CLASS PROGRAMME

Approval of manufacturers

DNVGL-CP-0351 Edition May 2016

Manufacture of heat treated products - heat treatment workshop
FOREWORD

DNV GL class programmes contain procedural and technical requirements including acceptance criteria for obtaining and retaining certificates for objects and organisations related to classification.

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Any comments may be sent by e-mail to rules@dnvgl.com

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This is a new document.
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SECTION 1 GENERAL

1 Objective

The objective of this class programme (CP) is to provide a description for which the Society bases its approval of manufacturers intending to deliver heat treated or surface hardened products in accordance with RU SHIP Pt.2 or other applicable standards provided by the Society.

2 Scope and application

This programme is applicable for approval of manufacturers for:

— heat treated products
— surface hardened products

as referred in the Society’s rules and standards. For a description of general requirements, conditions and procedures related to the approval, please refer to DNVGL CP 0346 which shall be applied in combination with this programme. The corresponding class programmes for the specific products shall also apply.

The approval will typically cover:

— an independent heat treatment company
— a manufacturer (e.g. foundry) in-house heat treatment facility
— a heat treatment sub-contractor

The corresponding requirements are given in App.B.

The programme is applicable for the approval of manufacturers for one or more of the heat treatments:

— normalizing or normalizing + tempering
— quenching\(^1\) and tempering
— solution heat treatment without quenching
— solution heat treatment with quenching\(^1\)
— tempering (e.g. malleable cast iron)
— stress relieving heat treatment
— soft annealing (spheroidize annealing)
— recrystallization annealing
— diffusion annealing/homogenizing annealing
— coarse grain annealing
— precipitation hardening
— case hardening
— nitriding
— induction hardening.

Some heat treatment processes may qualify other processes as indicated in App.A. Note that for any other process to be qualified in addition to the tested one, the heat treatment documentation and specifications, see Sec.2, shall be submitted and accepted by the Society.

Guidance note:

Other processes than those listed may be approved subject to case-by-case consideration. Adjusted scope of documentation and testing may be required as relevant.

Surface hardening by mechanical process such as shot peening is not covered by this approval programme.

\(^1\) Approval is limited to quenching media and quenching method.
3 Request for approval
The manufacturer shall indicate the application which approval is requested. For this a list or table shall be given, including at least:
— applicable heat treatment types (see App.A)
— reference to applicable material types and grades according to the Society’s rules and standards, (e.g. RU SHIP Pt.2 Ch.2 Sec.8 [2]) for the applicable chemical composition, mechanical properties and heat treatment, or subject to agreement, reference to other recognised standards
— type of products and manufacturing method (e.g. castings, forgings, rolled products etc.)
— range of applicable product sizes (dimensions, maximum thickness and weight).

4 References

<table>
<thead>
<tr>
<th>No.</th>
<th>Reference</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ASTM E 112</td>
<td>Standard test method for determining average grain size</td>
</tr>
<tr>
<td>2</td>
<td>ASTM E562</td>
<td>Standard test method for determining volume fraction by systematic manual point count</td>
</tr>
<tr>
<td>3</td>
<td>ISO 643</td>
<td>Steels – micrographic determination of the apparent grain size</td>
</tr>
<tr>
<td>4</td>
<td>ASTM A991</td>
<td>Standard test method for conducting temperature uniformity surveys of furnaces used to heat treat steel products</td>
</tr>
</tbody>
</table>
SECTION 2 DOCUMENTATION REQUIREMENTS

1 Incoming material and order documentation
Manufacturer’s requirements for and handling of order documentation and incoming material in terms of:
— a list of suppliers for starting material and a copy of their approval certificate
— handling of incoming material
— handling of incoming material certificates and verification of material identification
— specifications for chemical composition and procedure for validation of composition
— if relevant; specifications for hardenability
— documentation of heat treatment condition of incoming products (if applicable)
— specifications for and verification of surface condition of incoming products
— specification for/order information related to heat treatment, e.g. customer or manufacturers’ specification
— if relevant; order information and drawings indicating areas which shall (and shall not) be subjected to surface hardening
— specification for/order information related to properties to be achieved (mechanical, surface, dimensions) and methods for verification and reporting.

2 Identification and traceability
Procedures for identification and traceability (i.e. ensuring full traceability of the products and test samples at all times).

