Specification number	S000xxxx	Performance Specification For High Pressure Die Cast Aluminium Alloy Casting Components For Steering Systems	
Revision	A		
Date	18.03.2011		

ICS:
Descriptors: Porosity

Scope

Released by:	TRW Automotive GmbH, Tech Center Düsseldorf
Leader of the Working Committee:	EC-Number

Foreword

This specification is an extension of the released drawing of the affected parts. All requirements of this specification must be met, in addition to all other requirements of the part drawing. **The part drawing will always supersede the specification requirements.**

The engineering tests and values contained within this specification reflect minimum values established to provide conformation of design intent. The frequency of the tests, dimensional checking, in-process controls should be agreed upon between TRW Engineering, supplier quality and should be documented in the mutually agreed upon supplier control plan.

The function of the casting is to contain the electro-mechanical components that provide a directional control mechanism for vehicle steering.

1 Purpose

The purpose of this specification is to designate TRW requirements for aluminum casting components, specifically rack and pinion housings and other cast housing designs used in MSG (mechanical), HPS (hydraulic) and EPHS (electrical hydraulic) and EPS (electrical) Belt Drive steering gear applications.

2 Scope

This global specification is applicable to high pressure die casting aluminum components to be used for MSG, HPS, EPHS, EPS steering gears. It defines mechanical properties, porosity and other requirements of the castings.

Released by:	TRW Automotive GmbH, Tech Center Düsseldorf
Leader of the Working Committee:	EC-Number

3 Reference Documents

Drawing . #	Doc. #	Title	Place of location
1	ASTM E 505	Standard reference radiographs for inspection of aluminum and magnesium die casting (pressure die casting)	TCDweb
2	DIN 1688-1	Casting tolerances for sand die casting	TCDweb
3	DIN 1688-3	Casting tolerances for gravity die casting	TCDweb
4	DIN 1688-4	Casting tolerances for pressure die casting	TCDweb
5	DIN EN 12	Founding – Radiographic examination	TCDweb
6	DIN EN 444	Non-destructive testing; general principles for the radiographic examination of metallic materials using X-rays and gamma-rays	TCDweb
7	DIN EN 462 – 1	Non destructive testing – Image quality of radiographs	TCDweb
8	DIN EN 473	Non destructive testing – Qualification and Certification of NDT personnel- General principles	TCDweb
9	DIN EN ISO 10049	Aluminum Alloy Casting – Visual Method for Assessing	TCDweb
10	DIN ISO 13715	Edges of undefined shape (Vocabulary and indications)	TCDweb
11	ISO 8062	Castings – Systems of dimensional tolerances and machining allowances	TCDweb
12	ISO 8062-1	Geometrical product specifications (GPS) – Dimensional and geometrical tolerances for molded parts – Vocabulary	TCDweb
13	ISO 8062-3	Geometrical product specifications (GPS) – Dimensional and geometrical tolerances for molded parts – General dimensional and geometrical tolerances and machining allowances for castings	TCDweb
14	JIS B 0403 CT6	Casting tolerances for pressure die casting	TCDweb
15	TRW 31845101	Casting tolerances	PDM
16	TRW 62005004	Anodic Oxidation for Al casting	PDM
17	TRW 62045004	Contamination of components and assemblies of hydraulic systems, definition and classification	PDM
18	TRW 62050001	Design Verification and Product Validation of Rack and Pinion steering gears and Steering systems,	PDM

		Test program overview	
19	TRW 81000068	Resin Sealer (Europe)	PDM
20	TRW S0000266	Leakage test (Europe)	PDM
21	TRW S0000121	Resin Sealer (NA)	PDM
22	TRW S0000120	Leakage test (NA)	PDM
23	TRW S0000822	Leakage test (AP)	PDM
24	VDA 1	Quality Management in the Automobile Industry, Quality Evidence	TCDweb
25	VDA 2	Quality Management in Automotive Industry, Safeguard Quality of Suppliers	TCDweb
26	VDG P210	Volume deficits on castings in non-ferrous metal	TCDweb

4 Dimensional Properties

TRW recommends the use of a computerized coordinate measurement machine (CCMM) for evaluation of appropriate dimensions. The CCMM Type shall be the standard by which supplier gauging is measured. TRW recommends that suppliers fabricate CCMM fixtures similar in function to TRW MSG, HPS, EPHS or EPS production plants for the purpose of measurement correlation. A common design CCMM fixture should be agreed with TRW quality. Short term capability shall be evaluated statistically by the supplier. (Refer engineering drawing for specific requirements.)

5 Mechanical Tests

Mechanical test conduction shall be agreed between TRW quality, TRW product engineering and supplier. If the test is conducted by the supplier the complete documentation including test results, setup photographs, and post test data has to be distributed to TRW quality and Product engineering for approval.

5.1 Component Pulser Test (optional)

In order to compare the fatigue strength of the foot mount of different housing versions as well the structure, position and characteristic of the breakage this Pulser test can be performed during running production or as serial accompanying test.
Further if the fatigue of the foot mounts is adequately addressed within the TRW testing scope for the production release of the gear, this comparative test can be performed optionally when changes are to be implemented from the serial process in terms of cast process, material and heat treatment of the housing

Test as performed by TRW as shown in Figure 1. The housing has to be constrained to prevent rotation or movement.

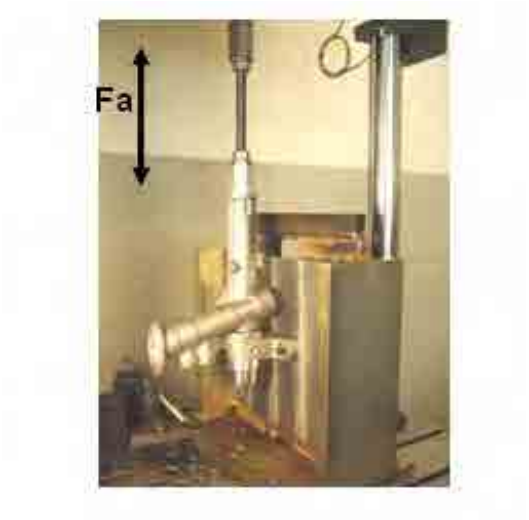


Figure 1

Test is to be conducted without rubber bushing or foot insert in order to have better crack detection and shut-off criterion and higher testing frequency.
Unless otherwise specified the following parameters should be used:

Load: (1/m) x 0.9 x F_n
Frequency: 10-50 Hz
Cycles: > 150000
Specimen: > 6

F_n = max. rack load
m = number of foot mounts

5.2 Component Bend Strength Test (optional).

In order to compare the fatigue strength of different housing batches (e.g. different supplier, mold changes etc.) the bend test may be performed as shown in the following figures.

General test procedure:

- Mount casting housing in test fixture supporting the ends and rack bore as shown in Figures 2.1-2.8. (Figures shown below are for schematic purpose only. Refer product drawing for actual geometry.)
  The length of the supports should be 15mm ± 2.0 mm. The centre of the housing is where the load should be applied if applicable. If there is a casting feature which prohibits applying load to the center it is then allowable to move the pusher to a different position, but this position has to be agreed with the TRW Engineering and the supplier.

- Orient the housing as determined by TRW Engineering and vehicle configuration. Extra fixturing may be used to maintain the pinion housing axis in the respective plane. However, the extra fixturing shall not bias the test results.

- Apply a load at the rate of 12.7mm ± 0.25mm per minute. Do not restrict lateral movement of housing during test. Load applicator to have a radius of 6.35 mm.

Housing Bending Load Requirement:

The bending load requirement shall be designated on the drawing if applicable.

Use Table 1 for new projects as a starting reference point in absence of any customer or internal requirements.

TABLE 1: REFERENCE PINION HOUSING BEND TEST REQUIREMENTS

Pinion Housing Bend Strength Test Reference Table Minimum Fracture Load			
Rack diameter [mm]	Housing design	Load applicator [mm]	Min. Fracture load [kN, (lbs)]
24/25	Short Hsg D-mount, inside, out side	R6.35	15.0 (3300) 14.0 (3100) 15.0 (3300)
	Long Hsg. HPS		8.0 (1700)
	Long Hsg. EPS		11.12 (2500)
28	Short Hsg D-mount, inside, out side	R6.35	15.0 (3300) 14.0 (3100) 15.0 (3300)
	Long Hsg. HPS		8.0 (1700)
	Long Hsg. EPS		11.12 (2500)
32	Short Hsg D-mount, inside, out side	R6.35	16.0 (3300) 14.0 (3100) 16.0 (3300)
	Long Hsg. HPS		8.0 (1700)
	Long Hsg. EPS		11.12 (2500)

5.2.1 Foot mount (inside) housing

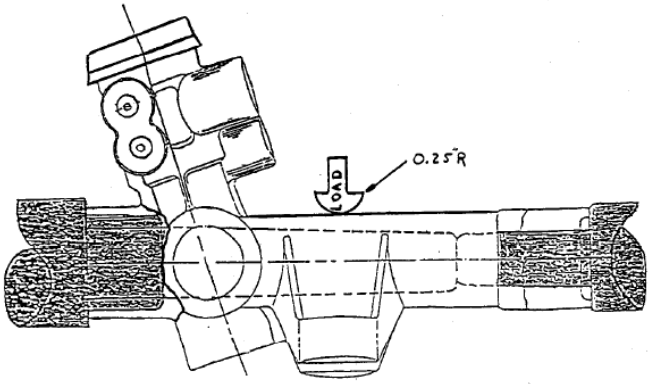


Figure 2.1

Requirements: See pinion housing print or Table 1.

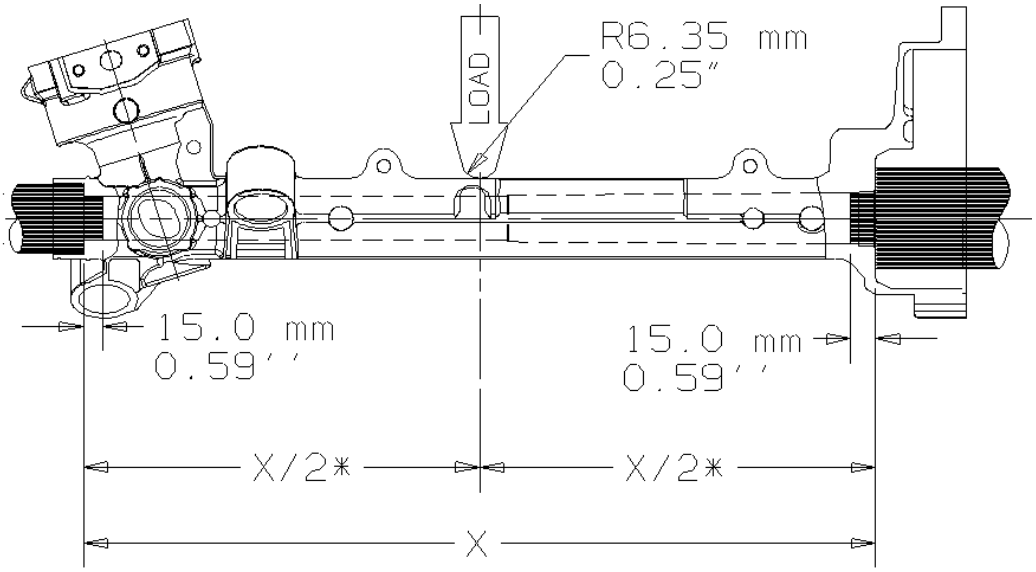


Figure 2.2

Requirements: See pinion housing print or Table 1.

5.2.2 D-mount housing

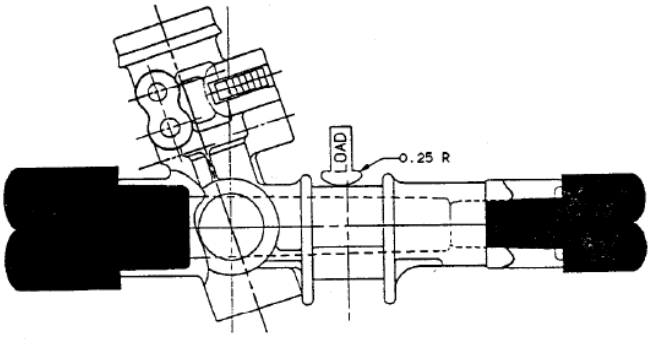


Figure 2.3

Requirements: See pinion housing print or Table 1.

5.2.3 Foot mount (outside) housing

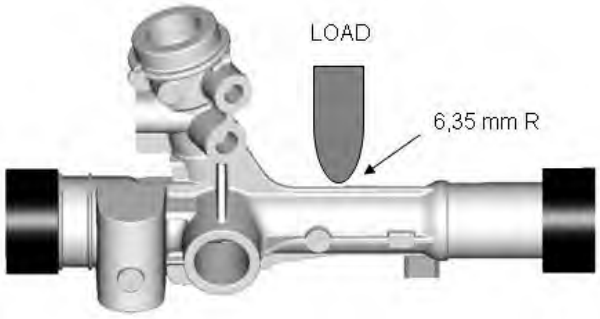


Figure 2.4

Requirements: See pinion housing print or Table 1.

5.2.4 Foot mount housing (split housing design)

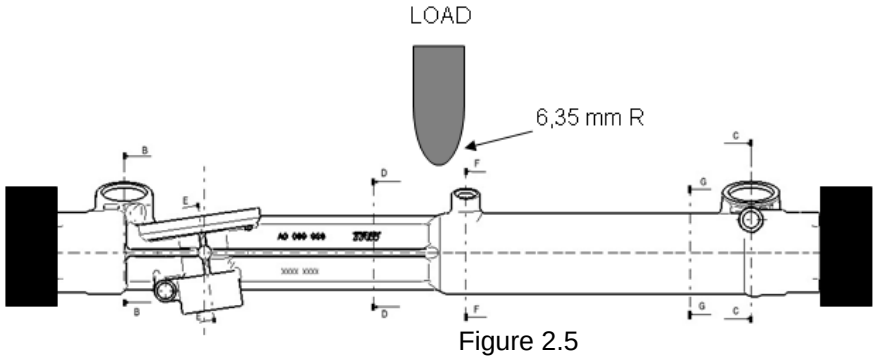


Figure 2.5

Requirements: See pinion housing print or Table 1.

The following three photographs show pinion housing bend setup currently used at TRW Washington, MI facility (see Figure 2.6 to 2.8).

Figure 2.6

Figure 2.7

Figure 2.8

5.3 Ports Torque To Failure Test For HPS And EPHS (optional)

A pinion valve housing typically contains at least 4 ports, two internal pressure ports which are commonly referred to as transfer ports as they help transfer fluid to the correct side of the cylinder which provides hydraulic assist while steering. The remaining two ports are typically the external pressure ports commonly referred to as the supply (or pressure) and return ports (see Figure 3 for tested part). These are the inlet to and outlet from the steering gear that are connected to the hydraulic pump and reservoir respectively. These sizes though common are not always standard as flow requirements dictate the various sizes.

The internal and external pressure port design depends on system and customer requirements. Port design has to be defined by Product engineering and OEM. The minimum accepted torque must be defined by product engineering.

During PPAP these ports on a machined housing shall be torqued to failure per procedure prescribed below.

(1) Torque the lower internal pressure port first to failure and record torque to failure using a calibrated static torque wrench.

(2) While torquing this port the flared tube, an un-deformed Teflon ring (if used) and the fitting shall be used. The flared tube and the fitting should not be used more than two times for the test. The max torque before either threads stripping or port breakage shall be communicated through a signed report to TRW. The report should include failure mode for each test. Sample photographs should also be provided. The assembly torque for these ports depends on the customer requirement. Hence, failure torque should be statistically (mean minus 3 sigma and min range) above defined torque.

(3) Next the upper internal pressure port should be torqued to failure as outlined through points 1 and 2. The only difference in this case is that the lower port should be torqued to the defined max. Torque before the upper port is torqued to failure. The acceptance criteria for the lower port and upper port are identical.

(4) Next the pressure line should be torqued to failure. If the internal pressure ports are in the same cluster then both these ports should be torqued to defined torque before the test. If the port is not in the same cluster as the internal pressure ports then it may be torqued to failure independently. Reuse of fittings is permissible up to two times. Acceptable parts are those that show are statistically capable to the defined torque requirements. Torque depends on customer requirements.

(5) The last step is to torque test the return port to failure. If the supply port is in the same cluster as the return port then the supply port fitting assembly should be torqued to defined torque before torquing the return line. Reporting for the pressure and return port failure modes should be similar to that specified for the internal pressure ports.

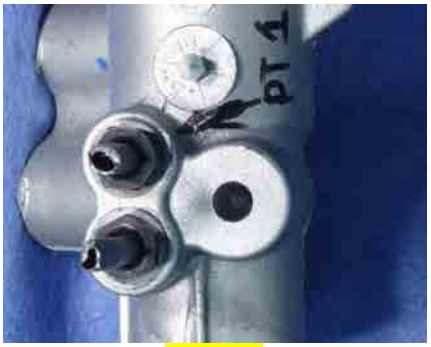


Figure 3

5.4 Foot Mount Shear Test (optional)

In order to test the strength of the foot mount of the housing in the axial direction the following test is performed in two directions as shown in Figures 4.1-4.5, Extra fixturing may be used to maintain the housing orientation to prevent rotation. However, the extra fixturing shall not bias the test results. Test should be conducted without bushings or inserts.

Apply a load at a rate of 12.7 mm/min ± 0.25mm to the rack stop end and the press fit end, constraining the housing at inner diameter of the foot mount as shown in Figure 4.3-4.5. Record the fracture loads and provide typical photographs showing fracture locations. A minimum fracture load is needed for acceptance. Use Table 2 for new projects as a starting reference point in absence of any customer or internal requirements.

The following three photographs show pinion housing foot mount shear setup currently used at TRW Washington, MI facility (see Figure 4.1 to 4.2).

Figure 4.1. Shear Bellows Down End

Figure 4.2 Shear Bellows Up End

Apply a load at the rate of 12.7 mm/ min to the rack stop end (see schematic for clarity), constraining the housing at the inner diameter of the foot mount as seen in Figures 4.3-4.5. Record the fracture loads and provide typical photographs showing fracture locations. A minimum fracture load is needed for acceptance. Use Table 2 for new projects as a starting reference point in absence of any customer or internal requirements.

