Note: This is a reference cited in *AP 42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

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Subject: Final Deck Fitting Loss Factors for AP-42 Section 7.1
EPA Contract 68-D2-0159; Work Assignment No. III-01
MRI Project No. 4603-01-02

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I. Background and Introduction

The purpose of this memo is to document recommendations for the final deck fitting loss factors for incorporation into the February 1996 version of AP-42 Section 7.1, Organic Liquid Storage Tanks. As documented in a May 25, 1994 memo from R. Jones and D. Wallace, MRI, to A. Pope, EPA, and memos from A. Parker, MRI, to the project file, analyses were conducted by the American Petroleum Institute (API) and MRI to determine loss factors for deck fittings under various control configurations.

Several discussions were held between EPA, API, and MRI regarding the best way to analyze the data, particularly the slotted guidepole data, and present the factors in the AP-42 document and in Chapter 19.2 of API's *Manual of Petroleum Measurement Standards*. In an April 27, 1995, conference call, it was recommended that data for several of the slotted guidepole configurations be combined when developing the fitting loss factors, because the fittings either exhibited similar levels of control or were similar in configuration. Data for slotted guidepoles with gasketed and ungasketed sliding covers were combined, as were data for configurations that varied only with the height of the float (at or 1 inch above the sliding cover) during testing. These factors were published in the draft Section 7.1.

During a conference call held on November 29, 1995, combining fitting Nos. 24 (gasketed, with float at cover elevation, pole sleeve, and pole wiper at sliding cover elevation) and 29 (gasketed, with float 1 inch above cover, pole sleeve, and pole wiper 6 inches above cover elevation) into a single set of loss factors was discussed. It had been decided in the April conference call that float height was not significant (between 0 and 1 inch above the sliding cover) and it was noted in the November call that the pole wiper had been elevated only for ease of construction of the test assembly. Also, the evaporative loss factors developed separately for the two fitting configurations showed comparable emissions. Therefore, it was recommended that the data for these fittings be combined to develop a single set of loss factors.

During the call, participants also recommended a footnote to the loss factor table that cautions the user against applying the slotted guidepole loss factors to configurations where the float wiper is below the sliding cover, unless a pole sleeve is employed, since the fitting tests for configurations without a pole sleeve were only conducted for float wipers at or 1 inch above the sliding cover. It was postulated that when a pole sleeve is used, the height of the float wiper (above or below the sliding cover) is not critical, since the pole sleeve restricts the flow of vapor from the well vapor space into the slotted guidepole. Data from a slotted guidepole configuration tested by Chicago Bridge and Iron (CBI) (fitting No. C01) that included a gasket, "short" float (5 inches below the sliding cover elevation), pole sleeve, and pole wiper confirmed this assumption. These data were analyzed by MRI in January 1996 and combined with the other slotted guidepole, gasketed with float, pole sleeve, pole wiper data (fitting Nos. 24 and 29) to develop a single set of loss factors for a slotted guidepole with a gasketed sliding cover, float, pole sleeve, and pole wiper. This single set of loss factors is recommended for use in AP-42.

In a January 23, 1996 meeting of API's Committee on Evaporative Loss Measurement (CELM) attended by EPA and MRI, an additional test (denoted as fitting No. 31) for a slotted guidepole with a pole sleeve was introduced by CBI. This test was a duplicate of fitting No. 2, but was conducted after the initial test program was completed. The data for fitting No. 31 were analyzed by MRI and combined with the data for fitting No. 2 to obtain a revised set of loss factors for a slotted guidepole with a gasketed sliding cover and pole sleeve. This revised set of loss factors is recommended for use in AP-42.

Also discussed at the January meeting was the designation of all slotted guidepole configurations as "gasketed or ungasketed." Only two of the configurations (with and without a float) were tested in both the gasketed and ungasketed condition. These two cases provided the basis for combining the gasketed and ungasketed data. Therefore, some API committee members reasoned that only those two configurations should be grouped and designated as "gasketed or ungasketed," and the other four configurations should be designated only as "gasketed." Upon reviewing the underlying reasons for grouping the configurations and the previous data analyses, there is no strong reason to object to API's proposal and MRI recommends that only the two configurations that were actually tested in both conditions be designated as "gasketed or ungasketed."

