Institute for Reference Materials and Measurements

European Reference Materials

CERTIFICATION REPORT

Certification of Charpy V-notch reference test pieces of 150 J nominal absorbed energy

Certified Reference Materials ERM®-FA415k, ERM®-FA415l, ERM®-FA415m, ERM®-FA415n, ERM®-FA415o

Report EUR 22699 EN

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

The mission of IRMM is to promote a common and reliable European measurement system in support of EU policies.

European Commission
Directorate-General Joint Research Centre
Institute for Reference Materials and Measurements

Contact information
CRM Sales
European Commission
Directorate-General Joint Research Centre
Institute for Reference Materials and Measurements
Retieseweg 111
B-2440 Geel • Belgium

Email: jrc-irmm-rm-sales@ec.europa.eu

Tel.: +32 (0)14 571 705
Fax: +32 (0)14 590 406

http://www.irmm.jrc.be
http://www.jrc.ec.europa.eu
http://www.erm-crm.org

EUR Report 22699 EN
ISSN 1018-5593
ISBN 978-92-79-05220-0
Luxembourg: Office for Official Publications of the European Communities

CERTIFICATION REPORT

Certification of Charpy V-notch reference test pieces of 150 J nominal absorbed energy

Certified Reference Materials ERM®-FA415k, ERM®-FA415l, ERM®-FA415m, ERM®-FA415n, ERM®-FA415o

G. Roebben, A. Lamberty

European Commission, Joint Research Centre
Institute for Reference Materials and Measurements (IRMM)
Geel, Belgium

Report EUR 22699 EN

Summary

This certification report describes the processing and characterisation of ERM®-FA415k, ERM®-FA415l, ERM®-FA415m, ERM®-FA415n, and ERM®-FA415o, five batches of Charpy V-notch certified reference test pieces. Sets of five of these test pieces are used for the verification of pendulum impact test machines according to EN 10045-2 (Charpy impact test on metallic materials, Part 2. Method for the verification of impact testing machines [1]) or according to ISO 148-2 (Metallic materials - Charpy pendulum impact test – Part 2: Verification of test machines [2]). The certified value for *KV* (= energy required to break a V-notched test piece using a pendulum impact test machine) and the associated uncertainty (k = 2 corresponding to a confidence level of 95 %) calculated for the mean of a set of five test pieces, are:

Batch-code	Certified KV-value	Expanded uncertainty (k=2, 95 % confidence level)
ERM®-FA415k	149.0	4.4
ERM®-FA415l	147.2	3.8
ERM®-FA415m	149.0	4.3
ERM®-FA415n	149.3	3.8
ERM®-FA415o	149.9	4.2

The certified values are traceable to the Charpy impact test method as described in EN 10045-1 [3] and ISO 148 [4], via the corresponding Master Batch ERM®-FA415b of the same nominal absorbed energy (150 J).

ERM®-FA415k, ERM®-FA415l, ERM®-FA415m, ERM®-FA415n, and ERM®-FA415o have been accepted as European Reference Material® (ERM®) after successful peer evaluation by the partners of the European Reference Materials consortium.

Table of Contents

Glossary

AISI	American Iron and Steel Institute
ASTM	American Society for Testing and Materials
BCR	Community Bureau of Reference
CEN	European Committee for Standardization
CRM	Certified Reference Material
EC	European Commission
EN	European Norm
ERM®	European Reference Material
g	Gravitation acceleration
IMB	International Master Batch
IRMM	Institute for Reference Materials and Measurements, Joint Research Centre, European Commission
ISO	International Organization for Standardization
JRC	Joint Research Centre, European Commission
k	Coverage factor
KV	Absorbed energy = energy required to break a V-notched test piece of defined shape and dimensions when tested with a pendulum impact testing machine
KV_{CRM}	Certified *KV* value of a set of 5 reference test pieces from the Secondary Batch
KV_{MB}	Certified *KV* value of the Master Batch test pieces
MB	Master Batch
m	Mass of pendulum
n_{MB}	Number of samples of the Master Batch tested during certification of the Secondary Batch
n_{SB}	Number of samples of the Secondary Batch tested for certification
RSD	Relative standard deviation

s	Standard deviation
SB	Secondary Batch
s_{MB}	Standard deviation of the n_{MB} results of the samples of the Master Batch tested for the certification of the Secondary Batch
s_{SB}	Standard deviation of the n_{SB} results of the samples of the Secondary Batch tested for its characterisation
u_{CRM}	Combined standard uncertainty of KV_{CRM}
U_{CRM}	Expanded uncertainty (k = 2, confidence level 95 %) of KV_{CRM}
u_{char}	Standard uncertainty of the result of the characterisation tests
u_h	Homogeneity contribution to uncertainty
u_i	Uncertainty contribution corresponding to effect i
u_{MB}	Standard uncertainty of KV_{MB}
$\overline{X}_{MB}$	Mean KV value of the n_{MB} measurements on samples of the Master Batch tested when characterising the Secondary Batch
$\overline{X}_{SB}$	Mean KV value of the n_{SB} results of the samples of the Secondary Batch tested for its characterisation
Δh	Difference between the height of the centre of gravity of the pendulum prior to release and at end of first half-swing, after breaking the test sample
ν_{eff}	Effective number of degrees of freedom associated with the uncertainty of the certified value

1 Introduction: the Charpy pendulum impact test

The Charpy pendulum impact test is designed to assess the resistance of a material to shock loading. The test, which consists of breaking a notched bar of the test material using a hammer rotating around a fixed horizontal axis, is schematically presented in Figure 1.

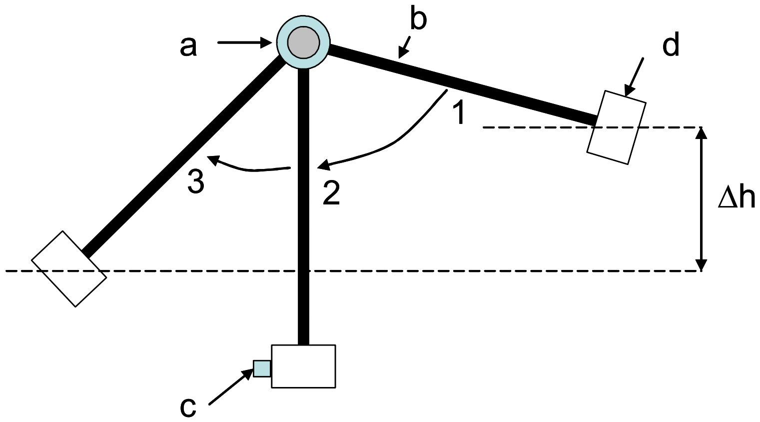

Figure 1: Schematic presentation of the Charpy pendulum impact test, showing a: the horizontal rotation axis of the pendulum, b: the stiff shaft on to which is fixed, d: the hammer, of mass m. The hammer is released from a well-defined height (position 1). The hammer strikes c: the test sample, when the hammer has reached maximum kinetic energy (shaft in vertical position 2). The height reached by the hammer after having broken the sample (position 3) is recorded. The difference in height between position 1 and 3 (Δh) corresponds with a difference in potential energy (= $m \times g \times \Delta h$, with g = gravitation acceleration), and is a measure of the energy required to break the test sample.

The energy absorbed by the test sample depends on the impact pendulum construction and its dynamic behaviour. Methods to verify the performance of an impact pendulum require the use of reference test pieces as described in European, American and ISO standards [1, 2, 5]. The reference test pieces dealt with in this report comply with a V-notched test piece shape of well-defined geometry [1, 2], schematically shown in Figure 2.

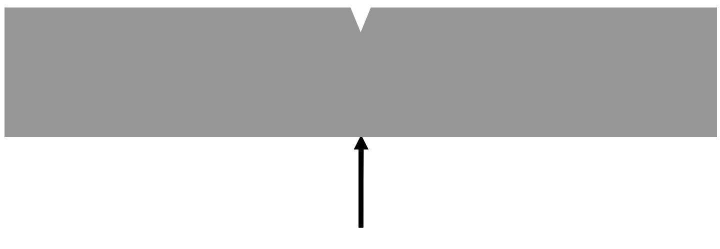

Figure 2: Schematic drawing of a V-notched Charpy sample (top-view), indicating the place and direction of impact.

