TEXAS UTILITIES GENERATING CO.
COMANCHE PEAK UNIT 2
CABLE TRAY HANGERS

7Q-D-2

CABLE TRAY HANGER LOAD LOCATION STUDIES

VOLUME I - BOOK 7

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COMANCHE PEAK UNIT NO. 2

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CABLE TRAY HANGER LOAD APPLICATION LOCATION STUDIES (2/20/86) R1

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CALCULATION COVER SHEET

CLIENT: TEXAS UTILITIES·GENERATING COMPANY

OFS NO. 3306.221

PROJECT: COMANCHE PEAK SES UNIT NO. 2

DEPT NO. 549

SUBJECT: CABLE TRAY HANGER LOAD APPLICATION LOCATION STUDIES

CALCULATION NO. VOLUME I - BOOK 7

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PROBLEM: Two studies, performed to determine realistic locations for points of application of cable tray vertical and longitudinal loads onto cable tray hanger tier members, are documented in this book.

CONTAINS ASSUMPTIONS WHICH REQUIRE CONFIRMATION YES ___ NO X

ASSUMPTIONS CONFIRMED ON — BY —

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BY A J Chen DATE 9/17/85 SHEET 2 OF 18

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CLIENT

PROJECT TEXAS UTILITIES GENERATING CO. COMANCHE PEAK UNIT 2

SUBJECT CABLE TRAY HANGERS - LOAD LOCATION STUDIES

VOLUME I - BOOK 7

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1.0 INTRODUCTION

Two studies have been performed to determine realistic locations for points of application of cable tray vertical and longitudinal loads onto cable tray hanger tier members. These studies were performed using manual calculation techniques. The conclusions of these studies provide the technical justification for the load locations presented in Attachments B1 and B2 of Reference 1.

2.0 REFERENCES

1. Ebasco General Instructions For Cable Tray Hanger Analysis for Comanche Peak SES No. 2, Rev. 1 August 23, 1985.

2. Advanced Mechanics of Materials, Seely and Smith, 2nd. Ed, 1952.

3.0 CONCLUSIONS

3.1 VERTICAL LOAD STUDY

For cable tray hanger configurations in which horizontal trays are attached to channel-section hanger tier members, the location of the point of application of vertical downward load induced onto the tier by the tray (tray dead weight and tray vertical seismic downward load) was studied. The results of this study demonstrate that the vertical load application point shown in Attachments B1 and B2 of Reference 1, at the tier channel web centerline, is realistic.

3.2 LONGITUDINAL LOAD STUDY

For longitudinal type cable tray hangers in which cable trays are clamped to channel-section hanger tier members, the location of the point of application of longitudinal load induced onto the tier by the tray (longitudinal horizontal seismic load and thermal load) was studied. It was concluded that the load application point is dependent on the number of bolts used to connect the tray side rails to the tray clamps. For configurations in which only one bolt is used to connect each tray side rail to its clamp, the longitudinal load must be applied at the bolt location. For configurations in which more than one bolt is used, the longitudinal load can be applied at the top of the channel-section tier member. These locations are shown in Attachment B2 of Reference 1.

