



THE EUROPEAN FOUNDRY ASSOCIATION  
STEEL CASTINGS GROUP



**GUIDE TO QUALITY AND INSPECTION REQUIREMENTS  
FOR STEEL CASTINGS**

## FOREWORD

This guide is issued by the Steel Castings Group of the CAEF for the attention of all steel founders, their customers and potential customers.

Steel Castings are quality products which often present attractive and economic solutions to many technical problems.

Its aim is, by way of example, to lead the founder and the purchaser, both of whom operate in international markets, to **THE QUALITY SOLUTION** needed by the customer without neglecting cost and benefit considerations (\*). This collaboration is very useful: Obviously, casting is the shortest way from raw material to the finished product (\*\*).

It would be negligible not to point out the importance of costs in this context. It is the proper concern of any manufacturer who is aware of his responsibility for his products and who wishes to sustain long-term customer relations, to ensure that quality aspects regarding costs are properly taken into account.

It would be desirable that purchasing agents, aware of the importance of a good and stable relationship between supplier and customer, were of the same mind in this matter.

CAEF Steel Castings Group

*E. Buttkus*

CHAIRMAN

(\*ISO 9004 "Quality management and quality system elements - Guidelines" (idem DIN - AFNOR - BS -...)

(\*\*)Steel foundry Costing - Appendix II (1978) + Extension (1980)

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# **GUIDE TO QUALITY AND INSPECTION COSTS FOR STEEL CASTINGS**

## **1. INTRODUCTION AND SCOPE**

Quality is "The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs"<sup>1</sup> To attain this quality, various elements of manufacturing, process control, inspection and general administration and eventually R and D have to be taken into account, with corresponding costs.

This guide aims to:

- point out that there are numerous process and inspection costs associated with quality in general
- illustrate by examples how these costs may be analyzed stage by stage
- gain transparency in quality costs, identify cost reduction potentials and achieve comparability of offers.

Especially the last stated point concerns the basic question this guide wishes to address. It occurs when casting prices from competitive steel foundries are compared, but the casting specifications are not treated in the same fashion by the competitors. Some requirements may be included in the basic price of one foundry A, whereas foundry B has omitted them altogether in order to present a more attractive quotation.

The Guide is structured as follows:

1. Introduction
2. Definition of quality costs
3. Determination of specific order-linked quality costs
  - a) Working Book
  - b) References to standards
  - c) Check-list
4. Practical examples of check-list
5. Quality cost calculations

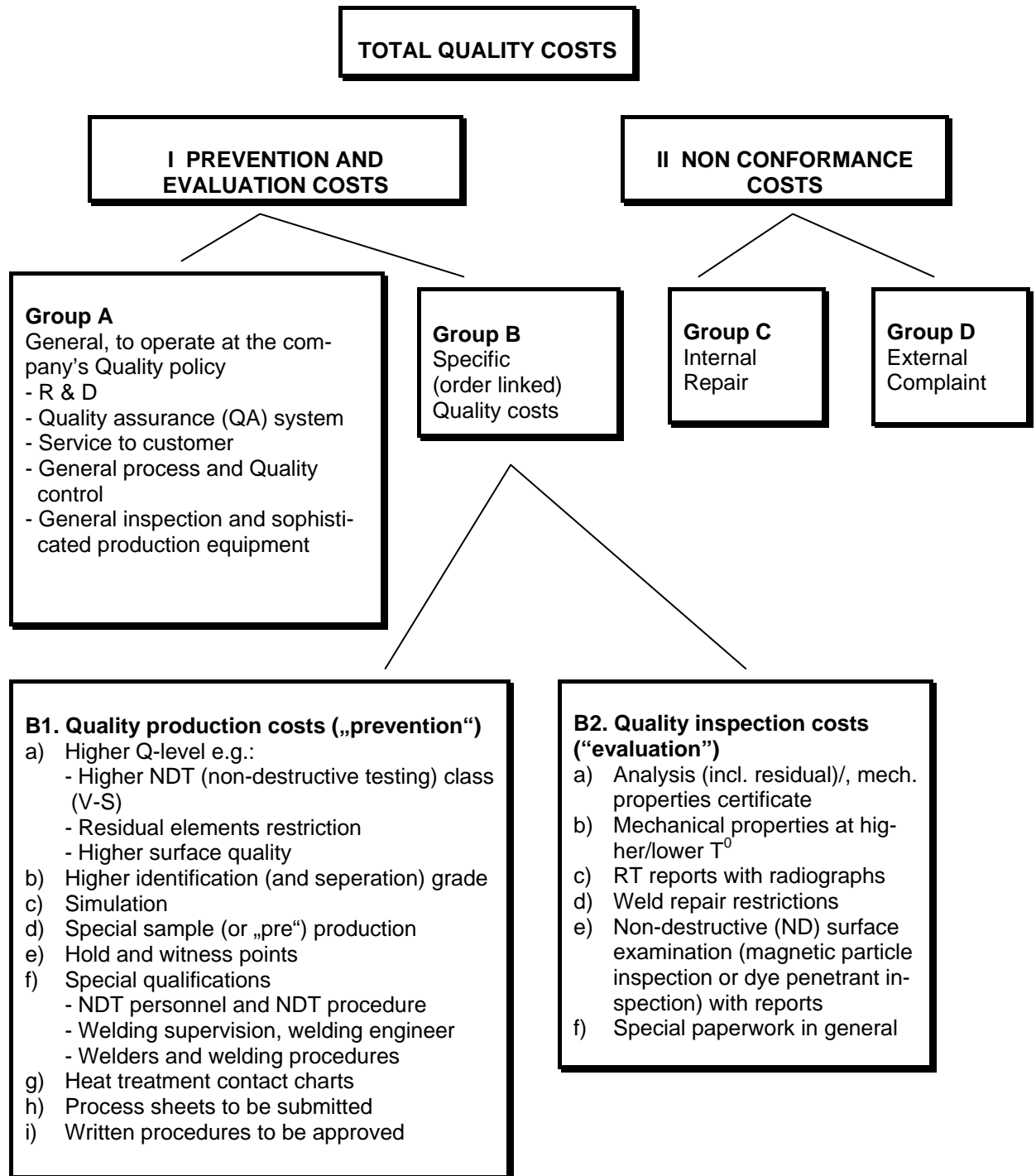
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<sup>1</sup> ISO 8402-1994

## 2. DEFINITION OF QUALITY COSTS

The table below (Table 1) which is divided into (I) Prevention and Evaluation costs and (II) Non Conformance costs, gives a schematic division of what may be understood by total quality costs (the vocabulary may change in the various referred sources).

**TABLE 1**



This guide is only concerned in dealing with - as presented on the left - Prevention and Evaluation Quality Costs (section I).

Prevention and Evaluation Costs may be divided into "General Quality Costs" and "Specific or Order Linked Quality Costs":

- "General Quality Costs" - Group A: These are all costs that a company expends in personnel and equipment to operate on the Quality level defined in the company's Quality Policy.
- "Specific or Order Linked Quality costs" - Group B: These are necessary to meet the customer's specific needs.

