LRFD Beam-Column Graphical Design Aid

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ABSTRACT

A graphical design aid is presented for beam-columns, members subjected to combined loading of axial forces and bending moments, designed in accordance with the American Institute of Steel Construction's (AISC) 1993 *LRFD Specification for Structural Steel Buildings*. Design aids have been published in the AISC *LRFD Manual of Steel Construction,* 2nd Edition, addressing many facets of structural steel design. These include the beam tables, beam charts, and column tables. However, meager information is available revealing how to design a beam-column accurately and quickly. The common method is entirely based on an assumed axial load due to bending moments which is then used via trial-and-error to size a member from the column (axial load only) design tables. There are various problems with this method of design.

This article presents an alternative design procedure based on the Equations H1-1a and H1-1b of the 1993 *LRFD Specification for Structural Steel Buildings*. The proposed design method consists of a standard set of graphs depicting the interaction diagram for steel W-shapes commonly used as column members. The diagrams are derived for structural members subjected to axial compression and strong-axis bending. This new procedure also utilizes a set of linear transformation factors applied to design conditions different from the graphical standard. This method is advantageous to design engineers because it facilitates the selection of a beam-column.

INTRODUCTION

The AISC *LRFD Manual of Steel Construction,* 2nd Edition, provides aids for the designer of steel columns and beams. The design of columns for axial loads only is precisely tabulated for several shapes commonly used as columns. The design of beams for strong-axis bending moments is accurately tabulated and plotted for several shapes commonly used as beams. However, a trial-and-error solution process is suggested to design a beam-column, a member subjected to combined axial load and bending moments (refer to Preliminary Beam-Columns, Table 3-2, LRFD Manual, Volume I, 2nd Edition). Design by trial-and-error is enlightening through chance and discovery but this process does consume valuable time. A more precise method would expedite the design procedure to repeat the task efficiently.

The scope of this article is to introduce and propose a simplified LRFD design aid for beam-columns. Wide-flange shapes normally used as structural columns, with a combined loading of an axial compressive load and a strong-axis bending moment are addressed. This document recommends a new design approach and demonstrates how to perform the required calculations. The proposed design procedure utilizes a standard interaction diagram and various conversion factors to efficiently design beam-columns. The conversion factors are necessary for the linear transformation of design conditions different from the graphical standards.

The proposed design procedure is derived from Equations H1-1a and H1-1b of the 1993 LRFD Specification which define the interaction diagram for the design of a beam-column (refer to Figure 1, which is identical to Figure C-H1.1 in the 1993 LRFD Specification). Any combination of axial load, P_u, and bending moment, M_u, that plots below or on the line indicates an acceptable result. Any condition plotted above the member interaction line is not adequate. Interaction diagrams have been developed for a compressive axial load and bending moment

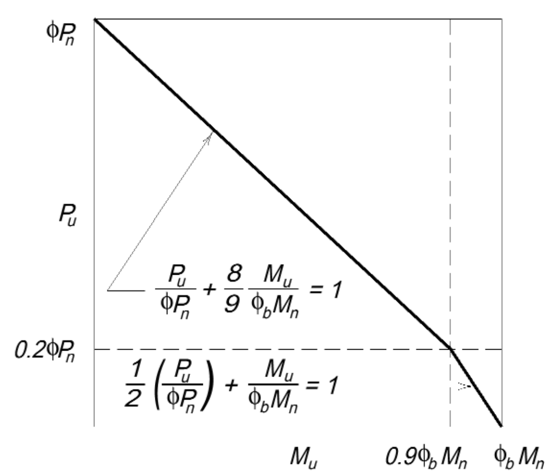

Fig. 1. Typical beam-column interaction curve per LRFD Specifications.

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about the major axis. These design curves comply with AISC's 1993 LRFD Specification.

DERIVATION OF THE DESIGN PROCEDURE

A beam-column must conform to the interaction Equations H1-1a and H1-1b defined in LRFD Specification Chapter H. The plot of both equations yields a continuous interaction diagram similar to Figure 1 for every member. This graph is affected by the column member size, column end conditions, the unbraced length, and lateral-torsional buckling criteria.

The following derivation by example illustrates the author's discovery process. Curves 1, 2, and 3 in Figure 2 are plotted with the assumption that the unbraced length is equal to the effective length. A single member, W14×61, is graphed with differing lengths and end conditions in Figure 2.

Curve 1 in Figure 2 depicts the interaction diagram for the following conditions:

Member Shape = W14×61
F_y = 50 ksi ϕP_n = 591 kips
K =1.0 ϕM_n = 361 kip-ft
KL_x, KL_y, L_b = 12 ft
C_b = 1.0

The point of intersection of lines H1-1a and H1-1b can be algebraically derived once all the other variables are known. The basis for the nominal axial strength is defined in LRFD Specification Chapter E. Likewise, the basis for the nominal moment strength is defined in LRFD Specification Chapter F.

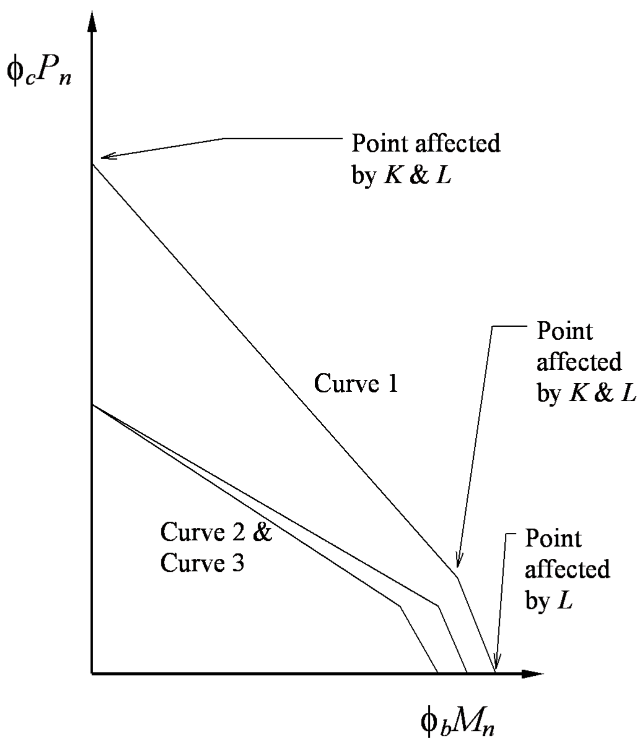

Fig. 2. Interaction diagram plots.

Conservative assumptions of C_b = 1.0 and $L_b = KL_x$, KL_y were selected to simplify the design standards. However, $L_b = KL$ is unconservative for values of K less than one. For example, if K is equal to 0.5 and L is equal to 40 ft, then the moment strength would be based on KL equal to 20 ft instead of the correct value of 40 ft. The designer must be aware of the magnitude of this assumption. Proper detailing of the structure to conform to the design calculations is essential.

For every possible length there exists a similar interaction diagram for the W14×61. In addition to an infinite number of lengths, there are multiple end conditions that will affect the plotted diagram. The end conditions are incorporated with the effective length factor, K, and it varies from 0.5 to 2.10. The theoretical K values and their physical interpretation can be found in Table C-C2.1 on page 6-184 of the LRFD Specification. The member length will also control what the plot looks like (see Figure 2 for affected points). An interaction diagram cannot be drawn for every member, every end condition and every length because there are an infinite number of combinations. Therefore, a correlation must be derived. The plots of Curve 2 and Curve 3 illustrate the graphical correlation.

Curve 2 in Figure 2 depicts the interaction diagram for the following conditions:

Member Shape = W14×61
F_y = 50 ksi ϕP_n = 276 kips
K =1.0 ϕM_n = 315 kip-ft
L_b = KL = 24 ft
C_b = 1.0

Curve 3 in Figure 2 depicts the interaction diagram for the following conditions:

Member Shape = W14×61
F_y = 50 ksi ϕP_n = 276 kips
K =2.0 ϕM_n = 315 kip-ft
L_x, L_y = 12 ft
$L_b = KL$ = 24 ft
C_b = 1.0

Notice that the last two conditions plot identically. Since both portions of the interaction diagram are straight lines, a simple linear transformation can be used to convert any length and end condition to a selected graphical standard.

Curve 3′ illustrates the interaction diagram for the W14×61 if the unbraced length is not equal to the effective length.

Curve 3′ in Figure 2 depicts the interaction diagram for the following conditions:

Member Shape = W14×61

$F_y = 50$ ksi $\phi P_n = 276$ kips
$K = 2.0$ $\phi M_n = 361$ kip-ft
$L_x, L_y = 12$ ft
$L_b = 12$ ft
$C_b = 1.0$

Take note that the maximum axial load remains the same as Curve 3 and therefore the axial portion of the point of intersection of Equations H1-1a and H1-1b remains the same. However, the flexural strength for the member plot for Curve 3′ has increased resulting in a shift in the curve. As long as KL is greater than L_b, the standard interaction graphs will be conservative. If KL is less than L_b, then the standard interaction graphs will be unconservative. In order to simplify the design procedure, the assumption that the limiting effective length, KL, is equal to L_b was used to construct the interaction diagrams.

As with all design aids there are assumptions that are included in the derivation of the method. The basic assumptions for the construction of the standard column interaction curves are:

- the material is A992 steel;
- the member is subjected to axial compression and strong-axis bending only;
- the member graphs are derived with $K = 1.0$ and $L =$ 12 ft;
- the flexural strength of the section is based on $L_b =$ KL and $C_b = 1.0$; and
- the point of intersection of Equations H1-1a and H1-1b is derived algebraically from the other known values.

With the above correlation, a set of conversion factors is defined that is used to perform the linear transformations. Two conversion factors are necessary because the end condition and the length affect the axial strength and the length of the member affects the flexural strength. Conversion factors were calculated for 50 ksi steel. Additional factors may be calculated by using the equations discussed below.

The end conditions and the length affect the axial strength. Therefore, to use an interaction diagram with $K =$ 1.0 and $L = 12$ ft a conversion factor is needed for a member that does not have $K = 1.0$ and $L = 12$ ft. The general form of the equation is:

$$\phi_c P_{n(KL = 12 \text{ ft})} = B_{KL} \times \phi_c P_{n(KL \neq 12 \text{ ft})}$$

In general, the conversion factor, B_{KL}, for a different effective length due to the end condition and length is defined as:

$$B_{KL} = [\phi_c P_{n(KL = 12 \text{ ft})}] \,/\, [\phi_c P_{n(KL \neq 12 \text{ ft})}]$$

The length of the member affects the flexural strength. Therefore, a conversion factor is needed for the bending moment when a member's effective length is not equal to 12 ft. The general form of the equation for the moment capacity factor is:

$$\phi_b M_{n(KL = 12 \text{ ft})} = B_{LM} \times \phi_b M_{n(KL \neq 12)}$$

In general, the conversion factor, B_{LM}, for a member's different effective length is defined as:

$$B_{LM} = [\phi_b M_{n(KL = 12 \text{ ft})}] \,/\, [\phi_b M_{n(KL \neq 12 \text{ ft})}]$$

Hence, if a member does not have $L = 12$ ft or $K = 1.0$ then two linear transformations are required: 1) for the axial load conversion due to the different effective length and 2) for the bending moment conversion due to the deviation of the member's effective length from the graphical standard. Since the conversion factors are based on the individual member's axial and flexural strength, a set of initial design approximations was created (see Appendix B). These approximations are an average of the exact values (see Appendix D) and allow the use of the design aid without previously knowing the member size, except for a target group size such as W14.

As can be determined from the list in Appendix D, the values of B_{KL} and B_{LM} vary within each group size. The lighter members of each group size vary by a greater margin than the heavier members of a group. So the lighter members were ignored when computing the average for the design approximations of B_{KL} and B_{LM}. The design approximations may be utilized for all member weights listed even if it was not included in the average calculation of the design approximation. The design approximations for W14s includes members weighing 90 pounds per linear foot (plf) to 730 plf. The design approximations for W12s includes members weighing 53 plf to 336 plf. The design approximations for W10s includes members weighing 49 plf to 112 plf. All W8s and W6s listed are included in the calculation of the design approximations.

The author must caution the designer to confirm that the design conditions, such as the effective slenderness ratio and the lateral-torsional buckling criteria, for the graphical standards, $K = 1.0$, $L = 12$ ft, and $F_y = 50$ ksi, are maintained at the differing condition requiring the transformation. In other words, verification that the effective slenderness ratio remains below 200 and that the section maintains the same lateral-torsional buckling criteria must be calculated for the actual conditions. Furthermore, the unbraced length, L_b, shall be considered equal to the effective length, KL. Review Appendix E to see a listing of conditions where the slenderness ratio would be exceeded for each conversion.

In summary, the tabulated values are for shapes typically used as columns; however, this graphical approach may be applied to all shapes provided that adherence to the graphical standards is maintained. The additional interaction diagrams may be plotted along with the curves in Appendix D. The graphical design method is limited to a combined loading of an axial compressive force and a major-axis bending moment because a graphical method for a column with biaxial bending would require a three-dimensional graph, one axis for the axial load and one axis each for the orthogonal bending moments.

PROPOSED DESIGN PROCEDURE

This graphical design procedure for a steel beam-column is a precise method that incorporates the correct interaction of a compressive axial load and a bending moment according to the LRFD Specification. The procedure is as follows:

1. Given the effective length factor, K, and the member length, L, find the appropriate design approximations for B_{KL} and B_{LM} from Appendix B where:
   B_{KL} = axial conversion factor
   B_{LM} = bending moment conversion factor
   Note: The tabulated design approximations deviate less than 10 percent from the true values for the majority of the shapes in a given group classification such as W14. Linear interpolation between the conversion factors is valid with the difference being less than 0.5 percent from the true value.
2. Calculate $P_u' = B_{KL} \times P_u$
   Calculate $Mu' = B_{LM} \times M_u$
   where:
   P_u = factored axial load, kips
   M_u = factored bending moment, kip-ft
   P_u' = transformed axial load, kips
   M_u' = transformed bending moment, kip-ft
3. Plot (M_u', P_u') on the appropriate graph in Appendix D and select a member whose interaction diagram lies above and to the right of the plotted point.
4. Find the exact values of B_{KL} and B_{LM} from Appendix C for the member selected.
5. Recalculate M_u' and P_u'.
6. Replot (M_u', P_u') on the appropriate graph in Appendix D to verify that the member selected is adequate.
7. Confirm the selected member is adequate with the applicable provisions of the AISC LRFD Specification.

ILLUSTRATIVE EXAMPLE

The following example demonstrates the application of the proposed method. Note, the interaction calculation checks use the actual unbraced length, L_b, to determine the bending moment.

Example

Given the loading below, select the lightest W14 and W12:

P_u = 3,400 kips $K = 1.0$
M_u = 650 kip-ft L = 16 ft
F_y = 50 ksi

Determine the design approximations for the W14 first (Appendix B):

$B_{KL} = 1.072$
$B_{LM} = 1.007$
$P_u' = B_{KL} \times P_u$
$= 1.072 \times 3{,}400 = 3{,}640$ kips
$M_u' = B_{LM} \times M_u$
$= 1.007 \times 650 = 655$ kip-ft

Plot the point $(M_u', P_u') = (655, 3{,}640)$ on the appropriate graph in Appendix D.

