AP42 Section:	7.1
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Title:	Development of Fitting Loss Factors "attachment IV"

DEVELOPMENT OF FITTING LOSS FACTORS

The procedure used to calculate the fitting loss factor (K_f) for internal floating-roof tanks, as presented in the third edition of API Publication 2519, is outlined below in Section 4.1. Section 4.2 contains the detailed calculations of the fitting loss factors.

Calculation Procedure

The following sources of information were used in developing the fitting loss factors: the reported data from the CBI bench test program and the survey information developed by the Generic Fitting Work Group.

After reviewing the data, the following procedure was used to calculate the fitting loss factors:

- Develop a "building block" approach by comparing tests which would identify various loss "elements".
- Use these loss "elements" in a systematic manner to "assemble" the losses for typical fittings.

Detailed Fitting Loss Calculations

Based on the procedure outlined above, the following presents the detailed calculations of the fitting loss factors. The basic equations and variables used in the calculations are defined below:

Total Deck Fitting Loss (L_f):

$$L_f \text{ (lb/yr)} = (F_f)\ P^*\ M_v\ K_c$$

Where: F_f = total deck fitting loss factor (lb·mole/yr)

$$= \sum_{i=1}^{n} (N_{f_i}\ K_{f_i})$$, where N_f = number of fittings

K_f = specific fitting loss factor

$$P^* = \text{vapor pressure function} = \frac{\left(\frac{P}{Pa}\right)}{\left[1 + \left(1 - \frac{P}{Pa}\right)^{0.5}\right]^2}$$

M_v = vapor molecular weight (lb/lb mole)

K_c = product factor

Calculation of Specific Fitting Loss Factors (K_{f_i}):

$$E \text{ (lb·mole/yr)} = N_f \, K_f \text{ (lb·mole/yr)} \, P^* \, K_c$$

Where: E = loss calculated for a given fitting type, based on bench test measurements (lb·mole/year)

N_f = number of fittings per bench test = 1

P^* = 0.1036 (for P = 5.0 psia) (all test results were normalized to this vapor pressure)

K_c = 1 (for octane/propane)

Therefore:

$$K_f = \frac{E}{(1)\ (0.1036)\ (1)} = E/(0.1036)$$

The basic data from the CBI Report is summarized in Table 4.1. The following calculations are summarized in Table 4.2. The calculated fitting loss factors are summarized in Table 4.3.

Fitting Loss Calculations

Table 5.1 of the CBI report ("Testing Program to Measure Hydrocarbon Emissions from a Controlled Internal Floating Roof Tank") is a summary of the IFR Deck Fitting Emission Tests. It lists an "Average Emission Rate (lb.mole/yr)" for each test. The Test No., Description and Average Emission Rate are repeated here in Table 4.1.

As shown above, the fitting factor, K_f, is derived for a particular test when the Average Emission Rate is divided by 0.1036. These results are shown in Table 4.1 under K_f. They will be referred to by F_x where x is the number of the particular fitting test. For example, F_{12} is the K_f Factor for Test 12, or 23.60.

The loss from various "generic" types of fittings can be determined by "adding up" the various "loss elements" contributing to the total loss, a "building block" approach. The "building block" approach to fitting loss requires that the individual "loss element" of each fitting type be explored as much as possible.

One important assumption that was made was that losses coming from relatively long, thin openings could be adjusted linearly. This was necessary primarily to make an adjustment from the test drum size (22.5 inches dia.) to the agreed upon "typical" fitting size (24 inches dia.). Thus the losses associated with the length of the perimeter were ratioed linearly to correct for this difference. I.E.;

$$\frac{\text{perimeter of typical fitting}}{\text{perimeter of test drum}} = \frac{24\ \pi}{22.5\ \pi} = \frac{24}{22.5} = \frac{D_s}{D_B}$$

The following notation is used throughout the remainder of this work when making these corrections.

D = well diameter (in)

D_s = standard column well diameter (24 in)

D_B = bench test drum diameter in most tests, except where noted (22.5 in)

$D_{B-11,\ B-15}$ = bench test drum diameter in test 11 and 15 (30 in)

D_L = diameter of ladder well (36 in)

D_V = diameter of vacuum breaker well (10 in)

P = perimeter (in)

P_L = ladder perimeter (66 in)

P_C = built-up column perimeter (40 in)

F_2, Test No. 2, represents a control case for many of the other tests. This test measured the losses from a clamped and gasketed flat plate which is the "edge" condition of many other tests. This loss will be subtracted from all tests that used this edge condition so only the loss due to the central "tested" condition, the "center loss," is considered. The subtraction of this loss (when applicable) will be shown using the notation $-F_2$.

Using the "building block" approach, each typical fitting type will be developed along with an explanation of the rational involved.

