LEAKAGE OF FUMIGATION TENTS

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The purpose of the present paper is the discussion of the significance of the leakage factor in fumigation and the development of a dosage system which shall be based upon the varying conditions of leakage tents found in actual operation in the field.

Every one unacquainted with the facts regarding the conditions under which fumigation is carried on will be inclined to enquire, "Why have any leakage at all?" No doubt there can be and should be much improvement in this respect but under the best conditions likely to be obtained, this factor will still remain a very important element in calculating the dose to be used.

The practice of fumigation has been developed without scientific supervision and the dose given to trees of varying sizes was determined by "cut and try" methods and the actual system used as a result of practical experience of hundreds of fumigators developed through a quarter of a century of practical work is entirely at variance with the suggestions of the scientific men who first developed the method.

Many present, perhaps, do not appreciate that fumigation is not only the most important insecticide operation in California as measured by its cost, but also that it is more important than the combined insecticide work of any other state or of any foreign country.

The development of the process to such proportions, amounting to an outlay of now about $500,000 per year, could only have occurred where the average practice has become approximately correct.

The first attempt to develop a system for the calculation of the dose consistent with the practice of fumigation was in 1903.[1] At that time there was no data in existence for dose calculation corresponding even approximately with the practice, and the scheduling of orchards was exclusively by the judgment of the fumigator, acquired by observing the work of the other fumigators and corrected from time to time by results obtained in fumigation.

Under such conditions there was bound to be much irregularity in individual cases even though the average results were certainly very dependable.

Several thousand measurements were made at that time showing that the average dose of four ounces corresponded with an average ten-foot tree; a dose consistently used by no fumigator but nevertheless that established, and firmly established, by practice for the destruction of the black scale.

[1]Bulletin No. 152, California Experiment Station.

This dose may be considered as ample or perhaps a little high, for the reason that it represents the average of all fumigation work though some of it (not a very large amount, however) was for red and purple scale work, both of which usually receive more than the black scale, and because fumigators would be more liable to give more than necessary since a slight injury to the tree is not considered as bad as a failure to kill the scale.

The measurements also gave data showing that the rate of increase of dose for larger trees and of decrease for smaller ones did not correspond with the changes in volume. While there was a great deal of diversity in the practice of different fumigators, they agreed in the one fact that the rate of change in dose was strikingly less than the rate of change in volume.

The suggestion made at that time based on the results of this study was that the area of the surface of the tent instead of the volume enclosed might be adopted as the measure of the dose. This suggestion has been followed by several writers and experimentors and is today the only basis of calculation that approximates the actual average practice.

At the time the above suggestion was made, it was clearly understood that the area basis of calculation gave only an approximation to the correct dose and did not by any means represent an accurate allowance for any particular degree of leakage. A recent student (Woglum) has offered a table calculated by the formula dose $= v \times \frac{a}{v}$ which he supposed did accurately allow for leakage but of course is only the area basis suggested by me years before.

Last year in presenting the methods available for scheduling trees for fumigation, the need of some method of measuring the leakage of tents and of accurately adjusting the dose to the leakage became very evident. Accordingly the present season over 5,000 determinations were made in the field of the leakage of fumigation tents in actual operation and in many cases of the same tent under varying weather conditions. The details of these results cannot be given at this time and we shall limit ourselves to the one problem of the application of the averages thus obtained to the production of a table of dosages.

Of course such a table must be taken as only an approximation but there seems to be sufficient data at hand to warrant us in considering this table accurate enough for practical use.

The other problems concerned are now the subject of investigation and will be presented in due time.

In the absence of accurate experimental data relative to the laws governing the escape of gases through such a net work as presented by the weave of a fumigation tent, we are forced to the assumption that the gas follows the laws of diffusion to the extent that the rate of escape is directly proportional to the differences in density. All the data at present at hand accords with the assumption with the limits involved; it is probably a very close approximation to the facts.

The *amount* of *leakage* may be stated in terms of percentage of the area of the surface; this is readily determined by finding the area of an orifice which will permit the flow of air at the same rate as through a portion of the canvas tested. The ratio of these two areas gives the percentage of leakage. For practical purposes it is better to determine the leakage of a doubled canvas and use this figure since when this is done one can easily make determinations at any part of the tent. The average leakage of doubled fumigation tents is .25% and the common range from .1% to .4% depends on the character of the canvas and on variations in weather conditions.