From the plotted point, proceed up and to the right across the page until the lightest W14 is found. Try W14×398.

Determine the exact values of B_{KL} and B_{LM} from Appendix C:

$B_{KL} = 1.066$
$B_{LM} = 1.002$
$P_u' = B_{KL} \times P_u$
$= 1.066 \times 3{,}400 = 3{,}620$ kips
$M_u' = B_{LM} \times M_u$
$= 1.002 \times 650 = 651$ kip-ft

The transformed point plots to the left of the first point, therefore select W14×398 again.

To confirm the procedure, verify the result by using Equation H1-1a:

ϕP_n = 4,300 kips via the column tables, Part 3, LRFD Manual, 2nd Edition.
ϕM_n = 2,997 kip-ft via Chapter F, Part 6, LRFD Specification (December 1993).

Interaction Calculation = 0.983

Use W14×398.

Determine the design approximations for the W12 (Appendix B):

$B_{KL} = 1.131$
$B_{LM} = 1.031$

By inspection of the graphs, the largest W12 is located down and to the left of the first plotted point. By inspection of the design approximation tables, the B_{KL} and B_{LM} factors are greater for a W12 than a W14. Therefore, it can be concluded that no adequate W12 section exists.

CONCLUSION

A graphical design aid for beam-column members has been presented. By utilizing a standard set of graphs conforming to the interaction Equations H1-1a and H1-1b and conversion factors, most members can be designed accurately and efficiently. The conversion factors allow many design conditions to be made equivalent to the graphical standards and facilitate the selection of a beam-column. This design method is advantageous to design engineers performing hand calculations or checking computer program results because it expedites the design of a complex framing member. Some advantages associated with this design procedure are it reduces the number of calculations required thereby reducing design time and cost and it is a more precise method based on the LRFD Specifications instead of an equivalent axial load equation involving trial-and-error.

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APPENDIX A—NOTATION

ϕ_b = resistance factor for flexure
ϕ_c = resistance factor for compression
B_{KL} = axial conversion factor for effective length, KL, not equal to 12 ft
B_{LM} = bending conversion factor for effective length, KL, not equal to 12 ft
C_b = bending coefficient dependent upon the moment gradient between bracing points.
F_y = specified minimum yield stress of the steel type being analyzed, ksi
K = effective length factor for a prismatic member
l = unbraced length of member, in.
L = unbraced length of member, ft
L_b = laterally unbraced length of member, ft
L_p = limiting laterally unbraced length of member for full plastic bending capacity, ft
L_r = limiting laterally unbraced member length for inelastic lateral-torsional buckling, ft
m = coefficient for converting bending to an approximate equivalent axial load in columns subjected to combined loading conditions
M_n = nominal flexural strength, kip-ft
M_u = required flexural strength, kip-ft
M_u' = transformed required flexural strength, kip-ft
P_n = nominal axial strength (compression), kips
P_u = required axial strength (compression), kips
P_u' = transformed required axial strength (compression), kips

APPENDIX B—DESIGN APPROXIMATIONS OF B_{KL} AND B_{LM}

	B_{KL} & B_{LM} Values (50 ksi)									
	KL (ft)									
	6.00		8.00		10.00		12.00		14.00	
Shape	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}
W14	0.935	1.000	0.952	1.000	0.973	1.000	1.000	1.000	1.033	1.001
W12	0.888	0.990	0.916	0.990	0.953	0.992	1.000	1.000	1.059	1.015
W10	0.845	0.971	0.883	0.971	0.934	0.979	1.000	1.000	1.084	1.022
W8	0.736	0.917	0.796	0.935	0.882	0.966	1.000	1.000	1.161	1.037
W6	0.607	0.874	0.691	0.912	0.816	0.954	1.000	1.000	1.271	1.051

	B_{KL} & B_{LM} Values (50 ksi)									
	KL (ft)									
	16.00		18.00		20.00		22.00		24.00	
Shape	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}
W14	1.072	1.007	1.118	1.015	1.172	1.023	1.235	1.032	1.308	1.041
W12	1.131	1.031	1.220	1.047	1.327	1.064	1.457	1.082	1.615	1.101
W10	1.190	1.045	1.323	1.069	1.489	1.094	1.698	1.121	1.959	1.149
W8	1.383	1.077	1.668	1.125	2.029	1.190	2.456	1.261	2.922	1.343
W6	1.656	1.107	2.096	1.177	2.588	1.287	3.131	1.416	3.727	1.560

	B_{KL} & B_{LM} Values (50 ksi)									
	KL (ft)									
	26.00		28.00		30.00		32.00		34.00	
Shape	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}
W14	1.392	1.050	1.489	1.059	1.601	1.069	1.730	1.078	1.879	1.088
W12	1.805	1.121	2.029	1.148	2.296	1.177	2.602	1.226	2.937	1.263
W10	2.290	1.178	2.656	1.210	3.048	1.249	3.468	1.298	3.916	1.353
W8	3.430	1.435	3.978	1.534	4.566	1.634	5.195	1.738	5.865	1.845
W6	4.373	1.704	5.072	1.848	5.823	1.990	6.625	2.132	7.479	2.274

	B_{KL} & B_{LM} Values (50 ksi)			
	KL (ft)			
	36.00		38.00	
Shape	B_{KL}	B_{LM}	B_{KL}	B_{LM}
W14	2.052	1.099	2.250	1.109
W12	3.293	1.303	3.669	1.345
W10	4.390	1.410	4.891	1.473
W8	6.575	1.952	7.326	2.061
W6	8.385	2.416	9.342	2.557

APPENDIX C—B_{KL} AND B_{LM} VALUES (50 ksi)

Shape	B_{KL} and B_{LM} Values (50 ksi)									
	KL (ft)									
	6.00		8.00		10.00		12.00		14.00	
	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}
W14x730	0.950	1.000	0.962	1.000	0.979	1.000	1.000	1.000	1.025	1.000
W14x665	0.948	1.000	0.961	1.000	0.979	1.000	1.000	1.000	1.026	1.000
W14x605	0.947	1.000	0.960	1.000	0.978	1.000	1.000	1.000	1.027	1.000
W14x550	0.945	1.000	0.959	1.000	0.977	1.000	1.000	1.000	1.028	1.000
W14x500	0.944	1.000	0.958	1.000	0.977	1.000	1.000	1.000	1.028	1.000
W14x455	0.942	1.000	0.957	1.000	0.976	1.000	1.000	1.000	1.029	1.000
W14x426	0.941	1.000	0.956	1.000	0.976	1.000	1.000	1.000	1.029	1.000
W14x398	0.941	1.000	0.956	1.000	0.975	1.000	1.000	1.000	1.030	1.000
W14x370	0.940	1.000	0.955	1.000	0.975	1.000	1.000	1.000	1.030	1.000
W14x342	0.939	1.000	0.954	1.000	0.975	1.000	1.000	1.000	1.031	1.000
W14x311	0.938	1.000	0.953	1.000	0.974	1.000	1.000	1.000	1.032	1.000
W14x283	0.937	1.000	0.953	1.000	0.974	1.000	1.000	1.000	1.032	1.000
W14x257	0.936	1.000	0.952	1.000	0.973	1.000	1.000	1.000	1.033	1.000
W14x233	0.935	1.000	0.951	1.000	0.973	1.000	1.000	1.000	1.033	1.000
W14x211	0.934	1.000	0.950	1.000	0.972	1.000	1.000	1.000	1.034	1.000
W14x193	0.933	1.000	0.950	1.000	0.972	1.000	1.000	1.000	1.034	1.000
W14x176	0.932	1.000	0.949	1.000	0.972	1.000	1.000	1.000	1.034	1.000
W14x159	0.931	1.000	0.949	1.000	0.971	1.000	1.000	1.000	1.035	1.000
W14x145	0.931	1.000	0.948	1.000	0.971	1.000	1.000	1.000	1.035	1.000
W14x132	0.923	1.000	0.942	1.000	0.968	1.000	1.000	1.000	1.039	1.006
W14x120	0.922	1.000	0.942	1.000	0.967	1.000	1.000	1.000	1.040	1.007
W14x109	0.922	1.000	0.941	1.000	0.967	1.000	1.000	1.000	1.040	1.008
W14x99	0.921	1.000	0.941	1.000	0.967	1.000	1.000	1.000	1.041	1.000
W14x90	0.920	1.000	0.940	1.000	0.967	1.000	1.000	1.000	1.041	1.000
W14x82	0.831	0.955	0.872	0.955	0.927	0.971	1.000	1.000	1.093	1.030
W14x74	0.831	0.951	0.872	0.951	0.927	0.969	1.000	1.000	1.093	1.033
W14x68	0.829	0.947	0.870	0.947	0.926	0.967	1.000	1.000	1.095	1.035
W14x61	0.827	0.943	0.869	0.943	0.926	0.965	1.000	1.000	1.096	1.037
W14x53	0.735	0.888	0.796	0.912	0.882	0.954	1.000	1.000	1.160	1.051
W14x48	0.732	0.880	0.794	0.906	0.881	0.951	1.000	1.000	1.162	1.055
W12x336	0.910	1.000	0.932	1.000	0.962	1.000	1.000	1.000	1.047	1.005
W12x305	0.907	1.000	0.931	1.000	0.961	1.000	1.000	1.000	1.048	1.006
W12x279	0.905	1.000	0.929	1.000	0.960	1.000	1.000	1.000	1.049	1.007
W12x252	0.903	0.999	0.927	0.999	0.959	0.999	1.000	1.000	1.050	1.008
W12x230	0.901	0.999	0.926	0.999	0.959	0.999	1.000	1.000	1.051	1.008
W12x210	0.900	0.998	0.925	0.998	0.958	0.998	1.000	1.000	1.052	1.009
W12x190	0.898	0.997	0.923	0.997	0.957	0.997	1.000	1.000	1.053	1.010
W12x170	0.896	0.997	0.922	0.997	0.956	0.997	1.000	1.000	1.054	1.011
W12x152	0.894	0.996	0.921	0.996	0.955	0.996	1.000	1.000	1.055	1.012
W12x136	0.892	0.994	0.919	0.994	0.955	0.994	1.000	1.000	1.056	1.014
W12x120	0.890	0.993	0.918	0.993	0.954	0.993	1.000	1.000	1.057	1.016
W12x106	0.889	0.991	0.917	0.991	0.953	0.991	1.000	1.000	1.058	1.018
W12x96	0.888	0.990	0.916	0.990	0.953	0.990	1.000	1.000	1.059	1.019
W12x87	0.886	0.988	0.915	0.988	0.952	0.988	1.000	1.000	1.060	1.021
W12x79	0.885	0.986	0.913	0.986	0.951	0.986	1.000	1.000	1.061	1.023
W12x72	0.884	0.985	0.913	0.985	0.951	0.985	1.000	1.000	1.061	1.025
W12x65	0.883	1.000	0.912	1.000	0.950	1.000	1.000	1.000	1.062	1.000
W12x58	0.835	0.952	0.875	0.952	0.929	0.969	1.000	1.000	1.091	1.033
W12x53	0.831	0.947	0.872	0.947	0.927	0.967	1.000	1.000	1.093	1.036
W12x50	0.744	0.902	0.803	0.921	0.886	0.959	1.000	1.000	1.153	1.045
W12x45	0.739	0.893	0.799	0.914	0.884	0.955	1.000	1.000	1.157	1.049
W12x40	0.737	0.884	0.798	0.908	0.883	0.952	1.000	1.000	1.158	1.053
W10x112	0.854	0.983	0.889	0.983	0.938	0.987	1.000	1.000	1.079	1.014
W10x100	0.851	0.980	0.887	0.980	0.936	0.985	1.000	1.000	1.081	1.016
W10x88	0.848	0.977	0.885	0.977	0.935	0.983	1.000	1.000	1.082	1.018
W10x77	0.845	0.973	0.883	0.973	0.934	0.981	1.000	1.000	1.084	1.020
W10x68	0.844	0.969	0.882	0.969	0.933	0.978	1.000	1.000	1.085	1.023
W10x60	0.842	0.965	0.880	0.965	0.932	0.976	1.000	1.000	1.086	1.026
W10x54	0.841	0.961	0.879	0.961	0.932	0.973	1.000	1.000	1.087	1.028
W10x49	0.838	0.957	0.878	0.957	0.931	0.971	1.000	1.000	1.089	1.031
W10x45	0.755	0.918	0.812	0.932	0.892	0.965	1.000	1.000	1.145	1.038
W10x39	0.748	0.906	0.807	0.923	0.889	0.960	1.000	1.000	1.150	1.044
W10x33	0.739	0.889	0.799	0.911	0.884	0.954	1.000	1.000	1.157	1.051
W8x67	0.776	0.959	0.829	0.964	0.902	0.981	1.000	1.000	1.130	1.019
W8x58	0.773	0.953	0.826	0.958	0.900	0.979	1.000	1.000	1.132	1.022
W8x48	0.769	0.943	0.823	0.950	0.898	0.974	1.000	1.000	1.135	1.027
W8x40	0.761	0.929	0.817	0.940	0.895	0.969	1.000	1.000	1.141	1.033
W8x35	0.759	0.920	0.815	0.933	0.894	0.965	1.000	1.000	1.142	1.037
W8x31	0.757	0.912	0.813	0.926	0.893	0.962	1.000	1.000	1.144	1.042
W8x28	0.648	0.869	0.725	0.909	0.838	0.952	1.000	1.000	1.232	1.053
W8x24	0.645	0.854	0.723	0.897	0.836	0.946	1.000	1.000	1.235	1.061
W6x25	0.611	0.886	0.694	0.921	0.818	0.959	1.000	1.000	1.267	1.045
W6x20	0.603	0.862	0.688	0.903	0.814	0.949	1.000	1.000	1.275	1.057

