Characterizing Dimensional Variability in HSS Members

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Background

The American Institute of Steel Construction (AISC) and its Hollow Structural Shape (HSS) Committee is formulating a proposal to the American Society for Testing Materials (ASTM) for a new standard for HSS members and their constituent materials. There are concerns that the new standard and some of its provisions are not consistent with mass and dimensional tolerances of HSS members supplied by producing companies and modern manufacturing techniques. As a result, the AISC sought further information with regard to the dimensional variability in HSS members so that the proposed standard and provisions within it are not unduly punishing to HSS manufacturers/suppliers. This additional information can also be used by the AISC specification committee to better understand the impact of these standard provisions on the design specification. Finally, a relatively recent conference publication (Poag and Zervoudis 2003) highlighted concerns that cracks may form in the corner region of HSS member cross-sections resulting severe cracking during galvanizing processes.

The proposed research effort can be classified as a pilot study that intends to characterize the variability of cross-sectional dimensions and design-related cross-sectional parameters for HSS members and evaluate the tendencies for cracking in the corners of HSS members. The results of the research will provide the AISC HSS Committee better information for the proposed ASTM standard and will also provide the AISC specification committee with valuable information related to cross-sectional variability in HSS members that can be used to influence design specification provisions.

The objectives of the pilot study are: (a) characterize the variation in HSS wall thickness for a representative sample of HSS members provided by HSS producers: (b) characterize the mass variability present in the sample; (c) characterize the variability of parameters used in the specification provisions (e.g. D/t, B/t, $R \le 3t$) for the representative sample; (d) characterize the variability in wall thickness to address the suitability of the inherent $0.93t$ limit on cross-sectional thickness present in the specifications; (e) characterize the variability in flat-to-flat dimensions of HSS members; and (f) examine the HSS member cross-sections for cracking present at the corners of the HSS shapes provided.

Research Approach

A series of sample members with typical cross-sections made by HSS producers were obtained from three HSS shape manufacturers. The samples received and their designations are given in Table 1. In some cases, four samples were received. Each sample was 13-inches to 15-inches long. The length was established to make shipping convenient.

Each specimen was milled to a length that was convenient using standard mill machine tools. Figure 1 illustrates the methodology used for milling the specimens to the defined lengths. Figure 1(a) illustrates how the smaller HSS 3x3 shapes were milled to length. Some of the heavier HSS shapes required a more extensive fixture arrangement (Figures 1d, 1e, and 1f), while others (smaller thickness) could be milled using relatively little supplemental fixturing (Figure 1c). The lengths were determined using a stone flat table and height gauge as shown in Figure 1b). This measurement was done to confirm the lengths being reported by the mill. The length of all specimens after milling was on the order of 11 to 13 inches. These lengths were later determined and confirmed using a coordinate measurement machine (later discussion).

The specimens were then measured. Sixteen (16) thickness measurements were taken at each end of each specimen. Figure 2 illustrates the locations where thickness was taken. The thickness measurements were taken at approximately 1-inch in from each end of the specimen. The thickness was measured using a standard point micrometer (Figure 5) accurate to +/- 0.0001 inches. The accuracy of the point micrometer was validated using standard machinist gauge blocks.

The length of the specimens was determined using a coordinate measurement machine (Figure 4a). This machine is accurate to +/- 0.0001 inches. Measurements are taken electronically via a ruby-tipped probe (Figure 4b) and a smooth/flat stone base platen is present. Weights of the specimens were then taken using two scales. The first scale was accurate to +/- 0.01 lbs (maximum weight 65 lbs) and the second scale was accurate to 0.1 lbs (maximum weight exceeding 65 lbs). Thus, when the specimen weighed less than 65 lbs the weight was determined using the more sensitive scale. When the specimen weight exceeded 65 lbs, the less sensitive scale was used. The lengths of the specimens determined using the coordinate measurement machine and the specimen weights were then used to pro-rate the specimen weights to a per-foot basis.

Major dimensions, *H* and *B*, for the HSS shapes were determined at three locations over the length of the specimen (Figure 2). The locations where lengths were taken are 1.5 inches in from the ends and at specimen mid-length. At each location along the length, the major dimensions were determined using three locations across the face: the radius/flat intersection (e.g. point 10); the mid-side (e.g. point 9); and the radius flat intersection (e.g. point 8). The coordinate measurement machine was used to take these three width values and average them to a single value at each location along the specimen length. In other words, the average of three width values taken via the coordinate measurement machine are used to define B_i or H_i at any given location, *i*.

Radius and flat dimensions for the samples were also taken at one side of the specimen. Each shape was very carefully traced onto a piece of clean white paper using a mechanical pencil. The radii and flat-side dimensions shown in Figure 3 were then measured using a standard digital micrometer accurate to +/- 0.0001 inches validated using standard machinist gauge blocks. The inside locations of all lines were utilized in the measurements.

A Magnaflux SpotCheck Liquid Penetrant Investigation kits was purchased to conduct dye penetrant testing on the HSS shapes received. All shapes received were examined using the manufacturer's recommended procedure. The inside of all corners of the HSS shapes were examined. In general, this was limited toward the ends of the specimen lengths. The outer surfaces of the HSS shape corners were also examined along virtually the entire specimen length.

Results and Discussion

Table 2 illustrates the thickness data obtained for the specimens received. There are two rows of thickness at each of the 16 points around the cross-section perimeter for each shape. These represent the thickness measurements taken at each end of the specimen (i.e. t_1 and t_2) as shown in Figure 2. It should be noted that the HSS shapes are grouped and include data from at least two different manufacturing sources.

Minimum and maximum values of thickness at each level along the specimen are given in the last two columns of the table. There is quite a bit of variation in thickness among the locations on the cross-section. In general, all specimens have the minimum thickness value at point 1 on the cross-section, which is mid-side of the flat HSS-face opposite the seam weld. Mean, standard deviation (STD), and coefficient of variation (COV) values for the common locations on all specimens are also given in the table in the three rows immediately below the grouped thickness values.

In general, all mean thickness values are less than the nominal thickness values for the HSS shape. Mean, STD, and COV values for all thickness measurements at the 16 locations around the perimeter (at two locations along the length) are then reported below the statistical data at any one location. The mean thickness for all thickness values taken for the HSS 4x4x1/4 is 0.2410 inches. The STD is 0.0123 inches and

the COV is 0.0512. If point 1 (i.e. the minimum thickness location on the cross-section) is removed, these become 0.2421, 0.0120, and 0.0497 for the mean, STD, and COV, respectively. The mean thickness with and without point 1 are also compared to the nominal thickness. When data at point 1 is included, the mean thickness is $0.964 \cdot t_{nom}$ for the HSS 8x4x1/4 and when point 1 is excluded, the mean thickness is $0.968 \cdot t_{nom}$. Data for six HSS cross-sections are given in the table. The mean thickness values range from $0.955 \cdot t_{nom}$ for the HSS 8x4x1/2 to $0.982 \cdot t_{nom}$ for HSS 3x3x3/16 when 15 thickness locations are utilized.