3 Heat treatment furnaces
The following information shall be submitted:
— type of furnace and dimensions, ID numbers
— heating source
— maximum operating temperature
— furnace control; manual or automatic. For automatic control; own system or commercial. Description of the furnace control system
— working zone; dimension and sketch of working zone
— furnace atmosphere (media): vacuum, low/medium/normal pressure, inert gas
— type of thermocouples
— sketch indicating the positions of thermocouples, and including position of contact thermocouples (i.e. connected to the products, where applicable)
— accuracy, calibration status and calibration certificates of temperature control devices, i.e. thermocouples and recorders.

4 Procedures and records
This shall give all relevant details including but not necessarily restricted to:
— applied heat treatment process
— heat treatment specifications with respect to:
  — heat treatment procedures, specifying temperatures (start, holding, stop cooling/quenching), holding and soaking times (thickness dependencies), heating rates, and cooling or quenching rates, time between quenching and tempering, etc.
  — any re-heat treatment procedure to be given, if applicable
The following reports and record shall be submitted:

— furnace temperature uniformity test report with records, particularly indicating the effective working zone with respect to the lowest locations towards furnace floor and nearest location to furnace door. ASTM A991 or other equivalent standard should be used
— furnace loading and unloading procedure and plan, i.e. including at least loading method, hot or cold loading/unloading, number and arrangement of products, distance between products, maximum loading mass, etc. Example loading maps indicating the positions of the products(s) in the furnace shall be submitted
— example records of representative actual heat treatments indicating temperature-time course.

5 Quenching and cooling process and media

The following information shall be submitted:

— type of cooling or quenching media
— type of process, separate or integrated process
— type of cooling/quenching (e.g. in air, fan, submerging in media, spraying, etc.)
— for basins/tanks: number and dimensions, media, agitation method, equipment for temperature monitoring
— for spraying: velocity, type and size of nozzles etc.

The following procedures shall be submitted:

— furnace unloading procedure, i.e. describing method of unloading, max time for removal from furnace to start quenching, e.g. entry in quench tank
— for quenching media:
  — control of circulation/agitation
  — control and monitoring of temperature
  — maintenance, control and renewal of media
  — holding time (calculation of, control of and recording of holding time, e.g. related to product thickness and mass).

6 Case hardening

Additional procedures, specifications and methods for:

— monitoring of furnace atmosphere and composition
— hardening process (direct, single or double hardening)
— protection of surfaces not to be hardened
— tempering.

7 Nitriding hardening (with/without carburizing)

Additionally, facilities (type and capacity), procedures, specifications and methods for:

— gas nitriding
— bath nitriding
— ion nitriding.

2 Loading on furnace floor without distance pieces or loading in bucket is in general not permitted unless otherwise agreed
3 Cooling media temperature shall normally be maintained below 50°C for the whole cooling process.
8 Induction hardening
Facilities (type and capacity), procedures, specifications and methods for:
— induction process, including quenching after heating
— inductors/induction coil.

9 Welding
The following information shall be submitted both for weld repair and for production welding:
— description of the welding:
  — equipment
  — qualifications of welders and welding supervisors. Welders certificates shall be submitted
  — welding procedure specifications (WPS)
  — the welding shall be qualified by welding procedure tests. Reports on welding procedure qualification
tests (WPQR).

Unless otherwise agreed with the Society, the scope of the welding procedure tests shall comply with RU
SHIP Pt.2 Ch.4 Sec.5, and documented as described in the approval of welding workshop (WWA) programme
DNVGL CP 0352.

10 Weld repairs
In addition to [4], the welding procedure specification (WPS) shall also include:
— extent and depths allowed for weld repair
— preparation of groove before welding
— non-destructive testing before and after welding
— surface preparation after welding
— heat treatment after welding
— reference to manufacturer’s procedure for the maintenance of records of weld repairs.

11 Other records, test facilities and procedures
The following shall be submitted:
— visual inspection: relevant templates for recording, and a few records of previously performed visual
  inspections of same or similar products
— details and description of relevant in-house testing facilities and calibration details, test procedures and
  qualification of testing personnel
— NDT procedures, equipment for NDT including calibration details, and qualification of personnel for NDT
— information about and procedures for important manufacturing and testing routines, such as cutting and
  macrographic inspection of products etc.
SECTION 3 APPROVAL TESTING

1 Test products and testing scope

1.1 General
The test products shall be selected so that the intended approval scope as outlined in Sec.1 is covered. Unless otherwise specified herein, the sampling, testing procedures and acceptance criteria shall comply with the relevant requirements of the DNV GL rules. Starting material for approval testing, e.g. semi-finished steel products, shall be produced at works approved by the Society.

