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SURFACE VEHICLE STANDARD

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AUTOMOTIVE STEEL CASTINGS

***Foreword*—**This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

***1. Scope*—**These specifications cover steel castings used in the automotive and allied industries.

2. References

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

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

SAE J406—Methods of Determining Hardenability of Steels
SAE J407—Hardenability Bands for Alloy H Steels
SAE J416—Tensile Test Specimens
SAE J420—Magnetic Particle Inspection

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 255—Method of End-Quench Test for Hardenability of Steel
ASTM A 370—Methods and Definitions for Mechanical Testing of Steel Products
ASTM A 609—Specification for Longitudinal Beam Ultrasonic Inspection
ASTM E 8—Methods of Tension Testing of Metallic Materials
ASTM E 52—Industrial Radiographic Terminology for Use in Radiographic Inspection of Castings and Weldments
ASTM E 71—Industrial Radiographic Standards for Steel Castings
ASTM E 94—Recommended Practice for Radiographic Testing
ASTM E 99—Reference Radiographs for Steel Welds
ASTM E109—Method for Dry Powder Magnetic Particle Inspection
ASTM E 113—Recommended Practice for Ultrasonic Testing by the Resonance Method
ASTM E 114—Recommended Practice for Ultrasonic Testing by the Reflection Method, Using Pulsed Longitudinal Waves Induced by Direct Contact
ASTM E 125—Methods for Reference Photographs for Magnetic Particle Indications on Ferrous Castings
ASTM E 138—Method for Wet Magnetic Particle Inspection
ASTM E 142—Method for Controlling Quality of Radiographic Testing
ASTM E 165—Methods for Liquid Penetrant Inspection

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ASTM E 186—Industrial Radiographic Reference for Steel Castings

2.1.3 STEEL FOUNDERS' SOCIETY OF AMERICA PUBLICATION—Available from Steel Founders' Society of America, Cast Metals Federation Building, 20611 Center Ridge Road, Rocky River, OH 44116.

ACI Surface Indicator Scale

2.1.4 AMERICAN WELDING SOCIETY PUBLICATION—Available from Steel Founders' Society of America, Cast Metals Federation Building, 20611 Center Ridge Road, Rocky River, OH 44116.

Recommended Practice for Repair Welding and Fabrication Welding of Steel Castings

3. ***General Data—***In order to cover adequately the varying requirements encountered, the cast steels are classified into the following groups:

a. Grade 00XX Steel Castings—These are specified by chemical composition and minimum mechanical properties (except the carburizing grade, which is based on chemical composition only).
b. Grade 0XX Steel Castings—These are specified by minimum mechanical properties, for miscellaneous uses where the requirements do not justify hardenability control.
c. Grade HX Steel Castings—These are specified by hardenability requirements.

3.1 All castings shall be furnished in the heat treated condition by one of the following heat treatments unless otherwise specified:

a. Annealed
b. Normalized
c. Normalized and tempered
d. Quenched and tempered

3.2 The choice of alloying elements used in the manufacture of the 0XX grades of steel castings shall be at the option of the foundry. Certain specific cases may arise where chemistry is a controlling factor in obtaining desired properties, such as wear resistance. Under these circumstances, chemistry may form part of this specification by specific agreement between the producer and purchaser, in inquiry and purchase order.

4. ***Grades of Steel Castings—***Grades and requirements of automotive cast steels are shown in Table 1. A typical material specification is: Steel casting, SAE J435 (0120).

TABLE 1A—GRADES OF CAST STEEL AND REQUIREMENTS
CHEMICAL COMPOSITION,% BY WT(1)

SAE Grade	Approx Equivalent ASTM	Approx Equivalent QQ-S-681d	Description	C	Mn	Sl	P, Max	S, Max
0022	A 27	—	Low carbon, suitable for carburizing	0.12-0.22	0.50-0.90	0.60 max	0.040	0.045
0025	A 27	—	Carbon steel welding grades	0.25 max	0.75 max(2)	0.80 max	0.040	0.045
0030	A 27	65-35	Carbon steel welding grades	0.30 max	0.70 max(2)	0.80 max	0.040	0.045
0050A	—	0050A	Carbon steel medium strength grades	0.40-0.50	0.50-0.90	0.80 max	0.040	0.045
0050B(3)	—	0050B	Carbon steel medium strength grades	0.40-0.50	0.50-0.90	0.80 max	0.040	0.045
080	A 148	80-50	Medium strength low alloy grades	Optional	Optional	Optional	0.040	0.045
090	A 148	90-60	Medium strength low alloy grades	Optional	Optional	Optional	0.040	0.045
0105	A 148	105-85	High strength alloy grades	Optional	Optional	Optional	0.040	0.045
0120	A 148	120-95	High strength alloy grades	Optional	Optional	Optional	0.040	0.045
0150	A 148	150-125	High strength alloy grades	Optional	Optional	Optional	0.040	0.045
0175	—	175-145	High strength alloy grades	Optional	Optional	Optional	0.040	0.045

HA, HB, HC Hardenability Grades, See Figures 1, 2, and 3.

