

Specification No. MP-0-3900-02
(This supersedes MP-0-3900-1)

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

SPECIFICATION FOR CAST STEEL WHEELS
MANUFACTURED BY GRIFFIN PROCESS
FOR LOCOMOTIVE AND COACHING STOCK

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SPECIFICATION FOR CAST STEEL WHEELS MANUFACTURED BY
GRIFFIN PROCESS FOR LOCOMOTIVE AND COACHING STOCK

1. SCOPE

1.1 This specification covers the requirements of one-wear, two-wear and multiple-wear, cast carbon steel wheels for locomotives and coaching stock, classes L, A & B heat treated wheels, manufactured by Griffin process.

1.2 The service for which the various classes are intended generally, is as follows:-

Class L - High Speed service with more severe braking conditions than other classes and moderate wheel loads.

Class A - High Speed Service with severe braking conditions but with moderate wheel loads.

Class B - High Speed Service with severe braking conditions and heavier wheel loads.

Note : Class L & A wheels shall be suitable for use with low friction composition brake blocks, with retardation rates of 0.14 g. maximum speed of 120 km/h is contemplated for all classes of wheels.

1.3 With regard to the test requirements specified for the various classes of wheels, the frequency of tensile test (Clause 8.1) and hardness survey on cut section (clause 7.3) may be reduced by the purchaser in stages depending upon the quality level of production achieved by a particular manufacture.

2. DESIGN

2.1 The detailed drawings for rough/machined wheels and design calculations for the locomotive and coaching stock wheels, shall be furnished by the contractor to RDSO (Research, Designs and Standards Organisations, Ministry of Railways, Government of India) for design appraisal, before undertaking any manufacture. The controlling dimensions for the tread diameter, rim thickness and width, hub thickness, width and bore, shall generally confirm to the following drawings which are in force for wrought steel wheels :

Locomotive wheels - 1092 mm \emptyset - Drg. No. D/WL-4948 Alt. 8 (for finished wheels).copy enclosed. Drg. No. D/WL-4948/R.Alt. 9 (for rough finished wheels). Copy enclosed.

Coaching stock wheels- 915 mm \emptyset - Drg. No. T-0-2-622 (for finished wheel).
Drg. No. T-O-2-514 (for rough finished wheel).

The Indian Railways would require rough finished wheels.

3. MANUFACTURE

3.1 Process of making steel - The steel shall be melted in electric furnaces.

3.2 Chemical Requirements :

3.2.1 Ladle analysis - The ladle analysis of steel when carried out in accordance with IS 228¹ shall be as follows:

Carbon:	Class L	0.47% maximum
	Class A	0.57% maximum
	Class B	0.57 to 0.67%
Manganese		0.60 to 0.85%
Phosphorus, not over		0.05%
Sulphur, Not over		0.05%
Silicon, not less than		0.15%

Note: In case of wheels to Class L and A, the percentage of Cr, Ni and Mb shall be limited to 0.15, 0.25 and 0.06 respectively.

3.2.2 Permissible variation in case of chemical analysis to be carried out as laid down in Clause 13 from the limits specified in Clause 3.2.1.

<u>Elements</u>	<u>Variation percent</u>
Carbon	+ 0.03 - 0.02
Manganese	+ 0.03
Silicon	+ 0.03
Phosphorus	+ 0.005
Sulphur	+ 0.005

3.3 Manufacturing Practice - The cast steel wheels shall be manufactured in accordance with the Griffin process. During the process of manufacture, necessary care in regulation of temperature gradient shall be exercised to prevent development of internal defects or injurious stresses.

3.4 Heat Treatment - The heat treatment shall consist of treatment of the rim only. For this purpose, the wheels shall be uniformly reheated to the proper temperature to refine the grain and then the rim shall be quenched. Following quenching, the wheels shall be charged into a furnace for tempering to meet the hardness requirements of Clause 7.1 and subsequently cooled under controlled conditions.

3.5 Shot Peening - Shot peening shall be carried out on all wheels, after any corrective surface preparation, in the plate area extending approximately one-half of the way into the hub and rim fillet radii on the front and on the back of the wheel. The peening intensity and time shall be sufficient to produce an average are height of not less than 0.2 mm and full coverage on an Almen 'C' strip as measured in accordance with IS:7001.²

¹ Method of chemical analysis of steels.

² Method for shot peening and test for shot peened ferrous mild parts.

4. QUALITY OF MATERIAL

- 4.1 The wheels shall be sound throughout and show no cracks, blow holes, inclusions, shrinkage cavities or any other harmful defects.