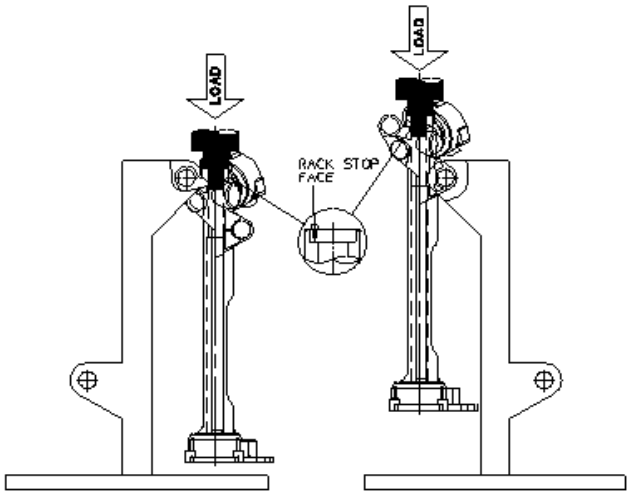


Figure 4.3

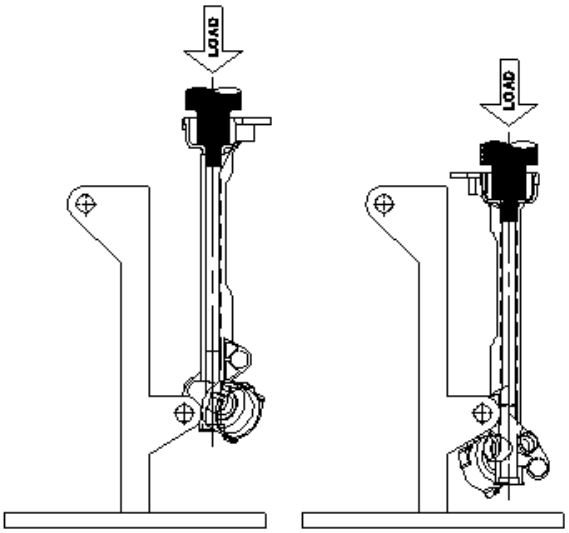


Figure 4.4

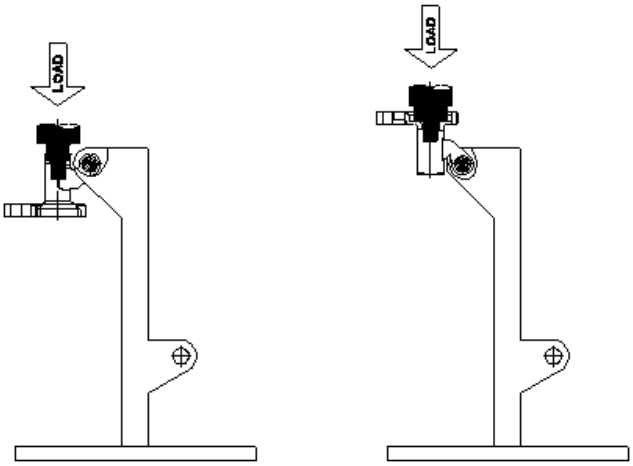


Figure 4.5

TABLE 2: RECOMMENDED REQUIREMENTS FOR FOOT MOUNT SHEAR TEST

Foot Mount Shear Test Minimum Fracture Lad		
Rack diameter [mm]	Housing design	Min. Fracture load [kN, (lbs)]
24/25	D-mount, inside, out side	22.3 (5000)
	Split	
28	D-mount, inside, out side	31.2 (7000)
	Split	
32	D-mount, inside, out side	44.5 (10000)
	Split	

Minimum quantity of 6 parts shall be tested unless specified otherwise by TRW Quality, Product Engineering and supplier.

5.5 Solid Mount / Threaded Torque to Strip Failure Test

Use customer specified or supplied bolts to perform test. See Figure 5 for overall view of setup.
Record load to strip thread using a calibrate static torque wrench.
Minimum torque to strip threads on housing should be at least 50% greater than maximum torque requirement by customer. The minimum accepted torque must be defined by TRW product engineering.

Reference minimum torque to strip values is M12 bolt is 90Nm, and M14 bolt is 165Nm.

Figure 5 Outboard Housing Torque to failure set-up

6 Crack Detection

Cracks at housing are not allowed. 100 % visual examination is required. A magnification of 3x is recommended.

Machined housings that are visually examined should be marked for traceability if supplier grid is used (optional).

Crack detection after foot insert assembly:

Cracks at housing are not allowed after foot insert assembly (see Figure 6).

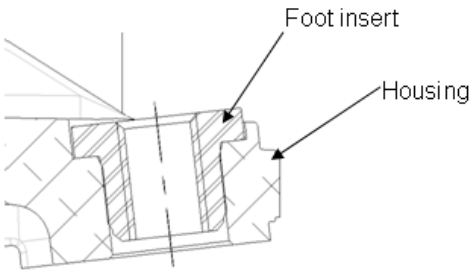


Figure 6

7 Porosity Evaluation

7.1 General requirements

Porosity shall be evaluated by the following methods: Computer Tomography (preferred for PPAP), Radiographic (radioscopy / x-ray) (internal), cut sections (internal), and visual inspection (external). The method usage and frequency to be established during APQP review and into production through the control plan, critical key characteristics (i.e. 6 pieces during PPAP or change in process or major die refurbishment).

TRW reserves the right to change stated porosity requirements if it is deemed necessary by Product Engineering or Quality.

All figures are general representation and actual product geometry and boundary may vary.

Requirements on product drawing supersedes specification.

General area definition
The part is to be classified in following areas:

Area A: Critical area (high stress areas; i.e. mounting foot, Bolt-on flange etc.)
Area B: Functional area (hydraulic area, supporting surface for screws etc.)
Area C: Non-critical area

Areas are to be explicit specified on the drawing.
X-Ray area definition is shown in the appendix in chapter 15.5.

- Foreign material:	No foreign material are allowed
- Cracks:	No cracks are allowed
- Cold fill:	No cold fills are allowed

7.2 Porosity Evaluation Methods

7.2.1 Radiographic Examination – Standard Grade

Radiographic inspection shall be done per latest version of ASTM E505. TRW requirements are listed in Table 3 (Reference Radiographs from ASTM E505 shall be used).
Radiographs from limit parts which was defined during PPAP phase should be used as master (see chapter 14.1, point 7 Release procedure)

TABLE 3: REFERENCE RADIOGRAPHS FOR ALUMINIUM CASTING – STANDARD GRADE

Discontinuity	Applicable Casting Thickness in. (mm)	TRW Requirements Levels per ASTM E505	REFERENCE ONLY – Maximum Area of Porosity (%)
Category A (Porosity)	Up to 3/8 (9.5), incl	Critical Areas: Level 1	1
		Function Areas: Level 2	17
		Non-Critical Areas: Level 3	26
Category A (Porosity)	Over 3/8 to 1 (9.5 to 25.4), incl	Critical Areas: Level 1	11
		Function Areas: Level 2	33
		Non-Critical Areas: Level 3	45
Category B (Cold fill)	Up to 3/8 (9.5), incl	No cold fills are allowed	----
Category C (Shrinkage)	Over 3/8 to 1 (9.5 to 25.4), incl	Critical Areas: Level 1	3
		Function Areas: Level 2	40
		Non-Critical Areas: Level 3	55
Category D (Foreign material)	Up to 1 (25.4), incl	No foreign material are allowed	----

Minimum image quality for x-ray and gamma-ray radiographic examination as applied to industrial radiographic film recording is 2% loss of sensitivity. Minimum image quality using a fluoroscope (real time x-ray) is 0.1mm or 4% loss of sensitivity, whichever is minimum.

Critical, Functional and Non-Critical areas are designated on product drawing (see Figure 7 for example).

7.2.2 Cut Section Examination – Standard Grade

(1) The criteria for evaluating areas of castings for visual porosity levels are based upon specification ISO 10049: “Aluminum Alloy Castings - Visual Method for Assessing Porosity”. This specification quantifies porosity.

(2) Areas of the casting deemed critical by TRW shall be required for inspection on a regular basis. The cut-section areas may change or increase in frequency & location to define critical areas as required after x-ray or computer tomography as per TRW Engineering. Acceptance or rejection shall be based upon the number of pores and their mean diameter, not their depth. The porosity levels are written in Table 4. For non-critical areas only, the degree of porosity exceeding the specified level by one degree is permitted provided the area rated at such a level does not exceed 25% of the total area under examination.

(3) All porosity indications shall have 1.0 mm minimum of sound material between them.

(4) The porosity levels as stated in Table 3 (Reference radiographs for aluminum die castings – standard grade) and Table 4 (Severity levels for visual assessment of casting porosity – standard grade) shall be used in conjunction with casting and / or machining print to identify locations of porosity requirements (see Figure 7 for example).

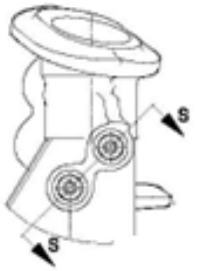


Figure 7
Radiograph Table 3 – Critical
Cut Section Visual Table 4 – Level 3

(5) All other areas not specified shall be considered as Level 5 per Table 4.
(6) All non-critical sections greater than 8x8 mm are permitted to have shrink porosity within the following boundaries shown in the Figure 8. Porosity must be below 4 mm from any surface with maximum dimensions of 10 mm long, 2 mm wide and 2 mm deep.

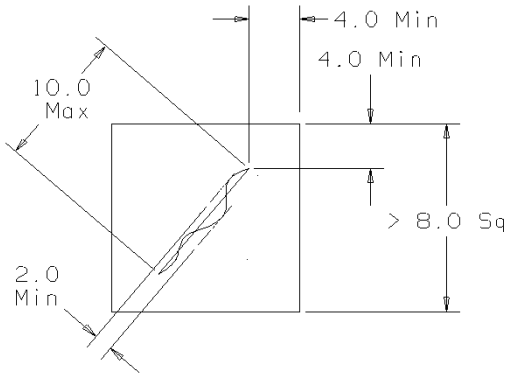


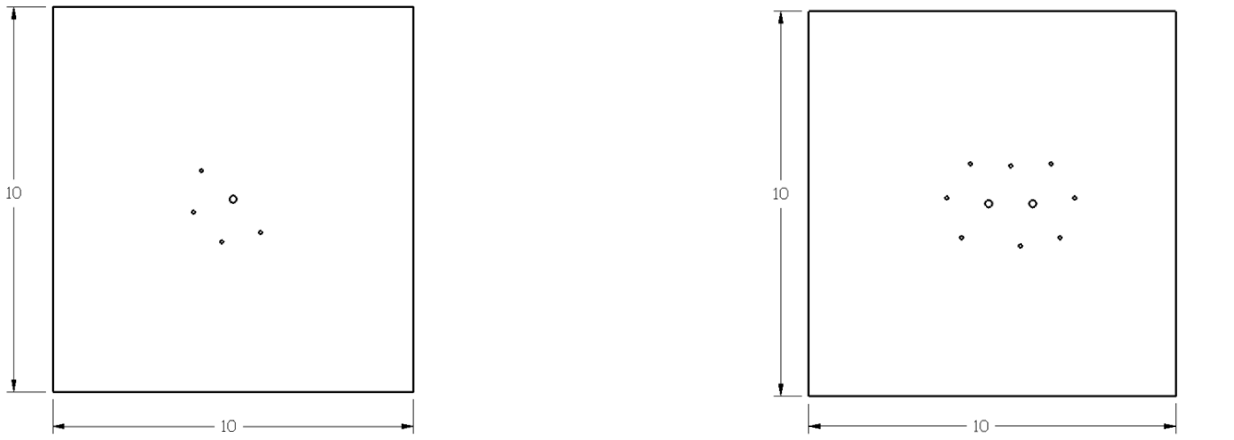
Figure 8

(7) Surfaces to be inspected shall be clean and free from grease or other impurities that may hinder the visual inspection process. The surface shall be machined or otherwise ground or polished to a finish equivalent to at least a 20-micron grinding paper. The inspection shall be done with a magnifying glass not more than 10X power (for measuring pore diameters). A 10mm x 10mm template shall be used to evaluate areas of the critical surfaces. If desired, the surface to be inspected can be chemically treated (etch) in order to improve the visibility of the porosity to be evaluated. The procedure for this process is given in ISO 10049, Sec 4.3 (Note 2). Inspection shall be done in environment with bright intensity greater then or equal to 100 lux. Supplier to specify inspection method on control plan, which will be signed off by TRW.

TABLE 4: SEVERITY LEVELS FOR VISUAL ASSESSMENT OF CASTING POROSITY IN 100mm2 AREA - STANDARD GRADE

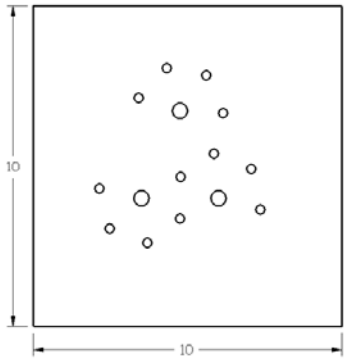
Level	Maximum Size Ø of Single Porosity	Maximum Area of Porosity	Maximum Area of Porosity	Number and Size of Porosity Voids per Viewing Area	
	(mm)	(%)	(mm^2)	Maximum Number	Maximum Size (mm)
1	0.2	0.06	0.06	4	0.1
				1	0.2
2	0.2	0.13	0.13	8	0.1
				2	0.2
3	0.5	1.4	1.4	12	0.3
				3	0.5
4	1	7.5	7.5	14	0.5
				6	1
5	1.5	13.7	13.7	15	0.5
				7	1
				3	1.5
6	5	FOR TOTAL CROSS-SECTION AS INDICATED		1	5
				5	0.5-3.0
				8	0.5-1.0

For more clarity the above level of Porosity are shown on 10 x 10 mm template (see Figure 9.1-9.2).

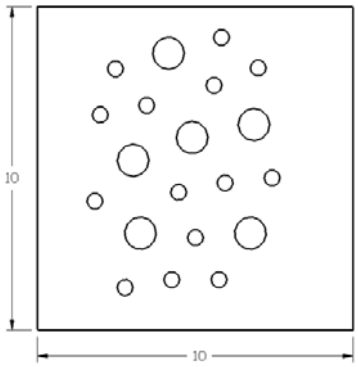


DEGREE OF POROSITY :1 - 4 NOS. OF ∅0.1MM & 1 NO. OF ∅0.2MM DEGREE OF POROSITY :2 - 8 NOS. OF ∅0.1MM & 2 NOS. OF ∅0.2MM

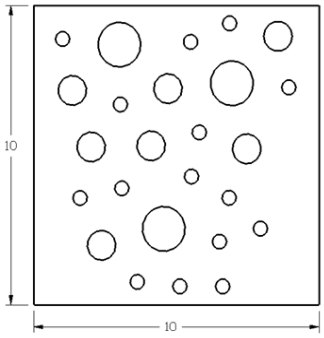
Figure 9.1



DEGREE OF POROSITY :3 - 12 NOS. OF ∅0.3MM & 3 NOS. OF ∅0.5MM



DEGREE OF POROSITY :4 - 14 NOS. OF ∅0.5MM & 6 NOS. OF ∅1.0MM



DEGREE OF POROSITY :5 - 15 NOS. OF ∅0.5MM, 7 NOS. OF ∅1.0MM & 3 NOS. OF ∅1.5MM

Figure 9.2

7.2.3 Visual Inspection (External) – Standard Grade

(1) Sample parts exhibiting the agreed upon conditions may be used as reference standards.
(2) The casting shall be inspected when deburred and cleaned and the visual control shall be done in environment with bright intensity greater than or equal to 100 lux.
(3) Visual inspection with a light source shall be used for checking porosity on sealing surfaces.
(4) Micro porosity other than areas specified, as defined in this specification or product drawing, shall not affect hardness, and part function, as determined by TRW Product Engineering or Quality.
- Areas of the casting shall have no paths for ingression. No internal or external leakage is permitted.

7.2.4 Acceptance Limits – Standard Grade

(1) Unprocessed (Non-machined) Surfaces:

- Visual marks as consequences of core movement are acceptable (only if it is not a machined area) for a maximum depth of 0.5mm in critical areas and 1.5mm in non critical areas and supplier need to confirm the strength and integrity of the part i.e. foot-mount shear, bend strength and any appropriate method.

(2) Shot blasting operation (max. Rz 80) is permitted for the raw part but must be explicit defined on the casting drawing. Stainless steel balls with sizes of 0.4 – 1.2 mm can be recommended to achieve a roughness of max. Rz 80. Master sample(s) shall be approved by TRW Engineering and Quality.

(3) Processed (Machined) Surfaces:

- Indication on the sealing surface shall not exceed Degree of Porosity Level 2 per Table 4 or specified on the product drawing. More details on sealing surface refer figure 10.1-10.4.
- Non-critical machined areas shall not exceed the following pores requirements: 1 pore – up to 5mm, 2 pore – up to 3mm, 8 pores – up to 1.5 mm, 15 pores – up to 0.5 mm for total machined surfaces. Location of pores greater than or equal to 1.5 mm should be identified and agreed with TRW and a master for visual should be retained at TRW receiving location and Supplier Quality location.