1. These analyses are mandatory, unless otherwise specified by the purchaser. The optional and alloying elements may be used at the producer's discretion to obtain the mechanical properties or hardenability specified, unless otherwise specified. Boron in the range of 0-.003-0.007% with 1.35% manganese maximum may be used as an optional alloying element by agreement between producer and purchaser.
2. For each reduction of 0.01% carbon below the maximum specified, an increase of 0.04% manganese above the maximum specified will be permitted to a maximum of 1% manganese.
3. Properties require a liquid quench and temper. Casting section should be 1 in (25.4 mm) or less.

TABLE 1B—GRADES OF CAST STEEL AND REQUIREMENTS TEST BAR MINIMUM MECHANICAL PROPERTIES

SAE Grade	Approx Equivalent ASTM	Approx Equivalent QQ-S-681d	Description	Tensile Strength psi	Tensile Strength MPa	Yield Strength psi	Yield Strength MPa	Elongation in 2 in,%	Reduction in Area,%	Brinell Hardness(1)
0022	A 27	—	Low carbon, suitable for carburizing	—	—	—	—		—	187 max
0025	A 27	—	Carbon steel welding grades	60 000	413.7	30 000	206.8	22	30	187 max
0030	A 27	65-35	Carbon steel welding grades	65 000	448.2	35 000	241.3	24	35	131-187
0050A	—	0050A	Carbon steel medium strength grades	85 000	586.0	45 000	310.3	16	24	170-229
0050B(2)	—	0050B	Carbon steel medium strength grades	100 000	689.5	70 000	482.6	10	15	207-255
080	A 148	80-50	Medium strength low alloy grades	80 000	551.6	50 000	344.7	22	35	163-207
090	A 148	90-60	Medium strength low alloy grades	90 000	620.5	60 000	413.7	20	40	187-241
0105	A 148	105-85	High strength alloy grades	105 000	723.9	85 000	586.0	17	35	217-248
0120	A 148	120-95	High strength alloy grades	120 000	827.4	95 000	655.0	14	30	248-311
0150	A 148	150-125	High strength alloy grades	150 000	1034.2	125 000	861.8	9	22	311-363
0175	—	175-145	High strength alloy grades	175 000	1206.6	145 000	999.7	6	21	363-415

HA, HB, HC Hardenability Grades, See Figures 1, 2, and 3.

1. Obtain from parts, not test bars, in location not over 3 in in thickness.
2. Properties require a liquid quench and temper. Casting section should be 1 in (25.4 mm) or less.

5. ***Mechanical Properties—***When steel castings are specified to minimum mechanical properties, the values shown for the appropriate grade in Tables 1A and 1B shall apply to the test bars. When test samples are to be taken from the castings, their location and the required mechanical properties shall be agreed upon in writing by the producer and user at the time of bidding.

5.1 The mechanical property requirements pertain to the properties of standard test bars that have been poured in accordance with ASTM A 370, Methods and Definitions for Mechanical Testing of Steel Products. They shall be poured with metal which has received deoxidation treatment identical to that metal from which the castings are poured. All test coupons from which specimens are to be prepared shall be given the same heat treatment as the castings, except that the tempering temperature for the castings are to be adjusted for equivalent Brinell hardness.

6. ***Tensile Test—***Tensile test specimens shall be machined to the dimensions shown in SAE J416 or in ASTM E 8, Methods of Tension Testing of Metallic Materials. One tensile test shall be made from each heat or lot.[1] If any specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted for the same lot.

7. ***Quality Control—***After meeting acceptance tests for ten consecutive heats used for making castings of any one grade, the manufacturer may assemble the castings from succeeding lots in groups of five heats each. The castings in each such group shall be accepted on the basis of one test specimen taken at random from one of the five heats provided that the chemical analysis of all heats in the group falls within the range established by the first ten consecutive acceptable heats as determined by both chemistry and mechanical testing.