1.2 Extent of approval testing
Qualification by approval testing is required for each:
— heat treatment process (delivery condition, condition of supply) as indicated in App.A
— material type, group or grade as indicated in App.A
   — some material grades may also cover other grades as indicated in App.A
— product type/manufacturing method (castings, forgings, rolled products etc.)
— maximum dimension for which approval testing is performed.
The allowable range of heat treatment temperature shall be proposed, agreed and qualified by the temperature(s) used for the approval testing.
Thickness dependency of holding and soaking time shall either be qualified by testing, or proposed based on documented and established industry practice. If manufacturer intend to change the holding and soaking time to other parameters than that established during the verification, new approval is required.

1.3 Selection and position of the test samples
Sampling shall be done in accordance with the Society's rules and in accordance with the relevant approval programme for the material/product being qualified, unless otherwise agreed. In absence of clear rule requirements, sampling positions may be proposed by the manufacturer and then agreed on case by case basis.
Additionally, the following test specimens are required. Test specimens shall be prepared from a sample product of dimensions representative for the maximum product size, for:
— tensile and impact test:
   — for thickness or diameter up to maximum 50 mm, the axis shall be at the mid-thickness or the centre of the cross section
   — for all delivery conditions except QT: For thickness or diameter greater than 50 mm, the axis shall be at one quarter thickness (mid-radius) below any heat treated surface
   — for delivery condition QT: For thickness or diameter greater than 50 mm, the axis shall be at one quarter thickness (mid-radius) or 80 mm, whichever is less, below any heat treated surface
— microstructure: near surface, at ¼ thickness, at mid thickness, and at tensile/impact test position if different from these
— hardness: at or near surface, at ¼ thickness, at mid thickness, and at tensile/impact test position if different from these.
Test samples shall be taken out in final heat treatment delivery condition and shall not be subjected to any separate heat treatment.
2 Testing requirements

2.1 General
For all processes and products as given in [1.2], extent of testing, methods, evaluation and requirements for the product shall be as given in the DNV GL rules and the corresponding AoM programme for the material/product being qualified, unless otherwise stated herein.

2.2 Temperature uniformity survey of furnaces
An extensive temperature uniformity survey (TUS) of heat treatment furnaces is required in order to assure uniform temperature and reliable control and checking of temperature. TUS shall be carried out with agreed procedure and witnessed by the Society’s representative at least once.
Calibration of furnaces shall at least include:
— temperature shall be measured using contact thermocouples on sample products located at each corner and of the center of the working zone
— temperature shall be measured at typical holding temperature for the products (in the upper range of applicable holding temperatures)
— holding time: minimum 30 minutes
— recording interval: minimum one recording per two minutes
— typical tolerances are: +/- 14°C at or above 800°C and +/- 10°C below 800°C.
Temperature shall be monitored by recorders with resolution sufficient to clearly define all aspects of the heating, holding and cooling process. From the recording of the temperatures of the contact thermocouples, a comparison shall be made with the records of the furnace thermocouples. The chart of time and temperature showing the output from contact thermocouples and furnace control thermocouples shall be submitted.
Temperature uniformity determined according to the methods described in ASTM A 991 or equivalent standard is acceptable.
TUS shall be carried out at least annually and TUS report shall be presented to the Society's surveyor on request. The periodical TUS may be carried out by the heat treatment company. Evidence of furnace surveys and calibration shall be provided.

2.3 Qualification of alternative heat treatment processes (as relevant)
Heat treatment processes not in line with common industry practice shall be qualified, e.g. a normalizing process being different from common practice with respect holding time at soaking temperature. Common industry practice is in this respect considered as the practice specified by nationally or internationally recognized standards or reference books. Approval may be given when found to be equivalent or better than normally accepted processes.

Note:
Such approval is applicable for the process, not the product. The final delivery condition of a "product" shall always follow the requirements of DNV GL rules. E.g. hull structural steel castings shall be delivered in the conditions given in RU SHIP Pt.2 Ch.2 Sec.8 [2.3].