	B_{KL} and B_{LM} Values (50 ksi)									
	KL (ft)									
	6.00		8.00		10.00		12.00		14.00	
Shape	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}
W14x730	0.950	1.000	0.962	1.000	0.979	1.000	1.000	1.000	1.025	1.000
W14x665	0.948	1.000	0.961	1.000	0.979	1.000	1.000	1.000	1.026	1.000
W14x605	0.947	1.000	0.960	1.000	0.978	1.000	1.000	1.000	1.027	1.000
W14x550	0.945	1.000	0.959	1.000	0.977	1.000	1.000	1.000	1.028	1.000
W14x500	0.944	1.000	0.958	1.000	0.977	1.000	1.000	1.000	1.028	1.000
W14x455	0.942	1.000	0.957	1.000	0.976	1.000	1.000	1.000	1.029	1.000
W14x426	0.941	1.000	0.956	1.000	0.976	1.000	1.000	1.000	1.029	1.000
W14x398	0.941	1.000	0.956	1.000	0.975	1.000	1.000	1.000	1.030	1.000
W14x370	0.940	1.000	0.955	1.000	0.975	1.000	1.000	1.000	1.030	1.000
W14x342	0.939	1.000	0.954	1.000	0.975	1.000	1.000	1.000	1.031	1.000
W14x311	0.938	1.000	0.953	1.000	0.974	1.000	1.000	1.000	1.032	1.000
W14x283	0.937	1.000	0.953	1.000	0.974	1.000	1.000	1.000	1.032	1.000
W14x257	0.936	1.000	0.952	1.000	0.973	1.000	1.000	1.000	1.033	1.000
W14x233	0.935	1.000	0.951	1.000	0.973	1.000	1.000	1.000	1.033	1.000
W14x211	0.934	1.000	0.950	1.000	0.972	1.000	1.000	1.000	1.034	1.000
W14x193	0.933	1.000	0.950	1.000	0.972	1.000	1.000	1.000	1.034	1.000
W14x176	0.932	1.000	0.949	1.000	0.972	1.000	1.000	1.000	1.034	1.000
W14x159	0.931	1.000	0.949	1.000	0.971	1.000	1.000	1.000	1.035	1.000
W14x145	0.931	1.000	0.948	1.000	0.971	1.000	1.000	1.000	1.035	1.000
W14x132	0.923	1.000	0.942	1.000	0.968	1.000	1.000	1.000	1.039	1.006
W14x120	0.922	1.000	0.942	1.000	0.967	1.000	1.000	1.000	1.040	1.007
W14x109	0.922	1.000	0.941	1.000	0.967	1.000	1.000	1.000	1.040	1.008
W14x99	0.921	1.000	0.941	1.000	0.967	1.000	1.000	1.000	1.041	1.000
W14x90	0.920	1.000	0.940	1.000	0.967	1.000	1.000	1.000	1.041	1.000
W14x82	0.831	0.955	0.872	0.955	0.927	0.971	1.000	1.000	1.093	1.030
W14x74	0.831	0.951	0.872	0.951	0.927	0.969	1.000	1.000	1.093	1.033
W14x68	0.829	0.947	0.870	0.947	0.926	0.967	1.000	1.000	1.095	1.035
W14x61	0.827	0.943	0.869	0.943	0.926	0.965	1.000	1.000	1.096	1.037
W14x53	0.735	0.888	0.796	0.912	0.882	0.954	1.000	1.000	1.160	1.051
W14x48	0.732	0.880	0.794	0.906	0.881	0.951	1.000	1.000	1.162	1.055
W12x336	0.910	1.000	0.932	1.000	0.962	1.000	1.000	1.000	1.047	1.005
W12x305	0.907	1.000	0.931	1.000	0.961	1.000	1.000	1.000	1.048	1.006
W12x279	0.905	1.000	0.929	1.000	0.960	1.000	1.000	1.000	1.049	1.007
W12x252	0.903	0.999	0.927	0.999	0.959	0.999	1.000	1.000	1.050	1.008
W12x230	0.901	0.999	0.926	0.999	0.959	0.999	1.000	1.000	1.051	1.008
W12x210	0.900	0.998	0.925	0.998	0.958	0.998	1.000	1.000	1.052	1.009
W12x190	0.898	0.997	0.923	0.997	0.957	0.997	1.000	1.000	1.053	1.010
W12x170	0.896	0.997	0.922	0.997	0.956	0.997	1.000	1.000	1.054	1.011
W12x152	0.894	0.996	0.921	0.996	0.955	0.996	1.000	1.000	1.055	1.012
W12x136	0.892	0.994	0.919	0.994	0.955	0.994	1.000	1.000	1.056	1.014
W12x120	0.890	0.993	0.918	0.993	0.954	0.993	1.000	1.000	1.057	1.016
W12x106	0.889	0.991	0.917	0.991	0.953	0.991	1.000	1.000	1.058	1.018
W12x96	0.888	0.990	0.916	0.990	0.953	0.990	1.000	1.000	1.059	1.019
W12x87	0.886	0.988	0.915	0.988	0.952	0.988	1.000	1.000	1.060	1.021
W12x79	0.885	0.986	0.913	0.986	0.951	0.986	1.000	1.000	1.061	1.023
W12x72	0.884	0.985	0.913	0.985	0.951	0.985	1.000	1.000	1.061	1.025
W12x65	0.883	1.000	0.912	1.000	0.950	1.000	1.000	1.000	1.062	1.000
W12x58	0.835	0.952	0.875	0.952	0.929	0.969	1.000	1.000	1.091	1.033
W12x53	0.831	0.947	0.872	0.947	0.927	0.967	1.000	1.000	1.093	1.036
W12x50	0.744	0.902	0.803	0.921	0.886	0.959	1.000	1.000	1.153	1.045
W12x45	0.739	0.893	0.799	0.914	0.884	0.955	1.000	1.000	1.157	1.049
W12x40	0.737	0.884	0.798	0.908	0.883	0.952	1.000	1.000	1.158	1.053
W10x112	0.854	0.983	0.889	0.983	0.938	0.987	1.000	1.000	1.079	1.014
W10x100	0.851	0.980	0.887	0.980	0.936	0.985	1.000	1.000	1.081	1.016
W10x88	0.848	0.977	0.885	0.977	0.935	0.983	1.000	1.000	1.082	1.018
W10x77	0.845	0.973	0.883	0.973	0.934	0.981	1.000	1.000	1.084	1.020
W10x68	0.844	0.969	0.882	0.969	0.933	0.978	1.000	1.000	1.085	1.023
W10x60	0.842	0.965	0.880	0.965	0.932	0.976	1.000	1.000	1.086	1.026
W10x54	0.841	0.961	0.879	0.961	0.932	0.973	1.000	1.000	1.087	1.028
W10x49	0.838	0.957	0.878	0.957	0.931	0.971	1.000	1.000	1.089	1.031
W10x45	0.755	0.918	0.812	0.932	0.892	0.965	1.000	1.000	1.145	1.038
W10x39	0.748	0.906	0.807	0.923	0.889	0.960	1.000	1.000	1.150	1.044
W10x33	0.739	0.889	0.799	0.911	0.884	0.954	1.000	1.000	1.157	1.051
W8x67	0.776	0.959	0.829	0.964	0.902	0.981	1.000	1.000	1.130	1.019
W8x58	0.773	0.953	0.826	0.958	0.900	0.979	1.000	1.000	1.132	1.022
W8x48	0.769	0.943	0.823	0.950	0.898	0.974	1.000	1.000	1.135	1.027
W8x40	0.761	0.929	0.817	0.940	0.895	0.969	1.000	1.000	1.141	1.033
W8x35	0.759	0.920	0.815	0.933	0.894	0.965	1.000	1.000	1.142	1.037
W8x31	0.757	0.912	0.813	0.926	0.893	0.962	1.000	1.000	1.144	1.042
W8x28	0.648	0.869	0.725	0.909	0.838	0.952	1.000	1.000	1.232	1.053
W8x24	0.645	0.854	0.723	0.897	0.836	0.946	1.000	1.000	1.235	1.061
W6x25	0.611	0.886	0.694	0.921	0.818	0.959	1.000	1.000	1.267	1.045
W6x20	0.603	0.862	0.688	0.903	0.814	0.949	1.000	1.000	1.275	1.057

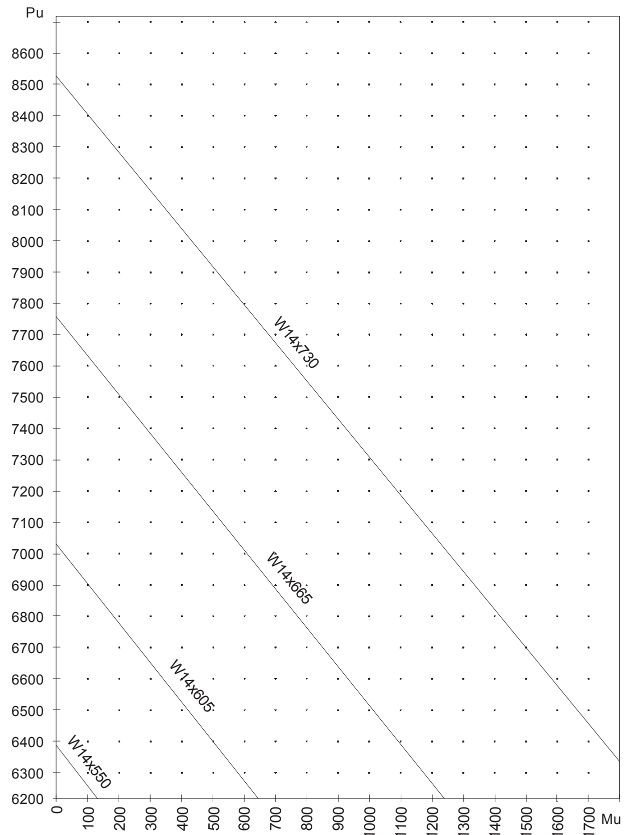
APPENDIX C—B_{KL} AND B_{LM} VALUES (50 ksi) (cont'd)

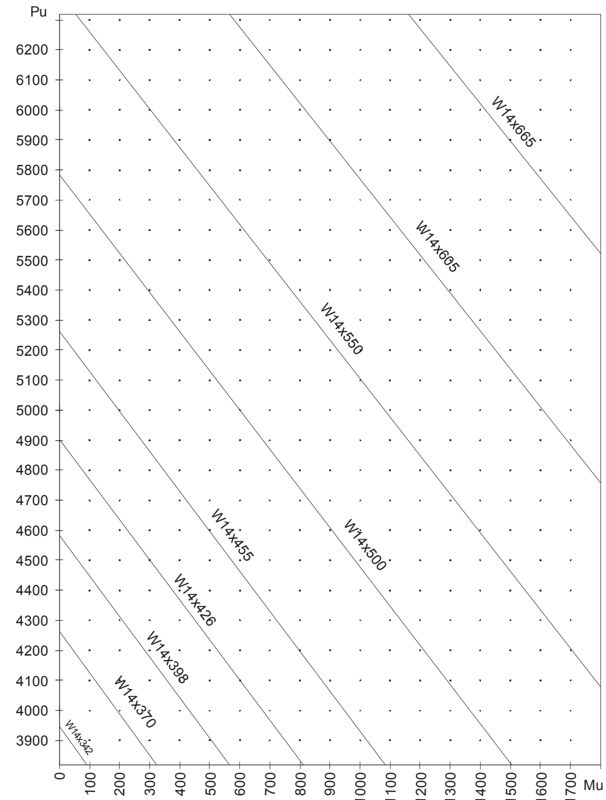
	B_{KL} and B_{LM} Values (50 ksi)									
	KL (ft)									
	6.00		8.00		10.00		12.00		14.00	
Shape	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}	B_{KL}	B_{LM}
W14x730	0.950	1.000	0.962	1.000	0.979	1.000	1.000	1.000	1.025	1.000
W14x665	0.948	1.000	0.961	1.000	0.979	1.000	1.000	1.000	1.026	1.000
W14x605	0.947	1.000	0.960	1.000	0.978	1.000	1.000	1.000	1.027	1.000
W14x550	0.945	1.000	0.959	1.000	0.977	1.000	1.000	1.000	1.028	1.000
W14x500	0.944	1.000	0.958	1.000	0.977	1.000	1.000	1.000	1.028	1.000
W14x455	0.942	1.000	0.957	1.000	0.976	1.000	1.000	1.000	1.029	1.000
W14x426	0.941	1.000	0.956	1.000	0.976	1.000	1.000	1.000	1.029	1.000
W14x398	0.941	1.000	0.956	1.000	0.975	1.000	1.000	1.000	1.030	1.000
W14x370	0.940	1.000	0.955	1.000	0.975	1.000	1.000	1.000	1.030	1.000
W14x342	0.939	1.000	0.954	1.000	0.975	1.000	1.000	1.000	1.031	1.000
W14x311	0.938	1.000	0.953	1.000	0.974	1.000	1.000	1.000	1.032	1.000
W14x283	0.937	1.000	0.953	1.000	0.974	1.000	1.000	1.000	1.032	1.000
W14x257	0.936	1.000	0.952	1.000	0.973	1.000	1.000	1.000	1.033	1.000
W14x233	0.935	1.000	0.951	1.000	0.973	1.000	1.000	1.000	1.033	1.000
W14x211	0.934	1.000	0.950	1.000	0.972	1.000	1.000	1.000	1.034	1.000
W14x193	0.933	1.000	0.950	1.000	0.972	1.000	1.000	1.000	1.034	1.000
W14x176	0.932	1.000	0.949	1.000	0.972	1.000	1.000	1.000	1.034	1.000
W14x159	0.931	1.000	0.949	1.000	0.971	1.000	1.000	1.000	1.035	1.000
W14x145	0.931	1.000	0.948	1.000	0.971	1.000	1.000	1.000	1.035	1.000
W14x132	0.923	1.000	0.942	1.000	0.968	1.000	1.000	1.000	1.039	1.006
W14x120	0.922	1.000	0.942	1.000	0.967	1.000	1.000	1.000	1.040	1.007
W14x109	0.922	1.000	0.941	1.000	0.967	1.000	1.000	1.000	1.040	1.008
W14x99	0.921	1.000	0.941	1.000	0.967	1.000	1.000	1.000	1.041	1.000
W14x90	0.920	1.000	0.940	1.000	0.967	1.000	1.000	1.000	1.041	1.000
W14x82	0.831	0.955	0.872	0.955	0.927	0.971	1.000	1.000	1.093	1.030
W14x74	0.831	0.951	0.872	0.951	0.927	0.969	1.000	1.000	1.093	1.033
W14x68	0.829	0.947	0.870	0.947	0.926	0.967	1.000	1.000	1.095	1.035
W14x61	0.827	0.943	0.869	0.943	0.926	0.965	1.000	1.000	1.096	1.037
W14x53	0.735	0.888	0.796	0.912	0.882	0.954	1.000	1.000	1.160	1.051
W14x48	0.732	0.880	0.794	0.906	0.881	0.951	1.000	1.000	1.162	1.055
W12x336	0.910	1.000	0.932	1.000	0.962	1.000	1.000	1.000	1.047	1.005
W12x305	0.907	1.000	0.931	1.000	0.961	1.000	1.000	1.000	1.048	1.006
W12x279	0.905	1.000	0.929	1.000	0.960	1.000	1.000	1.000	1.049	1.007
W12x252	0.903	0.999	0.927	0.999	0.959	0.999	1.000	1.000	1.050	1.008
W12x230	0.901	0.999	0.926	0.999	0.959	0.999	1.000	1.000	1.051	1.008
W12x210	0.900	0.998	0.925	0.998	0.958	0.998	1.000	1.000	1.052	1.009
W12x190	0.898	0.997	0.923	0.997	0.957	0.997	1.000	1.000	1.053	1.010
W12x170	0.896	0.997	0.922	0.997	0.956	0.997	1.000	1.000	1.054	1.011
W12x152	0.894	0.996	0.921	0.996	0.955	0.996	1.000	1.000	1.055	1.012
W12x136	0.892	0.994	0.919	0.994	0.955	0.994	1.000	1.000	1.056	1.014
W12x120	0.890	0.993	0.918	0.993	0.954	0.993	1.000	1.000	1.057	1.016
W12x106	0.889	0.991	0.917	0.991	0.953	0.991	1.000	1.000	1.058	1.018
W12x96	0.888	0.990	0.916	0.990	0.953	0.990	1.000	1.000	1.059	1.019
W12x87	0.886	0.988	0.915	0.988	0.952	0.988	1.000	1.000	1.060	1.021
W12x79	0.885	0.986	0.913	0.986	0.951	0.986	1.000	1.000	1.061	1.023
W12x72	0.884	0.985	0.913	0.985	0.951	0.985	1.000	1.000	1.061	1.025
W12x65	0.883	1.000	0.912	1.000	0.950	1.000	1.000	1.000	1.062	1.000
W12x58	0.835	0.952	0.875	0.952	0.929	0.969	1.000	1.000	1.091	1.033
W12x53	0.831	0.947	0.872	0.947	0.927	0.967	1.000	1.000	1.093	1.036
W12x50	0.744	0.902	0.803	0.921	0.886	0.959	1.000	1.000	1.153	1.045
W12x45	0.739	0.893	0.799	0.914	0.884	0.955	1.000	1.000	1.157	1.049
W12x40	0.737	0.884	0.798	0.908	0.883	0.952	1.000	1.000	1.158	1.053
W10x112	0.854	0.983	0.889	0.983	0.938	0.987	1.000	1.000	1.079	1.014
W10x100	0.851	0.980	0.887	0.980	0.936	0.985	1.000	1.000	1.081	1.016
W10x88	0.848	0.977	0.885	0.977	0.935	0.983	1.000	1.000	1.082	1.018
W10x77	0.845	0.973	0.883	0.973	0.934	0.981	1.000	1.000	1.084	1.020
W10x68	0.844	0.969	0.882	0.969	0.933	0.978	1.000	1.000	1.085	1.023
W10x60	0.842	0.965	0.880	0.965	0.932	0.976	1.000	1.000	1.086	1.026
W10x54	0.841	0.961	0.879	0.961	0.932	0.973	1.000	1.000	1.087	1.028
W10x49	0.838	0.957	0.878	0.957	0.931	0.971	1.000	1.000	1.089	1.031
W10x45	0.755	0.918	0.812	0.932	0.892	0.965	1.000	1.000	1.145	1.038
W10x39	0.748	0.906	0.807	0.923	0.889	0.960	1.000	1.000	1.150	1.044
W10x33	0.739	0.889	0.799	0.911	0.884	0.954	1.000	1.000	1.157	1.051
W8x67	0.776	0.959	0.829	0.964	0.902	0.981	1.000	1.000	1.130	1.019
W8x58	0.773	0.953	0.826	0.958	0.900	0.979	1.000	1.000	1.132	1.022
W8x48	0.769	0.943	0.823	0.950	0.898	0.974	1.000	1.000	1.135	1.027
W8x40	0.761	0.929	0.817	0.940	0.895	0.969	1.000	1.000	1.141	1.033
W8x35	0.759	0.920	0.815	0.933	0.894	0.965	1.000	1.000	1.142	1.037
W8x31	0.757	0.912	0.813	0.926	0.893	0.962	1.000	1.000	1.144	1.042
W8x28	0.648	0.869	0.725	0.909	0.838	0.952	1.000	1.000	1.232	1.053
W8x24	0.645	0.854	0.723	0.897	0.836	0.946	1.000	1.000	1.235	1.061
W6x25	0.611	0.886	0.694	0.921	0.818	0.959	1.000	1.000	1.267	1.045
W6x20	0.603	0.862	0.688	0.903	0.814	0.949	1.000	1.000	1.275	1.057

