

Chemical Compositions of SAE Carbon Steels

- 1. Scope**—In 1941, the SAE Iron and Steel Division, in collaboration with the American Iron and Steel Institute (AISI), made a major change in the method of expressing composition ranges for the SAE steels. The plan, as now applied, is based in general on narrower cast or heat analysis ranges plus certain product analysis allowances on individual samples, in place of the fixed ranges and limits without tolerances formerly provided for carbon and other elements in SAE steels.

For years the variety of chemical compositions of steel has been a matter of concern in the steel industry. It was recognized that production of fewer grades of steel could result in improved deliveries and provide a better opportunity to achieve advances in technology, manufacturing practices, and quality, and thus develop more fully the possibilities of application inherent in those grades.

Comprehensive and impartial studies were directed toward determining which of the many grades being specified were the ones in most common demand, and the feasibility of combining compositions having like requirements. From these studies, the most common grades of steel have been selected and kept in the current revision. The cast or heat chemical composition limits or ranges of these grades are given in Tables 1, 2, 3A, and 3B. These cast or heat limits or ranges are subject to standard variations for product analysis as given in SAE J409. Since AISI is no longer issuing steel grade designations, grades listed in this document are SAE grades.

It is recognized that chemical compositions other than those listed in the previously mentioned tables will at times be needed for specialized applications or processing. When such a steel is required, the elements comprising the desired chemical composition are specified in one of three ways: (a) by a minimum limit, (b) by a maximum limit, or (c) by minimum and maximum limits, termed a range.

Standard cast or heat analysis limits and ranges for the various elements of carbon steels are given in Table 4. In this table, range is the arithmetical difference between the minimum and maximum limits (that is, 0.19 to 0.25 is a 0.06 range). These cast or heat limits and ranges are also subject to standard variations for product analysis as given in SAE J409.

ISTC Division 1 has developed a procedure which allows for the maintenance of the grade lists in this document. This will involve conducting an industry-wide survey to solicit input. This survey will be conducted at a frequency deemed necessary by the technical committee.

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Criteria have been established for the addition to or the deletion of grades from the grade lists. New grades will be considered based on the grade meeting a SAE grade designation and chemistry, having a minimum production or consumption of 225 tonnes/year (250 tons/year) and has the sponsorship of at least two individual users or producers. New steel compositions will be considered as Potential Standard (PS) steels, based on the guidelines in SAE J1081, until such time as production of the new steel achieves a level of production or usage qualifying it for consideration as a standard steel.

Deletion of grades will be by consensus based on the grade survey. Deleted grades will be archived in SAE J1249.

When the cast or heat analysis is requested to be reported to demonstrate conformance to the chemical limits shown in Tables 1, 2, 3A, or 3B, in addition to the quantities of carbon, manganese, phosphorus, and sulfur, the following elements and their quantities shall also be reported: copper, chromium, nickel, molybdenum, and silicon. When the amount of any one of these last five elements is less than 0.02% that analysis may be reported as "<0.02%."

Based on a survey question in the 1998 Grade Survey, the grade lists have been revised such that chemistries of all product forms are now consolidated into single tables. The chemistry ranges listed will be the narrowest range for the various product forms with the exception of S content. It is acknowledged however that due to differences in the section size of the various product forms, chemical composition demands for the product forms should be different to allow for adequate flexibility of steel application. These differences are reflected in Tables 4 and 5.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAEJ409—Product Analysis—Permissible Variations from Specified Chemical Analysis of a Heat or Cast of Steel

SAEJ411—Carbon and Alloy Steel

SAE J1081—Potential Standard Steels

SAE J1249—Former SAE Standard and Former SAE Ex-Steels

SAE J1268—Hardenability Bands for Carbon and Alloy H Steels

SAE J1868—Restricted Hardenability Bands for Selected Alloy Steels

2.1.2 ISS PUBLICATION—Available from ISS, 410 Commonwealth Drive, Warrendale, PA 15086.

ISS Carbon and Alloy Steel Bar and Semi-Finished Products Manual

3. Chemical Reporting Requirements

3.1 When the cast or heat analysis is requested to be reported to demonstrate conformance to the chemical limits shown in Tables 1, 2, 3A, and 3B, in addition to the quantities of carbon, manganese, phosphorus, and sulfur, the elements and their quantities, as shown in Table 6, shall also be reported.