2 The certification concept of Master Batch and Secondary Batch

2.1 Difference between Master and Secondary Batches

The BCR reports by Marchandise et al. [6] and Varma [7] provide details of the certification of the BCR "Master Batches" (MB) of Charpy V-notch certified reference test pieces. The certified value of a Master Batch is obtained using an international laboratory intercomparison.

This report describes the production of a "Secondary Batch" (SB) of Charpy V-notch certified reference test pieces at the Institute for Reference Materials and Measurements (IRMM) of the European Commission (EC) Joint Research Centre (JRC). The work was performed in accordance with procedures described in the BCR reports [6] and [7]. The certification of a SB is based on the comparison of a set of SB test pieces with a set of test pieces from the corresponding MB under repeatability conditions on a single pendulum.

Since the uncertainty of the certified value of the MB contributes to the uncertainty of the certified value of the SB, the latter is necessarily larger than the former. Nevertheless, as will be shown also in this report, the uncertainty can be kept sufficiently small to meet the requirements of the intended use of the certified reference material (CRM). Avoiding the need for an international interlaboratory comparison for each produced batch, the MB-SB approach allows cost-efficient production of certified reference test pieces.

The BCR reports [6] and [7] were published in 1991 and 1999, respectively. Since 2000, the calculation of the certified value and the estimation of its uncertainty have been updated to an approach compliant with the ISO Guide to the Expression of Uncertainty in Measurement [8]. This revised approach was developed and presented by Ingelbrecht et al. [9, 10], and is summarised below.

2.2 Certification of a Secondary Batch of Charpy V-notch test pieces

The certified absorbed energy of a SB of Charpy V-notch reference test pieces (KV_{CRM}) is calculated from the mean KV-value of a set of SB-samples ($\overline{X}_{\mathrm{SB}}$) tested on a single pendulum. This value $\overline{X}_{\mathrm{SB}}$ has to be corrected for the bias of this particular pendulum. The bias of the pendulum at the moment of testing the samples of the SB, is estimated by comparing the mean KV-value of a number of samples of the MB ($\overline{X}_{\mathrm{MB}}$), tested together with the SB samples under repeatability conditions, with the certified value of the MB (KV_{MB}). KV_{CRM} is then calculated as follows [10]:

$$KV_{\mathrm{CRM}} = \left[\frac{KV_{\mathrm{MB}}}{\overline{X}_{\mathrm{MB}}} \cdot \overline{X}_{\mathrm{SB}} \right] \qquad \text{Eq. 1}$$

For this approach to be reliable, the pendulum used for the tests on MB and SB in repeatability conditions, must be well performing. This can be checked by comparing the certified value of the MB, KV_{MB}, with the results obtained on the MB samples when comparing SB and MB, $\overline{X}_{MB}$. IRMM now allows a difference of 5 % (if KV_{MB} > 40 J) or 2 J (if KV_{MB} < 40 J) between KV_{MB} and $\overline{X}_{MB}$, corresponding with the level of bias allowed for reference pendulums specified in EN 10045-2 [1] and ISO 148-3 [11].

Also, for reasons of commutability, a comparable response of the pendulum to the MB and SB samples is required. This is the reason why MB and SB samples are made from steel with nominally the same chemical composition, and similar heat treatments. These precautions have to result in a ratio $\frac{KV_{CRM}}{KV_{MB}}$ close to 1. IRMM now allows a difference of 20 % (KV_{MB} > 40 J) or 8 J (KV_{MB} < 40 J) between KV_{CRM} and KV_{MB}.

3 Participants

The processing of the SB test pieces was carried out by Cogne Acciai Speciali, Aosta (IT). The MB samples used in the characterisation of the SB were provided by IRMM, Geel (BE). Characterisation of the SB was carried out at Cogne Acciai Speciali, Aosta (IT) using a pendulum verified according to the criteria imposed by EN 10045-2 [1] and ISO 148-2 [2]. Data evaluation was performed at IRMM.

4 Processing

The ERM®-FA415k-l-m-n-o test pieces were prepared from ASTM 565 steel. The steel was cast and rolled into bars at Cogne Acciai Speciali (see section 4.1). Heat treatment and production of the test pieces from these bars were performed later, also at Cogne Acciai Speciali (see sections 4.2, 4.3, 4.4, and 4.5).

4.1 Processing of hot-rolled bars

The base material consisted of ASTM 565 – Grade XM32 steel, produced at Cogne Acciai Speciali. To limit the amount of impurities potentially affecting the homogeneity of the fracture resistance, the following compositional tolerances specified in Table 1 were imposed on the selected steel batch. These tolerances are stricter than generally allowed for ASTM 565.

Table 1: Adapted composition tolerances of ASTM 565 Grade XM32.

composition (mass %)						
C	S	P	Si	Mn	Cr	Ni
0.11 - 0.13	< 0.003	0.018	0.15 – 0.3	0.15 – 0.3	11.25 – 11.65	2.55 – 2.75
Mo	Cu	Al	V	W	N	
1.55 – 1.7	< 0.2	< 0.01	0.25 – 0.3	< 0.1	0.025 - 0.04	

The ingot billets were hot rolled, resulting in bars that were 4 m long and with a squared cross-section of 14 mm. For the ERM®-FA415k-l-m-n-o batches, steel was used from billet A from ingot number 360404. Before heat treatment, the hot rolled bars were cut into rectangular beams of 58 mm length. These rectangular beams were machined to 55 mm length and 11 mm x 11 mm cross-section. The batch code (3, K (or L or M or N or O), 160) was engraved on one end face of each sample (‘3’ indicates the steel type (ASTM 565); ‘160’ indicates the target absorbed energy level; ‘K (or L or M or N or O)’ is the letter as assigned consecutively to batches of nominally the same absorbed energy).

4.2 Heat-treatment of hot-rolled bars

The heat treatment of the test pieces was performed in salt baths. Samples were put into steel wire baskets containing 16 samples each. The baskets were fixed at regular spacing on a frame, collecting nominally 420 samples, which were immersed into two salt baths. Prior to immersion in the salt baths, the homogeneity of the temperature in these baths was checked with a calibrated mobile thermocouple unit (temperatures observed vary < 4 °C).

The first salt bath was at 1020 °C. Samples were kept at this temperature for 30 min for an austenisation treatment. From this bath, samples were quenched into oil at 40 °C for 15 min, and further cooled down in air. After the oil-quench, the samples were annealed twice in a second salt bath, first at 700 °C, then at 670 °C, each time for 120 min. After this annealing treatment, the samples were cooled down in oil. The suitability of the temperatures of the second bath, which strongly affect the KV value of the resulting samples, was checked as follows.

The FA415j batch was processed together with batches FA415k-l-m-n-o. A selection of 24 samples of the first batch (FA415j) and 24 samples of the last batch (FA415o) were submitted to a test heat treatment (performed on July 1, 1999). To create thermal inertia conditions similar to the treatment of a full batch, the 48 selected test samples were accompanied by about 370 dummy samples. After the heat treatment, samples were machined to final dimensions. The most important dimensions (sides, depth of notch, notch-tip radius) of the 48 samples were checked against the contractual criteria deduced from ISO 148 [3] and EN 10045 [1] before they were impact tested on the Metro Com (Serial No 2005) pendulum at Cogne (July 22, 1999; laboratory temperature 23 °C, relative humidity 49 %). The average KV of the 24 samples of batch FA415j was 162.10 J (s = 2.88 J, RSD = 1.78 %). The average KV of the 24 samples of batch FA415o was 163.75 J (s = 3.17 J, RSD = 1.93 %). Since the *KV*-values are slightly higher than the original target value (160 J), it was chosen to slightly decrease the annealing temperatures for the full batch from the initially chosen 705 °C to 700 °C and from 675 °C to 670 °C. After the test heat treatment, one heat treatment was carried out for each of the secondary batches (Table 2).

