DETERMINATION OF ULTIMATE STRENGTH OF WELDS SUBJECTED TO COMBINED SHEAR AND MOMENT LOADING.

by

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Submitted in Partial Fulfillment of the Requirements

for the Degree of

Master of Science in Engineering

in the

Civil Engineering

Program

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August, 1984

ABSTRACT

DETERMINATION OF ULTIMATE STRENGTH OF WELDS SUBJECTED TO COMBINED SHEAR AND MOMENT LOADING

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The objective of this thesis was to obtain the ultimate load of eccentrically loaded welded connections utilizing computer techniques. These computer programs were then used to generate design charts of weld groups for various eccentricities and weld geometries similar to those in the 8th Edition Manual of Steel Construction (1)* of the American Institute of Steel Construction, These new design charts are for weld groups free to deform when subjected to a rotational deformation in the tension zone and direct bearing of the connected plates in the compression zone, i. e., combined shear and moment, The charts currently available in the 8th Edition Manual of Steel Construction (1) of the American Institute of Steel Construction are for weld groups free to deform throughout its length, i. e., combined torsion and direct shear,

This study was accomplished, in part, by using an ultimate strength approach as well as two existing

*Number in parenthesis indicates reference cited, computer programs, one by J. L. Dawe and G. L. Kulak[2] of the University of Alberta, Edmonton, Alberta and the other by G. Donald Brandt[3] of City University of New York, New York. Test results from the Alberta study were used to verify computer results.

ACKNOWLEDGEMENTS

Special thanks to Dr. Jack D. Bakos for his help and advisement in writing this thesis, and to Dr. George Sutton for acting as the chairman of the examining committee. Thanks are also due to other committee members, Drs. R. Mirth and J. Alam. And thanks to my sister Mary Beth Tabak for typing it.

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LIST OF SYMBOLS

SYMBOL	DEFINITION	UNITS OR REFERENCE
Δ	Deformation	inches
R	Load at any given deformation	kips
R_{ult}	Ultimate load	kips
e	Base of natural logarithms	-
μ, λ	Experimentally determined regression coefficients	-
θ	Angle between resisting force of weld element and weld axis	degrees
σ_y	Yield stress	kips/in^2
TF	Thickness of flange	inches
TW	Thickness of web	inches
W	Width of flange	inches
y_o	Length of compression zone	inches
P	Ultimate load	kips
e	Eccentricity	inches
r_o	Instantaneous center	inches
H_b H_{bb}	Compression forces of flange and weld	kips
V_b	Shear force	kips
WL	Length of web weld	inches
y_i	Distance from neutral axis to centroid of weld element	inches
$(R_i)_v$	Summation of vertical resisting forces	kips
$(R_i)_h$	Summation of horizontal resisting forces	kips
WL1	Distance between two horizontal flange welds	inches
r	Radius vector	inches

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CHAPTER I

INTRODUCTION

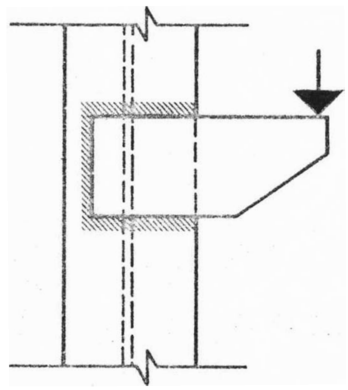
General

A weld group is loaded eccentrically when the line of action of the applied load does not pass through the centroid of a weld group. In some cases the weld is subjected to torsion and direct shear and is free to deform throughout its length. A typical example is a bracket connection, see Figure 1. 1 a, b. In other cases, the weld is subjected to combined shear and moment, and is not free to deform throughout its length. In addition, the neutral axis may not be located at midlength. A typical example is a beam-to-column connection, see Figure 1. 1, c.

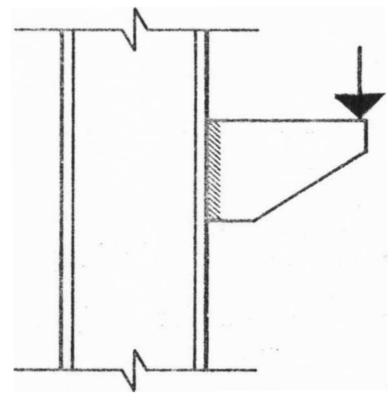
The latter type of weld group, where the weld group is subjected to combined moment and shear, is the subject of this thesis. Computer programs were written to obtain the ultimate load using the "ultimate strength method" described as follows.

Review of Previous Research

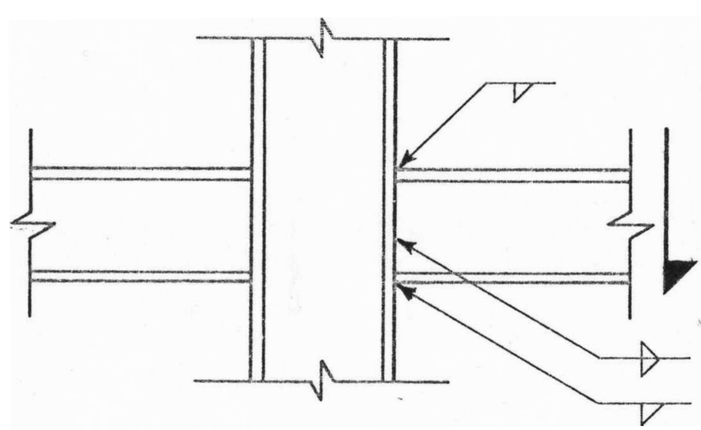
In 1972, J. L. Dawe and G. L. Kulak (2) conducted a study in which they wrote a computer program to obtain the ultimate load using the ultimate strength method,



a. BRACKET CONNECTION



b. BRACKET CONNECTION



c. BEAM-TO-COLUMN CONNECTION

Figure 1.1 Typical eccentrically loaded connections

of two vertical welds subjected to combined shear and moment, They developed equations for T-shaped welds, and discussed I-shaped welds, They verified their computer results by physical testing,

G, Donald Brandt,[3] in 1982, wrote a computer program to obtain the ultimate load and design load for any weld geometry subjected to torsion and direct shear, The ultimate load was obtained by the ultimate strength method, and the design load by applying Tide's[4] modification to the ultimate load.

An examination of the available literature to date reveals that little has been accomplished to obtain the ultimate load, using the ultimate strength method, of welds, under combined moment and shear for other than two vertical lines, This thesis will be the first to write computer programs to obtain the ultimate load, using the ultimate strength method for T-shaped, I-shaped, box-shaped and two horizontal welds subjected to combined shear and moment, The computer-obtained ultimate load must then be converted to design loads by applying Tide's[4] mod-ification,

Ultimate Strength Method

Originally, the ultimate strength method was developed by G, L. Kulak and S. F. Crawford[5] in 1971 to predict the ultimate capacity for eccentrically loaded bolted connections. This method is based on an experimentally determined relationship between the ultimate deformation of the fasteners (Δ_{ult}) and the ultimate load (R_{ult}) of the fasteners. The load-deformation response of a bolt is expressed as;

$$R = R_{ult}\ (1 - e^{-\mu\Delta})^{\lambda} \qquad (1.0)$$

Where R = bolt load at any given deformation, R_{ult} = ultimate load obtainable by fastener, Δ = deformation of fastener, e = base of natural logarithms and μ, λ = experimentally determined regression coefficients. In the 1971 study, tests were performed on bolted connections to obtain values for the ultimate strength, (R_{ult}) and maximum deformation, (Δ_{ult}), of the fasteners. A trial and error curve fitting procedure was then used to determine the values of μ and λ, which, when substituted into equation 1.0 best fitted the test data, (See Figure 1 2). Now, equation 1.0 can be used to obtain the ultimate load of a bolted connection by summing the individual bolt forces and moments,

The same load-deformation response equation-can be used to analyze welds, but must be modified. Welds, unlike bolts, are continuous fasteners and must be broken into elements, In addition, the maximum strength and deformation sustained by an element of weld depends on the angle between the applied load and the weld element axis, In order to incorporate the effect of angle of load further research was done by Butler, Pal and Kulak (6)

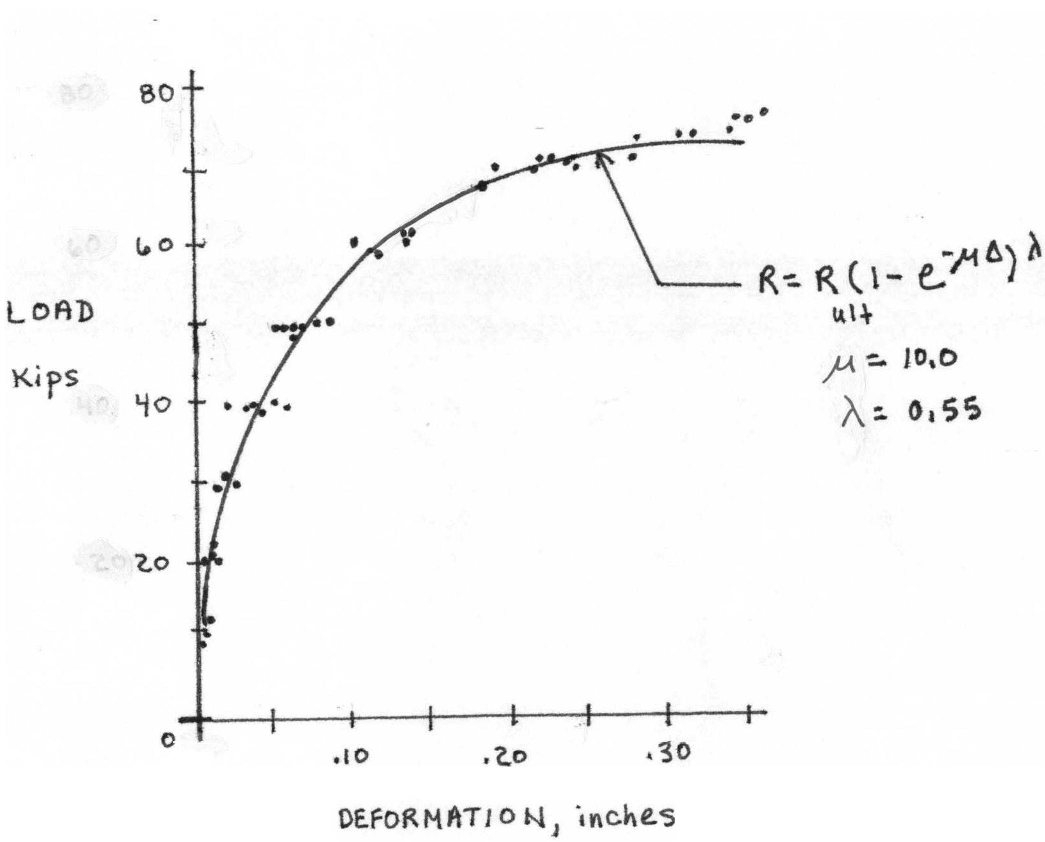


Figure 1.2 Load-deformation response of bolts

in 1972. In this study, four groups of welds were tested at angles of load of 0^{o} (longitudinal), 30^{o}, 60^{o} and 90^{o} (transverse) with respect to the weld axis. The ultimate strength (R_{ult}) and maximum deformation ($_{ult}$), were obtained for each different angle of loading. Again, a trial and error curve fitting procedure was used to determine the values of the regression coefficients, μ and λ. (See Figure 1.3). This time, the regression coefficients and R are also in terms of the angle of loading as follows:

$$R = \frac{10 + \theta}{0.92 + 0.0603\,\theta} \tag{1.1}$$

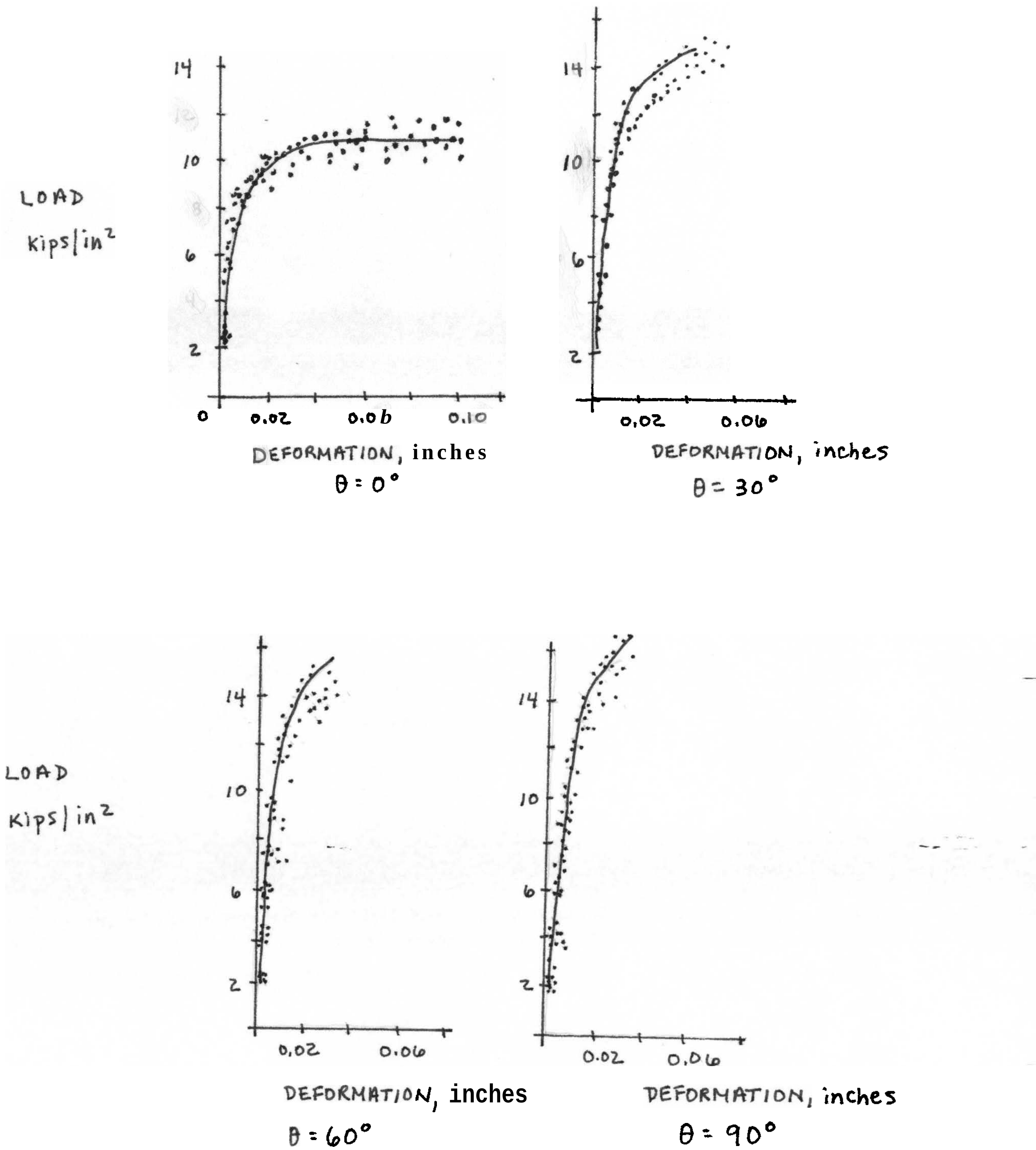
$$\mu = 75e^{0.0114\,\theta} \tag{1.2}$$

$$\lambda = 0.4e^{0.0146\,\theta} \tag{1.3}$$

Equation 1.0 for R can then be used for various values for the regression coefficients. The ultimate capacity of a weld can now be found by summing the elemental weld forces and moments just as for the bolted connections.

The basic theory of the ultimate strength method has been discussed. Next, how it applies to the eccentrically loaded welded connection subjected to combined moment and shear will be discussed. For the application, work from Brandt (3) and Kulak (2) will be summarized as follows:

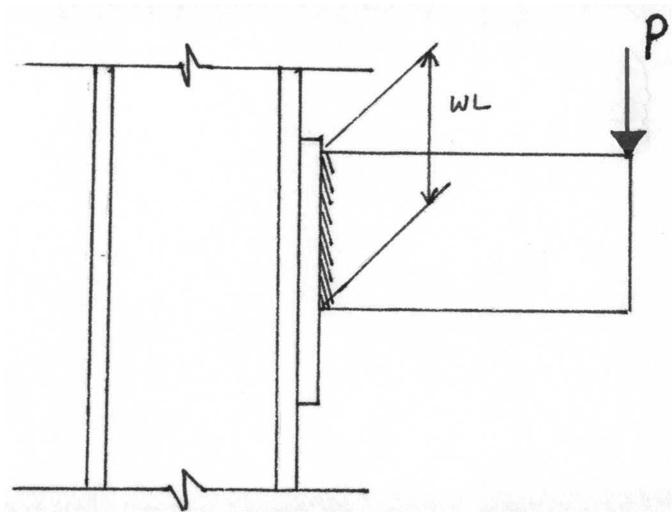
Figure 1.3 Load vs. deformation of welds for various θ ($\frac{1}{4}$ in. ⊏ - shaped welds)



1. Choose an instantaneous center of rotation, and a neutral axis. (See Figure 1.4)
2. Assume that the resisting force on any weld element acts perpendicularly to a radius connecting that element to the instantaneous center and let it act through the centroid of the weld element.
3. Calculate the angle, θ, between the elemental force of the weld element and the longitudinal axis of the weld element. (Angle θ is expressed in degrees).
4. Determine the ultimate deformation which can occur on each weld element from (See Figure 1.3)

$$\Delta_{max} = 0.225 \ (\theta + 5)^{-0.47} \qquad (1.4)$$

5. The weld element which will reach its ultimate deformation first, is usually, but not always, the weld element farthest from the instantaneous center. It is also the one for which the ratio of Δ max divided by the radius to the instantaneous center is the smallest. It is assumed that deformations vary linearly from the instantaneous center.
6. Consistent deformations (Δ), in inches, at all other weld elements are then



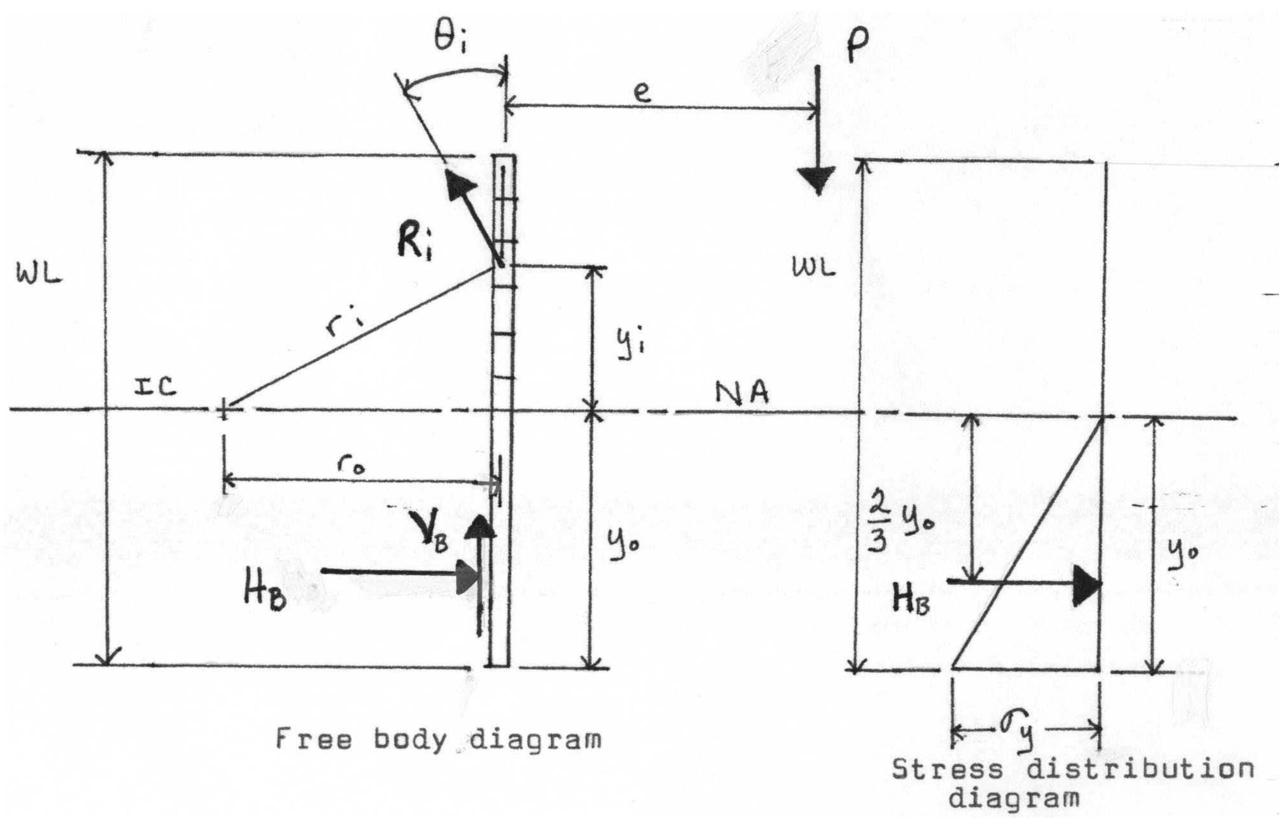


Figure 1.4 Eccentrically loaded fillet weld

found from

$$\Delta_i = r_i \, (\Delta max/r) \; min \tag{1.5}$$

7. The following parameters are then calculated for each weld element:

$$R_{ult,i} = \frac{10 + \theta_i}{0.92 + 0.0603\,\theta_i} \tag{1.6}$$

$$\mu_i = 75e^{0.0114\,\theta_i} \tag{1.7}$$

$$\lambda_i = 0.4e^{0.0146\,\theta_i} \tag{1.8}$$

$$R_i = R_{ult,i}(1-e^{-\mu_i \Delta_i})^{\lambda_i} \tag{1.9}$$

Where R_i and $R_{ult,i}$ are in kips/unit length, and θ_i is the angle, in degrees, defined in step 3. , and λ_i are experimentally determined regression coefficients as determined by Butler, Pal and Kulak[6] and e is the base of natural logarithms.

8. Assume the connecting plates in the compression zone are in direct bearing at the time that the ultimate load is reached. The stress distributions for the web is assumed to be triangular and rectangular for the flange. (See Figure 1.4, only the triangular distribution is shown.) Now, calculate the resisting forces, in kips, for the web and flanges

$$H_b = \frac{\sigma_y y_o (TW)}{2} \qquad (1.10)$$

$$H_{bb} = \sigma_y W (TF) \qquad (1.11)$$

Where σ_y is the yield stress, in kips/in^2, of the connected plates, TF is the thickness, in inches, of the flange, TW is the thickness, in inches, of the web, W is the width, in inches, of the flange, and y_o is the length, in inches, of the cornpression zone. In their 1974 study, Dawe and Kulak (2) tried other stress distributions and found the triangular and rectangular to be the best overall based upon test verification.

9. By statics, calculate the sum of all the forces and moments and solve for P, the ultimate load in kips.

The formulas given are for 1/4 - inch fillet welds made using E6U electrodes. The forces and moments calculated are ultimate values. These ultimate loads, P must be modified according to Tide's (4) modifications to create design tables listing permissible load values.