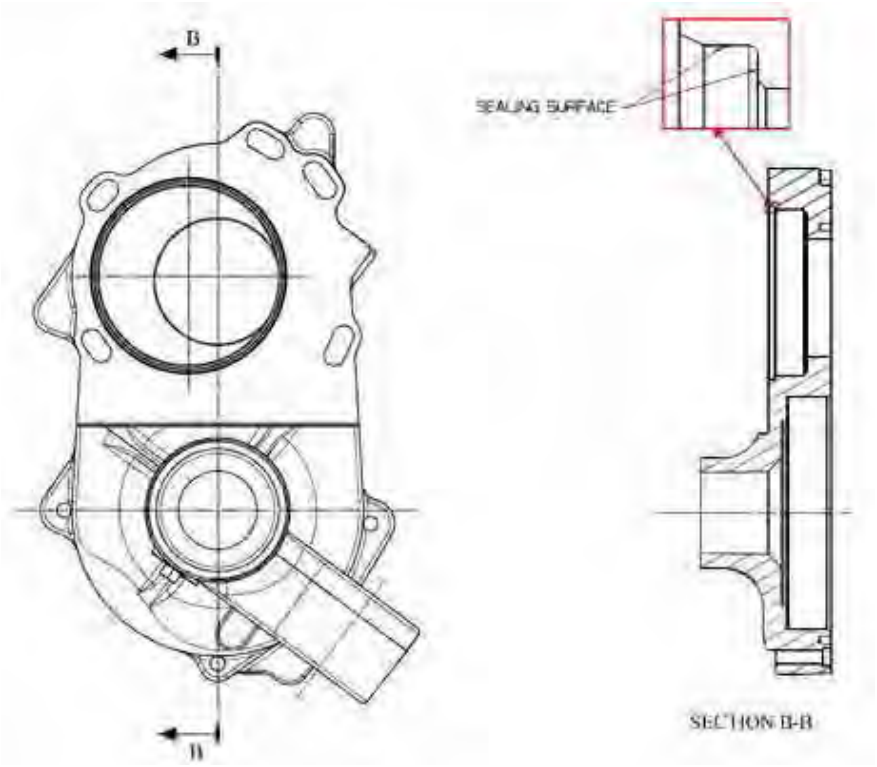


Figure 10.1

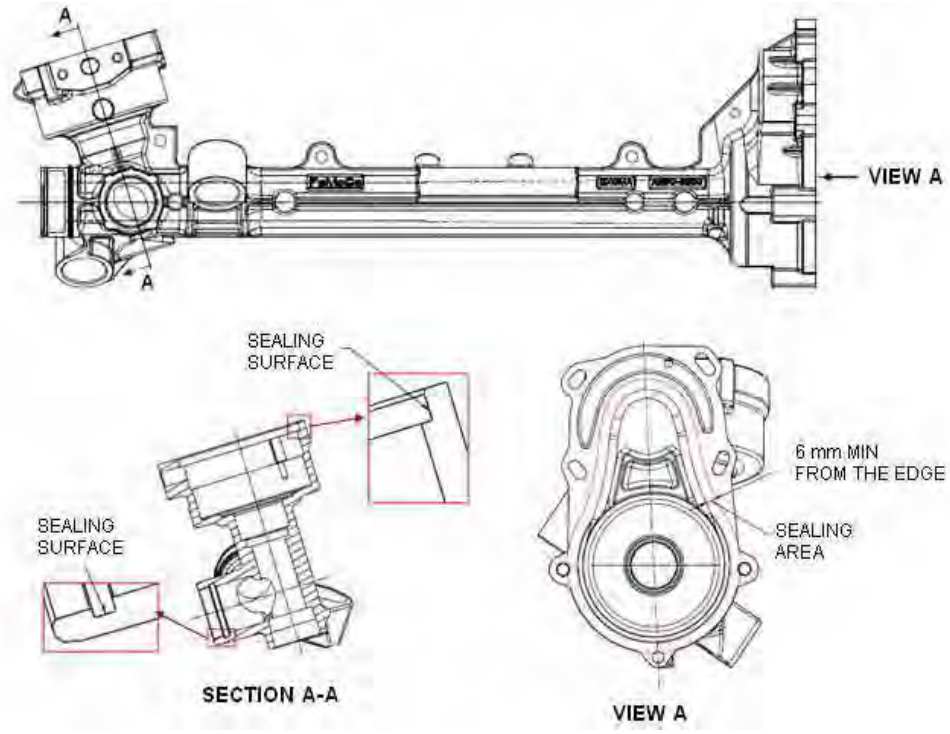


Figure 10.2

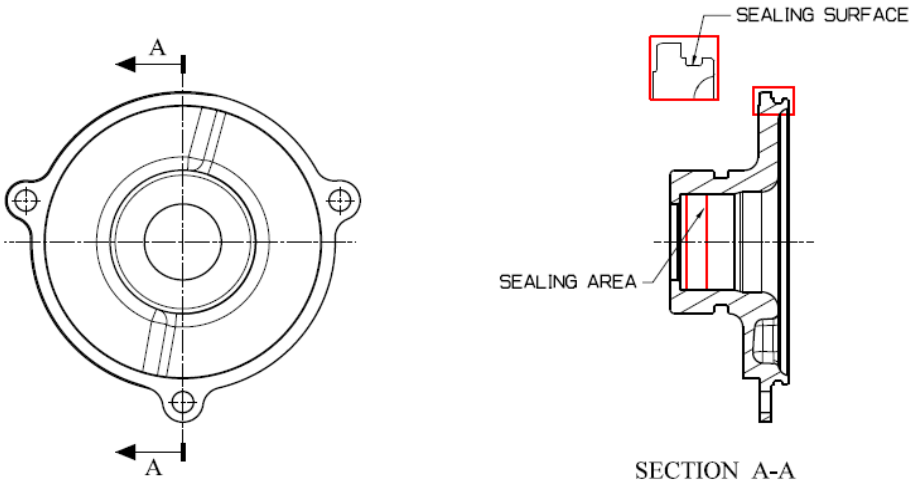
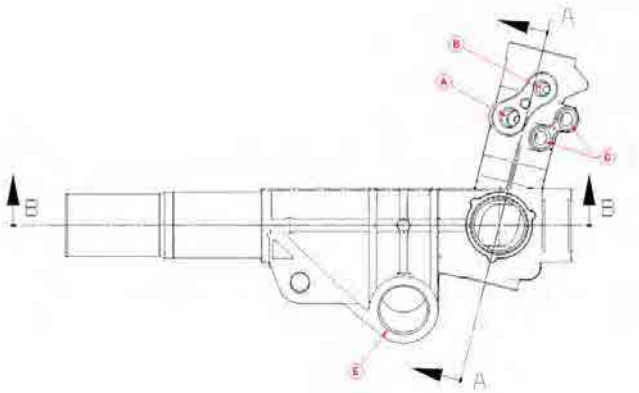


Figure 10.3



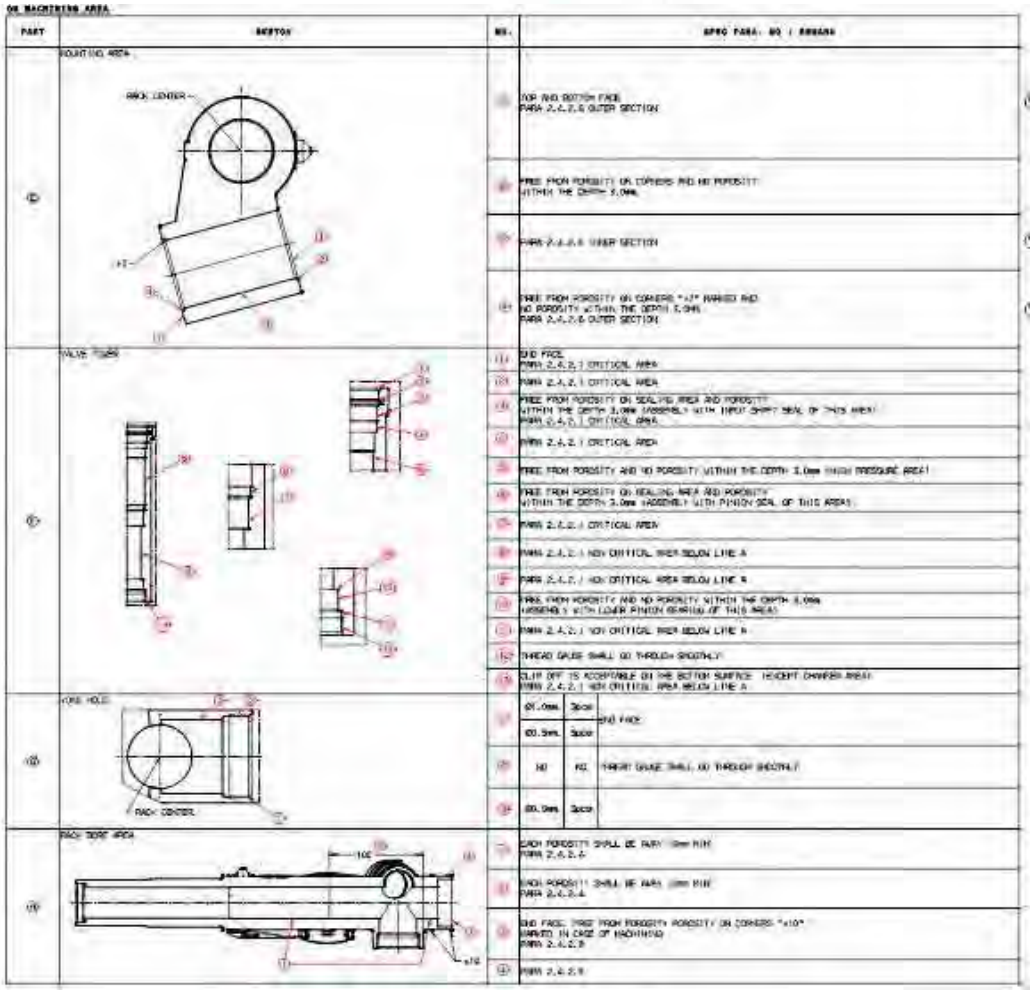


Figure 10.4. Hydraulic Cut Section Example
ADD TUBE AREA CUT SECTION PHOTO

Figures shown above are for schematic purpose only. Refer product drawing for actual geometry.

7.3 Porosity Evaluation Methods – Premium Grade (Applicable When Specified on Product Drawing)

7.3.1 Radiographic Examination General Notes – Premium Grade

- Shrinkage:	Area A: No shrinkage is allowed. Shrinkage in Areas B and C has to be agreed between TRW quality, TRW product engineering, OEM and foundry during release procedure (mentioned in chapter 14).
- Pore concentration:	No pore concentration is allowed in Area A and Area B. In Area C the maximum porosity must not be exceed a maximum value of 5 % and only permitted in cross points, in the centre of part and areas with mass of material.
- Micro porosity:	Defects shorter than the resolution cannot be evaluated by radiographic inspection. Micro porosity, as defined in this specification must not affect hardness or part function.
- Resolution:	Radiographic examination technique and equipment shall be able to resolve porosity size of 0.5 mm (500 µm) minimum. Minimum image quality is 2% loss of sensitivity. A pentrameter or line pair gage shall be used to determine the sensitivity of the x-ray unit. Resolution must not be higher than 800 µm.
- View area:	20 mm x 25 mm = 500 mm^2 (Image scale 1:1)

Area A, B, and C will be defined on product drawing (see Figure 11).

All the limits are minimal requirements for Product acceptance. Additional requirements may be specified by TRW Product Engineering, TRW Quality, or OEM. Changes to the size, number or % of area of the porosity requires TRW Product Engineering and TRW Quality approval.

There must be a minimum of 1.0 mm of sound material between porosity voids. The minimum distance should be calculated with the minimum pore size from neighboring pores.

Viewing area shall be 500 mm2. If another Image scale (viewing area) is used as Indications must be adapted to applied image scale.

Defects shorter than the resolution can not be evaluated by radiographic inspection. In additional to the assessment unless otherwise specified on the drawing the maximum porosity value of 5 % must not be exceeded for the entire part. This must be evidenced by sectioning as described in chapter 7.3.4.

The acceptable porosity size and distribution per % Viewing Area is defined in Table 5. In lieu of determining % Viewing Area, the supplier may use the planimetric (counting) method. The maximum number of porosity indications is listed in Table 1. TRW Product Engineering and TRW Quality shall define which method to use.

TABLE 5: POROSITY CRITERIA (Viewing area 500 mm^2; Image scale 1:1) – Premium Grade

Area	Area Description	Maximum Size Ø of Single Porosity [mm]	Maximum Area of Porosity [%]	Maximum Area of Porosity [mm^2]	Number and Size of Porosity Voids per Viewing Area	
					Maximum Number	Maximum Size [mm]
A	Critical Area	1.0 except on machined surface; Porosity on machined surface shall not exceed 0.5	1	5	9	0.5
					4	1.0
B	Functional Area	1.5	2	10	14	0.5
					4	1.5
C	Non-Critical Area	3.0	5	25	11	0.5
					9	1.5
					1	3.0

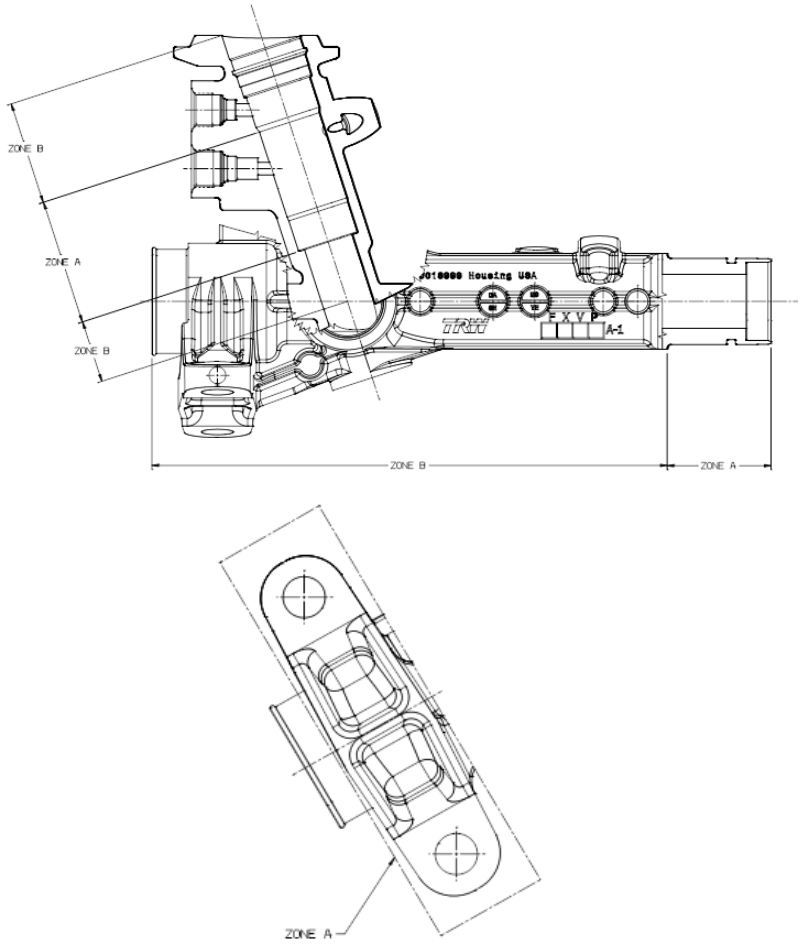


Figure 11 Premium Grade Cut Section Example

7.3.2 Radiographic inspection procedure – Premium Grade

Qualification and certification of NDT (Non Destructive Testing) personnel according to DIN EN 473

The x-ray examination has to be conducted operator-independent with fully automatically view evaluation under utilization of DIN EN 12681 and DIN EN 444.
A re-evaluation is permissible under following restrictions:

(1) Operator qualified and certified according to DIN EN 473 Step 2.
(2) Re-evaluation is only conducted with the former generated x-ray pictures (porosity and shrinkage size defined for all specified areas) from the approved part.
(3) X-ray pictures and inspection views to be agreed by TRW quality, TRW product engineering and foundry.
(4) The revaluation including operator name to be recorded in part documentation.
(5) Housings checked by x-ray to be marked for traceability (optional).

The defect size is to be evaluated by an equivalence-diameter (e.g. 1 mm ball) which describes the maximum allowable size in the defined part areas.

7.3.3 Cut Section Examination – Premium Grade

The examination should be conducted on machined parts to ensure that only the relevant areas will be evaluated in the sectioning. This assures that material which is removed by machining will not be considered.

The general release procedure is specified in chapter 14. Sectioning report (including detail radiographs from the cut areas and the corresponding porosity values) is to be submitted to TRW quality and TRW product engineering for approval.
This investigation can be delegated to an external supplier if the foundry is not able to conduct this investigation in-house (lack of software or lab equipment).

A short description is mentioned in the appendix (chapter 15.1).

7.3.4 Sectioning position or Location – Premium Grade

The following areas should be sectioned for visual inspection of porosity:

- Critical areas
- Functional areas
- Areas where porosity detected during radiographic inspection. The material cut surface position is to be chosen where the maximum porosity size will be achieved.
- Areas where the foundry may reasonably expect a significant amount of porosity. These additional areas shall be defined by foundry.
- Additional requirements may be specified by TRW Product Engineering, TRW Quality, or OEM.

Sections have to be explicit specified on the casting drawing.

The evaluation shall be conducted according Chapter 15.1 or OEM requirements. This evaluation shall be conducted by the foundry or by an external laboratory. This external laboratory has to be chosen by the foundry.

The measured porosity must correlate with the porosity values as defined in Table 5. Unless otherwise specified on the drawing the porosity must not be exceeded a maximum value of 5% in each analyzed sectioning.

7.3.5 Sectioning preparation and examination – Premium Grade

Castings being evaluated by Sectionings have to be prepared and tested according to following method:

Macro Structure
1. Preparation of section due per product drawing or specification.
2. Rough Grinding with wet disc with a graining of 80.
3. Macroscopic analysis and measuring with measuring eyepiece.

Micro Structure
1. Preparation of section due to drawing.
2. Grinding: wet on SiC paper with a graining of 500 or 600.
3. Polish with diamond paste/spray (graining 3 till 1 µm)
4. Microscopic analysis and photographic figure (V = 25:1)

7.3.6 Visual Inspection (External) – Premium Grade

(1) All castings are to be visually examined against approved master samples that have been agreed between TRW quality, TRW product engineering, OEM and supplier quality.
(2) In general parts have to be clean and free of loose chips and flash before inspection.
(3) Visual control shall be conducted in environment with bright intensity greater than or equal to 100 lux
(4) Visual inspection with a light source shall be used for checking porosity on sealing surfaces. No porosity shall be visible on sealing areas to the naked eye.
(5) The visual inspection is to be specified as critical characteristic on the machining drawing per OEM requirement.