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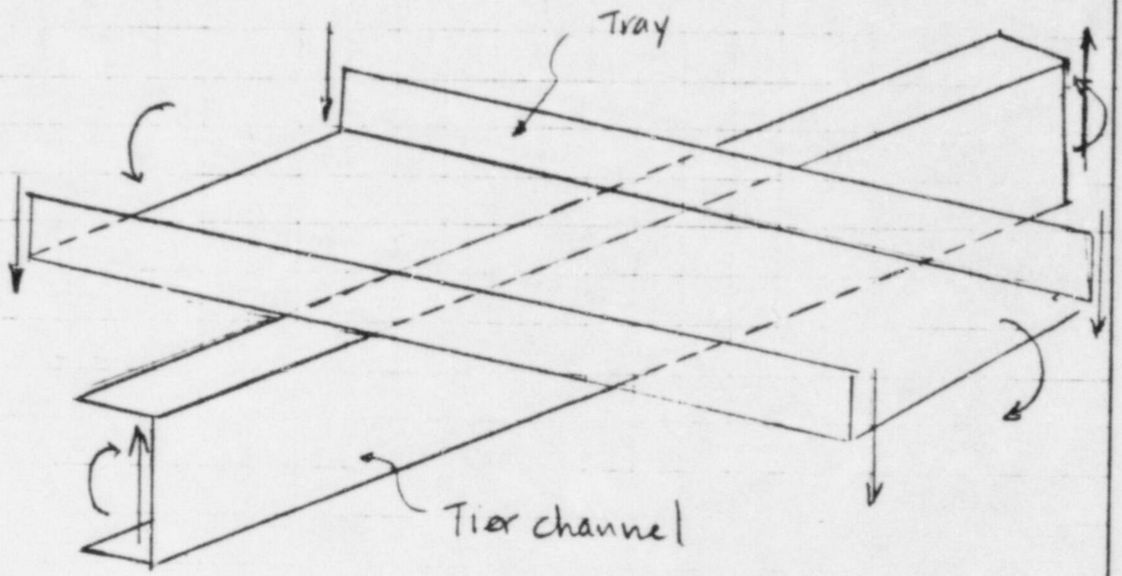
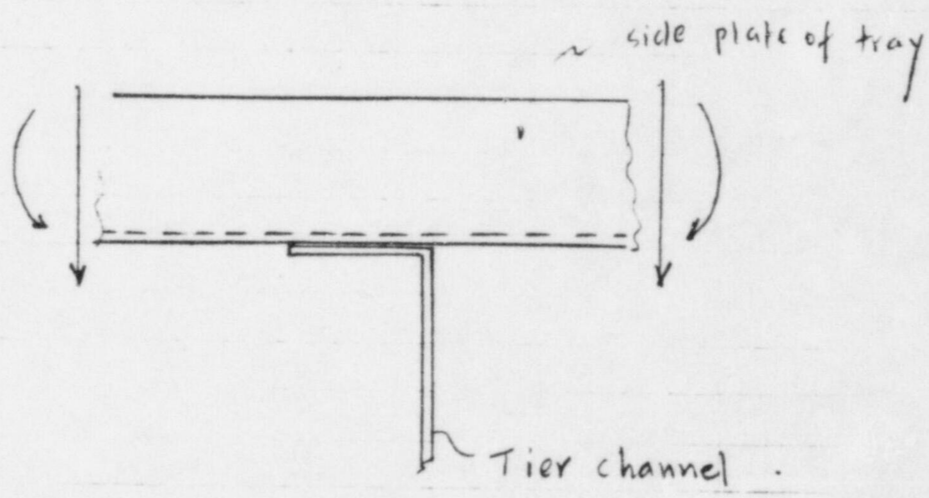
4.1 VERTICAL DOWNWARD LOAD STUDY

GEOMETRY:





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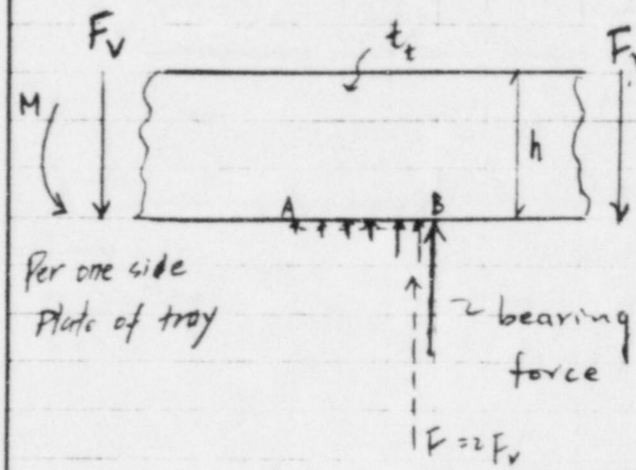
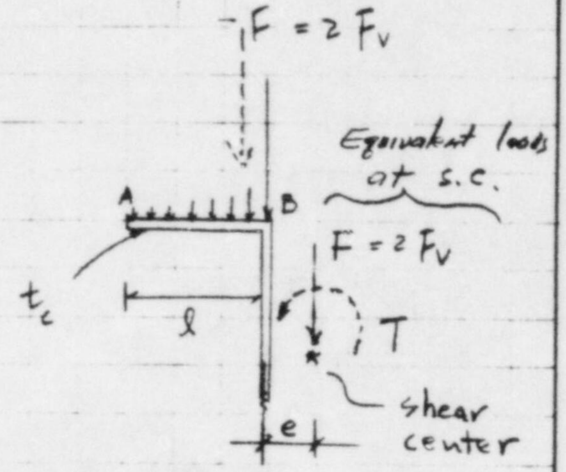


