

AISE STANDARD NO. 7

**SPECIFICATIONS FOR
DESIGN
OF LADLE HOOKS**



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by HGFD / Mech (Department)

In the name of P. Porter

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SPECIFICATIONS FOR DESIGN OF LADLE HOOKS

I. SCOPE

This specification shall be known as Specifications for Design of Ladle Hooks, AISE Standard No. 7 and shall cover new laminated ladle hooks, rectangular in cross section, used primarily for lifting hot metal ladles. They may also be applied to other lifting devices such as C-hooks, but should not be applied to hole arms, roll changing devices or other such specialty items. If a solid ladle hook should be specified, the following design procedure is generally applicable.

This voluntary consensus standard was developed by a representative committee comprised of users, manufacturers and the Association of Iron and Steel Engineers. This standard was developed by consideration of engineering methods currently available and is our recommended "best practice" under favorable conditions. It is not the minimum acceptable standard in all instances, nor should such "best practice" standard be required in all specifications.

II. MATERIALS

A. The following materials shall be used for the fabrication of ladle hooks: ASTM A242; A441; A516; A514; A515, Grade 55, 60, 65, 70. Other materials which are used shall have impact properties at least as good as those of the least established value for the above materials, for the plate thickness under consideration.

The purchaser or user may require in the purchase order that any of the material specified in the above listing and intended for use in the ladle hook be subjected to the same proof requirements of ASTM A593 (latest revision) to confirm the suitability of the material manufactured for use under this specification.

B. Rivets shall be made of materials compatible with the ladle hook materials. Recommended grades are: A502, Grade 2; A202, Grade A (75,000/90,000 psi U.T.S.) for A514 hooks; A31, Grade A.

C. Recommended materials for supporting bushings are A128, Grade A; A237, Class "E" or "F"; or forgings or round seamless tubing with the same chemical analysis as A514, quenched and tempered to 100,000 psi yield strength. If A237, Class "E" or "F" is used, doweling, instead of welding, is recommended.

D. Recommended materials for the trunnion seat wearing plate are: ASTM A128; A242; A441; A514; A515, Grade 55, 60, 65, 70; A516.

E. Ladle hooks may be made of a single plate provided the thickness does not exceed 2 in. When a solid hook is used, the material in the plate shall be tested in accordance with and shall comply with the requirements of ASTM A435-65, "Method and Specification for Longi-

tudinal Wave Ultrasonic Inspection of Steel Plates for Pressure Vessels."

All plates intended for use in ladle hooks shall be straight, flat and free of flaws and defects. No hook material which is dependent on heat treatment for its properties shall be straightened or flattened by the application of heat. Such material (i.e. ASTM A514) shall be received from the mill in a straight and flat condition.

III. FABRICATION

A. The thickness of laminated plates may be specified by the purchaser or user. The min thickness shall be 3/4 in. Individual plates shall be machine flame cut to size. All flame cut edges shall be dressed smooth by grinding. Any gouges produced by flame cutting shall be repaired by the following procedure: (Steel grades dependent on heat treatment, such as ASTM A514, shall not be repaired by this method.)

1. Clean out the gouge and perform dye-check test to detect cracks. (Remove such cracks by flame cutting.) Any cracks deeper than 1/8 in. shall be cause for rejection of the plate.
2. Fill the gouge, using a low hydrogen electrode compatible with and equivalent in strength to the plate material.
3. Grind flat.
4. Add reinforcing bead if necessary.
5. Grind reinforcing bead flush.
6. Test all repaired areas. If the repair is less than 1/8 in. deep, magnetic particle inspection may be used. If the repair is more than 1/8 in. deep, it shall be checked by ultrasonic inspection.

Surfaces where wearing plates are to be installed shall be machined after the hook is assembled.

B. Unless otherwise specified, the plates shall be held together by hot driven rivets which have been heated through their entire length. Whenever clearance permits, buttonhead rivets shall be used. In this case, rivets of sufficient length shall be used to overfill the hole. The rivets may then be chipped or ground flush. If clearance is insufficient, counter-sunk rivets will be used. Holes for rivets shall be drilled and reamed to size after plates have been assembled. Gap between laminations shall not exceed 0.001 in. for a distance of two rivet dia from the edge of a rivet hole. Gaps in other areas shall not exceed 0.010 in.