7.3.7 Acceptance limits – Premium Grade

(1) Shot blasting operation (max. Rz 80) is permitted for the raw part but must be explicit defined on the casting drawing. Stainless steel balls with sizes of 0.4 – 1.2 mm can be recommended to achieve a roughness of max. Rz 80. Master sample(s) shall be approved by TRW Engineering and Quality.
(2) Visual marks as consequences of core movement are acceptable only in casted areas for a maximum depth of 1.5 mm.
(3) No porosity allowed on sealing surfaces (drawing recommendation shown in chapter 15.12)
(4) Porosity on non-sealing areas must not exceed the maximum pore size. The maximum pore size definition results per the area definition (Chapter 7.3 General Requirements and Table 5).

8 Additional Quality Characteristics

8.1 Casting tolerances

Following casting tolerance specification shall be considered:

(1) TRW 31845101
(2) ISO 8062
(3) DIN 1688 – 4 Pressure die casting
(4) JIS B 0403 CT6
(5) ASTM B85 Section 10

Casting tolerance specification to be defined by Product engineering and must be specified on the casting drawing.

8.2 General casting design recommendations

Unless otherwise specified on drawings the following requirements are to be followed:

(1) All rib width:	4-5 mm min.
(2) Wall thickness :	5 mm min. (unless otherwise specified on drawing)
(3) Internal draft angle:	1 deg max per side (depends on mold design e.g. 2-cavity mold) a smaller internal draft angle (e.g. 0°20´ for rack area core) can be necessary. In this case additional machining effort has to be evaluated by supplier.
(4) External draft angle:	2 deg max per side
(5) Fillet radii:	3 mm min.
(6) Corner radii:	1 mm min.
(7) Blend radii:	5 mm min.
(8) Ejector pin tolerances:	+/- 0,5 mm
(9) Flash size:	max. 0,2 mm
(10) Shot blasting:	Rz 80 (to be explicit specified on the casting drawing)
(11) Part No.:	Casting No. to be chosen as purchasing part No. if casting and machining supplier are different. In other case the machining part No. can be used.
(11) Bore sizes:	All bores sizes stated as maximum
(12) Machining allowance:	min 1 mm
(13) Core shift:	0,25 with respect to centre
(14) Tolerance for RadII:	+/- 0,5 mm
(15) Angular tolerance	+/- 1 degree

Dimension not specified are reference and may be obtained from the 3D model.

The profiles, the fillets, and the internal dimensions non-noticeable by integrals castings shall be verified by sectioning.

8.3 Marking

It shall correspond to the type indicated on the drawing. The markings should be placed in a non-removable area by mechanical operations. The markings shall be easily readable and conform to OEM branding standards.

8.4 Contamination requirement

The cleanliness category must be explicit specified on the machining drawing.
Machined housing must be conform to the reference specification TRW S0001322.

8.5 Burnishing process (HPS & EPHS Only)

The burnishing (rolling process) shall be used for the valve area (valve sleeve) incl. return bore "deburring".
Burnishing areas are to be explicit defined on machining drawing.
A gap of 1-2 mm has to be considered for roller burnishing tool runout. Gap has to be referenced to the chamfer between sleeve bore and upper pinion bearing bore.
Drawing recommendation for burnishing process is shown in chapter 15.9

8.6 Deburring requirement

Unless otherwise specified on machining drawing the shape of edges has to correspond to the specification DIN ISO 13715.

The deburring process has to be agreed by TRW Quality, TRW Product Engineering, supplier and OEM.

ECM (Electrochemical machining) and Vibro-Deburring process are suitable processes to eliminate flashes.

Drawing recommendation is shown in chapter 15.9.

8.6.1 Electrochemical Deburring:

The ECM can be used for valve area incl. return bore and cross bore area (yoke bore/rack bore/valve bore).
If ECM deburring is demanded additional costs will occur.
ECM deburring process parameter has to be optimized when bores designed very close in the valve sleeve area. In this case higher roughness can be appeared between bores (see chapter 15.9).

Areas are to be explicit defined on the machining drawing.

8.6.2 Vibro Deburring (Vibratory finishing system):

The Vibro-Deburring with glass beads can be used for the complete housing. Deburring process has to be agreed with TRW quality and TRW engineering.

8.7 Traceability requirement

Unless otherwise specified the following recommendation to be considered for casting:

(1) Casting No. and Issue level (if casting and machining supplier different)
(2) Machining No. and Issue level (if casting and machining supplier are not different)
(3) Supplier control grid (optional → shown in chapter 15.14)
The supplier control grid shall be used by supplier to guarantee that parts checked by x-ray, visual control, leakage test can be tracked by TRW quality. Depends on the conducted tests parts have to be marked in specified area.
(4) Mold No.
(5) Cavity No.
(6) Manufacturing data (day, (month), year, shift)
(7) Machine name (optional)
(8) Material (recyclability code)
(9) Customer trade mark
(10) Supplier trade mark (optional)
(11) Country of origin (optional)

If the supplier creates drawings (casting or/and machining) by themselves TRW has to add those drawings on separate TRW drawings with TRW part No's. Those part No's have to be considered for the part (depends on point 1) and 2)).

8.8 Anodization (Optional)

Anodization can be optional defined on the machining drawing according to TRW 62005004 (S0000089) or to TPSC20631 to fulfill the steering gear requirements (protection against wear, corrosion (in ph-value range 5 -8) etc.).

Anodization (including layer thickness) has to be agreed by TRW Quality, TRW Product engineering, OEM and supplier. In general a layer thickness of 10-15 µm should be considered.

Besides oxide layer thickness the protective effect depends on the surface roughness (better protective effect on machined or polished surfaces) and purity grade of the material (e.g. a higher cooper portion >2% can effects that only a oxide layer thickness of 6-8 µm instead of max. 25 µm for "cooper free" Al alloy can be achieved).

The oxide layer grows (e.g. for coating in sulfuric acid) at the rate of 1/3 outwards and 2/3 inwards.
This has to be considered for fit parts.
Drawing entry recommendation shown in chapter 15.15.
A special variant describes the "Hard Anodization" to generate extra hard and wear resistant surfaces. It can be achieved oxide layer thicknesses from 30 to 250 µm depends on used material.

9 Burst Pressure Test (optional, only for integral housing)

A burst pressure test on a prepared casting (only the hydraulic area) can be performed by the foundry as internal test. After test the fracture position and characteristic to be analyzed and shall be achieved as master samples.

This test doesn't replace the internal TRW burst pressure test according to TRW 62052001 on entire steering gear. For the final product engineering approval the burst pressure test according to TRW 62052001 has to be successful completed.

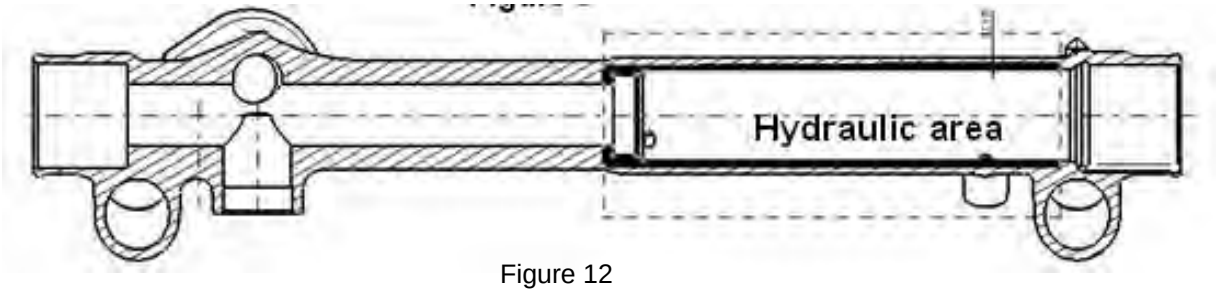


Figure 12

Hydraulic area as shown in figure 12 has to be machined to the upper diameter which specified on housing machining drawing to establish the maximum pressure.

This test has to be agreed by TRW quality, TRW product engineering and foundry.

Test including test requirements is to explicit defined on the casting drawing.

Requirements: A minimum pressure of 300 bars to be achieved. Respectively, the burst pressure shall not be below the OEM requirement.

10 Leakage Test

The gear assembly is installed under the hood of the car and it may come in contact with salt water and / or may be subjected to a high pressure wash. In order to ensure that water / moisture does not seep from the outside to the inside, the supplier has to perform a Air Decay and/or/both Dunk Test.

Unless otherwise agreed between TRW quality, TRW product engineering and supplier a 100 % leakage test is to be implemented during production.

The leakage test is to be specified on the machining drawing and to be defined as significant characteristic.

Tested areas have to be explicit described on the machining drawing (preferred line design).
Control plan and test rig (seal jig) drawings to be prepared by supplier and submitted to TRW quality and TRW product engineering for approval.

10.1 Air Leakage test

The air leakage test has the scope to define the degree of acceptability of casting or machined component defects that can cause external leakage (sees images).
The verification of conformity of the component is determined pressurizing the zones with air and measuring the pressure decay.

Components that are not impregnated shall be air leak tested (100% of all the parts).

Drawing entry for HPS and EPHS mentioned in chapter 15.14.

10.1.1 Test procedure and requirements

- The machined surfaces must be free from porosity or other defects that can cause external or internal leakage or that they can reduce the piece resistance.
- Before testing the component must be clean, dry and temperature stabilized.
- The component shall be mounted in a fixture, sealing the different areas. The fixture shall be designed to minimize the volume of air in the component during the test.
- The housing shall be sealed to divide the part into two pressurized test zones (for HPS and EPHS) All holes in the pressurized areas must be sealed.
- The period for system filling is not considered in the testing time. Filling values have to be specified in the work sheet.
- The defined leak values are reference values and can vary to second of the housing model, the effective value will appear on the specific work sheet or on drawing. Such value could be defined based on specific correlations between the results of the test carried out on the component and on the values found on the gear assembly line (see Table 6).

10.1.2 Air decay requirements

Table 6. Leak Rate Requirements for Housings

	HPS/ EPHS			MMSG Housing	EPS BD				EPP CD
	Pinion Housing / Motor Housing				Pinion Housing	Outboard Housing	EPP Housing	Sensor Cover	
	Mechanical Areas	Hydraulic Areas							
		Valve	Piston						
Test pressure (bar)	1,4±0,3	5±0,2	5±0,2	1,4±0,3	1,4±0,3	1,4±0,3	1,4±0,3	1,4±0,3	XXXX
Acceptable leakage rate (cc/min)	50	2	2	50	8	6	5,3	0,5	XXXX
May be impregnated if leak rate is between (cc/min)	>50	>2 to 15	>2 to 15	>50	>8 to 21	>6 to 19	>5,3 to 18,3	>0,5 to 13,5	XXXX
Shall be scraped if leak rate exceeds (cc/min)	>50 if impregrnated	>15	>15	>50 if impregnated	>21	>19	>18,3	>13,5	XXXX

The fill time, stabilization time, test time, and exhaust time is dependent on part geometry and shall be at the discretion of the supplier with the approval of TRW Engineering. ~~Typical stabilization time is xx- xx seconds. Typical test time is xx-xx seconds. Michael Smith will contact Paul Hanson (SDE) to discuss values.~~

Identify after successful air decay the following way: (Telius) year, month, day, and time for unique traceability identification or (Punch Mark) with Julian date and year or dot mark with approval of TRW Engineering / Quality.

Drawing entry recommendation mentioned in chapter 15.14.

10.1.3 Dunk test requirements

If air decay is not available then 100% dunk testing shall be performed.

(1) Submerge the housing under water or isopar.
(2) The air pressure used shall be 4.0 +/- 0.4 bar (58 +/- 5 psi)
(3) No bubbles are permitted after a period of 15 seconds under water.
(4) If there are no bubbles observed the housing shall be considered acceptable.
(5) No internal or external leakage is permitted.
(6) Dunk testing shall be permitted twice to check for sealing issues. After two dunk test attempts then part shall be scrapped.
(7) An equivalent test may be developed by the supplier instead of the dunk test with approval from TRW Product Engineering or Quality (see Figure 13-17).

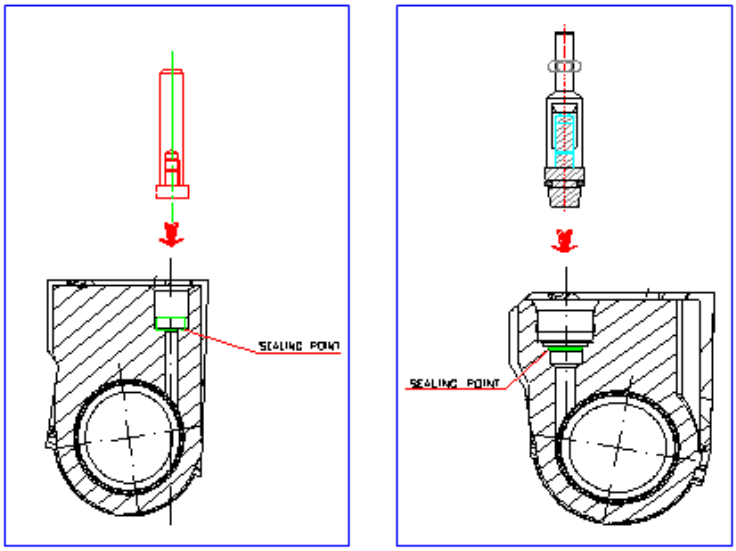


Figure 13 Hydraulic Port Seal

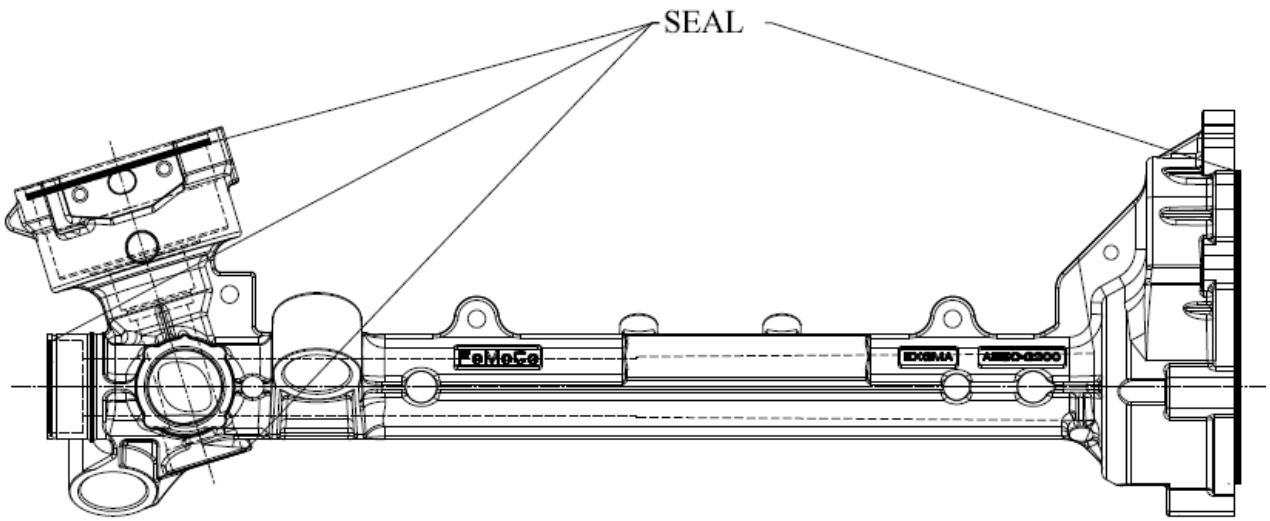


Figure 14.1

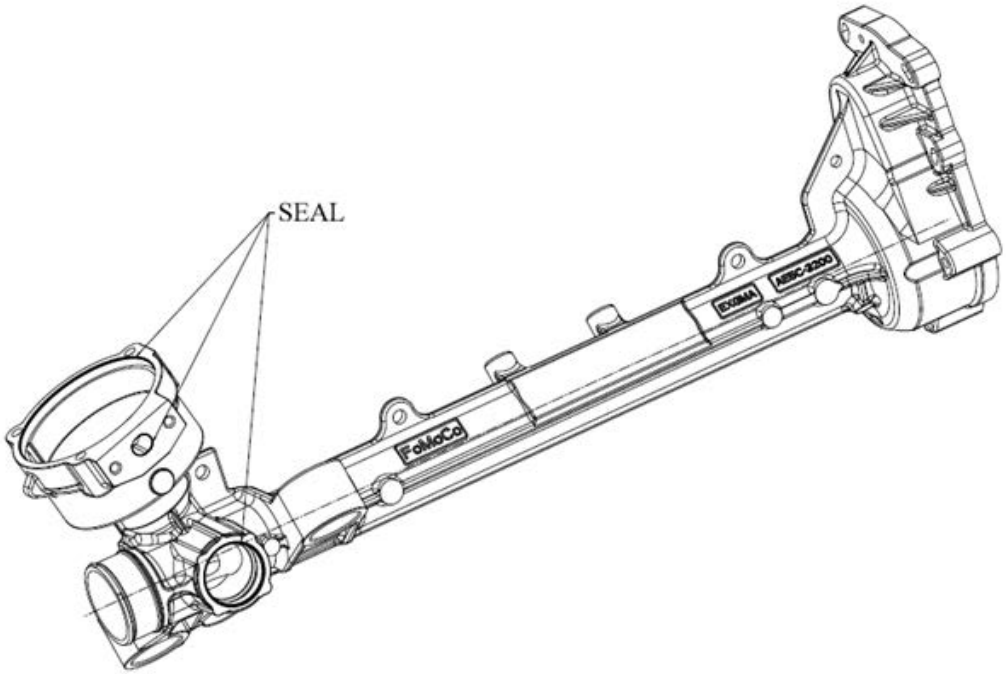


Figure 14.2

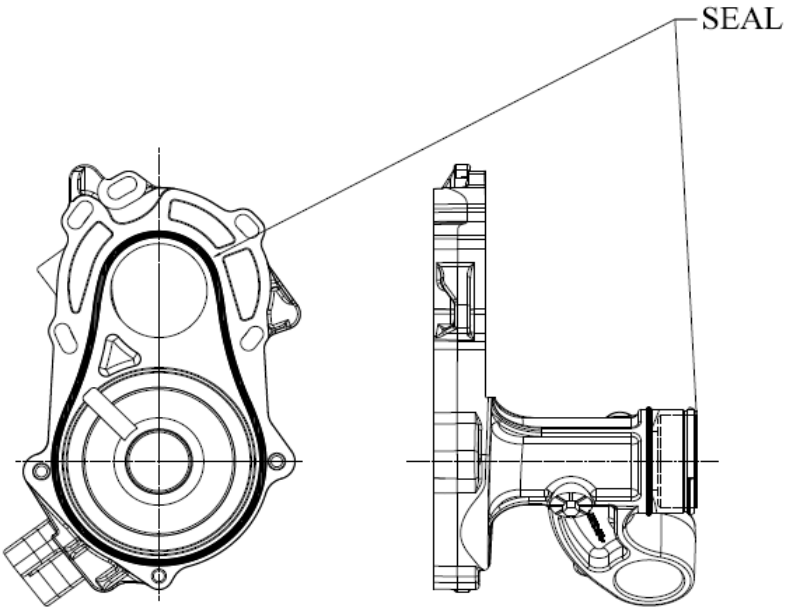


Figure 15

Released by:	TRW Automotive GmbH, Tech Center Düsseldorf
Leader of the Working Committee:	EC-Number