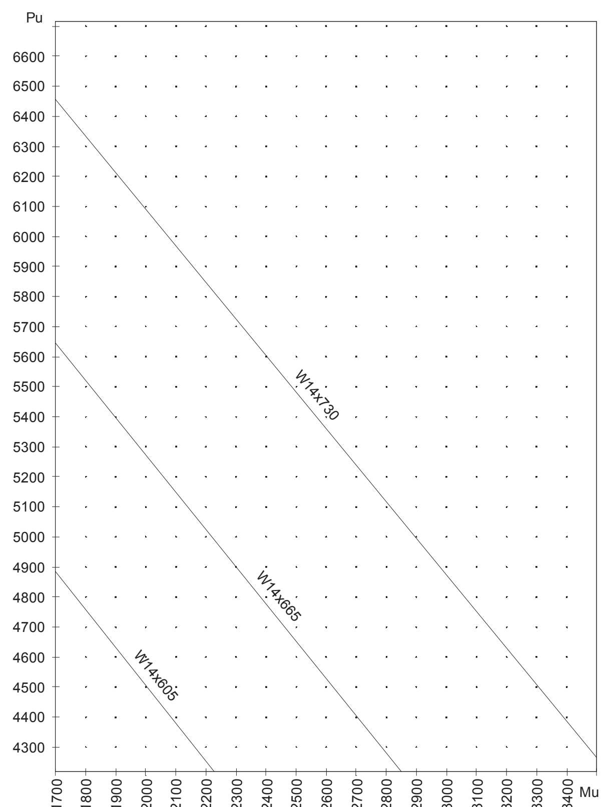
APPENDIX C—B_{KL} AND B_{LM} VALUES (50 ksi) (cont'd)

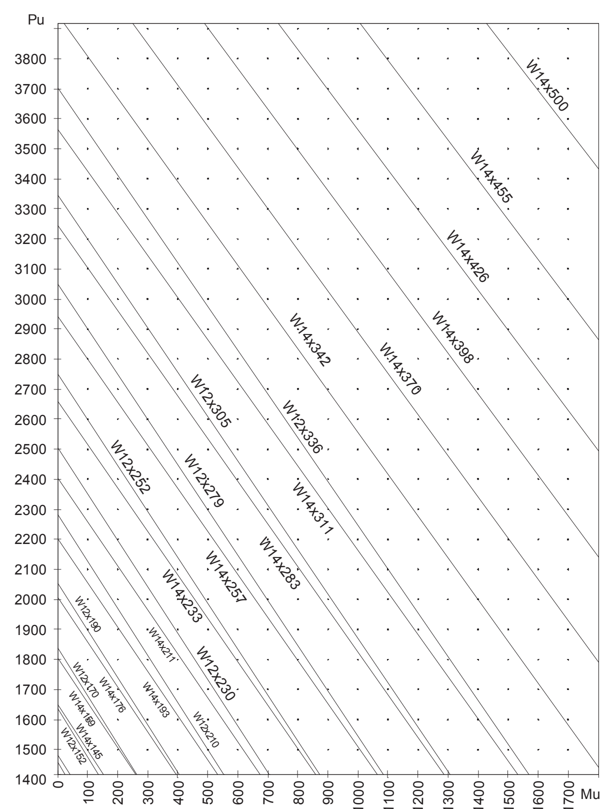
	B_{KL} and B_{LM} Values (50 ksi)			
	KL (ft)			
	36.00		38.00	
Shape	B_{KL}	B_{LM}	B_{KL}	B_{LM}
W14x730	1.736	1.034	1.863	1.038
W14x665	1.765	1.038	1.899	1.042
W14x605	1.797	1.041	1.937	1.045
W14x550	1.825	1.045	1.972	1.050
W14x500	1.855	1.050	2.009	1.055
W14x455	1.882	1.054	2.041	1.059
W14x426	1.904	1.058	2.068	1.064
W14x398	1.921	1.062	2.089	1.068
W14x370	1.945	1.066	2.118	1.073
W14x342	1.963	1.071	2.141	1.079
W14x311	1.989	1.079	2.173	1.087
W14x283	2.009	1.087	2.197	1.096
W14x257	2.036	1.097	2.231	1.107
W14x233	2.058	1.108	2.257	1.119
W14x211	2.080	1.120	2.285	1.133
W14x193	2.095	1.133	2.304	1.147
W14x176	2.118	1.148	2.333	1.164
W14x159	2.134	1.166	2.355	1.184
W14x145	2.151	1.183	2.376	1.203
W14x132	2.362	1.217	2.632	1.241
W14x120	2.385	1.243	2.657	1.270
W14x109	2.396	1.269	2.670	1.300
W14x99	2.419	1.000	2.695	1.000
W14x90	2.431	1.000	2.708	1.000
W14x82	4.724	1.699	5.263	1.807
W14x74	4.724	1.820	5.263	1.938
W14x68	4.781	1.949	5.328	2.078
W14x61	4.811	2.103	5.360	2.246
W14x53	6.684	2.575	7.447	2.739
W14x48	6.725	2.767	7.493	2.947
W12x336	2.722	1.077	3.033	1.084
W12x305	2.792	1.085	3.111	1.093
W12x279	2.850	1.093	3.175	1.101
W12x252	2.909	1.103	3.241	1.112
W12x230	2.955	1.111	3.292	1.122
W12x210	3.001	1.122	3.344	1.134
W12x190	3.049	1.136	3.397	1.149
W12x170	3.098	1.153	3.451	1.167
W12x152	3.147	1.174	3.507	1.191
W12x136	3.198	1.198	3.564	1.218
W12x120	3.250	1.228	3.622	1.252
W12x106	3.286	1.265	3.661	1.293
W12x96	3.322	1.297	3.701	1.330
W12x87	3.358	1.336	3.742	1.374
W12x79	3.395	1.386	3.783	1.479
W12x72	3.414	1.487	3.804	1.589
W12x65	3.452	1.598	3.846	1.710
W12x58	4.638	1.882	5.168	2.006
W12x53	4.724	2.021	5.263	2.158
W12x50	6.521	2.318	7.266	2.463
W12x45	6.602	2.519	7.356	2.679
W12x40	6.643	2.736	7.401	2.913
W10x112	4.191	1.195	4.669	1.215
W10x100	4.266	1.225	4.753	1.249
W10x88	4.317	1.262	4.809	1.290
W10x77	4.394	1.312	4.896	1.347
W10x68	4.421	1.365	4.925	1.449
W10x60	4.474	1.509	4.985	1.603
W10x54	4.501	1.640	5.015	1.744
W10x49	4.555	1.769	5.075	1.884
W10x45	6.322	2.029	7.044	2.153
W10x39	6.441	2.281	7.177	2.423
W10x33	6.602	2.628	7.356	2.797
W8x67	5.903	1.293	6.577	1.325
W8x58	5.977	1.353	6.660	1.414
W8x48	6.052	1.562	6.743	1.653
W8x40	6.205	1.832	6.914	1.942
W8x35	6.244	2.024	6.957	2.148
W8x31	6.283	2.215	7.000	2.352
W8x28	7.949	2.521	8.857	2.671
W8x24	7.990	2.814	8.903	2.985
W6x25	8.347	2.210	9.301	2.337
W6x20	8.422	2.622	9.384	2.776

APPENDIX D—STANDARD GRAPHS OF INTERACTION DIAGRAMS
(P_u in kips, M_u in kip-ft)

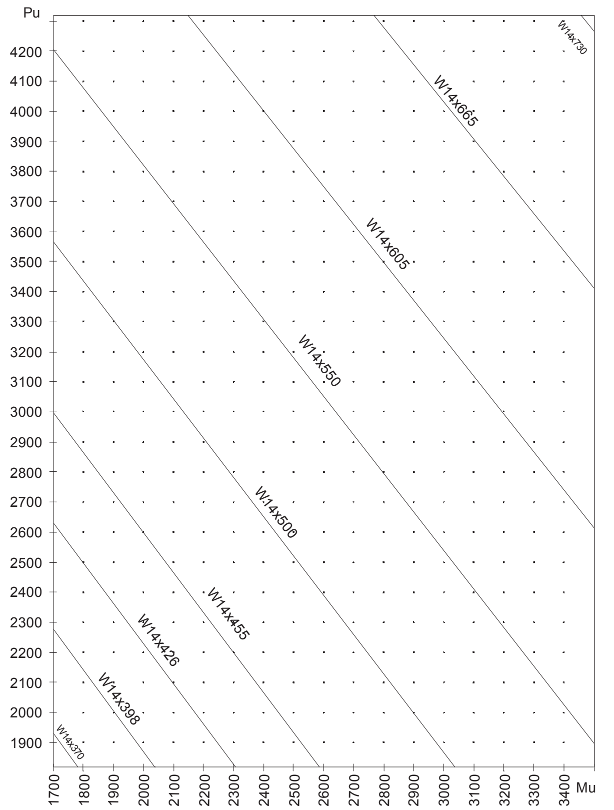


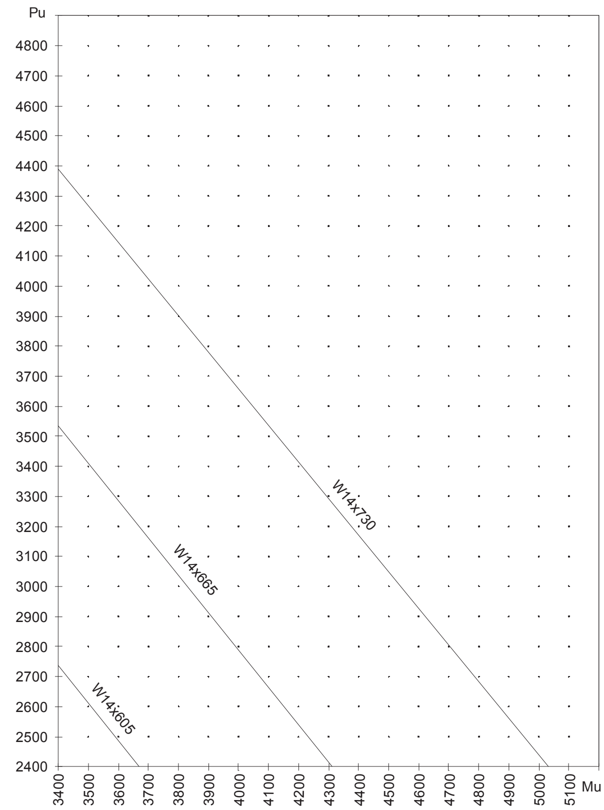


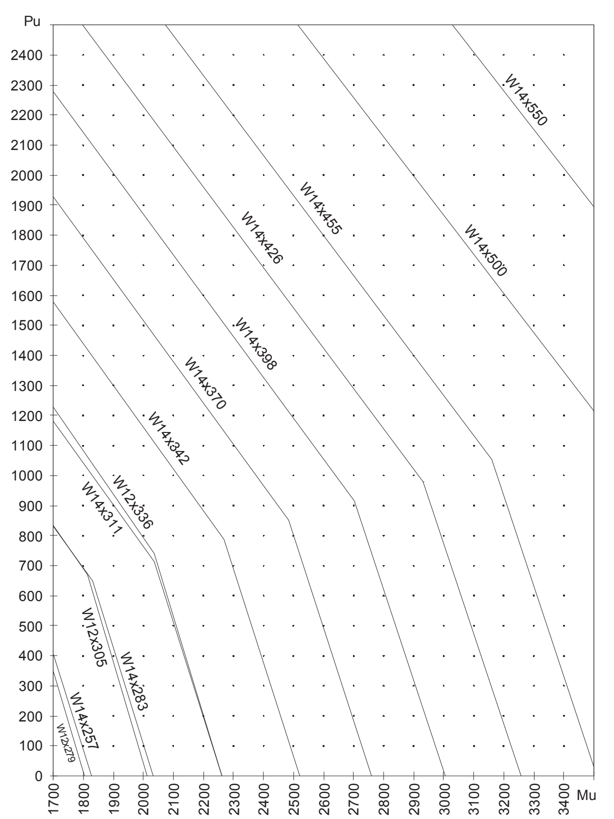


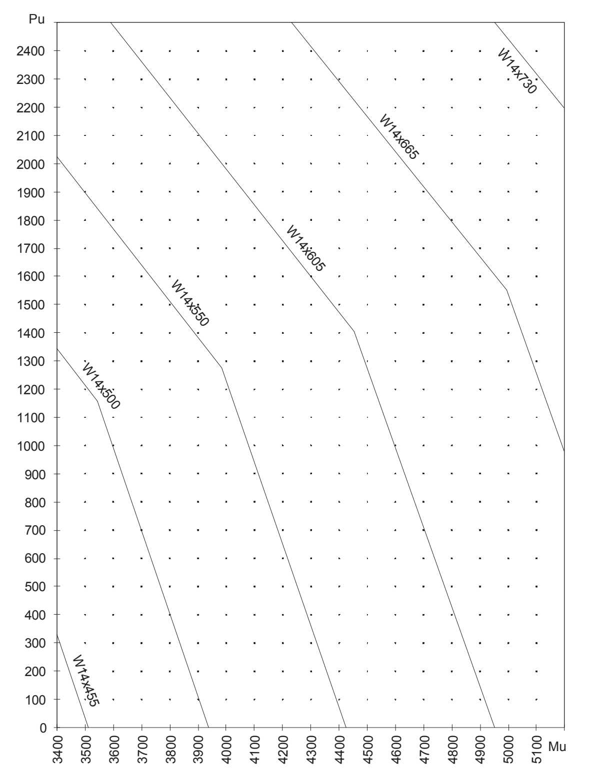


APPENDIX D—STANDARD GRAPHS OF INTERACTION DIAGRAMS (cont’d)
(P_u in kips, M_u in kip-ft)