Loads Acting On Tray



Loads Acting On Tier

The bearing force between tray and the tier is dependent on the relative deformation of each other, which can be affected by the following factors:

i) Deformed tray in region A-B as shown above will increase the bearing force.

ii) Since the resultant bearing is located on the left hand side of the channel shear center, the torsion will twist the channel's flange to separate from the tray, therefore will reduce the bearing force.

4.1 CONTINUED

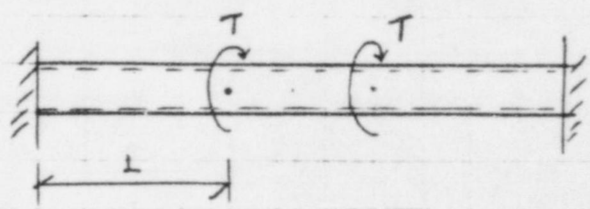
The above effects can be quantified as follows:

i) Deflection of point A relative to point B in the tray due to vertical downward load, δ_1:

$$\delta_1 = \frac{F_v\, l}{G \times h \times t_t} \quad \text{(shear deformation dominated)}$$

ii) Deflection of point A relative to point B in the channel due to torsion, δ_2:

Assuming the resultant force is acting on the center of web, the torsion $T = F \cdot e = 2F_v \cdot e$



For warping restraint at one end, the twist angle θ at distance L from restrained end due to T can be obtained by:

$$\theta = \frac{T}{JG}\left(L - a \tanh\frac{L}{a}\right)$$ – Ref. page 288 & 291 of Reference 2

where $a = \frac{h_c}{2}\sqrt{\frac{EI}{GJ}}$

$J = \frac{1}{3}\Sigma b t^3$

$\therefore\ \delta_2 = \theta \cdot l$

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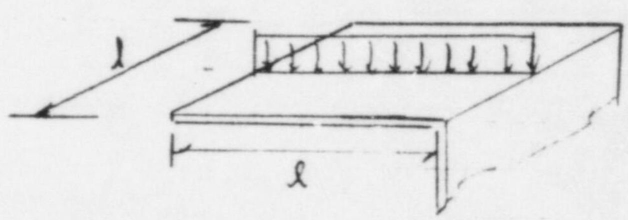
4.1 CONTINUED

If $\delta_2 > \delta_1$, then the resultant force F will be always acting at the center of the channel's web.

If $\delta_2 < \delta_1$, the following calculation can be performed to determine the portion of load acting on the surface of channel's flange:

$$\delta = \delta_1 - \delta_2$$

Assuming uniformly distribution force w



$$\delta = \frac{w l^4}{8EI}$$

or $$w = \frac{8EI\delta}{l^4}$$

Percentage of total load acting on channel's flange:

$$\frac{wl}{2F_v} \%$$

Calculation Of Actual Condition

Critical Condition – The following tray & tier geometric arrangement produces the largest δ_1 and smallest δ_2.

Tray : The critical δ_1 is when it's maximum. This will be produced by the tray with the maximum $(l / h \times t_e)$ value, which is the ratio of tier channel flange length to ½ tray vertical shear area. Use tier C4×7.25 (covers 95% of cases). Tray with minimum vertical shear area is 6" wide by 4" deep tray, with $A_s = 1.102$ in² (Refer to Attachment K of Ref. 1)

Tier:

C4×7.25

$$\delta_1 = \frac{F_v \, l}{G \times h \times t_e} = \frac{F_v \, (1.60)}{(1.115 \times 10^7)(1.102/2)}$$

$$= (2.28 \times 10^{-7}) F_v$$

$l = 1.721 - .321 = 1.40"$

$$G_{Tier} = G_{Tray} = \frac{E}{2(1+\nu)} = \frac{29 \times 10^6}{2(1+.3)}$$

$= 1.115 \times 10^7$ psi

$I_{weak\,axis} = 0.433$ in⁴

$J = 0.08$ in⁴

$h_c = 4.0"$

$e = 0.55"$

Tier : The critical δ_2 is when it's minimum.

$$\delta_2 = \theta l = \frac{T \cdot l}{GJ}\left(L - a \tanh\frac{L}{a}\right)$$

where $a = \frac{h_c}{2}\sqrt{\frac{EI}{GJ}} = \frac{4.0}{2}\sqrt{\frac{(29\times10^6)(0.43?)}{(1.115\times10^7)(0.08)}} = 7.504$

$$T = 2 F_v \cdot e = 2 \cdot F_v \times 0.55 = 1.1 F_v$$

For $L = 6''$:

$$\delta_2 = \frac{1.1 F_v (1.4)}{0.08(1.115\times10^7)}\left[6 - 7.504 \tanh\frac{6}{7.504}\right] = (1.76\times10^{-6})F_v$$

For $L = 10''$:

$$\delta_2 = \frac{1.1 F_v (1.4)}{0.08(1.115\times10^7)}\left[10 - 7.504 \tanh\frac{10}{7.504}\right] = (5.99\times10^{-6})F_v$$

For $L = 15''$:

$$\delta_2 = \frac{1.1 F_v (1.4)}{0.08(1.115\times10^7)}\left[15 - 7.504 \tanh\frac{15}{7.504}\right] = (1.34\times10^{-5})F_v$$

For $L = 3''$ (= smallest possible L values for at least 95% of CT configurations. This 3" spacing allows for tray clamps. Some cases have trays welded to tiers with almost zero clear space, for which the load will be transmitted to post, therefore, eccentricity will be not a concern)

$$\delta_2 = \frac{1.1 F_v (1.4)}{0.08(1.115\times10^7)}\left[3 - 7.504 \tanh\frac{3}{7.504}\right] = (2.59\times10^{-7})F_v$$

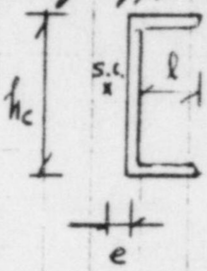
The critical condition shown on page 10 is critical for the most common C4×7.25 tier member. For the tier member with highest torsional rigidity, C6×13, the following applies:

$I_{weak\ axis} = 1.05\ in^4$

$J = 0.241\ in^4$

$h_c = 6.0\ in$

$e = 0.6\ in$



C6×13

$l = 2.157 - 0.437 = 1.72\ in$

$$\delta_2 = \theta l = \frac{T l}{G J}\left(L - a \tanh \frac{L}{a}\right)$$

where $a = \frac{h_c}{2}\sqrt{\frac{EI}{GJ}} = \frac{6.0}{2}\sqrt{\frac{(29\times10^6)(1.05)}{(1.115\times10^7)(0.241)}} = 10.10$

$$T = 2F_v \cdot e = 2 \cdot F_v \times 0.6 = 1.2 F_v$$

For $L = 6''$

$$\delta_2 = \frac{1.2 F_v (1.72)}{0.241(1.115\times10^7)}\left[6 - 10.10 \tanh \frac{6}{10.10}\right] = 4.75\times10^{-7} F_v$$

For $L = 3''$

$$\delta_2 = \frac{1.2 F_v (1.72)}{0.241(1.115\times10^7)}\left[3 - 10.10 \tanh \frac{3}{10.10}\right] = 6.55\times10^{-8} F_v$$

The tray deflection

$$\delta_1 = \frac{F_v l}{G \cdot h \cdot t_e} = \frac{F_v (1.72)}{(1.115\times10^7)(1.102/4)} = 2.80\times10^{-7} F_v$$