7.1 After meeting acceptance tests for ten consecutive heats, by mutual agreement between the producer and purchaser, subsequent castings may be accepted by hardness checking of the castings in lieu of mechanical properties of test bars, to the hardness ranges shown in Tables 1A and 1B, provided that the chemical falls within the range of the ten accepted heats.

7.2 **Retests—**If retest is required, the heat may be requalified by using another specimen, and the four other heats in the group shall be tested individually. The same heat treating procedure used for the first ten consecutive heats shall be used for all subsequent heats. This procedure shall be established for each grade separately.

8. ***Hardenability—***Whenever hardenability is specified on alloy steel castings that are to be heat treated by the purchaser or producer, the limits shown for grades HA, HB, or HC (Figures 1, 2, and 3) whichever is specified, shall apply. Alloy steels may thus be specified on drawings to hardenability in the following way: Steel Casting SAE HB.

8.1 Castings which are shipped to the buyer under hardenability requirements, and on which the buyer will do the heat treating, should not have a hardness greater than 284 Bhn for Grades HA and HB, and 269 Bhn for Grade HC when they leave the foundry.

8.2 The hardenability of the steel used shall be determined in accordance with SAE J406, or ASTM A 255, Method of End-Quench Test for Hardenability of Steel. Calculated hardenability may be used in lieu of actual test by agreement between producer and user. The specimens may be cast to size in molds or prepared from the standard test bar coupon. Unless otherwise agreed to between the producer and purchaser, the producer shall keep a record of the hardenability data representing all heats in question for a period of three months.

1. The term “lot” shall be considered as all castings in a heat subjected to the same heat treating procedure, for example, a heat of castings could be divided into several lots by virtue of different heat treatments, but all of the same chemistry.

8.3 The hardenability of cast steels is similar to that of wrought steels of the same chemical analysis. Details as discussed for wrought steels in SAE J407, apply equally to cast steels. The bands for cast steels given in Figures 1, 2, and 3 are based on a nominal carbon content of 0.30%. Bands for steel of other carbon contents shall be established by mutual consent of the purchaser and producer. It is suggested that H bands for wrought steels as shown in SAE J407 be used as guides.

9. ***Chemical Analysis*****—**All castings based on chemical analysis shall conform to the ranges given for each grade in Tables 1A and 1B. The only chemical requirements for the balance of the castings in these specifications will be maximum phosphorus and sulfur content as indicated. Chemical analysis of each melt of steel shall be made from a test specimen obtained by the producer during the pouring of the heat. Chemical analysis samples shall be taken from metal not less than ¼ in beneath the surface. The chemical composition thus determined shall conform to the requirements prescribed in Tables 1A and 1B.

9.1 When high strength cast steels are to be used for fabrication by fusion welding, it is recommended that the carbon content be limited to 0.35% carbon, max.

9.2 **Product Analysis—**When so desired, an analysis may be made by the purchaser from a test specimen or casting representing each melt. The procedure previously outlined shall be followed, and the chemical composition as determined shall conform with the requirements specified for the particular grade of steel in question.

9.3 **Residual Alloy Limitations—**When required, residual alloy limitations are subject to the specific agreement between producer and purchaser in inquiry and order. The following additional special conditions are noted:

Grade 0022—Maximum hardness in Tables 1A and 1B is before carburizing and provides a limit to residual alloys.

Grade 0025 and 0030—Residual alloys shall be limited by the ability of these grades to be readily welded.

9.4 If close control of residual alloys is required, the maximum DI (ideal diameter) to control hardenability should be negotiated between purchaser and producer.

10. ***Finish Requirement*****—**When so specified in the inquiry and purchase order and mutually agreed upon by the producer and purchaser, castings made to any SAE grade listed in Tables 1A and 1B may be subject to surface finish requirements. Such requirements shall be based upon comparison with the ACI Surface Indicator Scale (available from Steel Founders' Society of America, Cast Metals Federation Building, 20611 Center Ridge Road, Rocky River, OH 44116.) See Figure 4.

10.1 The SIS Scale is a comparator intended for visual inspection. Optical magnifiers and measuring instruments are not to be used, but it is permissible to judge similar surfaces by touch, that is, rubbing a finger across the casting and the scale, in addition to visual observation. Specifying one of the four SIS numbers is sufficient for purposes of designating general surface smoothness in a given area of a casting or over its entire surface. If control of localized surface irregularities is desired, it should be mutually agreed between producer and purchaser.