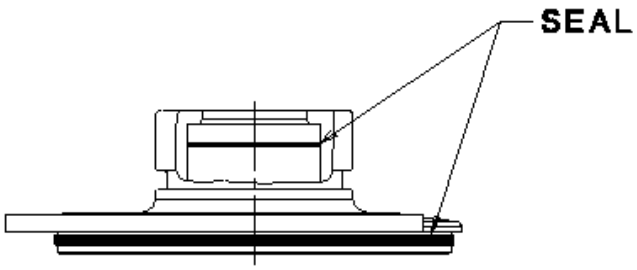


Figure 16

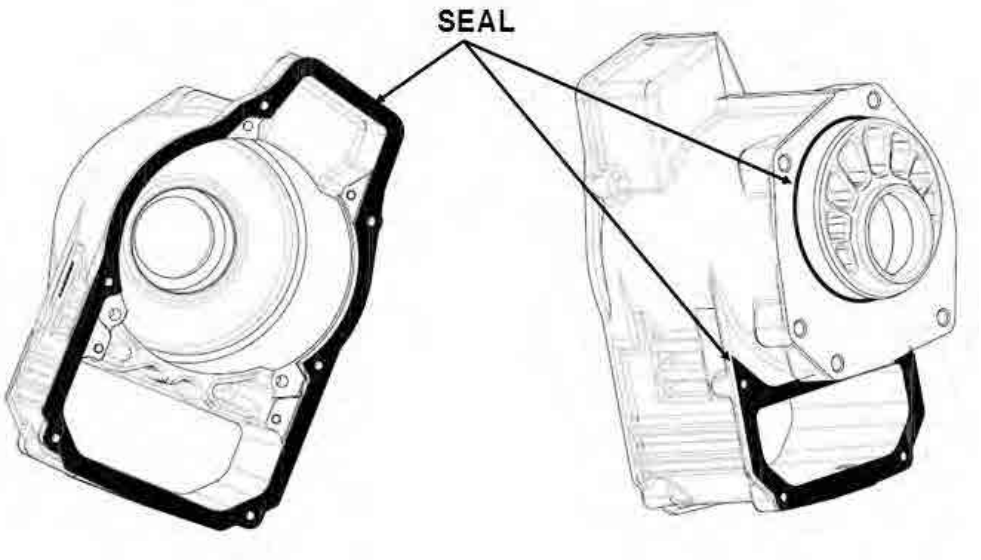


Figure 17

11 Vacuum impregnation (Optional)

Housings rejected by the air leakage test described in chapter 10 can be impregnated at maximum of 2 times.

Impregnation procedure:

(1) Housings are to be impregnated with anaerobic polyester resin described in the specifications TRW S0000121 or TRW 810000068 or TPSI20,107.
(2) After impregnation, housings must be washed to remove all resin from the surface.
(3) After washing operation housings must be air leak tested again as previous described.

Impregnation requirement is to be specified on the machining drawing.

12 Visual Appearance

Overall Appearance – parts to be clean and free of loose chips and flash.

Surface defects, such as lamination, solder, cold shut, blisters, surface porosity, core drag, and/or heat checking must not exceed the level approved by TRW Product Engineering, Supplier Quality and mutually agreed between TRW and the supplier. Sample parts exhibiting the agreed upon conditions may be used as reference standards.

Trim – unless otherwise specified, parts must be trimmed so that flash does not exceed the print requirements.

13 Casting Simulation

The flow simulation (temperature, air pressure etc.) has to be provided to TRW quality and TRW product engineering before production start.

14 Best Practices for Production Release

Any deviation to the Production Release process requires written approval from TRW Product Engineering and Quality.

14.1 New casting mold

For a new casting mold release the complete documentation mentioned in chapter 14 is required.

Release procedure:

(1) A CAE optimization model has to be defined by packaging and customer requirements. The CAE optimization as mentioned in chapter 17.10 should be carried out. The housing has to be designed based on the optimization results. CAE simulation has to be conducted.
(2) CAE simulation at TRW has to be successful completed before drawing can be released. Report has to be provided to TRW product engineering.
Unless otherwise defined the following tests acc. to TRW 62050001 to be simulated:
(3) Torque to failure if required
(4) Maximum rack load if required
(5) Burst pressure test if required
(6) Drawing release by foundry and TRW product engineering.
(7) A defined quantity of PV parts has to be produced from each cavity and in one batch by the foundry. The quantity [1)] is to be defined by TRW quality, TRW product engineering and foundry.
(8) 100% of the PV batch shall be examined by radiographic inspection preferred. X-ray frequency of production parts shall be determined by TRW Quality. It is recommended that the frequency be 100% until the rejection rate is below 5%. Parts shall be marked that have been x-rayed. Lowest acceptable parts (worst case parts) have to be sorted out and evaluated (i.e. cut section or foot mount shear or bend or gear level tests) for PV and customer requirements.
(9) Documentation (x-ray pictures from defined areas) shall be prepared and approved by TRW quality and TRW product engineering. Those x-ray pictures describe the minimum quality which can be accepted by TRW, foundry and OEM and shall be applied for radiographic examination during production.
(10) Accepted parts are to be machined off of production intent tooling and process.
(11) A leakage test (chapter 10**)** and a final visual inspection (chapters 7.2.3 or 7.3.6) to be performed.

(12) Machined parts have to be checked by radiographic at the foundry in the defined areas and documentation (i.e. x-ray radiographs or photographs of visual standards) must be provided by supplier. Visual standards needs to be defined by TRW Engineering and Quality (i.e. thread areas).
(13) Cut section report must be distributed to TRW quality and TRW product engineering.
(14) A defined quantity of “acceptable worst case parts” shall be provided to the assembly plant for PV or production trial run. Steering gear quantity to be defined by TRW Engineering and Quality. OEM samples quantities may be required in addition.
(15) Final approval by TRW will be given after successful PV validation respectively after OEM release.
(16) Parts manufactured during PPAP run, Production Validation (PV) and/or customer parts (e.g. 300 parts) should represent minimum baseline quality standards. Future production shall be same or better quality during PPAP run.

14.2 Repetition or repair die(s)

100 % carry over design assumed. No design changes are permitted. If design changes requested by foundry TRW product engineering as well TRW quality are to be informed. In this case the release procedure mentioned in chapter 14.3 respectively chapter 14.1 has to be followed.

The release of repetition dies are in charge of TRW quality located in the steering gear assembly plant.
The release procedure has to be defined by TRW production plant quality. If requested TRW product engineering can support those activities.

Recommendation:
(1) PPAP documentation with 100 % dimension check.
(2) Cut Section testing in defined areas.
(3) Dynamic load tests (e.g. Torque to failure test, Impact test, Maximum rack load, Parking test, etc) to be conducted within TRW.

14.3 Release after design change(s)

After design changes, production relocation or significant process changes (gating change, core change, material change etc.) of already released housings a re-release by TRW and OEM is necessary.
The release procedure described in chapter 14.1 is to be followed.

15 Appendix

15.1 Material cut instruction (according to VDG P201)

Sectionings are to be evaluated before production start, after tooling modification/ main- tenance or major process change (e.g. process relocation, gating change, core change etc.) on 5 limit machined parts by the foundry.

(1) Sectioning has to be conducted on machined parts.
(2) Areas where a sectioning shall be conducted to be defined by TRW product engineering and OEM as mentioned in chapter 7.3.4.
(3) After sectioning (plane cut) a sub-area appears.
(4) Sub-area to be polished as described in chapter 7.3.5 to obtain a metallographic microsection.
(5) The sub-area is to be classified in specified reference surfaces (quadrate, circle, triangle) as shown in Figure 18 for porosity evaluation.
(6) The porosity to be always evaluated on a metallographic microsection with a magnification of 25:1 (for premium and 10:1 for standard microscope.
(7) The porosity must not be exceeded a value of 5 % in each reference surface.

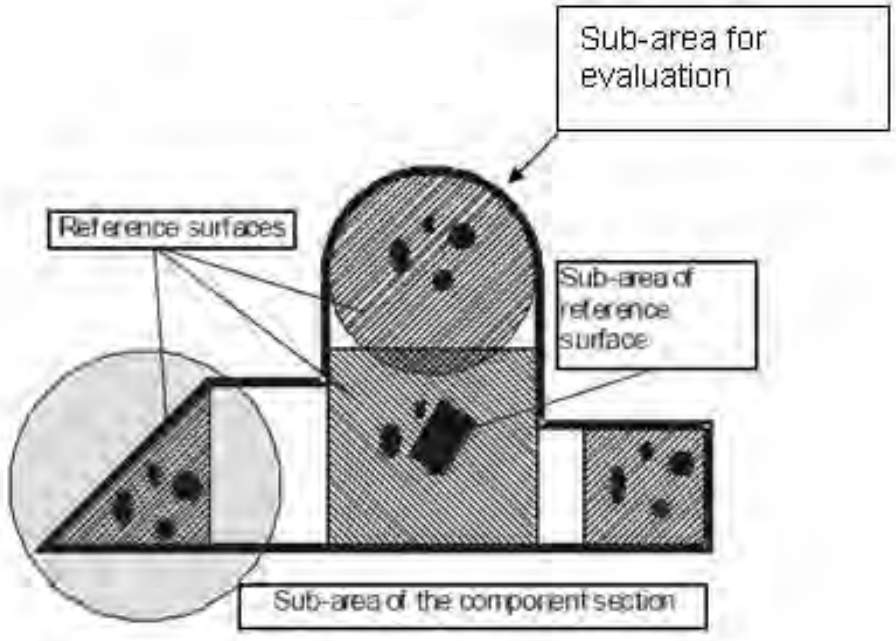
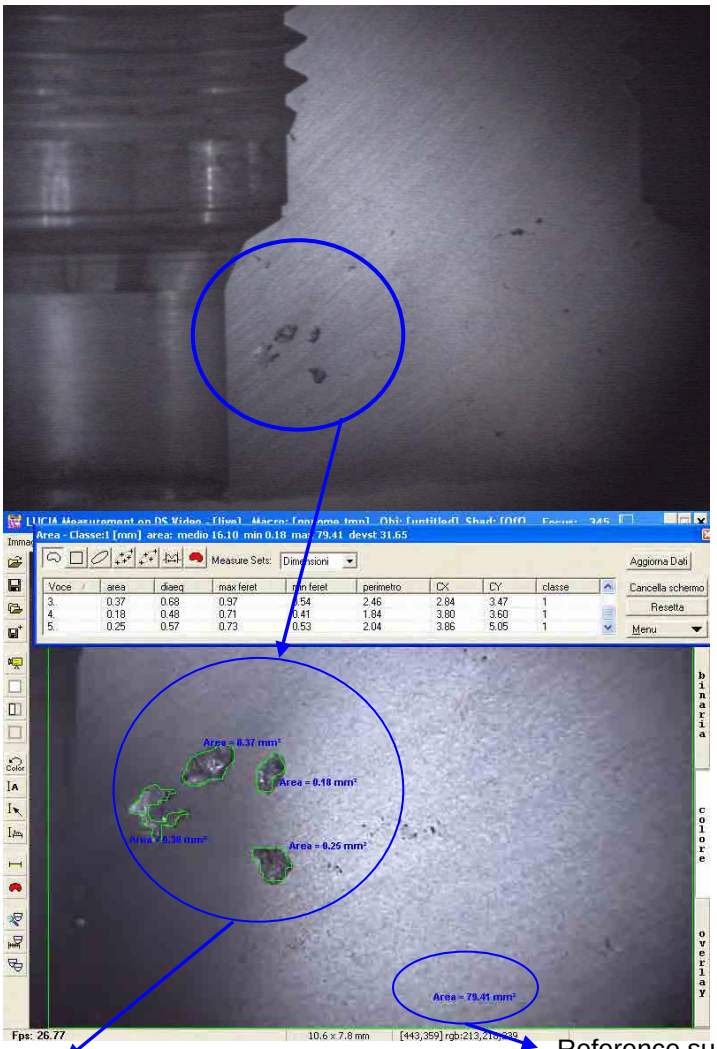


Figure 18.1

15.1.1 Examination example according to VDG P201



Sum of porosity surface: 1.1 mm^2

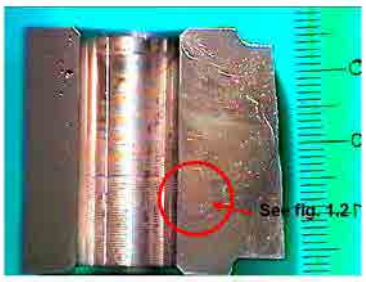
Reference surface (magnification 25:1)

Porosity in terms of reference surface (79,41 mm^2): 1,38 %

Figure 18.2

15.2 Defect explanation

15.2.1 Pore concentration (example)



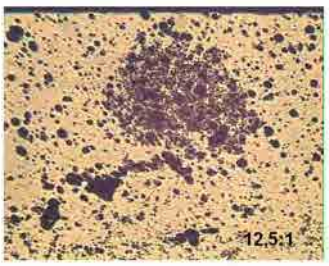


Fig.1.2: Accumulation of pores

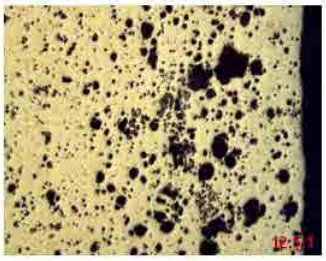
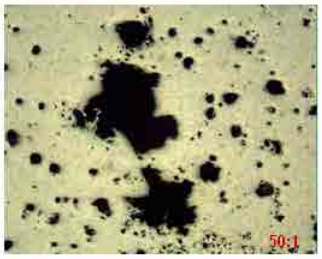
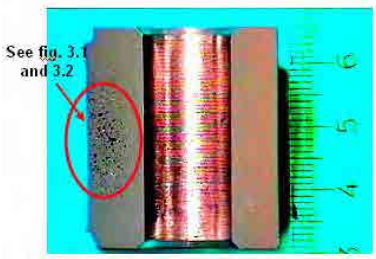


Fig.2.1: Pore accumulations



2.2 Pore size approx. 1,8 mm



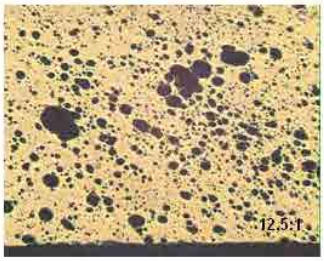


Fig.3.1: Accumulation of pores

15.2.2 Shrinkage (example)

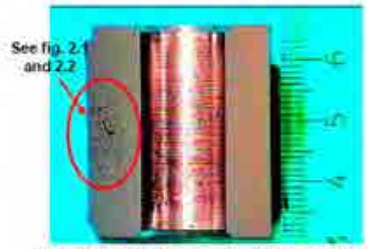


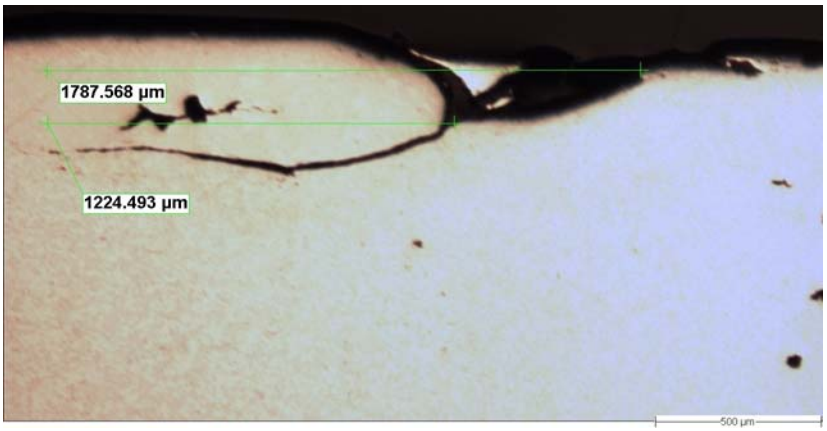
Fig.2: Foot „hydraulic area", Macrofigure, sample L2

Fig.2.2: Shrinkage cavity, size 2,6 mm

Fig.1: Foot „valve area", Macrofigure, sample L1

Fig.1.1: Shrinkage cavity, size 2,6 mm

15.2.3 Lamination (example)



15.2.4 Cold Flakes (examples)

15.2.5 Cracks (example)

Crack detection after machining in the sealing area (chamfer of internal pressure line).

