temperature. As live steam turned into the cold acid solution will condense and dilute it, it will be necessary to add sufficient strong acid to compensate for the reduction in strength. In order to know when to add more acid to the washing solution, the latter should be tested three or four times a day, using the method outlined below for the determination of the acid strength. The amount of strong acid necessary to add to the machine may then be estimated.

Precautions. Acid, either the concentrated or dilute, will attack metal, cloth, etc., and should be handled with care. When spilled, it may be neutralized with a little soda or dilute ammonia water.

A wooden bucket or porcelain pitcher holding about one gallon and marked accurately at each quart division should be used to measure out the acid.

Iron or other metal that comes in contact with the acid should be painted with asphaltum paint or heavily coated at intervals with a hard grease.

In the event of a breakdown, the apples should not be allowed to remain in the acid washing solution as danger of acid burn may occur after the apples have been in the washer about five minutes.

A good flow of fresh water should rinse the fruit as it leaves the machine.

METHOD FOR THE DETERMINATION OF ACID STRENGTH AND DESCRIPTION OF THE OPERATION

The careful washing-machine operator will determine the strength of the washing solution at least twice and preferably four times a day. Only in this way can the desired concentration be maintained. The following equipment will be necessary:

1 10-c.c. bulb pipette

1 10-c.c. measuring pipette, graduated in .1 c.c.

2 small bottles or glass tumblers

Standard sodium bicarbonate: 23.0 grams to 1,000 c.c. containing methyl orange indicator.

The pipettes may be obtained from any dealer in chemical apparatus. The standard bicarbonate solution may be obtained from the Chemistry Department of the Oregon Agricultural Experiment Station upon request. It may also be obtained from a local druggist by requesting that he dissolve 23.0 grams of pure sodium bicarbonate in 1 liter of distilled water, to which has been added enough methyl orange indicator to produce a good yellow color. The total equipment described above should not cost much more than $1.00.

Method. The procedure is as follows: With one of the tumblers dip into the acid tank and obtain a sample. Then fill the bulb pipette with acid from this tumbler, drawing it into the pipette by suction. Let the excess acid flow out until even with the mark on the upper part of the pipette. Then allow the measured acid to drain into the other glass tumbler or bottle.

Next, fill the measuring pipette from the standard sodium bicarbonate solution. Adjust the level of the liquid with the 0.0 c.c. mark. Let flow slowly into the bottle containing the measured acid, shaking the tumbler meanwhile. At the point where the color of the acid changes from red to yellowish, note the number of cubic centimeters (c.c.) of sodium bicarbonate that has been used. This will indicate directly the percentage of acid.

For example, if 5.3 c.c. of the standard sodium bicarbonate were used to neutralize 10 c.c. of the acid, the strength of the acid would be .53 per cent.

Precautions. Always use the bulb pipette for measuring out the acid and the other or measuring pipette for the soda. Rinse out the bulb pipette with acid each time a test is made.

METHOD FOR THE DETERMINATION OF SODIUM SILICATE

For the determination of the strength of the sodium silicate washing solution the following equipment will be necessary:

1 10-c.c. bulb pipette

1 10-c.c. measuring pipette, graduated in .1 c.c.

2 glass tumblers

Standardized .75 Normal hydrochloric acid solution containing methyl orange indicator.

The pipettes may be obtained from any dealer in chemical apparatus. Standardized .75 Normal hydrochloric acid containing methyl orange indicator may be obtained from the Chemistry Department of the Oregon Agricultural Experiment Station. The local druggists can not prepare this special solution.

Method. The procedure is as follows: Dip out sample of sodium silicate solution with one of the tumblers. Fill the bulb pipette with this sodium silicate solution, drawing it up into the pipette by suction. Be very careful that the silicate is not drawn into the mouth as it is exceedingly caustic. Let the excess sodium silicate flow out until even with the mark on the upper part of the pipette. Then allow the measured silicate to drain into the other clean tumbler.

Next, fill the measuring pipette with the standardized .75 Normal hydrochloric acid solution. Adjust the level of the liquid with the 0.0 c.c. mark. Then, let this flow *slowly* into the bottle containing the measured sodium silicate solution, shaking it meanwhile. As the acid drops into the silicate solution it turns to a yellowish color. Keep adding slowly drop by drop until one drop changes the color from a yellowish to a red. Note the number of tenths of cubic centimeters used, which will indicate directly the pounds of sodium silicate per 100 gallons of the wash solution.

For example, if 7.3 c.c. of the standard hydrochloric acid were used to neutralize 10 c.c. of the sodium silicate solution, the strength of the latter would be 73 pounds per 100 gallons.

Precautions. Always use the bulb pipette for measuring out the sodium silicate and rinse with water immediately after using. The measuring pipette need not be washed out but it should always be used for the standard hydrochloric acid solution.

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