Test scope for qualification of alternative heat treatment processes shall be agreed with the Society. It may typically include:
— to be qualified with thickest product for approval, or alternatively a heat sink/sample product of same thickness and composition, using heaviest furnace loading and/or most dense packed loading to be used for production
— contact thermocouples shall be placed both on the surface of the product extremities, and in a hole drilled into the mid-thickness position of the sacrificial product/heat sink, and the temperatures recorded
— furnace atmosphere temperature shall be measured and recorded in parallel
— readings from the contact thermocouples shall be compared with the temperature records from the
furnace atmosphere, and plotted on the same graph for comparison
— temperatures shall be monitored by a recorder with resolution sufficient to clearly define all aspects of the
heating, holding and cooling process
— allowable soaking temperature range is typically -10°C and +30°C.

2.4 Heat treatment sensitivity study, QT condition (as relevant)

For candidate alloys where quenching and tempering parameters are not standardised or established, a
heat treatment sensitivity study is required. The same applies for non-standard quenching and tempering
processes.

A heat treatment sensitivity study simulating production conditions shall be applied in order to check the
candidate material's sensitivity to deviations from a target (optimum) heat treatment specification. It is thus
essential that the target (optimum) heat treatment is performed in a manner simulating realistic conditions
for production. Extent of testing to qualify heat treatment sensitivity study may be proposed and should be
agreed in advance.

As an alternative to new 'heat treatment sensitivity study' during approval process, manufacturer may submit
existing data from their previous studies for consideration by DNV GL and based on evaluation a complete or
partial exception may be granted from this requirement.

Unless otherwise agreed or required, the following heat treatment conditions apply:

Table 1 Variables for temperature sensitivity study

<table>
<thead>
<tr>
<th>Austenitisation temperature</th>
<th>Time at austenitisation temperature</th>
<th>Tempering temperature</th>
<th>Tempering time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specified temperature -30°C</td>
<td>Specified time</td>
<td>Specified temperature -15 °C</td>
<td>Specified time</td>
</tr>
<tr>
<td>Specified temperature +30°C</td>
<td>Specified time</td>
<td>Specified temperature +15 °C</td>
<td>Specified time</td>
</tr>
<tr>
<td>Specified temperature</td>
<td>120% of specified time</td>
<td>Specified temperature</td>
<td>120% of specified time</td>
</tr>
<tr>
<td>Specified temperature</td>
<td>80% of specified time</td>
<td>Specified temperature</td>
<td>80% of specified time</td>
</tr>
</tbody>
</table>

2.5 Jominy end quench test, when required by purchaser (as relevant)

For quenched and tempered steels as well as case hardening steels (e.g. 16MnCr5, 20MnCr5, 18CrNiMo7-6
and equivalent), the hardenability shall, when required by the purchaser, be determined and reported using
Jominy end quench test. Testing shall be performed according to ASTM A255 or an equivalent standard.
The applied test method and obtained test results shall be reported.

2.6 Additional testing for case hardened products including gear
transmissions (as relevant)

The applicable minimum methods and requirements to be fulfilled in addition to this programme are indicated
in DNVGL CP 0247 and in RU SHIP Pt.4 Ch.4. Further requirements for qualification of case hardening of gear
transmission parts may be required by the Society.
2.7 Additional testing for nitrided products with or without carburizing (as relevant)

A coupon following the entire nitriding process shall be tested and documented with respect to:

- case depth (to 400 HV)
- white layer thickness (to be as specified, or < 0.025 mm)
- core properties.

2.8 Additional testing for induction hardened products (as relevant)

A coupon with the same profile as the actual product following the entire induction hardening process shall be tested and documented with respect to:

- hardness contour
- hardness contour at pitch diameter (for gears)
- hardness contour at tooth root (for gears)
- material microstructure at surface and through the hardened depth.
## APPENDIX A APPROVAL COVERAGE

### 1 Approval coverage of heat treatment processes, material types and grades

**Table 1 Approval coverage related to material types and grades given by RU SHIP Pt.2 Ch.2**

<table>
<thead>
<tr>
<th>Heat treatment process subjected to approval testing</th>
<th>Material grade tested</th>
<th>Approval coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat treatment without surface hardening</td>
<td>C and C-Mn steel grade</td>
<td>All C and C-Mn steel grades</td>
</tr>
<tr>
<td></td>
<td>Alloy steel grade</td>
<td>All alloy steel grades</td>
</tr>
<tr>
<td></td>
<td>Stainless steel grade</td>
<td>All stainless steel grades of same type (e.g. austenitic, duplex, martensitic, ferritic, etc.)</td>
</tr>
<tr>
<td></td>
<td>Cast iron grades</td>
<td>All cast iron grades</td>
</tr>
<tr>
<td></td>
<td>Non-iron metallic grade</td>
<td>All non-iron metallic grades of same type (e.g. bronze)</td>
</tr>
<tr>
<td>Heat treatment with surface hardening</td>
<td>-</td>
<td>Covers only the material grade and the surface hardening process subjected to approval testing</td>
</tr>
</tbody>
</table>