Inner crack detection after sectioning

Fig.1: Foot „valve area". Macrofigure, sample L1

Fig.1.1: Solidification crack , length 3,6 mm

Fig.1: Foot „valve area". Macrofigure, sample R1

Fig.1.1: Continuous solidification cracks

15.3 Component Pulsation test result (example)

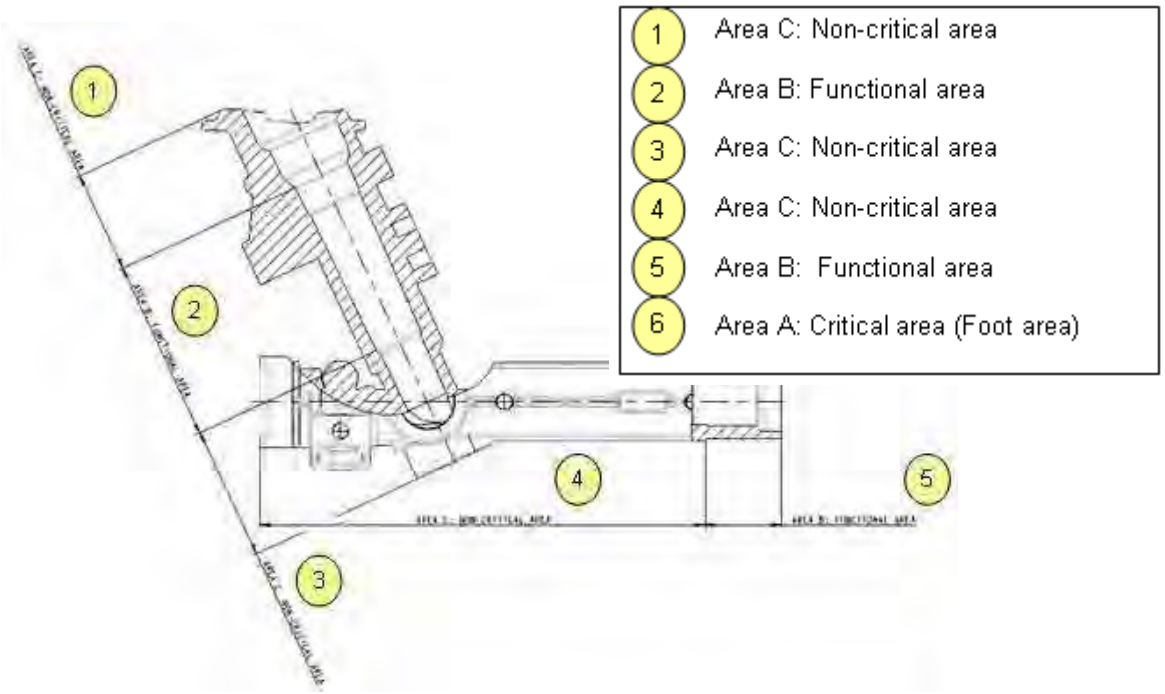
A comparable failure mode can be provoked by the pulsation test.

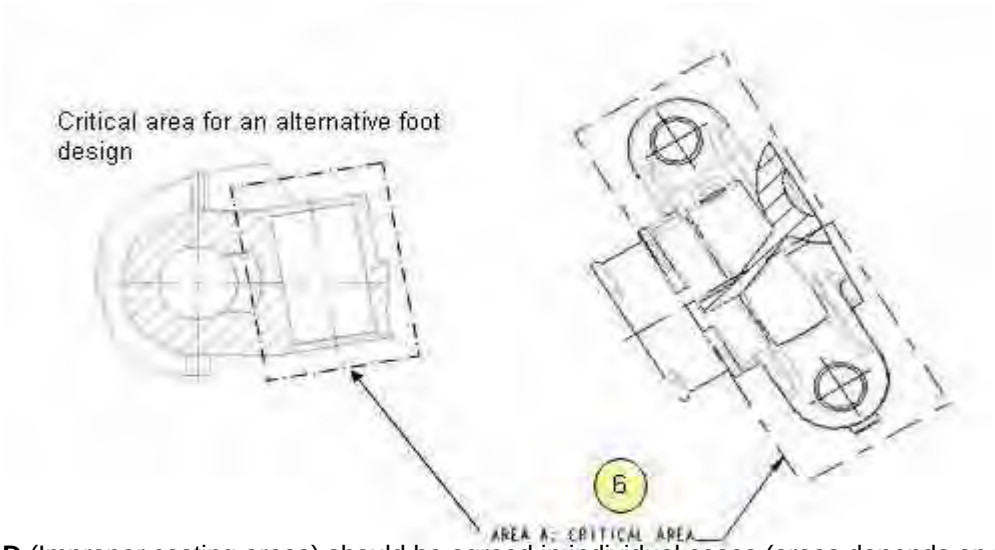
15.4 Cut section area definition (Example)

Evaluated limit parts to be archived as master samples for comparison by the foundry during the whole production life.

15.5 X-Ray area definition:

15.5.1 Short steering gear housing (HPS, EPHS) (Example)



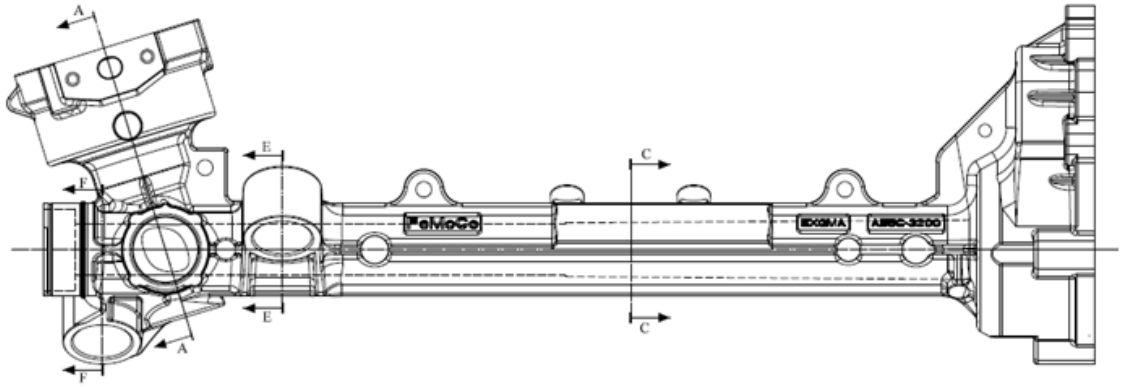


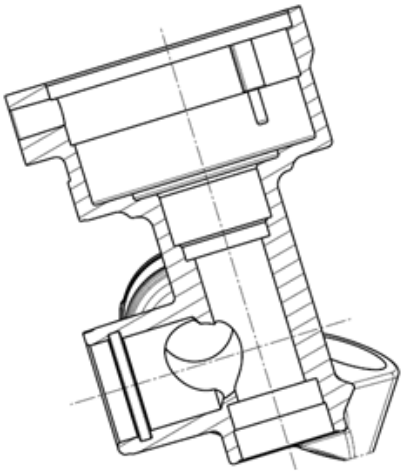
The **Area D** (Improper casting areas) should be agreed in individual cases (areas depends on the housing design) by TRW quality, TRW product engineering and supplier.

15.5.2 Short steering gear housing (EPS BD) (Example)

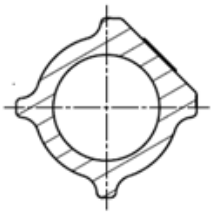
Non-Critical Area A-A: Degree of Porosity Level 5 per Table 4.

Non-Critical Area C-C: Degree of Porosity Level 4 per Table 4.





SECTION A-A



SECTION C-C

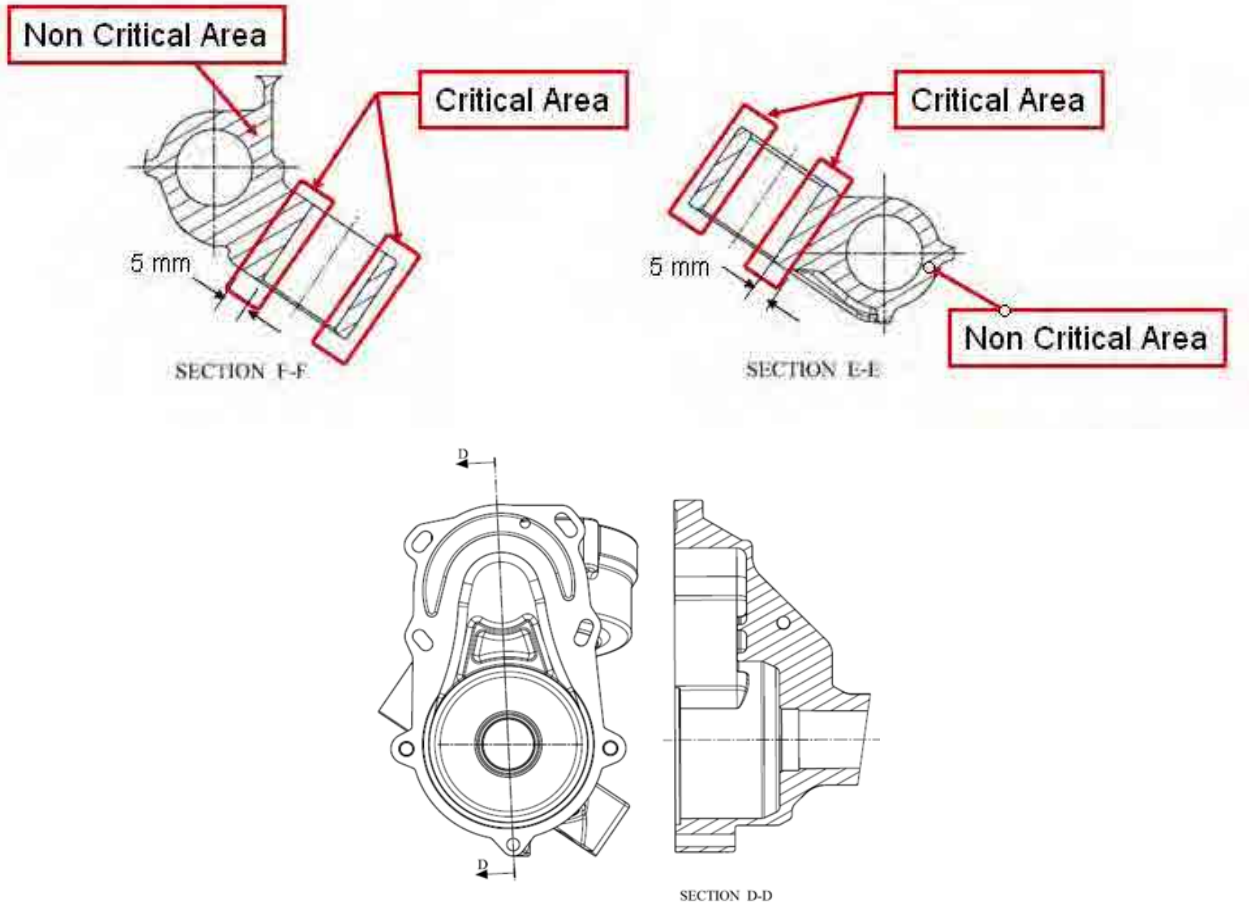
Critical Area F-F are highlighted in red[6]: Degree of Porosity Level 3 per Table 4.

Non-Critical Area F-F: Degree of Porosity Level 4 or Level 6 per Table 4.

Critical Area E-E are highlighted in red[6]: Degree of Porosity Level 3 per Table 4.

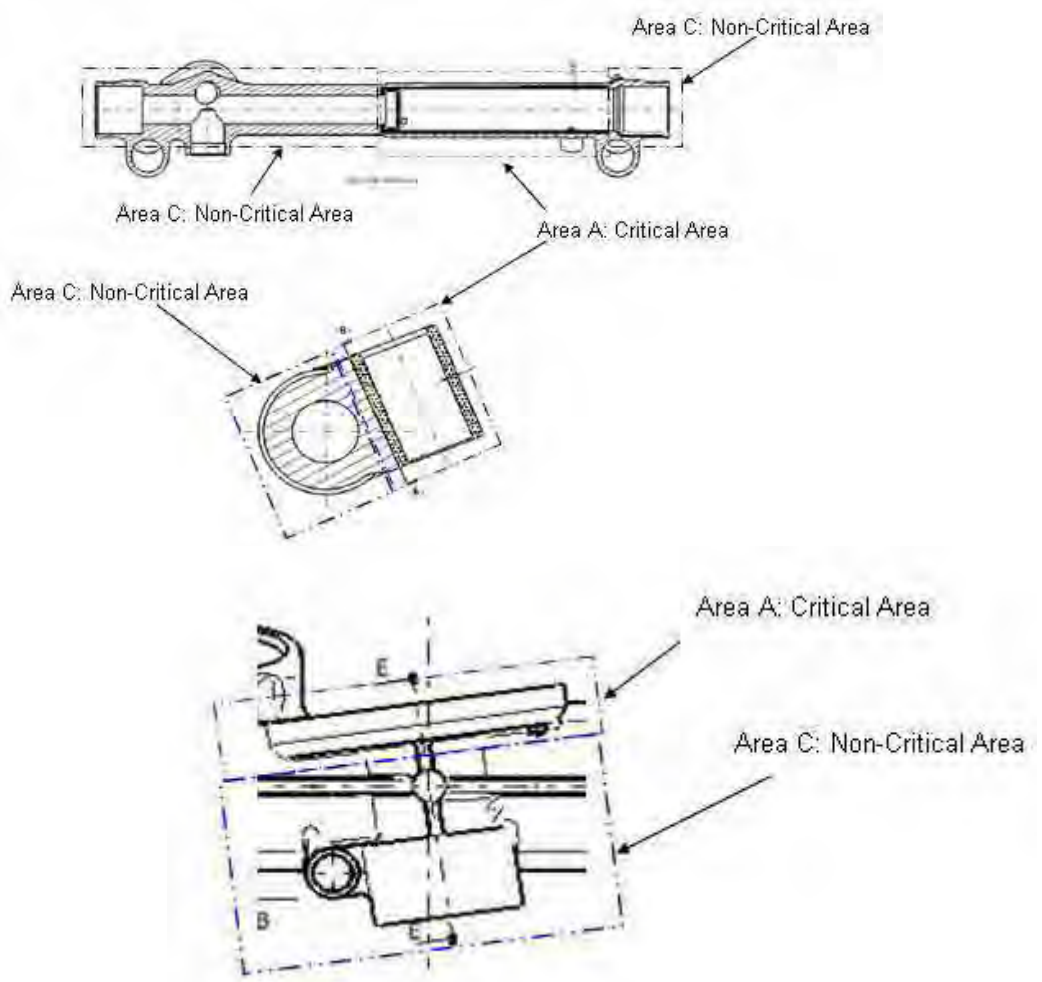
Non-Critical Area E-E: Degree of Porosity Level 4 or Level 6 per Table 4.

Non-Critical Area D-D: Degree of Porosity Level 4 or Level 6 per Table 4.



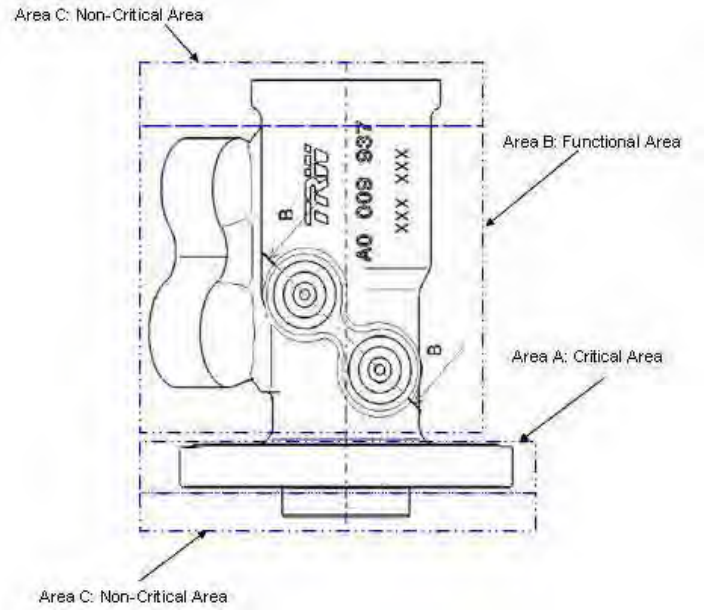
Released by:	TRW Automotive GmbH, Tech Center Düsseldorf
Leader of the Working Committee:	EC-Number

15.5.3 Long steering gear housing (with Bolt-On) (Example)



The **Area D** (Improper casting areas) should be agreed in individual cases (areas depends on the housing design) by TRW quality, TRW product engineering and supplier.

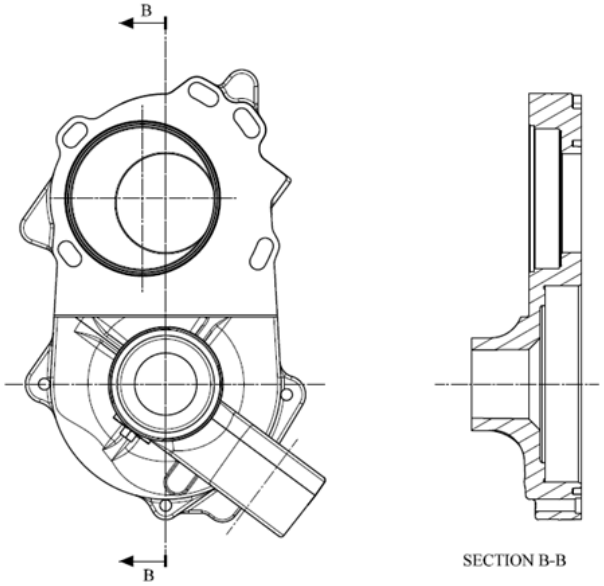
15.5.4 Bolt-On Valve housing (Example)



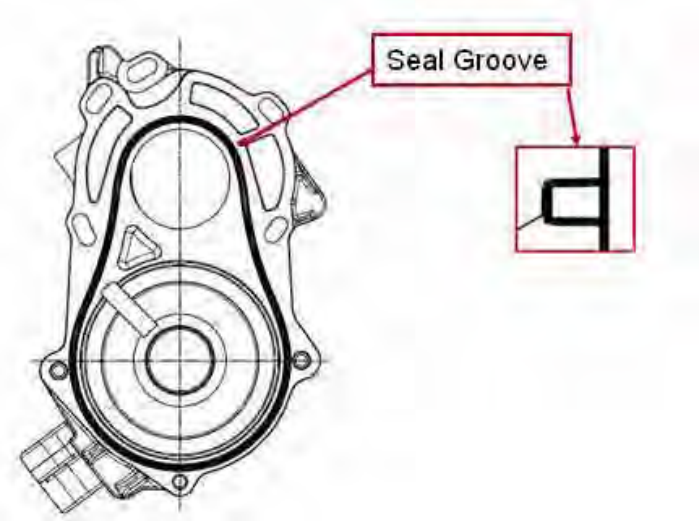
The **Area D** (Improper casting areas) should be agreed in individual cases (areas depends on the housing design) by TRW quality, TRW product engineering and supplier.