5. DIMENSIONS, TOLERANCE AND FINISH

- 5.1 The wheels shall conform to the dimensions with tolerances shown in the drawings to be furnished by the Contractor (Ref. Clause 2.1).
- 5.2 Wheels shall be rough bored and shall not have black spots in the rough bore. Front hub face of wheels shall be parallel to the plane of the vertical reference line and may be as cast or machined. The back face of the hub may be as cast or machined.
- 5.3 The contour of tread and flange as well as tolerances and surface finish shall be as shown in Drawings. Wheels may have the contour as cast or machined at the option of the purchaser.
- 5.4 Wheels shall be given a thorough surface examination and gauging at the place of manufacture before being offered for inspection. They shall have a workmanlike finish and must be free from defects liable to develop in or cause removal from service. No defects shall be corrected by welding. Spot grinding or machining for the removal of surface defects shall not exceed a depth of 3 mm nor shall it reduce any section below the minimum dimensional requirements. The depression produced by grinding shall be uniformly blended into the surrounding contour. "As cast" surfaces shall be free of abrupt change in section or grooves and in a clean condition free of scale prior to final inspection. Where corrective machining or grinding has been employed such surfaces shall not exceed in roughness, of 12.7 microns, (Ra value) and a uniform transition from the machined or ground surface into the plane of the "as cast" surface must be provided.
- 5.5 Wheels shall not be covered with any substance to such an extent as to hide defects.
- 5.6 Permissible variation in Dimensions not Toleranced in individual Drawings -
- 5.6.1 Thickness of rim - In any wheel the radial thickness of the rim shall not vary more than 3 mm around the wheel.
- 5.6.2 Plane of Back Face - When wheels are gauged with a straight edge applied to back face of the rim, no point on back face of the rim shall be more than 1 mm from straight edge.
- 5.6.3 Hub Wall Thickness - The thickness of the hub wall in any one wheel measured at any two points equidistant from the face of the hub shall not vary by more than 2 mm.
- 5.6.4 Rotundity - Tread when gauged with a ring gauge must not have opening between tread and the gauge at any point over 0.5 mm.
- 5.6.5 Diameter of Bore - The diameter of the rough finished bore shall not vary more than 2 mm nor less than 3 mm, than the dimension shown on the drawings.
- 5.6.6 Eccentricity Bore - Eccentricity between the rough bore and tread measured in the plane of the tapping line shall not exceed 3 mm.

- 5.6.7 In any one wheel the difference between the minimum and maximum thickness of web at any given radius shall not be more than 2 mm.

6. BRANDING

- 6.1 Each wheel shall be legibly stamped when hot on the outside face of the rim with the identifying cast number, the manufacturer's name, the date (month and year) of manufacture and such other marks as shown in Figure 1. The branding shall be in letters at least 10 mm high. The marking to designate heat treated wheels shall be as shown below:-

L - Class L, rim treated.
A - Class A, rim treated.
B - Class B, rim treated.

7. BRINELL HARDNESS TEST

- 7.1 The hardness of the rim of heat treated wheels, when measured in accordance with requirements of Clause 7.2 shall be within the following ranges:

<u>Class</u>	<u>Minimum</u>	<u>Maximum</u>
L	220	280
A	250	310
B	300	340

The hardening effect shall be to a depth of about 50 mm from the tread as measured on the front face of the rim. The hardness number at a depth of 30 mm from the tread shall not be less than the minimum value specified. Hardness survey shall indicate a smooth transition from the tread face to the radius face.

- 7.2 Method of Measurement: - Measurement shall be made on the front face of the rim with the edge of the impression not less than 12 mm from the radius joining face and tread. Before making the impression, any decarburised metal shall be removed from the front face of the rim at the point chosen for measurement. The surface of the wheel rim shall be properly prepared to permit accurate determination of hardness. The brinell hardness test may be carried out in accordance with IS:1500³ using a ball of 10 mm diameter or by a portable hardness tester as agreed to between the manufacturer and the Inspecting Officer.

7.3 Hardness Survey on cut-section :

- 7.3.1 This test shall be carried out on the same test wheel which has passed the tensile test and falling weight test as per clause 8 and 10 respectively.
- 7.3.2 A cut -section of the wheel shall be prepared, as shown in figure 2, for conducting a hardness survey. The surface should be properly prepared to permit accurate determination of hardness.

Note :- The test piece should be preferably saw-cut. Should flame-cutting be employed, sufficient discard should be made during shaping to eliminate the heat affected zone.

³ Method for Brinell Hardness test for steel.

