THE VOLUMES IN A HORIZONTAL CYLINDRICAL TANK AT VARIOUS DEPTHS

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A manager of a mosquito abatement district recently came to me for the solution of a problem. Since it is one that may occur in other districts, I offer a solution for the benefit of other managers who may have a similar problem.

The problem is this—how can you determine the amount of liquid (oil, gasoline, liquid insecticide, etc.) in a horizontal cylindrical storage tank by measuring the depth of the liquid with a gauging stick? Sometimes a tank manufacturer will provide a table or a diagram which will indicate the volume for each inch of depth above the bottom, but sometimes second-hand tanks may be purchased, or obtained from military surplus for which no such table or diagram is available.

The basic problem is to find the area of a segment of a circle. There are several approximate formulae, for example $A = \frac{2CM}{3}$, where A is the area, C is the length of the chord, and M is the middle ordinate (or depth), as shown in Figure 1.

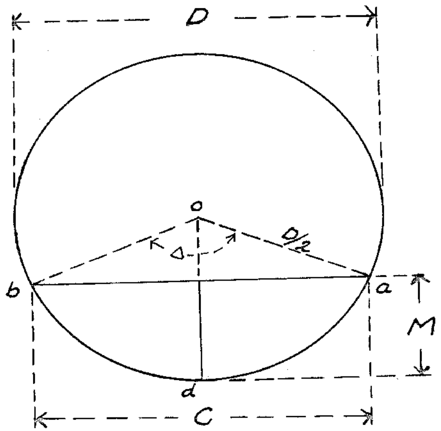

FIG. 1.—Diagram to assist in explaining steps in calculating volumes at different levels in tank.

However, the error will amount to about 3.5 percent at ¼ or ¾ depth, and it is necessary to compute the value of the chord C for various depths.

Exact formulae are available using radians as the angular measure, but trigonometric tables of angles in terms of radians are not usually available, and relatively few people are accustomed to this kind of circular measure.

A valid procedure for calculating the exact area of a segment of a circle is to compute the area of a sector (Fig. 1, oadb), compute the area of the triangle oab, and subtract the area of the triangle from the area of the sector. To do this it is necessary to compute the values of the middle ordinate M and of the chord C for various values of the central angle $\triangle$, from zero degrees to 360 degrees.

The formulae for these two factors are $C = D \sin \frac{1}{2} \triangle$, and $M = D/2\ (1 - \cos \frac{1}{2} \triangle)$, where D is the inside diameter of the tank. The area of the sector is $A_1 = \frac{\triangle^\circ}{360^\circ}(0.7854\ D^2)$, and the area of the triangle is $A_2 = C/2(D/2 - M)$. The area of the segment is then A_1 minus A_2.

For any individual tank this may be a bit laborious and subject to possible arithmetical errors. But if we once compute the values of the area of the segment, with the corresponding middle ordinate, for each 20° (say) of the central angle $\triangle$, using the value of one (1) for the diameter of the circle, we then can plot a curve of the area of the segment for any value of M, from zero to D, for any tank, by multiplying these tabular values by the tank diameter to get M (the depth), and by the square of the diameter to get the area. Then the area multiplied by the inside length of the tank will give the volume at the various depths (in cubic feet), and if this volume is multiplied by 7.48 the result is the volume in gallons.

The corresponding values of M and A, for a value of D equal to one (1), are set forth in the following table, for each 20° of the circle. The values were computed to the nearest four places, using a 20-inch slide rule, and are shown to the nearest three places.