15.5.5 Outboard housing (Example)

Non-Critical Area B-B: Degree of Porosity Level 4 or Level 6 per Table 4.



Critical Area is the Seal Groove: Degree of Porosity Level 3 per Table 4. No porosity or visual defects on as cast sealing surfaces that would affect the performance of sealing.

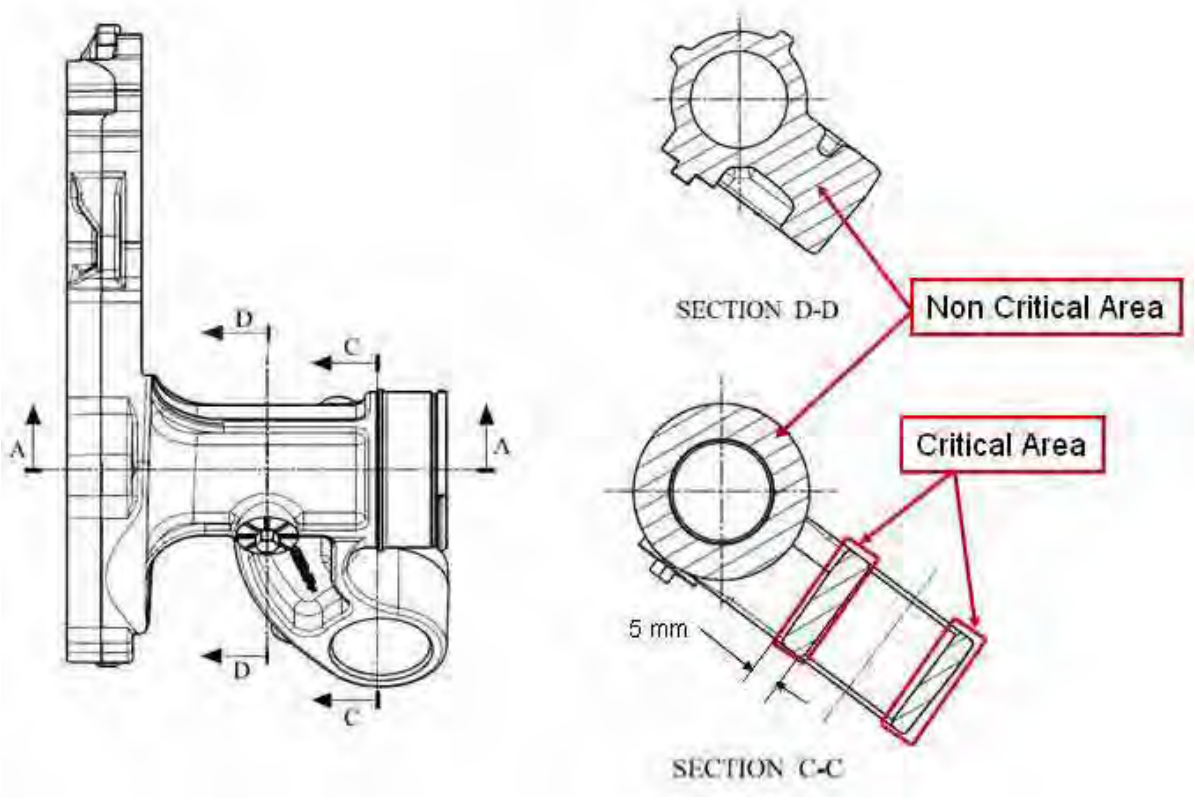


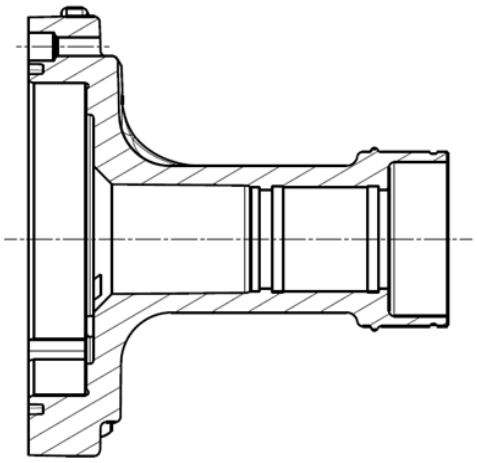
Non-Critical Area A-A: Degree of Porosity Level 4 or Level 6 per Table 4.

Critical Area C-C is highlighted in red[6]: Degree of Porosity Level 3 per Table 4.

Non-Critical Area D-D: Degree of Porosity Level 4 or level 6 per Table 4.

Non-Critical Area C-C: Degree of Porosity Level 4 or Level 6 per Table 4.

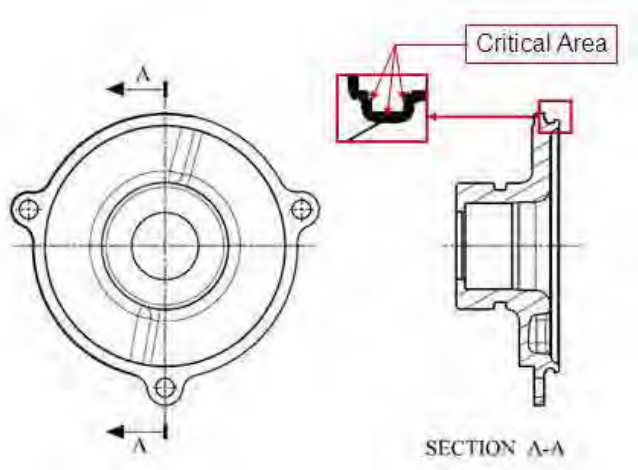




SECTION A-A

15.5.6 Sensor cover (Example)

Non-Critical Area A-A: Degree of Porosity Level 4 per Table 4



15.5.7 EPP housing (Example)

Sealing Surfaces as shown in red[6]: Degree of Porosity per section 16.6.8

Section Area A-A: Degree of Porosity Level 3 per Table 4.

Critical Area 1 in section K-K as shown in red[6]: Degree of Porosity per section 16.6.9 at each threaded locations.

Critical Area 2 in section K-K as shown in red[6]: Degree of Porosity per section 16.6.9

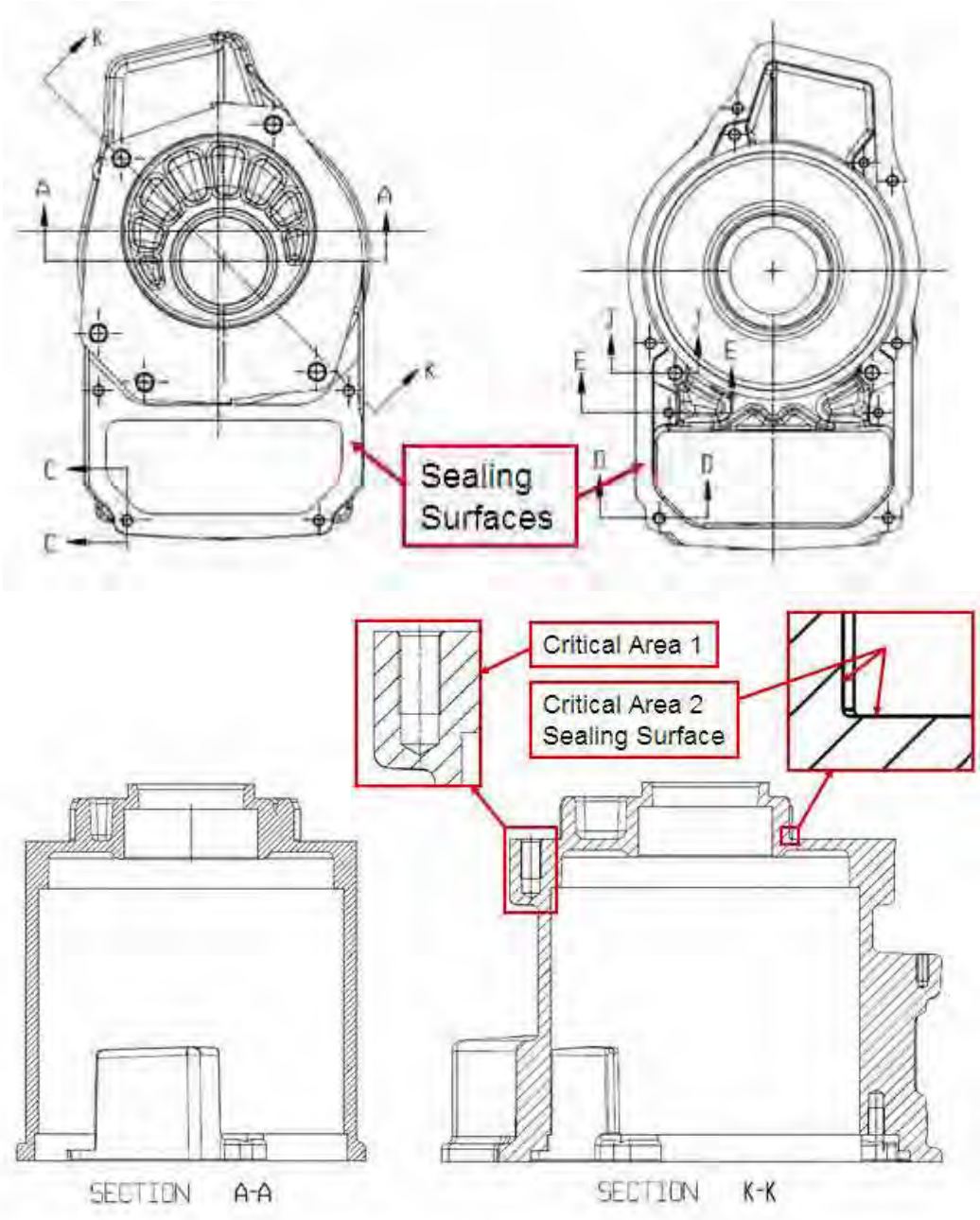
Section Area K-K: Degree of Porosity Level 4 per Table 4.

Section Area C-C: Degree of Porosity Level 3 per Table 4 at each threaded locations.

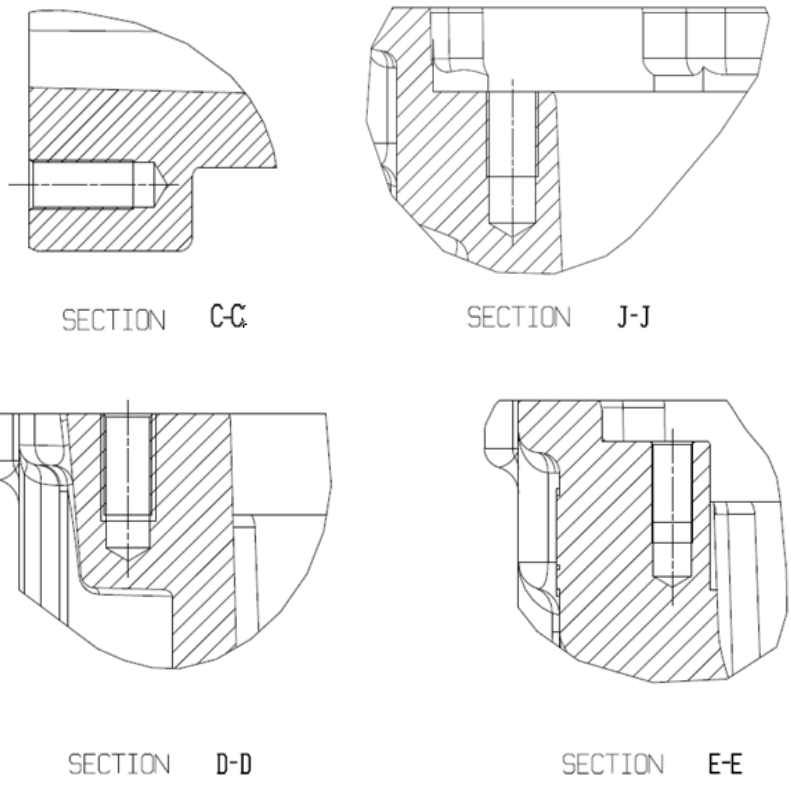
Section Area D-D: Degree of Porosity Level 3 per Table 4 at each threaded locations.

Section Area J-J: Degree of Porosity Level 4 per Table 4.

Section Area E-E: Degree of Porosity Level 4 per Table 4.



Released by:	TRW Automotive GmbH, Tech Center Düsseldorf
Leader of the Working Committee:	EC-Number



15.5.8 Visual porosity on sealing surface for EPP (Example)

(1) Porosity allowed within Zone 1 (Area within Ø 5.5mm and Axis of Ø 2.75mm hole)
- Within 120° shaded zone – up to 2 pores with maximum Ø 0.5mm porosity allowed. No neighboring pores within 300% of the longest measured pore dimension in any aspect.
- Around remainder of hole, up to 2 pores with maximum Ø 1.0mm porosity allowed. No neighboring pores within 300% of the longest measured pore dimension in any aspect.

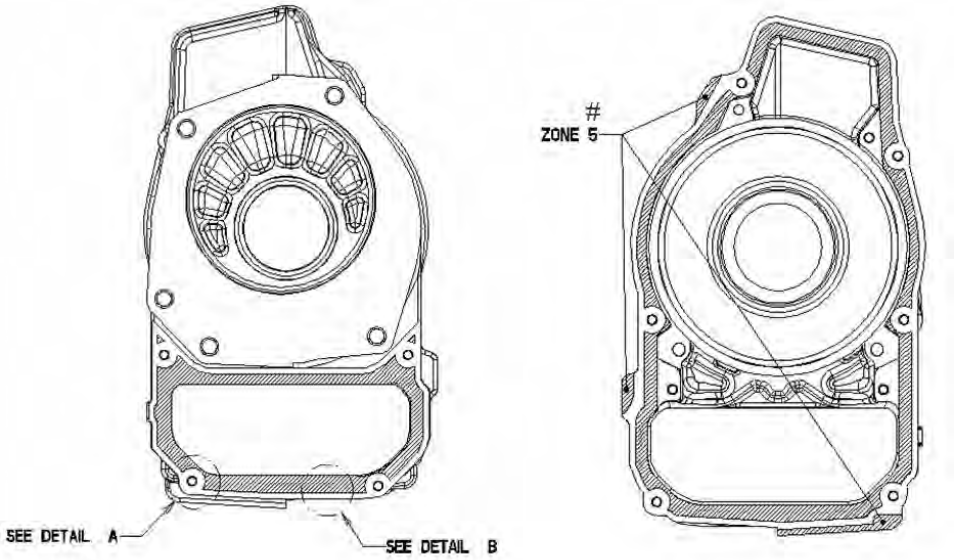
(2) Porosity allowed within Zone 2 (Area within Ø 5.5mm and Ø 9.0mm and Axis of Ø 2.75mm hole)
- Within 120° shaded zone – up to 2 pores with maximum Ø 1.0mm porosity allowed. No neighboring pores within 300% of the longest measured pore dimension in any aspect.
- Around remainder of hole, up to 2 pores with maximum Ø 1.0mm porosity allowed. No neighboring pores within 300% of the longest measured pore dimension in any aspect.

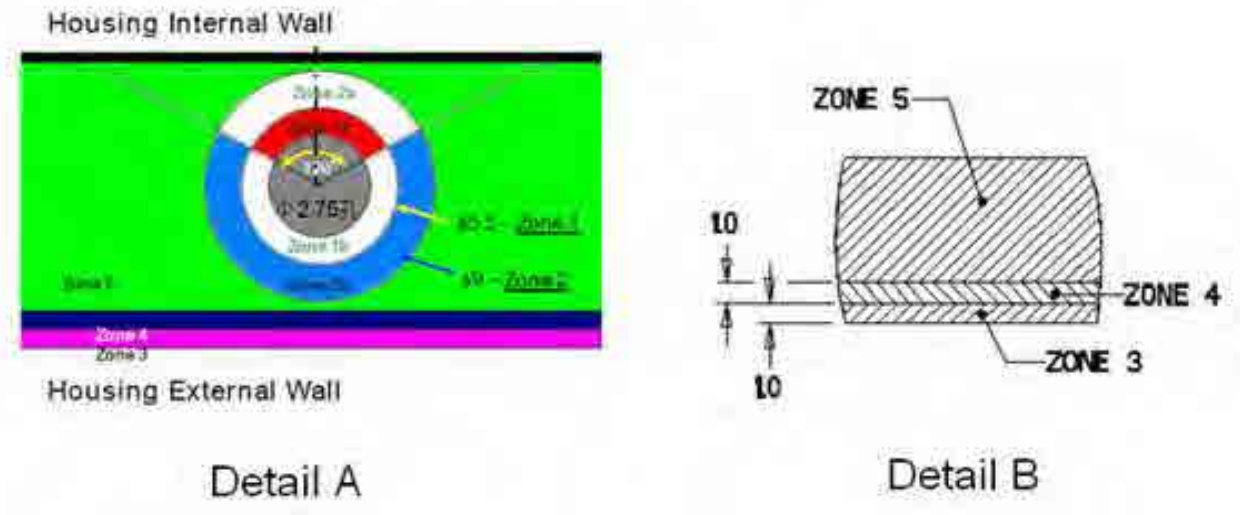
(3) Visible porosity allowed up to maximum Ø 1.0mm within 1mm from external wall of housing, assuming no more than 5 instances of porosity within any 20mm length and no neighboring pores within 300% of the longest measured pore dimension in any aspect. – Zone 3

(4) “Table 4 Level 4” porosity allowed between 1mm and 2mm of external wall of housing (excluding around holes which are defined in 16.6.8 (1) and 16.6.8 (2)) - Zone 4.