$\therefore \delta_2 < \delta_1$

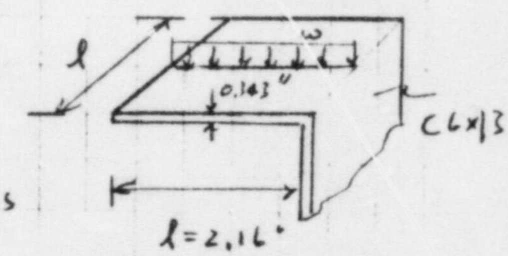
(FOLLOWING SHEET IS 11b)

From page 9, for $\delta_2 < \delta_1$, the percentage of total load acting on channel's flange can be estimated as follows:

$$\delta = \delta_1 - \delta_2 = 2.80\times10^{-7} F_v - 6.55\times10^{-8} F_v$$
$$= 2.15\times10^{-7} F_v$$

$$\omega = \frac{8EI\delta}{l^4} = \frac{8(29\times10^6)(\frac{1}{12}\times2.16\times0.343^3)(2.15\times10^{-7}F_v)}{(2.16)^4}$$

$$= 1.67\times10^{-2} F_v$$



The percentage of total vertical load acting on channel's flange is

$$\frac{\omega l}{2F_v} = \frac{1.67\times10^{-2} F_v \times 2.16}{2 F_v}$$

$$= 1.8\%$$ — negligible

Therefore, the resultant vertical force F can be assumed acting at the center of the web of the tier C6x13, which has the highest torsional rigidity in the tier members used.

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Conclusion :

For all possible L values, $\delta_2 > \delta_1$.
Thus, the resultant force F will always be acting at the center of the tier channel's web.

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Conclusion :

For all possible L values and tier member sizes, the resultant force F will always be acting at the center of the tier channel's web.

4.2 LONGITUDINAL LOAD STUDY

The effect of longitudinal load on the tier transmitted from tray is dependent on the connections at tray-to-clamp and clamp-to-tier. It is obvious that the longitudinal load acting on the tier should be applied at the bolt gage line if there is only one bolt (pin connection) connecting the tray to clamp. When there are two or more bolts at tray-to-clamp connection, the tray side plate and clamp will rotate together, therefore, the eccentricity of the longitudinal load will reduce significantly. The purpose of this study is to investigate the effect of longitudinal load on tier when there are two or more bolts at tray-to-clamp connection which represent majority of actual conditions.

