December 2, 1971

STRENGTH OF OVEN WALLS IN BENDING

The following pages outline a procedure for oven wall design. The method is based on papers by Ahlers and Yoshisato Suga (1,2). The calculations give a wall pressure, which strengthwise can be compared with existing ovens, assuming reasonably the same coal mixes. The absolute limit load on oven walls at present cannot be fully evaluated because of the unknown properties of construction materials and actual working pressures in ovens.

In derivations the following assumptions are made:

1. Oven walls are rigid plates with horizontal pressure load resisted in vertical direction only.
2. Under limit load plastic hinges are formed in brick liners at the top, middle and bottom.
3. Stiffening effect of top and bottom wall construction is disregarded.
4. The mortar joints have lower crushing strength than silica brick. Maximum calculation strength - 150 psi.
5. The oven wall has no tensile strength.
6. Elastic stabilizing effect of roof structure on wall is disregarded (possible increase of axial load above that of roof weight).
7. Larry car wheel load does not overstress top of oven wall liners.

REFERENCES:

(1) Yoshisato Suga: "Large scale coke oven batteries and High rate Operation of Coke Batteries at Fuji Iron and Steel Company".

(2) Walter Ahlers: Limit load of Coke oven Walls. (In German)

(3) Cohen and Laing: "Discussion of Journal, Structural Division, Proceedings of the ASCE pp. 23-40, SF5, September, 1956.

H. Stalis

NOV 11 1971

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SHEET 1

CALCULATION SHEET

OVEN WALL STRENGTH

H. ST.

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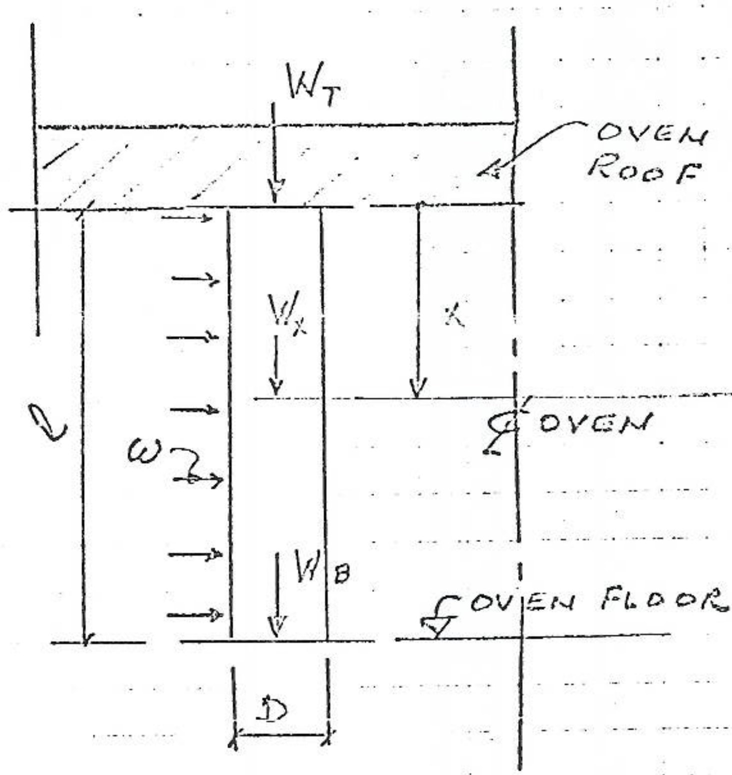
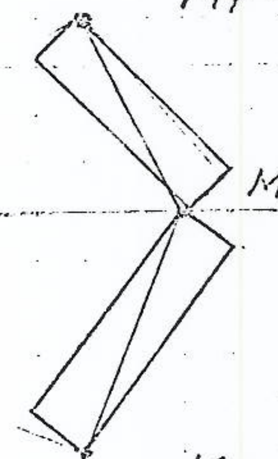