- 7.3.3 The hardening effect shall be to a depth as shown in figure 2 with the Brinell Hardness number ranging between the values specified in clause 7.1. The hardness survey shall indicate a smooth transition from the tread to the interior of the wheel vertically.
- 7.4 Number of Tests :
- 7.4.1 Where continuous heat treating furnaces are used in connection with clauses L, A & B wheels, Brinell hardness measurement shall be made on 10% of the wheels from each heat. Where batch type heat treating furnaces are used, Brinell hardness measurements shall be made on 10% of the wheels from each heat treatment lot, provided that at least one (1) wheel is selected for test from each heat represented in the heat treatment lot. For either process, when there are less than twenty (20) wheels from a heat, a minimum of two (2) wheels shall be checked for hardness except when there is only one wheel from a heat, in which case Brinell hardness measurements shall be made on the one wheel.
- 7.4.2 If the wheels tested meet the requirement of clauses 7.1 and 7.3 all of the wheels represented shall be accepted.
- 7.4.3 If any tested wheel fails to meet the requirements of clauses 7.1 and 7.3, it shall be checked by making two additional hardness measurements, one on each side of the point first measured and each approximately 25 mm from that point. If both of these check measurements meet the requirements of clauses 7.1 and 7.3, the wheel shall be considered to have met the requirements of clause 7.
- 7.4.4 When continuous heat treating furnaces are used, should any of the wheels tested fail on check test to meet the requirements of clause 7.1 the manufacturer may test for individual hardness measurements all of the wheels of that heat in that lot submitted for inspection and those meeting the requirements of clause 7 shall be accepted. Where batch - type heat treating furnaces are used, should any of the wheels tested fail on check to meet the requirements of clause 7.1 the manufacturer may test all of the wheels in the heat treatment lot for individual hardness measurement and those meeting the requirements of clause 7 shall be acceptable.

8. TENSILE TEST

- 8.1 The tensile test shall be carried out on one sample for every hundred wheels of the same class. Since each heat may consist of only 18 to 20-wheels for the purpose of the above test, 5 heats may be grouped for one lot, and out of the total of 10 heats, i.e. two groups covering about 200 wheels, the test shall be carried out by choosing one wheel having the lowest carbon from the first group and one wheel having the highest carbon from the second group, and if both these pass the test, the entire lot shall be deemed to satisfy the requirements of the specification.
- 8.2 The tensile test shall be carried out in accordance with IS:1608¹ using the standard proportional test piece having a gauge length equal to $5.65\sqrt{A}$, where A is the cross sectional area of the test piece. The test piece shall be machined from standard location of the rim and web as shown in fig. 3

The test pieces shall comply with the tensile test requirements as per clause 8.3 without further reheating or manipulation whatsoever.

8.3 The tensile breaking strength and elongation values of test piece from rim shall comply with the following:

Class	Tensile breaking strength in kgf/mm^2	Elongation % (min.)
L	78 to 90	11 to 9
A	86 to 98	9 to 8
B	100 min.	8

Note:- Intermediate elongation shall be in proportion to tensile strength occurring within the permissible limits.

Tensile test piece shall also be taken from the web as per figure 3 below. This shall be for reference only. The test requirements are :

Class	Tensile breaking strength in kgf/mm^2	Elongation
L & A	75 min.	14 min.
B	85 min.	12 min.

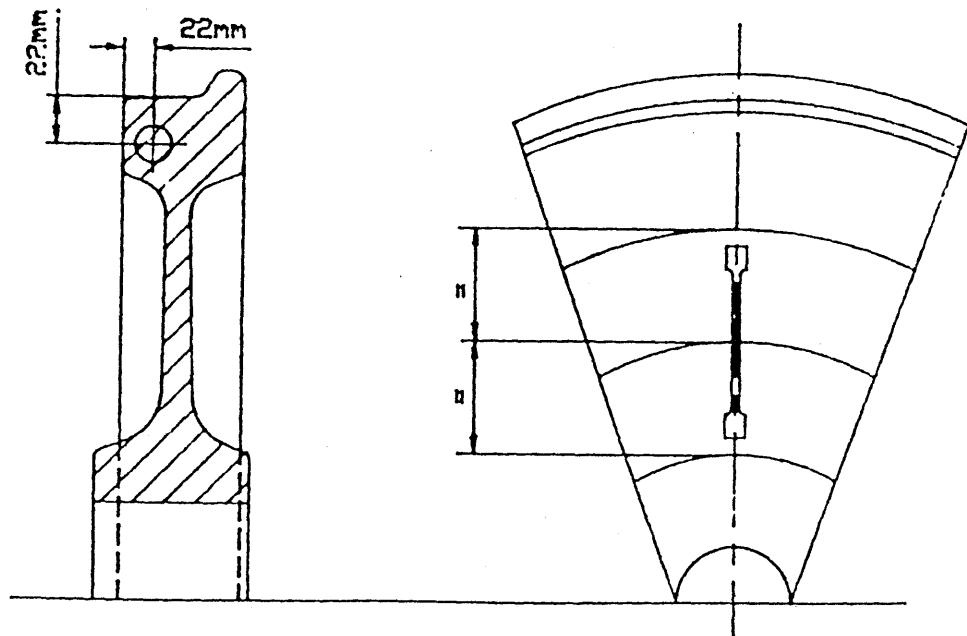


FIG-3

- 8.4 Should the wheel or wheels which have passed Brinell hardness test fail in tensile test, two more tensile test pieces shall be taken from the wheel which has given the defective tensile test for repeat test. The wheels shall be accepted if the result of these further tests are satisfactory. Should the repeat tensile tests not prove satisfactory, the manufacturer may with the concurrence of the purchaser or the Inspecting Officer heat treat or reheat the bulk and present them again for Brinell Hardness (and falling weight test where it is carried out) and tensile tests. Should the samples fail in any of the tests, the lot shall be rejected. Should the results of these repeat tests prove satisfactory, the wheels represented shall be accepted.

