THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

THE EFFECT OF COMPOSITION, HARDNESS AND GRAIN SIZE UPON THE IMPACT PROPERTIES OF THREE SPRING STEELS

by

L F Reynolds, M.Sc.Tech., C.Eng., M.I.M.

Report No 366

MARCH 1984

THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

Report No 366

THE EFFECT OF COMPOSITION, HARDNESS AND GRAIN SIZE UPON THE IMPACT PROPERTIES OF THREE SPRING STEELS

by

L F Reynolds, M.Sc.Tech., C.Eng., M.I.M.

SUMMARY

Hot formed springs may be heat treated at maximum temperatures of 860-900° or 950-1000°C, depending upon whether the springs are manufactured by the double stage or the single stage process respectively. The effects of heat treatment temperature upon the resistance of the materials to crack propogation, as exemplified by Charpy 'v' notch tests, forms the subjects of this report.

Charpy 'v' notch impact tests have been carried out over the temperature range -80°C to +100°C for 250A58, 735A50 and 805A60 spring steels heat treated from temperatures between 860°C and 1000°C to give hardness values in the range of 465-530 HV.

The work has shown that 250A58 and 805A60 steels exhibit very similar impact toughness properties, and that these steels are relatively insensitive to hardening temperatures up to 1000°C in the hardness range 465-475 HV. The impact toughness of these steels is generally lower than that for 735A50 of equivalent hardness.

The 735A50 steel exhibits the better impact toughness properties when hardened from 860°C to give a final hardness in the range 465-475 HV. The excellent impact toughness characteristics of 735A50 were severely impaired, however, by heat treating at 860°C to a hardness of 510-530 HV, or by heat treating at 1000°C to a hardness of 465-475 HV. In these two conditions, the impact toughness of 735A50 was similar to that of the other two steels.

Hardening at 1000°C to give a hardness of 510-530 Hv dramatically reduced the impact toughness of 735A50 steel, to values approximately 30% of those obtained for material heat treated from 860°C to a final hardness of 465-475 Hv.

It is concluded that, for maximum resistance to crack propogation at sub-zero temperatures, 735A50 springs in particular should be manufactured using the double stage heat treatment process.

MARCH 1984

CONTENTS

Page No

THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

Report No 366

THE EFFECT OF COMPOSITION, HARDNESS AND GRAIN SIZE UPON THE IMPACT PROPERTIES OF THREE SPRING STEELS

by

L F Reynolds, M.Sc.Tech., C.Eng., M.I.M.

1. INTRODUCTION AND OBJECTIVE

Notched impact tests, such as the Charpy 'v' test, are a convenient way of comparing materials with respect to their resistance to crack propogation from existing surface defects. This property is of some significance, since heavy springs are often manufactured using black bar, which can contain pre-existing surface defects such as seams.

A previous report presented Charpy 'v' notch impact transition data for a range of spring steels used for the manufacture of medium/heavy springs.(1) This previously reported work assumed that the hardening temperatures of the appropriate alloys would not exceed normal hardening temperatures of 900°C for 250A58 and 860°C for the 735A50/805A60 steels. ie The hardening temperatures were typical of those applied in the double stage heat treatment process, which would tend to produce a fine grained structure. In practise, however, hot formed springs are coiled at temperatures up to 1000°C to allow sufficient time for handling and the ancillary processes such as dimensional adjustment, where necessary.

Springs made by the single stage process will be hardened immediately after coiling, by quenching the hot formed spring, and hence the final grain size will be that resulting from the high temperature treatment. This grain size will tend to be larger than that produced by the double stage process, and hence differences in resistance to crack propogation might arise, since fine grained steels are generally tougher than their coarser grained equivalents.

The present work is intended to generate data for three spring materials commonly used for heavy springs, after heat treatment of "as rolled" bar material to simulate the thermal cycles which may be encountered during the manufacture of such springs.

2. EXPERIMENTAL PROCEDURE

2.1 Materials and Heat Treatment

The three materials investigated are given in Table I together with their analyses.