Tide's Modifications

In order to convert the calculated ultimate loads to more general design or more permissible loads similar to those in the 8th Edition Manual of Steel Construction (1) of the American Institute of Steel Construction, the following modifications are made:

1. Converting from 1/4 - inch weld to 1/16 - inch weld by dividing by 4.
2. Converting from E60 electrode to E70 electrode by multiplying by 70/60.
3. Introducing a safety factor conforming to AISC Specification Sect. 1.5.3 by multiplying by 0.3,
4. Checking the shear stress in the most highly stressed weld element and, if it exceeds 21 ksi, (for an E70 electrode) reducing the ultimate load by the ratio of 21.0 divided by that shear stress.

CHAPTER II

COMPUTER PROGRAM

General

As mentioned previously, the computer programs written in this thesis are a combination and modification of Brandt's (3) and Dawe and Kulak's (2) programs. The programs are written in Fortran and the basic flowchart (See Figure 2.1) of Dawe and Kulak (2) was followed, Brandt's (3) method for calculating the ultimate resisting forces of individual weld elements was used. Initially, two trial values for the instantaneous center, r_o, and two trials for the neutral axis, y_o, are chosen, The tension zone is then divided into half-inch weld increments, Next, the ultimate resisting forces of the weld in the tension zone are calculated and broken down into horizontal and vertical components. Then, the horizontal bearing forces in the compression zone are calculated. -Finally, the 3 equations of statics are- calculated as follows;

FLOWCHART

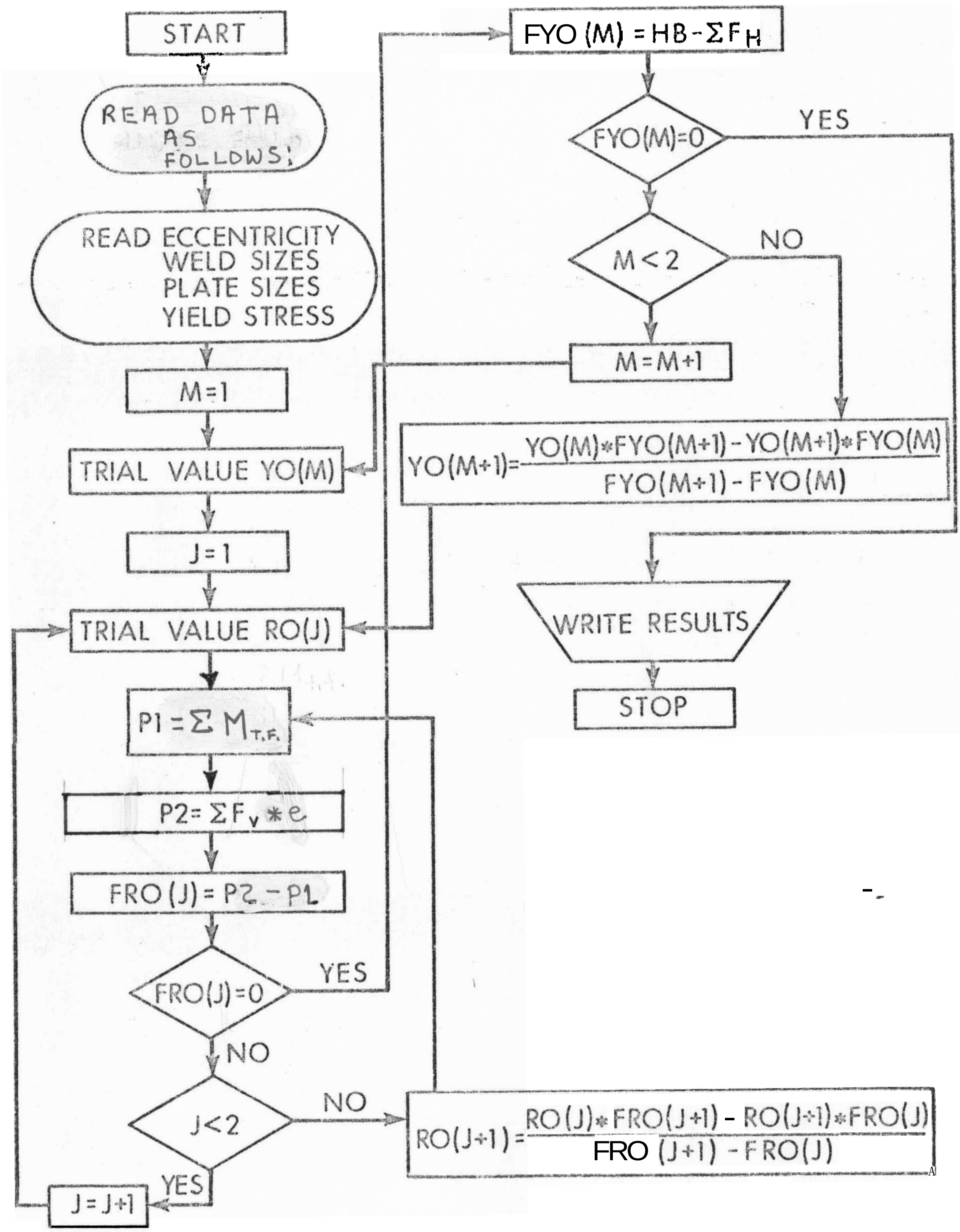


Figure 2.1 Flowchart

T-Shaped Welds

$$F_x = 0 \quad -R_n \cos\theta_t - \sum_{1}^{n-1} (R_i)_h + H_b + H_{bb} = 0 \qquad (2.1)$$

$$F_y = 0 \quad R_n \sin\theta_t + \sum_{1}^{n-1} (R_i)_v + V_b - P = 0 \qquad (2.2)$$

$$M_{\substack{top\\flange}} = 0 \quad Pe + \sum_{1}^{n-1} (R_i)_h (WL - y_o + TF - y_i)$$

$$- H_b(WL - y_o/3 + TF) - H_{bb}(WL + 3/2TF) = 0 \qquad (2.3)$$

(See Figure 2.2)

I-Shaped Welds

$F_x = 0$ Same as equation 2.1

$$F_y = 0 \quad R_n \sin\theta_t + \sum_{1}^{n-1} (R_i)_v + V_b - P + R_n \sin\theta_b = 0 \qquad (2.4)$$

$M_{\substack{top\\flange}} = 0$ Same as equation 2.2

(See Figure 2.3)

Two-Horizontal Welds

$$F_x = 0 \quad -R_n \cos\theta_t + H_b + H_{bb} = 0 \qquad (2.5)$$

$$F_y = 0 \quad R_n \sin\theta_t + R_n \sin\theta_b - P = 0 \qquad (2.6)$$

$$M_{\substack{top\\flange}} = 0 \quad Pe - H_b(WL - y_o/3 + TF) -$$

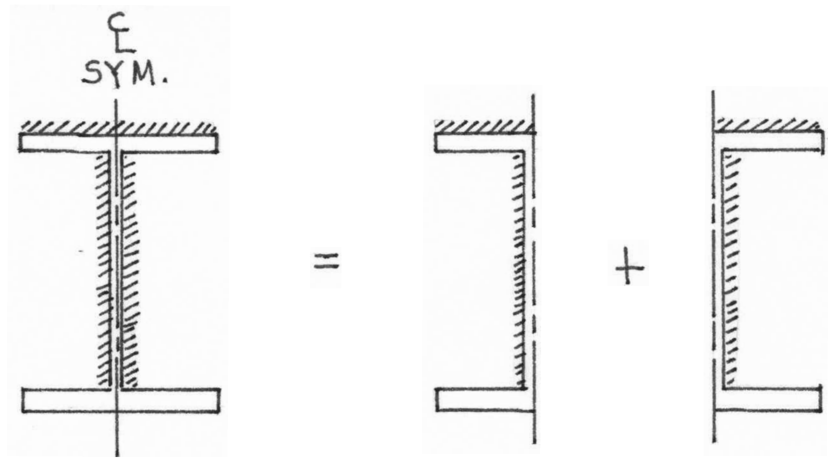
$$H_{bb}(WL + 3/2TF) = 0 \qquad (2.7)$$

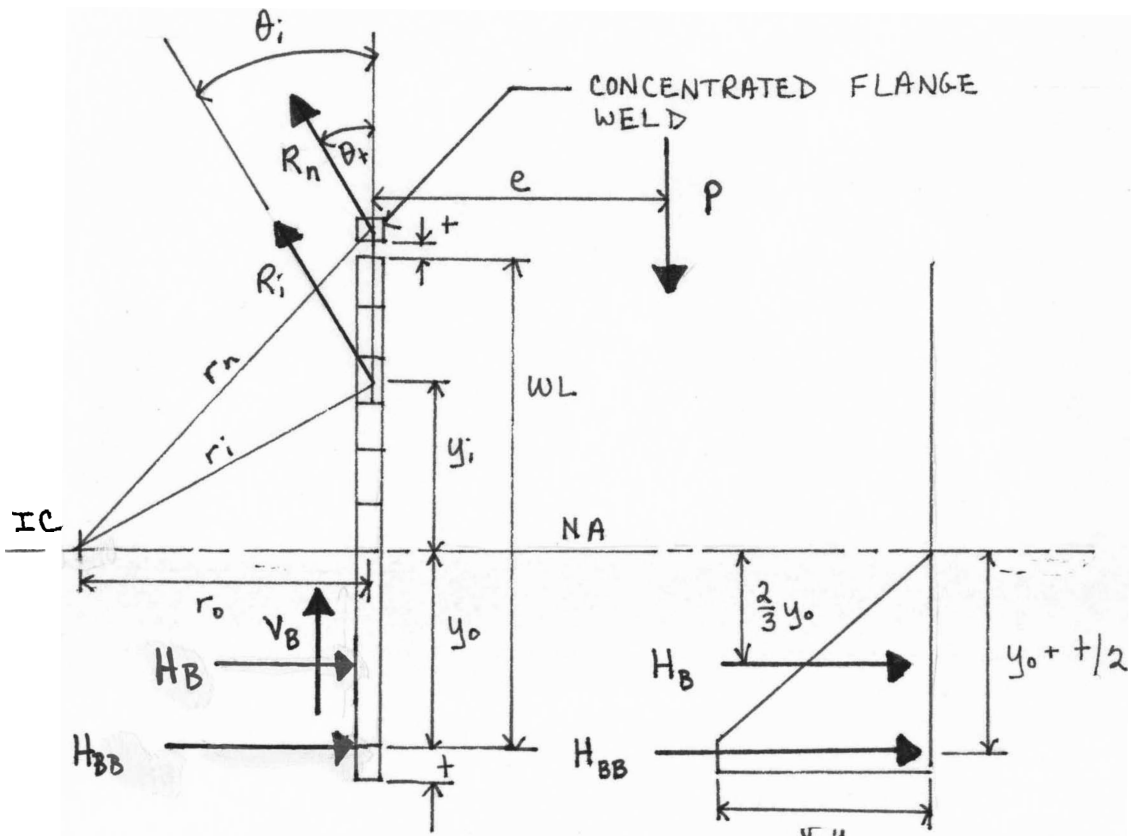
(See Figure 2.4)

Box-Shaped Welds

There are no equations of statics since the box-shaped welds are modeled as the sum of the two-horiztonal welds and the two-vertical welds from the 8th Edition Manual of Steel Construction (1) of the