9. MAGNETIC PARTICLES AND ULTRASONIC TESTS

- 9.1 Magnetic particle test - All wheels shall be tested by the magnetic particle method, preferably 'Magnaglo' technique, and shall not reveal any harmful surface defects. Wheels revealing harmful surface defects shall be rejected.
- 9.2 Ultrasonic Test - All wheels shall be ultrasonically tested for detecting internal discontinuities in the rims of the wheels. The method to be followed and the equipment to be used shall comply with the requirement of appendix A.

10. FALLING WEIGHT TEST

- 10.1 The falling weight test shall be carried out in the presence of the Inspecting Officer at the Works of the manufacturer. This test shall be carried out on the same wheel selected for the tensile test (Refer Clause 8), after it has passed the hardness test and before cutting the tensile test pieces from it.
- 10.2 The selected wheel shall be placed flat upon a circular rim of metal bearing only upon tyre portion of the wheel and resting upon a block of metal of not less than 5 tonnes weight supported on a rigid concrete or other solid foundation, and shall withstand, without fracture, three blows from a falling weight of one tonne. The weight shall be allowed to fall freely on the boss from a height of 3 metres in the case of wheels 840 mm in external diameter and over, and from a height of 1.5 metre in case of wheels under 840 mm in external diameter.
- 10.3 Retest - Should the wheel or wheels which have passed the brinell hardness test fail in falling weight test, two more wheels from the same lot shall be subjected to falling weight test. Should the results of these tests be satisfactory, the wheels represented shall be held to have passed the falling weight test. Should the repeat falling weight test not prove satisfactory, the Manufacturer may with the concurrence of the Purchaser or the Inspecting Officer heat treat or reheat treat the bulk and present them again for brinell hardness test and falling weight test. Should the results of these repeat tests prove satisfactory, the wheels represented shall be held to have passed the falling weight test.

11. NUMBER OF REHEAT-TREATMENT

In no case shall the total number of re-heat treatments exceed 2, should the test samples fail to satisfy the requirements of clause 7, 8 and 10.

12. OTHER TESTS

- 12.1 The following tests shall be carried out on one sample for every 500 wheels of the same class.

- 12.2 **Macroscopic test** - A full cut radial section extending from the tread upto the hub bore shall be taken and subjected to macro examination consisting of sulphur print etc. Macro examination shall not reveal any defects in the rim section more than what is stipulated as permissible in the Ultrasonic standard for the rim section. In the web section, the porosity and inclusion, if any, shall be evenly distributed and the total cross-sectional area of these defects shall not exceed 2% of the total cross-sectional area of the section, and any single flaw in the web and hub section shall not exceed 3 mm and 5 mm in dia respectively. Any two flaws shall be well separated. These defects should not be connected to the surfaces.
- 12.3 **Residual Stresses** - The residual stresses in the rim, if any, in the hardened zone shall be compressive. For this purpose, two punch marks are made 100 mm apart on middle of the rim in the side opposite of the flange. The radial cut as mentioned in clause 12.2 shall then be made from the tip of the flange to the bore half-way between the 2 marks. The distance between the marks is then measured which shall not show any increase.

13. CHEMICAL ANALYSIS

- 13.1 An analysis of each heat shall be made by the manufacturer to determine the percentage of elements specified in clause 3.2. This analysis shall be made from a test specimen taken during pouring. The chemical composition thus determined, together with such identifying record as may be desired, shall be reported to the purchaser or his representative and shall conform to the requirements specified in Clause 3.2.
- 13.2 An analysis may be made by the Purchaser from sample furnished by the manufacturer representing the day's heats, or from finished wheels selected from the heats in question by the purchaser's representative. The chemical composition thus determined shall conform to the requirements specified in Clause 3.2. Samples from a finished wheel shall be obtained at a location in the hub in such a manner as not to impair the usefulness of the wheels. Each sample shall be thoroughly mixed together and shall be clean and free from scale, oil and other foreign substances.

14. INSPECTION

- 14.1 The inspection shall be carried out by representative(s) of Indian Railways. The Inspecting Officer or the Purchaser shall have free access at all reasonable times to the Works in which wheels are being manufactured. He shall be at liberty to inspect the manufacture at any stage and to reject any material or supplies that do not conform to this Specification. The Inspecting Officer or the Purchaser shall have power to mark or deface in some easily distinguishable manner all rejected wheels, but they shall not be marked or defaced in such a manner as to render them unsaleable to other parties. No wheel will be despatched unless it has been inspected by the Indian Railway representative.
- 14.2 Power shall be reserved to the Purchaser or the Inspecting Officer to be present at, and take such part as he thinks fit, in all analysis and other chemical or physical examinations which the manufacturer may make for his own purpose or under the terms of this specification, during all stages of manufacture.
- 14.3 On submission, each batch of wheels shall be subjected to the following checks and tests as prescribed in this specification.