Table 3 illustrates weight data for the specimens received. Mean, STD, and COV for the weights relative to the nominal weights reported in the Manual (AISC 2005) are given. In general, the weights of the specimens range from $0.93 \cdot W_{nom}$ to $0.94 \cdot W_{nom}$. This is expected since the thickness values (in general) are less than the nominal thickness values given in the Manual (AISC 2005).

Table 4 illustrates major cross-section dimensional data for the specimens received. As discussed earlier, widths were taken at three locations along the specimen length. The mean, STD, and COV for all width dimension are given. These dimensions are also normalized relative to the nominal values. In general, mean dimensions range from 0.997 to 1.01 times the nominal widths.

Table 5 illustrates radii and flat surface dimensions for the specimens received. The average thickness (including all points around the cross-section perimeter) was used to normalize the data. The Manual (AISC 2005) contains flat surface slenderness ratios (b/t and h/t). These ratios were computed for all flat surfaces on the specimens received using the average thickness. These ratios are included in Table 5. The mean, STD, and COV for these slenderness ratios are given for each shape received. In general, the mean slenderness ratios for the specimens are less than those slenderness ratios listed in the Manual (AISC 2005).

Outer corner radii were also measured. A total of eight radius values were obtained and these are listed in Table 5. The average thickness was used to normalize this radial dimension. The normalized outer radii range from $1.33 \cdot t_{avg}$ to $3.14 \cdot t_{avg}$ for the specimens. It is expected that these normalized dimensions would be reduced if the nominal thickness was used as it exceeds the average thickness values. Table 5 also contains mean, STD, and COV data for the normalized radii (relative to the average thickness value). Mean radii are less than $3 \cdot t_{avg}$ for all specimens.

The LPI did not reveal cracks at the corners of the HSS shapes. Previous research (Poag and Zervoudis 2003) utilized microscopy to study crack formation within the HSS shapes examined. This was not done in the present study.

Conclusions and Recommendations

The LPI conducted revealed no cracks in the corners of the HSS shapes received. The mean HSS shape thickness for the specimens received ranged from $0.954 \cdot t_{nom}$ to $0.978 \cdot t_{nom}$ when all sixteen locations around the perimeter are utilized. Therefore, using a two standard deviation cushion, the minimum thickness expected may be defined as $0.879 \cdot t_{nom}$ and the maximum thickness expected may be defined as $1.064 \cdot t_{nom}$. The per-foot weights of the shapes received ranged from 93% to 97% of the nominal per-foot weights listed in the Manual (AISC 2005). If a two standard deviation cushion was utilized, the minimum expected weight could be defined as 90% of the nominal weight and the maximum expected weight could be defined as 100% of the nominal weight.

The major dimensions of the HSS cross-sections range from 0.997 to 1.01 times the nominal dimension reported. If two standard deviations are used as cushion, the major dimensions could range from 0.992 to 1.022 times the nominal values found in the Manual (AISC 2005).

References

AISC (2005). *Steel Construction Manual, 13th Edition,* American Institute of Steel Construction, Chicago, IL.

Poag, G. and Zervoudis, J. (2003). "Influence of Various Parameters on Steel Cracking During Galvanizing", AGA TechForum, November, American Galvanizers Association, Kansas City, MO, 16 pages.

Table 1 – HSS Shape Designations, Specimen Availability, Specimen Key

Designation	At MU (Y/N)	Specimen Key
HSS 3x3x3/16	Y,Y	D – 1 – 1,2
HSS 3x3x3/8	Y,Y	D – 2 – 1,2
HSS 8x4x1/4	Y,Y,Y,Y	D – 3 – 1,2,3,4
HSS 8x4x1/2	Y,Y,Y,Y	D – 4 – 1,2,3,4
HSS 12x6x5/16	Y,Y,Y,Y	D – 5 – 1,2,3,4
HSS 12x6x5/8	Y,Y,Y,Y	E – 6 – 1,2,3,4
HSS 3x3x3/16	Y,Y	B – 1 – 1,2
HSS 3x3x3/8	-	B – 2 – 1,2
HSS 8x4x1/4	-	B – 3 – 1,2
HSS 8x4x5/8	-	B – 4 – 1,2
HSS 12x6x5/16	-	B – 5 – 1,2
HSS 12x6x5/8	-	B – 6 – 1,2
HSS 3x3x3/16	Y,Y	A – 1 – 1,2
HSS 3x3x3/8	Y,Y	A – 2 – 1,2
HSS 8x4x1/4	Y,Y	A – 3 – 1,2
HSS 8x4x1/2	Y,Y	A – 4 – 1,2
HSS 12x6x5/16	Y,Y	A – 5 – 1,2
HSS 12x6x5/8	Y,Y	A – 6 – 1,2
HSS 3x3x3/16	-	C – 1 – 1,2
HSS 3x3x3/8	-	C – 2 – 1,2
HSS 8x4x1/4	-	C – 3 – 1,2
HSS 8x4x1/2	Y,Y	C – 4 – 1,2
HSS 12x6x5/16	-	C – 5 – 1,2
HSS 12x6x5/8	-	C – 6 – 1,2