Table 2: Size of heat treated batches and heat treatment date

Batch	Number of samples heat treated	Heat treatment date	Number of sets of 5 samples received at IRMM
ERM®-FA415k	450	21/09/1999	84
ERM®-FA415l	450	30/9/1999	84
ERM®-FA415m	450	26/10/1999	84
ERM®-FA415n	450	28/9/1999	74
ERM®-FA415o	426	28/10/1999	79

4.3 Machining of Charpy test pieces

After the heat treatment the samples were machined to dimensional tolerances imposed in EN 10045-2 [1]. First, the cross-section was reduced to 10 mm x 10 mm, respecting the orthogonality of the four long faces of the bar. Then the surface was finished to roughness R_a < 0.8 µm. Finally, the V-notch was introduced using a diamond grinding tool with the appropriate V-profile.

4.4 Quality control

When all samples from the batches were fully machined, for each batch a selection of 30 samples was made from different heat treatment baskets. The dimensions of the 30 samples were checked against criteria specified in EN 10045-2 [1] (height 10.00 ± 0.06 mm, width 10.00 ± 0.075 mm, depth of notch 2.00 ± 0.06 mm, radius at notch root 0.25 ± 0.025 mm). All samples met all requirements. Then, characterisation tests were performed (see section 5 and Annex 1). Having confirmed the suitability of the batches with respect to the average KV and standard deviation, the dimensions of 65 to 70 samples of each batch (about 20 % of the batch) were checked. None of the samples were outside ranges specified in EN 10045-2 [1].

4.5 Packaging and storage

Finally, the samples were cleaned and packed in sets of 5, in oil-filled and closed plastic bags. These oil-filled bags, together with a label, again were packed in a sealed plastic bag, and shipped to IRMM. After arrival, the number of sets specified in Table 2 were registered and stored at room temperature, pending distribution.

5 Characterisation

5.1 Characterisation tests

30 samples from each of the batches ERM®-FA415k-l-m-n-o were tested under repeatability conditions with 35 samples from MB ERM®-FA415b (sets 19, 20, 21, 22, 23, 27, and 28), using the Metro Com (serial number 2005) machine of Cogne Acciai Speciali, an impact pendulum yearly verified according to procedures described in EN 10045-2 [1]. Tests were performed on November 29, 1999 (laboratory temperature 21 °C, relative humidity 31 %), in accordance with EN 10045-1 and ISO 148. Data obtained on individual test pieces are shown in Figure 3 to 7 and in Annex 1. The results of the measurements are summarised in Table 3.

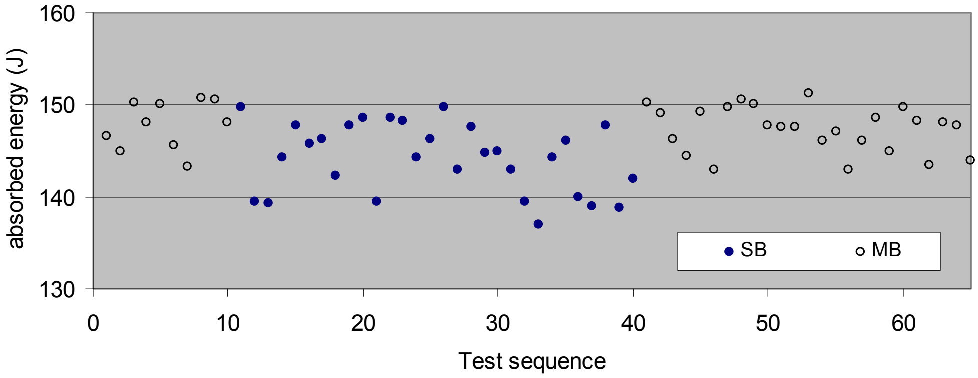

Figure 3: Absorbed energy values of the 30 test pieces of ERM®-FA415k and 35 test pieces of ERM®-FA415b displayed in the actual test sequence.

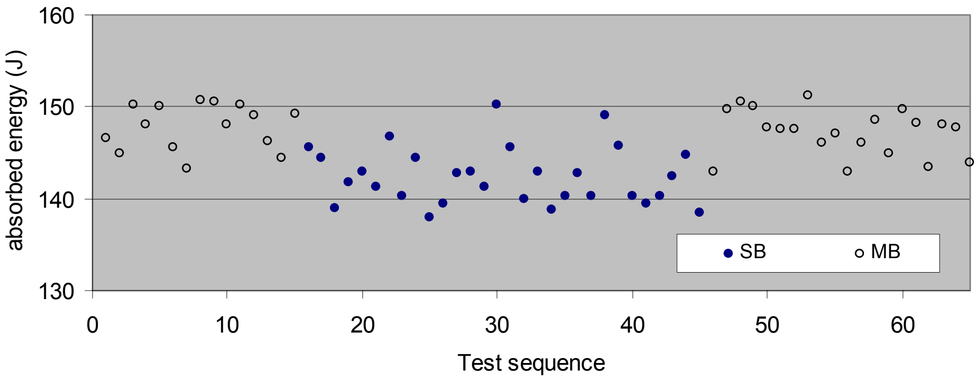

Figure 4: Absorbed energy values of the 30 test pieces of ERM®-FA415l and 35 test pieces of ERM®-FA415b displayed in the actual test sequence.

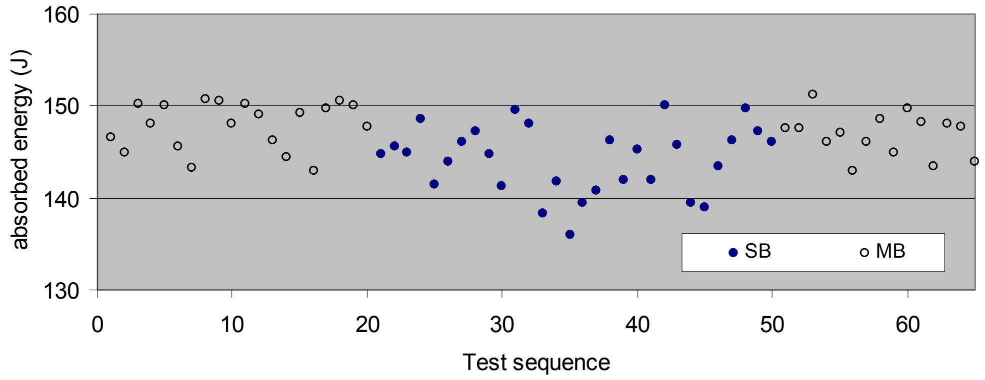

Figure 5: Absorbed energy values of the 30 test pieces of ERM®-FA415m and 35 test pieces of ERM®-FA415b displayed in the actual test sequence.

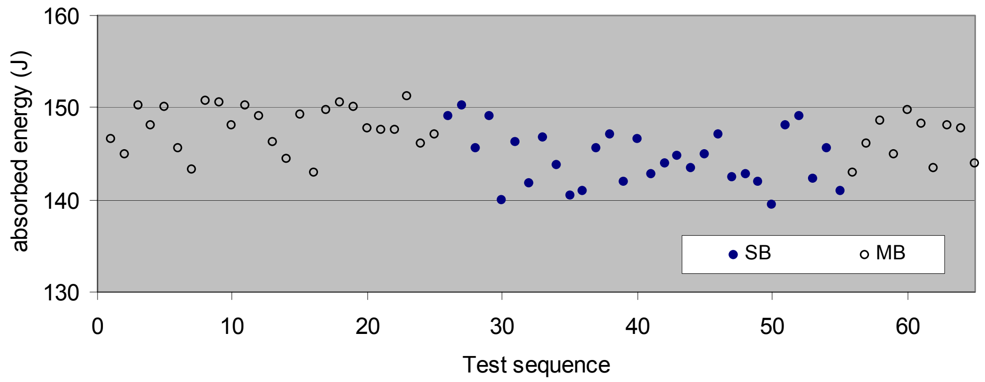

Figure 6: Absorbed energy values of the 30 test pieces of ERM®-FA415n and 35 test pieces of ERM®-FA415b displayed in the actual test sequence.