The last stated Specific or Order Linked Quality costs are the main subject of this guide.

Specific quality costs may be divided into Quality as applied to production costs centres (B 1) (these are "preventive costs", e.g. more sophisticated work preparation) and Quality of the "Inspection" or "Evaluation" type (B 2), more commonly referred to as "Quality control costs".

### **3. DETERMINATION OF SPECIFIC ORDER LINKED QUALITY COSTS**

#### **a) Working Book**

As a general rule, foundry technicians, who work daily with specifications and standards, maintain that there should be no doubt as to specific quality levels concerning prevention and evaluation, if both parties refer to a clearly defined material specification and/or standard of supply which is understood and agreed upon by both parties to apply to the product being tendered for. Therefore, it is useful to state here that any discussion concerning "Quality Costs" is facilitated considerably, if there exists a complete and coherent working book.

A complete working book in the case of a steel casting should include:

- A drawing of the as-cast casting and a drawing of the machined casting (failing a machined casting drawing, clear indications need to be given as to machining on the as-cast drawing).
- A material specification identified and applicable to a steel casting (either an European or an international standard or a specification agreed by both parties).
- If this is not indicated in the two above stated documents (nor in the related applicable documents) a specification as to the surface stated and the properties required of the casting.
- If necessary, the details of the application to which the casting is to be put and any necessary standards required by that industry.

The reader is advised that cases are excluded from consideration where the manufacturer tenders, directly and generally, for a casting to solve a particular problem set by the user, who does not refer to a precise material specification. In such a case, the manufacturer sets the specification since he carries the responsibility that his product will solve the problem set. His price, however, will reflect the cost of the quality he judges necessary.

## b) References to standards

The notions of "standard level" or "commercial quality " are very useful in a given context (and when they are closely defined) but they lose all reference outside such context.

Reference to a material specification by way of a standard is advised, since most actual standards supply very clear material specifications which meet most circumstances facing foundrymen and their customers.

However, it is of prime importance to verify the standard is referred to correctly without confusing the general number of the standard and the steel grade mentioned and without forgetting to specify exactly the correct option which the standard leaves to the user's discretion.

### A CLEAR SPECIFICATION

<b>DON'T SPECIFY ...</b>	<b>BUT</b>
"18-8 with Mo" "316"	CF-8M acc. to ASTM A 743 or A 744 or A 351 or 1.4408 to DIN EN 10283, etc. ...
X5 CrNiMo 18-10	GX5CrNiMo 19-11-2 acc. to DIN EN 10283 or DIN EN 10213 <sup>2</sup>
1.4569 acc. to DIN	1.4569 acc. to SEW 410
"C Steel 1 "	WCB acc. to ASTM A 216 (or ASTM A 216 Grade WCB)
42 CrMo 4	42CrMo 4 acc. to DIN EN 10293 <sup>3</sup> (+ Festigkeitsstufe) 42 CD4 - M I (or II) acc. to NF A 32-058
GS – 38	GE200 (or GS200) acc. to DIN EN 10293

<sup>2</sup> Replacement for DIN EN 10213-4.

<sup>3</sup> Replacement for DIN 17205, that is presently still valid.

A clear specification given at the moment of the first meeting, when everyone still believes that there is sufficient time to complete the potential order, saves time discussing details later on. Failure to agree upon a specification at the outset often leads to poor quality, failure to deliver on time and problems in performing to a "just in time" expectation.

### **c) Check-List**

In spite of reference to per se clear instructions, it does occur that partners are not sufficiently aware of consequences regarding the agreed upon QS input.

In order to avoid any misinterpretation, the CAEF "Steel Castings Group" suggests to use a check-list in addition to following the above stated advice regarding specifications; this check-list automatically shows the wishes of the parties (Foundryman and Customer). This enables the customer to indicate exactly what he wants and the foundryman will show how he answers his customer, which (quality) costs are included in his base price and what (quality) costs are charged as extras.

The following check-list specifies the main characteristics of a steel casting. Obviously, in particular circumstances the parties concerned may also specify additional requirements.

This check-list is not a specification. It does not invite to perform further tests, etc. ... The only aim of the check-list is to help the parties involved to define their points of view and come to an agreement.

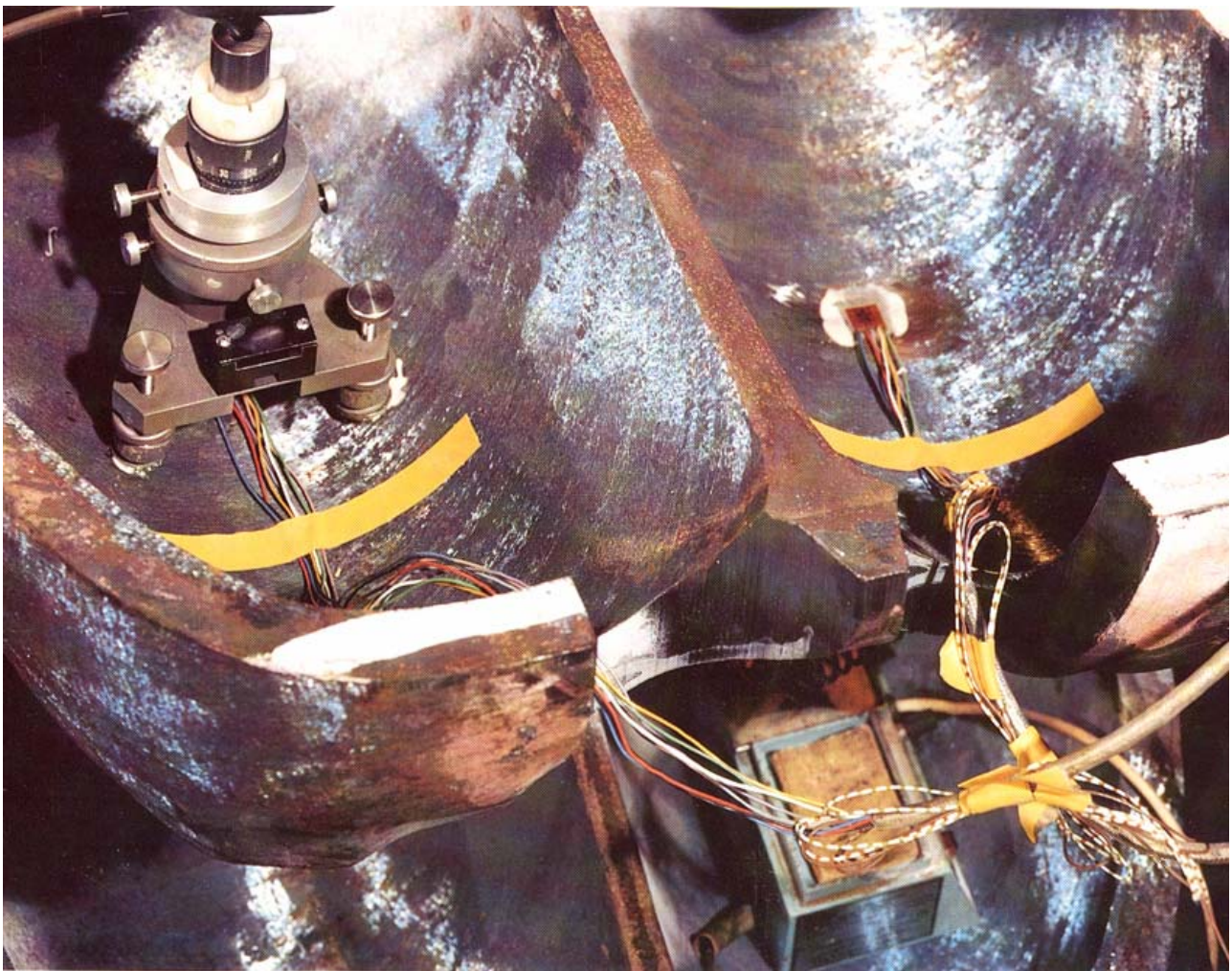


## Check-List

It is always possible to mark several lines, even if the subject is already covered by previous lines. Only enumerated lines with figures against a grey background are either/or situations. They are paired-off to indicate that one box only, per pair, should be ticked.