C. No rivets shall be closer than one third of the width of the plate (or 6 in. if the width exceeds 18 in.) to the inside surface of the wearing plate at the point of max stress, as shown in Fig. 1, Area b.

- D. The edge distance for rivets other than those at the critical sections in the bight shall be not less than 2-1/2 in. from the center of the rivet hole to the edge of the hook.
- E. In the eye section of the hook, no rivets will be located above a line which is located at a distance of 1-1/2 times the dia of the supporting pin and bushing hole below the center line of the supporting pin, as shown in Fig. 1.
- F. The portion of the plates above this line shall be welded together using low hydrogen electrodes having properties equivalent to the materials used in the laminations. Intermittent and transverse welding is not acceptable.
- G. Riveting work on hooks shall be completed before hooks are continuously edge welded.
- H. The net section of the hook at the eye (in the horizontal plane) shall have sufficient area so that the max stress at this section does not exceed that established by Clause VI, D. The thickness of this section will gradually be increased to a max through the vertical plane through the center of the hole for the eye pin. In the vertical plane, the section will have a min thickness which is equal to 1/2 the net section across the eye plus 1/4 the eye dia.
- I. To allow for clearance, the thickness of the hook shall be 1-1/2 in. less than the length of the trunnion pin bearing on the ladles between the flange and shoulder.

IV. WEARING PLATES

- A. The inner surface of the hook that comes in contact with the ladle trunnion and the outside tip of the hook shall be protected by a steel wearing plate not less than 3/4 in. thick. The trunnion seat wearing plate shall be made of material specified in Clause II, D, machined to fit the laminations and secured in place by welding. The outside edges of the wear plate and bumper plate shall be beveled and joined to the hook plates by continuous welds. Wearing plates in the bight should be continuous through the high stress area of the bight of the hook. No transverse welds shall be used.
- B. If specified by the purchaser or user, the wearing plate may be omitted; in which case, a layer of hard surface weld may be applied to the inside of the hook and ground smooth. Surface checking can be anticipated, with hard surface welding. This hard surface shall be applied before stress relieving and shall be checked by magnetic particle tests for cracks or other defects. When such defects are found, they shall be ground out and the process, including stress relieving, shall be repeated.

V. SUPPORTING BUSHING

- A. The eye end of laminated hooks may be provided with a steel bushing. A press fit will be used to insert the bushing into the eye of the hook and it shall be doweled, on the vertical axis only, or welded continuously, as specified by the purchaser or user.
- B. The min bushing thickness shall be not less than 1/8 the pin dia nor less than 1/2 in. for undoweled bushings, nor 1 in. for doweled bushings.

VI. COMPUTATION OF DESIGN STRESSES

- A. Hooks shall be designed for the sum of the stresses due to the following loads: (1) direct (vertical) load,

(2) bending in the plane of the hook about the major axis, and (3) lateral or sidewise bending about the minor axis of the hook.

1. The stress due to the direct load on a curved beam shall be determined by:

$$S_d = K_t \frac{P}{A} \text{ in the bight area}$$

P = Vertical load on hook

A = Net cross-sectional area at section being considered. The net cross-sectional area at each section is the gross area minus the area of the rivet holes.

$$K_t = \frac{2 - a(R/c - 1)}{3(Ra/c - 2)/(R/c - 1)}$$

$$\text{where } a = \log_e \frac{(R/c + 1)}{(R/c - 1)}$$

R = distance of centroidal axis of section to line of application of load. (Refer to Figure 1)

Values of K_t for a rectangular section are given in the following table:

TABLE I

$\frac{R}{c}$	K_t	$\frac{R}{c}$	K_t
1.2	2.89	1.8	1.63
1.3	2.39	1.9	1.57
1.4	2.10	2.0	1.52
1.5	1.92	2.1	1.48
1.6	1.79	2.2	1.45
1.7	1.70	2.3	1.42

2. The max stress due to bending in the plane of the hook will occur at the inside fiber of the bight section. It will be computed from the Winkler-Bach theory for curved beams as follows:

$$S_b = \frac{K_t M c}{I}$$

where M = applied bending moment about centroidal axis.

c = distance from centroidal axis to extreme fiber of the surface of the beam at the inside of the hook.