(5) Maximum allowable pore size in zone 5 are as follows:

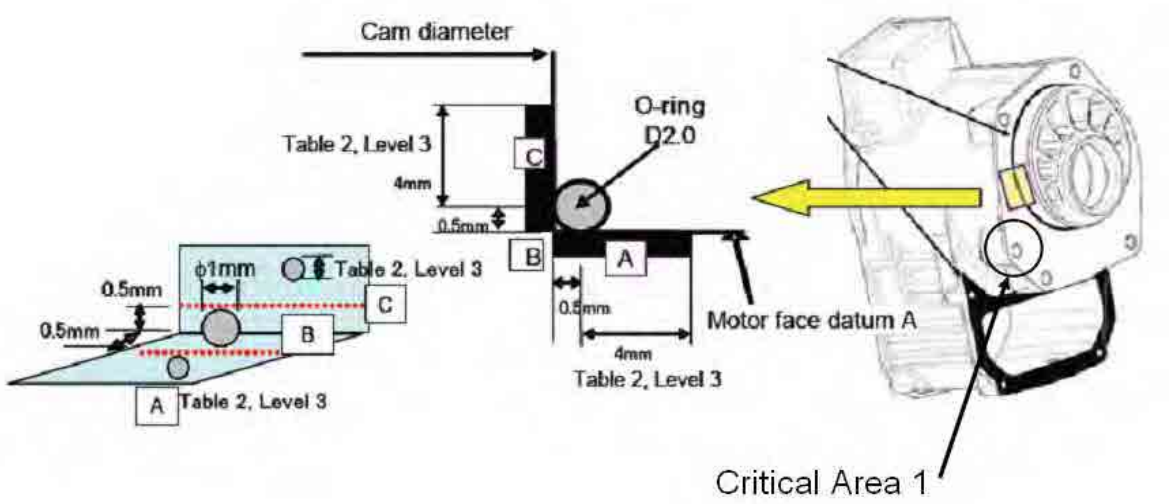
- 2.0mm long (parallel to housing wall), by 1.0mm wide (perpendicular to the housing wall), by 0.5mm deep.
- No neighboring pores within 150% of the longest measured pore dimension in any aspect.
- Ratio of visibly solid material to exposed porosity shall not exceed 10:1 by area along any 20mm length of sealing surface around the total perimeter of both cover and connector sealing surfaces. Total allowable porosity shall not exceed 20:1 over the total, defined sealing area.



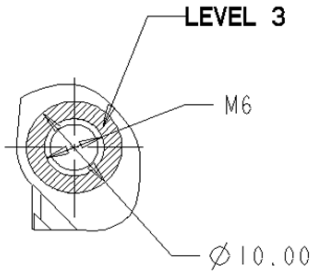


15.5.9 Porosity standard for EPP on motor face datum A & cam seal surface datum C (Example)

(1) Up-to Ø2.0mm (along circumference) x Ø 0.5mm wide, porosity allowed within zone B (sharing surface of 0.5mm from both area of motor face datum A and cam seal surface datum C). No neighboring pores within 150% of the longest measured pore dimension in any aspect.
(2) "Table 4 – Level 4" porosity allowed within zone A and zone C above (4mm from zone B).
(3) "Table 4 – Level 5" porosity allowed outside of both zone A and zone C (excluding around M6 holes).
(4) "Table 4 – Level 4" porosity allowed within Ø10mm from axes of M6 holes.



Critical Area 2 per Sec K-K



Critical Area 1 per Sec K-K

15.6 X-Ray test frequency recommendation

100 % examination at the beginning (e.g. 5000 parts) has to be conducted by supplier or as agreed with TRW product engineer, product quality.

The 100 % examination can be changed to random test (e.g. 5-6 % per shift) if process capability is assured by foundry. A correlation between x-ray and sectioning should be available before random test can be agreed

A sample from current production can be picked as a master for minimum quality requirement as agreed with TRW product engineer, product quality.

The change to the random test has to be agreed by TRW quality and OEM. In this case a detailed control plan for random testing is to be submitted to TRW quality and OEM for approval. This control plan shall also describe the test frequency (until 100 % checking) if process errors or n.o.k. parts occur.

Process errors defined as following:

- Set-up and maintenance times (mold and process devices) if process interruptions occur.
- Other process interruptions which cause process parameter errors (Mold temperature, process time, form matching velocity).

15.7 Port Torque to Failure recommendation (Example only HPS, EPHS)

It is recommended to conduct this test with 30 pieces for each thread. Fittings (e.g. 50 pieces of each fitting) have to be provided to the foundry for testing.

15.8 Prototype Control Plan (example)

Control Report for Dimensions, Appearence and Performance

Project: Control Plan Template PDC Housing

Tech Center Düsseldorf — Date: **01.06.2008** — **For Customer Delivery**

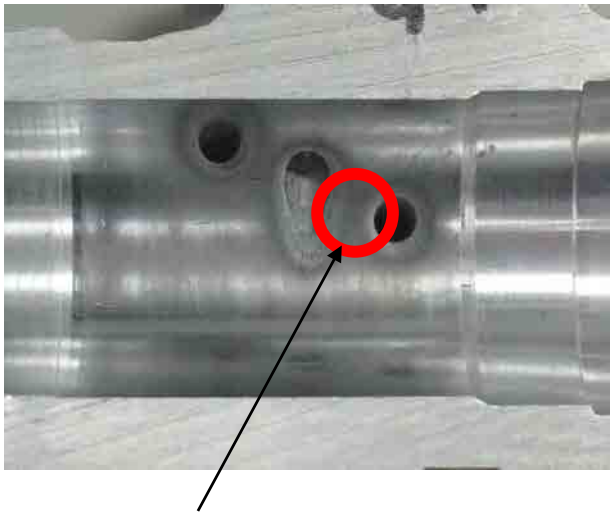
Valve-No.: Ventilnummer:

Drawing No.: A00XXXXX

Location	Sheet	#	Item	KPC	Specified	Actual	OK / NOK	Signature / Department
Drawing No & Issue level *Zeichnungsnummer & Änderungsindex*	A0008947 K	1	1	visual		According to drawing			Housing supplier
Material *Material*	WERKSTOFF: EN 1706 AC-AlSi9Cu3 (Fe)	1	1	Material anaysis	C	According Spec. S0000740 on casting drawing A00xxxxx			Housing supplier
Housing quality *Gehäusequalität*		2	2,1	Porosity requirement	C S	According Spec. S0000740 on casting drawing A00xxxxx			Housing supplier
	DEFINED AREA FOR LEAKAGE TEST 100% LEAKAGE TEST REQUIRED ACC. TO SPEC. S000206		2,2	Leackage test	C	According Spec. S0000740 on machining drawing A00xxxxx			Housing supplier
	IMPREGNATION SEE WERKSTOFF		2,3	Vaccum impregnation		According Spec. S0000740 on machining drawing A00xxxxx			Housing supplier

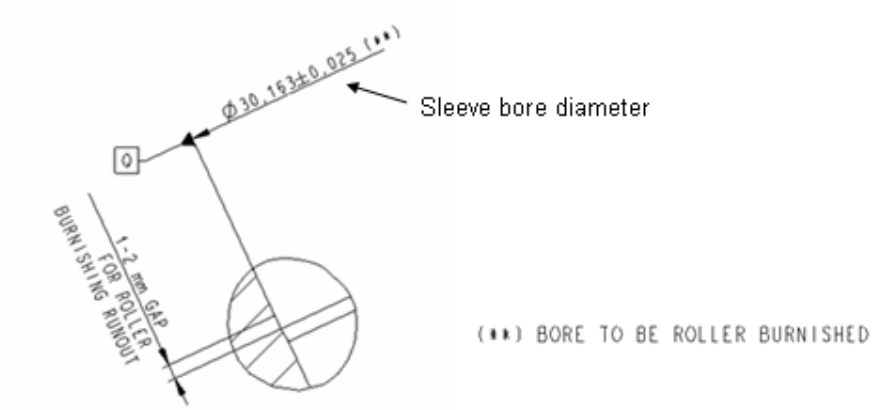
In alternative to the prototype inspection plan it can be agreed to check 3 parts according to the drawing (100 %). In this case the detailed measurement report must be provided to the prototype shop. This procedure has to be inquired by prototype shop and considered in the offer by supplier.

15.9 ECM Deburring Process (example)



Higher roughness due to small bore distance.

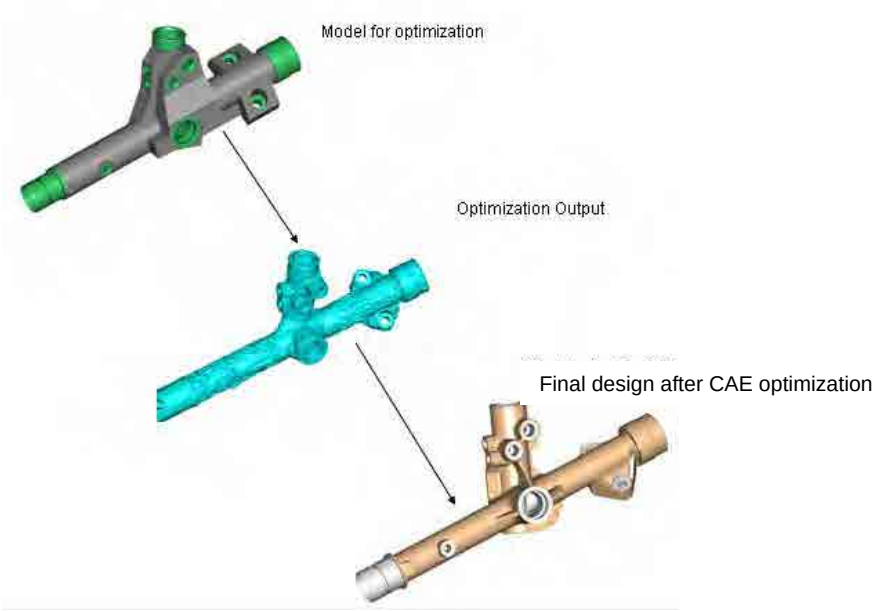
15.9.1 Deburring Drawing recommendation only HPS, EPHS)



15.10 CAE optimization (example)

In the planning phase, a fundamental structure of the object can be found using topology optimization. Starting from known loads and boundary conditions and the maximum design space available, a design concept can be found which is as light as possible while meeting all requirements. Areas that are not needed are removed from the given design space. The new structure shows an indication of the optimal energy flow. The result of the topology optimization serves as a design draft for the creation of a new FE model for the subsequent simulation calculation and shape optimization. This method provides the designer and the development engineer, even in the early planning stage, with a tool capable of creating a weight-optimized design proposal for a given space.

It is recommended to consider a CAE Optimization previously to obtain an optimized part to fulfill all functional, process and financial requirements.



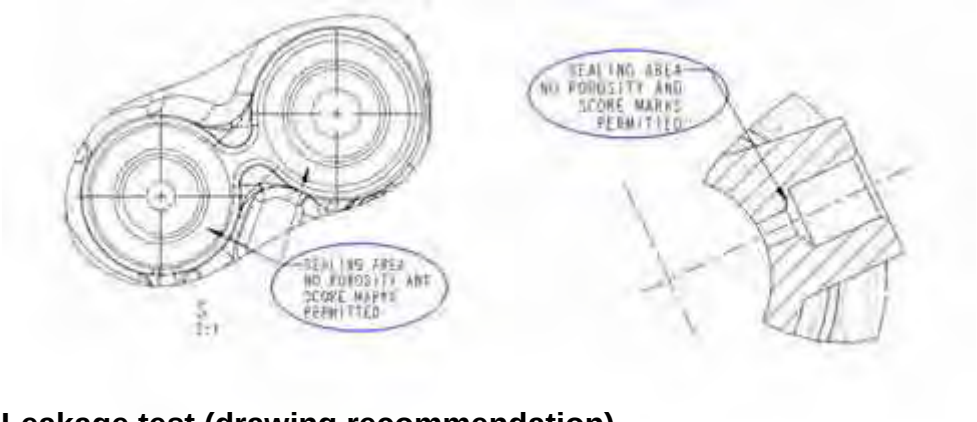
15.11 CAE simulation test (Example)

FE simulations which are currently conducted at TRW:

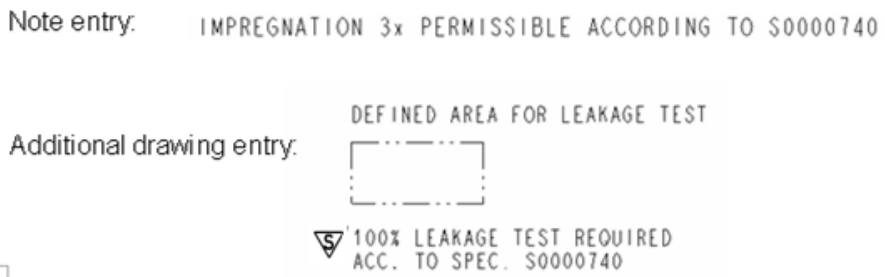
(1) TRW 62 052 001 Burst pressure test (min. customer requirement, e.g. 300 bar)
(2) TRW 62 052 003 Max. Rack load
(3) TRW 62 052 002 Torque to failure (depends on customer requirement, e.g. 300 Nm)
(4) Bolt pretension load – solid foot mount

Requirements to be defined by Product engineering and OEM

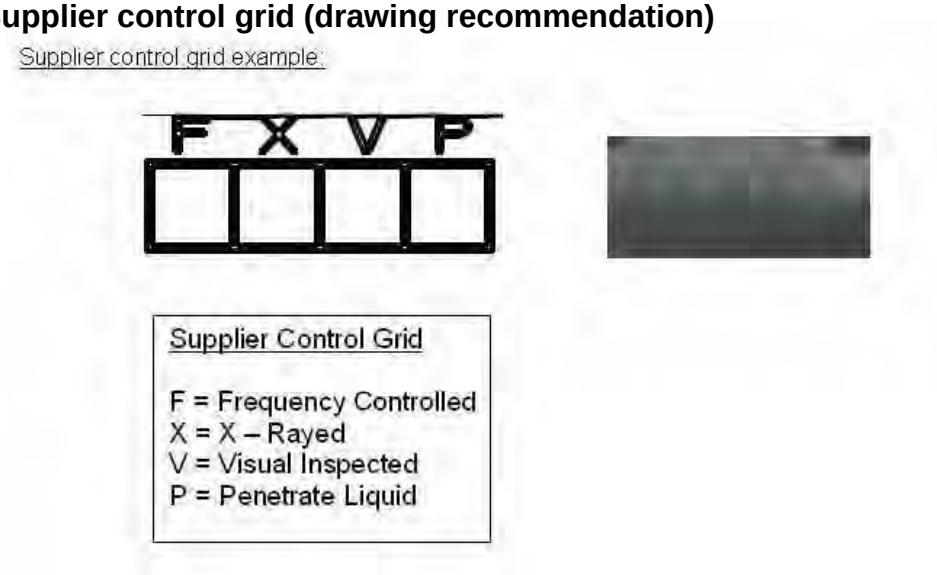
15.12 Sealing area (Drawing recommendation)



15.13 Leakage test (drawing recommendation)



15.14 Supplier control grid (drawing recommendation)



15.15 Anodization (Drawing recommendation)

Drawing entry:

Anodization according to TRW 62005004 / S0000089
Oxide layer thickness: minimum XX µm

15.16 Documentation (Optional Customer Requirement)

The general the documentation has to be prepared according to VDA 1.
The documentation for production release respectively PPAP should consider the following additional information and to be distributed to TRW quality and TRW product engineering:

(1) Material analysis
(2) Process flow chart
(3) Prototype inspection plan (for prototypes only)
(4) Flow simulation
(5) X-ray pictures from the defined views which shall be considered as masters during production examination.
(6) Material section cut report. This report includes material sectioning pictures with detailed porosity calculation (according to VDG P201).
(7) Process parameter overview. Those parameters should describe the final production release status. It can be necessary to adjust the process parameter during production.
In this case TRW quality has to be informed about parameter change. Parameter values have to be documented and provided to TRW quality. If optimization steps (tooling, parameter, design) are necessary during production it is proposed to implement changes step by step to evaluate the influence off each factor. Trials must be documented by foundry and should be provided to TRW quality.
(8) Mold drawing respectively Mold concept where Gating system, venting system, cooling system etc. is described.
(9) Emergency plan which describes the foundry strategy if non-planned situation will occur (e.g. short time capacity increase, maintenance, press breakdown, environmental conditions etc.).
(10) Ports Torque to Failure Test results (if required)

15.17 Applicable Specifications

DIN EN 462 – 1	Non destructive testing – Image quality of radiographics
DIN EN 1706	Material specification for Aluminum and Aluminum Alloy
DIN EN 10204	Metallic products – Types of inspection documents
DIN EN ISO 2360	Non-conductive coatings on non-magnetic basis metals – Measurement of coating thickness – Eddy current method
TRW EN 8800	Quality Guideline for Aluminum cast housing
TRW 31831112	Porosity specification (die casting)
TRW 81000106	Aluminum alloy casting porosity specification
TRW S0000059 / 62060001	Key Characteristic
IS0 100049	Aluminum alloy castings – Visual method for assessing the porosity
TMSA10307	Pinion valve housing –Casting
TS2-17-006	Global high pressure die cast Aluminum housing for hydraulic, manual & electrically assisted steering systems (Global material specification).

16 Change Control

Index	Release Date	Author	Comment
1	27.04.2011		Creation of the new specification.
2			
3			