Type of test	No. of wheels to be submitted to test
• Chemical Analysis	Ref. Clause 13
• Tensile Strength	Ref. Clause 8
• Falling Weight Test	Ref. Clause 10
• Hardness on the rim	
Hardness survey on cut section	Ref. Clause 7
• Macro structure	Ref. Clause 12.2
• Direction of residual stress	Ref. Clause 12.3
• Ultrasonic examination	100%. Ref. Clause 9.2
• Magnetic crack testing	100%. Ref. Clause 9.1
• Appearance and dimensions	100%. Ref. Clause 5
14.4	The Contractor shall also furnish a complete set of its own test certificates, covering all the wheels in the contract, pertaining to the above tests/checks.
14.5	The Inspecting Officer shall also furnish a complete set of his Test Certificates, pertaining to the above tests/checks, to RDSO. In addition, RDSO may also call for samples of test pieces for tensile strength, hardness survey and macrostructure, as also photographs of a few representative oscillograms of the ultrasonic tests, for reference.
15.	<u>TESTING FACILITIES:</u>
15.1	The manufacturer shall supply the material required for testing free of charge, and shall at his own cost, furnish and prepare the necessary test pieces, and supply labour and appliances for such testing as may be carried out in his own premises in accordance with this specification. Failing facilities at his own works for making the prescribed tests, the manufacturer shall bear the cost of carrying out the tests elsewhere.
16	PROTECTION
16.1	After inspection and approval, the wheels shall be carefully cleaned of all rust and protected with two coats of bituminous paint to IS:158 or any other approved rust preventive compound.
17.	GUARANTEE
17.1	The wheels shall be guaranteed by the supplier against any defect imputable to the manufacturer and not revealed during inspection at the works. This guarantee shall be applicable for three years from the date of delivery or two years of placing in service, whichever is earlier.
17.2	Wheels which during the guarantee period, show defect making them either unfit for service, or reducing their period of service, shall be rejected.
17.3	When two wheels from the same cast have failed in service or when more than 5% of the wheels from the same cast reveal manufacturing defects within the above conditions, the purchaser shall have the right to reject the wheels from the cast in question.
17.4	Rejected wheels shall be made available to the supplier with a view to their replacement or reimbursement of their value in new condition, at the time of withdrawal.

Method of ultrasonic testing and Acceptance Standard for cast steel wheels

A-1 For detecting internal discontinuities in the rims of cast steel wheels ultrasonic inspection shall be made by following the procedure shown below and by using equipment which complies with the following requirements.

A-2 Equipment :

A-2.1 The instrument shall have a pulse echo receiver and shall operate at frequencies of 2 to 5 MHz required for the test method and type of equipment being used.

A-2.2 The transducers shall be of normal / 0° type composed of highly sensitive Piezo electric ceramic crystal operating at 2 to 2.5 MHz and of appropriate dimensions to suit the method of tests.

A-2.3 An automatic flaw alarm system shall preferably be used in conjunction with the ultrasonic instrumentation.

A-2.4 A suitable couplant shall be used between the test surface and the transducer. An immersion testing technique could be used to facilitate automatic in-line testing.

A-3 Time of inspection :

Inspection shall be performed after final thermal processing.

A-4 Calibration :

A-4.1 Calibration shall be conducted using a reference standard of a wheel or portion of a wheel rim containing simulated defects. The instrument sensitivity level should be adjusted to produce an approximate half-full scale reflection from the reference standards of A-4.2, A-4.3, A-4.4 and A-4.5.

A-4.2 For axial testing the reference Standard shall be a 3.2mm diameter flat bottom hole drilled perpendicular to the rim face and to a depth of 25.0 to 38 mm at the mid-thickness of the rim. See fig. A-1. a.

A-4.3 For radial testing the reference standard shall be a 3.2 mm diameter flat bottom hole drilled from the inside diameter of the rim essentially parallel to the rim face. It shall be a minimum of 32mm from the tread surface. See fig. A2a.

A-4.4 The side of a small diameter hole of the order of 1.6mm to 3.2mm in diameter may be used when it is drilled the same distance from the testing surface. The instrument shall be adjusted to give an equal test value to that of a 3.2mm diameter flat bottom hole. This practice is an alternate for the reference standards of Sections A-4.2 & A-4.3. See Figures A1b & A2b.

A-4.5 For axial testing when determining loss of back reflection, the reference standard shall be a 9.5 mm diameter concave bottom hold drilled to a depth of 3.2 mm at the front rim face and perpendicular to the back rim face. See Figure A3 and footnote.