Table 2 – Thickness Dimensional Data for Specimens

HSS	Key	t_{nom}	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	t_{max}	t_{min}
8X4X/1/4	A-3-1	0.2500	0.2260	0.2484	0.2595	0.2613	0.2299	0.2645	0.2257	0.2463	0.2332	0.2412	0.2546	0.2605	0.2313	0.2621	0.2579	0.2421	0.2645	0.2257
			0.2266	0.2475	0.2544	0.2629	0.2359	0.2563	0.2610	0.2472	0.2320	0.2464	0.2558	0.2583	0.2305	0.2585	0.2552	0.2418	0.2629	0.2266
8X4X1/4	A-3-2	0.2500	0.2270	0.2465	0.2495	0.2610	0.2299	0.2693	0.2512	0.2252	0.2353	0.2502	0.2520	0.2670	0.2303	0.2589	0.2486	0.2444	0.2693	0.2252
			0.2262	0.2470	0.2505	0.2618	0.2323	0.2720	0.2518	0.2495	0.2327	0.2498	0.2502	0.2520	0.2292	0.2614	0.2481	0.2457	0.2720	0.2262
8X4X1/4	D-3-1	0.2500	0.2248	0.2445	0.2418	0.2408	0.2255	0.2418	0.2412	0.2438	0.2293	0.2441	0.2480	0.2395	0.2275	0.2419	0.2425	0.2430	0.2480	0.2248
			0.2258	0.2456	0.2427	0.2404	0.2288	0.2398	0.2433	0.2451	0.2289	0.2440	0.2428	0.2384	0.2258	0.2379	0.2441	0.2442	0.2456	0.2258
8X4X1/4	D-3-3	0.2500	0.2224	0.2285	0.2405	0.2266	0.2226	0.2261	0.2422	0.2285	0.2222	0.2306	0.2405	0.2270	0.2238	0.2270	0.2407	0.2278	0.2422	0.2222
			0.2232	0.2309	0.2422	0.2276	0.2240	0.2304	0.2435	0.2325	0.2225	0.2279	0.2476	0.2340	0.2234	0.2337	0.2418	0.2298	0.2476	0.2225
		Mean	0.2253	0.2424	0.2476	0.2478	0.2286	0.2500	0.2450	0.2398	0.2295	0.2418	0.2489	0.2471	0.2277	0.2477	0.2474	0.2399	0.2500	0.2253
		STD	0.0015	0.0074	0.0065	0.0148	0.0041	0.0167	0.0096	0.0089	0.0046	0.0078	0.0050	0.0134	0.0029	0.0132	0.0060	0.0065	0.0167	0.0015
		COV	0.0069	0.0306	0.0262	0.0595	0.0181	0.0668	0.0393	0.0370	0.0199	0.0322	0.0202	0.0542	0.0127	0.0532	0.0241	0.0271	0.0668	0.0069
		Mean	0.2410	0.9641	0.2421	0.9683														
		STD	0.0123		0.0120															
		COV	0.0512		0.0497															
8X4X1/2	A-4-1	0.5000	0.4464	0.4766	0.4795	0.5027	0.4589	0.5048	0.4813	0.4836	0.4537	0.4791	0.4802	0.4972	0.4555	0.5084	0.4813	0.4779	0.5084	0.4464
			0.4507	0.4742	0.4794	0.5061	0.4559	0.4935	0.4778	0.4770	0.4584	0.4810	0.4814	0.5026	0.4583	0.5050	0.4805	0.4753	0.5061	0.4507
8X4X1/2	A-4-2	0.5000	0.4504	0.4782	0.4840	0.5089	0.4582	0.5018	0.4853	0.4586	0.4822	0.4833	0.4836	0.5048	0.4583	0.5160	0.4799	0.4700	0.5160	0.4504
			0.4574	0.4690	0.4798	0.5116	0.4580	0.4990	0.4805	0.4531	0.4569	0.4776	0.4828	0.5002	0.4572	0.5035	0.4886	0.4696	0.5116	0.4531
8X4X1/2	C-4-1	0.5000	0.4542	0.4627	0.4560	0.4741	0.4549	0.4737	0.4617	0.4696	0.4586	0.4640	0.4567	0.4742	0.4545	0.4657	0.4666	0.4514	0.4742	0.4514
			0.4543	0.4540	0.4517	0.4706	0.4548	0.4750	0.4771	0.4560	0.4613	0.4607	0.4629	0.4734	0.4547	0.4741	0.4547	0.4512	0.4771	0.4512
8X4X1/2	C-4-2	0.5000	0.4553	0.4533	0.4642	0.4710	0.4548	0.4754	0.4647	0.4609	0.4628	0.4761	0.4619	0.4748	0.4552	0.4819	0.4552	0.4644	0.4819	0.4533
			0.4566	0.4660	0.4592	0.4800	0.4566	0.4743	0.4626	0.4708	0.4643	0.4673	0.4620	0.4740	0.4580	0.4800	0.4573	0.4578	0.4800	0.4566
8X4X1/2	D-4-1	0.5000	0.4879	0.4979	0.4922	0.5012	0.4613	0.5122	0.4876	0.4973	0.4645	0.5050	0.4863	0.5110	0.4623	0.5067	0.4839	0.4989	0.5122	0.4613
			0.4630	0.4983	0.4843	0.5052	0.4615	0.5068	0.4849	0.4985	0.4664	0.5000	0.4859	0.5210	0.4609	0.5097	0.4910	0.4977	0.5210	0.4609
8X4X1/2	D-4-2	0.5000	0.4367	0.4889	0.4862	0.5180	0.4593	0.5035	0.4838	0.4872	0.4657	0.4923	0.4847	0.5035	0.4599	0.5157	0.4851	0.4850	0.5180	0.4367
			0.4608	0.4971	0.4885	0.5115	0.4608	0.5070	0.4858	0.4931	0.4656	0.4890	0.4852	0.5050	0.4596	0.5139	0.4866	0.4924	0.5139	0.4596
		Mean	0.4561	0.4764	0.4754	0.4967	0.4579	0.4939	0.4778	0.4755	0.4634	0.4813	0.4761	0.4951	0.4579	0.4984	0.4759	0.4743	0.4984	0.4561
		STD	0.0121	0.0163	0.0138	0.0176	0.0025	0.0150	0.0095	0.0164	0.0072	0.0137	0.0115	0.0166	0.0025	0.0178	0.0136	0.0167	0.0178	0.0025
		COV	0.0266	0.0342	0.0291	0.0353	0.0055	0.0303	0.0198	0.0345	0.0154	0.0284	0.0241	0.0336	0.0055	0.0357	0.0285	0.0353	0.0357	0.0055
		Mean	0.4770	0.9540	0.4774	0.9548														
		STD	0.0187		0.0182															
		COV	0.0373		0.0381															
12X6X5/8	A-6-1	0.6250	0.5695	0.6006	0.6018	0.5933	0.5735	0.5919	0.5977	0.6214	0.5809	0.6186	0.5948	0.5973	0.5756	0.5908	0.5999	0.5877	0.6214	0.5695
			0.5684	0.6254	0.6020	0.5907	0.5746	0.6031	0.5985	0.6202	0.5797	0.6232	0.5956	0.5967	0.5733	0.5916	0.6026	0.6210	0.6254	0.5684
12X6X5/8	A-6-2	0.6250	0.5615	0.5827	0.5977	0.5784	0.5715	0.5805	0.6011	0.5815	0.5761	0.5919	0.5927	0.5889	0.5642	0.5804	0.5997	0.5807	0.6011	0.5615
			0.5594	0.5834	0.6018	0.5777	0.5643	0.5798	0.6015	0.5801	0.5707	0.5819	0.5936	0.6029	0.5754	0.5855	0.5968	0.5773	0.6029	0.5594
12X6X5/8	E-6-1	0.6250	0.5895	0.6079	0.5997	0.6155	0.5826	0.6320	0.6100	0.6145	0.5779	0.6054	0.6000	0.6200	0.5828	0.6387	0.6084	0.6150	0.6387	0.5779
			0.5888	0.6157	0.6069	0.6295	0.5812	0.6190	0.5999	0.6039	0.5801	0.6129	0.6079	0.6303	0.5808	0.6204	0.5983	0.6084	0.6303	0.5801
12X6X5/8	E-6-2	0.6250	0.5872	0.6025	0.5988	0.6131	0.5830	0.6410	0.6075	0.6129	0.5763	0.6038	0.6003	0.6179	0.5864	0.6366	0.6072	0.6147	0.6410	0.5763
			0.5875	0.6185	0.6080	0.6324	0.5813	0.6192	0.6016	0.6046	0.5789	0.6154	0.6082	0.6310	0.5844	0.6160	0.5998	0.6066	0.6324	0.5789
		Mean	0.5765	0.6046	0.6021	0.6038	0.5765	0.6083	0.6022	0.6049	0.5776	0.6066	0.5991	0.6106	0.5779	0.6075	0.6016	0.6014	0.6106	0.5765
		STD	0.0130	0.0156	0.0037	0.0217	0.0067	0.0231	0.0043	0.0162	0.0033	0.0140	0.0061	0.0162	0.0072	0.0233	0.0042	0.0170	0.0233	0.0033
		COV	0.0226	0.0258	0.0061	0.0360	0.0116	0.0380	0.0072	0.0267	0.0057	0.0231	0.0103	0.0266	0.0125	0.0384	0.0069	0.0282	0.0384	0.0057
		Mean	0.5976	0.9561	0.5990	0.9584														
		STD	0.0180		0.0174															
		COV	0.0301		0.0291															
12X6X5/16	A-5-1	0.3125	0.2884	0.3017	0.3038	0.2992	0.2901	0.3028	0.3027	0.3020	0.2921	0.3023	0.3057	0.2967	0.2890	0.3128	0.3063	0.3063	0.3128	0.2884
			0.2886	0.3086	0.3095	0.3070	0.2890	0.3039	0.3048	0.3036	0.2996	0.3020	0.3042	0.3025	0.2896	0.3060	0.3016	0.3012	0.3095	0.2886
12X6X5/16	A-5-2	0.3125	0.2955	0.3099	0.3133	0.3150	0.2920	0.3095	0.3128	0.3058	0.3027	0.3080	0.3128	0.3110	0.2951	0.3194	0.3132	0.3113	0.3194	0.2920
			0.2954	0.3124	0.3154	0.3198	0.2967	0.3087	0.3134	0.3072	0.2947	0.3056	0.3116	0.3105	0.2950	0.3131	0.3118	0.3113	0.3198	0.2947
12X6X5/16	D-5-1	0.3125	0.2865	0.2998	0.3058	0.3007	0.2858	0.3005	0.3039	0.3006	0.2857	0.2984	0.3020	0.2930	0.2843	0.2992	0.3001	0.2917	0.3058	0.2843
			0.2866	0.2997	0.3000	0.2985	0.2836	0.2896	0.3020	0.2990	0.2858	0.3008	0.3001	0.2975	0.2853	0.2972	0.3002	0.2995	0.3020	0.2836
12X6X5/16	D-5-2	0.3125	0.2860	0.2950	0.3012	0.3019	0.2834	0.2938	0.2985	0.2972	0.2877	0.2985	0.3003	0.3047	0.2829	0.3126	0.3018	0.2965	0.3126	0.2829
			0.2858	0.2975	0.3016	0.3049	0.2832	0.3051	0.3010	0.2954	0.2967	0.2993	0.2990	0.2950	0.2827	0.3031	0.2978	0.2992	0.3051	0.2827
		Mean	0.2891	0.3031	0.3063	0.3059	0.2880	0.3017	0.3049	0.3014	0.2931	0.3019	0.3045	0.3014	0.2880	0.3079	0.3041	0.3021	0.3079	0.2880
		STD	0.0041	0.0064	0.0058	0.0078	0.0049	0.0069	0.0054	0.0041	0.0064	0.0034	0.0053	0.0069	0.0050	0.0078	0.0057	0.0070	0.0078	0.0034
		COV	0.0140	0.0210	0.0190	0.0254	0.0169	0.0230	0.0178	0.0136	0.0219	0.0114	0.0173	0.0230	0.0175	0.0252	0.0188	0.0231	0.0254	0.0114
		Mean	0.3002	0.9607	0.3009	0.9630														
		STD	0.0086		0.0083															
		COV	0.0286		0.0276															