While preparing the check-list, the parties may quote the inspection conditions (internal specifications or customer's or authorized agency's specifications).

The user may discover areas where questions exist as to what is meant exactly by the specification. In every case, it is essential that these questions are answered, so that the quoting foundry can ascertain whether or not the matter is covered in its normal level of supply.



**Measurement of residual stress**



		Customer Specification	Founder's Offer	
			Base price incl.	Supp.
<b>(A)</b>	<b>QUALITY ASSURANCE REQUIREMENTS</b>			
1)	Manufacturing procedure required by specification			
2)	Hold points <sup>4</sup> on manufacturing procedure			
3)	Inspection plan required by specification			
4)	Customer approval required of manufacturing procedure and / or inspection plan prior to commencement on each order			
5)	Written quality-assurance (QA) programme required acc. to .....			
6)	.....			

<b>(B)</b>	<b>METALLURGICAL AND MATERIAL DOCUMENTATION</b>			
	Standard specification: ..... Grade.....			
1)	Analysis / mechanical certificates			
2)	Analysis / mechanical certificates. Include hardness			
3)	Analysis / mechanical certificates. Include residuals			
4)	Specific certificate or report <sup>5</sup> acc. to .....			
5)	Heat treatment charts			
6)	Heat treatment contact charts			
7)	Heat treatment certification (statement of treatment carried out)			
8)	Special mechanical requirements – e.g. low T° test			
9)	Special testing requirements (e.g. grain size, ferrite content, etc.): .....			
10)	Witnessed mechanical tests. Also mark L.2.			
11)	.....			

<b>(C)</b>	<b>SIMULATION</b>			
1)	Solidification simulation			
2)	Further simulations (e.g. residual stress, structure, ...)			

<sup>4</sup> An event or stage of manufacture which actually stops the manufacturing sequence, i.e. manufacture cannot proceed until the point has been cleared.

<sup>5</sup> BS certificate of conformance or DIN EN 10204, Inspection certificate 3.1 B

		Customer Specification	Founder's Offer	
			Base price incl.	Supp.
<b>(D)</b>	<b>SAMPLES OR PREPRODUCTION<sup>6</sup></b>			
1)	Quantity (.... % or n = .....			
2)	Visual inspection			
3)	Magnetic particle inspection or Dye penetrant inspection			
4)	Ultrasonic inspection			
5)	Radiographic examination			
6)	Other, e.g. machining trials or sectioning or dimensional check			
7)	.....			
<b>(E)</b>	<b>VISUAL AND SURFACE INSPECTION</b>			
1) <sup>7</sup>	Visual inspection only – domestic standard			
2)	Visual inspection only – to nominated standard, e. g. SP 55 or DIN EN 12454			
3)	Surface inspection acc. to f.i. DIN 1370			
4)	Report <sup>8</sup>			
5)	.....			
<b>(F)</b>	<b>DIMENSIONAL INSPECTION</b>			
1)	Founder's normal commercial tolerances acc. to .....			
2)	Special cast tolerances acc. to .....			
3)	Dimensional report			
4)	Minimal wall thickness chart			
5)	.....			
<b>(G)</b>	<b>WELDING</b>			
1)	Defect sketch – all welded joints			
2)	Defect sketch – major welded joints only			
3)	Welding restrictions			

<sup>6</sup> For important pre-production requirements, a complete and separate check-list may be used as for a separate order.

<sup>7</sup> Please note: Figures in grey boxes represent either/or options, please tick only one box.

<sup>8</sup> May concern roughness, contamination, special protection checking, etc..

		Customer Specification	Founder's Offer	
			Base price incl.	Supp.
4)	Approval to weld by customer			
5)	Weld procedure			
6)	Weld procedure qualifications			
7)	Prior approval required of 5) or 6)			
8)	Welder qualification records			
9)	Non-destructive testing (NDT) of the welded areas			
10)	.....			

(H)	<b>MACHINING</b>			
1)	Proof machining required for non-destructive testing (NDT) or for.....			
2)	.....			

(I)	<b>MAGNETIC PARTICLE OR DYE PENETRANT INSPECTION , ACC. TO STANDARD</b> .....			
1)	Approved procedure required			
2)	Prior approval required for each order			
3) <sup>9</sup>	Magnetic particle inspection (MPI) – Wet method			
4)	Magnetic particle inspection (MPI) – Dry method			
5)	Dye penetrant inspection			
6)	Coverage of casting surface – 100% <sup>10</sup>			
7)	Coverage of casting surface – selected areas			
8)	Quantity inspected – 100 % of delivered quantity (batch size)			
9)	Quantity inspected .....% of delivered quantity (batch size)			
10)	Personnel qualification records			
11)	Reports			
12)	.....			

<sup>9</sup> Please note: Figures in grey boxes represent either/or options, please tick only one box.

<sup>10</sup> It is considered that 100% of the casting surface can be interpreted as "all accessible surfaces". Where butt weld ends only are required to be inspected to a particular standard then this is indicated as "selected areas".

		Customer Specification	Founder's Offer	
			Base price incl.	Supp.
<b>(J)</b>	<b>ULTRASONIC EXAMINATION ACC. TO STANDARD.....</b>			
1)	Approved procedure required			
2)	Prior approval required for each order			
3) <sup>11</sup>	Coverage of volume – 100%			
4)	Coverage of volume – selected areas			
5)	Quantity inspected – 100 % of delivered quantity (batch size)			
6)	Quantity inspected .....% of delivered quantity (batch size)			
7)	Personnel qualification records			
8)	Ultrasonic testing (UT) report/ Photos to customer			
9)	.....			

<b>(K)</b>	<b>RADIOGRAPHIC EXAMINATION ACC. TO STANDARD .....</b>			
1)	Approved procedure required			
2)	Prior approval required for each order			
3)	Shooting sketches			
4)	Coverage of casting volume – 100%			
5)	Coverage of casting volume – selected area			
6)	Quantity inspected – 100 % of delivered quantity (batch size)			
7)	Quantity inspected .....% of delivered quantity (batch size)			
8)	Personnel qualification records			
9)	Reports/ Radiographs to customer			
10)	.....			