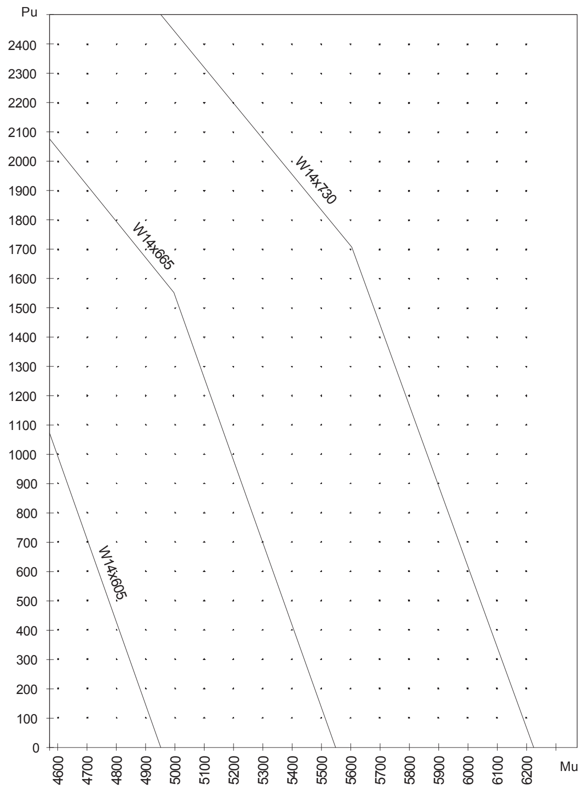


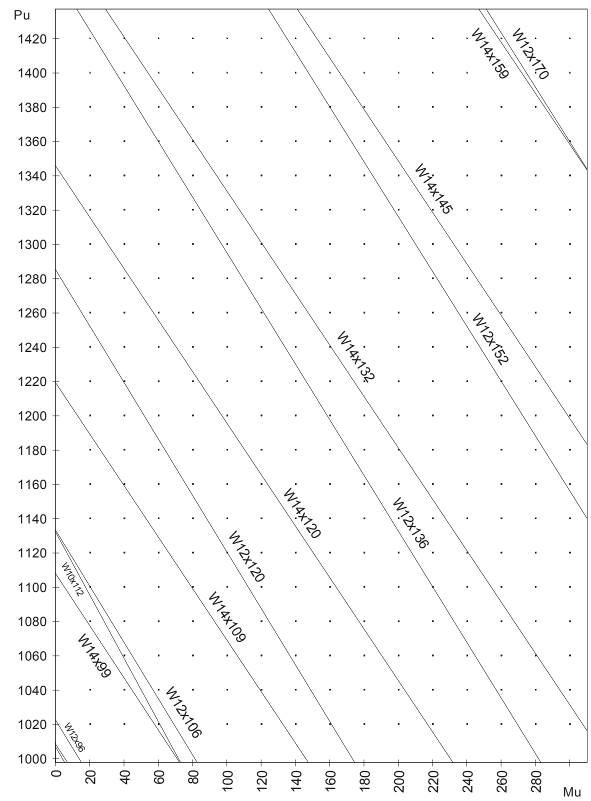


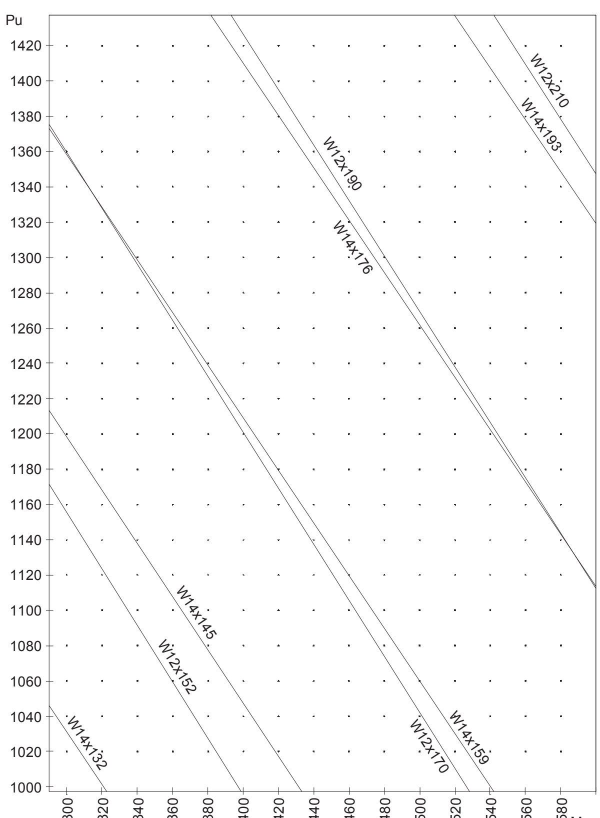


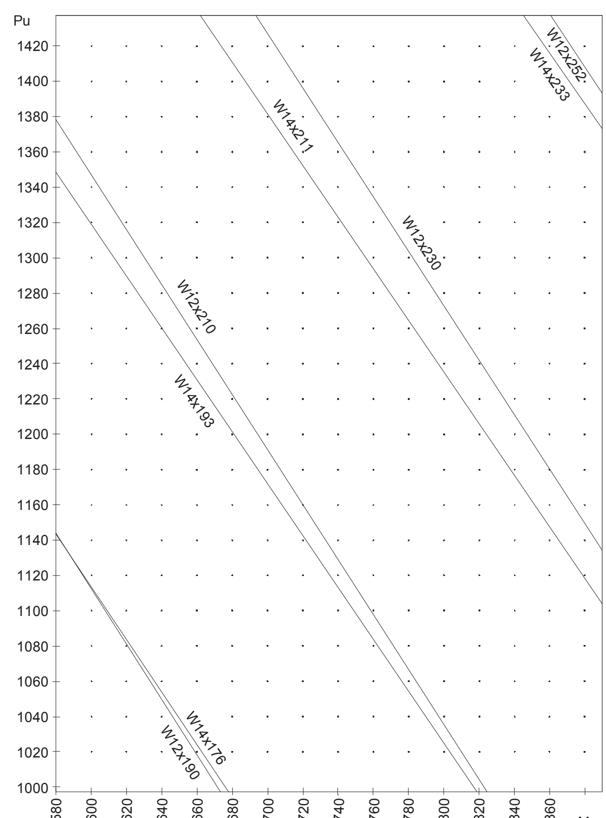


APPENDIX D—STANDARD GRAPHS OF INTERACTION DIAGRAMS (cont'd)
(P_u in kips, M_u in kip-ft)

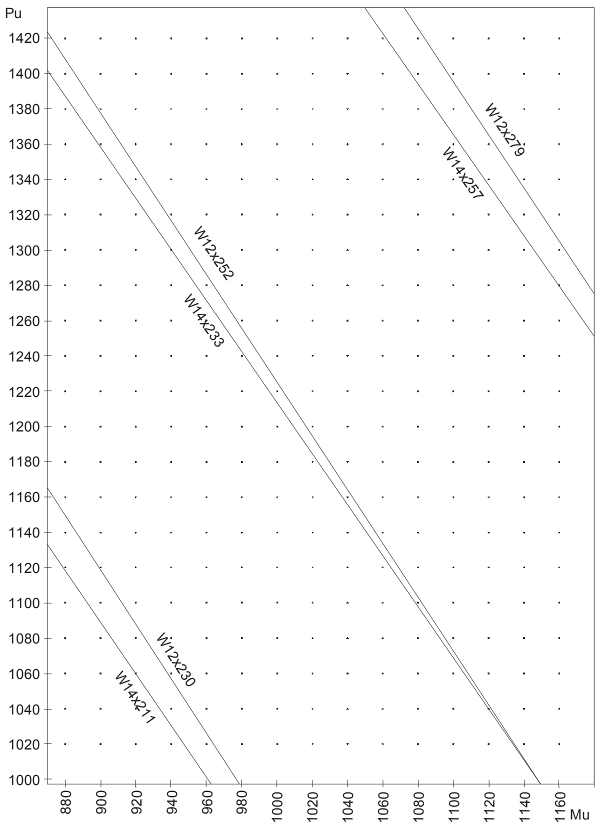


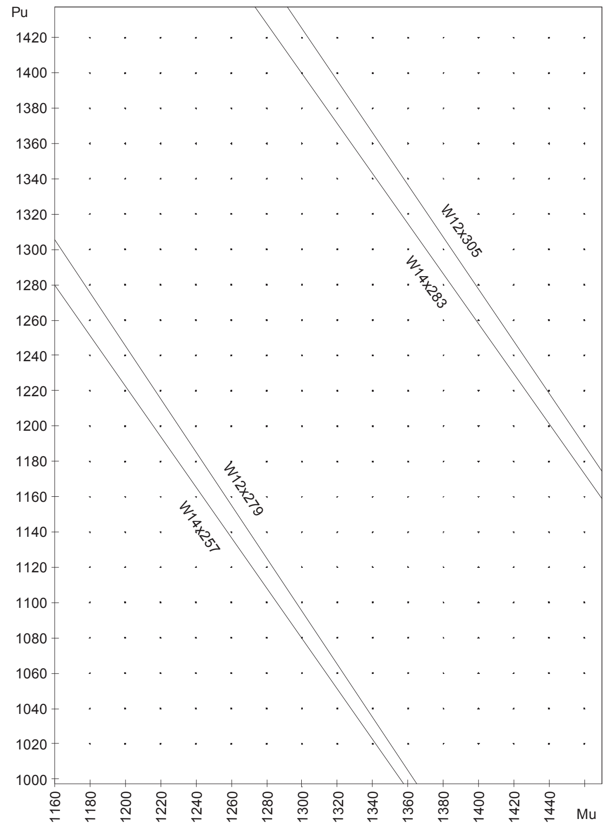


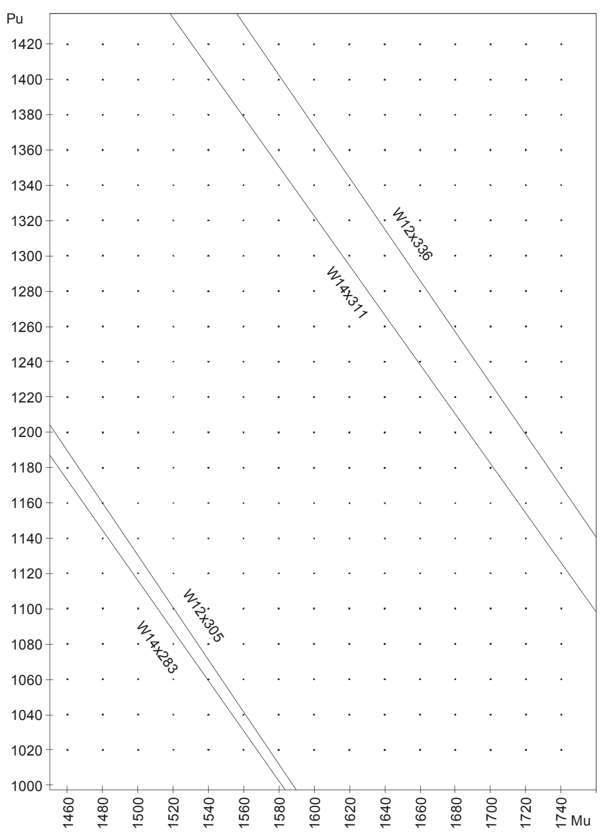


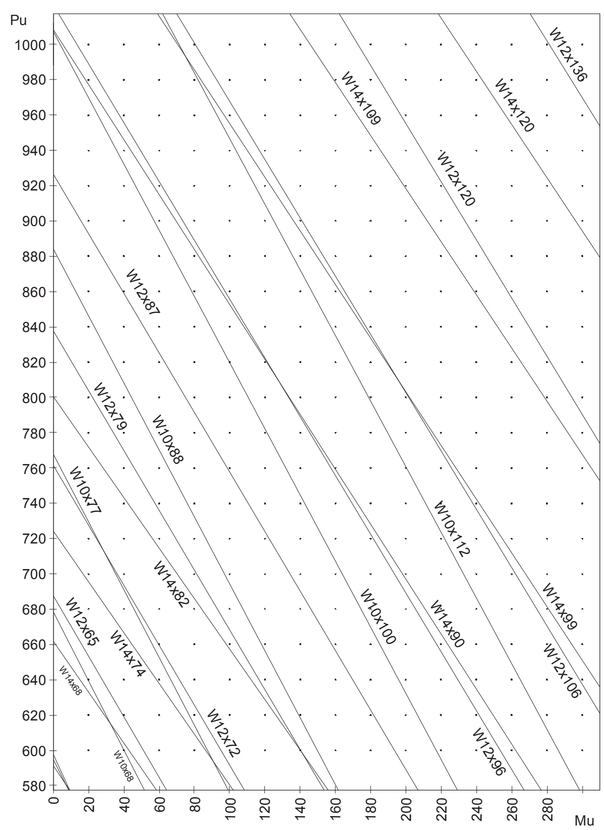


APPENDIX D—STANDARD GRAPHS OF INTERACTION DIAGRAMS (cont'd)
(P_u in kips, M_u in kip-ft)