Table 2 – Thickness Dimensional Data for Specimens (continued)

HSS	Key	t_{nom}	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	t_{max}	t_{min}
3X3X3/16	A-1-1		0.1696	0.1830	0.1818	0.1922	0.1698	0.1940	0.1857	0.1825	0.1744	0.1814	0.1845	0.1897	0.1714	0.1982	0.1862	0.1896	0.1982	0.1696
		0.1875	0.1678	0.1883	0.1932	0.1990	0.1704	0.1910	0.1830	0.1819	0.1725	0.1839	0.1840	0.1925	0.1704	0.1933	0.1834	0.1845	0.1990	0.1678
3X3X3/16	A-1-2		0.1723	0.1893	0.1905	0.2006	0.2007	0.1953	0.1885	0.1896	0.1741	0.1896	0.1926	0.1930	0.1989	0.1999	0.1883	0.1898	0.2007	0.1723
		0.1875	0.1730	0.1917	0.1872	0.1975	0.1734	0.1952	0.1893	0.1891	0.1746	0.1960	0.1888	0.2006	0.1755	0.2001	0.1900	0.1930	0.2006	0.1730
3X3X3/16	B-1-1		0.1748	0.1809	0.1925	0.1912	0.1755	0.1838	0.1844	0.1775	0.1717	0.1793	0.1837	0.1795	0.1742	0.1862	0.1945	0.1838	0.1945	0.1717
		0.1875	0.1753	0.1825	0.1894	0.1894	0.1742	0.1813	0.1904	0.1749	0.1734	0.1813	0.1853	0.1834	0.1750	0.1863	0.1952	0.1858	0.1952	0.1734
3X3X3/16	B-1-2		0.1759	0.1948	0.1889	0.1987	0.1757	0.1899	0.1851	0.1830	0.1743	0.1834	0.1843	0.1906	0.1747	0.1982	0.1868	0.1902	0.1987	0.1743
		0.1875	0.1751	0.1913	0.1869	0.2002	0.1741	0.1878	0.1849	0.1820	0.1754	0.1828	0.1843	0.1906	0.1749	0.2000	0.1862	0.1938	0.2002	0.1741
3X3X3/16	D-1-1		0.1707	0.1844	0.1836	0.1922	0.1691	0.1858	0.1819	0.1804	0.1722	0.1804	0.1823	0.1857	0.1683	0.1840	0.1800	0.1781	0.1922	0.1683
		0.1875	0.1705	0.1804	0.1816	0.1844	0.1685	0.1874	0.1812	0.1780	0.1738	0.1789	0.1836	0.1855	0.1694	0.1920	0.1844	0.1837	0.1920	0.1685
3X3X3/16	D-1-2		0.1730	0.1799	0.1815	0.1806	0.1692	0.1798	0.1805	0.1799	0.1782	0.1816	0.1857	0.1816	0.1701	0.1812	0.1821	0.1820	0.1857	0.1692
		0.1875	0.1748	0.1807	0.1818	0.1807	0.1708	0.1816	0.1806	0.1830	0.1724	0.1808	0.1805	0.1832	0.1694	0.1804	0.1818	0.1805	0.1832	0.1694
		Mean	0.1727	0.1856	0.1866	0.1922	0.1743	0.1877	0.1846	0.1818	0.1739	0.1833	0.1850	0.1880	0.1744	0.1917	0.1866	0.1862	0.1922	0.1727
		STD	0.0026	0.0052	0.0044	0.0073	0.0087	0.0055	0.0034	0.0043	0.0018	0.0049	0.0031	0.0059	0.0082	0.0077	0.0048	0.0050	0.0087	0.0018
		COV	0.0151	0.0281	0.0236	0.0380	0.0500	0.0291	0.0184	0.0237	0.0101	0.0266	0.0168	0.0316	0.0468	0.0401	0.0257	0.0269	0.0500	0.0101
		Mean	0.1834	0.9782	0.1841	0.9820														
		STD	0.0081		0.0078															
		COV	0.0441		0.0425															
3X3X3/8	A-2-1		0.3434	0.3759	0.3707	0.3879	0.3544	0.3792	0.3648	0.3577	0.3476	0.3719	0.3687	0.3816	0.3559	0.3869	0.3672	0.3719	0.3879	0.3434
		0.3750	0.3438	0.3760	0.3713	0.3852	0.3571	0.3830	0.3676	0.3714	0.3453	0.3620	0.3655	0.3763	0.3545	0.3835	0.3691	0.3748	0.3852	0.3438
3X3X3/8	A-2-2		0.3424	0.3712	0.3654	0.3833	0.3546	0.3791	0.3638	0.3669	0.3463	0.3686	0.3639	0.3784	0.3517	0.3832	0.3694	0.3742	0.3833	0.3424
		0.3750	0.3450	0.3743	0.3746	0.3861	0.3535	0.3755	0.3679	0.3656	0.3426	0.3700	0.3683	0.3797	0.3564	0.3839	0.3642	0.3743	0.3861	0.3426
3X3X3/8	D-2-1		0.3451	0.3738	0.3577	0.3683	0.3398	0.3743	0.3589	0.3690	0.3568	0.3773	0.3580	0.3737	0.3404	0.3683	0.3594	0.3704	0.3773	0.3398
		0.3750	0.3445	0.3704	0.3600	0.3673	0.3416	0.3771	0.3602	0.3705	0.3611	0.3697	0.3625	0.3772	0.3396	0.3725	0.3609	0.3720	0.3772	0.3396
3X3X3/8	D-2-2		0.3414	0.3678	0.3588	0.3747	0.3399	0.3772	0.3554	0.3655	0.3493	0.3683	0.3579	0.3731	0.3369	0.3745	0.3545	0.3671	0.3772	0.3369
		0.3750	0.3408	0.3695	0.3567	0.3733	0.3382	0.3733	0.3568	0.3677	0.3495	0.3670	0.3571	0.3741	0.3402	0.3717	0.3558	0.3681	0.3741	0.3382
		Mean	0.3433	0.3724	0.3644	0.3783	0.3474	0.3773	0.3619	0.3668	0.3498	0.3694	0.3627	0.3768	0.3470	0.3781	0.3626	0.3716	0.3783	0.3433
		STD	0.0016	0.0031	0.0070	0.0083	0.0081	0.0031	0.0048	0.0043	0.0062	0.0043	0.0047	0.0030	0.0084	0.0070	0.0058	0.0029	0.0084	0.0016
		COV	0.0047	0.0082	0.0193	0.0220	0.0234	0.0082	0.0132	0.0116	0.0176	0.0117	0.0129	0.0081	0.0242	0.0186	0.0161	0.0078	0.0242	0.0047
		Mean	0.3644	0.9716	0.3658	0.9753														
		STD	0.0127		0.0118															
		COV	0.0347		0.0322															
		Mean		0.9641		0.9670														