Figure 2.2 T– Shaped weld diagram





free body diagram

Stress distribution diagram

Figure 2.3 I-shaped weld diagram

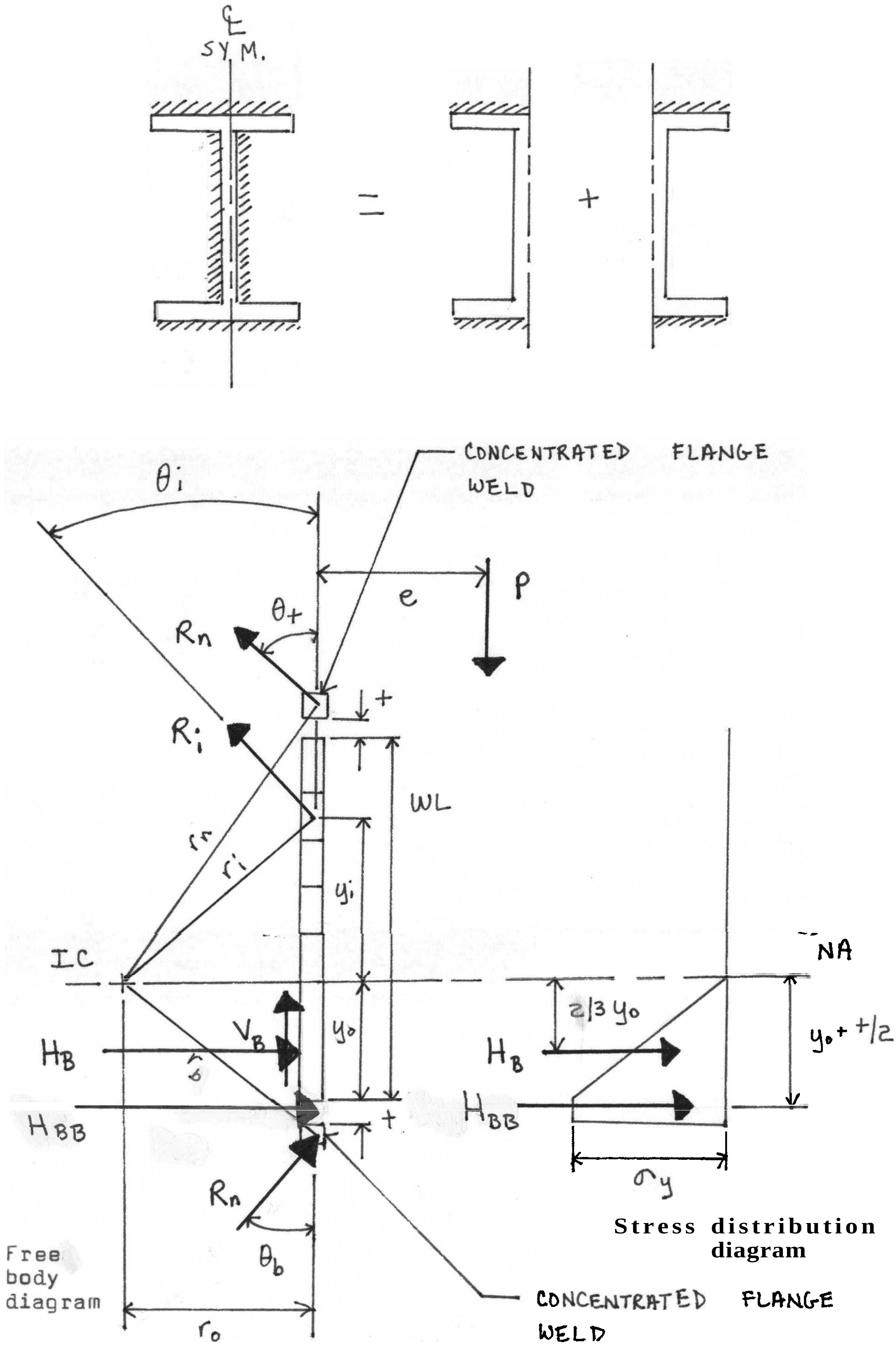
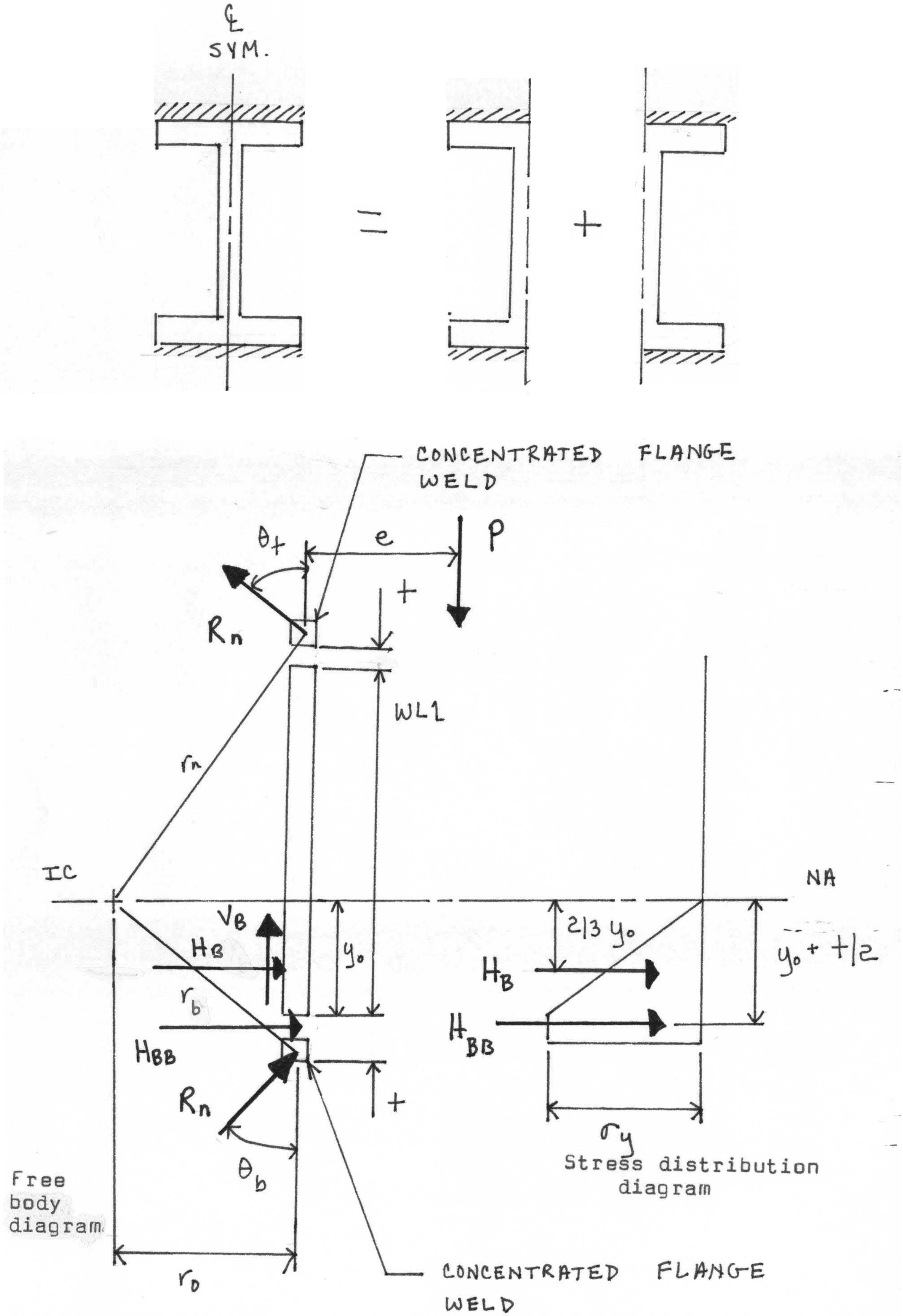


Figure 2.4 Two horizontal welds diagram



American Institute of Steel Construction.

In these equations, R_n is the flange ultimate force, and the angle θ_t, θ_b are tho angles that force makes with the top flange and bottom flange, respectively. WL is the length of the web weld, in inches, y_i, is the length, in inches, from the neutral axis to the centroid of the weld element, and e is the eccentricity, in inches, of the load. And $(R_i)_v$ and $(R_i)_h$ are the vertical and horizontal components of the resisting forces, respectively. All the other quantities have been defined earlier.

Solution of the Statics Equations for The Correct Neutral Axis and Instantaneous Center of Rotation

The two equations, which contain the unknown ultimate load, P, are the sum of the moments about the top flange and the sum of the vertical forces. Cornbining these two equations, to eliminate P, yields the following expression, which should be approximately zero if the correct neutral axis and instantaneous center of rotation have been assumed:

$$R_n \sin\theta_t + \sum_{1}^{n-1}(R_i)_v + V_b - \frac{1}{e}\Big[-\sum_{1}^{n-1}(R_i)_h\,(WL - y_o + TF - y_i)$$

$$+ H_b(WL - y_o/3 + TF) + H_{bb}(WL + 3/2\,TF)\Big] = 0 \qquad (2.8)$$

Equation 2.8 is for T-welds and similar equations are obtained for I-welds and two horizontal welds. Since equation 2.8 is evaluated using trial values, it may or may not approach zero. Therefore, the initial trial for r_o and y_o are tested in equation 2.8. If it is not approximately zero, then y_o is held constant and the second trial for r_o is tested in equation 2.8. If it is not satisfied, then the Regula Falsi[7] iterative procedure is employed, to iterate between the two trials for r_o until equation 2.8 is satisfied.

Next, the iterated value for r_o in final form and the initial value for y_o are tested in the sum of the horizontal forces, such as equation 2.1. If this is not approximately zero then the iterated r_o value and the second trial for y_o are tested in equation 2.1. If this equation is not satisfied, the Regula Falsi[7] iterative technique is employed again to iterate between the two values of y_o until it is satisfied. The iterated y_o value is substituted into equation 2.8 and this equation is reiterated for r_o, this time with a new y_o iterated value. The process continues until both equations 2.8 and 2.1 are satisfied. (See Flowchart) The ultimate load P is finally calculated using equation 2.2, i. e., sum of the verticals -forces.

Regula Falsi[7] Iterative Technique

This technique is expected to converge at x_2, when $f(x_{L1})$ is negative, and $f(x_{R1})$ is positive, with x_2 somewhere in between. (see Figure 2.5). This method is faster than other methods since it uses the sign and

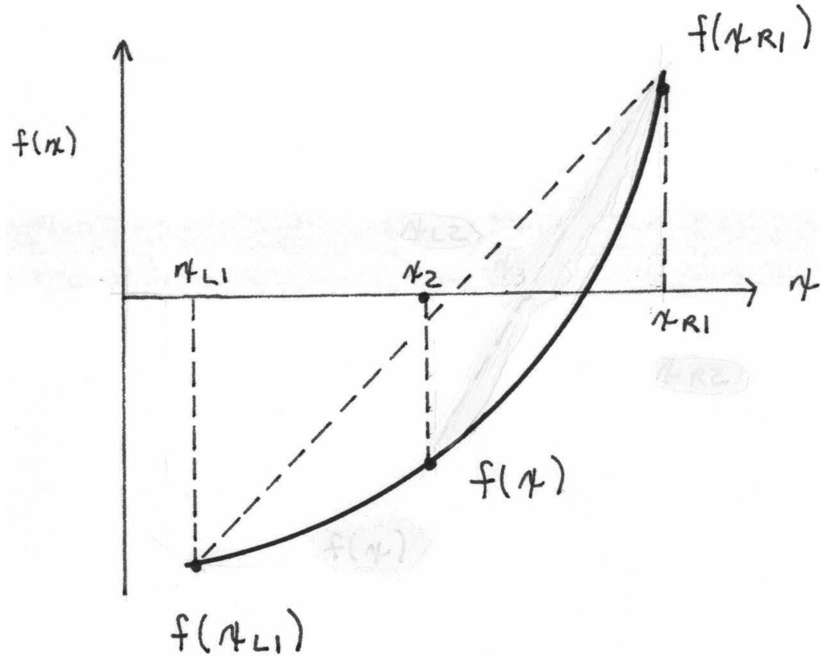


Figure 2.5 **Regula** Falsi **method**

value of the functions to reduce the interval, rather than just reducing the interval as in the bisection method. The new root is calculated as followsr

$$x_2 = \frac{x_{L1}f(x_{R1}) - x_{R1}f(x_{L1})}{f(x_{R1}) - f(x_{L1})} \quad (2.9)$$

A drawback of the method is that a positive and negative function must be located.

