A Short Method For Calculating Outage For Loading of Molasses Tank Cars

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It is required by railroad companies thai, molasses cars set for loading shall be loaded within certain limits of weight. It is desirable, and generally permissible, to load over the ''capaeily" weight stenciled on the car but not to exceed a certain maximum weight. This maximum is usually 110 percent of the "capacity" weight, or the maximum may in some instances be stenciled on 1he car as " Ld. Limit" (load limit). Where track scales are not provided at the loading station, it is necessary to calculate the required outage in order that the weight of the load will more than equal the indicated railroad capacity weight but be less than the maximum of 110 percent of the capacity weight, or that it shall not exceed the stipulated load limit.

The computation of outage for the filling of a car to tin; proper load weight involves essentially a calculation of the volume of the liquid of given density, in this case molasses, such that the calculated volume of liquid will have a weight equal to the desired loading. Calculations with this object can be greally simplified by the use of tables of constants. Tt is the purpose of this paper to show how such tables can be constructed and applied.

Development of Procedure

Assuming that the volume capacity of a car is greater than the permissible loading, the relationship between the loading permitted or desired and the total weight capacity of the car, which relationship we may designate by the factor f, would be expressed by the equation

$$(1) \quad f = \frac{\text{Load weight desired (pounds)}}{\text{Load weight of completely filled car (pounds)}}$$

Since a certain overload of defined limitations in excess of the indicated weight capacity is permitted, and usually desired, equation (1) may be written

$$(2) \quad f = \frac{\text{Indicated load weight capacity (pounds)} \times \text{Percent capacity loading}}{\text{Volume capacity in gallons} \times \text{weight per gallon}}$$

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This paper was presented by F. W. Weitz. General Chemist, American Crystal Sugar Co. The author wishes to express his appreciation for the many valuable suggestions made by Mr. F. W. Weitz while this paper was being prepared.

or

$$(3)\quad f = \frac{\text{Indicated load weight capacity (pounds)}}{\text{Volume capacity in gallons}} \times \frac{\text{Percent capacity loading}}{\text{Weight per gallon}}$$

Now, letting K represent the second factor in equation (3)

$$(4)\quad K = \frac{\text{Percent capacity loading}}{\text{Weight per gallon}}, \text{ then}$$

$$(5)\quad f = \frac{\text{Indicated load weight capacity (pounds)}}{\text{Volume capacity in gallons}} \times K$$

Values for the factor K can be set up in a table for molasses of various densities and for a range of percentage of loadings over the capacity loadings. In table 1 values for the factor K are given for molasses densilies ranging from 77.5 to 87.5 Brix by stages of 0.5 Brix and for fill of 100 to 110 percent of indicated capacity loadings.

Table 1.—Factor K.

Brix	Percent indicated capacity load						Pounds per gallon
	100	102	104	106	108	110	
77.5	.08594	.08766	.08938	.09110	.09282	.09453	11.635
78.0	.08574	.08746	.08917	.09089	.09260	.09432	11.662
78.5	.08554	.08725	.08896	.09068	.09239	.09410	11.690
79.0	.08534	.08705	.08876	.09047	.09217	.09388	11.717
79.5	.08514	.08684	.08855	.09025	.09195	.09366	11.745
80.0	.08494	.08664	.08834	.09004	.09174	.09343	11.773
80.5	.08474	.08643	.08813	.08982	.09152	.09321	11.800
81.0	.08454	.08623	.08793	.08962	.09131	.09300	11.828
81.5	.08435	.08603	.08772	.08941	.09109	.09278	11.856
82.0	.08415	.08583	.08751	.08920	.09088	.09256	11.884
82.5	.08395	.08563	.08731	.08899	.09066	.09234	11.912
83.0	.08375	.08543	.08710	.08878	.09045	.09213	11.940
83.5	.08355	.08522	.08689	.08856	.09023	.09190	11.968
84.0	.08335	.08502	.08669	.08836	.09002	.09169	11.997
84.5	.08316	.08482	.08649	.08815	.08981	.09148	12.025
85.0	.08296	.08462	.08628	.08794	.08960	.09126	12.054
85.5	.08277	.08442	.08608	.08773	.08939	.09104	12.082
86.0	.08257	.08422	.08587	.08752	.08918	.09083	12.111
86.5	.08237	.08402	.08567	.08731	.08896	.09061	12.139
87.0	.08218	.08383	.08547	.08711	.08876	.09040	12.168
87.5	.08199	.08363	.08527	.08691	.08855	.09019	12.197

Values for pounds per gallon used in deriving above K factors represent the weights in air calculated from apparent specific gravity 20/20 equivalent to the degree Brix, Table 114, Circular C 440, National Bureau of Standards.

Weight of 1 gallon of water at 20^{0} C. in air against brass weights=8.3216 pounds.