Table 3 – Length and Weight Data for Specimens

HSS	Key	L (in)	L (ft)	W_T (lb)	W (lb/ft)	W_{nom} (lb/ft)	W / W_{nom}
8X4X/1/4	A-3-1	12.9499	1.0792	19.20	17.7917	18.99	0.9369
8X4X1/4	A-3-2	12.8453	1.0704	19.14	17.8805	18.99	0.9416
8X4X1/4	D-3-1	13.2018	1.1001	19.36	17.5976	18.99	0.9267
8X4X1/4	D-3-3	12.9030	1.0753	18.66	17.3540	18.99	0.9139
						Mean	0.9298
						STD	0.0123
						COV	0.0132
8X4X1/2	A-4-1	12.8521	1.0710	35.30	32.9595	35.11	0.9388
8X4X1/2	A-4-2	13.0002	1.0834	35.68	32.9349	35.11	0.9380
8X4X1/2	C-4-1	12.9000	1.0750	35.00	32.5580	35.11	0.9273
8X4X1/2	C-4-2	12.8006	1.0667	34.86	32.6797	35.11	0.9308
8X4X1/2	D-4-1	13.0050	1.0837	36.50	33.6794	35.11	0.9593
8X4X1/2	D-4-2	12.9010	1.0751	36.06	33.5415	35.11	0.9553
						Mean	0.9432
						STD	0.0164
						COV	0.0174
12X6X5/8	A-6-1	13.0070	1.0839	68.00	62.7353	67.62	0.9278
12X6X5/8	A-6-2	12.8484	1.0707	66.70	62.2955	67.62	0.9213
12X6X5/8	E-6-1	13.0486	1.0874	68.80	63.2712	67.62	0.9357
12X6X5/8	E-6-2	13.0421	1.0868	68.80	63.3029	67.62	0.9362
						Mean	0.9302
						STD	0.0071
						COV	0.0076
12X6X5/16	A-5-1	12.9959	1.0830	36.44	33.6475	36.10	0.9321
12X6X5/16	A-5-2	13.0210	1.0851	37.48	34.5411	36.10	0.9568
12X6X5/16	D-5-1	13.0022	1.0835	35.96	33.1881	36.10	0.9193
12X6X5/16	D-5-2	13.0618	1.0885	36.00	33.0735	36.10	0.9162
						Mean	0.9311
						STD	0.0185
						COV	0.0198
3X3X3/16	A-1-1	12.9515	1.0793	6.98	6.4672	6.85	0.9441
3X3X3/16	A-1-2	12.9530	1.0794	7.10	6.5776	6.85	0.9602
3X3X3/16	B-1-1	12.9006	1.0750	7.02	6.5300	6.85	0.9533
3X3X3/16	B-1-2	12.9067	1.0756	7.06	6.5640	6.85	0.9583
3X3X3/16	D-1-1	14.0148	1.1679	7.48	6.4047	6.85	0.9350
3X3X3/16	D-1-2	14.0269	1.1689	7.48	6.3991	6.85	0.9342
						Mean	0.9452
						STD	0.0124
						COV	0.0131
3X3X3/8	A-2-1	13.0020	1.0835	12.96	11.9613	12.09	0.9894
3X3X3/8	A-2-2	13.0052	1.0838	12.92	11.9214	12.09	0.9861
3X3X3/8	D-2-1	14.0127	1.1677	13.58	11.6295	12.09	0.9619
3X3X3/8	D-2-2	13.9258	1.1605	13.46	11.5986	12.09	0.9594
						Mean	0.9742
						STD	0.0157
						COV	0.0161