10.2 The surface finishes represented by the SIS numbers are typical of the major processes employed in the production of steel castings. The molding material and molding technique together are the principal factors in determining the as-cast smoothness. Surface as smooth as or smoother than SIS-1 can be attained by ceramic molding or, in some instances, by shell molding. Usually, shell molding surfaces will fall between SIS-1 and SIS-2. Fine dry sand molding can produce surfaces equal to SIS-2. Green sand molding will generally produce casting surfaces equivalent to SIS-3. Castings of large size are usually made in molds using coarse sand and may be as rough as SIS-4.

HARDNESS LIMITS FOR SPECIFICATION PURPOSES		
"J" DISTANCE SIXTEENTHS OF AN INCH	H	
	MAX	MIN
1	54	46
2	53	45
3	51	40
4	48	35
5	44	30
6	41	27
7	39	25
8	37	22
9	34	21
10	32	20
11	31	—
12	29	—
13	28	—
14	27	—
15	26	—
16	25	—
18	24	—
20	23	—
22	22	—
24	20	—
26	—	—
28	—	—
30	—	—
32	—	—

HEAT TREATING TEMPERATURES
RECOMMENDED BY SAE
NORMALIZE 1650 °F
AUSTENITIZE 1600 °F

HARDENABILITY BAND GRADE HA

C	Mn	Si	Ni	Cr	Mo	
.25/.34	ANALYSIS TO BE SELECTED BY FOUNDRY					

DIAMETERS OF ROUNDS WITH SAME AS QUENCHED HARDNESS	LOCATION IN ROUND	QUENCH
3.8	SURFACE	MILD
1.1 2.0 2.9 3.8 4.8 5.8 6.7	3/4 RADIUS FROM CENTER	WATER
0.7 1.2 1.6 2.0 2.4 2.8 3.2 3.6 3.9	CENTER	QUENCH
0.8 1.8 2.5 3.0 3.4 3.8	SURFACE	MILD
0.5 1.0 1.6 2.0 2.4 2.8 3.2 3.6 4.0	3/4 RADIUS FROM CENTER	OIL
0.2 0.6 1.0 1.4 1.7 2.0 2.4 2.8 3.1	CENTER	QUENCH

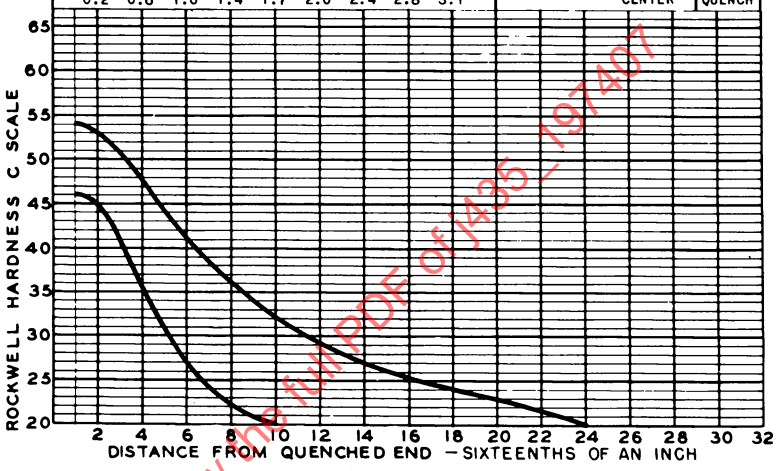

FIGURE 1—

HARDNESS LIMITS FOR SPECIFICATION PURPOSES		
"J" DISTANCE SIXTEENTHS OF AN INCH	H	
	MAX	MIN
1	56	46
2	55	46
3	55	44
4	54	42
5	53	40
6	52	38
7	51	36
8	50	35
9	48	33
10	46	32
11	44	31
12	42	30
13	41	29
14	40	28
15	39	27
16	38	27
18	37	25
20	35	24
22	34	22
24	34	20
26	33	—
28	33	—
30	32	—
32	32	—