Royce Laverman of CBI also presented a method for developing loss factors for center-area deck legs with gaskets and with socks (test data are available only for ungasketed center-area deck legs). He applied "control efficiencies" for gaskets and for socks (based on a comparison of the loss factors for pontoon-area deck legs with gaskets and socks to the ungasketed pontoon-area deck leg loss factors) to the ungasketed center-area deck leg factors and obtained new factors for center-area deck legs with gaskets and with socks. For example, applying a gasket to a pontoon-area deck leg reduces K_{Fa} by 35 percent, K_{Fb} by 78 percent, and m by 29 percent from the factors for the ungasketed pontoon-area deck leg. These reductions were applied to the loss factors for the ungasketed center-area deck leg to obtain loss factors for a gasketed center-area deck leg. The same method was applied to obtain factors for an ungasketed center-area deck leg with a sock.

The justification for estimating loss factors for these configurations is that currently, facilities receive no credit for controlling their center-area deck legs on floating roof tanks. The CBI method was reviewed by MRI, but this approach is not recommended due to reservations about its mathematical validity and inconsistency with the methodology used for estimating rim seal loss factors.

The methodology was discussed with Mr. Rob Ferry of TGB; we agreed that a slight modification to the extrapolation method used with rim seal loss factors is more appropriate; the methodology and results are discussed in attachment 1.

The results obtained using this method are similar to the CBI results, as shown in Table 1. The method presented here is recommended to maintain consistency. However, because test data for these configurations are not currently available, no conclusion can be drawn with respect to the accuracy of either method.

II. Deck Fitting Loss Factors

Table 2 presents the recommended final deck fitting loss factors for floating roof tanks for AP-42 Section 7.1, Organic Liquid Storage Tanks, and the software program TANKS 3.0. Table 3 indicates the slotted guidepole configurations that were combined to develop a single set of factors.

TABLE 1. DECK LEG LOSS FACTORS, K_{Fa}, K_{Fb}, AND m

Configuration	Method	K_{Fa}	K_{Fb}	m
Center-area leg, ungasketed		0.82	0.53	0.14
Center-area leg, gasketed	CBI	0.53	0.11	0.10
	TGB/MRI	0.53	0.11	0.13
Center-area leg, with sock	CBI	0.49	0.20	0.10
	TGB/MRI	0.49	0.16	0.14

TABLE 2. DECK FITTING LOSS FACTORS, K_{Fa}, K_{Fb}, AND m, AND TYPICAL NUMBER OF DECK FITTINGS, N_F[a]

Fitting Type And Construction Details	Loss Factors			Typical Number Of Fittings, N_F
	K_{Fa} (lb-mole/yr)	K_{Fb} (lb-mole/(mph)^m-yr)	m (dimensionless)	
Access hatch (24-inch diameter well)				1
Bolted cover, gasketed[b]	1.6	0	0	
Unbolted cover, ungasketed	36[c]	5.9	1.2	
Unbolted cover, gasketed	31	5.2	1.3	
Fixed roof support column well[d]				N_C (Table 7.1-11)
Round pipe, ungasketed sliding cover	31			
Round pipe, gasketed sliding cover	25			
Round pipe, flexible fabric sleeve seal	10			
Built-up column, ungasketed sliding cover[c]	47			
Built-up column, gasketed sliding cover	33			
Unslotted guide-pole and well (8-inch diameter unslotted pole, 21-inch diameter well)				1
Ungasketed sliding cover[b]	31	150	1.4	
Ungasketed sliding cover w/pole sleeve	25	2.2	2.1	
Gasketed sliding cover	25	13	2.2	
Gasketed sliding cover w/pole wiper	14	3.7	0.78	
Gasketed sliding cover w/pole sleeve	8.6	12	0.81	
Slotted guide-pole/sample well (8-inch diameter slotted pole, 21-inch diameter well)[e]				f
Ungasketed or gasketed sliding cover	43	270	1.4	
Ungasketed or gasketed sliding cover, with float[g]	31	36	2.0	
Gasketed sliding cover, with pole wiper	41	48	1.4	
Gasketed sliding cover, with pole sleeve	11	46	1.4	
Gasketed sliding cover, with float and pole wiper[g]	21	7.9	1.8	
Gasketed sliding cover, with float, pole sleeve, and pole wiper[h]	11	9.9	0.89	
Gauge-float well (automatic gauge)				1
Unbolted cover, ungasketed[b]	14[c]	5.4	1.1	
Unbolted cover, gasketed	4.3	17	0.38	
Bolted cover, gasketed	2.8	0	0	
Gauge-hatch/sample port				1
Weighted mechanical actuation, gasketed[b]	0.47	0.02	0.97	
Weighted mechanical actuation, ungasketed	2.3	0	0	
Slit fabric seal, 10% open area[c]	12			
Vacuum breaker				N_{vb} (Table 7.1-13)[j]
Weighted mechanical actuation, ungasketed	7.8	0.01	4.0	
Weighted mechanical actuation, gasketed[b]	6.2[c]	1.2	0.94	
Deck drain (3-inch diameter)				N_d (Table 7.1-13)
Open[b]	1.5	0.21	1.7	
90% closed	1.8	0.14	1.1	
Stub Drain (1-inch diameter)[k]	1.2			N_d (Table 7.1-15)