<sup>11</sup> Please note: Figures in grey boxes represent either/or options, please tick only one box.

		Customer Specification	Founder's Offer	
			Base price incl.	Supp.
<b>(L)</b>	<b>WITNESS<sup>12</sup> POINTS</b>			
1)	Weld approval			
2)	Mechanical requirements			
3)	Magnetic particle inspection (MPI) / Dye penetrant inspection			
4)	Ultrasonic testing (UT) and/or radiographic examination			
5)	Dimensional inspection			
6)	Documentation			
7)	Final inspection			
8)	.....			
<b>(M)</b>	<b>SPECIAL MARKING OR IDENTIFICATION REQUIREMENTS</b>			
1)	.....			
2)	.....			
<b>(N)</b>	<b>SPECIAL NOTES</b>			
1)	.....			

<sup>12</sup> Witness points require the physical presence of the witness (the customer or his representative).

#### 4. PRACTICAL EXAMPLES OF CHECK-LIST

Two examples have been chosen to illustrate the use of the check-list. The examples are realistic, nevertheless not obligatory.

##### a) Example 1: Valve body

Typical shell moulded corrosion resistant valve bodies ordered to a demanding surface quality standard

##### MATERIAL SPECIFICATION for example 1

<b>0</b>	Parts: Valves
<b>1</b>	Material / Standard: ASTM A 744 (98) Grade CF-8M
<b>2</b>	Mechanical requirements:
<b>2.1</b>	$\left. \begin{array}{l} R_m : \text{min. 485 MPa} \\ R_{p0.2} : \text{min. 205 MPa} \\ A : \text{min. 30 \%} \end{array} \right\} \text{acc. to A 370}$
<b>2.2</b>	Brinell hardness : 130 - 200 HBN acc. to DIN EN ISO 6506-1
<b>3</b>	Resistance to intergranular attack acc. to A 262 Practice B
<b>4</b>	Non destructive testing (acceptance standard and operation practice)
<b>4.1</b>	V4 acc. to DIN 1690 part 2 on 10 % of the complete castings. Operation practice: DIN EN 462 <sup>13</sup> and DIN EN 444 <sup>14</sup>
<b>4.2</b>	S2 acc. to DIN 1690 part 2 on all the complete castings. Operation practice: SEP 1936 / DIN EN 571-1
<b>4.3</b>	Qualified operators and qualified methods are requested for § 4.1 and § 4.2
<b>5</b>	Surface : pickled and passivated
<b>6</b>	Identification : melt and serial numbers
<b>7</b>	Certification : certified material test report for the following items :
<b>7.1</b>	Chemical composition for each melt as required per A 744
<b>7.2</b>	Heat treatment (certification of compliance is sufficient)
<b>7.3</b>	Mechanical results for each melt
<b>7.4</b>	Intergranular corrosion test results for each melt
<b>7.5</b>	Tests reports for radiographic testing (films to be kept at disposal) and dye penetrant testing.
<b>8</b>	Hold points: At the final stage for § 4.2 (call Mr. X).

<sup>13</sup> Was DIN 54109.

<sup>14</sup> Was DIN 54111.



**CHECK-LIST FOR EXAMPLE 1**

		Founder's Offer		
		Customer Specification	Base price incl.	Supp.
<b>(A)</b>	<b>QUALITY ASSURANCE REQUIREMENTS</b>			
1)	Manufacturing procedure required by specification			
2)	Hold points on manufacturing procedure			
3)	Inspection plan required by specification			
4)	Customer approval required of manufacturing procedure and / or inspection plan prior to commencement on each order <sup>15</sup>	X	X	
5)	Written quality-assurance (QA) programme required acc. to .....			
6)	.....			
<b>(B)</b>	<b>METALLURGICAL AND MATERIAL DOCUMENTATION</b>			
	Standard specification: <u>A.744</u> Grade <u>CF-8M</u>			
1)	Analysis / mechanical certificates			
2)	Analysis / mechanical certificates. Include hardness <sup>16</sup>	X	X	X
3)	Analysis / mechanical certificates. Include residuals			
4)	Specific certificate or report acc. to .....			
5)	Heat treatment charts			
6)	Heat treatment contact charts			
7)	Heat treatment certification (statement of treatment carried out) <sup>17</sup>	X	X	
8)	Special mechanical requirements - e. g. low T° test			
9)	Special testing requirements <sup>18</sup> (e.g. grain size, ferrite content, etc): <u>ICC</u>		X	
10)	Witnessed mechanical tests. Also mark L.2.			
11)	.....			

<sup>15</sup> Paragraph 4.3 of the customer's specification requires that test methods are approved and personnel qualified. However, the specification omits to say how the customer will verify this. By marking the second column, the founder indicates that these matters are covered by his domestic system. Such a system forms part of his quality organisation and it is obvious that his base price will be affected by the cost of providing this service and thus higher than a foundry that does not apply such a quality system.

<sup>16</sup> As far as the collection and storage of the data required for the certificates is concerned, the foundry considers this to be regarded as being included in its base price. However, the preparation of certificates required by paragraphs 7.1 and 7.3 of the specification are considered supplements.

Another foundry however might include the cost of preparation for such certificates in its base price. It is one of the benefits of the check-list that such a distinction can be drawn and the matter is not overlooked. These statements apply in the same way to other points in the specification / check-list but will not be repeated in this text.

The specification does not contain any specific reference to the test coupon required for the sampling of the tensile test. This means separate keel blocks may be cast as this is permitted in the different ASTM standards associated with A 744.

<sup>17</sup> No price supplement is requested. If the customer required a copy of the temperature chart then this may be charged.

<sup>18</sup> This is a similar point to footnote 16 B2 and the same approach may be adopted. However, it is more common for supplementary charges to be levied for the test as specified in the ASTM standard.

CHECK-LIST FOR EXAMPLE 1 (cont.)

		Customer Specification	Founder's Offer	
			Base price incl.	Supp.
<b>(C)</b>	<b>SIMULATION</b>			
1)	Solidification Simulation			
2)	Further simulations (e.g. residual stress, structure, ...).....			
<b>(D)</b>	<b>SAMPLES OR PREPRODUCTION</b>			
1)	Quantity (.... % or n = ....)			
2)	Visual inspection			
3)	Magnetic particle inspection or Dye penetrant inspection			
4)	Ultrasonic inspection			
5)	Radiographic examination			
6)	Other, e.g. machining trials or sectioning or dimensional check			
7)	.....			
<b>(E)</b>	<b>VISUAL AND SURFACE INSPECTION</b>			
1) <sup>19</sup>	Visual inspection only – domestic standard <sup>20</sup>	X	X	
2)	Visual inspection only – to nominated standard, e. g. SP 55 or DIN EN 12454			
3)	Surface inspection acc. to f.i. DIN EN 1370			
4)	Report			
5)	.....			
<b>(F)</b>	<b>DIMENSIONAL INSPECTION</b>			
1)	Founder's normal commercial tolerances acc. to drawing xy <sup>21</sup>		X	
2)	Special cast tolerances acc. to .....			
3)	Dimensional report			
4)	Minimal wall thickness chart			
5)	.....			