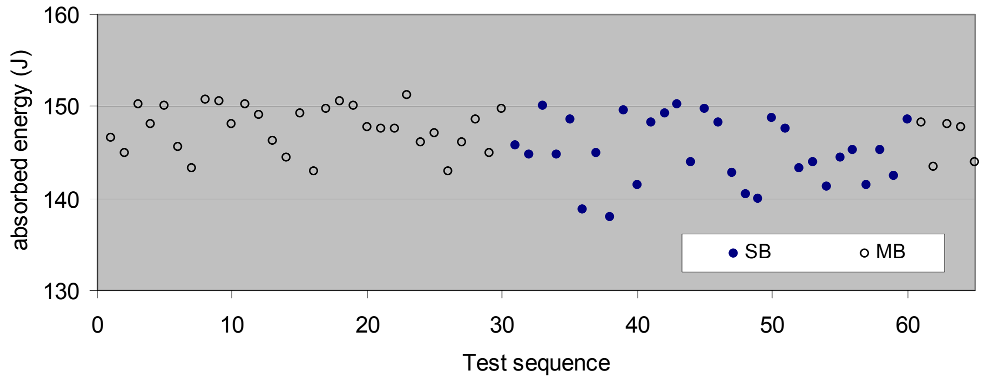

Figure 7: Absorbed energy values of the 30 test pieces of ERM®-FA415o and 35 test pieces of ERM®-FA415b displayed in the actual test sequence.

Table 3: Characterisation measurements of Batches ERM®-FA415k-l-m-n-o.

	Number of test pieces n_{MB} or n_{SB}	**Mean value** $\overline{X}_{MB}$, $\overline{X}_{SB}$ (J)	**Standard deviation** s_{MB} , s_{SB} (J)	**Relative standard deviation** RSD (%)
ERM®-FA415b (MB)	35	147.46	2.47	1.7
ERM®-FA415k (SB)	30	144.17	3.75	2.6
ERM®-FA415l (SB)	30	142.41	3.10	2.2
ERM®-FA415m (SB)	30	144.16	3.64	2.5
ERM®-FA415n (SB)	30	144.48	2.98	2.1
ERM®-FA415o (SB)	30	145.06	3.57	2.5

The relative standard deviations of the 30 SB-results (between 2.1 % and 2.6 %) meet the EN 10045-2 and ISO 148-3 acceptance criteria for a batch of reference materials (s_{SB} < 5 %), as well as the more stringent acceptance criterion (s_{SB} < 3 %) contractually fixed between IRMM and its sample supplier. In addition, the difference between $\overline{X}_{MB}$ and $\overline{X}_{SB}$ is smaller than 20 %, the level used to assess the similarity of Master Batch and Secondary Batch behaviour (see 2.2).

5.2 Data from Master Batch ERM®-FA415b

To calculate KV_{CRM} for ERM®-FA415j one needs KV_{MB} of the MB used, i.e. ERM®-FA415b. Table 4 shows the main MB-data, taken from the Certificate of Analysis of ERM®-FA415b (Annex 2), which is the revised, ERM®-version of the originally issued certificate, based on the certification report of the MB [7]. The certified value was obtained from an interlaboratory comparison with 9 laboratories.

Table 4: Data from the certification of Master Batch ERM®-FA415b [6].

	Certified absorbed energy of Master Batch KV_{MB} (J)	**Standard uncertainty of KV_{MB}** u_{MB} (J)	**Standard uncertainty of KV_{MB}** u_{MB} (%)
ERM®-FA415b	152.4	1.1	0.7

The values KV_{MB} (Table 4) and $\overline{X}_{MB}$ (Table 3) are less than 5 % different, confirming that the pendulum used for the characterisation of the secondary batch is functioning with a sufficiently low bias (see 2.2).

5.3 *Calculation of KV_{CRM} and of u_{char}*

From the data in Table 3 and Table 4, and using Eq. 1, one readily obtains KV_{CRM}. The results are summarised in Table 5.

Table 5: Results of the calculation of KV_{CRM} from Eq. 1.

	ERM®-FA415k	ERM®-FA415l	ERM®-FA415m	ERM®-FA415n	ERM®-FA415o
KV_{CRM} (J)	149.0	147.2	149.0	149.3	149.9

The uncertainty associated with the characterisation of the SB, u_{char}, is assessed as in Eq. 2 [10], which sums the relative uncertainties of the three factors appearing in Eq. 1:

$$u_{\text{char}} = KV_{\text{CRM}} \sqrt{\frac{u_{\text{MB}}{}^2}{KV_{\text{MB}}^2} + \frac{s_{\text{SB}}^2}{n_{\text{SB}} \cdot \overline{X}_{\text{SB}}^2} + \frac{s_{\text{MB}}^2}{n_{\text{MB}} \cdot \overline{X}_{\text{MB}}^2}} \qquad \text{Eq. 2}$$

$\overline{X}_{\text{SB}}$ and $\overline{X}_{\text{MB}}$ were obtained under repeatability conditions. Therefore, the uncertainty of the ratio $\overline{X}_{\text{SB}} / \overline{X}_{\text{MB}}$ is not affected by the contributions from reproducibility and bias of the pendulum used to compare MB and SB.

Table 6 to 10 summarise the input quantities of the u_{char} uncertainty budget, their respective statistical properties, and show how they were combined. The effective number of degrees of freedom for u_{char} is obtained using the Welch-Satterthwaite equation [8].

Table 6: Uncertainty budget for u_{char} of ERM®-FA415k

symbol	measured value (J)	source of uncertainty	uncertainty value (J)	probability distribution	divisor	sensitivity coefficient	relative standard uncertainty (%)	degrees of freedom
KV_{MB}	152.4	certification of MB	1.1	Normal	1	1	0.72	8
$\overline{X}_{\text{SB}}$	144.17	comparison of SB and MB in repeatability conditions	0.68	Normal	1	1	0.47	29
$\overline{X}_{\text{MB}}$	147.46		0.42	normal	1	1	0.28	34
						u_{char} (%)	0.91	19
						u_{char} (J)	1.35	

[1] Divisor: number used to calculate standard uncertainty from non-standard-uncertainty expression of uncertainty (e.g.: coverage factor to adapt expanded uncertainty to standard uncertainty, or factor to transform bounds of rectangular distribution into standard uncertainty of equivalent normal distribution).
[2] Sensitivity coefficient: partial derivative $\partial f / \partial x_i$ describing how an output estimate (here KV_{CRM}) varies with changes in the values of input estimates (here KV_{MB}, $\overline{X}_{\text{SB}}$ and $\overline{X}_{\text{MB}}$). If the functional relationship is a product or quotient, as in Eq. 1, it is advantageous to combine relative instead of absolute standard uncertainties, as in this case the sensitivity coefficients are equal to 1 [12]; this has been done here.

Table 7: Uncertainty budget for u_{char} of ERM®-FA415l

symbol	measured value (J)	source of uncertainty	uncertainty value (J)	probability distribution	divisor	sensitivity coefficient	relative standard uncertainty (%)	degrees of freedom
KV_{MB}	152.4	certification of MB	1.1	normal	1	1	0.72	8
$\overline{X}_{SB}$	142.41	comparison of SB and MB in repeatability conditions	0.57	normal	1	1	0.40	29
$\overline{X}_{MB}$	147.46		0.42	normal	1	1	0.28	34
						u_{char} (%)	0.87	16
						u_{char} (J)	1.28	

[1] Divisor: number used to calculate standard uncertainty from non-standard-uncertainty expression of uncertainty (e.g.: coverage factor to adapt expanded uncertainty to standard uncertainty, or factor to transform bounds of rectangular distribution into standard uncertainty of equivalent normal distribution).
[2] Sensitivity coefficient: partial derivative $\partial f / \partial x_i$ describing how an output estimate (here KV_{CRM}) varies with changes in the values of input estimates (here KV_{MB}, $\overline{X}_{SB}$ and $\overline{X}_{MB}$). If the functional relationship is a product or quotient, as in Eq. 1, it is advantageous to combine relative instead of absolute standard uncertainties, as in this case the sensitivity coefficients are equal to 1 [12]; this has been done here.