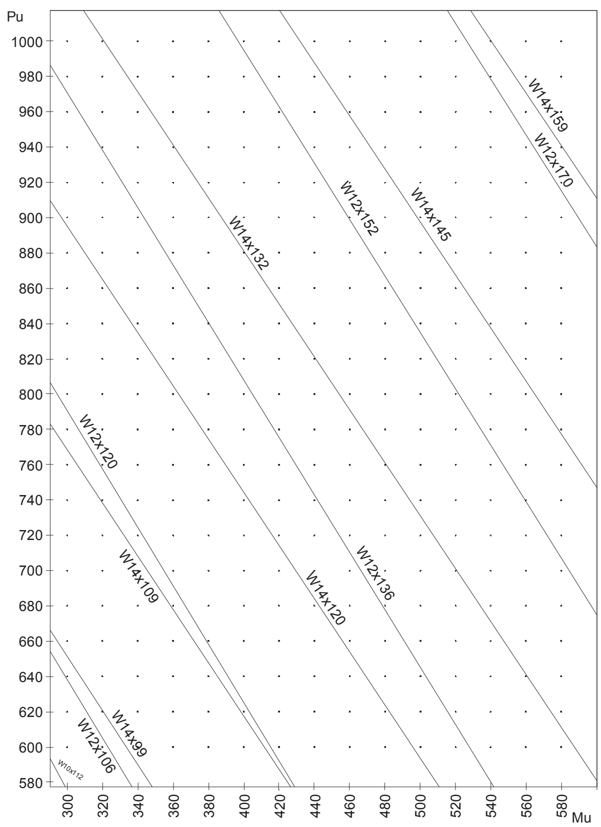


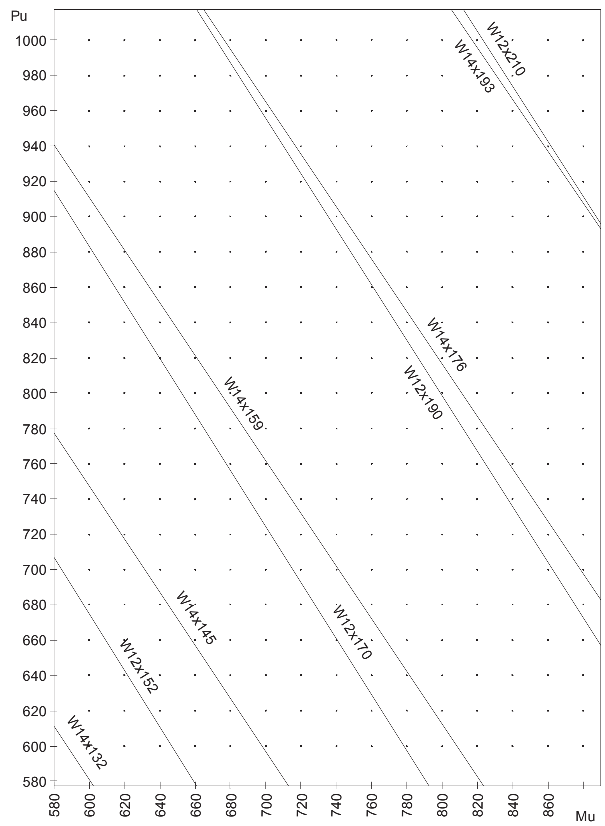


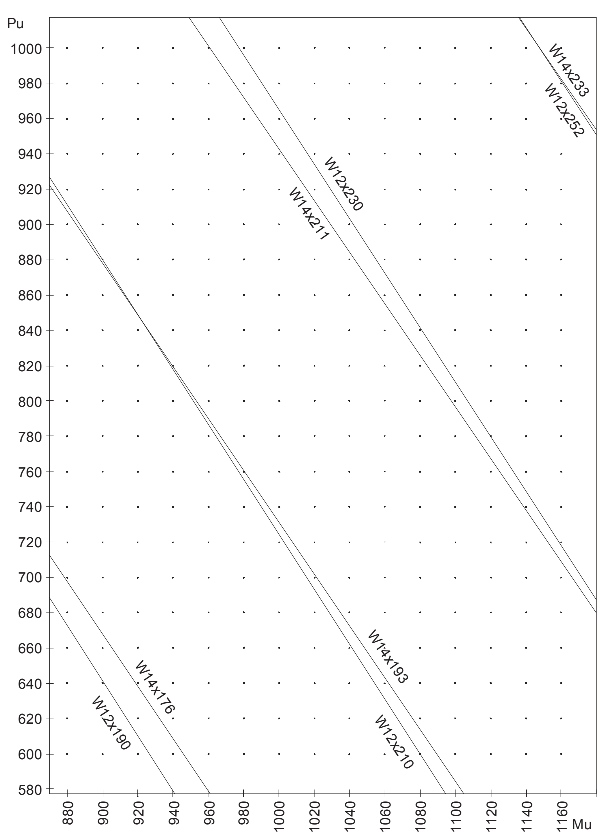


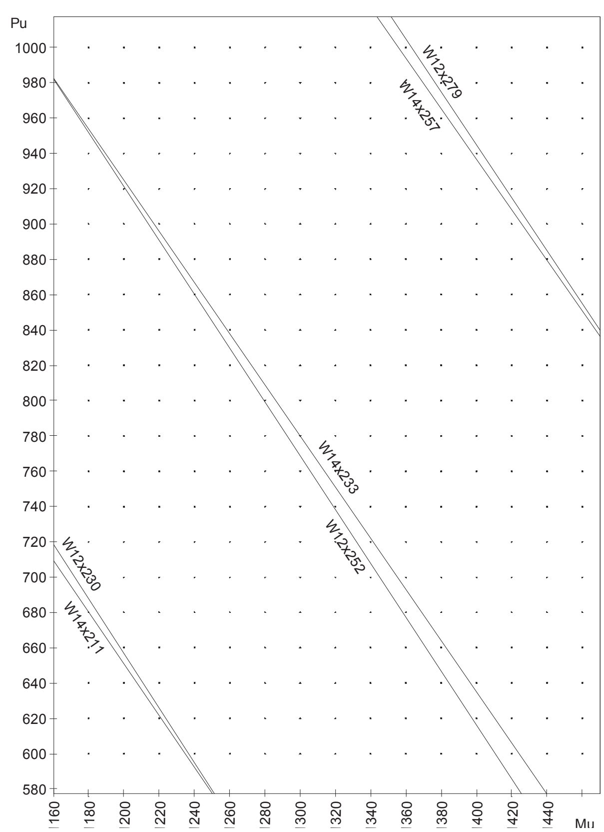


APPENDIX D—STANDARD GRAPHS OF INTERACTION DIAGRAMS (cont'd)
(P_u in kips, M_u in kip-ft)

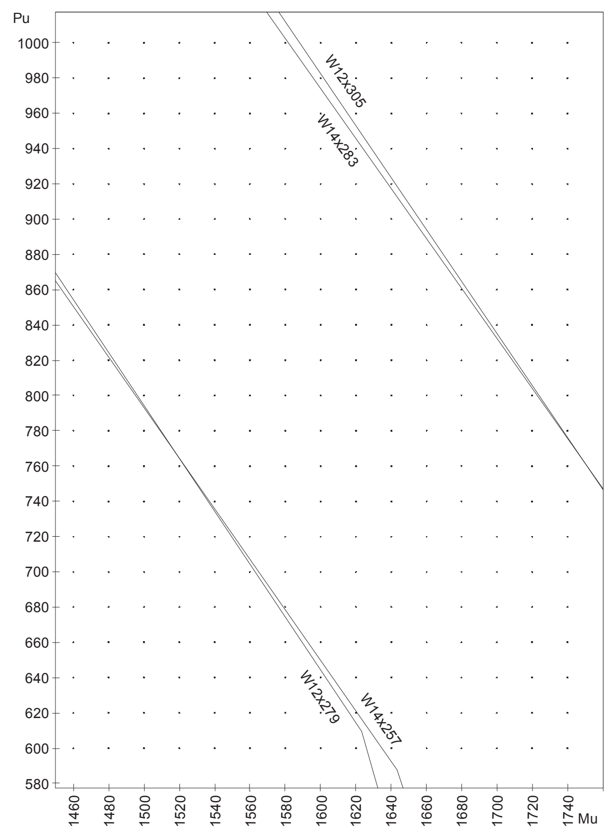


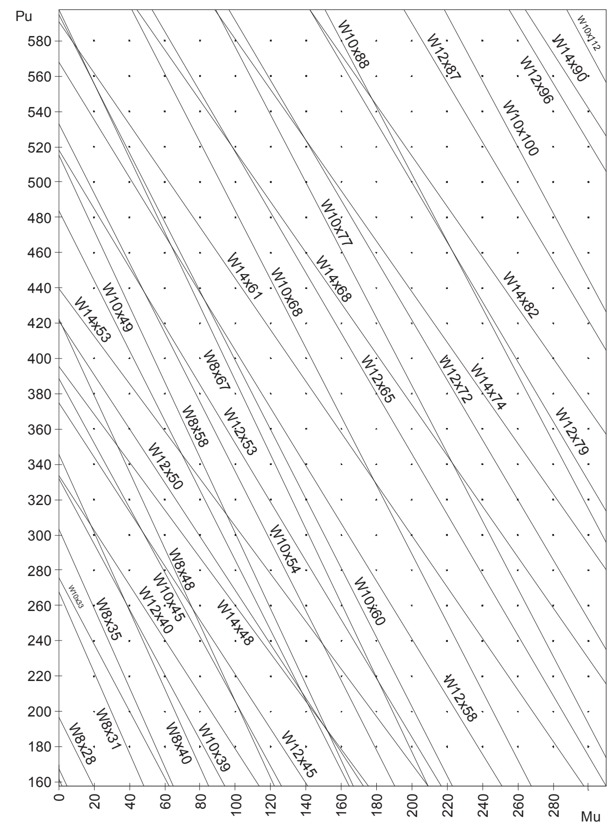


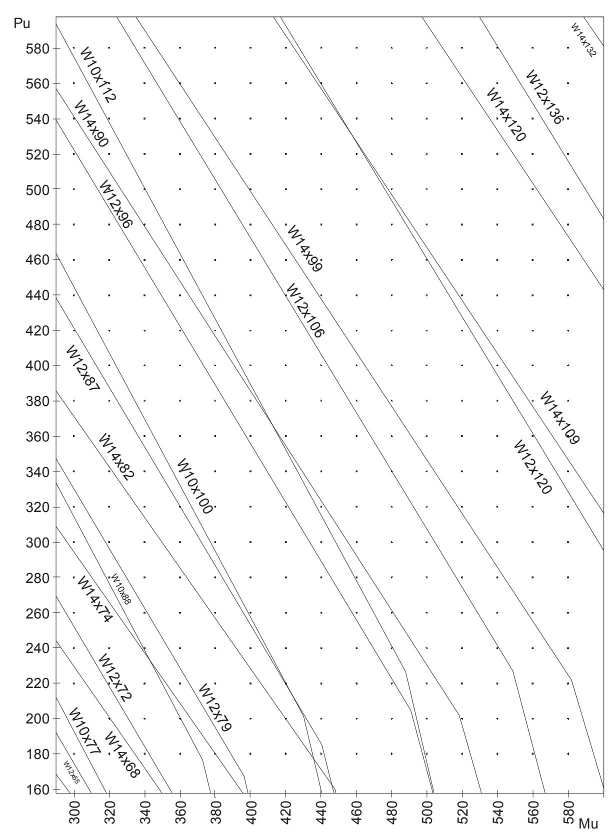


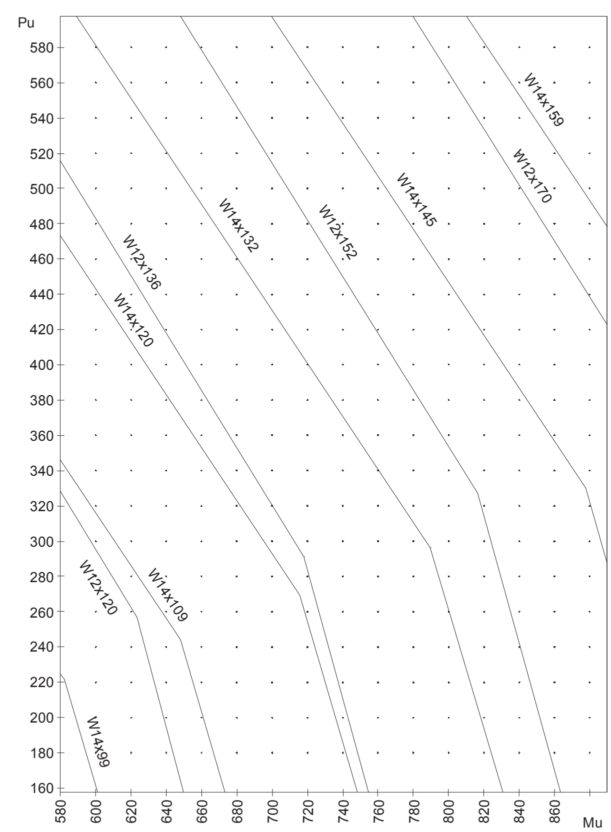


APPENDIX D—STANDARD GRAPHS OF INTERACTION DIAGRAMS (cont'd)
(P_u in kips, M_u in kip-ft)