Table 4 – Major Dimension Information

HSS	Key	H_{nom}	B_{nom}	H_1	H_2	H_3	B_1	B_2	B_3
8X4X/1/4	A-3-1	8.00	4.00	7.9956	7.9604	7.9795	4.0163	4.0521	4.0367
8X4X1/4	A-3-2	8.00	4.00	8.0001	7.9746	8.0003	4.0441	4.0825	4.0271
8X4X1/4	D-3-1	8.00	4.00	8.0169	7.9945	8.0063	4.0141	4.0745	4.0192
8X4X1/4	D-3-3	8.00	4.00	8.0084	7.9913	8.0084	4.0226	4.0673	4.0244
				Mean	7.9947	0.9993		4.0401	1.0100
				STD	0.0162			0.0239	
				COV	0.0020			0.0059	
8X4X1/2	A-4-1	8.00	4.00	8.0308	8.0110	8.0264	4.0430	4.0614	4.0382
8X4X1/2	A-4-2	8.00	4.00	8.0159	7.9954	8.0205	4.0221	3.9978	4.0379
8X4X1/2	C-4-1	8.00	4.00	7.9561	7.9721	7.9768	4.0128	4.0301	4.0107
8X4X1/2	C-4-2	8.00	4.00	7.9512	7.9855	7.9609	4.0065	4.0086	4.0053
8X4X1/2	D-4-1	8.00	4.00	8.0177	7.9981	8.0128	4.0272	4.0088	4.0307
8X4X1/2	D-4-2	8.00	4.00	8.0115	7.9994	8.0084	4.0522	4.0434	4.0515
				Mean	7.9972	0.9997		4.0271	1.0068
				STD	0.0247			0.0189	
				COV	0.0031			0.0047	
12X6X5/8	A-6-1	12.00	6.00	12.0451	12.0241	12.0374	6.0615	6.0082	6.0520
12X6X5/8	A-6-2	12.00	6.00	12.0277	12.0150	12.0454	6.0452	6.0787	6.0474
12X6X5/8	E-6-1	12.00	6.00	11.9918	11.9487	11.9796	6.0356	6.0397	6.0333
12X6X5/8	E-6-2	12.00	6.00	11.9813	11.9529	11.9885	6.0339	6.0452	6.0306
				Mean	12.0031	1.0003		6.0426	1.0071
				STD	0.0341			0.0174	
				COV	0.0028			0.0029	
12X6X5/16	A-5-1	12.00	6.00	12.0052	11.9586	11.9883	6.0116	6.0347	6.0111
12X6X5/16	A-5-2	12.00	6.00	12.0207	11.9916	12.0081	6.0274	6.1490	6.0270
12X6X5/16	D-5-1	12.00	6.00	11.9542	11.9229	11.9643	6.0202	6.0759	5.9844
12X6X5/16	D-5-2	12.00	6.00	11.9598	11.9099	11.9478	6.0131	6.0771	5.9702
				Mean	11.9693	0.9974		6.0335	1.0056
				STD	0.0342			0.0478	
				COV	0.0029			0.0079	
3X3X3/16	A-1-1	3.00	3.00	3.0114	2.9928	3.0130	2.9996	2.9920	3.0042
3X3X3/16	A-1-2	3.00	3.00	3.0011	3.0000	3.0054	3.0136	3.0059	3.0138
3X3X3/16	B-1-1	3.00	3.00	2.9972	3.0032	2.9932	3.0014	3.0070	2.9997
3X3X3/16	B-1-2	3.00	3.00	3.0004	3.0061	2.9986	2.9970	3.0020	2.9919
3X3X3/16	D-1-1	3.00	3.00	3.0054	2.9963	3.0066	3.0083	3.0007	3.0041
3X3X3/16	D-1-2	3.00	3.00	3.0020	3.0023	3.0092	3.0027	2.9980	3.0032
				Mean	3.0024	1.0008		3.0025	1.0008
				STD	0.0057			0.0060	
				COV	0.0019			0.0020	
3X3X3/8	A-2-1	3.00	3.00	3.0033	2.9960	3.0023	3.0271	3.0127	3.0278
3X3X3/8	A-2-2	3.00	3.00	3.0202	3.0069	3.0205	2.9978	2.9896	2.9988
3X3X3/8	D-2-1	3.00	3.00	3.0132	3.0040	3.0106	3.0138	3.0043	3.0132
3X3X3/8	D-2-2	3.00	3.00	3.0024	2.9812	3.0018	3.0157	2.9859	3.0125
				Mean	3.0052	1.0017		3.0083	1.0028
				STD	0.0107			0.0133	
				COV	0.0035			0.0044	

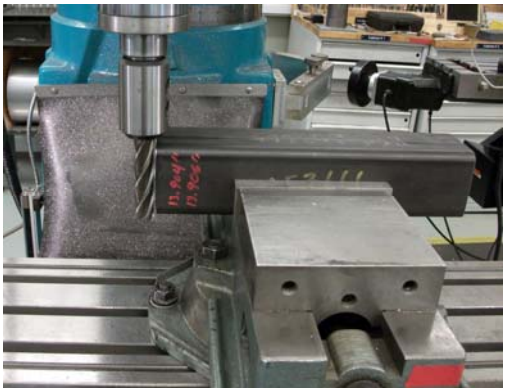
Table 5 – Other Pertinent Dimensional Information