LOADING

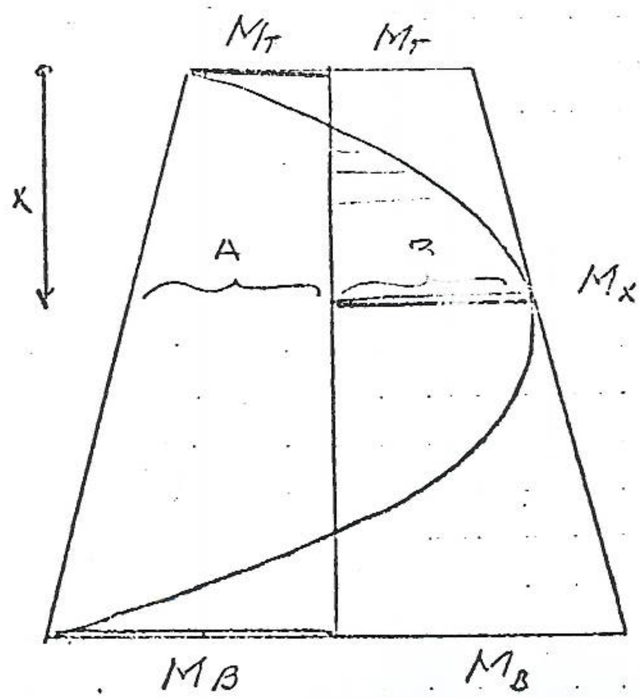


$M_T = W_T \cdot \frac{D}{2}$

$M_x = W_x \cdot \frac{D}{2}$

$M_B = W_B \cdot \frac{D}{2}$

FAILURE MECHANISM WITH LIMIT MOMENTS



$$M_x = \frac{\omega x}{2}(l - x) - \left[M_T + \frac{x}{l}(M_B - M_T)\right]$$

FROM SYMMETRY A = B AND

$$\frac{\omega x}{4}(l - x) = M_T + \frac{x}{l}(M_B - M_T$$

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CALCULATION SHEET

OVEN WALL STRENGTH

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FIND X FOR $M_x = MAX$ WITH $\frac{dF}{dx} = 0$

$$\frac{\omega l}{4} - \frac{(M_B - M_T)}{l} = \frac{\omega x}{2}$$

$$\boxed{X = \frac{l}{2} - \frac{2(M_B - M_T)}{\omega l}}$$

$$M_x = M_T + \frac{X}{l}(M_B - M_T) = \frac{\omega x}{2}(l - x) - \left[M_T + \frac{x}{l}(M_B - M_T)\right)$$

$$M_T + \frac{(M_B - M_T)}{l}\left[\frac{l}{2} - \frac{2(M_B - M_T)}{\omega l}\right] =$$

$$= \frac{\omega l}{4}\left[\frac{l}{2} - \frac{2(M_B - M_T)}{\omega l}\right] - \frac{\omega}{4}\left[\frac{l}{2} - \frac{2(M_B - M_T)}{\omega l}\right]^2$$

$$\frac{M_B + M_T}{2} - \frac{2(M_B - M_T)^2}{\omega l^2} = \frac{\omega l^2}{16} - \frac{(M_B - M_T)^2}{\omega l^2}$$

$$\left[\omega l^2\right]^2 - 8(M_B + M_T)\left[\omega l^2\right] + 16\left[M_B - M_T\right)^2 = 0$$

PROJECT N

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CALCULATION SHEET

OVEN WALL STRENGTH
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AND FINALLY

$$\boxed{W_{ULT} = \frac{4\left(\sqrt{M_B} + \sqrt{M_T}\right)^2}{l^2}} \qquad (1)$$

BUT $M_B = W_B \frac{D}{2}$ $\qquad M_T = W_T \frac{D}{2}$

$$\boxed{w_{ULT} = \frac{D\left(\sqrt{W_B} + \sqrt{W_T}\right)^2}{6\, l^2}} \qquad (2)$$

WHERE W_{ULT} - ULTIMATE LOAD ON OVEN WALL IN psi

D - THICKNESS OF OVEN WALL IN INCHES

l - HEIGHT OF OVEN IN INCHES

W_T - ROOF LOAD IN LBS/OVEN/FT W

W_B - LOAD AT OVEN FLOOR IN LBS/FT OF WALL

AN APPROXIMATE EXPRESSION FOR ω_{ULT} MAY BE DERIVED BY INSERTING

$$\omega_N \ell = \alpha W_T$$

WHERE ω_N - WEIGHT OF WALL (LBS/SQ. FT)

and $\sqrt{1+\alpha} \approx 1.66$

$$\boxed{\omega_{ULT} = \frac{D}{6\ell^2}\left(\frac{\omega_N \ell}{12} + 5.32\, W_T\right)} \qquad (3)$$

