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Cooperative Engineering Program

SAE J1397 DEC88

**Estimated
Mechanical
Properties and
Machinability of Steel
Bars**

SAE Information Report
Reaffirmed December 1988

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ESTIMATED MECHANICAL PROPERTIES AND
MACHINABILITY OF STEEL BARS

1. INTRODUCTION:

This SAE Information Report is intended to provide a guide to mechanical properties and machinability characteristics of some SAE steel grades. The ratings and properties shown are provided as general information and not as requirements for specifications unless each instance is approved by the source of supply.

2. CARBON STEEL:

Mechanical properties and machinability ratings for carbon steel grades 10xx, 11xx, 12xx, 15xx are listed in Tables 1, 2, and 3 and can generally be expected from bars in sizes ranging from 3/4 - 1-1/4 in (20-30 mm) based on the standard round tensile test specimen with 2-in (50-mm) gage length.

Sizes under 3/4 in (20 mm) will show slightly higher strength than those shown in the Tables. The mass effect of larger sections has a direct influence on mechanical properties and results in slightly lower values as the section increases.

Properties of turned and polished or turned and ground types of cold finished material will correspond to the hot rolled values.

The cold drawn properties are based on conventional production from hot rolled bars.

Cold drawn carbon steel bars in grades 1042 and higher are frequently thermally treated prior to cold drawing to enhance machinability.

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3. ALLOY STEEL:

Hardness and machinability ratings for cold drawn alloy steel bars are listed in Table 4 with the appropriate microstructure. The microstructure listed for alloy steels in Table 4 is identified as follows:

Type A: Predominantly lamellar pearlite and ferrite.

Type B: Predominantly spheroidized.

Type C: This is a hot rolled structure which depends upon grade, size, and rolling conditions of the producing mill. The structure may be coarse or fine pearlite or bainite. The pearlite at low magnification may be blocky or acicular. For descriptive information, see U. S. Air Force Machinability Report, Volume 2, 1951, published by Curtiss-Wright Corporation.

Type D: This is a structure resulting from a subcritical anneal or temper anneal. It is usually a granular or spheroidized carbide condition confined to the hot rolled grain pattern, which may be blocky or acicular.

4. MACHINABILITY:

While it is recognized that there is a considerable difference of views regarding alloy steel machinability, it is believed that the ratings contained in this report reflect current industry experience. The data on which they were based were obtained by a detailed survey of both producers and users and summarize the combined experience of both groups. Various factors influence machinability and, therefore, results shown in Table 1 are average and may be affected to some degree by amount of cold reduction, mechanical properties, grain size, microstructure, type of tooling, and machining operation performed.

The machinability ratings listed are based on a value of 100% for SAE 1212 cold drawn. This value involves turning at a cutting speed of 180 surface feet (55 m) per minute for feeds up to 0.007 in (0.18 mm) per revolution and depths of cut up to 0.250 in (6.4 mm), using appropriate cutting fluids with high speed steel tools, SAE Grade T-1 (18-4-1) hardened to 63-65 HRC (SAE J437, J438).

Most low carbon alloy steels are machined in the as-rolled or as-rolled and cold drawn or cold finished condition. Higher carbon alloy steels and high hardenability low carbon steels, such as SAE 9310, may be conditioned for machining by subcritical annealing, annealing for softening to no specified structure, annealing to a specified structure such as lamellar pearlite or a percentage of lamellar pearlite and spheroidization, or to a fully spheroidized condition.

The structures imparted to the bars are evaluated in the machining operation by the tooling setup and type of tool used. It is possible to use widely diverging hardnesses and structures with different tooling setups and obtain satisfactory results both as to finish and parts per hour.

5. REFERENCES:

Metals Handbook, 8th ed., Vol. 3, Machining, American Society for Metals, Metals Park, OH 44073.

Machining Data Handbook, Vols. 1 and 2.

Machinability Data Center, Metcut Research Associates, 3980 Rosslyn Drive, Cincinnati, OH 45209.

U.S. Air Force Machinability Report, Vol. 2, 1951, Published by Curtiss-Wright Corp., Wood-Ridge, NJ 07075.

