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THE PRODUCTION OF CALIBRATION SPECIMENS FOR IMPACT TESTING OF SUBSIZE CHARPY SPECIMENS*

David J. Alexander, William R. Corwin, and Thomas D. Owings†

Metals and Ceramics Division
Oak Ridge National Laboratory
P.o. Box 2008
Oak Ridge, Tn 37831-6151

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†Retired from Oak Ridge National Laboratory.

David J. Alexander,[1] William R. Corwin,[1] and Thomas D. Owings[2]

THE PRODUCTION OF CALIBRATION SPECIMENS FOR IMPACT TESTING OF SUBSIZE CHARPY SPECIMENS

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ABSTRACT: Calibration specimens have been manufactured for checking the performance of a pendulum impact testing machine that has been configured for testing subsize specimens, both half-size (5.0 × 5.0 × 25.4 mm) and third-size (3.33 × 3.33 × 25.4 mm). Specimens were fabricated from quenched-and-tempered 4340 steel heat treated to produce different microstructures that would result in either high or low absorbed energy levels on testing. A large group of both half- and third-size specimens were tested at −40°C. The results of the tests were analyzed for average value and standard deviation, and these values were used to establish calibration limits for the Charpy impact machine when testing subsize specimens. These average values plus or minus two standard deviations were set as the acceptable limits for the average of five tests for calibration of the impact testing machine.

KEYWORDS: impact testing, calibration, subsize specimens

Extensive characterization of the impact properties of a variety of materials is conducted at Oak Ridge National Laboratory (ORNL). Base metal, heat-affected zone, and weldments of ferritic pressure vessel steels and stainless steels are often studied, as well as newly developed alloys such as nickel and iron aluminides and low-activation ferritic/martensitic steels. The

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[1]Oak Ridge National Laboratory, Metals and Ceramics Division, 4500S, MS-6151, P.O. Box 2008, Oak Ridge, TN 37831-6151.

[2]Retired from Oak Ridge National Laboratory.

effects of irradiation on the ductile-to-brittle transition temperature and the upper-shelf energy level are also examined. To allow a greater number of specimens to be irradiated within a given capsule, subsize specimens are frequently used. In addition, these smaller specimens allow data to be produced from small heats of developmental alloys. As a result, subsize specimen testing is a significant fraction of the impact testing conducted at ORNL.

The use of these small specimens necessitates changes in the test system to accommodate the reduced specimen dimensions [1]. As a result, changes in the calibration procedures for the test machine are necessary. After the test system is set up and calibrated with full-size specimens, it must be modified with a smaller tup and relocation of the anvils to test the subsize specimens. This change in critical components of the system would raise concerns about the previous calibration. Therefore, it was decided to develop subsize calibration specimens analogous to the full-size specimens presently supplied by the National Institute for Standards and Technology (NIST) and previously supplied by the Army Materials and Mechanics Research Center (AMMRC) in Watertown, Massachusetts. Both half-size (5 × 5 × 25.4 mm long) and third-size (3.33 × 3.33 × 25.4 mm long) specimens are used in irradiation programs at ORNL. To allow equipment to be set up in a remote hot cell for the appropriate specimen size, and thus reduce the number of cell entries, calibration specimens of both sizes were fabricated.

The use of the subsize calibration specimens is not intended to serve as the primary calibration of the Charpy impact machine. That is accomplished in the usual manner as prescribed by ASTM Standard Test Methods for Notched Bar Impact Testing of Metallic Materials (E 23) using full-size calibration specimens from NIST. The original purpose and principal value of the subsize specimens is to provide a direct means of checking the reproducibility of the Charpy machine after it has been reconfigured to test subsize specimens.