TABLE 2 (CONT.).

Fitting Type And Construction Details	Loss Factors K_{Fa} (lb-mole/yr)	K_{Fb} (lb-mole/(mph)^m-yr)	m (dimensionless)	Typical Number Of Fittings, N_F
Deck leg (3-inch diameter)				N_l (Table 7.1-15), (Table 7.1-14)
Adjustable, internal floating deck[c]	7.9			
Adjustable, pontoon area - ungasketed[b]	2.0	0.37	0.91	
Adjustable, pontoon area - gasketed	1.3	0.08	0.65	
Adjustable, pontoon area - sock, ungask.	1.2	0.14	0.65	
Adjustable, center area - ungasketed[b]	0.82	0.53	0.14	
Adjustable, center area - gasketed[m]	0.53	0.11	0.13	
Adjustable, center area - sock, ungask.[m]	0.49	0.16	0.14	
Adjustable, double-deck roofs	0.82	0.53	0.14	
Fixed	0	0	0	
Rim Vent[n]				1
Weighted mechanical actuation, ungasketed	0.68	1.8	1.0	
Weighted mechanical actuation, gasketed[b]	0.71	0.10	1.0	
Ladder well				1[d]
Sliding cover, ungasketed[c]	76			
Sliding cover, gasketed	56			

Note: The deck fitting loss factors, K_{Fa}, K_{Fb}, and m, may only be used for wind speeds below 15 miles per hour.

[a]Reference 5, unless otherwise indicated.

[b]If no specific information is available, this value can be assumed to represent the most common or typical roof fitting currently in use for external and domed external floating roof tanks.

[c]If no specific information is available, this value can be assumed to represent the most common or typical roof fitting currently in use for internal floating roof tanks.

[d]Column wells and ladder wells are not typically used with self supported fixed roofs.

[e]References 16,20.

[f]A slotted guide-pole/sample well is an optional fitting and is not typically used.

[g]Tests were conducted with floats positioned with the float wiper at and 1 inch above the sliding cover. The user is cautioned against applying these factors to floats that are positioned with the wiper or top of the float below the sliding cover ("short floats"). The emission factor for such a float is expected to be between the factors for a guidepole without a float and with a float, depending upon the position of the float top and/or wiper within the guidepole.

[h]Tests were conducted with float wipers positioned at varying heights with respect to the sliding cover. This fitting configuration also includes a pole sleeve which restricts the airflow from the well vapor space into the slotted guidepole. Consequently, the height of the float within the guidepole (at, above, or below the sliding cover) is not expected to significantly affect emission levels for this fitting configuration.

[j]N_{vb} = 1 for internal floating roof tanks.

[k]Stub drains are not used on welded contact internal floating decks.

[m]These loss factors were projected using the results from pontoon-area deck legs.

[n]Rim vents are used only with mechanical-shoe primary seals.