A-4.6 Reference standards for the inspection of heat treated and untreated wheels shall be fabricated from heat treated and untreated wheel respectively.

A-5. Scanning :

A-5.1 Wheels shall be inspected axially from either the front or back rim face and radially from the tread surface by manual or automatic scanning. See Figures A1a, A1b, A2a, A2b and A3.

A-5.2 One or more transducers shall be designed and located to give maximum coverage of the rim section-both radially and axially. Maximum possible area shall be scanned.

A-5.3 In case of automatic scanning the speed of scanning shall permit detection of the reference standard discontinuities.

A-6. Rejection :

A-6.1 Any wheel with a flaw indication equal to or larger than that from the reference discontinuity shall be cause for rejection.

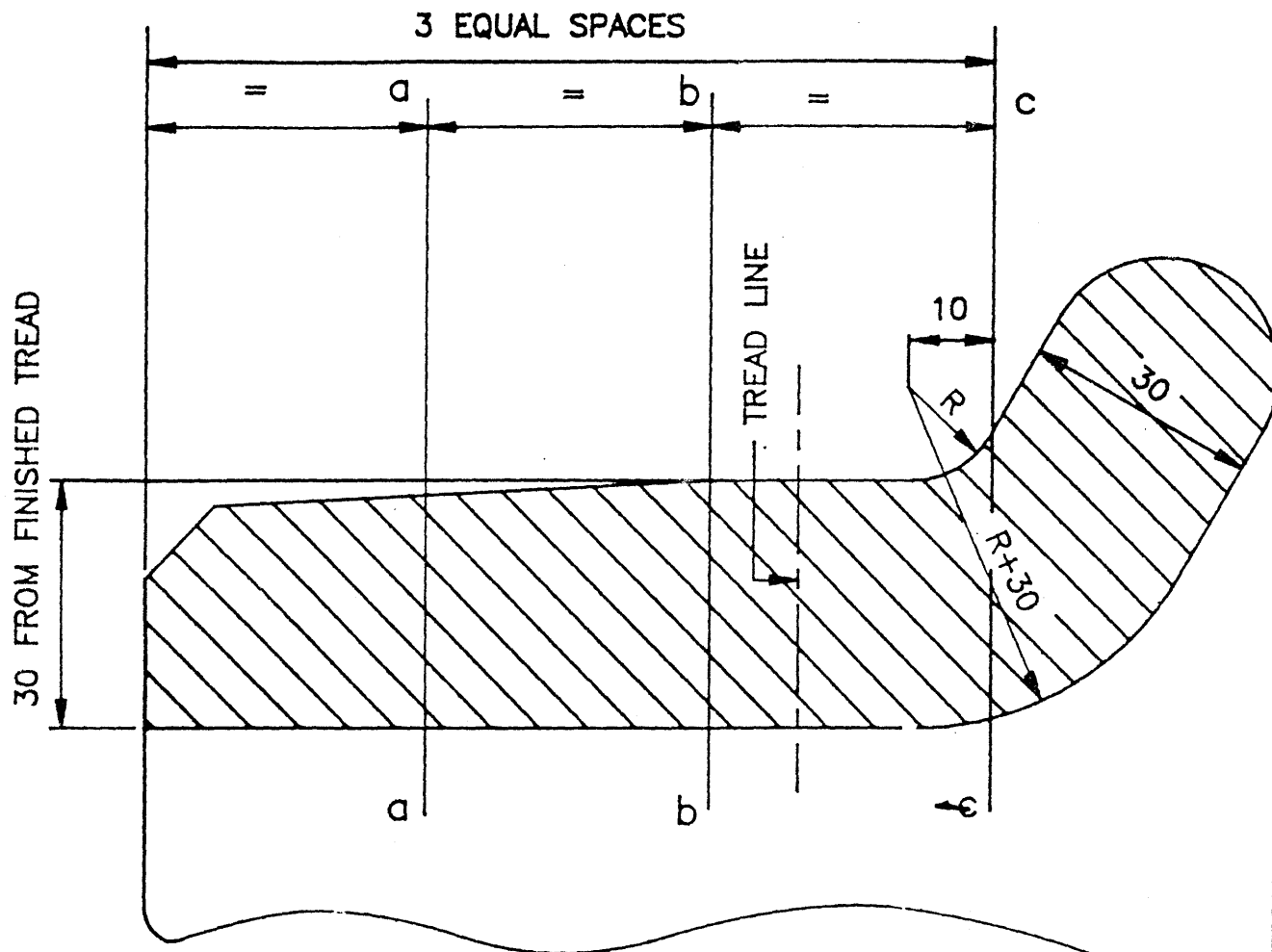
A-6.2 Any indication from a discontinuity giving a loss of back reflection equal to or greater than the reference standard covered in 4.50 during axial scanning may be cause for rejection

A.6.3 Ultrasonic indications that result from wheel geometry or spurious electrical signals shall not be valid cause for rejection.