EXPERIMENTAL PROCEDURE

With the aid of information supplied by AMMRC,[1] aircraft-quality vacuum arc remelted 4340 steel was selected. This steel was purchased as bars 14.3 by 14.3 mm (0.56 by 0.56 in.) that were machined into pieces 11.4 × 11.4 × 57.2 mm long (0.45 × 0.45 × 2.25 in.). The bars were the excess portion of a lot produced for AMMRC for their use in manufacturing standard full-size calibration specimens. These bars were heat treated to produce microstructures that would provide either high or low energy levels. The bars

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[1] Roy, W. N., Chief, NDT Training and Certification Office, Army Materials and Mechanics Research Center, Watertown, MA 02172, personal communication with W. R. Corwin, Oak Ridge National Laboratory, Oak Ridge, TN 37831, March 1981.

were held in wire racks so that a suitable gap was present around each bar. All of the bars were normalized for 1 h at 899°C (1650°F) followed by an air cool, and then austenitized for 1 h at 871°C (1600°F) with an oil quench. The bars for high-energy specimens were tempered for 1.25 h at 593°C (1100°F) and oil quenched. The bars for low energy specimens were tempered for 1.5 h at 399°C (750°F) and oil quenched. These heat treatments were those specified by AMMRC for their own fabrication of full-size calibration specimens.[1]

Eight specimens were sectioned from each of the heat-treated bars. The half-size specimens were 5.0 × 5.0 × 25.4 mm long (0.197 × 0.197 × 1.00 in.) with a 0.76-mm-deep (0.030-in.) 45°-included-angle notch with a 0.08-mm (0.003-in.) root radius. The third-size specimens were 3.33 × 3.33 × 25.4 mm (0.131 × 0.131 × 1.00 in.) with a 0.51-mm-deep (0.020-in.) 30°-included-angle notch with a 0.08-mm (0.003-in.) root radius.

In order to verify the performance of the testing system, the calibration of the impact tester was checked with full-size specimens supplied by AMMRC. The anvils and tup were then changed to allow subsize specimens to be tested [1]. Fifty low-energy and fifty-one high-energy half-size specimens were tested, with twenty-five each of the third-size high- and low-energy specimens. Specimens were tested in a semiautomated test system adapted for testing subsize specimens [1,2]. The testing machine had a capacity of 407 J (300 ft-lb). The absorbed energies were indicated by a digital readout and recorded to the nearest 0.1 ft-lb. All data were originally recorded in English units, and have been converted to metric values. Gas from liquid nitrogen was used for cooling. Specimens were tested at −40°C, as are full-size specimens. The subsize specimens were slightly undercooled to compensate for their rapid warming during the interval between their removal from the cooling chamber and the hammer impact (less than 5 s), based on temperature readings taken on dummy specimens instrumented with surface and buried thermocouples.

RESULTS

The results of the testing are shown in Figs. 1 and 2 as histograms for the half- and third-size specimens, respectively, and are summarized in Table 1. The data have been plotted in columns of equal width to allow a fair comparison of the histograms. Since twice as many half-size as third-size specimens were tested, the vertical axes for the half-size specimens have been doubled.

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[1]Roy, W. N., Chief, NDT Training and Certification Office, Army Materials and Mechanics Research Center, Watertown, MA 02172, personal communication with W. R. Corwin, Oak Ridge National Laboratory, Oak Ridge, TN 37831, March 1981.