Referring again to equation (1)

$$f = \frac{\text{Load weight desired (pounds)}}{\text{Load weight of completely filled car (pounds)}}$$

If we let

l=length of the tank
d=diameter of the tank
h=height of fill in the tank
V=total volume of tank
V_1=volume of tank to height of fill

then

$$(6) \quad f = \frac{V_1 \times \text{Weight per unit volume}}{V \times \text{Weight per unit volume}}$$

The volume of the tank to the height of fill is computed by the formula

$$(7) \quad V_1 = l \left\{ \frac{3.1416\ d^2}{8} + \frac{2h\text{-}d}{2} \sqrt{hd\text{-}h^2} + \frac{d^2}{4} \text{ arc sin } \frac{2h\text{-}d}{d} \right\}$$

and

$$(8) \quad V = l \left\{ \frac{3.1416\ d^2}{4} \right\}$$

Substituting these values for V_1 and V respectively in equation (6) we have

$$(9) \quad f = \frac{\dfrac{3.1416\ d^2}{8} + \dfrac{2h\text{-}d}{2} \sqrt{hd\text{-}h^2} + \dfrac{d^2}{4} \text{ arc sin } \dfrac{2h\text{-}d}{d}}{\dfrac{3.1416\ d^2}{}}$$

Values for f as the above with relation to the ratio h/d from .01 to 1.00 are available in a table published originally in Central blatt der Zneker Industrie, Feb. 10, 1911, page 108-109, and reprinted in General Methods and Data, 1925, page 124, American Crystal

Sugar Company. Several of the values as given in the table were selected at random and compared for agreement, with values calculated by means of the above formula. Since the values agreed, at the several random points checked in the table, free use was made of that table in arranging another table of factors.

The table referred to, as noted above, gives the factors f in relation 1o the ratio of the height of fill, i. e., the depth of the liquid, to the diameter of the tank. In loading tank cars, rather than to measure the height of fill it is more convenient to have the desired fill defined as outage, or the distance from the top of the tank to the top of the liquid. The table of factors of f for the ratios h/d was therefore rearranged for greater convenience to give values for u/d, where u stands for outage. The term outage as herein used is defined as the distance from the top of the tank to the top of the liquid, measured from the inside edge at the top of the main body of the tank and below the dome. Since u equals d-h then the factor f corresponding to u/d for given values of d and h is the same as the factor for l-('h/d). Values for u/d equivalent to factor f are given in table 2.

Application of the Table for Computing Outage

With a few pertinent items of information relative to the loading and by the application of the tables, the determination of the appropriate outage for loading to the desired load weight can be reduced to one reference to each of the tables and a few simple calculations.

The required items of information pertaining to the loading will be the following :

(a) Brix of the molasses

(b) Desired percentage of indicated load weight capacity

(c) Indicated load weight capacity in pounds

(d) Volume capacity of the car in gallons (body only, see note below)

(e) Inside diameter of tank in inches

Item (a) will be provided from the analysis.

Item (b), the maximum, will usually be established by railroad rulings.

Items (c) and (d) will usually be found stenciled on the car body, either on the side or end of the tank. In this connection it is to be noted that, if no designation is made otherwise, the gallons capacity stenciled on the car usually includes the dome. The capacity of the dome can be computed; however no appreciable error will be introduced if it is estimated and a, deduction made accordingly from

Table 2.—Factor $\frac{u}{d}$

f	$\frac{u}{d}$	f	$\frac{u}{d}$	f	$\frac{u}{d}$	f	$\frac{u}{d}$
1.0000	.00	.8045	.25	.5000	.50	.1955	.75
.9983	.01	.7934	.26	.4873	.51	.1845	.76
.9952	.02	.7822	.27	.4745	.52	.1738	.77
.9913	.03	.7708	.28	.4618	.53	.1631	.78
.9866	.04	.7593	.29	.4491	.54	.1527	.79
.9813	.05	.7477	.30	.4364	.55	.1424	.80
.9755	.06	.7360	.31	.4238	.56	.1323	.81
.9692	.07	.7241	.32	.4112	.57	.1224	.82
.9625	.08	.7122	.33	.3986	.58	.1127	.83
.9554	.09	.7002	.34	.3860	.59	.1033	.84
.9480	.10	.6881	.35	.3735	.60	.0941	.85
.9402	.11	.6759	.36	.3611	.61	.0851	.86
.9320	.12	.6636	.37	.3487	.62	.0764	.87
.9236	.13	.6513	.38	.3364	.63	.0680	.88
.9149	.14	.6389	.39	.3241	.64	.0598	.89
.9059	.15	.6265	.40	.3119	.65	.0520	.90
.8967	.16	.6140	.41	.2998	.66	.0446	.91
.8873	.17	.6014	.42	.2878	.67	.0375	.92
.8776	.18	.5888	.43	.2759	.68	.0308	.93
.8677	.19	.5762	.44	.2640	.69	.0245	.94
.8576	.20	.5636	.45	.2523	.70	.0187	.95
.8473	.21	.5509	.46	.2407	.71	.0134	.96
.8369	.22	.5382	.47	.2292	.72	.0087	.97
.8262	.23	.5255	.48	.2178	.73	.0048	.98
.8155	.24	.5127	.49	.2066	.74	.0017	.99
						.0000	1.00

u = Outage (main body of tank, not including dome)
d = Diameter of tank

$$f = \frac{\text{Indicated load weight capacity (pounds)}}{\text{Volume capacity (gallons)}} \times K \text{ (from table 1)}$$

the total stenciled capacity to obtain the gallons capacity of the body only.