TABLE 1—NONRESULFURIZED CARBON STEEL COMPOSITIONS APPLICABLE TO SEMIFINISHED PRODUCTS FOR FORGING, TO HOT-ROLLED AND COLD-FINISHED BARS, TO WIRE RODS, PLATES, STRIP, SHEETS, WELDED TUBING, AND TO SEAMLESS TUBING CAST OR HEAT CHEMICAL RANGES AND LIMITS

UNS No.	SAE No.	Chemical Composition Limits, % ⁽¹⁾⁽²⁾	Chemical Composition Limits, % ⁽¹⁾	Chemical Composition Limits, % ⁽¹⁾	Chemical Composition Limits, % ⁽¹⁾
		C	Mn	P, Max	S, Max
G10050	1005	0.06 Max	0.35 Max	0.030	0.050
G10060*	1006	0.08 Max	0.25–0.40	0.030	0.050
G10080*	1008	0.10 Max	0.30–0.50	0.030	0.050
G10090	1009	0.15 Max	0.60 Max	0.030	0.050
G10100	1010	0.08–0.13	0.30–0.60	0.030	0.050
G10120	1012	0.10–0.15	0.30–0.60	0.030	0.050
G10130	1013	0.11–0.16	0.30–0.60	0.030	0.050
G10150	1015	0.13–0.18	0.30–0.60	0.030	0.050
G10160	1016	0.13–0.18	0.60–0.90	0.030	0.050
G10170	1017	0.15–0.20	0.30–0.60	0.030	0.050
G10180	1018	0.15–0.20	0.60–0.90	0.030	0.050
G10190	1019	0.15–0.20	0.70–1.00	0.030	0.050
G10200	1020	0.18–0.23	0.30–0.60	0.030	0.050
G10210	1021	0.18–0.23	0.60–0.90	0.030	0.050
G10220	1022	0.18–0.23	0.70–1.00	0.030	0.050
G10230	1023	0.20–0.25	0.30–0.60	0.030	0.050
G10250	1025	0.22–0.28	0.30–0.60	0.030	0.050
G10260	1026	0.22–0.28	0.60–0.90	0.030	0.050
G10290	1029	0.25–0.31	0.60–0.90	0.030	0.050
G10300	1030	0.28–0.34	0.60–0.90	0.030	0.050
G10330	1033	0.30–0.36	0.70–1.00	0.030	0.050
G10350	1035	0.32–0.38	0.60–0.90	0.030	0.050
G10370	1037	0.32–0.38	0.70–1.00	0.030	0.050
G10380	1038	0.35–0.42	0.60–0.90	0.030	0.050
G10390	1039	0.37–0.44	0.70–1.00	0.030	0.050
G10400	1040	0.37–0.44	0.60–0.90	0.030	0.050
G10420	1042	0.40–0.47	0.60–0.90	0.030	0.050
G10430	1043	0.40–0.47	0.70–1.00	0.030	0.050
G10440	1044	0.43–0.50	0.30–0.60	0.030	0.050
G10450	1045	0.43–0.50	0.60–0.90	0.030	0.050
G10460	1046	0.43–0.50	0.70–1.00	0.030	0.050
G10490	1049	0.46–0.53	0.60–0.90	0.030	0.050
G10500	1050	0.48–0.55	0.60–0.90	0.030	0.050
G10530	1053	0.48–0.55	0.70–1.00	0.030	0.050
G10550	1055	0.50–0.60	0.60–0.90	0.030	0.050
G10600	1060	0.55–0.65	0.60–0.90	0.030	0.050
G10650	1065	0.60–0.70	0.60–0.90	0.030	0.050
G10700	1070	0.65–0.75	0.60–0.90	0.030	0.050
G10740	1074	0.70–0.80	0.50–0.80	0.030	0.050
G10750	1075	0.70–0.80	0.40–0.70	0.030	0.050
G10780	1078	0.72–0.85	0.30–0.60	0.030	0.050
G10800	1080	0.75–0.88	0.60–0.90	0.030	0.050
G10840	1084	0.80–0.93	0.60–0.90	0.030	0.050
G10850	1085	0.80–0.93	0.70–1.00	0.030	0.050
G10860	1086	0.80–0.93	0.30–0.50	0.030	0.050
G10900	1090	0.85–0.98	0.60–0.90	0.030	0.050
G10950	1095	0.90–1.03	0.30–0.50	0.030	0.050

1. Certain qualities and commodities are customarily produced to lower limits of phosphorus and sulfur. (See SAE J411, Table 1.)