Although the Regula-Falsi[7] iterative method is expected to converge, it is more difficult in this case, since there are two iterations occurring simultaneously. It was necessary, therefore, to relax the constraints on the remainders obtained in equations 2.8 and 2.1, based on the relative size of the individual terms, and the number of terms.

CHAPTER III

DISCUSSIONS AND CONCLUSIONS

Computer-Obtained Ultimate Load vs. Test Results

The validity of the computer-obtained ultimate loads was verified utilizing the tests performed by Dawe and Kulak.[2] The computer-obtained ultimate loads were within 8% of the test results, which is acceptable for the purpose of this thesis. See Table 3.1 for the exact percentages.

Dawe and Kulak's test results[2] verified the validity of the computer ultimate strength method and model. Therefore, it was assumed that for weld groups other than those tested by Dawe and Kulak,[2] the computer ultimate strength method can predict the ultimate load within 8% of test results. And 8% is generally acceptable.

Computer-Obtained Ultimate Load vs. Current Allowable Elastic Load

For the sake of comparison, Table 3.1 also includes the current allowable elastic loads. Utilization of the computer-obtained ultimate load would result in safety factors lower than the current safety factors.

SPECIMEN NUMBER	ULTIMATE LOAD (kips) TEST	ULTIMATE LOAD (kips) COMPUTER	% ERROR	CURRENT ALLOWABLE LOAD (kips)	CURRENT FACTOR OF SAFETY
T WELDS	46.60	45.30	-2.78	5.8	8.0
	37.80	33.40	-11.60	4.5	8.4
	62.50	72.00	+15.20	8.4	7.5
	51.00	52.90	+ 3.70	6.4	8.0
I WELDS	46.60	41.30	-11.30	8.8	5.3
	38.40	33.30	-13.20	6.6	5.8
	66.00	64.00	- 3.03	11.9	5.6
	46.10	47.30	+ 2.60	8.5	5.5

Table 3.1 Computer Results

Discussion of Constraints on Equations 2.1 and 2.8

As mentioned in chapter two, it was necessary to relax the constraints on the remainders of Equations 2.8 and 2.1 based on the relative size of the individual terms, and the number of terms. For Equation 2.1 where the terms were smaller, the remainders were kept within 5 - 10% of the terms, since neither percentage affected the accuracy of the ultimate load significantly. And for Equation 2.8, where the terms were much larger than those in Equation 2.1, the remainders were kept within 5 - 10% also, since neither percentage affected the ultimate load significantly. However, for very small eccentricities, the remainders were on the higher side of the percentages for both equations, since the θ become smaller. And the large eccentricities the remainders were on the lower side of the percentages, since θ become larger.

Further Study

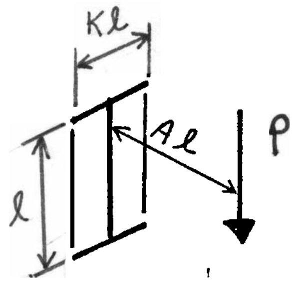
It is felt that there is a need for extensive testing over a wider range of weld geometries and eccentricities than those done by Dawe and Kulak (2) to give further validity to the computer-obtained ultimate loads. However, such testing was not in the scope of this thesis. It is hoped that someone else will take over where this thesis left off and undertake such testing.

Conclusion

In conclusion, it can be said that there now exist three computer programs to obtain the ultimate load for T-shaped, I-shaped, and two horizontal weld groups subjected to combined shear and moment. (See Appendix A), There also exist design charts similar to those already existing in the 8th Edition Manual of Steel Construction [1] of the American Institute of Steel Construction for the aforementioned weld groups and box-shaped weld groups. (See pp. 27-34). The values for ultimate load have been validated by tests results.

It is hoped that the design charts can be used by design engineers just as the already existing ones in the 8th Edition Manual of Steel Construction [1] of the American Institute of Steel Construction are used. It is recommended that someone take over where this study ended, and perform extensive testing for various weld groups subjected to combined moment and shear.

Table 3.2 I Shaped Weld Design Chart



$P = C \, C_1 \, D \, l$

P = permissible load, in kips
l = length of web weld, in in.
C = coefficients in tables below
D = no. of 1/16 of an in. weld size
C_1 = coefficient for electrode used (see p. 51)

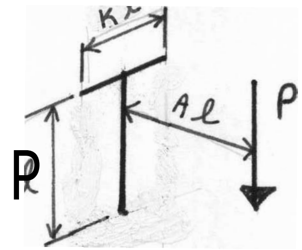
A	K														
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.0	1.2	1.4	1.6	1.8	2.0
0.20	-	-	-	1.09	1.24	1.38	1.[illegible]22	1.60	1.72	2.14	2.41	2.80	3.[illegible]8	3.15	3.36
0.40	-	-	-	1.05	1.19	1.32	1.[illegible]65	1.52	1.59	1.64	2.02	2.32	2.[illegible]7	2.97	3.26
0.60	-	-	-	.67	.770	.955	1.[illegible]65	1.17	1.27	1.37	1.59	1.81	2.[illegible]1	2.23	2.46
0.80	-	-	-	.57	.658	.745	.[illegible]336	.923	1.00	1.06	1.26	1.46	1.[illegible]0	1.76	1.94
1.00	.362	.499	.605	.78	.822	.932	1.[illegible]44	1.09	1.23	1.32	1.50	1.61	18 5	2.08	2.33
1.20	.330	.459	.518	.66	.703	.791	.[illegible]773	.907	1.05	1.12	1.27	1.55	16 7	1.88	1.95
1.40	.285	.418	.436	.52	.610	.688	.[illegible]658	.792	.923	.990	1.10	1.48	1.[illegible] 5	1.63	1.80
1.60	.256	.373	.401	.40	.545	.613	.[illegible]880	.750	.818	.795	.963	1.26	1.[illegible] 5	1.56	1.62
1.80	.233	.333	.360	.46	.489	.549	.[illegible]113	.676	.729	.786	.974	1.01	1.[illegible] 5	1.43	1.46
2.00	.211	.305	.330	.38	.442	.498	5 55	.609	.664	.740	.866	.906	9 50	1.28	1.30
2.20	.192	.277	.301	.3[illegible]	.403	.458	5 08	.560	.607	.72	.795	.834	8 80	1.17	1.19

	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.0	1.2	1.4	1.6	1.8	2.0
2.4	.177	.255	.278	.326	.372	.421	.468	.516	.564	.665	.690	.771	.818	1.07	1.09
2.6	.165	.238	.257	.303	.347	.391	.437	.478	.521	.564	.619	.717	.765	.913	1.01
2.8	.153	.223	.240	.283	.322	.365	.405	.447	.486	.527	.579	.670	.720	.854	.950
3.0	.124	.297	.227	.264	.302	.342	.382	.417	.455	.494	.545	.630	.710	.803	.892

Table 3.2 cont'd

TW = TF = 0.50 **inches below dotted line**
= 0.25 **inches above dotted**

Table 3.3 T - Shaped Weld Design Chart



$P = C\, C_1 D\, l$

P = permissible load, in kips
l = length of web weld, in inches
C = coefficient in tables below
D = no. of 1/16 of an inch in weld
C_1 = coefficient for electrode used (see p. 51)

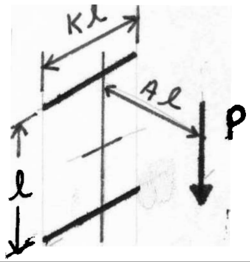
4	K														
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.0	1.2	1.4	1.6	1.8	2.0
0.20	-	-	-	.959	1.04	1.12	1.20	1.28	1.37	1.45	1.61	1.77	1.94	2.10	2.26
0.40	-	-	-	.932	1.00	1.09	1.16	1.24	1.32	1.40	1.56	1.72	1.88	2.05	2.19
0.60	-	-	-	.686	.791	.872	.967	1.09	1.16	1.26	1.48	1.60	1.72	1.90	2.08
0.80	-	-	-	.582	.587	.738	.750	.806	.880	.953	1.10	1.12	1.37	1.52	1.66
1.0	.353	.494	.521	.573	.660	.882	.914	.930	1.06	1.14	1.32	1.49	1.71	1.82	2.03
1.2	.313	.401	.488	.515	.674	.756	.793	.873	.961	1.05	1.24	1.35	1.55	1.75	1.82
1.4	.277	.357	.432	.527	.555	.645	.742	.818	.885	.913	1.06	1.15	1.41	1.49	1.60
1.6	.247	.316	.422	.446	.515	.562	.756	.769	.817	.974	1.10	1.22	1.30	1.46	1.46
1.8	.227	.285	.339	.400	.455	.517	.555	,689	.737	.793	.917	.985	1.09	1.16	1.30
2.0	.205	.261	.313	.371	.417	.472	.518	.633	.650	.775	.827	.886	.977	1.13	1.25
2.2	.188	.239	.286	.339	.390	.432	.478	.577	.595	.694	.752	.810	.985	1.03	1.14

	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.0	1.2	1.4	1.6	1.8	2.0
2.4	.174	.221	.268	.311	.357	.399	.446	.529	.559	.640	.694	.746	.900	.951	1.05
2.6	.163	.206	.242	.290	.333	.371	.416	.503	.544	.594	.690	.693	.834	.884	.982
2.8	.151	.191	.228	.273	.312	.350	.389	.473	.510	.556	.596	.647	.782	.826	.917
3.0	.142	.189	.215	.255	.294	.330	.364	.441	.475	.518	.565	.611	.733	.775	.862

Table 3.3 cont'd

TW = TF = 0.25 inches above dotted line
= 0.50 inches below dotted line

Table 3.4 Two Horizontal Weld Design Table



$P = C\ C_1 D\ l$

P = permissible load, in kips
l = length of web weld, in in.
C = coefficient in table below
D = no. of 1/16 weld size
C_1 = coefficient for electrode used (see p. 51)

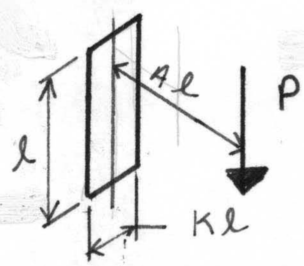
A	K														
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.0	1.2	1.4	1e6	1.8	2.0
0.20	.186	.336	.460	.553	.695	.757	.884	1.01	1.14	1,20	1.44	1.68	2.02	2.16	2.40
0.40	.184	.320	.417	.502	.632	.721	.841	.965	1.08	1.15	1.37	1.60	1.92	2.06	2.28
0.60	.178	.305	.402	.489	.593	.694	.787	.857	.965	1.06	1.23	1.41	1.80	1.92	2.00
0.80	.162	.233	.297	.372	.451	.527	.605	.660	.751	.818	.968	1.12	1.27	1.41	1.53
1.0	.127	.185	.245	.293	.364	.426	.485	.537	.607	.665	.787	.904	1.03	1.33	1.46
1.2	.107	.156	.206	.256	.305	.358	.410	.452	.512	.561	.664	.768	1.01	1.12	1.23
1.4	.088	.135	.180	.222	.268	.310	.355	.400	.445	.488	.576	.589	.890	.980	1.08
1.6	.080	.117	.157	.196	.237	.274	.313	.353	.395	.433	.512	.531	.790	.873	.960
1.8	.069	.105	.140	.178	.209	.246	.283	.319	.352	.388	.458	.481	.707	.784	
2.0	.063	.094	.128	.160	.191	.224	.256	.289	.320	.353	.417	.441	.642	.711	.779
2.2	.057	.087	.116	.146	.174	.206	.234	.263	.293	.322	.382	.407	.588	.650	.713