Table 8: Uncertainty budget for u_{char} of ERM®-FA415m

symbol	measured value (J)	source of uncertainty	uncertainty value (J)	probability distribution	divisor	sensitivity coefficient	relative standard uncertainty (%)	degrees of freedom
KV_{MB}	152.4	certification of MB	1.1	normal	1	1	0.72	8
$\overline{X}_{SB}$	144.16	comparison of SB and MB in repeatability conditions	0.66	normal	1	1	0.46	29
$\overline{X}_{MB}$	147.46		0.42	normal	1	1	0.28	34
						u_{char} (%)	0.90	18
						u_{char} (J)	1.34	

[1] Divisor: number used to calculate standard uncertainty from non-standard-uncertainty expression of uncertainty (e.g.: coverage factor to adapt expanded uncertainty to standard uncertainty, or factor to transform bounds of rectangular distribution into standard uncertainty of equivalent normal distribution).
[2] Sensitivity coefficient: partial derivative $\partial f / \partial x_i$ describing how an output estimate (here KV_{CRM}) varies with changes in the values of input estimates (here KV_{MB}, $\overline{X}_{SB}$ and $\overline{X}_{MB}$). If the functional relationship is a product or quotient, as in Eq. 1, it is advantageous to combine relative instead of absolute standard uncertainties, as in this case the sensitivity coefficients are equal to 1 [12]; this has been done here.

Table 9: Uncertainty budget for u_{char} of ERM®-FA415n

symbol	measured value (J)	source of uncertainty	uncertainty value (J)	probability distribution	divisor	sensitivity coefficient	relative standard uncertainty (%)	degrees of freedom
KV_{MB}	152.4	certification of MB	1.1	normal	1	1	0.72	8
$\overline{X}_{SB}$	144.48	comparison of SB and MB in repeatability conditions	0.54	normal	1	1	0.38	29
$\overline{X}_{MB}$	147.46		0.42	normal	1	1	0.28	34
						u_{char} (%)	0.86	15
						u_{char} (J)	1.29	

[1] Divisor: number used to calculate standard uncertainty from non-standard-uncertainty expression of uncertainty (e.g.: coverage factor to adapt expanded uncertainty to standard uncertainty, or factor to transform bounds of rectangular distribution into standard uncertainty of equivalent normal distribution).
[2] Sensitivity coefficient: partial derivative $\partial f / \partial x_i$ describing how an output estimate (here KV_{CRM}) varies with changes in the values of input estimates (here KV_{MB} , $\overline{X}_{SB}$ and $\overline{X}_{MB}$). If the functional relationship is a product or quotient, as in Eq. 1, it is advantageous to combine relative instead of absolute standard uncertainties, as in this case the sensitivity coefficients are equal to 1 [12]; this has been done here.

Table 10: Uncertainty budget for u_{char} of ERM®-FA415o

symbol	measured value (J)	source of uncertainty	uncertainty value (J)	probability distribution	divisor	sensitivity coefficient	relative standard uncertainty (%)	degrees of freedom
KV_{MB}	152.4	certification of MB	1.1	normal	1	1	0.72	8
$\overline{X}_{SB}$	145.06	comparison of SB and MB in repeatability conditions	0.65	normal	1	1	0.45	29
$\overline{X}_{MB}$	147.46		0.42	normal	1	1	0.28	34
						u_{char} (%)	0.90	18
						u_{char} (J)	1.34	

[1] Divisor: number used to calculate standard uncertainty from non-standard-uncertainty expression of uncertainty (e.g.: coverage factor to adapt expanded uncertainty to standard uncertainty, or factor to transform bounds of rectangular distribution into standard uncertainty of equivalent normal distribution).
[2] Sensitivity coefficient: partial derivative $\partial f / \partial x_i$ describing how an output estimate (here KV_{CRM}) varies with changes in the values of input estimates (here KV_{MB} , $\overline{X}_{SB}$ and $\overline{X}_{MB}$). If the functional relationship is a product or quotient, as in Eq. 1, it is advantageous to combine relative instead of absolute standard uncertainties, as in this case the sensitivity coefficients are equal to 1 [12]; this has been done here.

6 Homogeneity

The test pieces constituting a CRM unit are sampled from the SB, which is sufficiently homogeneous (s_{SB} < 5 %, as required in EN 10045-2 [1] and ISO 148-3 [11]), but not perfectly homogeneous. Therefore, as for most reference materials, a separate homogeneity contribution u_h to the uncertainty of the certified value is required.

Here, u_h is estimated from s_{SB}, the standard deviation of the results shown in Table 3. As is required for a homogeneity test, the samples were randomly selected from the whole batch. The number of samples tested (30) is largely sufficient to reflect the homogeneity of the full SBs (nominal batch sizes 450 samples).

The effect of s_{SB} on the uncertainty of the certified value depends on the number of samples over which the KV-value is averaged. EN 10045-2 [1] and in ISO 148-2 [2] specify that pendulum 'indirect verification' with CRMs must be performed using 5 test pieces. Therefore, a CRM-unit consists of 5 test pieces, and $u_h = \frac{s_{SB}}{\sqrt{5}}$. u_h is probably a slight overestimation, since it contains also the repeatability of the instrument. However, the latter cannot be separated or separately measured. The u_h values are reported for each batch in Table 11 to 15.

7 Stability

Microstructural stability of the certified reference test pieces is obtained by the annealing treatment to which the samples were subjected after the austenisation treatment. Annealing is performed at temperatures where the equilibrium phases are the same as the (meta-)stable phases at ambient temperature (α-Fe and Fe_3C). The only driving force for instability stems from the difference in solubility of interstitial elements in the α-Fe matrix, between annealing and ambient temperature. Relaxation of residual (micro-)stress by short-range diffusion or the additional formation or growth of precipitates during the shelf-life of the certified reference test pieces is expected to proceed but slowly. Given the large sample-to-sample heterogeneity, the ageing effects are undetectable when testing limited numbers of samples, and the uncertainty contribution from instability is considered to be insignificant. Until further notice, it is decided to specify a limited shelf-life. A period of 10 years is chosen, counting from the date of the characterisation tests on the SB. Since the batches ERM®-FA415k-l-m-n-o were characterised in November, 1999, the validity of the respective certificates stretches until November, 2009. This validity may be extended as further evidence of stability becomes available.

Rather than neglecting the stability issue, efforts are spent to better establish the stability of the certified values of batches of Charpy CRMs. The stability of the absorbed energy of Charpy V-notch certified reference test pieces was first systematically investigated for samples of nominally 120 J by Pauwels et al., who did not observe measurable changes of absorbed energy over 18 months at temperatures up to 90 °C [13]. New evidence for the stability of the reference test pieces produced from AISI 4340 steel of other energy levels (nominally 15 J, 30 J and 100 J) has been obtained recently, during the International Master Batch (IMB) project [14]. In the IMB-project, the stability of the certified test pieces is confirmed by the unchanged value of the mean of means of the absorbed energy obtained on 7 reference pendulums over a three year period.

8 Evaluation of results

8.1 Calculation of certified value, combined and expanded uncertainty

The model used to calculate the certified value is explained in ISO Guide 35 [15], and consists of correcting the KV-value obtained during the characterisation with error terms assessed during homogeneity and stability tests. While the values of these error terms are most often zero, their uncertainties are most often not.