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TABLE 1 - Estimated Mechanical Properties and Machinability Ratings of Nonresulfurized Carbon Steel Bars, Manganese 1.00% Maximum

UNS No.	SAE and/or AISI No.	Type of Processing	Tensile Strength		Yield Strength		Estimated Minimum Values Elongation in		Reduction in Area, %	Brinell Hardness	Average Machinability Rating (Cold Drawn 1212=100%)
			psi	MPa	psi	MPa	2 in, %				
G10060	1006	Hot Rolled	43 000	300	24 000	170	30	55	86		
		Cold Drawn	48 000	330	41 000	280	20	45	95	50	
G10080	1008	Hot Rolled	44 000	303	24 500	170	30	55	86		
		Cold Drawn	49 000	340	41 500	290	20	45	95	55	
G10100	1010	Hot Rolled	47 000	320	26 000	180	28	50	95		
		Cold Drawn	53 000	370	44 000	300	20	40	105	55	
G10120	1012	Hot Rolled	48 000	330	26 500	180	28	50	95		
		Cold Drawn	54 000	370	45 000	310	19	40	105	55	
G10150	1015	Hot Rolled	50 000	340	27 500	190	28	50	101		
		Cold Drawn	56 000	390	47 000	320	18	40	111	60	
G10160	1016	Hot Rolled	55 000	380	30 000	210	25	50	111		
		Cold Drawn	61 000	420	51 000	350	18	40	121	70	
G10170	1017	Hot Rolled	53 000	370	29 000	200	26	50	105		
		Cold Drawn	59 000	410	49 000	340	18	40	116	65	
G10180	1018	Hot Rolled	58 000	400	32 000	220	25	50	116		
		Cold Drawn	64 000	440	54 000	370	15	40	126	70	
G10190	1019	Hot Rolled	59 000	410	32 500	220	25	50	116		
		Cold Drawn	66 000	460	55 000	380	15	40	131	70	
G10200	1020	Hot Rolled	55 000	380	30 000	210	25	50	111		
		Cold Drawn	61 000	420	51 000	350	15	40	121	65	
G10210	1021	Hot Rolled	61 000	420	33 000	230	24	48	116		
		Cold Drawn	68 000	470	57 000	390	15	40	131	70	
G10220	1022	Hot Rolled	62 000	430	34 000	230	23	47	151		
		Cold Drawn	69 000	480	58 000	400	15	40	137	70	
G10230	1023	Hot Rolled	56 000	370	31 000	210	25	50	111		
		Cold Drawn	62 000	430	52 500	360	15	40	121	65	
G10250	1025	Hot Rolled	58 000	400	32 000	220	25	50	116		
		Cold Drawn	64 000	440	54 000	370	15	40	126	65	
G10260	1026	Hot Rolled	64 000	440	35 000	240	24	49	126		
		Cold Drawn	71 000	490	60 000	410	15	40	143	75	
G10300	1030	Hot Rolled	68 000	470	37 500	260	20	42	137		
		Cold Drawn	76 000	520	64 000	440	12	35	149	70	
G10350	1035	Hot Rolled	72 000	500	39 500	270	18	40	143		
		Cold Drawn	80 000	550	67 000	460	12	35	163	65	
G10370	1037	Hot Rolled	74 000	510	40 500	280	18	40	143		
		Cold Drawn	82 000	570	69 000	480	12	35	167	65	
G10380	1038	Hot Rolled	75 000	520	41 000	280	18	40	149		
		Cold Drawn	83 000	570	70 000	480	12	35	163	65	
G10390	1039	Hot Rolled	79 000	540	43 500	300	16	40	156		
		Cold Drawn	88 000	610	74 000	510	12	35	179	60	

(Table continued on next page)

TABLE 1 - Estimated Mechanical Properties and Machinability Ratings of Nonresulfurized Carbon Steel Bars, Manganese 1.00% Maximum (Continued)