HSS	Key	t_{avg}	R_1	R_2	h_1	h_1/t_{avg}	R_3	R_4	b_1	b_1/t_{avg}	R_5	R_6	h_2	h_2/t_{avg}	R_7	R_8	b_2	b_2/t_{avg}
8X4X/1/4	A-3-1	0.2473	0.36	0.52	6.89	27.84	0.55	0.40	3.22	13.01	0.39	0.51	6.96	28.15	0.50	0.38	3.24	13.09
	R / t_{avg}		1.47	2.12			2.24	1.61			1.56	2.06			2.02	1.55		
8X4X1/4	A-3-2	0.25	0.37	0.48	6.95	28.14	0.55	0.42	3.18	12.87	0.39	0.46	7.07	28.61	0.46	0.38	3.24	13.11
	R / t_{avg}		1.48	1.95			2.21	1.70			1.59	1.85			1.85	1.53		
8X4X1/4	D-3-1	0.2387	0.45	0.40	7.12	29.85	0.44	0.46	3.10	12.98	0.42	0.39	7.10	29.75	0.52	0.48	3.06	12.81
	R / t_{avg}		1.87	1.66			1.85	1.94			1.77	1.64			2.19	2.03		
8X4X1/4	D-3-3	0.2310	0.44	0.40	7.14	30.89	0.44	0.46	3.04	13.17	0.48	0.46	7.07	30.61	0.48	0.31	3.22	13.95
	R / t_{avg}		1.89	1.75			1.90	1.99			2.06	1.98			2.09	1.35		
		Mean	1.68	1.87	7.02	29.18	2.05	1.81	3.13	13.01	1.75	1.88	7.05	29.28	2.04	1.61	3.19	13.24
		STD	0.24	0.21	0.12	1.44	0.21	0.18	0.08	0.13	0.23	0.18	0.06	1.11	0.14	0.29	0.09	0.49
		COV	0.14	0.11	0.02	0.05	0.10	0.10	0.03	0.01	0.13	0.10	0.01	0.04	0.07	0.18	0.03	0.04
8X4X1/2	A-4-1	0.4789	0.75	0.95	6.09	12.71	0.97	0.78	2.29	4.79	0.93	1.11	5.84	12.20	1.07	0.85	2.43	5.07
	R / t_{avg}		1.56	1.98			2.03	1.64			1.95	2.32			2.24	1.77		
8X4X1/2	A-4-2	0.4796	0.80	1.07	5.92	12.34	1.00	0.73	2.39	4.99	0.86	0.98	6.04	12.60	0.97	0.92	2.29	4.78
	R / t_{avg}		1.67	2.24			2.09	1.53			1.78	2.04			2.02	1.92		
8X4X1/2	C-4-1	0.4620	1.11	0.91	6.20	13.42	0.84	1.15	1.63	3.54	1.19	0.78	6.29	13.61	0.92	0.94	1.94	4.19
	R / t_{avg}		2.40	1.97			1.82	2.49			2.58	1.68			1.99	2.03		
8X4X1/2	C-4-2	0.4650	0.92	0.68	6.45	13.88	0.80	1.39	1.31	2.82	1.26	0.82	6.38	13.72	0.79	1.36	1.72	3.71
	R / t_{avg}		1.99	1.46			1.72	2.99			2.72	1.77			1.69	2.92		
8X4X1/2	D-4-1	0.4904	0.75	0.90	6.23	12.71	0.85	0.89	2.30	4.68	0.83	0.90	6.12	12.48	0.97	0.85	2.40	4.90
	R / t_{avg}		1.52	1.83			1.74	1.80			1.69	1.83			1.98	1.74		
8X4X1/2	D-4-2	0.4862	0.80	1.02	6.12	12.58	0.85	0.77	2.39	4.92	0.87	0.93	5.97	12.28	1.09	0.98	2.25	4.63
	R / t_{avg}		1.65	2.09			1.76	1.59			1.79	1.92			2.24	2.01		
		Mean	1.80	1.93	6.17	12.94	1.86	2.01	2.05	4.29	2.08	1.93	6.11	12.82	2.03	2.07	2.17	4.55
		STD	0.34	0.26	0.18	0.58	0.16	0.60	0.46	0.90	0.45	0.23	0.20	0.68	0.20	0.44	0.28	0.51
		COV	0.19	0.14	0.03	0.05	0.09	0.30	0.23	0.21	0.22	0.12	0.03	0.05	0.10	0.21	0.13	0.11
12X6X5/8	A-6-1	0.5957	1.11	0.94	9.98	16.76	1.08	1.15	3.71	6.22	1.22	1.21	9.60	16.12	1.22	1.27	3.71	6.23
	R / t_{avg}		1.86	1.58			1.81	1.93			2.04	2.03			2.04	2.12		
12X6X5/8	A-6-2	0.5832	1.13	1.04	9.95	17.06	1.05	0.97	4.01	6.87	1.05	1.05	9.75	16.71	1.24	1.15	3.77	6.47
	R / t_{avg}		1.94	1.79			1.80	1.66			1.80	1.81			2.13	1.97		
12X6X5/8	E-6-1	0.6057	1.14	1.24	9.48	15.65	1.24	1.21	3.57	5.89	1.22	1.34	9.29	15.33	1.36	1.22	3.65	6.03
	R / t_{avg}		1.88	2.05			2.04	1.99			2.01	2.21			2.25	2.02		
12X6X5/8	E-6-2	0.6057	1.14	1.36	9.36	15.46	1.24	1.12	3.62	5.97	1.27	1.30	9.50	15.68	1.20	1.12	3.76	6.20
	R / t_{avg}		1.89	2.24			2.04	1.84			2.10	2.14			1.98	1.84		
		Mean	1.89	1.91	9.69	16.23	1.92	1.86	3.72	6.24	1.99	2.05	9.53	15.96	2.10	1.99	3.72	6.23
		STD	0.04	0.29	0.32	0.80	0.14	0.14	0.20	0.44	0.13	0.18	0.19	0.59	0.12	0.12	0.05	0.18
		COV	0.02	0.15	0.03	0.05	0.07	0.08	0.05	0.07	0.07	0.09	0.02	0.04	0.06	0.06	0.01	0.03

Table 5 – Other Pertinent Dimensional Information (continued)

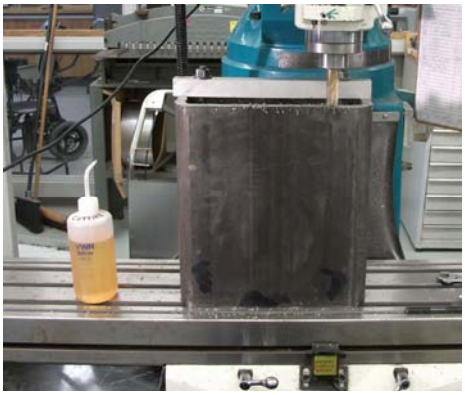
HSS	Key	t_{avg}	R_1	R_2	h_1	h_1/t_{avg}	R_3	R_4	b_1	b_1/t_{avg}	R_5	R_6	h_2	h_2/t_{avg}	R_7	R_8	b_2	b_2/t_{avg}
12X6X5/16	A-5-1	0.3007	0.85	0.69	10.58	35.18	0.72	0.66	4.58	15.22	0.74	0.70	10.54	35.05	0.72	0.65	4.44	14.76
	R / t_{avg}		2.84	2.29			2.39	2.18			2.44	2.34			2.41	2.17		
12X6X5/16	A-5-2	0.3078	0.60	0.66	10.72	34.82	0.62	0.75	4.63	15.05	0.59	0.70	10.55	34.27	0.76	0.70	4.69	15.23
	R / t_{avg}		1.96	2.13			2.01	2.43			1.91	2.28			2.47	2.26		
12X6X5/16	D-5-1	0.2957	0.67	0.74	10.33	34.94	0.87	0.73	4.48	15.13	0.74	0.94	10.28	34.75	0.75	0.65	4.64	15.70
	R / t_{avg}		2.28	2.49			2.94	2.47			2.49	3.17			2.54	2.19		
12X6X5/16	D-5-2	0.2965	0.69	0.88	10.35	34.89	0.70	0.62	4.62	15.59	0.69	0.74	10.31	34.75	0.93	0.83	4.42	14.92
	R / t_{avg}		2.31	2.95			2.37	2.07			2.34	2.48			3.14	2.81		
		Mean	2.35	2.47	10.49	34.96	2.43	2.29	4.58	15.25	2.30	2.57	10.42	34.71	2.64	2.36	4.55	15.15
		STD	0.37	0.36	0.19	0.15	0.38	0.19	0.07	0.24	0.27	0.41	0.15	0.32	0.34	0.31	0.14	0.41
		COV	0.16	0.14	0.02	0.00	0.16	0.08	0.02	0.02	0.12	0.16	0.01	0.01	0.13	0.13	0.03	0.03
3X3X3/16	A-1-1	0.1835	0.28	0.30	2.35	12.82	0.34	0.27	2.39	13.03	0.33	0.35	2.29	12.46	0.36	0.28	2.43	13.25
	R / t_{avg}		1.54	1.61			1.87	1.49			1.81	1.92			1.95	1.53		
3X3X3/16	A-1-2	0.1896	0.34	0.28	2.41	12.68	0.30	0.27	2.38	12.57	0.32	0.27	2.36	12.44	0.34	0.28	2.38	12.57
	R / t_{avg}		1.79	1.49			1.57	1.44			1.70	1.43			1.80	1.49		
3X3X3/16	B-1-1	0.1824	0.26	0.24	2.49	13.65	0.24	0.28	2.44	13.39	0.28	0.33	2.25	12.34	0.41	0.30	2.44	13.39
	R / t_{avg}		1.40	1.29			1.33	1.51			1.54	1.81			2.23	1.65		
3X3X3/16	B-1-2	0.1858	0.30	0.33	2.35	12.64	0.29	0.28	2.38	12.82	0.33	0.42	2.16	11.61	0.40	0.44	2.26	12.17
	R / t_{avg}		1.60	1.75			1.58	1.50			1.78	2.23			2.17	2.38		
3X3X3/16	D-1-1	0.1801	0.29	0.31	2.30	12.78	0.36	0.35	2.34	12.99	0.34	0.43	2.21	12.29	0.33	0.33	2.37	13.16
	R / t_{avg}		1.58	1.72			1.97	1.94			1.88	2.38			1.80	1.83		
3X3X3/16	D-1-2	0.1791	0.31	0.38	2.25	12.56	0.33	0.30	2.33	13.02	0.35	0.34	2.28	12.75	0.35	0.30	2.37	13.25
	R / t_{avg}		1.73	2.12			1.87	1.68			1.94	1.90			1.95	1.67		
		Mean	1.61	1.66	2.36	12.86	1.70	1.59	2.38	12.97	1.78	1.94	2.26	12.31	1.98	1.76	2.38	12.97
		STD	0.14	0.28	0.08	0.40	0.24	0.19	0.04	0.27	0.14	0.33	0.07	0.38	0.18	0.33	0.06	0.48
		COV	0.09	0.17	0.04	0.03	0.14	0.12	0.02	0.02	0.08	0.17	0.03	0.03	0.09	0.19	0.03	0.04
3X3X3/8	A-2-1	0.3679	0.49	0.55	1.90	5.15	0.55	0.59	1.87	5.09	0.56	0.65	1.80	4.89	0.54	0.52	1.99	5.41
	R / t_{avg}		1.34	1.50			1.50	1.59			1.52	1.76			1.46	1.40		
3X3X3/8	A-2-2	0.3670	0.49	0.53	1.91	5.22	0.53	0.49	1.95	5.31	0.56	0.55	1.84	5.00	0.60	0.56	1.97	5.36
	R / t_{avg}		1.34	1.45			1.45	1.34			1.52	1.50			1.63	1.52		
3X3X3/8	D-2-1	0.3624	0.61	0.64	1.76	4.85	0.62	0.67	1.68	4.64	0.65	0.66	1.69	4.65	0.65	0.63	1.76	4.85
	R / t_{avg}		1.69	1.77			1.71	1.84			1.79	1.82			1.80	1.72		
3X3X3/8	D-2-2	0.3601	0.54	0.60	1.79	4.96	0.60	0.54	1.87	5.18	0.60	0.65	1.74	4.82	0.60	0.53	1.91	5.31
	R / t_{avg}		1.51	1.65			1.67	1.49			1.65	1.79			1.67	1.47		
		Mean	1.47	1.59	1.84	5.04	1.58	1.56	1.84	5.05	1.62	1.72	1.76	4.84	1.64	1.53	1.91	5.23
		STD	0.17	0.14	0.08	0.17	0.12	0.21	0.11	0.29	0.13	0.15	0.07	0.15	0.14	0.14	0.10	0.26
		COV	0.11	0.09	0.04	0.03	0.08	0.14	0.06	0.06	0.08	0.09	0.04	0.03	0.09	0.09	0.05	0.05