Item (e), the diameter of the tank, is the only item of measurement on the car required for the calculation of the loading outage.

In table 1, in line with a Brix value in the first column, under the caption Brix, closest to that of the determined Brix of the molasses, and in the selected column under the heading of the desired percentage indicated capacity load, the appropriate factor K is found.

From equation (5)

$$f = \frac{\text{Indicated load weight capacity (pounds)}}{\text{Volume capacity in gallons}} \times K$$

By inserting in this equation items (e) and (d), established from the information stenciled on the car as mentioned above, and the numerical value for factor K derived from the table, the factor f is calculated.

Referring to table 2 the appropriate factor u/d will be found, corresponding to the factor f. Since u/d is the ratio factor of outage of the loaded tank to the total diameter, then

$$\text{Outage in inches} = \frac{u}{d} \times \text{diameter of the tank in inches.}$$

Note: The factors in table 2 are set up for a tank with straight parallel ends. Most cars have ends bumped outward, however, these ends should not be considered in the calculations. When a car is, as in the usual case, loaded nearly full,any small error introduced from this source will be more than compensated by the coil of pipe commonly found in the bottom of the car and used for heating the load. One of the greatest errors made in loading cars to predetermined weight is usually that of not loading the car to the calculated outage. This error, along with other unavoidable errors introduced in Brix determinations, temperature, foam measurement, and so forth will affect the final load weight to the extent that it will usually vary from the selected value by less than 1 percent.

An example will illustrate the procedure of calculation. The values were taken from our notebook and cover a car actually loaded.

(a) Brix of the molasses.. 82

(b) Desired percent of indicated load weight........................ 108.
(108 percent was used rather than 110 percent to allow for any small errors.)

(c) Indicated load weight capacity in pounds............... 80,000.

(d) Volume capacity of the car in gallons
(8,044 stenciled on car, estimate dome 44, body only)...................".. 8,000.

(d) Diameter of car in inches.. 79.

Prom table 1 it is found that
K = 0.09088

Prom equation (5) above

$$f = K \times \frac{\text{Indicated load weight capacity (pounds)}}{\text{Volume capacity (gallons)}}$$

$$f = 0.09088 \times \frac{80{,}000}{8{,}000} = 0.9088$$

Now finding u/d from table 2 that most nearly corresponds to 0.9088

$$u/d = .15$$

Then

$$\text{Outage} = u/d \times \text{diameter in inches}$$

$$\text{Outage} = .15 \times 79 = 11.85 \text{ inches}$$

The actual railroad weight of this load was **86,880** pounds. We attempted to load this car to 108 percent of 80,000 pounds or **86,400** pounds.

The percentage error then was

$$\frac{86{,}880}{86{,}400} \times 100 - 100 = 0.56 \text{ percent}$$

Application of the Tables in Estimating Load Weight of Cars

It is of frequent occurence that cars of molasses for processing are received in advance of receipt of their bills of lading, and it becomes necessary for immediate accounting purposes to apply temporarily, in lieu of the actual railroad weights, an estimated weight of the molasses received. By reversing the above procedure of calculation for estimation of required outage for loading of tank cars, the formulae and tables may likewise be used for approximating the load weight of a loaded car.

From the measured outage and the diameter of the tank the ratio of outage to diameter, u/d,, may be determined and in table 2 a factor f equivalent to the ratio u/d will be found.

By substituting in equation (1) "load weight contained" for "load weight desired", we have

$$f = \frac{\text{load weight contained (pounds)}}{\text{Load weight of completely filled car (pounds)}}$$

which may be expressed as

$$f = \frac{\text{load weight contained (pounds)}}{\text{Volume capacity in gallons} \times \text{pounds per gallon}}$$

Then

load weight contained = volume capacity in gallons × pounds per gallon × f

An example will illustrate

Let d, diameter, inches	=	81	
u, outage, inches	=	11	
Volume capacity in gallons	=	8,023	(body only)
Brix of molasses	=	81.5	

$$\text{Then } \frac{u}{d} = \frac{11}{81} = .136$$

From table 2 where $\frac{u}{d} = .136$, by interpolation it is found that

$$f = .918$$

From table 1 at 81.5 Brix

weight per gallon = 11.86 pounds

Then

Load weight contained = 8,023 x 11.86 x .918 = 87,350 pounds.