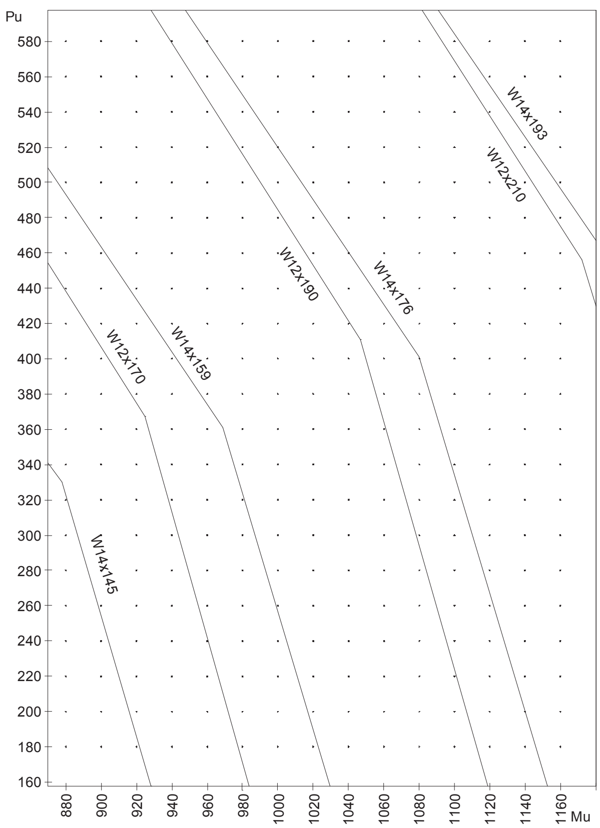


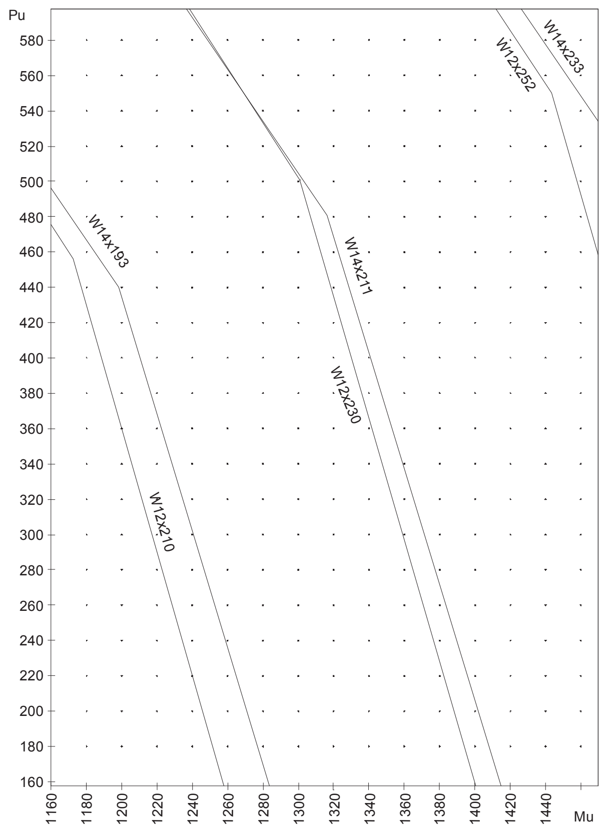


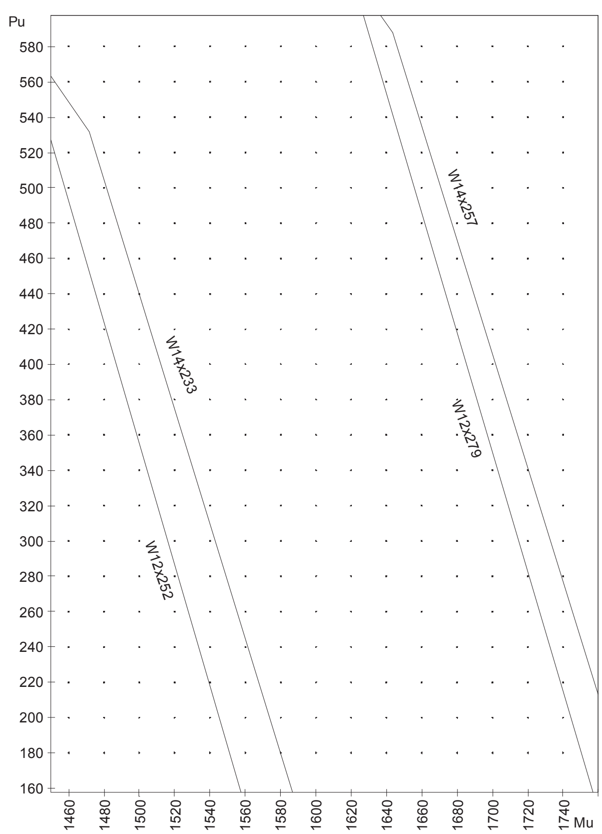


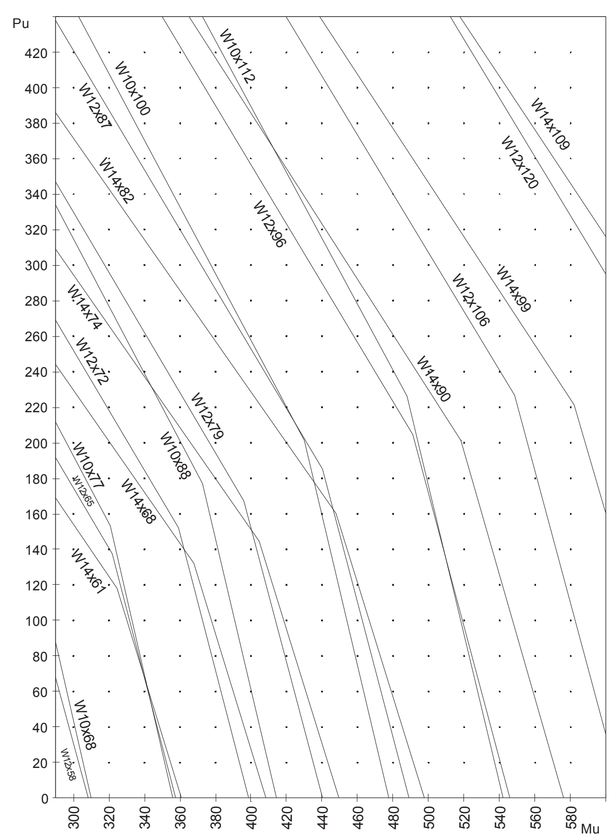


APPENDIX D—STANDARD GRAPHS OF INTERACTION DIAGRAMS (cont'd)
(P_u in kips, M_u in kip-ft)

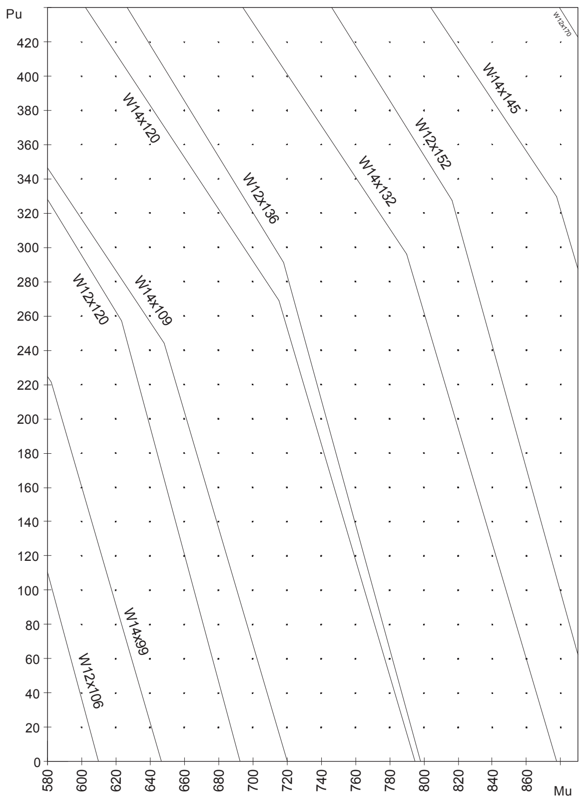


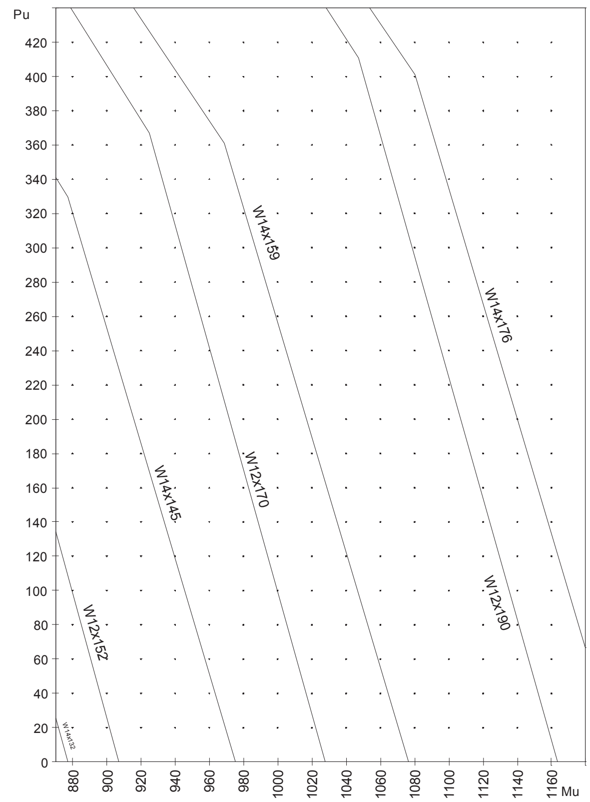


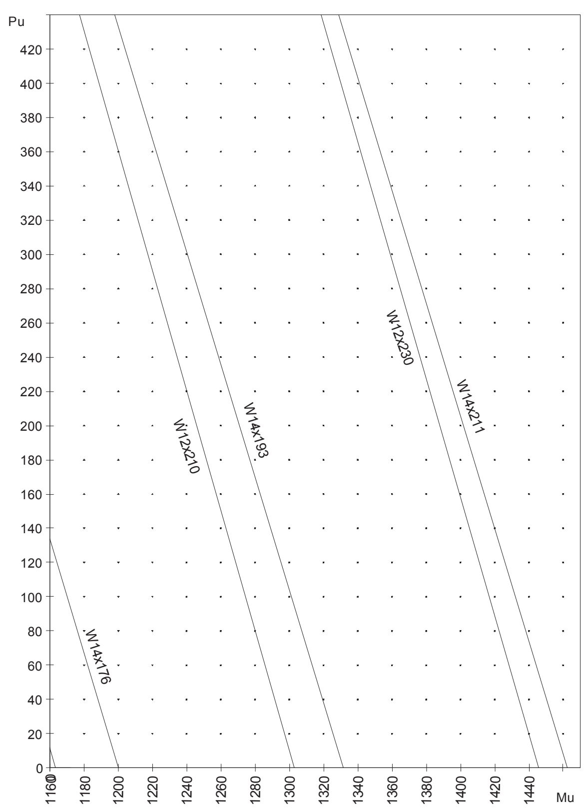


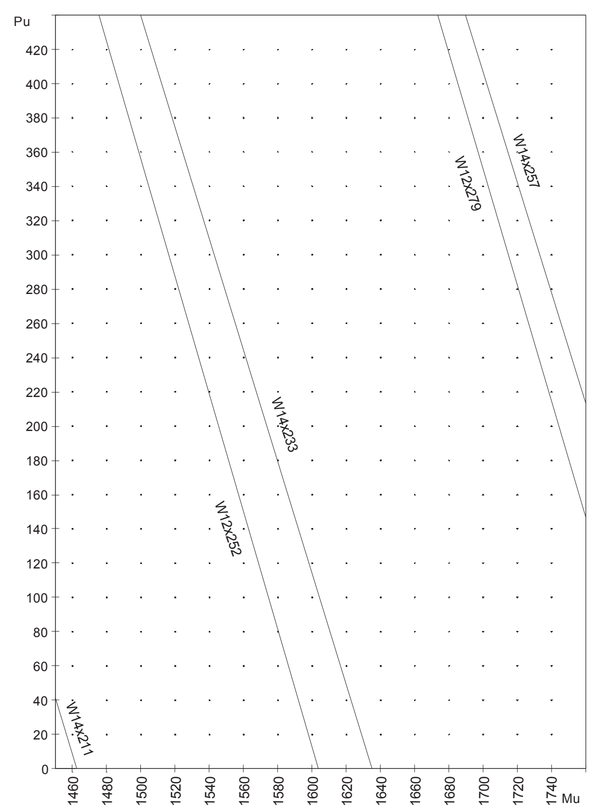


APPENDIX D—STANDARD GRAPHS OF INTERACTION DIAGRAMS (cont'd)
(P_u in kips, M_u in kip-ft)

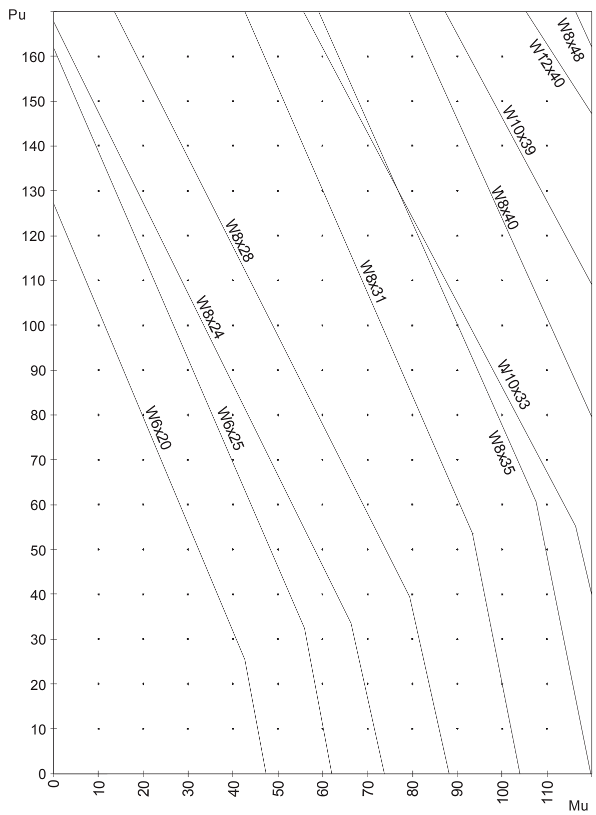


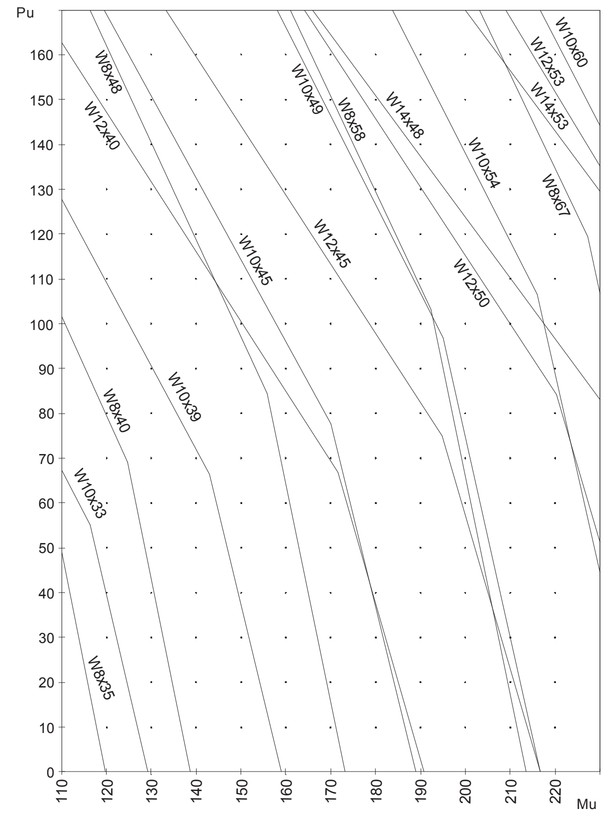


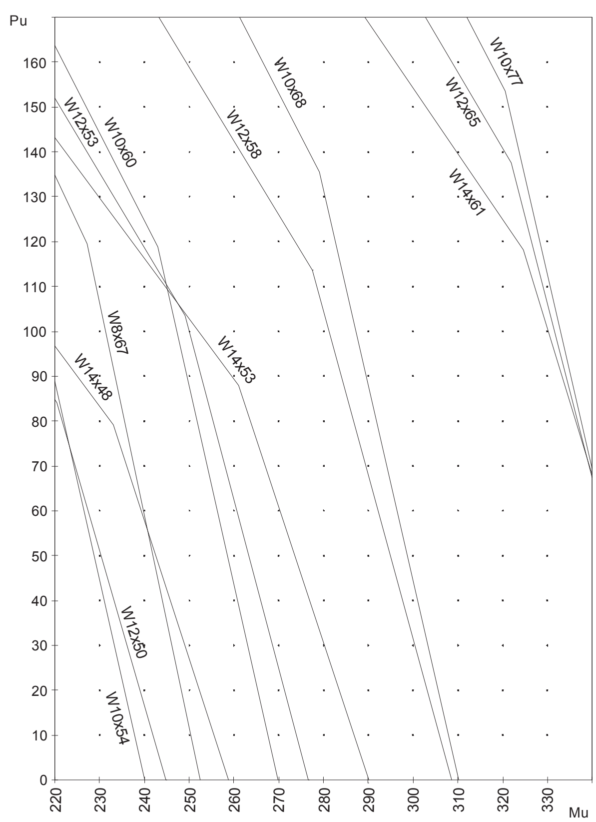




APPENDIX D—STANDARD GRAPHS OF INTERACTION DIAGRAMS (cont'd)
(P_u in kips, M_u in kip-ft)