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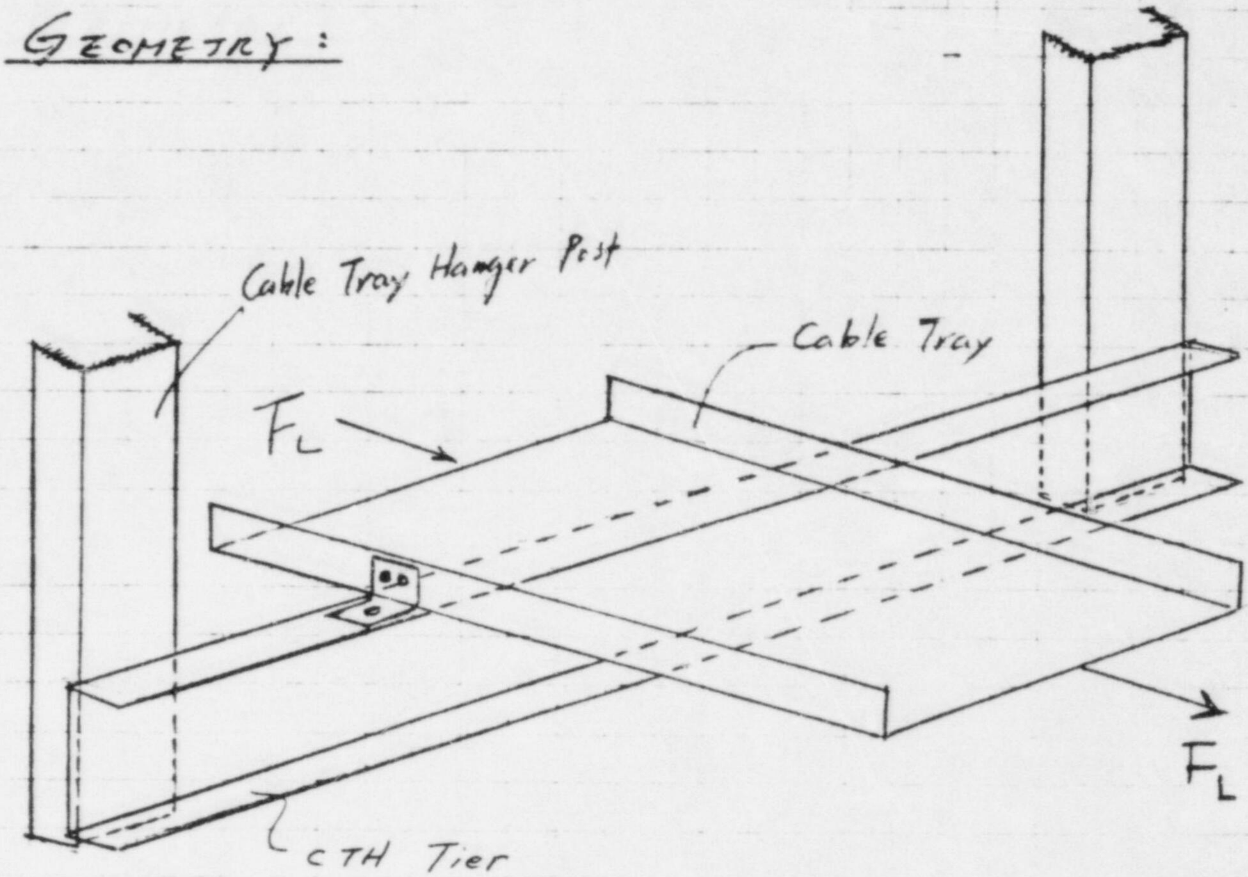
