

(R) TOOL AND DIE STEELS

Foreword—This Document has also changed to comply with the new SAE Technical Standards Board format.

1. **Scope**—This standard covers the identification, classification, and chemical composition of tool and die steels for use by engineers, metallurgists, tool designers, tool room supervisors, heat treaters, and tool makers.
2. **References**—There are no referenced publications specified herein.
3. **Definitions**—Tool and die steels are defined as certain carbon or alloy steels, capable of being hardened and tempered. They are usually melted in electric furnaces and produced to meet special requirements. They may be used in certain hand tools, precision gages, or in mechanical fixtures for cutting, shaping, forming, and blanking of materials at either cold or elevated temperatures.

This definition is not intended to include that type of tonnage production open hearth steel used in the manufacture of ordinary mechanics' hand tools, nor steel used in the manufacture of such products as hammers, picks, files, hollow drill steel, mining bits and cutters, large rolling mill rolls, and low alloy medium carbon forging die blocks. These exceptions are stated as a matter of guidance only and are not inclusive.

4. **Identification and Classification of Tool Steels**—This method of identification and classification of tool steels was designed to follow the most commonly used and generally accepted terminology of tool steel types of classes. It includes such basic principles as method of quenching, applications, special characteristic, and steels for particular industries. The method is believed to be as simplified as possible and aims to avoid complications in details composition or metallurgical specifications. The method provides appropriate symbols for generally accepted types of tool steel. It also provides for the addition of new products as they may be developed. See Table 1.

The present commonly used tool steels have been grouped into 6 major headings and each commonly accepted group of tool steels under these headings has been assigned an alphabetical letter symbol. Each major group identified by a letter symbol may contain a number of individual types of tool steels. These types are identified by a suffix number which follows the letter symbol. For water hardening tool steels this number suffix consists of three digits, the last two digits representing the approximate mean of the carbon content in tenths of one percent. To the above may be added after a dash (-) a suffix to further designate the grade and hardenability of W1 steels. (Examples: W110-2R would indicate a Grade 2 with regular hardenability. W110-3 would indicate a Grade 3 not controlled for hardenability.)

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Water Hardening Tool Steels: W

Shock Resisting Tool Steels: S

Cold Work Tool Steels: O—Oil Hardening Types
A—Medium Alloy Air Hardening Types
D—High Carbon High Chromium Types

Hot Work Tool Steels: H—H1-H19 incl—Chromium Base Types
H20-H39 incl—Tungsten Base Types
H40-H59 incl—Molybdenum Base Types

High Speed Tool Steels: T—Tungsten Base Types
M—Molybdenum Base Types

Special Purpose Tools Steels: L—Low Alloy Type

The chemical composition¹ of each type is given only as a representative type analysis. The carbon content is shown only in those cases where it is considered an identifying element to the steel.

5. **Standards for Austenitic Grain Size of Tool and Die Steels**—It is recommended that the following method be used for the determination of austenitic grain size of hardened tool steels:

The Shepherd Penetration Fracture Test—This test is used to determine hardenability and fracture grain size on tool and die steels. It is generally applied to carbon tool steels. To perform the test, a sample is machined to $\frac{3}{4}$ in diameter x 3 in long and pretreated by holding at 1600 F for 30 min and quenching in oil, followed by a retreatment by holding for 30 min at 1450 F, then quenching in brine. The specimen is notched midway and fractured by impact.

The penetration of hardening is measured in 64ths of an inch on half of the fractured sample after grinding and etching lightly in hot 50% hydrochloric acid solution.

The grain size is judged by comparing the surface of the fracture of the hardened case with Shepherd fracture grain size standards.