TABLE 1.—Values of middle ordinate M and area A of a circular segment for a diameter D of 1

Middle ordinate M (depth)	Area of segment A
0.007	0.001
0.030	0.007
0.067	0.023
0.117	0.051
0.179	0.095
0.250	0.154
0.329	0.225
0.413	0.306
0.500	0.393
0.587	0.479
0.671	0.560
0.750	0.632
0.821	0.691
0.883	0.734
0.933	0.763
0.970	0.780
0.993	0.785
1.000	0.7854

After you have transformed the above values into feet and inches and into gallons, for a particular tank's diameter, they should be plotted on a rectangular coordinate chart, using feet and inches for the abscissas and gallons for the ordinates, and then drawing in the curve. The chart should be about 30 inches tall by about 20 inches wide. If you know an engineering draftsman perhaps he can be persuaded to draw the chart for you, and thus you could get a more accurate curve and a neater drawing. If desired, from this curve you can make up a table of volumes for each inch of depth.

The basic figures given are for a cylindrical tank with flat ends. If the tank has dished ends, it will be necessary to multiply the cross-sectional area of the tank by the varying lengths at the different depths. For example, if a tank which is 12 feet long has ends dished out 6 inches, the length at mid-depth will be 13 feet, and will be about 12 feet 6 inches long at about 30 percent and 70 percent of the depth. In this case it will be advisable to draw the curve in pencil as if it had flat ends, and then plot the volumes at 30 percent, 50 percent and 70 percent, and then redraw the final curve through these points and approximately parallel to the flat end curve.

Too great an attempt at mathematical accuracy is not justified, as a cylindrical tank lying on its side, whether in the ground or above ground, will be distorted slightly from a true circle by either its own weight or the varying weight of its contents if above ground, or by earth pressure if below ground.

DIELDRIN CEMENT BRIQUETTES IN CONTROLLING *Aedes aegypti* IN FIRE BARRELS

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This study deals with testing the effectiveness of dieldrin cement briquettes for *Aedes aegypti* (Linn.) control in fire barrels under field conditions.

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Elliot (1955) found that briquettes of sand and cement mixed with 50 percent water wettable dieldrin controlled *aegypti* in water jars in Africa for up to a year.

The Communicable Disease Center, Public Health Service, in its report on "Public Health Pesticides" for 1960, suggests the use of dieldrin briquettes as a possible technique for controlling *aegypti* and *Culex quinquefasciatus* Say in fire barrels.

METHODS AND MATERIALS. Dieldrin briquettes were made according to Elliot's formula of sand and cement (5:1) mixed with 50 percent water wettable dieldrin (2:1). Five grams of briquette (16.6 percent dieldrin) were added for each one gallon of water (Anon. 1960), or 275 grams for a 55-gallon fire barrel.

Aegypti were breeding heavily in 18 fire barrels located in a cotton warehouse along the waterfront in New Orleans. Ten of these barrels were selected at random for treatment with briquettes; eight were untreated and used as controls. The barrels, except the controls, were treated on July 21, 1959, and inspected at intervals for 150 days. All of the barrels contained waste cotton and organic refuse.

When inspections were made for the *aegypti* larvae, an additional check of the residual effectiveness of the insecticide was made by taking a 50 ml. sample of water from each barrel. The water sample was taken to the laboratory and placed in a bowl. Ten *aegypti* larvae, from the untreated barrels at the warehouse, were added to each bowl of water. The percent mortality was recorded after 24 hours. Immobile larvae or those unable to surface were considered dead.

RESULTS. The results of the fire barrel inspections are as follows:

No live *aegypti* larvae were recovered from treated barrels after the first day. *Aegypti* larvae were recovered from untreated control barrels from July through December 7, 1959, after which the weather became very cold. Contrariwise, *quinquefasciatus* continued to breed in control and treated barrels. Fire barrels having a mixed population of *aegypti* and *quinquefasciatus* had a complete mortality of *aegypti* 24 hours after treatment, but there was no apparent effect upon *quinquefasciatus*.

Water samples were taken from each barrel at 30-day intervals to test for insecticide content in

TABLE 1.—Percent of fire barrels positive for *A. aegypti* larvae in days after treatment

Treatment	No. of fire barrels	Average percent of barrels positive by days								
		0	1	10	20	30	60	90	120	150
Dieldrin	10	100	0	0	0	0	0	0	0	0
Control	8	100	100	75	87	87	75	75	25	0