In the case of ERM®-FA415k-l-m-n-o, the error terms are zero (the KV_{CRM} values are reported in Section 5.3). While the uncertainty contribution from stability is assumed negligible (see Section 7), the uncertainty of the homogeneity error term is not zero. Therefore, the uncertainty of the certified value is obtained by combining the contributions from the characterisation study, u_{char}, and from the homogeneity assessment, u_h. Since the functional relationship between the certified value and the error terms is an addition, the sensitivity coefficients of the different terms are all unity. Therefore, the absolute values of these contributions can directly be combined (square root of sum of squares) [12]. This approach is summarized in the uncertainty budgets shown in Table 11 to Table 15.

Table 11: Uncertainty budget of KV_{CRM} for ERM®-FA415k

symbol	source of uncertainty	absolute value (J)	Divisor	sensitivity coefficient	u_i (J)	degrees of freedom
u_{char}	characterisation of SB	1.35	1	1	1.35	19
u_h	homogeneity of SB	1.68	1	1	1.68	29
				Combined standard uncertainty, u_{CRM}	2.15 J	47
				Expanded Uncertainty, k = 2, U_{CRM}	4.4 J	ν_{eff}

[1] Divisor: number used to calculate standard uncertainty from non-standard-uncertainty expression of uncertainty (see Table 4).
[2] Sensitivity coefficient: partial derivative $\partial f / \partial x_i$ describing how the output estimate (here u_{CRM}) varies with changes in the values of the input estimates (here u_{char} and u_h), evaluated at their actual values. Since the functional relationship between certified value and the characterisation, stability and homogeneity terms, is an addition, the sensitivity coefficients are equal to 1.

Table 12: Uncertainty budget of KV_{CRM} for ERM®-FA415l

symbol	source of uncertainty	absolute value (J)	Divisor	sensitivity coefficient	u_i (J)	degrees of freedom
u_{char}	characterisation of SB	1.28	1	1	1.28	16
u_h	homogeneity of SB	1.39	1	1	1.39	29
Combined standard uncertainty, u_{CRM}					1.89 J	42
Expanded Uncertainty, k = 2, U_{CRM}					3.8 J	ν_{eff}

[1] Divisor: number used to calculate standard uncertainty from non-standard-uncertainty expression of uncertainty (see Table 4).
[2] Sensitivity coefficient: partial derivative $\partial f / \partial x_i$ describing how the output estimate (here u_{CRM}) varies with changes in the values of the input estimates (here u_{char} and u_h), evaluated at their actual values. Since the functional relationship between certified value and the characterisation, stability and homogeneity terms, is an addition, the sensitivity coefficients are equal to 1.

Table 13: Uncertainty budget of KV_{CRM} for ERM®-FA415m

symbol	source of uncertainty	absolute value (J)	Divisor	sensitivity coefficient	u_i (J)	degrees of freedom
u_{char}	characterisation of SB	1.34	1	1	1.34	18
u_h	homogeneity of SB	1.63	1	1	1.63	29
Combined standard uncertainty, u_{CRM}					2.11 J	46
Expanded Uncertainty, k = 2, U_{CRM}					4.3 J	ν_{eff}

[1] Divisor: number used to calculate standard uncertainty from non-standard-uncertainty expression of uncertainty (see Table 4).
[2] Sensitivity coefficient: partial derivative $\partial f / \partial x_i$ describing how the output estimate (here u_{CRM}) varies with changes in the values of the input estimates (here u_{char} and u_h), evaluated at their actual values. Since the functional relationship between certified value and the characterisation, stability and homogeneity terms, is an addition, the sensitivity coefficients are equal to 1.

Table 14: Uncertainty budget of KV_{CRM} for ERM®-FA415n

symbol	source of uncertainty	absolute value (J)	divisor	sensitivity coefficient	u_i (J)	degrees of freedom
u_{char}	characterisation of SB	1.29	1	1	1.29	15
u_h	homogeneity of SB	1.33	1	1	1.33	29
Combined standard uncertainty, u_{CRM}					1.85 J	40
Expanded Uncertainty, k = 2, U_{CRM}					3.8 J	ν_{eff}

[1] Divisor: number used to calculate standard uncertainty from non-standard-uncertainty expression of uncertainty (see Table 4).
[2] Sensitivity coefficient: partial derivative $\partial f / \partial x_i$ describing how the output estimate (here u_{CRM}) varies with changes in the values of the input estimates (here u_{char} and u_h), evaluated at their actual values. Since the functional relationship between certified value and the characterisation, stability and homogeneity terms, is an addition, the sensitivity coefficients are equal to 1.

Table 15: Uncertainty budget of KV_{CRM} for ERM®-FA415o

symbol	source of uncertainty	absolute value (J)	divisor	sensitivity coefficient	u_i (J)	degrees of freedom
u_{char}	characterisation of SB	1.34	1	1	1.34	18
u_h	homogeneity of SB	1.59	1	1	1.59	29
				Combined standard uncertainty, u_{CRM}	2.08 J	46
				Expanded Uncertainty, k = 2, U_{CRM}	4.2 J	ν_{eff}

[1] Divisor: number used to calculate standard uncertainty from non-standard-uncertainty expression of uncertainty (see Table 4).
[2] Sensitivity coefficient: partial derivative $\partial f / \partial x_i$ describing how the output estimate (here u_{CRM}) varies with changes in the values of the input estimates (here u_{char} and u_h), evaluated at their actual values. Since the functional relationship between certified value and the characterisation, stability and homogeneity terms, is an addition, the sensitivity coefficients are equal to 1.

The relevant number of degrees of freedom calculated using the Welch-Satterthwaite equation [8], is sufficiently large (all $\nu_{eff} \geq 40$) to justify the use of a coverage factor k = 2 to expand the confidence level to about 95 %. The obtained expanded uncertainty provides justification for the SB-MB approach followed: U_{CRM} is sufficiently smaller (all ≤ 3.0 %) than the verification criterion of 10 % (for industrial pendulums [1, 2]) or even 5 % (for reference pendulums [1, 11]).

8.2 Traceability

The absorbed energy *KV* is a method-specific value, and can only be obtained by following the procedures specified in EN 10045-1 [3] and ISO 148 [4]. The certified value of the MB ERM®-FA415b is traceable to these standard procedures as it was obtained using an interlaboratory comparison, involving a representative selection of qualified laboratories performing the tests in accordance with the standard procedures.

The certified values of ERM®-FA415k-l-m-n-o are made traceable to the certified value of the MB using tests on SB and MB samples under repeatability conditions. Therefore the certified values of ERM®-FA415k-l-m-n-o are traceable to the Charpy impact test as described in EN 10045-1 and ISO 148.

8.3 Commutability

Commutability of the reference material is obtained when the pendulum response to reference samples is similar to the pendulum response to daily-life test samples. For this reason, a commercially available and significant material (ASTM 565, martensitic stainless steel) was selected as a base material.

8.4 Summary of results

The certified values and associated uncertainties are summarized in Table 16.

Table 16: Certified value and associated uncertainties for ERM®-FA415k-l-m-n-o.

	Certified mean value for set of 5 test pieces KV_{CRM} **(J)**	**Combined standard uncertainty** u_{CRM} **(J)**	**Expanded uncertainty (k = 2)** U_{CRM} **(J)**
ERM®-FA415k	149.0	2.15	4.4
ERM®-FA415l	147.2	1.89	3.8
ERM®-FA415m	149.0	2.11	4.3
ERM®-FA415n	149.3	1.85	3.8
ERM®-FA415o	149.9	2.08	4.2

9 Instructions for use

9.1 Intended use

Samples of ERM®-FA415k-l-m-n-o correspond with the '(certified) BCR test pieces' as referred to in EN 10045-2 [1], as well as with the 'certified reference test pieces' as defined in ISO 148-3 [11]. Sets of five of these certified reference test pieces are intended for the indirect verification of impact testing machines with a striker of 2 mm tip radius according to procedures described in detail in EN 10045-2 [1] and ISO 148-2 [2]. The indirect verification provides a punctual assessment of the bias of the user's Charpy pendulum impact machine.