	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.0	1.2	1.4	1.6	1.8	2.0
2.4	.054	.080	.108	.135	.161	.190	.217	.243	.270	.277	.354	.378	.542	.602	.660
2.6	.049	.074	.100	.125	.150	.176	.201	.226	.252	.263	.328	.378	.505	.560	.614
2.8	.046	.070	.093	.116	.141	.163	.259	.212	.235	.259	.307	.354	.471	.524	.575
3.0	.044	.066	.088	.110	.132	.154	.159	.164	.221	.243	.289	.334	.377	.493	.540

Table 3.4 cont'd

TW = TF = 0.25 inches

Table 3.5 Box - Shaped Weld Design Chart



$P = C\ C_1 D\ l$

P = permissible load, in kips
l = length of web weld, in inches
C = coefficient in tables below
D = no. of 1/16 of an in. weld size
C_1 = coefficient for electrode used (see p. 51)

A	K														
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.00	1.20	1.40	1.60	1.80	2.00
0.2	1.58	1.73	1.85	1.94	2.09	2.20	2.33	2.40	2.53	2.59	2.83	3.07	3.41	3.83	3.79
0.4	1.12	1.26	1.36	1.44	1.57	1.66	1.78	1.90	2.02	2.09	2.31	2.54	2.86	3.00	3.22
0.6	.851	.978	1.08	1.16	1.27	1.37	1.46	1.53	1.64	1.73	1.90	2.08	2.55	2.47	2.67
0.8	.679	.750	.814	.891	.968	1.04	1.12	1.18	1.27	1.34	1,49	1.64	1.79	1.93	2.05
1.0	.546	.604	.664	.712	.783	.845	.904	.956	1.03	1.08	1.21	1.32	1.45	1.75	1.88
1.2	.458	.507	.557	.607	.656	.709	.761	.803	.863	.912	1.02	1.12	1.36	1.47	1.58
1.4	.390	.437	.482	.524	.570	.612	.657	.702	.747	.790	.878	.891	1.19	1.28	1.38
1.6	.345	.382	.422	.461	.502	.539	.578	.618	.660	.698	.777	.796	1.05	1.14	1.23
1.8	.305	.341	.376	.414	.445	.482	.519	.555	.588	.624	.694	.717	.943	1.02	1.10
2.0	.276	.307	.341	.373	.404	.437	.469	.502	.533	.566	.630	.654	.855	.924	.992
2.2	.250	.280	.309	.339	.367	.400	.427	.456	.486	.515	.575	.600	.781	.843	.906

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.00	1.20	1.40	1.60	1.80	2.00
2.4	.231	.257	.285	.312	.338	.367	.394	.420	.447	.454	.531	.555	.719	.779	.837
2.6	.213	.238	.264	.289	.314	.340	.365	.390	.416	.427	.492	.542	.669	.724	.778
2.8	.198	.222	.245	.268	.293	.315	.411	.364	.387	.411	.459	.506	.623	.676	.727
3.0	.186	.208	.230	.252	.274	.296	.301	.306	.363	.385	.431	.476	.519	.635	.682

Table 3.5 cont'd

TW= TF = 0.25 inches

APPENDIX A

Computer Program Description

A.1 Computer Input

Data is inputed into the computer programs in the form of data statements at the end of the program in the following form:

WL, e, σ_y, TF, W, TW, WLF

Therefore, the data for the sample problem is inputed as follows:

5.52, 15.0, 43.8, 0.438, 6.13, 0.313, 2.24

```
FILE: OUTPUT   FILE     A    ***** YOUNGSTOWN STATE UNIVERSITY COMPUTER CENTER *****

R; T=0.01/0.01 13:21:04
WATFIV TVWELDS (XT

                    PROBLEM NO.= 1

          WEB WELD=  5.52      FLANGE WELD=  4.47

          YIELD STRESS= 43.80      WEB THICK.=        0.31

          FLANGE THICK.=  0.44

          ECC.= 15.00      FLANGE WIDTH=  6.13

          I.C.=  7.6844

          DIST. TO N.A.=  2.5091      ULT LOAD,IN KIPS= 45.2766
```

A.2 Figure A.1 Computer Output

```
FILE: TVWELDS   WATFIV   A   ***** YOUNGSTOWN STATE UNIVERSITY COMPUTER CENTER **

CMS
:READ  TVWELDS  WATFIV   A1 -FREE  05/22/84 14:11:00
//E1234567 JOB ($$ROUTE4),
// FR021302.DILLON,CLASS=G
// EXEC WATFIV
//SYSIN DD *
$JOB
C     PROGRAM TO CALCULATE THE INST. CENTER* NEUTRAL AXIX, AND ULTIMATE
C     LOAD IN KIPS OF ECC. LOADED WELDED CONNECTIONS SUBJECTED TO RO-
C     TATIONAL-DEFORMATION IN THE TOP TENSION ZONE AND BEARING IN THE
C     BOTTOM COMPRESSION ZONE.
C     THIS PROGRAM IS FOR T-SHAPED WELDS ONLY-
      DIMENSION DEL(100),RAD(100),THETA(100),RO(200)
      DIMENSION FRO(100),RV(100),RH(100),Y(100),FM(100)
      DIMENSION YO(200),FYO(200),F(100),DEL1(100),DELTA(100)
      REAL MU,LAMDA
      II=0
    7 II=II+1
C     READ IN WELDED CONNECTION DATA WHERE: JL IS THE-LENGTH OF THE
C     WEB WELD,ECC IS THE ECCENTRICITY,SIGY IS THE YIELD STRESS OF THE
C     WEB A h FLANGE MATERIAL,TF IS THE FLANGE THICKNESS,TW IS THE
C     WEB THICKNESS, W IS THE FLANGE WIDTH,WLF IS HALF OF THE FLANGE
C     UELO LENGTH.
      READ,WL,ECC,SIGY,TF,W,TW,WLF
      M=0
      IF(WL.LE.0.) STOP
      LRITE (6,90) II
   90 FORMAT(///T10,20X,'PROBLEM NO.=',I2//)
C     CALCULATE 2 INITIAL VALUES FOR NEUTRAL AXIS LOCATED FROM BOTTOM
C     OF WELD LENGTH (YO(1),YO(1))
      YO(1)=WL/4.
      YO(2)=3.*WL/4.00
  200 CONTINUE
      J=0
      M=M+1
C     CALCULATE UW - LENGTH OF WELD IN TENSION
      UW=WL-YO(M)
C     DIVIDE TOP TENSION WELD INTO HALF INCH INCREMENTS
      DO 21 I=1,1000
      GW=UW/FLOAT(I)
      N=I
      IF(QW.LE.0.5) GO TO ?
   21 CONTINUE
    9 FLW=GW
C     LOCATE CENTER OF FIRST UELD ELEMENT
      Y(1)=FLU/?-
C     CHOOSE TVC INITIAL VALUES F?R INST. CENTER - RO(1),RO(2)
      RO(1)=0.1
      RO(2)=50.00
   25 CONTINUE
      J=J+1
C     CALCULATE FED AND AAGLE BETWEEN RAT) VECTOR AND WELD AXIS FOR FIRST
C     YELC ELEMENT
      RAD(1)= SQRT(RO(J)**2+Y(1)**2)
      TI-ETA(1)=( ARSIN(RO(J)/RAD(1))) 180./3.14159
```

```
C       CALCULATE ANGLE BETWEEN FORCE AND WELD AXIS FOR FIRST ELEMENT
        THETA(1)=90-THETA(1)
        DEL1(1)=0.225*(THETA(1)+5.0)**(-.47)
        DELTA(1)=DEL1(1)/RAD(1)
C       CALCULATE RAD AND ANGLE BETWEEN RAD VECTOR AND WELD AXIS FOR REST
C       OF WELD ELEMENTSAND ANGLE BETWEEN FORCE VECTOR AND WELD AXIS AND
C       CENTER OF REST OF THE ELEMENTS LOCATED UP FROM THE NEUTRAL AXIS.
        DO 3 I=2,N
        Y(I)=Y(I-1)+ELW
        IF(N.EQ.I)GO TO 39
        RAD(I)= SQRT(RO(J)**2+Y(I)**2)
        THETA(I)=( ARSIN(RO(J)/RAD(I))) 180./3.14159
        THETA(I)=90-THETA(I)
        DEL1(I)=0.225*(THETA(I)+5.)**(-.47)
        DELTA(I)=DEL1(I)/RAD(I)
      3 CONTINUE
     39 RAD(N)= SQRT(RO(J)**2+(WL-YO(M)+TF)**2)
        THETA(N)=( ARSIN(RO(J)/RAD(N)))*180./3.14159
        THETA(N)=90-THETA(N)
C       RTH IS THE SUM OF HORIZ. RES. FORCES OF WELDS
C       RTV IS THE SUM OF VERT. RES. FORCES OF WELDS
        THRM IS SUM OF MOM. DUE TO RTH
        CALCULATE RES. FORCES OF WELDS WITH ABOVE NOTATION
        DEL IS THE DEFLECTION OF WELD ELEMENT,F(I) IS RES. FORCE OF WELD
        ELEMENT. MU,LAMDA AND RULT ARE VALUES USED IN DETERMINING F(I).
        RTH=0.
        RTV=0.
        THRM=0.
        DO 5 I=1,N
        DEL(I)=(RAD(I)/RAD(N))*.225*(THETA(N)+5.)**(-.47)
        RULT=(10.+THETA(I))/(.92+.0603*THETA(I))
        MU=75.* EXP(.0114*THETA(I))
        LAMDA=.4* EXP(.0146*THETA(I))
        F(I)=RULT*ELW*(1.-EXP(-MU*DEL(I)))** LAMDA
        RV(I)=(Y(I)/RAD(N))*F(I)
        RH(I)=(RO(J)/RAD(N))*F(I)
        THRM=RH(I) (WL-YO(M)+TF-Y(I))+THRM
        IF(I.EQ.N)GO TO 60
        RTV=RTV+RV(I)
        RTH=RTH+RH(I)
      5 CONTINUE
C       HB,HBB ARE RES. BELOW N.A. OF THE WEB AND FLANGE RESP.
C       VB IS RES. FORCE OF WELDS BELOW N.A.
C       RN IS THE RES. FORCE OF THE FLANGE WELD.
C       C,S ARE THE HORIZ. AND VER. ANGLES RN MAKES WITH THE VERT.
C       FRO(J) IS THE SUM OF THE VERT. FORCES AND THE MOMENTS ABOUT
C       THE TED FLANGE COMBINED.
     60 DEL(N)=.225*(THETA(N)+5.)**(-.47)
        RULT=(10.+THETA(N))/(.92+.0603*THETA(N))
        MU=75.*EXP(.0114*THETA(N))
        LAMDA=.4*EXP(.0146*THETA(N))
        F(N)=RULT*(1.-EXP(-MU*DEL(N)))**LAMDA
        RN=WLF*F(N)
        HB=SIGY*YO(M)*TW/4.
        HBB=SIGY*W*TF/2.
```

```
      VB=YO(M)*RTV/(UW)
      S=(WL-YO(M)+TF)/RAD(N)
      C=RO(J)/RAD(N)
      FRO(J)=(+RN*S+RTV+VB)+ECC+(+THRM-HB*(WL-(YO(M)/3.)+TF)
     *-HBB*(WL+(3./2.)*TF))
      IF( ABS(FRO(J)).LE.( A    ))GO TO 23
      IF (J.LT.2) GO TO 25
      IF(FRO(1)*FRO(2).GT.0) GO TO 40
      IF(J.EQ.2) GO TO 107
      IF(FX1*FRO(J)) 108,23,109
C     ITERATION PROCEDURE FOR RO(J) BEGINS.
  108 X2=RO(J)
      FX2=FRO(J)
      GO TO 110
  109 FX1=FRO(J)
      X1=RO(J)
      GO TO 110
  107 IF (FRO(2).LE.0) GO TO 12
      X1=RO(1)
      FX1=FRO(1)
      X2=RO(2)
      FX2=FRO(2)
      GO TO 110
   12 X1=RO(2)
      FX1=FRO(2)
      X2=RO(1)
      FX2=FRO(1)
      GO TO 110
C     ITERATION PROCEDURE FOR RO(J) ENDS.
   40 WRITE (6,41)
   41 FORMAT('0','POSSIBLY NO ROOT ON STARTING INTERVAL FOR RO')
      GO TO 7
   50 WRITE (6,51)
   51 FORMAT('0','POSSIBLY NO ROOT ON STARTING VALUE FOR YO')
      GO TO 7
C     CALCULATE NEW VALUE FOR RO(J) BASED UPON PREVIOUS ITERATION.
  110 RO(J+1)=(X1*FX2-X2*FX1)/(FX2-FX1)
      GO TO 25
C     FYO(M) IS THE SUM OF THE HORIZ. FORCES.
   23 FYO(M)=+HB+HBB-RTH-RN*C
      IF( ABS(FYO(M)).LE.( B   ))GO TO 202
      IF(M.LT.2) GO TO 200
      IF (FYO(1)*FYO(2).GT.0) GO TO 50
      IF(M.EQ.2) GO TO 117
      IF(FY1*FYO(M)) 118,202,119
C     ITERATION PROCEDURE FOR YO(M) BEGINS.
  118 FY2=FYO(M)
      Y2=YO(M)
      GO TO 120
  119 FY1=FYO(M)
      Y1=YO(M)
      GO TO 120
  117 IF (FYO(2).LE.0) GO TO 13
      Y1=YO(1)
      FY1=FYO(1)
```

```
      FY2=FYO(2)
      Y2=YO(2)
      GO TO 120
   13 Y1=YO(2)
      FY1=FYO(2)
      Y2=YO(1)
      FY2=FYO(1)
      GO TO 120
C     ITERATION PROCEDURE FOR YO(M) ENDS.
C     CALULATE NEW VALUE FOR YO(M) BASED UPON PREVIOUS ITERATION.
  120 YO(M+1)=(Y1*FY2-Y2*FY1)/(FY2-FY1)
      GO TO 230
C     A IS TV' LOCAION OF NEUTRAL AXIS, IN INCHES, FROM THE BOTTOM.
C     B IS THE LOCATION OF INST. CENTER, IN INCHES.
  202 A=YO(M)
      B=RO(J)
C   . CALCULATE THE ULTIMATE LOA? - PULT - IN KIPS.
C     PULT IS TYICE THE VALUES SINCE THE CONNECTION IS CUT IN HALF.
      PULT=2.*(RTV+VB+RN*S)
      WLF2=2.*WLF
      WRITE(6,25) WL,WLF2
   25 FORMAT('0',20X,'WEB WELD=',F6.2,6X,'FLANGE WELD=',F6.2//)
      WRITE(6,30) SIGY,TW
   30 FORMAT('0',20X,'YIELD STRESS=',F6.2,6X,'WEB THICK.=',6X,F6.2//)
      WRITE(6,210) TF
  210 FORMAT('0',20X,'FLANGE THICK.=',F6.2//)
      WRITE(6,205) ECC,W
  205 FORMAT('0',20X,'ECC.=',F6.2,6X,'FLANGE WIDTH=',F6.2//)
      WRITE(6,24) B
   24 FORMAT('0',20X,'I.C.=',F8.4//)
      WRITE(6,28) A, PULT
   28 FORMAT('0',20X,'DIST. TO N.A.=',F8.4,6X,'ULT LOAD,IN KIPS=',
     1F8.4/)
   10 GO TO 7
      END
$ENTRY
5.52  15.0   43.8  0.438   6.125  0.313  2.235
```