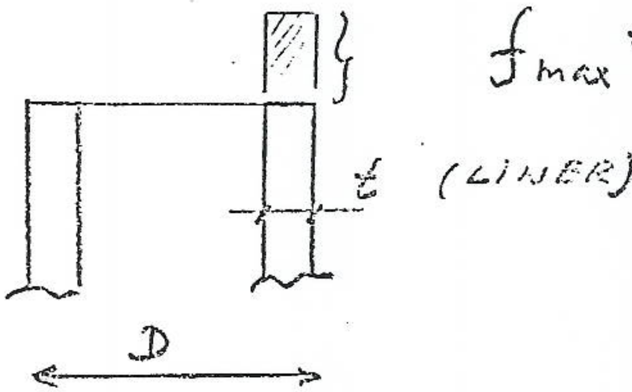
RECOMMENDED MINIMUM REQUIRED DESIGN PRESSURE

$$\boxed{\omega_{\substack{ULT\\DES}} = 1.25 \text{ psi}} \qquad (4)$$

USE OF FORMULAE

1/ EVALUATE W_B AND W_T

2/ CHECK STRESS AT PLASTIC HINGE



$$f_{max} = \frac{W}{t \cdot 1}$$

UNIT WIDTH

3/ $f_{max} < 150$ psi $\therefore$ FORMULAE (1) OR (2) MAY BE USED

4/ $f_{max} \geq 150$ $\therefore$ USE (1)

LET $M_{MAX} = 150 \cdot t \cdot 1 \cdot \left(\frac{D}{2} - \frac{t}{2} \right)$

OVEN WALL STRENGTH

INFLUENCE OF LARRY CAR ON WALL STRENG

A/ LOADING CENTERED ON WALL

CHECK COMPRESSIVE STRESS AT BOTTOM OF WALL

$$\boxed{f_L = \frac{W_B + W_L}{12 \cdot t} \leq f_{L\,MAX}}$$

← ASSUMED CRUSHING STRENGTH OF MORTAR

WHERE f_L - LINER STRESS [psi]

W_L - LARRY LOAD [LBS/FT]