<sup>19</sup> Please note: Figures in grey boxes represent either/or options, please tick only one box.

<sup>20</sup> The foundry considers that the pickling and passivation required are part of its basic service.

<sup>21</sup> The specification refers to a material specification without further qualification. Obviously other matters have to be taken into account e.g. those tolerances referred to on the drawing. By marking the base price column and referring to a specific tolerance standard, the foundry indicates that it is aware of this fact and that its normal procedure will cover the matter.

**CHECK-LIST FOR EXAMPLE 1 (cont.)**

		Customer Specification	Founder's Offer	
			Base price incl.	Supp.
<b>(G)</b>	<b>WELDING<sup>22</sup></b>			
1)	Defect sketch – all welded jointss			
2)	Defect sketch – major welded joints only			
3)	Welding restrictions			
4)	Approval to weld by customer			
5)	Weld procedure			
6)	Weld procedure qualifications			
7)	Prior approval required of 5) or 6)			
8)	Welder qualification records			
9)	Non-destructive testing (NDT) of the welded areas			
10)	<b><u>PWHT (post weld heat treatment)</u></b>	<b>X</b>	<b>X</b>	
<b>(H)</b>	<b>MACHINING</b>			
1)	Proof machining required for non-destructive testing (NDT) or for.....			
2)	.....			
<b>(I)</b>	<b>MAGNETIC PARTICLE OR DYE PENETRANT INSPECTION , ACC. TO STANDARD <u>DIN EN 1369 AND DIN EN 1371-1, DIN EN 1371-2</u></b>			
1)	Approved procedure required <sup>23</sup>			
2)	Prior approval required for each order			
3) <sup>24</sup>	Magnetic particle inspection - Wet method	<b>X</b>	<b>X</b>	
4	Magnetic particle inspection - Dry method			

<sup>22</sup> The customer's specification makes no mention of welding requirements. Therefore ASTM A 744 applies. The founder interprets this to mean that his base price will include post weld heat treatment of defects that cannot be considered minor. The customer might argue that he merely requires good castings and should not have to pay for repair work. However, whereas repairs are obviously a cost payable by the founder and have to be kept as low as possible, in order to be competitive the costs of re-treatment, even if they are charged for in the base price, cannot be ignored. In fact, it is possible to overlook such costs in estimating the price, as less demanding standards for the same alloy do exist (e.g. ASTM A 743).

<sup>23</sup> See footnote 15 regarding check-list position A 4

<sup>24</sup> Please note: Figures in grey boxes represent either/or options, please tick only one box.

CHECK-LIST FOR EXAMPLE 1 (cont.)

		Customer Specification	Founder's Offer	
			Base price incl.	Supp.
5)	Dye penetrant inspection <sup>25</sup>	X		X
6) <sup>26</sup>	Coverage of casting surface – 100%	X		X
7)	Coverage of casting surface – selected areas			
8)	Quantity inspected – 100 % of delivered quantity (batch size)	X		X
9)	Quantity inspected .....% of delivered quantity (batch size)			
10)	Personnel qualification records	X	X	
11)	Reports	X		X
12)	<b><u>Customer will be present</u></b>	X		X
(J)	<b>ULTRASONIC EXAMINATION ACC. TO STANDARD DIN EN 12680-1</b>			
1)	Approved procedure required			
2)	Prior approval required for each order			
3)	Coverage of volume – 100%			
4)	Coverage of volume – selected areas			
5)	Quantity inspected – 100 % of delivered quantity (batch size)			
6)	Quantity inspected .....% of delivered quantity (batch size)			
3)	Coverage of volume – 100%			
4)	Coverage of volume – selected areas			
5)	Quantity inspected – 100 % of delivered quantity (batch size)			
6)	Quantity inspected .....% of delivered quantity (batch size)			
7)	Personnel qualification records			
8)	Ultrasonic testing (UT) report/ Photos to customer			
9)	.....			

<sup>25</sup> It is helpful that the customer in this specification indicates an applicable test practice (SEP 1936) and acceptance criteria (EN 1360). This quality level is considered demanding. Consequently, the base price of the product will rise to take into account the additional production (prevention) costs and repair/upgrading (non conformance) costs. These costs are not specifically mentioned in the check-list, but in view of the requested surface quality level, it is important to cover this point. The founder considers the inspection and related reports as extras and charges them as supplements. It should be noted that if the customer had asked for this quality level without inspection reports, then the founder would have had to point out that the inspection would still have to be paid for, as it is essential to guaranteeing the required quality level.

<sup>26</sup> Please note: Figures in grey boxes represent either/or options, please tick only one box.

CHECK-LIST FOR EXAMPLE 1 (cont.)

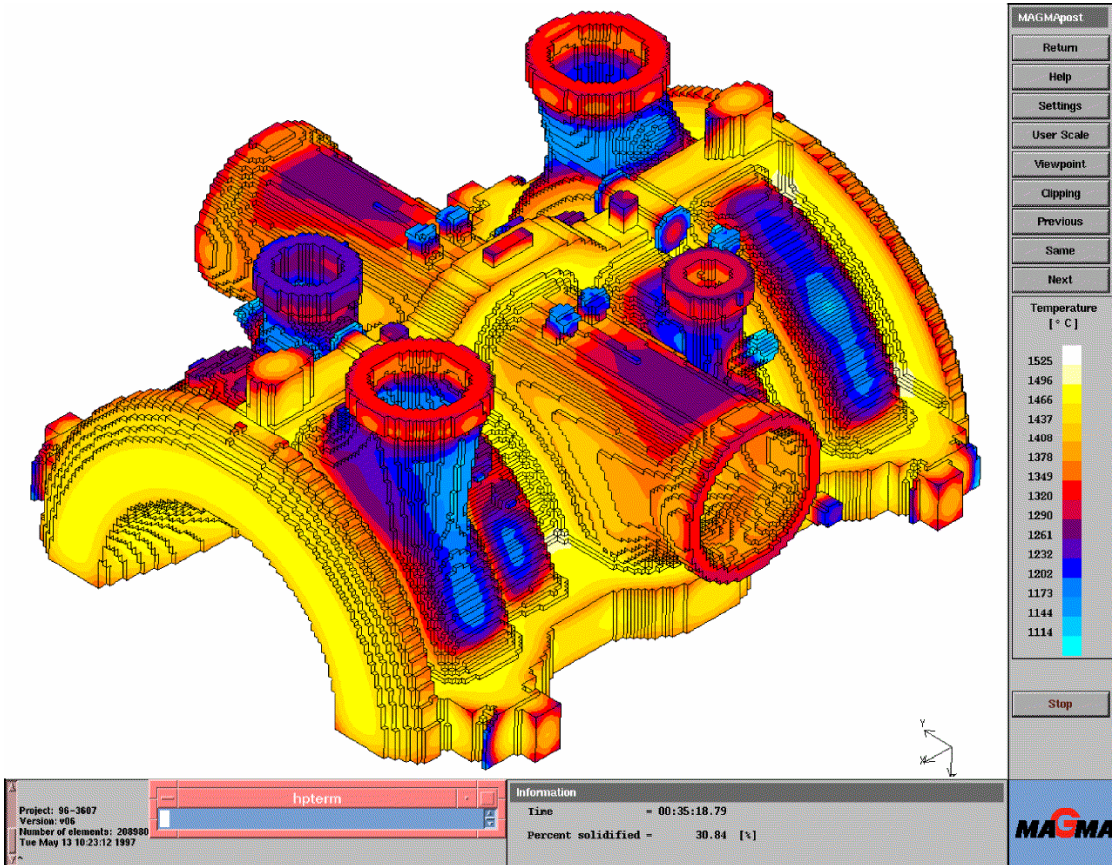
		Customer Specification	Founder's Offer	
			Base price incl.	Supp.
<b>(K)</b>	<b>RADIOGRAPHIC EXAMINATION ACC. TO STANDARD DIN EN 12681<sup>27</sup></b>			
1)	Approved procedure required <sup>28</sup>			
2)	Prior approval required for each order			
3)	Shooting sketches <u>with the reports</u>			
4) <sup>29</sup>	Coverage of casting volume – 100%	X	X	X
5)	Coverage of casting volume – selected area			
6)	Quantity inspected – 100 % of delivered quantity (batch size)			
7)	Quantity inspected <u>10.</u> % of delivered quantity (batch size)	X	X	X
8)	Personnel qualification records			
9)	Reports/ Radiographs to customer	X		X
10)	.....			
<b>(L)</b>	<b>WITNESS POINTS</b>			
1)	Weld approval			
2)	Mechanical requirements			
3)	Magnetic particle inspection / Dye penetrant inspection			
4)	Ultrasonic testing and/or radiographic examination			
5)	Dimensional inspection			
6)	Documentation			
7)	Final inspection			
8)	.....			
<b>(M)</b>	<b>SPECIAL MARKING OR IDENTIFICATION REQUIREMENT</b>			
1)	<u>Heat and serial numbers</u> <sup>30</sup>	X	X	X
2)	.....			
<b>(N)</b>	<b>SPECIAL NOTES</b>			
1)	<u>The report will be CMTR (Certified material test report) issued by the founder's quality department</u>	X		X