1. In cooperation with the American Iron and Steel Institute.

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TABLE 1—CHEMICAL COMPOSITIONS OF TOOL AND DIE STEELS⁽¹⁾

SAE Steel Designation	C	Mn	Si	Cr	V	W	Mo	Co
Water Hardening Tool Steels								
W108 ⁽²⁾	0.70–0.85	— ⁽²⁾	— ⁽²⁾	— ⁽²⁾	—	—	—	—
W109 ⁽²⁾	0.85–0.95	— ⁽²⁾	— ⁽²⁾	— ⁽²⁾	—	—	—	—
W110 ⁽²⁾	0.95–1.10	— ⁽²⁾	— ⁽²⁾	— ⁽²⁾	—	—	—	—
W112 ⁽²⁾	1.10–1.30	— ⁽²⁾	— ⁽²⁾	— ⁽²⁾	—	—	—	—
W209	0.85–0.95	— ⁽²⁾	— ⁽²⁾	— ⁽²⁾	0.15–0.35	—	—	—
W210	0.95–1.10	— ⁽²⁾	— ⁽²⁾	— ⁽²⁾	0.15–0.35	—	—	—
W310	0.95–1.10	— ⁽²⁾	— ⁽²⁾	— ⁽²⁾	0.35–0.50	—	—	—
Shock Resisting Tool Steels								
S1—Chromium-Tungsten	0.45–0.55	0.20–0.40	0.25–0.45 ⁽³⁾	1.25–1.75	0.15–0.30	1.00–3.00	0.40 ⁽⁴⁾	—
S2—Silicon-Molybdenum	0.45–0.55	0.30–0.50	0.80–1.20	—	0.25 ⁽⁴⁾	—	0.40–0.60	—
S5—Silicon-Manganese	0.50–0.60	0.60–0.90	1.80–2.20	0.30 ⁽⁴⁾	0.25 ⁽⁴⁾	—	0.30–0.50	—
Cold Work Tool Steels								
Oil Hardening Types								
O1—Low Manganese	0.85–0.95	1.00–1.30	0.20–0.40	0.40–0.60	0.20 ⁽⁴⁾	0.40–0.60	—	—
O2—High Manganese	0.85–0.95	1.40–1.80	0.20–0.40	0.35 ⁽⁴⁾	0.20 ⁽⁴⁾	—	0.30 ⁽⁴⁾	—
O6—Molybdenum Graphitic	1.35–1.55	0.30–1.00	0.80–1.20	—	—	—	0.20–0.30	—
Medium Alloy Air Hardening Types								
A2—5% Chromium Air Hard	0.95–1.05	0.45–0.75	0.20–0.40	4.75–5.50	0.40 ⁽⁴⁾	—	0.90–1.40	—
High Carbon-High Chromium Types								
D2—High Carbon-High Chromium (Air)	1.40–1.60	0.30–0.50	0.30–0.50	11.00–13.00	0.80 ⁽⁴⁾	—	0.70–1.20	0.60 ⁽⁴⁾
D3—High Carbon-High Chromium (Oil)	2.00–2.35	0.24–0.45 ⁽³⁾	0.25–0.45	11.00–13.00	0.80 ⁽⁴⁾	0.75 ⁽⁴⁾	0.80 ⁽⁴⁾	—
D5—High Carbon-High Chromium (Cobalt)	1.40–1.60	0.30–0.50	0.30–0.50	11.00–13.00	0.80 ⁽⁴⁾	—	0.70–1.20	2.50–3.50
D7—High Carbon-High Chromium-High Vanadium	2.15–2.50	0.30–0.50	0.30–0.50	11.50–13.50	3.80–4.40	—	0.70–1.20	—
Hot Work Tool Steels								
Chromium Base Types								
H11—Chromium-Molybdenum-V	0.30–0.40	0.20–0.40	0.80–1.20	4.75–5.50	0.30–0.50	—	1.25–1.75	—
H12—Chromium-Molybdenum-Tungsten	0.30–0.40	0.20–0.40	0.80–1.20	4.75–5.50	0.10–0.50	1.00–1.70	1.25–1.75	—
H13—Chromium-Molybdenum-V	0.30–0.40	0.20–0.40	0.80–1.20	4.75–5.50	0.80–1.20	—	1.25–1.75	—
Tungsten Base Types								
H21—Tungsten	0.30–0.40	0.20–0.40	0.15–0.30	3.00–3.75	0.30–0.50	8.75–10.00	—	—
High Speed Tool Steels								
Tungsten Base Types								
T1—Tungsten 18-4-1	0.65–0.75	0.20–0.40	0.20–0.40	3.75–4.50	0.90–1.30	17.25–18.75	—	—
T2—Tungsten 18-4-2	0.75–0.85	0.20–0.40	0.20–0.40	3.75–4.50	1.80–2.40	17.50–19.00	0.70–1.00	—
T4—Cobalt-Tungsten 18-4-1-5	0.70–0.80	0.20–0.40	0.20–0.40	3.75–4.50	0.80–1.20	17.25–18.75	0.70–1.00	4.25–5.75
T5—Cobalt-Tungsten 18-4-2-8	0.75–0.85	0.20–0.40	0.20–0.40	3.75–4.50	1.80–2.40	17.50–19.00	0.70–1.00	7.00–9.00
T8—Cobalt-Tungsten 14-4-2-5	0.75–0.85	0.20–0.40	0.20–0.40	3.75–4.50	1.80–2.40	13.25–14.75	0.70–1.00	4.25–5.75
Molybdenum Base Types								
M1—Molybdenum 8-2-1	0.75–0.85	0.20–0.40	0.20–0.40	3.75–4.50	0.90–1.30	1.15–1.85	7.75–9.25	—
M2—Molybdenum-Tungsten 6-6-2	0.78–0.88	0.20–0.40	0.20–0.40	3.75–4.50	1.60–2.20	5.50–6.75	4.50–5.50	—
M3—Molybdenum-Tungsten 6-6-3	1.00–1.25	0.20–0.40	0.20–0.40	3.75–4.50	2.25–3.25	5.50–6.75	4.75–6.25	—
M4—Molybdenum-Tungsten 6-6-4	1.25–1.40	0.20–0.40	0.20–0.40	4.00–4.75	3.90–4.50	5.25–6.50	4.50–5.50	—