The *density of the gas* depends upon the relation of the dose to the volume of the tent. According to the universal practice of fumigators, the density used will be greater in small tents and less in large tents. If the dose were made exactly proportional to the area then the density would be represented by the ratio $\frac{a}{v}$ and be therefore inversely proportional to the diameters in trees of similar shapes. Thus it will be seen that while the area basis of scheduling may give a rough approximation of the dosage of the average leakage .25%, it will clearly not apply even roughly to tents showing any other per cent of leakage.

The *effect of leakage* upon the density in a small tent is greater than in a large tent because each unit of surface covers less average depth of gas; the quantity escaping per minute depending upon the density. It is evident that if a gram escape from each unit of surface the first minute from each of two tents, the remaining gas is a larger percentage of the original amount in the case of the larger tent. The volume behind each unit of surface of tent is indicated by the ratio $\frac{v}{a}$ and for tents of uniform shape is directly proportional to the diameters.

Stated in other words the time required to reduce the gas to 50% of its original strength is twice as long in the case of a tree 20 ft. in diameter as would be required for a tree 10 ft. in diameter when each is covered with a tent showing the same percentage of leakage.

The *per cent of leakage* determines the time required to reduce the density to any given percentage. Very evidently the size of the orifice in the escape either of a liquid or of a gas determines the rate of escape. Two openings will cause it to pass out in half the time and so will one orifice with twice the effective area. The density of the gas in a tent of .2% leakage will require twice as long to drop to 50% as it would in the same sized tent having .4% leakage.

The *time required to kill* will be somewhat dependent upon the density of the gas. Years ago thirty minutes were employed for fumigation but all fumigators now use forty to fifty minutes. One of the investigations now under way is the determining of the killing strength of gas for different times of exposure.

We do not know when the maximum density of gas is obtained in the generation which sometimes takes as much as fifteen minutes; it is probable that a greater or less time elapses after the killing has been accomplished before the tents are actually removed. Under average conditions the present period may be considered justified. When we have sufficient data we may be able to reduce the time in certain cases and advise the extending of it in others. For the present, however, we must accept the time and suppose that the dose of four ounces for a ten-foot tree maintains the killing strength of gas for the necessary period under the average conditions of leakage and it is not necessary to know exactly what this period is.

To calculate the dose for trees of different size and for tents of different leakage we need but to know that the above dose applies to .25% leakage for a 10 ft. tree and that in the case of other trees the ratio of increase or decrease of dose corresponds approximately with the area, that is, when the volumes are in the ratio of 1:8, the dose is in the ratio of 1:4.

The correct dose for a tent consists of two factors, (1) the theoretical amount necessary to kill when the tent is tight; (2) the amount of increase to allow for leakage. When one tent has twice the diameter of another, provided they are of the same shape, they have the ratio 1:8 in volume and if 1 is the theoretical dose of the smaller, 8 is the theoretical dose of the other. The second factor for these two tents consists of numbers, one the square root of the other. If half the gas escapes in ten minutes, half of the remainder will have escaped at the end of twenty minutes. Now with a tent of twice the diameter the loss in twenty minutes will only be that occurring in the smaller tent in ten minutes. The dose to compensate for the losses in these two tents during twenty minutes would require in one case a doubling and in the other case a fourfold increase. The ratio between these two rates of increase is that one is the square root of the other.

The formula would be

$$\text{dose } d^3 \times \sqrt[d]{1}$$

in which d = diameter and 1 = leakage factor.

Our unit diameter is 10 ft. and the leakage factor that satisfies the condition of the average dosage practice is four as shown by the following calculation:

	10 ft.	20 ft.
Theoretical	1 oz.	——
Leakage factor	4 oz.	$2^3=8$
	——	$\sqrt[2]{4}=2$
Product = dose	4	——
		16

Since the amount of leakage has precisely the same effect on the leakage factor as the size of tent the formula becomes

$$\text{dose} = d^3 \times \sqrt[pd]{1}$$

in which p = per cent of leakage with .25 as the unit.