I = static moment of inertia of the cross-sectional area about the short centroidal axis.

3. The max stress due to lateral bending will be computed from the simple beam formula, with the rated load applied 1 in. in from the outside edge of the hook.

$$S = \frac{P(t/2 - 1)t/2}{I_{lateral}}$$

where t = thickness of hook and

$I_{lateral}$ = the lateral moment of inertia of the cross-sectional area about the long centroidal axis.

- B. The stresses in the bight will be the sum of the three stresses enumerated above or:

$$S = K_t (P/A + Mc/I) + \frac{P(t/s - 1)t/2}{I_{lateral}}$$

- C. The shanks shall be designed for the sum of the following two stresses:

$$S = \frac{P}{A} + \frac{P(t/2 - 1)t/2}{I_{lateral}}$$

Areas, moments of inertia and other applicable values will correspond to the section for which the stress is being computed.

- D. The stress at the section through the eye shall be computed as follows:

$$S = \frac{3P}{A} + \frac{P(t/2 - 1)t/2}{I_{lateral}}$$

- E. If the hook load, in combination with other requirements, is so high as to result in a deep slender hook, designer should contact purchaser or user on possibility of using longer trunnions on ladles to permit use of a thicker hook.
- F. Refer to AISE Standard No. 9 (latest revision) section 5D to determine required dimensions of trunnion pin which affects eye geometry.

VII. COMPUTATION OF ALLOWABLE STRESSES

The following allowable stresses in various categories shall not be exceeded in the design by the method of elastic analysis of the hook. These stresses are based on the use of materials that meet the requirement of this standard.

- A. The allowable stress in the bight shall not be exceeded by the sum of the primary general membrane (direct stress), bending stress in the plane of the hook, and the lateral bending stress. The allowable stress shall be determined by equation A or B, whichever yields the lower value:

$$\sigma_{au} = \frac{F_f F_t \sigma_u}{F_i (SF)_u} \quad (A)$$

$$\sigma_{ay} = \frac{F_f F_t \sigma_y}{F_i (SF)_y} \quad (B)$$

where σ_{au} = allowable stress, based on min ultimate strength, psi

σ_{ay} = allowable stress, based on min yield strength, psi

σ_u = min ultimate strength at room temperature, psi

σ_y = min yield strength at room temperature, psi

F_f = fabrication derating factor

F_t = temperature derating factor

F_i = impact factor

$(SF)_u$ = safety factor against ultimate strength

$(SF)_y$ = safety factor against yielding

NOMENCLATURE FOR STRESS FORMULAE AND LIMITING DIMENSIONS FOR LADLE HOOKS.

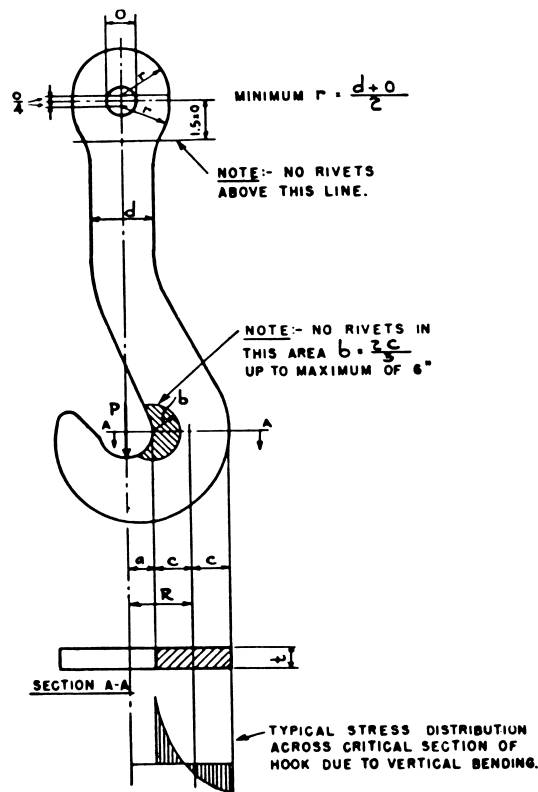


Figure 1

In this current standard the following values shall be used:

Impact factor $F_i = 1.2$

Temperature derating factor F_t = Given in Table II as a function of design temperature and material specified.