HEAT TREATING TEMPERATURES
RECOMMENDED BY SAE
NORMALIZE 1650 °F
AUSTENITIZE 1600 °F

HARDENABILITY BAND GRADE HB

C	Mn	Si	Ni	Cr	Mo
.25/.34	ANALYSIS TO BE SELECTED BY FOUNDRY				

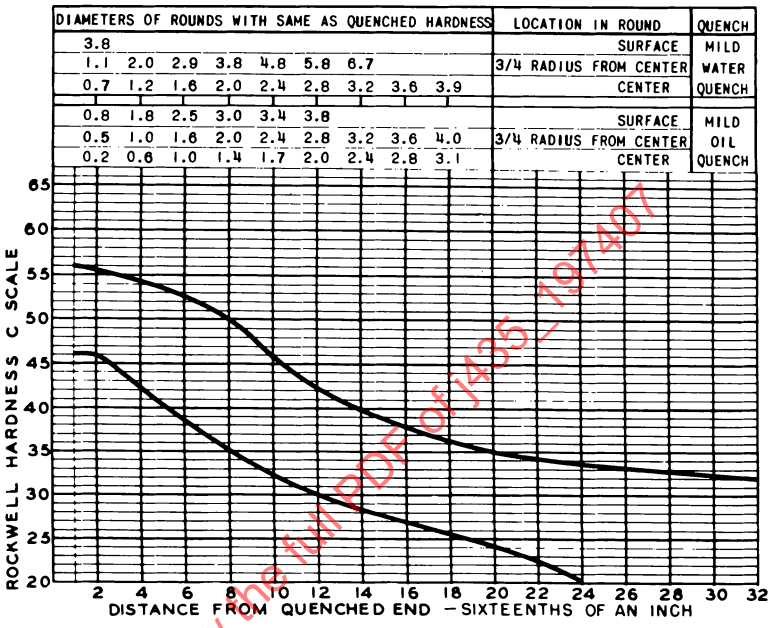

FIGURE 2—

HARDNESS LIMITS FOR SPECIFICATION PURPOSES		
"J" DISTANCE SIXTEENTHS OF AN INCH	H	
	MAX	MIN
1	57	49
2	56	48
3	56	48
4	55	47
5	55	46
6	55	46
7	55	45
8	55	44
9	55	44
10	55	43
11	55	42
12	55	42
13	55	42
14	55	41
15	54	41
16	54	40
18	54	40
20	54	39
22	54	39
24	53	38
26	53	38
28	53	38
30	52	37
32	51	37

HEAT TREATING TEMPERATURES RECOMMENDED BY SAE

NORMALIZE 1600 °F

AUSTENITIZE 1550 °F

HARDENABILITY BAND GRADE HC

C	Mn	Si	Ni	Cr	Mo	
.25/.34	ANALYSIS TO BE SELECTED BY FOUNDRY					

DIAMETERS OF ROUNDS WITH SAME AS QUENCHED HARDNESS	LOCATION IN ROUND	QUENCH
3.8	SURFACE	MILD
1.1 2.0 2.9 3.8 4.8 5.8 6.7	3/4 RADIUS FROM CENTER	WATER
0.7 1.2 1.6 2.0 2.4 2.8 3.2 3.6 3.9	CENTER	QUENCH
0.8 1.8 2.5 3.0 3.4 3.8	SURFACE	MILD
0.5 1.0 1.6 2.0 2.4 2.8 3.2 3.6 4.0	3/4 RADIUS FROM CENTER	OIL
0.2 0.6 1.0 1.4 1.7 2.0 2.4 2.8 3.1	CENTER	QUENCH

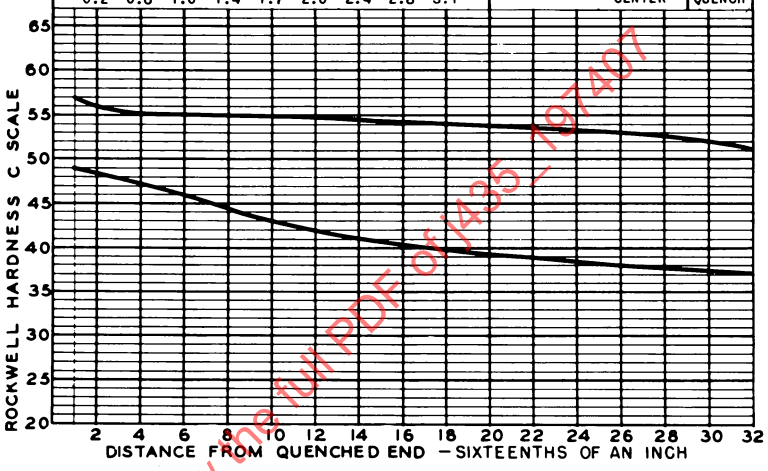

FIGURE 3—

NOTE—Notes for Figures 1, 2, and 3: The experience of users of steel castings of these general types indicates that Grade HA can be used for steel castings with critical sections up to 2-1/2 in (63.5 mm), Grade HB for castings with critical sections from 2-1/4—4 in (63.5—102 mm), and Grade HC for castings with critical sections from 4—7 in (102—178 mm). It should be pointed out that the above recommendations will not result in thorough hardening on the quench. They are based on a compromise between ideal microstructure and production difficulties, particularly quench cracking. The castings so treated will not shown uniform properties throughout the section.