(1) ACCESS HATCH

a. Bolted Cover with Gasket.
Derived directly from Test 2.

$$F_2 \left(\frac{D_s}{D_B} \right) = 1.53 \left(\frac{24}{22.5} \right) = 1.63$$

b. Gasketed, Unbolted Cover.
Similar to a column well loss but without the center loss element where the column passes through the plate. Test 9A is a loose lid built-up column and the "center loss" from Test 12 is a built-up column without a rim loss.

$$(F_{9A} - (F_{12} - F_2))\ (\frac{D_s}{D_B})$$

$$= (32.60 - (23.60 - 1.53))\ (\frac{24}{22.5}) = 11.23$$

c. Ungasketed, Unbolted Cover
One element common to many different fittings is the difference in loss between a "gasketed" and "ungasketed" fitting. This refers to the presence or absence of a seal material around the edge (or rim) of the fitting neck on which the sliding cover plate rests. This seal reduces this rim loss by forming a better fit across this juncture than a metal-to-metal joint. Generally this joint must be free to slide freely to allow out-of-plumb appurtanances to move relative to the floating roof as the liquid level rises (or falls). Both Test 7 (41.7) and Test 9B (48.90) are tests of an Ungasketed Column Well except Test 7 is tested with nC6 while Test 9B used C3/nC8. By averaging Test 7 and Test 9B, we develop a loss element for a built-up column well with an Ungasketed Rim. From this we must substract the "center loss" element from Test 12, as in 1 b above. Again, since the Test drums were 22.5 in. in dia. and a typical column well has been determined to be 24 in. in dia., this element must be adjusted by D_S/D_B, (24/22.5).

$$((\frac{F_7 + F_{9B}}{2}) - (F_{12} - F_2))\ (\frac{D_s}{D_B})$$

$$= ((\frac{41.70 + 48.90}{2}) - (23.60 - 1.53))\ (\frac{24}{22.5}) = 24.78$$

(2) AUTOMATIC GAUGE FLOAT WELL

This fitting is similar to fitting (1) except it has 3 small holes in the lid to pass the automatic gauge tape and guide wires. The "center loss" from Test 6 is the loss from a 1 in. dia. Stub Drain which we will use to use to estimate these hole losses.

a. Bolted Cover with Gasket.
Same as (1) a. plus 3 times the "center loss" from Test 6

$$1\text{ a} + 3\ (F_6 - F_2) = 1.63 + 3\ (2.69 - 1.53) = 5.11$$

b. Gasketed, Unbolted Cover.
Same as (1) b. plus 3 times the "center loss" from Test 6

$$1\ b + 3\ (F_6 - F_2) = 11.23 + 3\ (2.69 - 1.53) = 14.71$$

c. Ungasketed, Unbolted Cover.
Same as (1) c. plus 3 times the "center loss" from Test 6

$$1\ c + 3\ (F_6 - F_2) = 24.78 + 3\ (2.69 = 1.53) = 28.26$$

(3) BUILT-UP COLUMN WELL

This fitting loss is similar to the losses calculated for fitting (1) except an irregular opening is allowing a loss at the center. While this "center loss" will vary depending on fit-up and size of the opening, it was judged that the losses from Test 12 are representative and conservative (i.e., potentially over-estimating loss) for the vast majority of cases.

a. Gasketed Sliding Cover.
Same as (1) b. plus the "center loss" from Test 12

$$1\ b + (F_{12} - F_2) = 11.23 + (23.60 - 1.53) = 33.30$$

b. Ungasketed Sliding Cover.
Same as (1) c. plus the "center loss" from Test 12

$$1\ c + (F_{12} - F_2) = 24.78 + (23.60 - 1.53) = 46.85$$

PIPE COLUMN WELL

This fitting is similar to the Built-Up Column Well but was judged to generally have a better seal fit-up due to the uniform nature of a round pipe.

c. Flexible Fabric Sleeve Seal.
Derived directly from the "center loss" from Test 10

$$F_{10} - F_2 = 11.80 - 1.53 = 10.27$$

d. Gasketed Sliding Cover.
Test 11 is almost a direct test except the drum was 30 in. diameter. (1) b above is the loss from a 24 in. well without a center loss. Thus, we can use (1) b to adjust Test 11 to compensate for it's large well to determine a "center loss" from Test 11.

$$1\ b + (F_{11} - 1\ b\ (\frac{D_{B-11}}{D_s})) = 11.23 + (21.70 - 11.23\ (\frac{30}{24}))$$
$$= 18.89$$

e. Ungasketed Sliding Cover
Similarly, Test 11 minus it's "rim" loss can be added to (1) c. from above.

$$1\ c + (F_{11} - 1\ b\ (\frac{D_{B-11}}{D_s})) = 24.78 + (21.70 - 11.23\ (\frac{30}{24}))$$
$$= 32.44$$

(4) LADDER WELL

A ladder well is similar in form and function to a column but is generally larger with a larger opening for the ladder. The typical ladder well was determined to be 36 in. dia., D_L. Thus the "rim" loss from a ladder well was calculated from the "rim" loss, (1) b. or (1) c., ratioed by the relative diameters (D_L / D_S). The center loss element is similar to the center loss around a built-up column well, as adjusted for a longer perimeter. The built-up column consisting of a 9" and 7" channel, has about 40 in. of perimater, P_C, and has a fit-up similar in complexity to a ladder. The ladders pipe and 16 in. long rungs have a combined perimeter of about 66 inches, P_L. Therefore, the average center loss from Tests 12 and 15, corrected by a ratio of perimeters, will yield the ladder center loss. (Test 15 used a 30 in. dia. drum, D_{B-15}, so the correction factor, f_2 must also be adjusted by the ratio $D_{B-15}D_B$).