<sup>27</sup> By marking columns 2 and 3 of K 4 and K 7, the founder indicates that part of the inspection requirements is covered in the base price and customer is only charged for the reports and that element of the inspection that is additional to his standard practice e.g. 5%. On the other hand the base price will not increase for any production (prevention) costs nor repair (non conformance) costs since the specified quality level is not high and will not influence them.

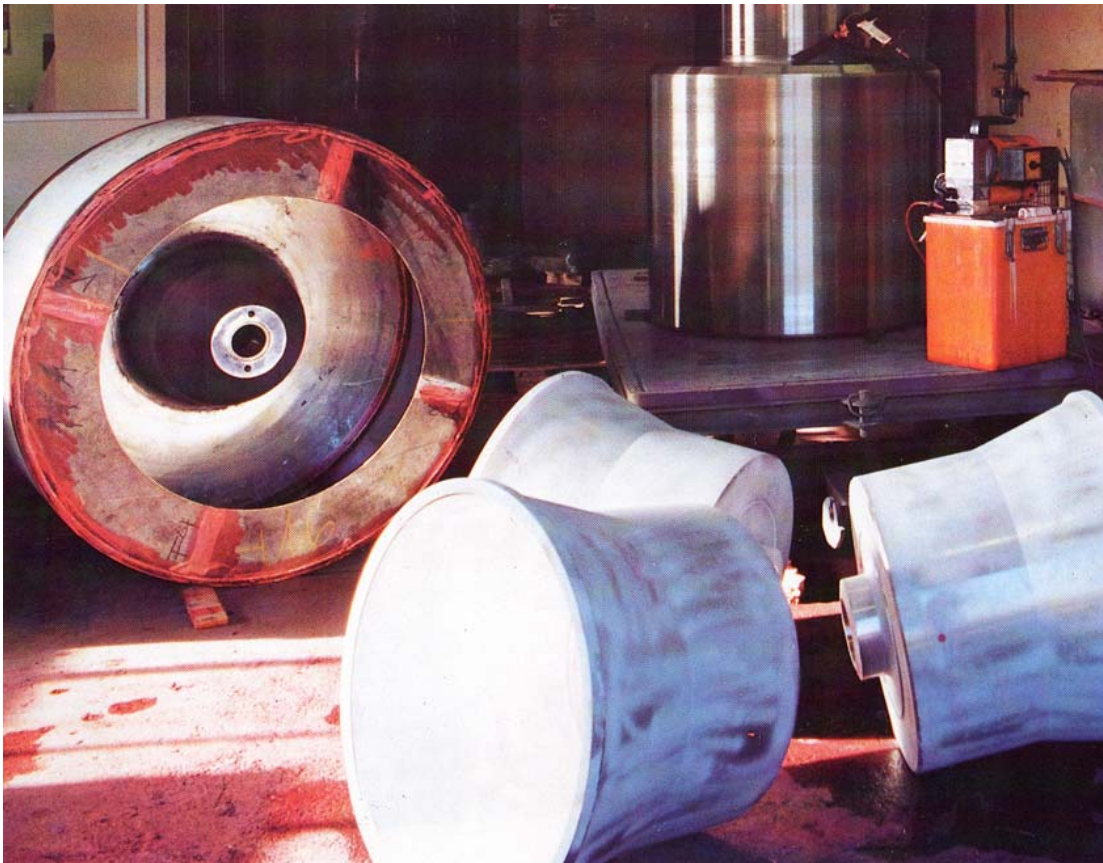
<sup>28</sup> See footnote 15 regarding check-list position A 4

<sup>29</sup> Please note: Figures in grey boxes represent either/or options, please tick only one box.

<sup>30</sup> The founder considers melt identification being standard practice that can be covered for in the base price. However, serial numbering castings is considered an extra. Other marks required and specified on the drawing are treated as being included in the base price.