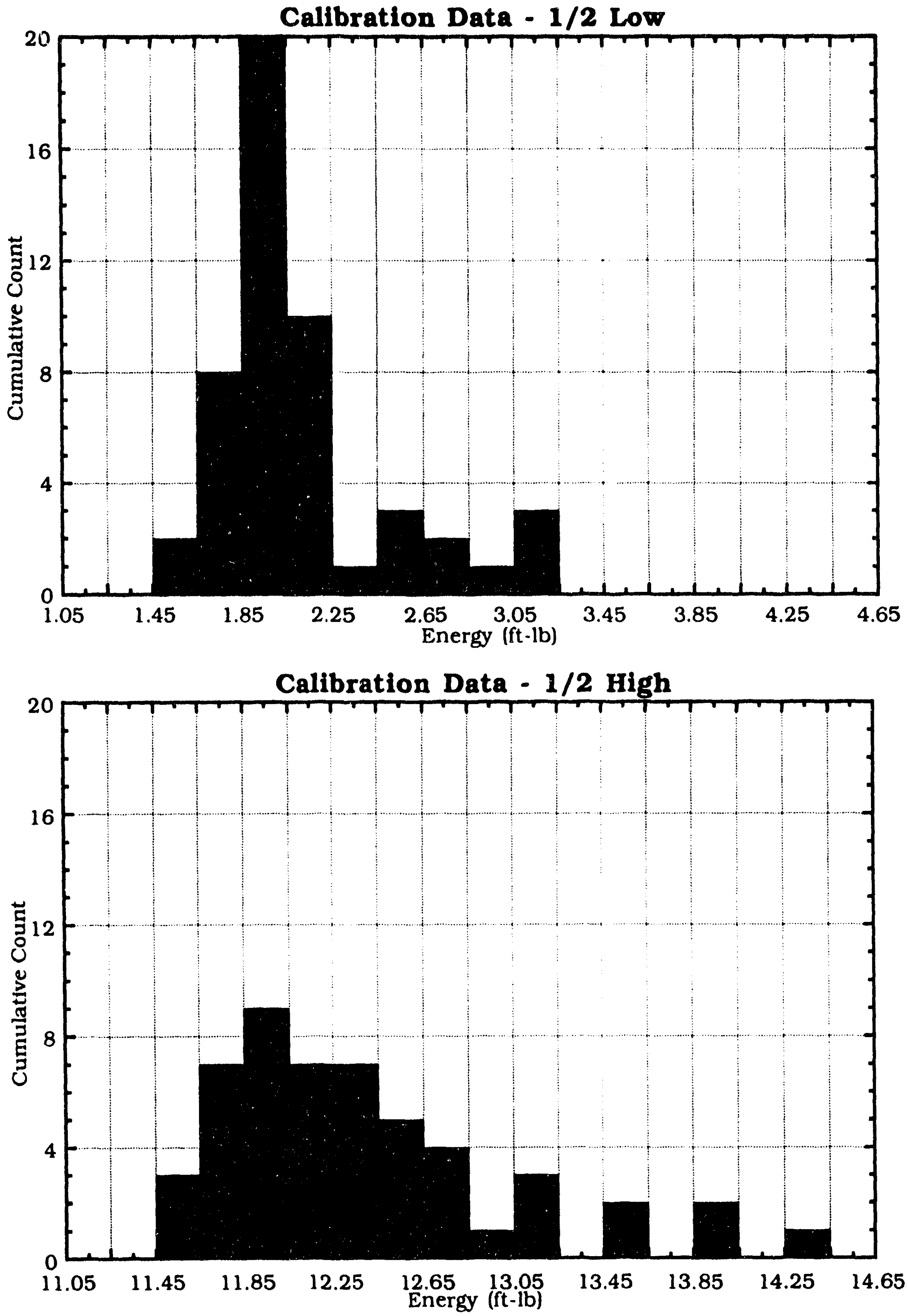