UNS No.	SAE and/or AISI No.	Type of Processing	Tensile Strength		Estimated Minimum Values Yield Strength		Elongation in 2 in, %	Reduction in Area, %	Brinell Hardness	Average Machinability Rating (Cold Drawn 1212=100%)
			psi	MPa	psi	MPa				
G10400	1040	Hot Rolled	76 000	520	42 000	290	18	40	149	
		Cold Drawn	85 000	590	71 000	490	12	35	170	60
G10420	1042	Hot Rolled	80 000	550	44 000	300	16	40	163	
		Cold Drawn	89 000	610	75 000	520	12	35	179	60
		NCD ^b	85 000	590	73 000	500	12	45	179	70
G10430	1043	Hot Rolled	82 000	570	45 000	310	16	40	163	
		Cold Drawn	91 000	630	77 000	530	12	35	179	60
		NCD ^b	87 000	600	75 000	520	12	45	179	70
G10440	1044	Hot Rolled	80 000	550	44 000	300	16	40	163	
G10450	1045	Hot Rolled	82 000	570	45 000	310	16	40	163	
		Cold Drawn	91 000	630	77 000	530	12	35	179	55
		ACD ^a	85 000	590	73 000	500	12	45	170	65
G10460	1046	Hot Rolled	85 000	590	47 000	320	15	40	170	
		Cold Drawn	94 000	650	79 000	540	12	35	187	55
		ACD ^a	90 000	620	75 000	520	12	45	179	65
G10490	1049	Hot Rolled	87 000	600	48 000	330	15	35	179	
		Cold Drawn	97 000	670	81 500	560	10	30	197	45
		ACD ^a	92 000	630	77 000	530	10	40	187	55
G10500	1050	Hot Rolled	90 000	620	49 500	340	15	35	179	
		Cold Drawn	100 000	690	84 000	580	10	30	197	45
		ACD ^a	95 000	660	80 000	550	10	40	189	55
G10550	1055	Hot Rolled	94 000	650	51 500	360	12	30	192	
		ACD ^a	96 000	660	81 000	560	10	40	197	55
G10600	1060	Hot Rolled	98 000	680	54 000	370	12	30	201	
		SACD ^c	90 000	620	70 000	480	10	45	183	60
G10640	1064	Hot Rolled	97 000	670	53 500	370	12	30	201	
		SACD ^c	89 000	610	69 000	480	10	45	183	60
G10650	1065	Hot Rolled	100 000	690	55 000	380	12	30	207	
		SACD ^c	92 000	630	71 000	490	10	45	187	60
G10700	1070	Hot Rolled	102 000	700	56 000	390	12	30	212	
		SACD ^c	93 000	640	72 000	500	10	45	192	55
G10740	1074	Hot Rolled	105 000	720	58 000	400	12	30	217	
		SACD ^c	94 500	650	73 000	500	10	40	192	55
G10780	1078	Hot Rolled	100 000	690	55 000	380	12	30	207	
		SACD ^c	94 000	650	72 500	500	10	40	192	55
G10800	1080	Hot Rolled	112 000	770	61 500	420	10	25	229	
		SACD ^c	98 000	680	75 000	520	10	40	192	45
G10840	1084	Hot Rolled	119 000	820	65 500	450	10	25	241	
		SACD ^c	100 000	690	77 000	530	10	40	192	45
G10850	1085	Hot Rolled	121 000	830	66 500	460	10	25	248	
		SACD ^c	100 500	690	78 000	540	10	40	192	45

(Table continued on next page)

TABLE 1 - Estimated Mechanical Properties and Machinability Ratings of Nonresulfurized Carbon Steel Bars, Manganese 1.00% Maximum (Continued)

UNS No.	SAE and/or AISI No.	Type of Processing	Tensile Strength		Estimated Minimum Values Yield Strength		Elongation in 2 in, %	Reduction in Area, %	Brinell Hardness	Average Machinability Rating (Cold Drawn 1212=100%)
			psi	MPa	psi	MPa				
G10860	1086	Hot Rolled SACD ^c	112 000	770	61 500	420	10	25	229	45
			97 000	670	74 000	510	10	40	192	
G10900	1090	Hot Rolled SACD ^c	122 000	840	67 000	460	10	25	248	45
			101 000	700	78 000	540	10	40	197	
G10950	1095	Hot Rolled SACD ^c	120 000	830	66 000	460	10	25	248	45
			99 000	680	76 000	520	10	40	197	

^aACD represents annealed cold drawn.^bNCD represents normalized cold drawn.^cSACD represents spheroidized annealed cold drawn.

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TABLE 2 - Estimated Mechanical Properties and Machinability Ratings of Resulfurized Carbon Steel Bars^a

UNS No.	SAE and/or AISI No.	Type of Processing	Tensile Strength		Estimated Minimum Values		Elongation in 2 in, %	Reduction in Area, %	Brinell Hardness	Average Machinability Rating (Cold Drawn 1212=100%)
			psi	MPa	Yield Strength	MPa				
G11080	1108	Hot Rolled	50 000	340	27 500	190	30	50	101	80
		Cold Drawn	56 000	390	47 000	320	20	40	121	
G11170	1117	Hot Rolled	62 000	430	34 000	230	23	47	121	90
		Cold Drawn	69 000	480	58 000	400	15	40	137	
G11320	1132	Hot Rolled	83 000	570	45 500	310	16	40	167	75
		Cold Drawn	92 000	630	77 000	530	12	35	183	
G11370	1137	Hot Rolled	88 000	610	48 000	330	15	35	179	70
		Cold Drawn	98 000	680	82 000	570	10	30	197	
G11400	1140	Hot Rolled	79 000	540	43 500	300	16	40	156	70
		Cold Drawn	88 000	610	74 000	510	12	35	170	
G11410	1141	Hot Rolled	94 000	650	51 500	360	15	35	187	70
		Cold Drawn	105 100	720	88 000	610	10	30	212	
G11440	1144	Hot Rolled	97 000	670	53 000	370	15	35	197	80
		Cold Drawn	108 000	740	90 000	620	10	30	217	
G11460	1146	Hot Rolled	85 000	590	47 000	320	15	40	170	70
		Cold Drawn	94 000	650	80 000	550	12	35	187	
G11510	1151	Hot Rolled	92 000	630	50 500	340	15	35	187	65
		Cold Drawn	102 000	700	86 000	590	10	30	207	
G12110	1211	Hot Rolled	55 000	380	33 000	230	25	45	121	95
		Cold Drawn	75 000	520	58 000	400	10	35	163	
G12120	1212	Hot Rolled	56 000	390	33 500	230	25	45	121	100
		Cold Drawn	78 000	540	60 000	410	10	35	167	
G12130	1213	Hot Rolled	56 000	390	33 500	230	25	45	121	135
		Cold Drawn	78 000	540	60 000	410	10	35	167	
G12144	12L14	Hot Rolled	57 000	390	34 000	230	22	45	121	160
		Cold Drawn	78 000	540	60 000	410	10	35	163	