TABLE 3. SLOTTED GUIDEPOLE CONFIGURATION COMBINATIONS

Fitting No.	Configuration
1 25	Ungasketed sliding cover Gasketed sliding cover
3 26	Ungasketed sliding cover, with float 1 inch above sliding cover Gasketed sliding cover, with float 1 inch above sliding cover
20	Gasketed sliding cover, with pole wiper
2 31	Gasketed sliding cover, with pole sleeve Gasketed sliding cover, with pole sleeve
23 4	Gasketed sliding cover, with float at cover elevation, pole wiper Gasketed sliding cover, with float 1 inch above sliding cover, pole wiper
24 29 C01	Gasketed sliding cover, with float at cover elevation, pole sleeve, pole wiper Gasketed sliding cover, with float 1 inch above cover, pole sleeve, pole wiper six inches above sliding cover Gasketed sliding cover, with float 5 inches below cover, pole sleeve, pole wiper

Attachment 1. Deck leg loss factors extrapolation methodology

The methodology recommended for extrapolating loss factors for center-area deck legs with gaskets and with socks is illustrated below. First, loss factors for the controlled center-area deck leg are projected by applying the percent reduction achieved by gaskets and socks on pontoon-area deck legs to the ungasketed center-area deck leg, using the following equation.

$$E_{xc} = E_x\left(\frac{E_{yc}}{E_y}\right) \qquad (1)$$

where:

E_{xc} = the emissions level at a given wind speed for the control configuration under consideration, determined by factoring the emissions level of the uncontrolled case, E_x, by the ratio of the emission levels from a similar device, with and without the control (E_{yc}/E_y);

E_x = the emissions level at the indicated wind speed for the device under consideration, without the subject control; and

E_{yc}, E_y = the emissions levels at the indicated wind speed for the similar device, with (E_{yc}) and without (E_y) the subject control.

Using the rim seal methodology, values of E_{xc} are projected at three wind speeds (0, v_i, and v_j), and the form of the loss equation is assumed to be:

$$E = K_a + K_b v^m \qquad (2)$$

The zero miles per hour value for E_{xc} is assigned to K_a, and using the values of E_{xc} and v at wind speeds v_i and v_j, the values for K_b and m are determined as follows:

$$E_{xc} - K_a = K_b v^m \qquad (3)$$

$$E_{net} = E_{xc} - K_a \tag{4}$$

$$\log(E_{net}) = \log K_b + m \log v \tag{5}$$

Having projected values for E and v at wind speeds v_i and v_j, as well as for K_a ($v = 0$), the slope, m, of the $\log(E_{net})$ versus $\log(v)$ curve is determined as follows:

$$m = \frac{\log(E_{net,j}/E_{net,i})}{\log(v_j/v_i)} \tag{6}$$

Finally, K_b is determined as follows:

$$E_{net,v_j} = K_b v_j^m \tag{7}$$

$$K_b = \frac{E_{net,j}}{v_j^m} \tag{8}$$

When using the above method to estimate rim seal loss factors, the wind speeds selected were $v_i = 4$ mph and $v_j = 10$ mph. When this method is applied to deck leg loss factors, however, the estimated emissions decrease at high wind speeds. This result was deemed unrealistic, and the method was modified by setting $v_i = 0$ mph and $v_j = 4$ mph. Since using $v_i = 0$ results in dividing by zero to determine m, zero was approximated as 1×10^{-100} ($v_i = 1 \times 10^{-100}$ mph). The results are summarized in Tables 1 and 2.

Table 1. Extrapolation of loss factors for center-area deck legs, gasketed

		Ka	Kb	m		vi 1E-100	vj 4
Center-area, ungasketed	Ex	0.82	0.53	0.14	Ex =	0.8200	1.4635
Pontoon-area, gasketed	Eyc	1.3	0.08	0.65	Eyc =	1.3000	1.4970
Pontoon-area, ungasketed	Ey	2	0.37	0.91	Ey =	2.0000	3.3064
	Exc	0.5330			Exc =	0.5330	0.6626
					Enet =	3.44E-15	0.1296
		Ka	**Kb**	**m**			
		0.53	**0.11**	**0.13**			

Table 2. Extrapolation of loss factors for center-area deck legs, sock

		Ka	Kb	m		vi 1E-100	vj 4
Center-area, ungasketed	Ex	0.82	0.53	0.14	Ex =	0.8200	1.4635
Pontoon-area, sock	Eyc	1.2	0.14	0.65	Eyc =	1.2000	1.5447
Pontoon-area, ungasketed	Ey	2	0.37	0.91	Ey =	2.0000	3.3064
	Exc	0.4920			Exc =	0.4920	0.6837
					Enet =	3.22E-15	0.1917
		Ka	**Kb**	**m**			
		0.49	**0.16**	**0.14**			