**Table 2 Approval coverage related to heat treatment process as per RU SHIP Pt.2 Ch.2**

<table>
<thead>
<tr>
<th>Heat treatment process subjected to approval testing</th>
<th>Heat treatment process qualified in addition to the tested heat treatment 1, 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalizing, normalizing and tempering</td>
<td>Soft annealing, tempering, stress relieving</td>
</tr>
<tr>
<td>Quenching and tempering</td>
<td>Quenching, tempering, stress relieving</td>
</tr>
<tr>
<td>Solution heat treatment without quenching</td>
<td>Soft annealing, tempering, stress relieving</td>
</tr>
<tr>
<td>Solution heat treatment with quenching</td>
<td>Solution heat treatment without quenching, soft annealing, tempering, stress relieving</td>
</tr>
<tr>
<td>Tempering</td>
<td>Stress relieving</td>
</tr>
<tr>
<td>Stress relieving heat treatment</td>
<td>-</td>
</tr>
<tr>
<td>Soft annealing (spheroidize annealing)</td>
<td>Tempering, stress relieving</td>
</tr>
<tr>
<td>Recrystallization annealing</td>
<td>Tempering, stress relieving</td>
</tr>
<tr>
<td>Diffusion annealing, homogenization annealing</td>
<td>Tempering, stress relieving</td>
</tr>
<tr>
<td>Coarse grain annealing</td>
<td>Tempering, stress relieving</td>
</tr>
<tr>
<td>Precipitation hardening</td>
<td>Tempering, stress relieving</td>
</tr>
<tr>
<td>Case hardening</td>
<td>-</td>
</tr>
<tr>
<td>Nitriding</td>
<td>-</td>
</tr>
<tr>
<td>Heat treatment process subjected to approval testing</td>
<td>Heat treatment process qualified in addition to the tested heat treatment $^1, 2)$</td>
</tr>
<tr>
<td>----------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Induction hardening</td>
<td>-</td>
</tr>
</tbody>
</table>

1) On condition that the heat treatment workshop provides sufficient evidence about their knowledge and capability (ref. documentation requirements given by Sec.2) of listed heat treatment processes.

2) Additional processes not listed in this column may be accepted by the Society, e.g. taking into consideration the heat treatment parameters (temperature, quenching, complexity, material types, etc.) In such cases, the manufacturer shall apply for extended coverage and obtain acceptance before start of testing.
APPENDIX B APPROVAL SCOPE

1 Approval scope, major approval requirements and certification scope

Table 1 The manufacturers may typically be approved within the following scopes

<table>
<thead>
<tr>
<th>Approval scope:</th>
<th>Approval is required for 1)</th>
<th>Certification of materials/products by manufacturer (W-certificate)</th>
<th>Guidance note:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material manufacturers in-house heat treatment facility</td>
<td>— Each furnace</td>
<td>Limited to grade/products mentioned in the AoM certificate</td>
<td>Furnace calibration (furnace uniformity test), HT procedure verification and process qualification as relevant, may be performed simultaneously</td>
</tr>
<tr>
<td>Heat treatment subcontractor</td>
<td>— Each furnace</td>
<td>Not allowed</td>
<td>Furnace calibration (furnace uniformity test), HT procedure verification and process qualification as relevant, may be performed simultaneously</td>
</tr>
<tr>
<td>Independent Heat treatment company</td>
<td>— Each furnace</td>
<td>— Limited to grade/products group mentioned in the AoM certificate</td>
<td>— Material shall be provided from DNV GL approved manufacturer(s)</td>
</tr>
<tr>
<td></td>
<td>— Per product/material group:</td>
<td>— Original material certificates for semi-finished products shall be attached to material/product certificates</td>
<td>— Furnace calibration (furnace uniformity test), HT procedure verification and process qualification as relevant, may be performed simultaneously</td>
</tr>
<tr>
<td></td>
<td>— casting and forging group</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>— pipes and fitting group</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>— plate and section group</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>— surface hardened products except parts for gears</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>— surface hardened parts for gears</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>— non-ferrous group</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>— other/miscellaneous group</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) For full details, see the approval programme requirements.
CHANGES – HISTORIC

There are currently no historical changes for this document.
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