^aAll 1100 and 1200 series steels are rated on the basis of 0.10% max. silicon or coarse grain melting practice.

TABLE 3 - Estimated Mechanical Properties and Machinability Ratings of Nonresulfurized Carbon Steel Bars, Manganese Maximum Over 1.00%

UNS No.	SAE and/or AISI No.	Type of Processing	Tensile Strength		Estimated Minimum Values Yield Strength		Elongation in 2 in, %	Reduction in Area, %	Brinell Hardness	Average Machinability Rating (Cold Drawn 1212=100%)
			psi	MPa	psi	MPa				
G15240	1524	Hot Rolled	74 000	510	41 000	280	20	42	149	60
		Cold Drawn	82 000	570	69 000	480	12	35	163	
G15270	1527	Hot Rolled	75 000	520	41 000	280	18	40	149	65
		Cold Drawn	83 000	570	70 000	480	12	35	163	
G15360	1536	Hot Rolled	83 000	570	45 500	310	16	40	163	55
		Cold Drawn	92 000	630	77 500	530	12	35	187	
G15410	1541	Hot Rolled	92 000	630	51 000	350	15	40	187	45
		Cold Drawn	102 500	710	87 000	600	10	30	207	
		ACD ^a	94 000	650	80 000	550	10	45	184	
G15480	1548	Hot Rolled	96 000	660	53 000	370	14	33	197	45
		Cold Drawn	106 500	730	89 500	620	10	28	217	
		ACD ^a	93 500	640	78 500	540	10	35	192	
G15520	1552	Hot Rolled	108 000	740	59 500	410	12	30	217	50
		ACD ^a	98 000	680	83 000	570	10	40	193	

^aACD represents annealed cold drawn.

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TABLE 4 - Machinability of Alloy Steels