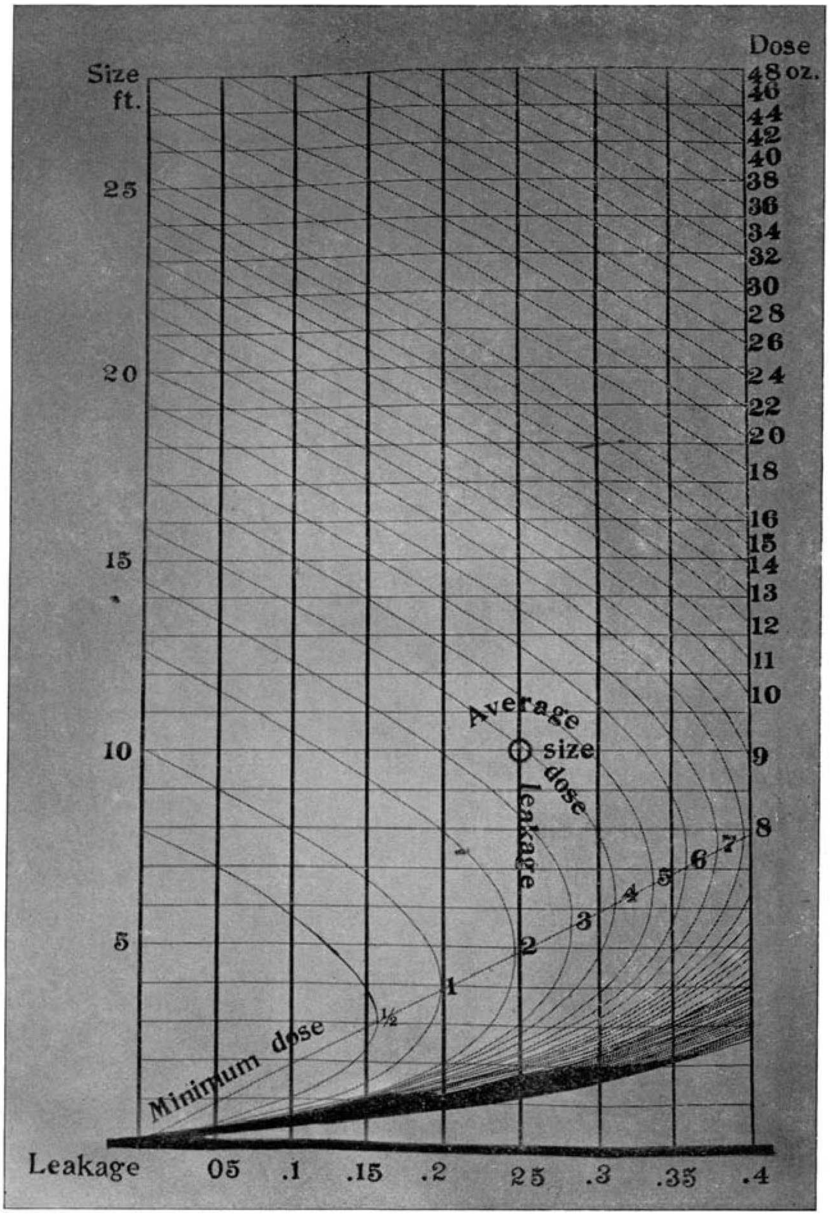
Applying this formula tables were calculated for the dose corresponding to the size of the tree and the degrees of leakage indicated by the straight lines of the chart and the curves indicating the dosages were drawn in accordance with these calculations.

The table is based as already indicated upon the actual practice of fumigators as regards the dose for a 10 ft. tree with average leakage. The portions of the table nearest this average therefore can be looked upon as having an accuracy independent of the calculations.

The most probable error is in the determination of 4 as the leakage factor; 4 is right if 16 oz. is right for a 20 ft. tree but most fumigators in fact give a 20 ft. tree less than 16 oz. which would indicate a larger factor. In case the leakage factor should be more than 4, the result would be the slight widening of all the curves, making still more pronounced the difference between the dosage of the tight and leaky tents of the same size.

It seems safe to say that the importance of leakage is not less than that indicated by the chart.

Of recent years there has been a very general appreciation of the necessity of measuring the sizes of trees when scheduling. There is no doubt that grave mistakes are made where measuring is not done but no matter how accurate one may be in the measuring of a tree, this chart shows that the fumigator may make the dose only a quarter as large as it should be or three or four times as great as is necessary in case the tents are leaky or tight. No mistakes anywhere near as large as these were found in all of the thousands of measurements made by us to test the relation of dosage to size of tree. We are led to conclude, therefore, that it is very much more important to measure the leakage than to measure the size.



Fumigation dosage for black scale based on size of tent and leakage of gas