Freezing simulation



Dye penetrant inspection



## b) Example 2: Casting Knot

Order of a casting knot

### MATERIAL SPECIFICATION for example 2

	Check List Reference
1. <b>Material:</b> G20Mn5 acc. to DIN EN 10293 quenched and tempered and stress relief annealed, pre-roughed as per drawing.....	B1, H1
2. <b>Test block:</b> Location to be approved by customer	A6
3. <b>Identification :</b> <ul style="list-style-type: none"> <li>- Producer mark</li> <li>- Material code</li> <li>- Melt number</li> <li>- External inspection mark</li> </ul> All marks are to be made on specified area as per drawing.	M1 M1 M1 M1 M1
4. <b>Welding:</b> Defect sketch for all welds necessary Prior customer approval for all welds Welding instructions and welders qualifications Full stress relieving after welding Hardness test of a welded area after stress relieving	G1 G4 G5, G6, G7, G8  B11
5. <b>Testing</b>	
	Reports acc. to DIN EN 10204: <sup>31</sup>
5.1 <b>Chemical analysis</b>	3.1.B
5.2 <b>Mechanical properties</b> acc. to DIN 17182 <sup>32</sup> <ul style="list-style-type: none"> <li>- <math>R_m \geq 510 - 610</math> Mpa</li> <li>- <math>R_{p0.2\%} \geq \text{min. } 315</math> Mpa</li> <li>- <math>A \geq \text{min. } 22\%</math></li> <li>- ISO V acc. to DIN 50115</li> </ul> at 20°C $\geq 40$ J. at -30°C $\geq 27$ J	3.2  3.2
5.3 <b>Heat treatment specification</b>	3.1.B
5.4 <b>Visual inspection</b>	3.1.B
5.5 <b>Non destructive testing (NDT)</b> <ul style="list-style-type: none"> <li>- Magnetic particle inspection (MPI) acc. to CCH 70-3, MT 70-3, classes acc. to drawing, 100% of the surface, every casting</li> <li>- MPI all excavations</li> <li>- Ultrasonic testing (UT) acc. to CCH 70-3, UT 70-3 classes acc. to drawing, 100% of the volume, every casting</li> <li>- RT acc. to CCH 70-3, RT 70-3 Verification of indistinct UT-signals</li> </ul>	3.2  3.2  3.2

<sup>31</sup> Certificate acc. to DIN EN 10204. Changes are to be expected with new version.

<sup>32</sup> Parameters acc. to DIN 17182 are to be applied until DIN EN 10293 is valid, parameters acc. to DIN EN 10293 are as follows:  
 $R_m \geq 480-620$  MPa,  $R_{p0.2\%} \geq 300$  MPa,  $A \geq 20\%$ , KV at 20°C (RT)  $\geq 40$  J., at -30°C  $\geq 27$  J.

## **Check-List for example 2**

This check-list is prepared from the point of view of a foundry that does not normally supply to this specific market. Therefore, the majority of marks is in the supplementary column as the quality required is higher than the normal standard of that foundry.

As can be seen from examining the specification, the relevant check-list reference numbers have been inserted in a column to the right. Most of the points in the specification translate easily without any confusion into specific headings in the check-list.

CHECK-LIST FOR EXAMPLE 2

		Founder's Offer		
		Customer Specification	Base price incl.	Supp..
<b>(A)</b>	<b>QUALITY ASSURANCE REQUIREMENTS</b>			
1)	Manufacturing procedure required by specification			
2)	Hold points on manufacturing procedure			
3)	Inspection plan required by specification			
4)	Customer approval required of manufacturing procedure and / or inspection plan prior to commencement on each order			
5)	Written quality-assurance (QA) programme required acc. to .....			
6)	<b><u>Approval to test block location</u></b>	X	X	
<b>(B)</b>	<b>METALLURGICAL AND MATERIAL DOCUMENTATION</b>			
	Standard specification: <b>DIN EN 10293</b> Grade: <b>G20 Mn5</b>			
1)	Analysis / mechanical certificates	X	X	
2)	Analysis / mechanical certificates. Include Hardness			
3)	Analysis / mechanical certificates. Include residuals			
4)	Specific certificate or report acc. to .....			
5)	Heat treatment charts			
6)	Heat treatment contact charts			
7)	Heat treatment certification (statement of treatment carried out)	X		X
8)	Special mechanical requirements – e. g. low T° test	X		X
9)	Special testing requirements (e.g. grain size, ferrite content, etc.): .....			
10)	Witnessed mechanical tests. Also mark L.2.	X		X
11)	<b><u>Hardness test of heat affected zone (HAZ)</u></b> <sup>33</sup>	X		X
<b>(C)</b>	<b>SIMULATION</b>			
1)	Solidification Simulation			
2)	Further simulations (e.g. residual stress, structure, ...).....			
<b>(D)</b>	<b>SAMPLES OR PREPRODUCTION</b>			
1)	Quantity (.... % or n = ....)			
2)	Visual inspection			
3)	Magnetic particle inspection or Dye penetrant inspection			
4)	Ultrasonic inspection			

<sup>33</sup> There is some room for doubt in this specification since no definitive testing method is named (e.g. Vickers). This needs to be clarified so that the foundry knows exactly what to do and can evaluate the extra charge accurately.

**CHECK-LIST FOR EXAMPLE 2 (cont.)**

		Founder's Offer		
		Customer Specification	Base price incl.	Supp.
5)	Radiographic examination			
6)	Other, e.g. machining trials or sectioning or dimensional check			
7)	.....			
<b>(E)</b>	<b>VISUAL AND SURFACE INSPECTION</b>			
1) <sup>34</sup>	Visual inspection only – domestic standard	X	X	
2)	Visual inspection only – to nominated standard, e. g. SP 55 / DIN EN 12454			
3)	Surface inspection acc. to f.i. DIN EN 1370.....			
4)	<b>Report</b>	X		X
<b>(F)</b>	<b>DIMENSIONAL INSPECTION</b>			
1)	Founder's normal commercial tolerances acc. to .....	X	X	
2)	Special cast tolerances acc. to .....			
3)	Dimensional report			
4)	Minimal wall thickness chart			
5)	<b>Certificate of conformance</b>	X		X
<b>(G)</b>	<b>WELDING</b>			
1)	Defect sketch – all welded joints	X		X
2)	Defect sketch – major welded joints only			
3)	Welding restrictions			
4)	Approval to weld by customer	X	X	
5)	Weld procedure	X		X
6)	Weld procedure qualifications	X		X
7)	Prior approval required of 5) or 6)	X	X	
8)	Welder qualification records	X		X
9)	Non destructive testing (NDT) of the welded areas			
10)	.....			

<sup>34</sup> Please note: Figures in grey boxes represent either/or options, please tick only one box.

CHECK-LIST FOR EXAMPLE 2 (cont.)

		Founder's Offer		
		Customer Specification	Base price incl.	Supp.
<b>(H)</b>	<b>MACHINING</b>			
1)	Proof machining required for non-destructive testing (NDT) or for.....	X	X	
2)	.....			
<b>(I)</b>	<b>MAGNETIC PARTICLE OR DYE PENETRANT INSPECTION , ACC. TO STANDARD CCH 70-3</b>			
1)	Approved procedure required			
2)	Prior approval required for each order			
3) <sup>35</sup>	Magnetic particle inspection – Wet method	X	X	
4)	Magnetic particle inspection – Dry method			
5)	Dye penetrant inspection			
6)	Coverage of casting surface – 100%	X	X	
7)	Coverage of casting surface – selected areas			
8)	Quantity inspected – 100 % of delivered quantity (batch size)	X	X	
9)	Quantity inspected .....% of delivered quantity (batch size)			
10)	Personnel qualification records			
11)	Reports	X		X
12)	<b><u>Magnetic particle inspection of excavation prior to weld repair</u></b>	X		X
<b>(J)</b>	<b>ULTRASONIC EXAMINATION ACC. TO STANDARD CCH 70-3</b>			
1)	Approved procedure required			
2)	Prior approval required for each order			
3)	Coverage of volume – 100%	X	X	
4)	Coverage of volume – selected areas			
5)	Quantity inspected – 100 % of delivered quantity (batch size)	X	X	
6)	Quantity inspected .....% of delivered quantity (batch size)			
7)	Personnel qualification records			
8)	Ultrasonic testing (UT) report/ Photos to customer			
9)	.....			