Safety factor against ultimate strength $(SF)_u = 3.15$

Safety factor against yielding $(SF)_y = 1.75$

Fabricating derating factor $F_f = f_1 \times f_2 \times f_3 \times f_4$

$f_1 = 1.0$ for welded construction
0.95 for riveted or bolted construction

$f_2 = 1.0$ for cold forming
1.05 for hot forming
1.0 if not applicable

$f_3 = 1.0$ for thermally cut surface
1.10 for machined or plasma-cut surface
0.90 for sheared surface
1.0 if not applicable

$f_4 = 1.0$ for straightening by cutting and rewelding
1.05 for flame straightening
1.0 if not applicable

- B. The allowable stress in the shank shall not be exceeded by the sum of the primary general membrane and by the lateral bending stress; and shall be determined by equations A or B, whichever is the lower value.
- C. The allowable stress in the eye shall not be exceeded by the sum of peak membrane and the lateral bending stress; and shall be determined by equations A or B, whichever is the lower value.
- D. Shear stress in the rivets is not to exceed the allowable stress given by equations A or B, whichever is the lower value.
- E. The primary plus secondary stress intensity (includes structural discontinuities and thermal stresses) shall not exceed the allowable stress given by equations C or D, whichever is the lower value.

$$\sigma_A = 3\sigma_{au} \quad (C)$$

$$\sigma_A = 3\sigma_{ay} \quad (D)$$

TABLE II
TEMPERATURE DERATING FACTORS FOR
LADLE HOOKS

Maximum Design Temperature (°F)	Materials Group (ASTM Designations)	
	I	II
	A515 Grade 55, 60, 65, 70 A516 Grade 55, 60, 65, 70 A514	A202 Grade A A242 A441
100	1.000	0.986
200	0.911	0.932
300	0.886	0.896
400	0.857	0.870
500	0.808	0.848
600	0.739	0.813
700	0.720	0.766
800	0.657	0.713
900	0.634	0.654

VIII. RIVET DESIGN

Rivets located near the load application received the highest shear loads and will become loose with use. The load will then be taken by the next rivet until it becomes loose and the loosening process will progress. The requirement that the total rivet cross-sectional area carry the hook rating is not technically sound.

The primary function of the rivets, therefore, is to hold the lamination pack together. The use of tight rivets (diametral clearances less than 0.003 in.) is not recommended. The practice of using a ratio of hook face area to total rivet cross-sectional area of 75 is recommended.

Laminated hooks handling hot metal ladles are subject to temperature gradients and overstressing of rivets in the heated and adjacent zones results. The same loosening mechanism that exists for the mechanical load applies to the thermal case.

For tight rivets the use of a heat shield shown in Fig. 2 is recommended. Heat shields are not required for loose rivets.

RECOMMENDED THERMAL SHIELD DESIGN

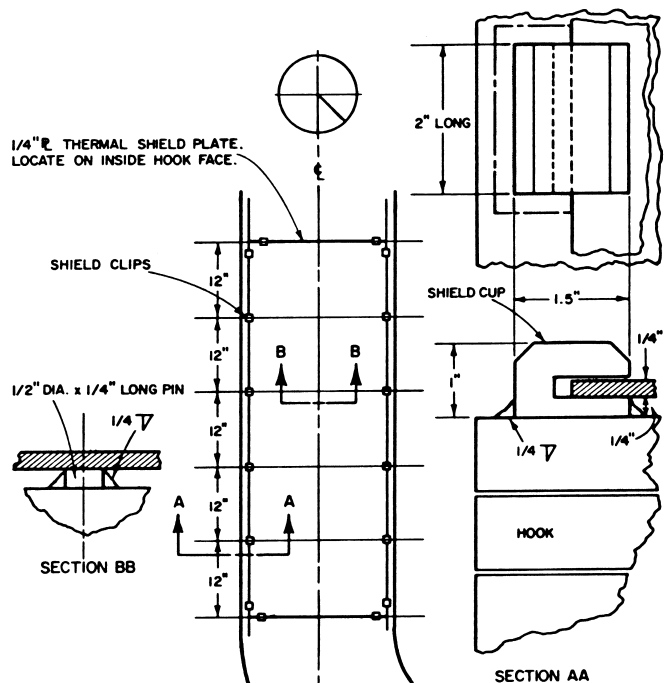


Figure 2

IX. C-HOOKS AND SOLID LADLE HOOKS

- A. This specification can be used for C-hooks and solid ladle hooks with a max metal thickness of 4 in.
- B. Plates for solid ladle hooks should be free of injurious flaws and defects as determined by ultrasonic or other nondestructive testing techniques.
- C. Critical areas, such as the "throat" of a C-hook, should be machined to a radius of 2 in. min with a 125 RMS micro-in. finish.