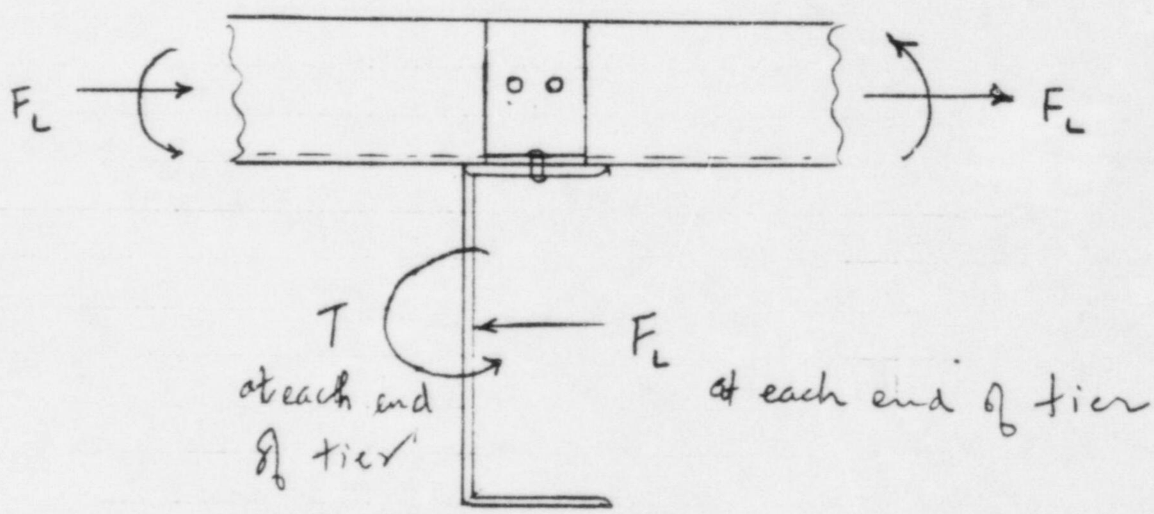
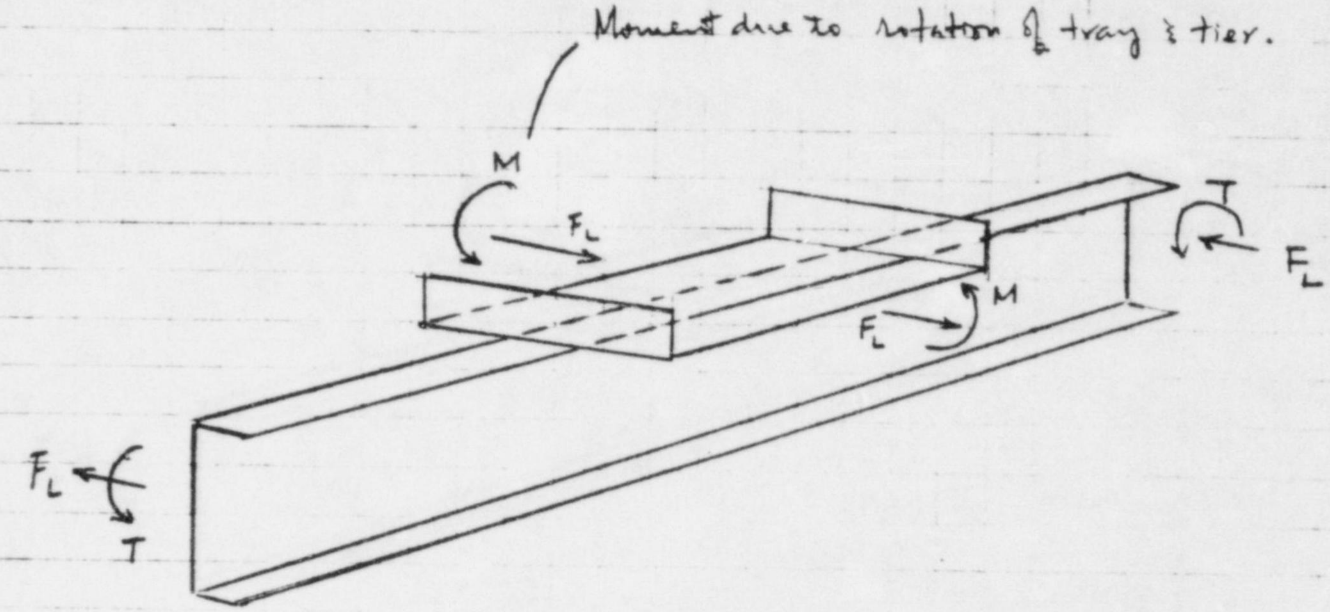
GEOMETRY:





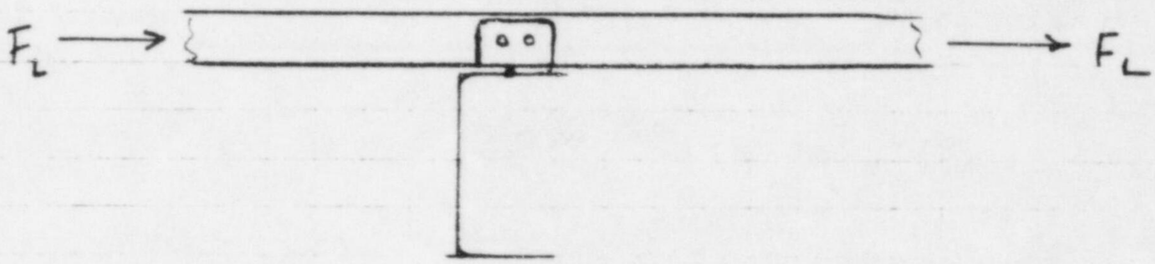


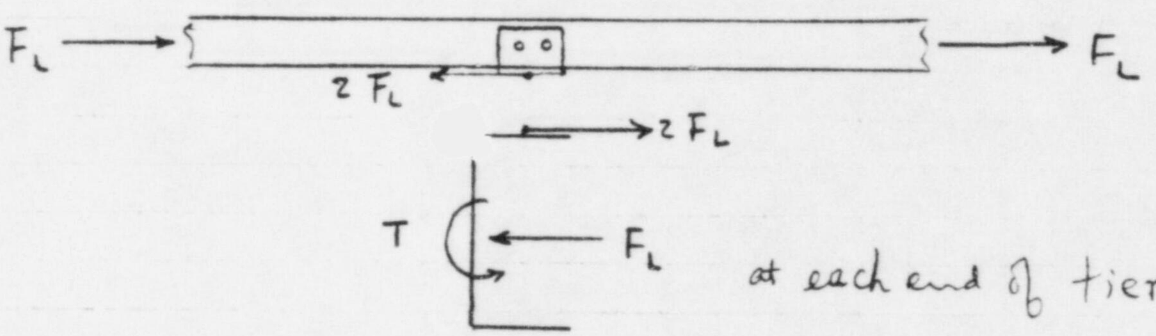
As the tray moves in the longitudinal direction, the longitudinal earthquake load F_L is transmitted to the tier through the clamp. Since the tier is restrained from twisting at the ends by the post, the F_L load will twist the tier. The torsion T is dependent on the degree of moment connection between tray & tier. The two following extreme conditions can be considered:

(i). Tray & tier rotate independently. For example, when there is a gap between tray and tier.

(ii) Tray & tier rotate together — clamp-to-tier connection is fixed.

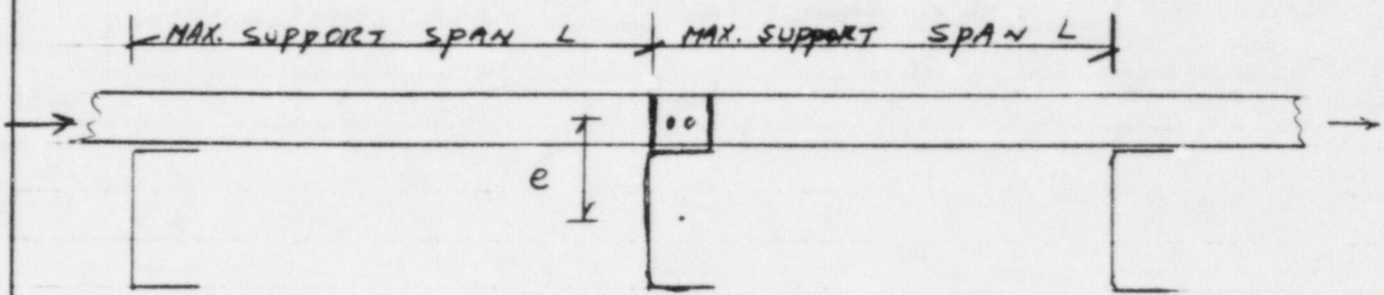
(i) Tray & tier rotate independently — If there is a gap between tray and tier and clamp-to-tier connection is not rigid.

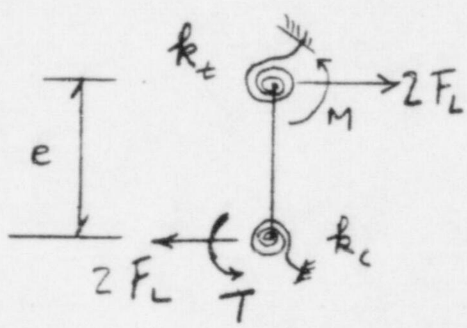




Since the tray & tier rotate independently, the clamp-to-tier connection is a pin connection. Therefore, the torsion T can be determined by applying the load F_L on the top of the flange of the tier. Thus the longitudinal load can be applied at the top of tier's flange.

(ii) Tray & tier rotate together (clamp-to-tier connection is fixed)





If the tray & the tier channel rotate together at the connection, the moment due to the offset e will be shared by the torsion T at the tier channel and the moment M at the tray. They are distributed according to the rotational rigidities k_t & k_c of the tray & tier channel respectively, as shown in the above sketches. Even for conservative bounds of tray and tier stiffness, the effective torsion T

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at the tier will be smaller than that of Case (i) when clamp-to-tier connection is assumed to be pin.

Conclusion :

As discussed in the above, if the clamp-to-tier connection has some degree of moment connection the effective torsion T at the tier will be reduced since the tray will share the moment due to eccentricity. Therefore, it will be conservative to assume that the clamp-to-tier connection is a hinge. Thus, the effective load on the hanger tier will be the cable tray longitudinal load acting at the top of the tier channel.