2. NOTES

Lead—Standard carbon steels can be produced with a lead range of 0.15 to 0.35% to improve machinability. Such steels are identified by inserting the letter "L" between the second and third numerals of the grade number, for example, 10L45. The UNS designation is also modified by changing the last digit to "4" to indicate lead, for example, G10454.

BORON—Standard killed carbon steels, which are fine grain, may be produced with a boron addition to improve hardenability. Such steels are produced to a range of 0.0005 to 0.003% boron. These steels are identified by inserting the letter "B" between the second and third numerals of the grade number, for example, 10B46. The UNS designation is also modified by changing the last digit to "1" to indicate boron, for example, G10461.

COPPER—When copper is required, 0.20% minimum is generally specified.

*MANGANESE—For grades G10060 and G10080 applicable to Structural Shapes, Plates, Strip, Sheets and Welded Tubing, the manganese limit is 0.45% maximum and 0.50% maximum, respectively, with no minimum.

SILICON—BARS AND SEMIFINISHED—When silicon ranges or limits are required, the following ranges are commonly used: 0.10% max; 0.10 to 0.20%; 0.15 to 0.35%; 0.20 to 0.40%; or 0.30 to 0.60%.

RODS—When silicon is required, the following ranges and limits are commonly used for nonresulfurized steels: 0.10% max; 0.07 to 0.15%; 0.10 to 0.20%; 0.15 to 0.35%; 0.20 to 0.40%; 0.30 to 0.60%.

ADDITIONAL ELEMENTS—See 3.1 for additional elements to be reports

TABLE 2—HIGH MANGANESE CARBON STEEL COMPOSITIONS APPLICABLE ONLY TO SEMIFINISHED PRODUCTS FOR FORGING, TO HOT-ROLLED AND COLD-FINISHED BARS, PLATES, STRIP, SHEETS, AND TO SEAMLESS TUBING CAST OR HEAT CHEMICAL RANGES AND LIMITS

UNS No.	SAE No.	Chemical Composition Limits, % C	Chemical Composition Limits, % Mn	Chemical Composition Limits, % P, Max	Chemical Composition Limits, % S, Max
G15220	1522	0.18–0.24	1.10–1.40	0.030	0.050
G15240	1524	0.19–0.25	1.35–1.65	0.030	0.050
G15260	1526	0.22–0.29	1.10–1.40	0.030	0.050
G15270	1527	0.22–0.29	1.20–1.50	0.030	0.050
G15360	1536	0.30–0.37	1.20–1.50	0.030	0.050
G15410	1541	0.36–0.44	1.35–1.65	0.030	0.050
G15470	1547	0.43–0.51	1.35–1.65	0.030	0.050
G15480	1548	0.44–0.52	1.10–1.40	0.030	0.050
G15520	1552	0.47–0.55	1.20–1.50	0.030	0.050
G15660	1566	0.60–0.71	0.85–1.15	0.030	0.050

LEAD—See footnote under Table 1.

BORON—See footnote under Table 1.

PHOSPHORUS AND SULFUR—See footnote under Table 1.

SILICON—See footnote under Table 1.

ADDITIONAL ELEMENTS—For additional elements to be reported, see 3.1.

Chemical analyses of additional high-manganese steels produced to hardenability requirements are shown in SAE J1268 and SAE J1868

TABLE 3A—FREE CUTTING CARBON STEEL COMPOSITIONS APPLICABLE TO SEMIFINISHED PRODUCTS FOR FORGING, HOT-ROLLED AND COLD-FINISHED BARS, WIRE RODS, AND SEAMLESS TUBING—RESULFURIZED CARBON STEELS CAST OR HEAT CHEMICAL RANGES AND LIMITS