<sup>35</sup> Please note: Figures in grey boxes represent either/or options, please tick only one box.

CHECK-LIST FOR EXAMPLE 2 (cont.)

		Founder's Offer		
		Customer Specification	Base price incl.	Supp.
<b>(K)</b>	<b>RADIOGRAPHIC EXAMINATION ACC. TO STANDARD CCH 70-3</b>			
1)	Approved procedure required			
2)	Prior approval required for each order			
3)	Shooting sketches			
4) <sup>36</sup>	Coverage of casting volume – 100%			
5)	Coverage of casting volume – selected area			
6)	Quantity inspected – 100 % of delivered quantity (batch size)			
7)	Quantity inspected <u>10</u> % of delivered quantity (batch size)			
8)	Personnel qualification records			
9)	Reports/ Radiographs to customer	X		X
10)	<u>Verifying of indistinct ultrasonic testing (U.T.) indications</u>	X		X
<b>(L)</b>	<b>WITNESS POINTS</b>			
1)	Weld approval	X	X	
2)	Mechanical requirements	X		X
3)	Magnetic particle inspection / Dye penetrant inspection	X		X
4)	Ultrasonic testing and/or radiographic examination	X		X
5)	Dimensional inspection			
6)	Documentation	X		X
7)	Final inspection	X		X
8)	.....			
<b>(M)</b>	<b>SPECIAL MARKING OR IDENTIFICATION REQUIREMENT</b>			
1)	<u>Acc. to customer's specification</u>	X	X	
2)	.....			
<b>(N)</b>	<b>SPECIAL NOTES</b>			
1)	.....			

<sup>36</sup> Please note: Figures in grey boxes represent either/or options, please tick only one box.



## 5. QUALITY COST CALCULATIONS

This guide does not presume to supply a complete inspection cost calculation scheme.

However, it should be stated that there is a substantial difference between identifying an inspection cost and calculating the cost effect on the product. Opportunities for error abound and the founder may make expensive mistakes in quoting for castings if costs are neither correctly identified nor correctly costed.

This problem is a general one of cost control and what follows concentrates on "order linked" costs since general quality costs are normally treated as part of a company's overhead.

If the reader refers to the classification of quality costs set out in Table 1 in the main text, he will quickly realize that there is a close relationship between Quality production costs (B 1) and "Upgrading / Repairing costs" (non conformance costs Group C). The more that is spent on production costs in assuring quality the less has to be laid out in rectification etc. ... Naturally it is the aim of the founder to find the optimal solution minimising the total of both these costs and obviously this will vary from foundry to foundry and depend on the level of quality required by the order.

Two examples shall give the parties some assistance with quality cost calculations. It should be emphasised that these examples serve only to illustrate the importance of correct calculation of costs of inspection and the other related operations. They do not show how to carry out these calculations.

### **Example 1: Inspection for mechanical properties**

In this example the full costs of a typical inspection procedure in a foundry are listed.

Costs in this case are not limited to the obvious instances, namely sample machining, maintenance, certification and depreciation of the tensile test machine, labour of technician, etc. ...

The following also need to be included:

**1.**

Moulding, melting, casting plus material costs of the test block used for the sample (or an equivalent cost for a casting if this is used instead). In cases where a test block is attached to the casting additional costs have to be allowed for.

**2.**

Heat treatment, identification, marking, handling, pre-machining, etc. ... and all costs pertaining to the sample before it arrives at the test shop.

**3.**

Data collection and storage, certificate writing costs plus costs relating to staff time used to subsequent storage both of data and samples, whether the data costs relate to a computer system or not.

**4.**

In the case where the tests are required to be witnessed, then costs relating to staff time used in accompanying the outside inspector, the costs of interrupting workflow to accommodate his visit as well as delays involved in waiting for inspectors to come and costs associated with marking castings to denote the inspection has taken place.

## **Example 2: Costs relating to castings with high quality surface requirements**

In example 2 the relationship between production, inspection and repair costs is illustrated.

### **1.**

Such castings typically illustrate the relationship between production, inspection and repair costs.

#### **1.1**

The better the quality of the casting surface has to be, the more the moulding and melting techniques have to be improved, elaborated and generally made more cost intense. This might involve more expensive sand, superior quality cores and more and better quality labour, working to tighter specifications and thus more time intense.

#### **1.2**

Even after improving such techniques, castings demanding very high quality surfaces will still require up-grading and perhaps some repair.

#### **1.3**

The inspection of such casting surfaces constitutes only a very small part of the total cost involved.

### **2.**

Concerning such inspection costs the following points are relevant:

#### **2.1**

As well as the direct cost of the inspection, other costs to be considered are staff training and in some cases where the order requires it, staff qualification, as well as the qualification of the procedure itself and the materials used by an external authority. All these costs, as well as the costs of report preparation, have to be added to the basic inspection cost price. In the case of special orders, costs of audits, etc. ... have also to be included.

#### **2.2,**

If witness points are involved then in addition to those costs already outlined in paragraph 4 (example 1) the fact that a foundry will need to perform the inspection operation a first time before the customer's visit must be taken into account - especially if the inspection is a demanding test. Thus the inspection is carried out at least twice.

#### **2.3**

Handling costs influence both laboratory and production cost centres. High quality surface castings when handled several times may require additional grinding or a change in the grinding cycle and the pickling operation. In the case of high integrity castings, non-destructive testing (NDT) lengthens the production cycle thus causing greater investment and higher capital service costs.

## STANDARDS

Standard	Quoted on page
ASTM A 216	6
ASTM A 351	6
ASTM A 743	6, 17
ASTM A 744	14, 6, 17
DIN 1690 part 2	14
DIN 17182	21
DIN 17205	6
DIN 54109	14
DIN 54111	14
DIN EN 10204	9, 21
DIN EN 10213	6
DIN EN 10213-4	6
DIN EN 10283	6
DIN EN 10293	6, 21, 23
DIN EN 12454	9, 16, 24
DIN EN 12680-1	18
DIN EN 12681	19
DIN EN 1370	10, 16, 24
DIN EN 1371-1	17
DIN EN 1371-2	17
DIN EN 444	14
DIN EN 462	14
DIN EN 571-1	14
DIN EN ISO 6506-1	14
ISO 8402-1994	3
ISO 9004	2
SEW 410	6

DIN EN ISO 9000, Edition 2000-12

Qualitätsmanagementsysteme – Grundlagen und Begriffe (ISO 9000:2000); Three Language Version  
EN ISO 9000:2000

DIN EN ISO 9001, Edition 2000-12

Qualitätsmanagementsysteme – Grundlagen und Begriffe (ISO 9001:2000-09); Three Language Version  
EN ISO 9001:2000

DIN EN 10204, Edition 1995-08

Metallische Erzeugnisse – Arten von Prüfbescheinigungen (enthält Änderung A1:1995); German Version  
EN 10204:1991 + A1:1995)

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