If the particular application requires that the casting possess the ultimate in mechanical properties, particularly notched impact strength at the center of the section, the following limitations should be observed in selecting the hardenability bands. Grade HA, lower band for 3/4 in (19 mm), maximum section, upper band for 1-1/4 in (32 mm), maximum section; Grade HB, lower band 1-1/4 in (32 mm), maximum section, upper band 1-3/4 in (44 mm), maximum section; Grade HC, lower band 2-3/4 in (70 mm), maximum section, upper band 4 in (102 mm), maximum section.

These values for section thicknesses are applicable only if water quenching is used. If oil quenching is used, reference should be made to a text on hardenability. Such a text should also be consulted for details as to the application of hardenability data.

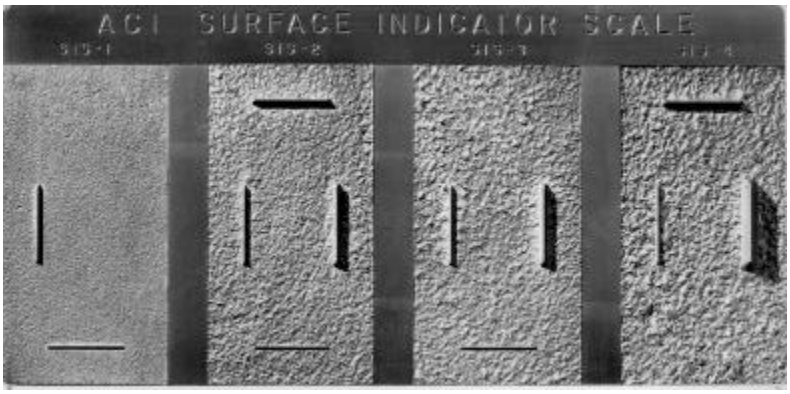

FIGURE 4—

10.3 Different parts of the same casting may have different surface smoothness. Variations can result from casting design, position in the mold, and other factors. Therefore, critical surfaces, where smoothness must be equal to or better than the designated SIS number should be noted on the drawing. A rougher surface may be acceptable in noncritical areas of the same casting and the appropriate SIS number should be so noted on the drawing. Engineers should recognize that smooth surface finishes are obtained, generally, by going to a more costly molding process and that the practice of specifying finishes in excess of those required for the application should be avoided.

10.4 This standard does not include the use of the raised bars (on the ACI SIS replica) which indicate the height and depth of localized irregularities extending beyond the range of general variations.

11. Inspection of Castings

11.1 General—This section covers methods for qualifications and routine control of characteristics and properties indigenous to the dimensions, shape, and molding practice of the casting, as opposed to methods used to qualify and control the mechanical properties of the steel used to produce the casting. Such methods are primarily nondestructive in nature, but simulated service loading and destructive tests on the casting may also be part of initial qualification and routine quality control procedures. All testing procedures and tooling which are to be used should be decided upon at the time an inquiry is submitted and must be on the order and agreed upon by both parties prior to the start of bidding on any item.

11.2 Test Procedure—Areas to be inspected, minimum number of pieces from each lot which shall be inspected, and standards of acceptability must be agreed upon by producer and purchaser. Proper application and interpretation of all test procedures must be understood by all involved in the inspection.

11.2.1 CASTING STRENGTH

11.2.1.1 Proof Testing—Simulated service loading may constitute one basis for acceptance of individual castings.

11.2.1.2 Destructive Tests—Loading to destruction may be used and may be based on loads, fracture mode, soundness, and so on.

11.2.2 INTERNAL QUALITY—Specifications for internal quality, when agreed upon by purchaser and producer, require the use of radiography, ultrasonics, or destructive testing methods.

11.2.2.1 Destructive Testing—Usually involves cross-sectioning or machining the casting at critical areas with visual inspection for defects.