UNS No.	SAE No.	Chemical Composition Limits, % C	Chemical Composition Limits, % Mn	Chemical Composition Limits, % P, Max	Chemical Composition Limits, % S, Max
G11170	1117	0.14–0.20	1.00–1.30	0.030	0.08–0.13
G11180	1118	0.14–0.20	1.30–1.60	0.030	0.08–0.13
G11260	1126	0.23–0.29	0.70–1.00	0.030	0.08–0.13
G11320	1132	0.27–0.34	1.35–1.65	0.030	0.08–0.13
G11370	1137	0.32–0.39	1.35–1.65	0.030	0.08–0.13
G11380	1138	0.34–0.40	0.70–1.00	0.030	0.08–0.13
G11400	1140	0.37–0.44	0.70–1.00	0.030	0.08–0.13
G11410	1141	0.37–0.45	1.35–1.65	0.030	0.08–0.13
G11440	1144	0.40–0.48	1.35–1.65	0.030	0.24–0.33
G11460	1146	0.42–0.49	0.70–1.00	0.030	0.08–0.13
G11510	1151	0.48–0.55	0.70–0.90	0.030	0.08–0.13

LEAD—See footnote under Table 1.

SILICON—Bars and Semifinished—See footnote under Table 1.

RODS—When silicon is required, the following ranges and limits are commonly used: 0.10 Max, 0.10–0.20 or 0.15–0.35.

ADDITIONAL ELEMENTS—For additional elements to be reported, see 3.1.

TABLE 3B—FREE CUTTING CARBON STEEL COMPOSITIONS APPLICABLE TO SEMIFINISHED PRODUCTS FOR FORGING, HOT-ROLLED AND COLD-FINISHED BARS, WIRE RODS, AND SEAMLESS TUBING—REPHOSPHORIZED AND RESULFURIZED CARBON STEELS CAST OR HEAT CHEMICAL RANGES AND LIMITS

UNS No.	SAE No.	Chemical Composition Limits, % C, Max	Chemical Composition Limits, % Mn	Chemical Composition Limits, % P	Chemical Composition Limits, % S	Chemical Composition Limits, % Pb
G12120	1212	0.13	0.70–1.00	0.07–0.12	0.16–0.23	—
G12130	1213	0.13	0.70–1.00	0.07–0.12	0.24–0.33	—
G12150	1215	0.09	0.75–1.05	0.04–0.09	0.26–0.35	—
G12144	12L14	0.15	0.85–1.15	0.04–0.09	0.26–0.35	0.15–0.35

LEAD—See footnote under Table 1.

SILICON—It is not common practice to produce the 12xx series of steels to specified silicon because of its adverse effect on machinability.

ADDITIONAL ELEMENTS—For additional elements to be reported, see 3.1.

TABLE 4—CARBON STEEL CAST OR HEAT CHEMICAL LIMITS AND RANGES APPLICABLE ONLY TO SEMIFINISHED PRODUCTS FOR FORGING, HOT-ROLLED AND COLD-FINISHED BARS, WIRE RODS, AND SEAMLESS TUBING

Element	Chemical Ranges and Limits, % When Maximum of Specified Element	Chemical Ranges and Limits, % Range	Chemical Ranges and Limits, % Lowest Max
Carbon ⁽¹⁾	To 0.12 incl. Over 0.12 to 0.25 incl. Over 0.25 to 0.40 incl. Over 0.40 to 0.55 incl. Over 0.55 to 0.80 incl. Over 0.80	0.05 0.05 0.06 0.07 0.10 0.13	0.06
Manganese	To 0.40 incl. Over 0.40 to 0.50 incl. Over 0.50 to 1.65 incl.	0.15 0.20 0.30	0.35
Phosphorus	Over 0.040 to 0.08 incl. Over 0.08 to 0.13 incl.	0.03 0.05	0.040
Sulfur	Over 0.05 to 0.09 incl. Over 0.09 to 0.15 incl. Over 0.15 to 0.23 incl. Over 0.23 to 0.35 incl.	0.03 0.05 0.07 0.09	0.050
Silicon ⁽²⁾ Bars	To 0.15 incl. Over 0.15 to 0.20 incl. Over 0.20 to 0.30 incl. Over 0.30 to 0.60 incl.	0.08 0.10 0.15 0.20	
Rods	When silicon is required, the following ranges and limits are commonly used: 0.10max; 0.07–0.15, 0.10–0.20, 0.15–0.35, 0.20–0.40, or 0.30–0.60		
Copper	When copper is required, 0.20 minimum is commonly used.		
Lead ⁽³⁾	When lead is required, a range of 0.15–0.35 is generally used.		
Boron	Boron treated fine grain steels are produced to a range of 0.0005 to 0.003% boron.		