t - THICKNESS OF LINER

1) $f_L < f_{L\,MAX}$ LARRY LOAD WILL INCREASE LATTERAL RESISTANCE OF WALL .. DISREGARD LARRY LOA IN CALCULATIONS

2) $f_L > f_{L\,MAX}$

SET $$\boxed{M_{B_{MAX}} = \frac{f_{L\,MAX} \times t \times (D - t)}{2}}$$

USE $M_{B_{MAX}}$ FOR CALCULATION OF W_{ULT}

B/ LARRY LOAD EXCENTRIC ON WALL

CHECK COMPRESSIVE STRESSES ON BOTTOM LINERS

REQUIRED $\boxed{f_L \leq f_{L_{MAX}}}$

$$\boxed{\frac{M_L}{W_T + W_L} < \frac{D}{6}}$$

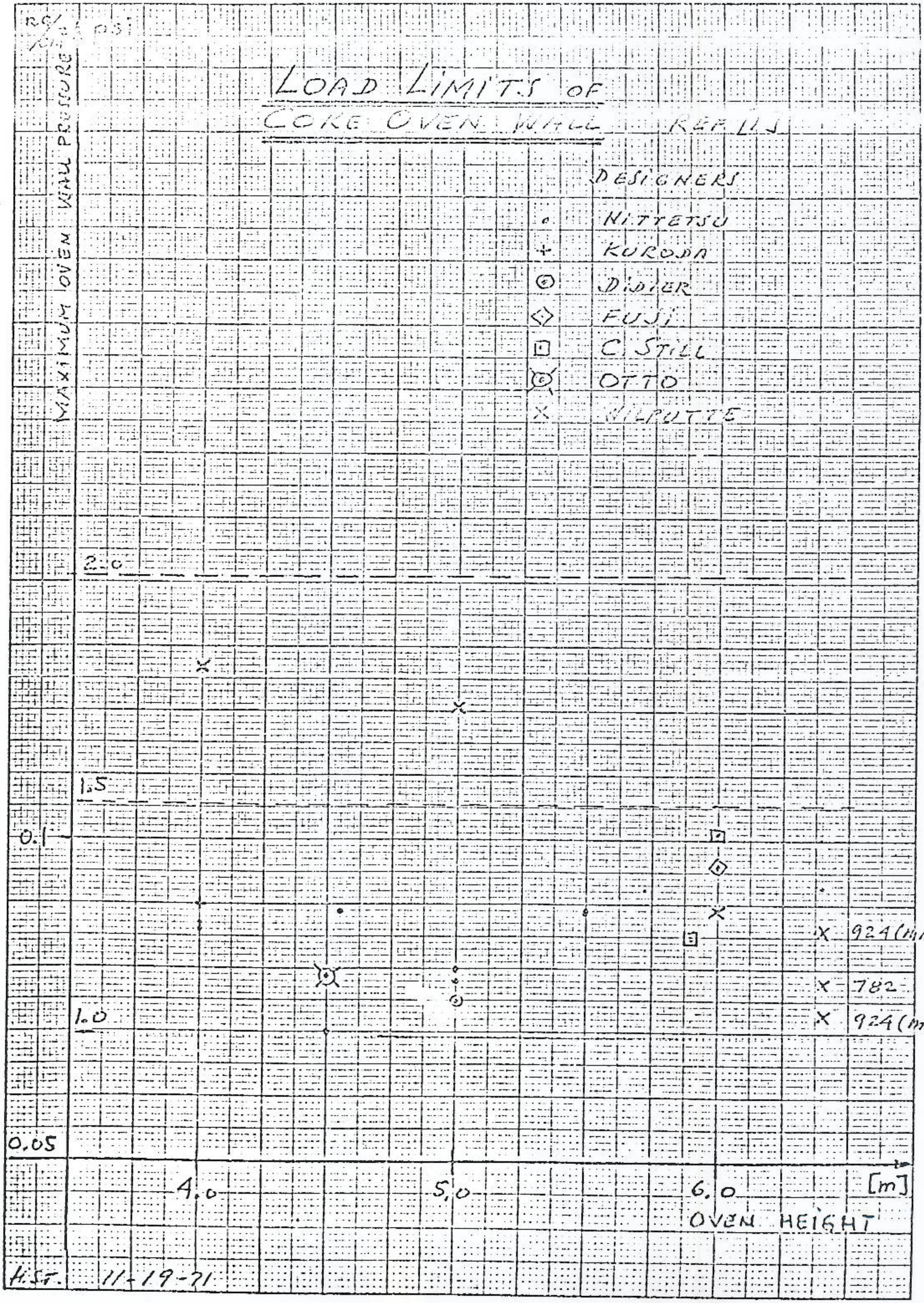
FOR CALCULATIONS OF W_{ULT} USE

$$M_{T_L} = M_T - M_L$$

AND

$$M_{B_L} = M_B - M_L$$

OR $M_{B_L} = M_{S_{MAX}} - M_L$


kg/cm² psi
MAXIMUM OVEN WALL PRESSURE
LOAD LIMITS OF COKE OVEN WALL REF [1]
DESIGNERS
NITTETSU
KURODA
DIDIER
FUJI
C. STILL
OTTO
WILPUTTE
2.0
1.5
0.1
1.0
0.05
924 (MAX)
782
924 (min)
4.0
5.0
6.0
[m]
OVEN HEIGHT
H.ST. 11-19-71

924

OVEN WALL STRENGTH

H.ST. 12-1 7

LIMIT LOAD ON OVEN WALLS - NO LARRY CAR

OVEN DIMENSIONS

FACE TO FACE OF BRICKWORK	49'-1 3/4"
ROOF THICKNESS	5'-0"
CENTER TO CENTER OVENS	4'-0"
AVERAGE OVEN WALL	2'-6"
l OVEN - HOT	254 3/4"

	ROOF - HAYDITE FILL		ROOF - 3RD QUALITY F - CLAY	
	NO CHARGE HOLES	4 CHARGE HOLES	NO CHARGE HOLES	4 CHARGE HOLES
W_T [LBS/FT]	2021	1890	2371.5	2122.4
W_B "	5595	5464	5945.5	5696.4
$\sqrt{W_T}$	44.95	43.47	48.7	46.07
$\sqrt{W_B}$	74.8	73.92	77.11	75.4
$\sqrt{W_T}+\sqrt{W_B}$	118.75	117.39	125.81	121.54
$\left(\frac{\sqrt{W_T}+\sqrt{W_B}}{l}\right)^2$	0.2[illegible]7	0.212	0.244	0.228
ω_{ULT} [psi]	1.086	1.062	1.219	1.138
f_L - LINER STRESS [psi]	116.56	113.83	123.86	118.68

LIMIT LOAD ON OVEN WALLS - WITH LARRY CAR

LOADING :- 2 WHEELS ON OVEN - 2000 LBS/FT OF W.
LOAD EXCENTRICITY - BRICK FILL - $e = 0''$
HAYDITE $e = 7\frac{1}{2}''$

	HAYDITE FILL ; LARRY LOAD EXCENTRIC	CLAY BRICK FILL - NO LARRY LOAD EXCENTRICITY
W_T [LBS]	3890	4122.5
W_B ["]	7464	7696.5
f_c [psi]	155.5	160.34
REDUCED $W_B = \max f_c \times 4'' \times 12''$ ($=150$ psi)	7200	7200
$M_T = W_T\left(\frac{D}{2} - \frac{t}{2}\right) = W_T \times 13^{in}$	50570	53592.5
RED. M_B	93600	93600
M_{LARRY}	15000	—
ΔM_T	35570	—
ΔM_B	78600	—
$\sqrt{M_T}$	188.6	231.5
$\sqrt{M_B}$	280.4	305.9
$\sqrt{M_T} + \sqrt{M_B}$	469	537.4
ω_{ULT}	1.13	1.48