A.6.4 When automated equipment is used the final disposal of rejectable wheels may be determined by manual testing of questioned area.

A-7 Marking :

A.7.1 Wheels that conform to the above ultrasonic stipulations shall be stamped "OT" on the outside face of the rim having the branded marking or at such locations as may be shown on the drawing or specified by the purchaser.



BRINELL HARDNESS NUMBERS MEASURED ON
LINES 'aa' 'bb' 'cc' IN THE SHADED ZONE
SHALL SHOW A RANGE BETWEEN 300 TO 341

FIG 2- (Refer cl 7.3.2 & 7.3.3)

SKETCH SHOWING HARDENED ZONE FOR
MONO-BLOC WHEEL TO SPECIFICATION

NO. MP-0-3900-02

CAST FOLLOWED BY MAKER'S
CAST NO:

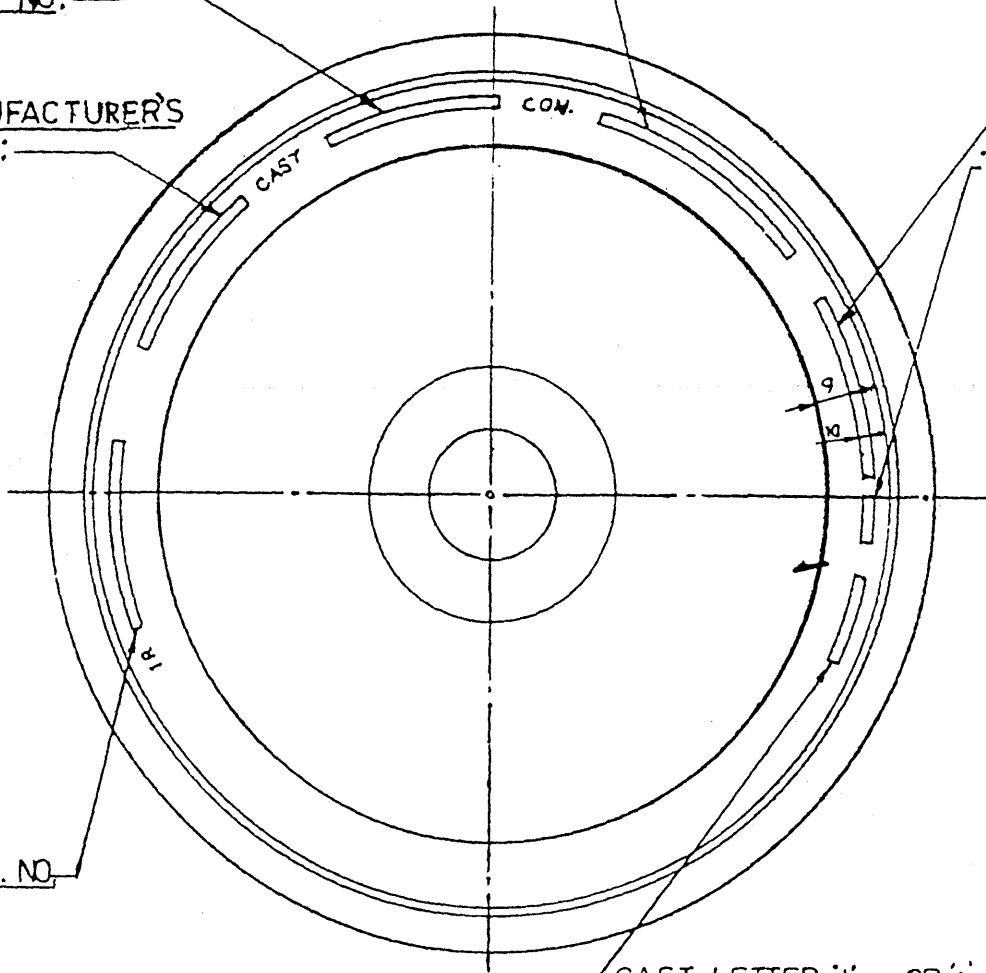
MANUFACTURER'S
NAME:

DRG. NO.

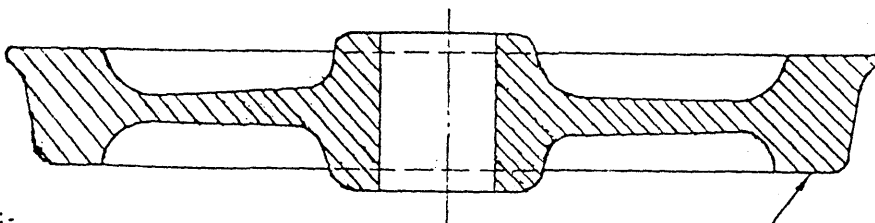
CON: FOLLOWED BY CONTRACT NO.
MONTH & YEAR OF MANUFACTURE.