X. REFERENCES

1. ASME Boiler and Pressure Vessel Code, Sect. VIII, Division 2, 1971.
2. "Structural Properties of High Strength Steels at Elevated Temperatures," AISI Committee on Building Research and Technology, Jan. 28, 1965.
3. "Analytical and Experimental Studies of Ladle Hooks," by Prof. Carl W. Muhlenbruch, p 586, AISE 1949.
4. "Analysis of Ladle Hooks," AISE Report.

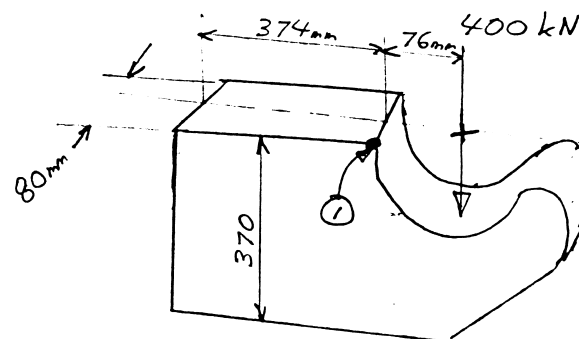
APPENDIX A

RECOMMENDED HOOK MAINTENANCE AND INSPECTION PROCEDURES, HOOK PLACEMENT CRITERIA

Laminated ladle hooks should be visually inspected weekly for any indication of cracked plates and welds.

Project Site Sheet of Computation of Lifting Beam - Grapple ClawComputed by PJP Date Oct 12, 83Stress at section shown

Ref: AISE Standard No. 7(1949)

1) Direct load

$$P = 400 \times 10^3 \text{ N}$$

$$A = 374 \times 80 = 29.9 \times 10^3 \text{ mm}^2$$

$$S_d = \frac{P}{A} = \frac{400}{29.9} = \underline{13.4 \text{ MPa}}$$

2) Bending in the plane of the hook

$$M = 400 \times 10^3 \times \left(76 + \frac{374}{2} \text{ mm} \right) = 400 \times 10^3 \times 263 = 105 \times 10^6 \text{ N-mm}$$

$$C = \frac{1}{2}(374) = 187 \text{ mm}$$

$$I_{xx} = \frac{th^3}{12} = \frac{80 \times (374)^3}{12} = 349 \times 10^6 \text{ mm}^4$$

$$R = 263 \text{ mm}$$

$$\frac{R}{C} = 1.41$$

$$\alpha = \ln \left(\frac{R/C + 1}{R/C - 1} \right) = \ln \left(\frac{1.41 + 1}{1.41 - 1} \right) = 1.78$$

$$K_t = \frac{2 - \alpha(R/C - 1)}{3 \left(\frac{R^\alpha}{C} - 2 \right) \left(\frac{R}{C} - 1 \right)} = 2.09$$

$$S_b = K_t \frac{Mc}{I} = 2.09 \times \frac{105 \times 10^6 \times 187}{349 \times 10^6} = 2.09 \times 56.3 = \underline{118 \text{ MPa}}$$

3) Lateral or sideways bending

$$I_y = \frac{ht^3}{12} = \frac{(374)(80)^3}{12} = 16.0 \times 10^6 \text{ mm}^4$$

$$t = 80 \text{ mm}$$

$$S_l = \frac{P(t/2 - 25)t/2}{I_y} = \frac{400 \times 10^3 (40 - 25) 40}{16.0 \times 10^6} = \underline{15.0 \text{ MPa}}$$

4) Combined stress at point where max. stress occurs ①

$$S = S_d + S_b + S_l = 13.4 + 118 + 15.0 = \underline{146 \text{ MPa}} \longrightarrow$$