1. The carbon ranges shown customarily apply when the specified maximum limit for manganese does not exceed 1.10%. When the maximum manganese limit exceeds 1.10%, it is customary to add 0.01 to the carbon range shown.
2. It is not common practice to produce a rephosphorized and resulfurized carbon steel to specified limits for silicon because of its adverse effect on machinability.
3. Lead is reported only as a range of 0.15 to 0.35% since it is usually added to the mold or ladle stream as the steel is poured.

TABLE 5—CARBON STEEL CAST OR HEAT CHEMICAL LIMITS AND RANGES APPLICABLE ONLY TO STRUCTURAL SHAPES, PLATES, STRIP, SHEETS, AND WELDED TUBING

Element	Standard Chemical Ranges and Limits, % Limit or Max of Specified Range	Standard Chemical Ranges and Limits, Range	Standard Chemical Ranges and Limits, % Lowest Max
Carbon ⁽¹⁾	To 0.15 incl.	0.05	0.08 ⁽²⁾
	Over 0.15 to 0.30 incl.	0.06	
	Over 0.30 to 0.40 incl.	0.07	
	Over 0.40 to 0.60 incl.	0.08	
	Over 0.60 to 0.80 incl.	0.11	
	Over 0.80 to 1.35 incl.	0.14	
Manganese	To 0.50 incl.	0.20	0.40
	Over 0.50 to 1.15 incl.	0.30	
	Over 1.15 to 1.65 incl.	0.35	
Phosphorus	To 0.08 incl.	0.03	0.04
	Over 0.08 to 0.15 incl.	0.05	
Sulfur	To 0.08 incl.	0.03	0.05
	Over 0.08 to 0.15 incl.	0.05	
	Over 0.15 to 0.23 incl.	0.07	
	Over 0.23 to 0.33 incl.	0.10	
Silicon	To 0.15 incl.	0.08	0.10
	Over 0.15 to 0.30 incl.	0.15	
	Over 0.30 to 0.60 incl.	0.30	
Copper	When copper is required, 0.20 minimum is commonly specified.		

1. The carbon ranges shown in the column headed "Range" apply when the specified maximum limit for manganese does not exceed 1.00%. When the maximum manganese limit exceeds 1.00%, add 0.01 to the carbon ranges shown in the table.
2. 0.12 carbon maximum for structural shapes and plates.

TABLE 6—ADDITIONAL ELEMENTS TO BE REPORTED

Table Number	Additional Elements
1, 2, and 3A	Cu, Cr, Ni, Mo and S ⁽¹⁾ Al, Nb (Cb), Ti and V ⁽²⁾
3B	Cu, Cr, Ni, Mo and Si ⁽¹⁾
4 and 5	Cu, Cr, Ni, Mo and Si ⁽¹⁾ Al ⁽³⁾ , Nb (Cb) and V ⁽⁴⁾

1. When the amount of any one of these five elements is less than 0.02%, that analysis may be reported as "<0.02%."
2. When the amount of these elements is less than 0.008%, that analysis may be reported as "<0.008%."
3. Applicable to Structural Shapes, Plates, and Welded Tubing.
4. Applicable to Sheet and Strip.

4. Notes

- 4.1 Marginal Indicia**—The change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE IRON AND STEEL DIVISION 1—CARBON AND ALLOY STEELS

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Rationale—To remove the disclaimer of the JUN2000 document.

Relationship of SAE Standard to ISO Standard—Not applicable.

Application—In 1941, the SAE Iron and Steel Division, in collaboration with the American Iron and Steel Institute (AISI), made a major change in the method of expressing composition ranges for the SAE steels. The plan, as now applied, is based in general on narrower cast or heat analysis ranges plus certain product analysis allowances on individual samples, in place of the fixed ranges and limits without tolerances formerly provided for carbon and other elements in SAE steels.

Reference Section

SAEJ409—Product Analysis—Permissible Variations from Specified Chemical Analysis of a Heat or Cast of Steel

SAE J411—Carbon and Alloy Steel

SAE J1081—Potential Standard Steels

SAE J1249—Former SAE Standard and Former SAE Ex-Steels

SAE J1268—Hardenability Bands for Carbon and Alloy H Steels

SAE J1868—Restricted Hardenability Bands for Selected Alloy Steels

ISS Carbon and Alloy Steel Bar and Semi-Finished Products Manual

Developed by the SAE Iron and Steel Division 1—Carbon and Alloy Steels

Sponsored by the SAE Iron and Steel Executive Committee