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TABLE 1—CHEMICAL COMPOSITIONS OF TOOL AND DIE STEELS⁽¹⁾ (CONTINUED)

SAE Steel Designation	C	Mn	Si	Cr	V	W	Mo	Co
Special Purpose Tool Steels								
Low Alloy Types								
L6—Nickel-Chromium ⁽⁵⁾	0.65–0.75	0.55–0.85 ⁽³⁾	0.20–0.40	0.65–0.85	0.25 ⁽⁴⁾	—	0.25 ⁽⁴⁾	—
L7—Chromium	0.95–1.05	0.25–0.45	0.20–0.40	1.25–1.75	—	—	0.30–0.50	—

- These compositions are not intended for forging die steels.
- Water hardening steels listed herein are usually available in four grades or qualities as follows:
 Special (Grade 1)—The highest quality water hardening carbon tool steel, controlled for hardenability, chemistry held to closest limits, and subject to most rigid tests to insure maximum uniformity in performance.
 Extra (Grade 2)—A high quality water hardening carbon tool steel, controlled for hardenability, subject to tests to insure good service for general application.
 Standard (Grade 3)—A good quality water hardening carbon tool steel, not controlled for hardenability, recommended for application where some latitude with respect to uniformity is permissible.
 Commercial (Grade 4)—A commercial quality water hardening carbon tool steel, not controlled for hardenability, not subject to special tests. On Special and Extra Grades, limits on manganese, silicon, and chromium are not generally required in lieu of the following Shepherd hardenability limits:

	0.70–0.85 C and 0.85–0.95 C		0.95–1.10 C and 1.10–1.30 C	
	Hardenability, 64ths In. Penetration	Fracture Grain Size, min	Hardenability, 64ths In. Penetration	Fracture Grain Size, min
Shallow.....	10 max	8	8 max	9
Regular.....	9 to 13	8	7 to 11	9
Deep.....	12 min	8	10 to 16	8

On Standard and Commercial Grades, the following limits on composition are generally required:

	Mn	Si	Cr
Standard, max	0.35	0.35	0.15
Commercial, max	0.35	0.35	0.20

Total of manganese, silicon, and chromium not to exceed 0.75%.

- May be present in percentages other than shown.
- Optional element. Steels have found satisfactory application either with or without the element present.
- Nickel content 1.25–1.75.

6. Notes

6.1 **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 SAE IRON AND STEEL TECHNICAL COMMITTEE