FTLE: I2WELDS WATFIV A ***** YOUNGSTOWN STAT' UNIVERSITY COMPUTER CENTER

```
CMS
:READ  TVWELDS  WATFIV   A1 *FREE* 05/22/84 14:11:00
//E1234567 JOB ($$ROUTE4),
// FR021302.DILLON,CLASS=G
// EXEC WATFIV
//SYSIN DD *
$JOB
C      THIS PROGRAM WILL LOCATE THE INST. CENTER* NEUTRAL AXIS, AND
C      CALCULATE THE ULTIMATE LOAD, IN KIPS FOR ECC. WELDS.
C      THIS PROGRAM IS FOR I-SHAPED WELDS ONLY.
       DIMENSION DEL(100),RAD(100),THETA(100),RO(200)
       DIMENSION FRO(100)
       DIMENSION RV(100),RH(100),Y(100),F(100),FM(100)
       DIMENSION YO(200),FYO(200)
       REAL MU,LAMDA
       II=0
     7 II=II+1
C      READ IN WELD DATA  YHERE :
C      WL, IS THE LENGTH OF THE WEB WELDS, ECC, IS THE ECCENTRICITY,
C      SIGY, IS THE YIELC STRESS OF THE PLATES, TF, IS THE THICKNESS
C      CF THE FLANGE, W, IS THE WIDTH OF THE FLANGE.  TW, IS THE
C      THICKNESS OF THE WEB, WLF, IS THC LENGTH OF THE FLANGE WELDS
       READ,WL,ECC,SIGY,TF,W,TW,WLF
       M=C
       IF(WL.LE.0.) STOP
       WRITE (6,90) II
    90 FORMAT(///T10,'PROBLEM NO. =',I2)
C      CALCULATE 2 INITIAL VALLES FJR  NEUTRAL AXIS LCCATEO FROM BOTTOM
C      CF WELD LENGTH (YO(1),YO(1))
       YO(1)=WL/4.
       YO(2)=9.*WL/10.
   20G CONTINUE
       J=0
       M=M+1
C      CALCULCTE UW - LENGTH CF WELD IN TENSION
       UW=WL-YO(M)
C      DIVIDE TGP TENSION WELD INTO HALF INCH INCREMENTS
       DO 21 I=1,1000
       GW=UW/FLOAT(I)
       N=I
       IF(GW.LE.1.0) GO TO 9
    21 CONTINUE
     9 ELW=GW
C      LOCATE CENTER OF FIQST WELD ELECEN?
       Y(1)=ELW/2.
C      CHOOSE TWO INITIAL VALUES FJR INST. CENTER - RO(1),RO(2)
       RO(1)=0.10
       RO(2)=30.000
    25 CONTINUE
       J=J+1
C      CALCULATE RAD AND ANGLE BETUEEN RAD VECTOR AND YELC AXIS FOR FIRST
C      YELC ELEMENT
       RAD(1)= SQRT(RO(J)**2+Y(1)**2)
       THETA(1)=( ARSIN(RO(J)/RAD(1))) 180./3.14159
C      CALCULATE ANGLE BETWEEN FORCE AND WELD AXIS FOR FIRST ELEMENT
```

```
      THETA(1)=90-THETA(1)
C     CALCULATE RAD AND ANGLE BETWEEN RAD VECTOR AND UELD AXIS FOR REST
C     OF WELD ELEMENTSAND ANGLE BETWEEN FORCE VECTOR AND WELD AXIS
      DO 3 I=2,N
      Y(I)=Y(I-1)+ELW
      IF(N.EQ.I)GO TO 39
      RAD(I)= SQRT(RO(J)**2+Y(I)**2)
      THETA(I)=( ARSIN(RO(J)/RAD(I)))*180./3.14159
      THETA(I)=90-THETA(I)
    3 CONTINUE
   39 RAD(N)= SQRT(RO(J)**2+(WL-YO(M)+TF)**2)
      THETA(N)=( ARSIN(RO(J)/RAD(N)))*180./3.14159
      THETA(N)=90-THETA(N)
      RTH IS THE SUM OF HORIZ. RES. FORCES OF WELDS
      RTV IS THE SUM OF VERT. RES. FORCES OF WELDS
      THRM IS SUM OF MOM. DUE TO RTH
      CALCULATE RES. FORCES OF WELDS YITH ABOVE NOTATION
      RTH=0.
      RTV=0.
      THRM=0.
      DO 5 I=1,N
      DEL(I)=(RAD(I)/RAD(N))*.225*(THETA(N)+5)**(-.47)
      RULT=(10.+THETA(I))/(.92+.0603*THETA(I))
      MU=75.* EXP(.0114*THETA(I))
      LAMDA=.4* EXP(.0146*THETA(I))
      F(I)=RULT*ELW*(1.-EXP(-MU*DEL(I)))**LAMDA
      RV(I)=(Y(I)/RAD(N))*F(I)
      RH(I)=(RO(J)/RAD(N))*F(I)
      THRM=RH(I)*(WL-YO(M)+TF-Y(I))+THRM
      IF(I.EQ.N)GO TO 60
      RTV=RTV+RV(I)
      RTH=RTH+RH(I)
    5 CONTINUE
C     HB,HBB ARE RES. BELOW N.A.
C     VB IS RES. FORCE OF WELDS BELOW N.A.
   60 DEL(N)=.225*(THETA(N)+5)**(-.47)
      RULT=(10.+THETA(N))/(.92+.0603*THETA(N))
      MU=75.*EXP(.0114*THETA(N))
      LAMDA=.4*EXP(.0146*THETA(N))
      F(N)=RULT*(1.-EXP(-MU*DEL(N)))**LAMDA
      PRINT,F(N)
      RN=WLF*F(N)
      HB=SIGY*YO(M)*TW/4.
      HBB=SIGY*W*TF/2.
      VB=YO(M)*RTV/UW
      S=(WL-YO(M)+TF)/RAD(N)
      C=RO(J)/RAD(N)
      RAD2=SQRT((RO(J))**2+(YO(M)+TF)**2)
      S2=(YO(M)+TF)/RAD2
      FRO(J)=(+RN*S+RTV+VB)*ECC+(+THRM-HB*(WL-(YO(M)/3.)+TF)
     -HBB*(WL+(3./2.)*TF))+(RN*S2)*ECC
      IF( ABS(FRO(J)).LE.(    A    ))GO TO 23
      IF(J.LT.2) GO TO 25
      ERR1=(FRO(J)-FRO(J-1))/FRO(J)
      IF(FRO(1)*FRO(2).GT.0) GO TO 40
```

```
      IF (ABS(ERR1).LT.0.01) GO TO 23
      IF(J.EQ.2) GO TO 107
      IF(FX1*FRO(J)) 108,23,109
  108 X2=RO(J)
      FX2=FRO(J)
      GO TO 110
  109 FX1=FRO(J)
      X1=RO(J)
      GO TO 110
  107 IF (FRO(2).LE.0) GO TO 12
      X1=RO(1)
      FX1=FRO(1)
      X2=RO(2)
      FX2=FRO(2)
      GO TO 110
   12 X1=RO(2)
      FX1=FRO(2)
      X2=RO(1)
      FX2=FRO(1)
      GO TO 110
   40 WRITE (6,41)
   41 FORMAT('0','POSSIBLY NO ROOT ON STARTING INTERVAL FOR RO')
      GO TO 7
   50 WRITE (6,51)
   51 FORMAT('0','POSSIBLY NO ROOT ON STARTING VALUE FOR YO')
      GO TO 7
  110 RO(J+1)=(X1*FX2-X2*FX1)/(FX2-FX1)
      GO TO 25
   23 FYO(M)=+HB+HBB-RTH-RN*C
      PRINT,FYO(M)
      IF( ABS(FYO(M)).LE.( B    )) GO TO 202
      IF(M.LT.2) GO TO 200
      ERR2=(FYO(M)-FYO(M-1))/FYO(M)
      IF (FYO(1)*FYO(2).GT.0) GO TO 50
      IF ( ABS(ERR2).LT.0.01) GO TO 202
      IF(M.EQ.2) GO TO 117
      IF(FY1*FYO(M)) 118,202,119
  118 FY2=FYO(M)
      Y2=YO(M)
      GO TO 120
  119 FY1=FYO(M)
      Y1=YO(M)
      GO TO 120
  117 IF (FYO(2).LE.0) GO TO 13
      Y1=YO(1)
      FY1=FYO(1)
      FY2=FYO(2)
      Y2=YO(2)
      GO TO 120
   13 Y1=YO(2)
      FY1=FYO(2)
      Y2=YO(1)
      FY2=FYO(1)
      GO TO 120
  120 YO(M+1)=(Y1*FY2-Y2*FY1)/(FY2-FY1)
```

```
      GO TO 100
  202 A=YO(M)
      B=RO(J)
      WLF2=2.*WLF
      CALCULATE THE ULTIMATE LOAD - PULT
      PULT=2.*(RTV+VB+RN*S+RN*S2)
      WRITE(6,29) WL,ECC
   29 FORMAT('0','WEB WELD LENGTH=',F6.2,6X,'ECCENTRICITY=',F6.2//
      WRITE(6,30) SIGY,TW
   30 FORMAT('0','YIELD POINT =',F5.2,7X,'WEB THICKNESS=',1F5.3//)
      WRITE(6,105) W,WLF2
  105 FORMAT('0','FLANGE WIDTH=',F5.2,7X,'FLANGE WELD =',F5.2//)
      WRITE(6,24) B
   24 FORMAT('0','INSTANTANEOUS CENTER =',F8.4//)
      WRITE(6,28) A, PULT
   28 FORMAT('0','DISTANCE TO N.A. =',F8.4,4X,'ULT LOAD, IN KIPS='
     1F8.4//)
   10 GO TO 7
      END
$ENTRY
5.52  20.0   43.6   0.4375 6.125 0.3125 2-22
```

```
FILE: HWELDS    LATFIV    A    ****  YOUNGSTOWN STATE UNIVERSITY COMPUTER CENTER **

:READ  TVWELDS  WATFIV    A1 *FREE* 05/22/34  14:11:00
//E1234567 JOB ($$ROUTE4),
// FR021302.DILLON,CLASS=G
// EXEC WATFIV
//SYSIN DD *
$JOB
      DIMENSION DEL(100),RAD(100),THETA(100),RO(200)
      DIMENSION FRO(100)
      DIMENSION RV(100),RH(100),Y(100),F(100),FM(100)
      DIMENSION YO(200),FYO(200)
      REAL MU,LAMDA
      II=0
    7 II=II+1
C     READ IN LELD DATA  WHERE:
C     WL,IS THE DISTANCE BETWEEN THE FLANGES,ECC,IS THE ECCENTRICITY,SIGY,IS TH
C     YIELD STRESS OF THE PLATES.  TF,IS THE FLANGE THICKNESS* W,IS THE FLANGE
C     WIDTH, TW,IS THE LEP THICKNESS* WL, IS THE LENGTH OF THF FLANGE UELDS
      READ,WL,ECC,SIGY,TF,W,TW,WLF
      M=0
      IF(WL.LE.0.) STOP
      WRITE (6,90) II
   90 FORMAT(///T10,'PROBLEM NO. =',I2)
C     CALCULATE 2 INITIAL VALUES FOR NEUTRAL AXIS LOCATED FROM BOTTOM
C     OF WELD LENGTH (YO(1),YO(1))
      YO(1)=WL/4.
      YO(2)=3.*WL/4.
  200 CONTINUE
      J=0
      M=M+1
      CHOOSE TUC INITIAL VALUES FOR INST. CENTER - RO(1),RO(2)
      RO(1)=0.10
      RO(2)= 50.0
   25 CONTINUE
      J=J+1
      CALCULATE RAD AND ANGLE BETWEEN RAD VECTOR AND WELDS AXIS FOR TOP
      FLANGE ELEMENT
      RAD(1)= SQRT(RO(J)**2+(WL-YO(M)+TF)**2)
      THETA(1)=( ARSIN(RO(J)/RAD(1)))*180./3.14159
      CALCULATF ANGLE BETWEEN RES. FORCE ANC WELD AXIS  FOR TOP FLANGE
      THETA(1)=90-THETA(1)
      HB,HBB ARE RES. BELOW N.A.
      CALCULATE RESISTIVE FCRCE FOR BOTH FLAGES
      DEL(1)=.225*(THETA(1)+5)**(-.47)
      RULT=(10.+THETA(1))/(.92+.0603*THETA(1))
      MU=75.*EXP(.0114*THETA(1))
      LAMDA=.4*EXP(.0146*THETA(1))
      F(1)=RULT*(1.-EXP(-MU*DEL(1)))**LAMDA
      PRINT,F(1)
      RN=WLF*F(1)
      HB=SIGY*YO(M)*TW/4.
      HBB=SIGY*W*TF/2.
      S=(WL-YO(M)+TF)/RAD(1)
      C=RO(J)/RAD(1)
      RAD2=SQRT((RO(J))**2+(YO(M)+TF)**2)
      S2=(YO(M)+TF)/RAD2
```

```
      FRO(J)=(+RN*S)*ECC+(-HB*(WL-(YO(M)/3.)+TF)
     -HBB*(WL+(3./2.)*TF))+(RN*S2)*ECC
      IF( ABS(FRO(J)).LE.(   A    ))GO TO 23
      IF(J.LT.2) GO TO 25
      ERR1=(FRO(J)-FRO(J-1))/FRO(J)
      IF(FRO(1)*FRO(2).GT.0) GO TO 40
      IF (ABS(ERR1).LT.0.01) GO TO 23
      IF(J.EQ.2) GO TO 107
      IF(FX1*FRO(J)) 108,23,109
  108 X2=RO(J)
      FX2=FRO(J)
      GO TO 110
  109 FX1=FRO(J)
      X1=RO(J)
      GO TO 110
  107 IF (FRO(2).LE.0) GO TO 12
      X1=RO(1)
      FX1=FRO(1)
      X2=RO(2)
      FX2=FRO(2)
      GO TO 110
   12 X1=RO(2)
      FX1=FRO(2)
      X2=RO(1)
      FX2=FRO(1)
      GO TO 110
   40 WRITE (6,41)
   41 FORMAT('0','POSSIBLY NO ROOT ON STARTING INTERVAL FOR RO')
      GO TO 7
   50 WRITE (6,51)
   51 FORMAT('0','POSSIBLY NO ROOT ON STARTING VALUE FOR YO')
      GO TO 7
  110 RO(J+1)=(X1*FX2-X2*FX1)/(FX2-FX1)
      GO TO 25
   23 FYO(M)=+HB+HBB-RN*C
      IF( ABS(FYO(M)).LE.(   B   )) GO TO 202
      IF(M.LT.2) GO TO 200
      ERR2=(FYO(M)-FYO(M-1))/FYO(M)
      IF (FYO(1)*FYO(2).GT.0) GO TO 50
      IF ( ABS(ERR2).LT.0.01) GO TO 202
      IF(M.EQ.2) GO TO 117
      IF(FY1*FYO(M)) 118,202,119
  118 FY2=FYO(M)
      Y2=YO(M)
      GO TO 120
  119 FY1=FYO(M)
      Y1=YO(M)
      GO TO 120
  117 IF (FYO(2).LE.0) GO TO 13
      Y1=YO(1)
      FY1=FYO(1)
      FY2=FYO(2)
      Y2=YO(2)
      GO TO 120
   13 Y1=YO(2)
```

```
      FY1=FYO(2)
      Y2=YO(1)
      FY2=FYO(1)
      GO TO 120
  120 YO(M+1)=(Y1 FY2-Y2*FY1)/(FY2-FY1)
      GO TO 200
  202 A=YO(M)
      B=RO(J)
C     CALCULATE THE ULTIMATE LOAD - PULT
      PULT=2. (RN S+RN*S2)
      FL=WLF 2.
      WRITE(6,29) WL,FL
   29 FORMAT('0','WEB   DISTANCE  =',F6.2,6X,'FLANGE WELDS =',F6.2//)
      WRITE(6,30) SIGY,TW
   30 FORMAT('0','YIELD POINT =',F5.2,7X,'WEB THICKNESS=',1F5.3//)
      WRITE(6,100) W,TF
  100 FORMAT('0','FLANGE WIDTH =',F5.2,7X,'FLANGE THICKNESS= ',1F5.3//)
      WRITE(6,24) B,ECC
   24 FORMAT('0','INSTANTANEOUS CENTS? =',F8.4,7X,'ECC=',1F8.3//)
      WRITE(6,28) A, PULT
   28 FORMAT('0','DISTANCE TO N.A. =',F8.4,4X,'ULT LOAD=',1F8.4/)
   10 GO TO 7
      END
$ENTRY
10.0  2.0  36.0  0.25 20.00  0.25 10.0
/*
```