Figure 1 – Specimen Milling Operations



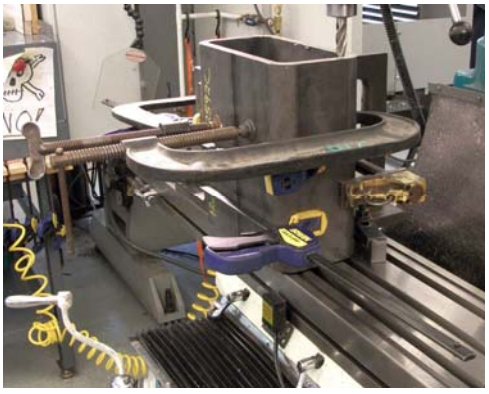
(a)

(b)



(c)

(d)



(e)

(f)

F**igure 2** – Thickness and Major Dimension Measurement Locations

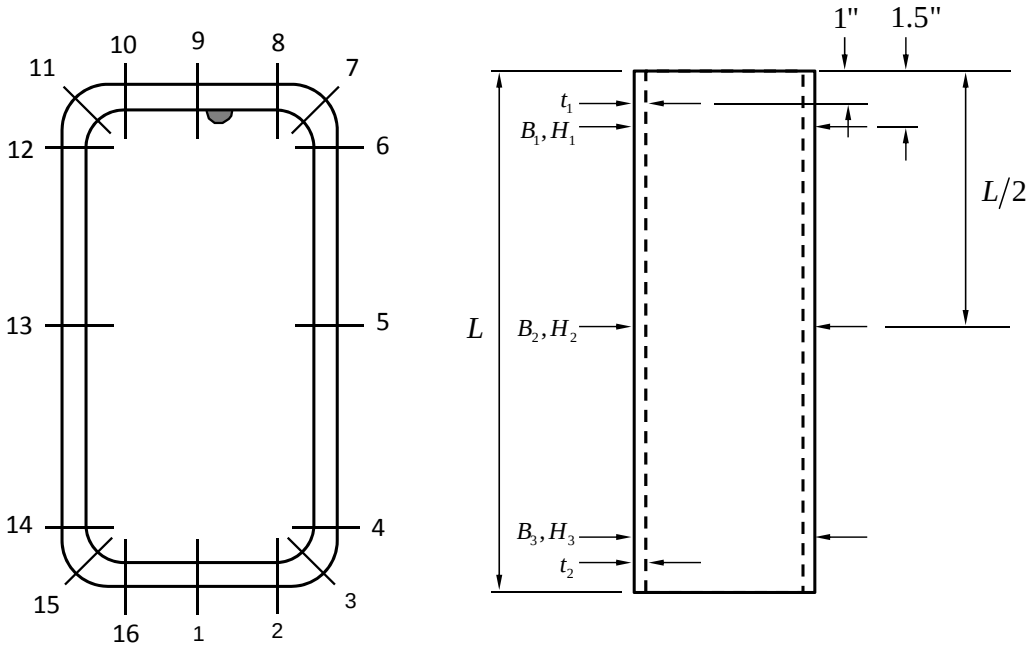


Figure 3 – Flat and Radial Dimension Keys

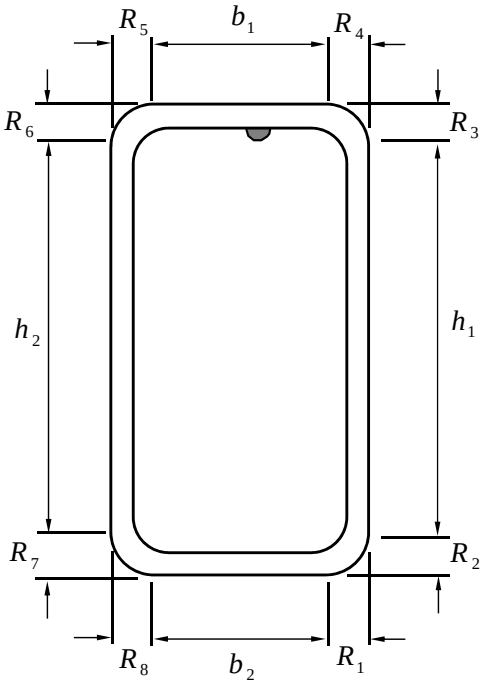


Figure 4 – Coordinate Measurement Machine.

(a)

(b)

Figure 5 – Point Micrometer