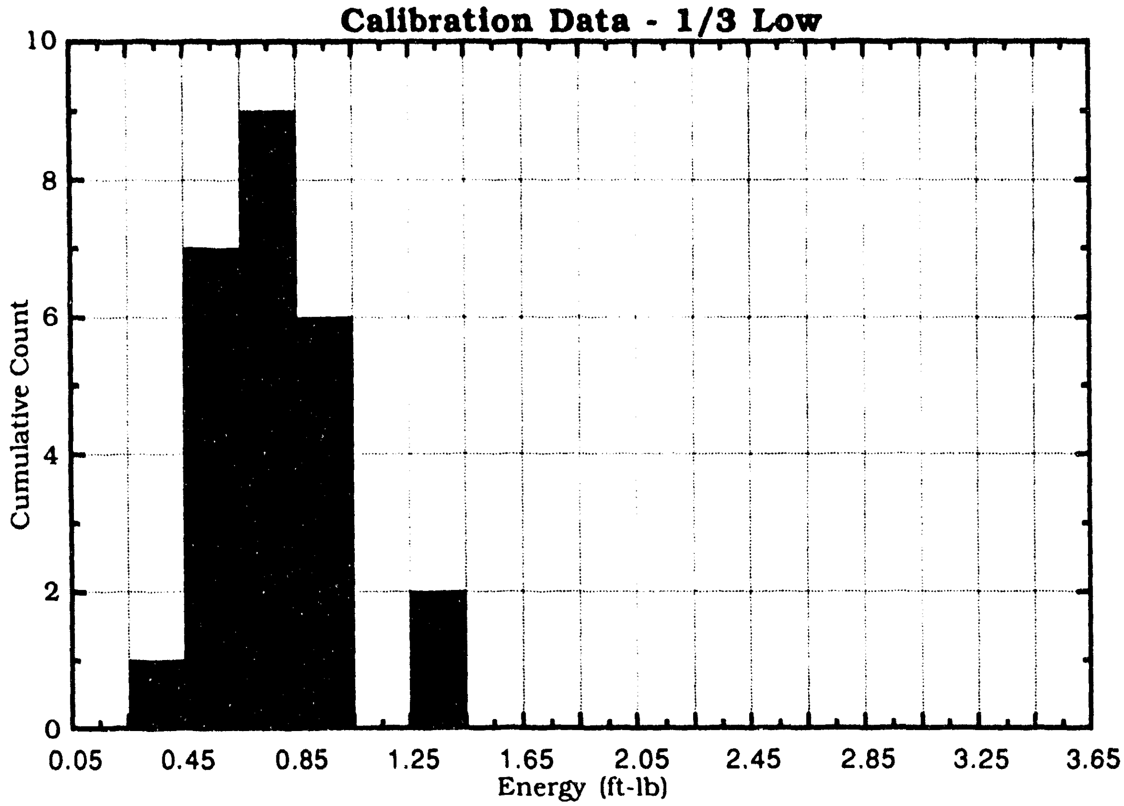