APPENDIX 8

Design Chart Details

B.1 Sample conversion from ultimate load to design load

Ultimate load, in kips = 45.27

Tide's modificationss

1. Convert from 1/4 in. to 1/16 in. welds

   45.27 * 4 = 11.32

2. Convert from €60 to €70 electrode:

   11.32 * 70/60 = 13.21

3. Safety factors

   13.21 * 0.30 = 3.96

4. Checking shear stressr

   3.96 * 10.61/14.27 = 2.94

Maximum permissible, or design load = 2.94 kips

Multiply the design by the number of sixteenths of weld

B.2 Design Chart Formula

The loads from the design charts are calculated from the followina equation:

$$P = C\ C_1 D l$$

where:

P= Permissible eccentric load, in kips

l = Length of each weld in inches

D= Number of sixteenths of an inch in fillet weld size

C= Coefficients in tables

C_1= Coefficient for electrode used

= 1.0 for E70XX electrodes

= 1.14 for E80XX electrodes

= 1.29 for E90XX electrodes

= 1.43 for E100XX electrodes

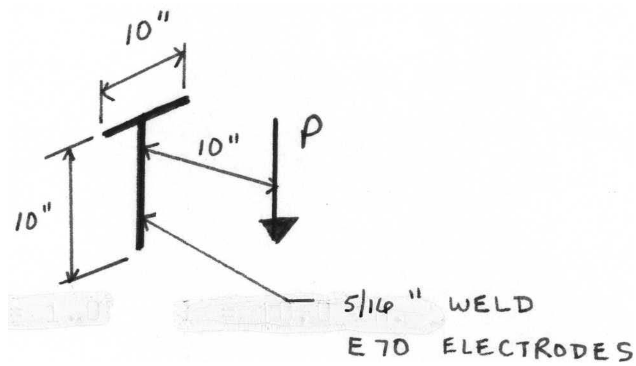
= 1.57 for E110XX electrodes

= 0.857 for E60XX electrodes

The design charts are for 36 ksi yield stress, and for flange and web thickness as noted on charts. The flange width is one inch greater than the flange weld.

B.3 Design chart problem

T - Shaped weld



Therefore:

$1 = 10.0$ in. $\quad K1 = 1.0 \quad A1 = 1.0$

$C = 1.14$ (from design tables) $\quad C_1 = 1.0$

$D = 5$

Solving for P

$$P = C_1 C\ D\ 1$$

$$= (1.0)*(1.14)*(5)*(10.0)$$

$$= 57 \text{ kips}$$

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