Standard Charpy 'v' samples were prepared from 16 mm diameter hot rolled bar, and these were heat treated at appropriate temperatures to simulate the effects of single heat and double heat manufacturing processes. Tempering curves were determined at SRAMA, and were used to establish the tempering temperatures necessary for the required material hardness. Table II gives details of the heat treatments and hardness ranges investigated in this work.

2.2 Grain Size and Hardness Tests

Samples included in the appropriate heat treatment batches were sectioned for measurements of hardness and grain size.

Hardness testing was carried out using a Vickers Hardness Machine, whilst measurement of grain size was carried out on polished microsections after preparation using suitable etchants. The latter results were corraborated by examination of appropriate fractures using the Scanning Electron Microscope.

2.3 Charp 'v' Notch Impact Tests

Triplicate impact tests were carried out commercially on clearly identified samples at each of ten temperatures within the range -80°C to +1000°C, the results being supplied in tabular form for futher analysis at SRAMA.

3. RESULTS AND DISCUSSION

The tempering curves derived at SRAMA are shown in Figs 1-3, whilst the results of the hardness and grain size measurements are given in Table III. It is apparent from the latter results that the grain size of the 735A50 steel was significantly affected by the higher austencitizing temperatures, but that 250A58 and 805A60 were much less influenced by hardening temperature in this respect.

The results of the Charpy 'v' impact tests are shown in Figs 4-6. These mean curves of 50% confidence were derived by a polynomical "least squares" technique and, for clarity, impact results for the indicated treatments were combined where appropriate, when there was little difference in the impact values obtained for the particular steels.

The increments of impact toughness which must be added to or subtracted from the appropriate mean curves for 95% confidence are shown in Table IV.

The results portrayed in Figs 4-6 indicate that 250A58 was slightly affected by austenitizing temperature, the results for samples austenitized at 1000°C being approximately 1-3 Joules lower than those austenitized at 900°C. The hardness of the samples exerted little effect on the impact properties for hardness values within the range 440-480 Hv, 250A58 apparently being relatively insensitive to changes in either austenitizing temperature and/or hardness within the quoted range.

Very similar conclusions can be drawn from the results obtained for 805A60 with hardness values in the range 440-475 Hv, although the combination of high austenitizing temperature and highest hardness did tend to produce slightly reduced toughness as measured by the Charpy 'v' impact test. Nevertheless, 805A60 was also relatively insensitive to changes in hardening temperature and/or hardness within the stipulated range.

The 735A50 alloy, however, was very sensitive to changes in both hardening temperature and hardness value in the range 470-530 Hv.

For this material, hardening from 860°C with a final hardness of 465 Hv gave the best impact toughness, whilst hardening from 1000°C with a final hardness of 530 Hv reduced the impact toughness by a factor of 3. The combination of high hardening temperature/low hardness and low hardening temperature/high hardness both gave very similar impact toughness values, which lay between the above indicated extremes and were comparable with the results obtained for the other two alloys. Heat treatment of 735A50 at 1000°C had clearly resulted in pronounced grain growth, with an accompanying reduction in toughness.

This indicates that the grain boundary vanadium carbides had lost their abilility to prevent grain growth by restricting grain boundary movement.

Comparisons between the alloys are illustrated in Figs 7 and 8 which depict the behaviour of the three alloys, for equal hardness, after hardening from appropriate temperatures of 860°C/900°C and 1000°C respectively. It is apparent, from these presentations, that the impact toughness of 250A58 and 805A60 is relatively unaffected by high hardening temperatures, whilst that of 735A50 is dramatically reduced to the general level displayed by the other two steels.

4. CONCLUSIONS

1. Hardening from a temperature of 1000°C had relatively little effect on the grain size and impact toughness properties of 250A58 and 805A60 steel within the hardness range 440-480 Hv.

2. The 735A50 alloy gave the best impact properties of all the materials investigated, when hardened from 860°C and tempered to a hardness of 450-470 Hv.