UNS No.	AISI and/or SAE No.	Machinability Rating	Condition	Range of Typical Hardness HB	Microstructure Type
G13300	1330	55	Annealed and Cold Drawn	179/235	A
G13350	1335	55	Annealed and Cold Drawn	179/235	A
G13400	1340	50	Annealed and Cold Drawn	183/241	A
G13450	1345	45	Annealed and Cold Drawn	183/241	A
G40230	4023	70	Cold Drawn	156/207	C
G40240	4024	75	Cold Drawn	156/207	C
G40270	4027	70	Annealed and Cold Drawn	167/212	A
G40280	4028	75	Annealed and Cold Drawn	167/212	A
G40320	4032	70	Annealed and Cold Drawn	174/217	A
G40370	4037	70	Annealed and Cold Drawn	174/217	A
G40420	4042	65	Annealed and Cold Drawn	179/229	A
G40470	4047	65	Annealed and Cold Drawn	179/229	A
G41180	4118	60	Cold Drawn	170/207	C
G41300	4130	70	Annealed and Cold Drawn	187/229	A
G41350	4135	70	Annealed and Cold Drawn	187/229	A
G41370	4137	70	Annealed and Cold Drawn	187/229	A
G41400	4140	65	Annealed and Cold Drawn	187/229	A
G41420	4142	65	Annealed and Cold Drawn	187/229	A
G41450	4145	60	Annealed and Cold Drawn	187/229	A
G41470	4147	60	Annealed and Cold Drawn	187/235	A
G41500	4150	55	Annealed and Cold Drawn	187/241	A, B
G41610	4161	50	Spheroidized and Cold Drawn	187/241	B, A
G43200	4320	60	Annealed and Cold Drawn	187/229	D, B, A
G43400	4340	50	Annealed and Cold Drawn	187/241	B, A
G43406	E4340	50	Annealed and Cold Drawn	187/241	B, A
G44220	4422	65	Cold Drawn	170/212	C
G44270	4427	65	Annealed and Cold Drawn	170/212	A
G46150	4615	65	Cold Drawn	174/223	C
G46170	4617	65	Cold Drawn	174/223	C
G46200	4620	65	Cold Drawn	183/229	C
G46260	4626	70	Cold Drawn	170/212	C
G47180	4718	60	Cold Drawn	187/229	C
G47200	4720	65	Cold Drawn	187/229	C
G48150	4815	50	Annealed and Cold Drawn	187/229	D, B
G48170	4817	50	Annealed and Cold Drawn	187/229	D, B
G48200	4820	50	Annealed and Cold Drawn	187/229	D, B
G50401	50B40	65	Annealed and Cold Drawn	174/223	A
G50441	50B44	65	Annealed and Cold Drawn	174/223	A
G50460	5046	60	Annealed and Cold Drawn	174/223	A
G50461	50B46	60	Annealed and Cold Drawn	174/223	A
G50501	50B50	55	Annealed and Cold Drawn	183/235	A
G50600	5060	55	Spheroidized Annealed and Cold Drawn	170/212	B
G50601	50B60	55	Spheroidized Annealed and Cold Drawn	170/212	B
G51150	5115	65	Cold Drawn	163/201	C
G51200	5120	70	Cold Drawn	163/201	C
G51300	5130	70	Annealed and Cold Drawn	174/212	A
G51320	5132	70	Annealed and Cold Drawn	174/212	A
G51350	5135	70	Annealed and Cold Drawn	179/217	A
G51400	5140	65	Annealed and Cold Drawn	179/217	A
G51470	5147	65	Annealed and Cold Drawn	179/229	A
G51500	5150	60	Annealed and Cold Drawn	183/235	A, B
G51550	5155	55	Annealed and Cold Drawn	183/235	A, B
G51600	5160	55	Spheroidized Annealed and Cold Drawn	179/217	B
G51601	51B60	55	Spheroidized Annealed and Cold Drawn	179/217	B
G50986	50100	40	Spheroidized Annealed and Cold Drawn	183/241	B
G51986	51100	40	Spheroidized Annealed and Cold Drawn	183/241	B
G52986	52100	40	Spheroidized Annealed and Cold Drawn	183/241	B
G61180	6118	60	Cold Drawn	179/217	C
G61500	6150	55	Annealed and Cold Drawn	183/241	B, A
G81150	8115	65	Cold Drawn	163/202	C
G81451	81B45	65	Annealed and Cold Drawn	179/223	A

(Table continued on next page)

TABLE 4 - Machinability of Alloy Steels (Continued)

UNS No.	AISI and/or SAE No.	Machinability Rating	Condition	Range of Typical Hardness HB	Microstructure Type
G86150	8615	70	Cold Drawn	179/235	C
G86170	8617	70	Cold Drawn	179/235	C
G86200	8620	65	Cold Drawn	179/235	C
G86220	8622	65	Cold Drawn	179/235	C
G86250	8625	60	Annealed and Cold Drawn	179/223	A
G86270	8627	60	Annealed and Cold Drawn	179/223	A
G86300	8630	70	Annealed and Cold Drawn	179/229	A
G86370	8637	65	Annealed and Cold Drawn	179/229	A
G86400	8640	65	Annealed and Cold Drawn	184/229	A
G86420	8642	65	Annealed and Cold Drawn	184/229	A
G86450	8645	65	Annealed and Cold Drawn	184/235	A
G86451	86B45	65	Annealed and Cold Drawn	184/235	A
G86500	8650	60	Annealed and Cold Drawn	187/248	A, B
G86550	8655	55	Annealed and Cold Drawn	187/248	A, B
G86600	8660	55	Spheroidized Annealed and Cold Drawn	179/217	B
G87200	8720	65	Cold Drawn	179/235	C
G87400	8740	65	Annealed and Cold Drawn	184/235	A
G88220	8822	55	Cold Drawn	179/223	B
G92540	9254	45	Spheroidized Annealed and Cold Drawn	187/241	B
G92600	9260	40	Spheroidized Annealed and Cold Drawn	184/235	B
G93106	9310	50	Annealed and Cold Drawn	184/229	D
G94151	94B15	70	Cold Drawn	163/202	C
G94171	94B17	70	Cold Drawn	163/202	C
G94301	94B30	70	Annealed and Cold Drawn	170/223	A

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