9.2 Sample preparation

Special attention is drawn to the cleaning and conditioning of the specimens prior to testing. It is mandatory to remove the oil from the sample surface prior to testing, without damaging the edges of the sample. Between the moment of removing the protective oil layer and the actual test, corrosion can occur. Visual signs of corrosion must and can be avoided by keeping the sample clean and by limiting the time between cleaning and testing.

The following procedure is considered good practice.

1. First use absorbent cleaning-tissue to remove the excess oil. Pay particular attention to the notch of the sample, but do not use hard (e.g. steel) brushes to remove the oil from the notch.
2. Submerge the samples in ethanol for about 5 minutes. Use of ultrasonication is encouraged, but only if the edges of the samples are prevented from rubbing against each other. To reduce the consumption of solvent, it is allowed to make a first cleaning step with detergent, immediately prior to the solvent step.
3. Once samples are removed from the solvent, only manipulate the samples wearing clean gloves. This is to prevent development of corrosion between the time of cleaning and the actual test.
4. Before testing, bring the specimens to the test temperature (20 ± 2 °C). To assure thermal equilibrium is reached, move the specimens to the test laboratory at least 3 hours before the tests.

9.3 Pendulum impact tests

After cleaning, the 5 samples which together constitute one CRM-unit, need to be broken with a pendulum impact test machine in accordance with EN 10045-2 [1] or ISO 148-2 [2] standards. Prior to the tests, the anvils must be cleaned. It must be noted that Charpy test pieces sometimes leave debris on the Charpy pendulum anvils. Therefore, the anvils must be checked regularly and if debris is found, it must be removed.

The comparison of the indirect verification results with the certified value and uncertainty must be based on the mean of the 5 measured *KV* values, because the calculation of the uncertainty of the certified value is based on this sample size.

10 Acknowledgements

The authors wish to thank D. Charels (IRMM), P. Corbisier (IRMM) and H. Emons (IRMM) for reviewing the certification report.

11 References

1. *EN 10045-2: 1992 - Metallic Materials - Charpy impact test - Part 2: Verification of the testing machine (pendulum impact)*, European Committee for Standardization: Brussels (1993).
2. *ISO 148-2: Metallic materials - Charpy pendulum impact test - Part 2: verification of test machines*, International Organization for Standardization: Genève (1998).
3. *EN 10045-1: 1989 Metallic materials - Charpy impact test - Part 1: Test method*, European Committee for Standardization: Brussels (1990).
4. *ISO 148: Steel - Charpy impact test (V-notch)*, International Standardization Organization: Genève (1983).
5. *ASTM E 23 - 02a Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*, ASTM International: West Conshohocken (2002).
6. Marchandise, H., Perez-Sainz, A, Colinet, E, *Certification of the impact toughness of V-notch Charpy specimens*, Community Bureau of Reference - BCR: Brussels (1991).
7. Varma, R.K., *The certification of two new master batches of V-notch Charpy impact toughness specimens in accordance with EN 10045-2: 1992*, Office for the Official Publications of the European Communities: Luxembourg (1999).
8. *Guide to the expression of uncertainty in measurement*, International Organization for Standardization: Genève (1998).
9. Ingelbrecht, C. and J. Pauwels, *EC Reference Materials for Impact Toughness - Traceability and uncertainty*, presented at Eurachem Eurolab symposium on Reference Materials for Technologies in the New Millennium, Berlin, May 22-23, 2000.
10. Ingelbrecht, C., J. Pauwels, and D. Gyppaz, *Charpy specimens from BCR for machine verification according to EN 10045-2*. Presented at the Charpy Centenary Conference, Poitiers, October 2-5, 2001.
11. *ISO 148-3 Metallic materials - Charpy pendulum impact test - Part 3: Preparation and characterization of Charpy V reference test pieces for verification of test machines*, International Organization for Standardization: Genève (1998).
12. UKAS, *The expression of uncertainty and confidence in measurement*, United Kingdom Accreditation Service: Feltham, Middlesex (1997).
13. Pauwels, J., Gyppaz, D., Varma, R., Ingelbrecht, C. *European certification of Charpy specimens: reasoning and observations*. in *Pendulum Impact testing: A Century of Progress*. Ed. Siewert, T. A., Manahan, M. P. Sr. Seattle, Washington: American Society for Testing and Materials (1999).
14. McCowan, C.N., Roebben, G., Yamaguchi, Y., Lefrançois, S., Splett, J. D., Takagi, S., Lamberty, A., *International Comparison of Impact Reference Materials (2004).* J. ASTM International, Vol. 3 (2), (2006).
15. *ISO Guide 35: Reference Materials - General and statistical principles for certification*. International Organization for Standardization: Geneva (2005).

Annex 1

Results of characterisation measurements of ERM®-FA415k-l-m-n-o measured according to EN 10045-1 and ISO 148 (Cogne, 29/11/1999).

	Master Batch	**Secondary Batches**				
	ERM®-FA415b	**ERM®-FA415k**	**ERM®-FA415l**	**ERM®-FA415m**	**ERM®-FA415n**	**ERM®-FA415o**
	***KV* (J)**	***KV* (J)**	***KV* (J)**	***KV* (J)**	***KV* (J)**	***KV* (J)**
1	146.50	149.75	145.50	144.75	149.00	145.75
2	145.00	139.50	144.50	145.50	150.25	144.75
3	150.25	139.25	139.00	145.00	145.50	150.00
4	148.00	144.25	141.75	148.50	149.00	144.75
5	150.00	147.75	143.00	141.50	140.00	148.50
6	145.50	145.75	141.25	144.00	146.25	138.75
7	143.25	146.25	146.75	146.00	141.75	145.00
8	150.75	142.25	140.25	147.25	146.75	138.00
9	150.50	147.75	144.50	144.75	143.75	149.50
10	148.00	148.50	138.00	141.25	140.50	141.50
11	150.25	139.50	139.50	149.50	141.00	148.25
12	149.00	148.50	142.75	148.00	145.50	149.25
13	146.25	148.25	143.00	138.25	147.00	150.25
14	144.50	144.25	141.25	141.75	142.00	144.00
15	149.25	146.25	150.25	136.00	146.50	149.75
16	143.00	149.75	145.50	139.50	142.75	148.25
17	149.75	143.00	140.00	140.75	144.00	142.75
18	150.50	147.50	143.00	146.25	144.75	140.50
19	150.00	144.75	138.75	142.00	143.50	140.00
20	147.75	145.00	140.25	145.25	145.00	148.75
21	147.50	143.00	142.75	142.00	147.00	147.50
22	147.50	139.50	140.25	150.00	142.50	143.25
23	151.25	137.00	149.00	145.75	142.75	144.00
24	146.00	144.25	145.75	139.50	142.00	141.25
25	147.00	146.00	140.25	139.00	139.50	144.50
26	143.00	140.00	139.50	143.50	148.00	145.25
27	146.00	139.00	140.25	146.25	149.00	141.50
28	148.50	147.75	142.50	149.75	142.25	145.25
29	145.00	138.75	144.75	147.25	145.50	142.50
30	149.75	142.00	138.50	146.00	141.00	148.50
31	148.25					
32	143.50					
33	148.00					
34	147.75					
35	144.00					
Mean (J)	**147.46**	**144.17**	**142.41**	**144.16**	**144.48**	**145.06**
Standard deviation (J)	**2.47**	**3.75**	**3.10**	**3.64**	**2.98**	**3.57**
***RSD* (%)**	**1.7**	**2.6**	**2.2**	**2.5**	**2.1**	**2.5**

Annex 2

Institute for Reference Materials and Measurements

European Reference Materials

CERTIFICATE OF ANALYSIS

ERM®- FA415b

Steel Charpy V-notch test pieces (nominal absorbed energy[1)] 150 J, Master Batch)		
Parameter	Certified value [2)] (J)	Uncertainty [3)] (J)
Absorbed energy (KV) at 20 ± 2 °C, according to EN 10045-1 and ISO 148	152.4	1.1

1) The term absorbed energy is defined in EN 10045-1 and ISO 148 and refers to the impact energy required to break a V-notched bar of standardised dimensions.