SPACE FOR MARKING PRESSING
IN PRESSURE (TO BE STAMPED
AFTER WHEEL PRESSING)

'OT' TO INDICATE
ULTRASONIC
TESTING
REF. CL.A-7.1



CAST LETTER 'L' OR 'A' OR 'B'
TO INDICATE CLASS 'L' RIM TREATED
CLASS 'A' RIM TREATED CLASS
'B' RIM TREATED.



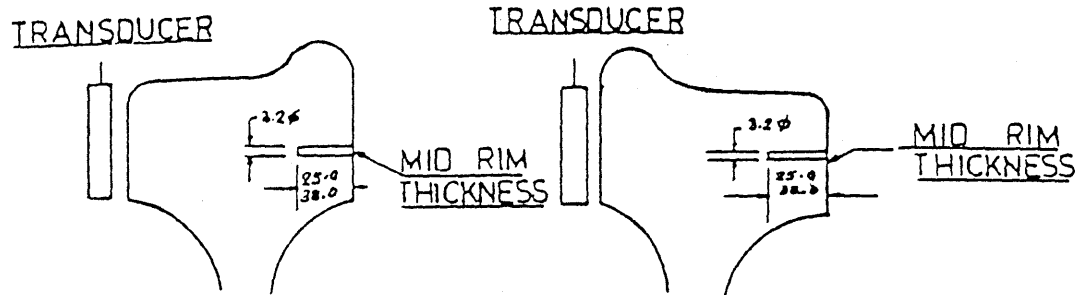
NOTE:-

1. HOT STAMP ON OUTSIDE FACE OF WHEEL.
2. HEIGHT OF THE LETTER TO BE 10mm.

WHEEL MARKINGS.

FIG. 1.

TEST FROM FRONT RIM FACE. TEST FROM BACK RIM FACE.
A-1a- REFERENCE STANDARD.



A-1b - ALTERNATE REFERENCE STANDARD.
TRANSUCER. TRANSUCER

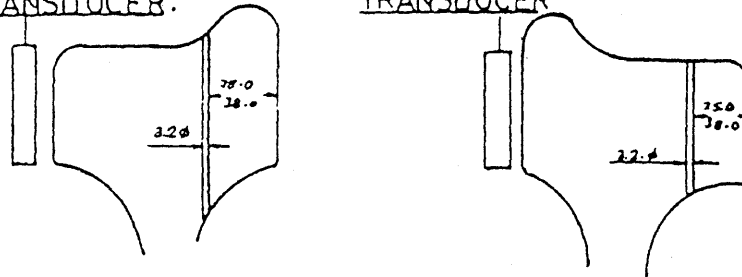
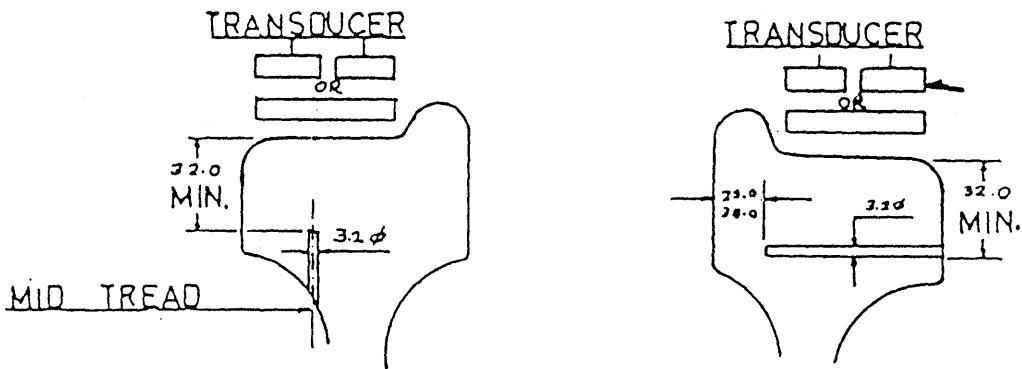


FIG.-A.1- TYPICAL REFERENCE STANDARDS FOR RIM FACE TEST.



A-2a- REFERENCE STANGARD.

A-2.b-ALTERNATE REFERENCE.

FIG:A.2- TYPICAL REFERENCE STANDARDS FOR RIM TREAD TEST.

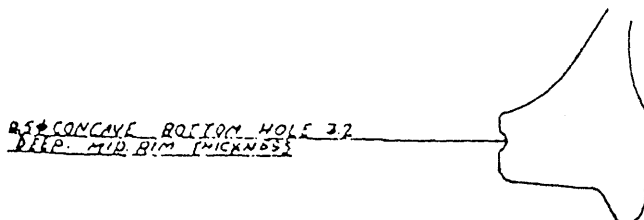


FIG:A.3- TYPICAL SIGNIFICANCE STANDARD DETERMINE LOSS.
OF BACK REFLECTION.