Fig. 1. Results from testing of half-size calibration specimens. Top: low-energy specimens. Bottom: high-energy specimens.



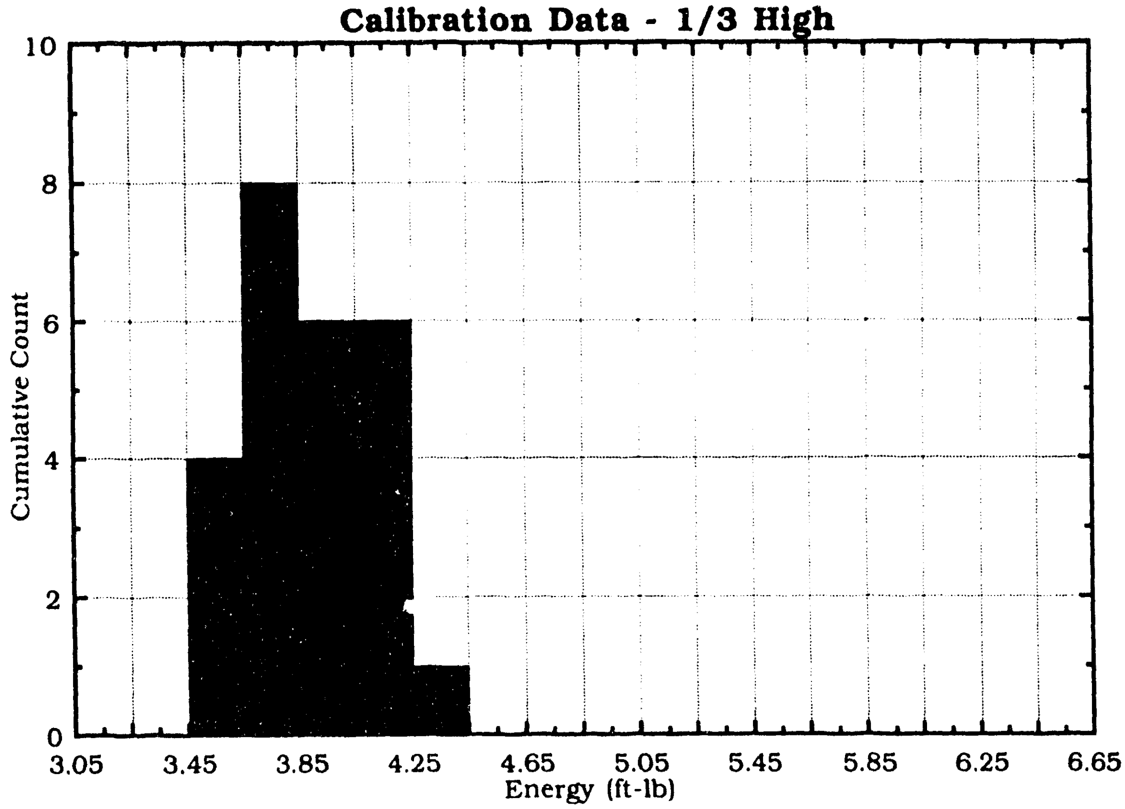


Fig. 2. Results from testing of third-size calibration specimens. Top: low-energy specimens. Bottom: high-energy specimens.

Table 1. Summary of subsize Charpy calibration specimen results

Specimen size	Energy level	Number of specimens	Average energy (J)	Standard deviation (J)	Coefficient of variation
Half	High	51	16.79	0.88	0.05
	Low	50	2.85	0.54	0.19
Third	High	25	5.28	0.31	0.06
	Low	25	1.04	0.31	0.30

For the half-size specimens, the average energy level for the low-energy material was 2.85 J (2.10 ft-lb) with a standard deviation of 0.54 J (0.40 ft-lb). The high-energy material gave an average value of 16.79 J (12.38 ft-lb) and a standard deviation of 0.88 J (0.65 ft-lb). For the third-size specimens, the averages and standard deviations were 1.04 and 0.31 J (0.76 and 0.23 ft-lb) for the low-energy material, and 5.28 and 0.31 J (3.89 and 0.23 ft-lb) for the high-energy material, respectively.

DISCUSSION

The histograms show that the half-size specimens exhibit longer tails and more spread in the data than do the third-size specimens. The standard deviations for the half-size specimens are much larger also.

The average value plus or minus two standard deviations has been chosen for use as the criterion to evaluate the test machine performance. Therefore, the allowable range for the half-size specimens is 1.75 to 3.94 J (1.29 to 2.91 ft-lb) and 15.03 to 18.54 J (11.09 to 13.68 ft-lb) for the low- and high-energy specimens, respectively. Similarly, the allowable range for the third-size specimens is 0.42 to 1.65 J (0.31 to 1.22 ft-lb) and 4.66 to 5.90 J (3.43 to 4.35 ft-lb) for the low- and high-energy specimens, respectively. The calibration of the test system is checked by testing five specimens of each energy level at −40°C. The average of these five tests must fall within these limits for both energy levels.

The subsize calibration specimens are now in routine use at ORNL. They have been used in both laboratory and hot cell machines, in both specimen sizes. No problems have been encountered in their use. They have successfully demonstrated that the impact machines are reproducibly measuring impact energies when configured to test subsize specimens.

There is a need within the technical community at large to establish some means of calibrating the testing machines used for subsize impact testing. There are currently a wide range of testing techniques, specimens, and types of impact machines that are being utilized to obtain data on impact properties of materials. The need for standardization for testing full-size Charpy specimens has long been recognized and is jointly addressed by ASTM E 23 and the NIST calibration specimens. Unfortunately, neither of these means of standardization have an established counterpart for subsize impact specimens. Ongoing efforts in ASTM Committee E 28 are aimed at formulating standards for testing techniques of subsize specimens. It would be very useful to establish a subsize counterpart to the NIST calibration specimens in support of these standardization activities as well as to provide a more reliable means for accurate comparisons of the data produced by the various subsize specimens currently in use.

CONCLUSIONS

Subsize Charpy impact specimens have been produced from 4340 steel heat treated to produce microstructures that will absorb either high or low energies when tested in impact. These specimens have been successfully used to check the operation of impact machines in both laboratory and hot cell locations.

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