2) Mean absorbed energy of test pieces from batch ERM®-FA415b. The certified value was obtained as the mean of means of absorbed energies measured at 9 laboratories. At each laboratory, 10 test pieces were broken. The certified value is traceable to the Charpy impact test method as described in EN 10045-1 and ISO 148. The certified value is valid only for impact hammers with a 2 mm striker tip radius.

3) Half-width of the 68 % confidence interval of the mean absorbed energy defined in 2), estimated as $\frac{\sigma_m}{\sqrt{9}}$, with σ_m the standard deviation of the mean of the mean values obtained at the 9 participating laboratories.

This certificate is valid until October 2009; this validity may be extended as further evidence of stability becomes available.

NOTE

European Reference Material ERM®-FA415b was originally certified as BCR-415 B. It was produced and certified under the responsibility of IRMM according to the principles laid down in the technical guidelines of the European Reference Materials® co-operation agreement between BAM-IRMM-LGC. Information on these guidelines is available on the Internet (http://www.erm-crm.org).

Accepted as an ERM®, Geel, July 2005

Signed:

Prof. Dr. Hendrik Emons
Unit for Reference Materials
EC - JRC - IRMM
Retieseweg 111
2440 Geel, Belgium

All following pages are an integral part of the certificate.

DESCRIPTION OF THE SAMPLE

A unit consists of five Charpy V-notch test pieces, which are rectangular steel bars of nominal dimensions 55 mm x 10 mm x 10 mm, with one V-notch, accurately machined to tolerances imposed in EN 10045-1 and ISO 148. The five specimens are packed together in a plastic bag filled with oil to prevent oxidation.

INSTRUCTIONS FOR USE

The ERM-FA415b batch is intended to be used as a 'Master Batch'. Master Batch test pieces are not for sale. They are used to traceably certify Secondary Batches of Charpy V-notch reference test pieces of the same type of steel with the same nominal absorbed energy (here 150 J).

To characterise a secondary batch, a selection of samples from the secondary batch have to be broken under repeatability conditions together with Master Batch test pieces. The certified value of the Master Batch and its associated uncertainty are used in the calculation of the certified value and its combined and expanded uncertainty of a set of 5 specimens from a Secondary Batch. Sets of 5 samples of Secondary Batches are distributed as certified reference test pieces for the verification of Charpy impact test machines in accordance with EN 10045-2 and ISO 148-2.

Special attention is drawn to cleaning and conditioning of the specimens prior to testing. The following procedure is recommended:

1. Wipe excess oil from the specimens with cellulose paper.

2. Immerse the specimens in a clean bath of degreasing solvent for about 5 min.

3. Wipe the specimens with cellulose paper and let dry.

4. Before testing, bring the specimens to the test temperature (20 ± 2 °C). To assure thermal equilibrium is reached, move the specimens to the test laboratory at least 12 h before the tests.

After cleaning, the user must avoid touching the specimens with the fingers (wear clean gloves). Vigorous cleaning methods affecting the roughness of the specimen surface or possibly causing deformation or indentation of the specimen edges should be avoided, as this can result in obtaining erroneous data.

The cleaned samples need to be broken with an impact pendulum in accordance with EN 10045-1 or ISO 148 standards.

Unlike Charpy test pieces of lower nominal impact energies, samples from ERM-FA415 batches sometimes leave debris on the Charpy pendulum anvils. Therefore, after each impact, the anvils must be checked and if debris is found, it must be removed.

After testing, the user is recommended to inspect the traces/imprints left behind by the anvils and hammer on the two halves of the broken specimen. Asymmetry of these marks can indicate problems with the machine geometry or the positioning of the sample prior to impact. If so desired, broken samples can be stored for later inspection of the anvil and striker marks.

STORAGE

Specimens should be kept at ambient temperature in their original packing until used. The European Commission cannot be held responsible for changes that happen during storage of the material at the customer's premises, especially of opened samples.

SAFETY INFORMATION

Precautions need to be taken to avoid injury of the operator by broken specimens when operating the Charpy impact pendulum.

METHOD USED FOR CERTIFICATION

Charpy pendulum impact tests in accordance with EN 10045-1 and ISO 148, using pendulum impact machines with a 2 mm striker tip radius.

PARTICIPANTS

- Ansaldo Energia S.p.A., Legnano (IT)
- Bundesanstalt für Materialforschung und –prüfung (BAM), Berlin (DE)
- Cogne Acciai Speciali srl, Aosta (IT)
- Inco Test, Hereford (UK)
- Instron Ltd., High Wycombe (UK)
- Instituto de Soldadura e Qualidade (ISQ), Oeiras (PT)
- Laboratoire National d'Essais (LNE), Trappes (FR)
- Lloyd's Register, Croydon (UK)
- National Institute of Standards and Technology (NIST), Boulder, CO (US)
- National Physical Laboratory (NPL), Teddington (UK)
- Rolls Royce Ltd., Derby (UK)
- Studiecentrum voor Kernenergie (SCK•CEN), Mol (BE)
- Universidad Carlos III, Madrid (ES)

LEGAL NOTICE

NOTE

A detailed technical report of the Master Batch certification project ("The certification of two new Master Batches of V-notch Charpy impact toughness specimens in accordance with EN 10045-2: 1992", R. K. Varma, bcr information, EUR 18947 EN, 1999) can be obtained from IRMM on explicit request. In this report, the ERM-FA415b batch is called 'CRM 415 B'.

European Commission – Joint Research Centre
Institute for Reference Materials and Measurements (IRMM)
Retieseweg 111, B - 2440 Geel (Belgium)
Telephone: +32-14-571.722 - Telefax: +32-14-590.406

European Commission

EUR 22699 EN – DG Joint Research Centre, Institute for Reference Materials and Measurements –
Certification of charpy V-notch reference test pieces of 150 J nominal absorbed energy, ERM®-FA415k, ERM®-FA415l, ERM®-FA415m, ERM®-FA415n, ERM®-FA415o
*Authors :*G. Roebben, A. Lamberty
Luxembourg: Office for Official Publications of the European Communities
2007 – 33 pp. – 21.0 x 29.7 cm
EUR - Scientific and Technical Research series; ISSN 1018-5593
ISBN 978-92-79-05220-0

Abstract

This certification report describes the processing and characterisation of ERM®-FA415k, ERM®-FA415l, ERM®-FA415m, ERM®-FA415n, and ERM®-FA415o, five batches of Charpy V-notch certified reference test pieces. Sets of five of these test pieces are used for the verification of pendulum impact test machines according to EN 10045-2 (Charpy impact test on metallic materials, Part 2. Method for the verification of impact testing machines [1]) or according to ISO 148-2 (Metallic materials - Charpy pendulum impact test – Part 2: Verification of test machines [2]). The certified value for *KV* (= energy required to break a V-notched test piece using a pendulum impact test machine) and the associated uncertainty (*k* = 2 corresponding to a confidence level of 95 %) calculated for the mean of a set of five test pieces, are:

Batch-code	Certified KV-value	Expanded uncertainty (k=2, 95 % confidence level)
ERM®-FA415k	149.0	4.4
ERM®-FA415l	147.2	3.8
ERM®-FA415m	149.0	4.3
ERM®-FA415n	149.3	3.8
ERM®-FA415o	149.9	4.2

The certified values are traceable to the Charpy impact test method as described in EN 10045-1 [3] and ISO 148 [4], via the corresponding Master Batch ERM®-FA415b of the same nominal absorbed energy (150 J).

ERM®-FA415k, ERM®-FA415l, ERM®-FA415m, ERM®-FA415n, and ERM®-FA415o have been accepted as European Reference Material® (ERM®) after successful peer evaluation by the partners of the European Reference Materials consortium.

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

The mission of the Joint Research Centre is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of European Union policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Community. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

15 LA-NA-22699-EN-C

Publications Office
Publications.eu.int

ISBN 978-92-79-05220-0
9 789279 052200