APPENDIX E—*Kl/r* VERIFICATIONS

Shape	*Kl/r* Calculations										
	KL (ft)										
	6.00	8.00	10.00	12.00	14.00	16.00	18.00	20.00	22.00	24.00	26.00
W14x730	15.4	20.5	25.6	30.7	35.8	40.9	46.1	51.2	56.3	61.4	66.5
W14x665	15.6	20.8	26.0	31.2	36.4	41.6	46.8	51.9	57.1	62.3	67.5
W14x605	15.8	21.1	26.4	31.6	36.9	42.2	47.5	52.7	58.0	63.3	68.6
W14x550	16.0	21.4	26.7	32.1	37.4	42.8	48.1	53.5	58.8	64.1	69.5
W14x500	16.3	21.7	27.1	32.5	37.9	43.3	48.8	54.2	59.6	65.0	70.4
W14x455	16.4	21.9	27.4	32.9	38.4	43.8	49.3	54.8	60.3	65.8	71.2
W14x426	16.6	22.1	27.6	33.2	38.7	44.2	49.8	55.3	60.8	66.4	71.9
W14x398	16.7	22.3	27.8	33.4	39.0	44.5	50.1	55.7	61.3	66.8	72.4
W14x370	16.9	22.5	28.1	33.7	39.3	45.0	50.6	56.2	61.8	67.4	73.1
W14x342	17.0	22.6	28.3	34.0	39.6	45.3	50.9	56.6	62.3	67.9	73.6
W14x311	17.1	22.9	28.6	34.3	40.0	45.7	51.4	57.1	62.9	68.6	74.3
W14x283	17.3	23.0	28.8	34.5	40.3	46.0	51.8	57.6	63.3	69.1	74.8
W14x257	17.4	23.2	29.1	34.9	40.7	46.5	52.3	58.1	63.9	69.7	75.5
W14x233	17.6	23.4	29.3	35.1	41.0	46.8	52.7	58.5	64.4	70.2	76.1
W14x211	17.7	23.6	29.5	35.4	41.3	47.2	53.1	59.0	64.9	70.8	76.7
W14x193	17.8	23.7	29.6	35.6	41.5	47.4	53.3	59.3	65.2	71.1	77.0
W14x176	17.9	23.9	29.9	35.8	41.8	47.8	53.7	59.7	65.7	71.6	77.6
W14x159	18.0	24.0	30.0	36.0	42.0	48.0	54.0	60.0	66.0	72.0	78.0
W14x145	18.1	24.1	30.2	36.2	42.2	48.2	54.3	60.3	66.3	72.4	78.4
W14x132	19.1	25.5	31.9	38.3	44.7	51.1	57.4	63.8	70.2	76.6	83.0
W14x120	19.3	25.7	32.1	38.5	44.9	51.3	57.8	64.2	70.6	77.0	83.4
W14x109	19.3	25.7	32.2	38.6	45.0	51.5	57.9	64.3	70.8	77.2	83.6
W14x99	19.4	25.9	32.3	38.8	45.3	51.8	58.2	64.7	71.2	77.6	84.1
W14x90	19.5	25.9	32.4	38.9	45.4	51.9	58.4	64.9	71.4	77.8	84.3
W14x82	29.0	38.7	48.4	58.1	67.7	77.4	87.1	96.8	106.5	116.1	125.8
W14x74	29.0	38.7	48.4	58.1	67.7	77.4	87.1	96.8	106.5	116.1	125.8
W14x68	29.3	39.0	48.8	58.5	68.3	78.0	87.8	97.6	107.3	117.1	126.8
W14x61	29.4	39.2	49.0	58.8	68.6	78.4	88.2	98.0	107.8	117.6	127.3
W14x53	37.5	50.0	62.5	75.0	87.5	100.0	112.5	125.0	137.5	150.0	162.5
W14x48	37.7	50.3	62.8	75.4	88.0	100.5	113.1	125.7	138.2	150.8	163.4
W12x336	20.7	27.7	34.6	41.5	48.4	55.3	62.2	69.2	76.1	83.0	89.9
W12x305	21.1	28.1	35.1	42.1	49.1	56.1	63.2	70.2	77.2	84.2	91.2
W12x279	21.3	28.4	35.5	42.6	49.7	56.8	63.9	71.0	78.1	85.2	92.3
W12x252	21.6	28.7	35.9	43.1	50.3	57.5	64.7	71.9	79.0	86.2	93.4
W12x230	21.8	29.0	36.3	43.5	50.8	58.0	65.3	72.5	79.8	87.0	94.3
W12x210	22.0	29.3	36.6	43.9	51.2	58.5	65.9	73.2	80.5	87.8	95.1
W12x190	22.2	29.5	36.9	44.3	51.7	59.1	66.5	73.8	81.2	88.6	96.0
W12x170	22.4	29.8	37.3	44.7	52.2	59.6	67.1	74.5	82.0	89.4	96.9
W12x152	22.6	30.1	37.6	45.1	52.7	60.2	67.7	75.2	82.8	90.3	97.8
W12x136	22.8	30.4	38.0	45.6	53.2	60.8	68.4	75.9	83.5	91.1	98.7
W12x120	23.0	30.7	38.3	46.0	53.7	61.3	69.0	76.7	84.3	92.0	99.7
W12x106	23.2	30.9	38.6	46.3	54.0	61.7	69.5	77.2	84.9	92.6	100.3
W12x96	23.3	31.1	38.8	46.6	54.4	62.1	69.9	77.7	85.4	93.2	101.0
W12x87	23.5	31.3	39.1	46.9	54.7	62.5	70.4	78.2	86.0	93.8	101.6
W12x79	23.6	31.5	39.3	47.2	55.1	63.0	70.8	78.7	86.6	94.4	102.3
W12x72	23.7	31.6	39.5	47.4	55.3	63.2	71.1	78.9	86.8	94.7	102.6
W12x65	23.8	31.8	39.7	47.7	55.6	63.6	71.5	79.5	87.4	95.4	103.3
W12x58	28.7	38.2	47.8	57.4	66.9	76.5	86.1	95.6	105.2	114.7	124.3
W12x53	29.0	38.7	48.4	58.1	67.7	77.4	87.1	96.8	106.5	116.1	125.8
W12x50	36.7	49.0	61.2	73.5	85.7	98.0	110.2	122.4	134.7	146.9	159.2
W12x45	37.1	49.5	61.9	74.2	86.6	99.0	111.3	123.7	136.1	148.5	160.8
W12x40	37.3	49.7	62.2	74.6	87.0	99.5	111.9	124.4	136.8	149.2	161.7
W10x112	26.9	35.8	44.8	53.7	62.7	71.6	80.6	89.6	98.5	107.5	116.4
W10x100	27.2	36.2	45.3	54.3	63.4	72.5	81.5	90.6	99.6	108.7	117.7
W10x88	27.4	36.5	45.6	54.8	63.9	73.0	82.1	91.3	100.4	109.5	118.6
W10x77	27.7	36.9	46.2	55.4	64.6	73.8	83.1	92.3	101.5	110.8	120.0
W10x68	27.8	37.1	46.3	55.6	64.9	74.1	83.4	92.7	101.9	111.2	120.5
W10x60	28.0	37.4	46.7	56.0	65.4	74.7	84.0	93.4	102.7	112.1	121.4
W10x54	28.1	37.5	46.9	56.3	65.6	75.0	84.4	93.8	103.1	112.5	121.9
W10x49	28.3	37.8	47.2	56.7	66.1	75.6	85.0	94.5	103.9	113.4	122.8
W10x45	35.8	47.8	59.7	71.6	83.6	95.5	107.5	119.4	131.3	143.3	155.2
W10x39	36.4	48.5	60.6	72.7	84.8	97.0	109.1	121.2	133.3	145.5	157.6
W10x33	37.1	49.5	61.9	74.2	86.6	99.0	111.3	123.7	136.1	148.5	160.8
W8x67	34.0	45.3	56.6	67.9	79.2	90.6	101.9	113.2	124.5	135.8	147.2
W8x58	34.3	45.7	57.1	68.6	80.0	91.4	102.9	114.3	125.7	137.1	148.6
W8x48	34.6	46.2	57.7	69.2	80.8	92.3	103.8	115.4	126.9	138.5	150.0
W8x40	35.3	47.1	58.8	70.6	82.4	94.1	105.9	117.6	129.4	141.2	152.9
W8x35	35.5	47.3	59.1	70.9	82.8	94.6	106.4	118.2	130.0	141.9	153.7
W8x31	35.6	47.5	59.4	71.3	83.2	95.0	106.9	118.8	130.7	142.6	154.5
W8x28	44.4	59.3	74.1	88.9	103.7	118.5	133.3	148.1	163.0	177.8	192.6
W8x24	44.7	59.6	74.5	89.4	104.3	119.3	134.2	149.1	164.0	178.9	193.8
W6x25	47.4	63.2	78.9	94.7	110.5	126.3	142.1	157.9	173.7	189.5	205.3
W6x20	48.0	64.0	80.0	96.0	112.0	128.0	144.0	160.0	176.0	192.0	208.0

Note: Shading indicates *Kl/r* greater than 200.

APPENDIX E—*Kl/r* VERIFICATIONS (cont'd)

	Kl/r Calculations					
	KL (ft)					
Shape	28.00	30.00	32.00	34.00	36.00	38.00
W14x730	71.6	76.8	81.9	87.0	92.1	97.2
W14x665	72.7	77.9	83.1	88.3	93.5	98.7
W14x605	73.8	79.1	84.4	89.7	94.9	100.2
W14x550	74.8	80.2	85.5	90.9	96.2	101.6
W14x500	75.8	81.3	86.7	92.1	97.5	102.9
W14x455	76.7	82.2	87.7	93.2	98.6	104.1
W14x426	77.4	82.9	88.5	94.0	99.5	105.1
W14x398	78.0	83.5	89.1	94.7	100.2	105.8
W14x370	78.7	84.3	89.9	95.6	101.2	106.8
W14x342	79.2	84.9	90.6	96.2	101.9	107.5
W14x311	80.0	85.7	91.4	97.1	102.9	108.6
W14x283	80.6	86.3	92.1	97.8	103.6	109.4
W14x257	81.4	87.2	93.0	98.8	104.6	110.4
W14x233	82.0	87.8	93.7	99.5	105.4	111.2
W14x211	82.6	88.5	94.3	100.2	106.1	112.0
W14x193	83.0	88.9	94.8	100.7	106.7	112.6
W14x176	83.6	89.6	95.5	101.5	107.5	113.4
W14x159	84.0	90.0	96.0	102.0	108.0	114.0
W14x145	84.4	90.5	96.5	102.5	108.5	114.6
W14x132	89.4	95.7	102.1	108.5	114.9	121.3
W14x120	89.8	96.3	102.7	109.1	115.5	121.9
W14x109	90.1	96.5	102.9	109.4	115.8	122.3
W14x99	90.6	97.0	103.5	110.0	116.4	122.9
W14x90	90.8	97.3	103.8	110.3	116.8	123.2
W14x82	135.5	145.2	154.8	164.5	174.2	183.9
W14x74	135.5	145.2	154.8	164.5	174.2	183.9
W14x68	136.6	146.3	156.1	165.9	175.6	185.4
W14x61	137.1	146.9	156.7	166.5	176.3	186.1
W14x53	175.0	187.5	200.0	212.5	225.0	237.5
W14x48	175.9	188.5	201.0	213.6	226.2	238.7
W12x336	96.8	103.7	110.7	117.6	124.5	131.4
W12x305	98.2	105.3	112.3	119.3	126.3	133.3
W12x279	99.4	106.5	113.6	120.7	127.8	134.9
W12x252	100.6	107.8	115.0	122.2	129.3	136.5
W12x230	101.5	108.8	116.0	123.3	130.5	137.8
W12x210	102.4	109.8	117.1	124.4	131.7	139.0
W12x190	103.4	110.8	118.2	125.5	132.9	140.3
W12x170	104.3	111.8	119.3	126.7	134.2	141.6
W12x152	105.3	112.9	120.4	127.9	135.4	142.9
W12x136	106.3	113.9	121.5	129.1	136.7	144.3
W12x120	107.3	115.0	122.7	130.4	138.0	145.7
W12x106	108.0	115.8	123.5	131.2	138.9	146.6
W12x96	108.7	116.5	124.3	132.0	139.8	147.6
W12x87	109.4	117.3	125.1	132.9	140.7	148.5
W12x79	110.2	118.0	125.9	133.8	141.6	149.5
W12x72	110.5	118.4	126.3	134.2	142.1	150.0
W12x65	111.3	119.2	127.2	135.1	143.0	151.0
W12x58	133.9	143.4	153.0	162.5	172.1	181.7
W12x53	135.5	145.2	154.8	164.5	174.2	183.9
W12x50	171.4	183.7	195.9	208.2	220.4	232.7
W12x45	173.2	185.6	197.9	210.3	222.7	235.1
W12x40	174.1	186.5	199.0	211.4	223.8	236.3
W10x112	125.4	134.3	143.3	152.2	161.2	170.1
W10x100	126.8	135.8	144.9	154.0	163.0	172.1
W10x88	127.8	136.9	146.0	155.1	164.3	173.4
W10x77	129.2	138.5	147.7	156.9	166.2	175.4
W10x68	129.7	139.0	148.3	157.5	166.8	176.1
W10x60	130.7	140.1	149.4	158.8	168.1	177.4
W10x54	131.3	140.6	150.0	159.4	168.8	178.1
W10x49	132.3	141.7	151.2	160.6	170.1	179.5
W10x45	167.2	179.1	191.0	203.0	214.9	226.9
W10x39	169.7	181.8	193.9	206.1	218.2	230.3
W10x33	173.2	185.6	197.9	210.3	222.7	235.1
W8x67	158.5	169.8	181.1	192.5	203.8	215.1
W8x58	160.0	171.4	182.9	194.3	205.7	217.1
W8x48	161.5	173.1	184.6	196.2	207.7	219.2
W8x40	164.7	176.5	188.2	200.0	211.8	223.5
W8x35	165.5	177.3	189.2	201.0	212.8	224.6
W8x31	166.3	178.2	190.1	202.0	213.9	225.7
W8x28	207.4	222.2	237.0	251.9	266.7	281.5
W8x24	208.7	223.6	238.5	253.4	268.3	283.2
W6x25	221.1	236.8	252.6	268.4	284.2	300.0
W6x20	224.0	240.0	256.0	272.0	288.0	304.0

Note: Shading indicates *Kl/r* greater than 200.