a. Gasketed Sliding Cover.

$$1\ b\ (\frac{D_L}{D_s}) + (\frac{(F_{12} - F_2) + (F_{15} - (F_2\ (\frac{D_{B-15}}{D_B})))}{2})\ (\frac{P_L}{P_c})$$

$$= 11.23\ (\frac{36}{24}) + (\frac{(23.60 - 1.53) + (27.10 - (1.53\ (\frac{30}{22.5})))}{2}\ (\frac{66}{40})$$

$$= 16.845 + (23.565)\left(\frac{66}{40}\right)$$

$$= 55.73$$

b. Ungasketed Sliding Cover.

$$1\ c\left(\frac{D_L}{D_s}\right) + \left(\frac{(F_{12} - F_2) + (F_{15} - (F_2 (\frac{D_{B-15}}{D_B})))}{2}\right)\left(\frac{P_L}{P_c}\right)$$

$$= 24.78\left(\frac{36}{24}\right) + \left(\frac{(23.60 - 1.53) + (27.10 - (1.53 (\frac{30}{22.5})))}{2}\right)\left(\frac{66}{40}\right)$$

$$= 37.17 + (23.565)\left(\frac{66}{40}\right)$$

$$= 76.05$$

(5) DECK LEG OR HANGER WELL

a. Adjustable
Derived directly from the "center loss" from Test 3

$$F_3 - F_2 = 9.43 - 1.53 = 7.90$$

(6) SAMPLE PIPE OR WELL

<u>Sample Pipe</u>

This fitting is identical to the Pipe Column Wells in (3) d and (3) e except the pipe is slotted to allow a representative sample of the product to be taken.

a. Gasketed Sliding Cover.
Test 4 and 5 are identical except the pipe in Test 4 was slotted. Therefore, the loss element of a slotted pipe should be Test 4 minus Test 5 ($F_4 - F_5$). This difference is added to the pipe column loss in (3) d. above.

$$3\ d + (F_4 - F_5) = 19.89 + (45.30 - 20.40) = 43.79$$

b. Ungasketed Sliding Cover.
Same as (6) a. except added to the pipe column loss from (3) e. above.

$$3e + (F_4 - F_5) = 32.44 + (45.30 - 20.40) = 57.34$$

Sample Well

c. Slit Fabric Seal, 10% open area.
Derived directly from the "center Loss" from Test 14

$$F_{14} - F_2 = 14 - 1.53 = 12.47$$

(7) STUB DRAIN

a. 1 inch Dia.
Derived directly from the "center loss" from Test 6

$$F_6 - F_2 = 2.69 - 1.53 = 1.16$$

(8) VACUUM BREAKER

a. Gasketed, Weighted Mechanical Actuation.
Same conditions as Test 2 but smaller rim (10 inch dia.) - Ratio by diameter.

$$F_2 \left(\frac{D_v}{D_B} \right) = 1.53 \left(\frac{10}{22.5} \right) = 0.68$$

b. Ungasketed, Weighted Mechanical Actuation.
Fit of metal surfaces usually similar to Test 1 except smaller rim (10 inch dia.)-Ratio by diameter.

$$F_1 \left(\frac{D_v}{D_B} \right) = 1.97 \left(\frac{10}{22.5} \right) = 0.88$$

Other fittings may be derived from this data using the same "building block" approach.

Due to the inherent inaccuracies in such an analysis it was determined by the steering committee to round off all results to two significant figures. These values were placed in Table 4.3 and in Table 1 in the Bulletin titled "Deck Fitting Loss Factors (K_f) and Typical Number of Deck Fittings (N_f)".

TABLE SUMMARY OF DEPR FITTING TEST FACTORS

Test No.	Description	Average Emmission (lb·mole/yr @ 5lb.)	K_F (lb.mole/yr)
1	Access Hatch Cover, Ungasketed	0.204	1.97
2	Access Hatch Cover, Gasketed and Clamped	0.158	1.53
3	1 ½ In. dia. Adjustable Roof Leg	0.977	9.43
4	8 In. dia. Slotted Pipe Sample Well	4.69	45.30
5	8 In. dia. Pipe Column Well	2.11	20.40
6	1 In. dia. Stub Drains	0.279	2.69
7	Phase 1 Column Well, Ungasketed	4.32	41.70
8	½ In. Gap Around Built-up Column	5.42	52.30
9A	Phase 1 Column Well, Gasketed	3.38	32.60
9B	Phase 1 Column Well, Ungasketed	5.07	48.90
10	Phase 2 Column Well	1.22	11.80
11	Phase 3 Column Well (30 In. dia. drum)	2.25	21.70
12	1/8 In. Gap Around Built-up Column	2.44	23.60
13	Access Hatch Cover with 1/8 In. Gap	5.61	54.20
14	Sample Well with 10% Gap Area	1.45	14.00
15	1/8 In. Gap Around Built-up Column	2.81	27.10