3. Hardening from 1000°C caused a significant increase in the grain size of 735A50, together with a concommittant decrease in the impact toughness. In particular, hardening the 735A50 alloy from 1000°C to give a final tempered hardness over 500 Hv yielded impact properties which were amongst the lowest observed in this work.

RECOMMENDATIONS

Of the three alloys investigated, 735A50 appears to be the best choice for low temperature applications, the impact toughness at 465-475 Hv being higher than that of other alloys at all temperatures down to -40°C.

The good impact properties of 735A50 can only be developed by hardening from the normal hardening temperature of 860°C, however. Hence 735A50 heavy springs for low temperature service should be re-heat treated after hot coiling, where possible, by hardening from 860°C and tempering to give a hardness not in excess of 465-475 Hv.

In particular, the impact toughness advantage of 735A50 will be effectively eliminated by hardening from temperatures of 1000°C.

REFERENCES

1. Owen, A P, "The Impact Transition Properties of Spring Materials".
SRAMA Report No 199, April 1972.

TABLE I CHEMICAL COMPOSITION OF 16 MM DIAMETER BAR STOCK USED FOR MANUFACTURE OF CHARPY 'V' NOTCH IMPACT SPECIMENS

Bar Indent	Steel Type	Chemical Composition, wt %									
		C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu
A	250A58	0.60	1.90	0.76	0.018	0.042	0.19	0.03	0.14	-	0.20
B	735A50	0.52	0.27	0.74	0.019	0.032	0.94	0.04	0.16	0.18	0.21
C	805A60	0.61	0.31	0.87	0.03	0.026	0.53	0.20	0.67	-	0.19

TABLE II HEAT TREATMENTS AND HARDNESS RANGES INVESTIGATED

Steel	Batch Ident	Heat Treatment	Hardness Range, HV
250A58	AI	900°C/15 mins, OQ Tempered 530°C/1 hour	420-450
	AII	900°C/15 mins, OQ Tempered 495°C/1 hour	460-490
	AIII	1000°C/15 mins; OQ from 900°C Tempered 530°C/1 hour	420-450
	AIV	1000°C/15 mins; OQ from 900°C Tempered 495°C/1 hour	460-490
735A50	BI	860°C/15 mins, OQ Tempered 470°C/1 hour	450-470
	BII	860°C/15 mins, OQ Tempered 395°C/1 hour	500-520
	BIII	1000°C/15 mins; OQ from 860°C Tempered 470°C/1 hour	450-470
	BIV	1000°C/15 mins; OQ from 860°C Tempered 395°C/1 hour	500-520
805A60	CI	860°C/15 mins, OQ Tempered 520°C/1 hour	420-450
	CII	860°C/15 mins, OQ Tempered 465°C/1 hour	460-490
	CIII	1000°C/15 mins; OQ from 860°C Tempered 520°C/1 hour	420-450
	CIV	1000°C/15 mins; OQ from 860°C Tempered 465°C/1 hour	460-490

TABLE III RESULTS OF HARDNESS AND GRAIN SIZE MEASUREMENTS

Steel	Batch Ident	Hardness, HV20*		ASTM Grain Size
		Mean	Standard Deviation	
250A58	AI	441	5	8-9
	AII	474	5	8-9
	AIII	445	4	6-7
	AIV	479	7	6-7
735A50	BI	466	0	10-11
	BII	510	10	10-11
	BIII	471	3	5-6
	BIV	528	4	5-6
805A60	CI	446	6	7-8
	CII	474	5	7-8
	CIII	443	5	6-7
	CIV	465	9	6-7

* 8 measurements per sample

TABLE IV IMPACT TEST RESULTS; INCREMENTS FOR 95% CONFIDENCE, DERIVED FROM SCATTER OF RESULTS ABOUT MEAN CURVES

Figures to which Increments Relate	Curves for Batches	Increment,* Joules
Figure 4	AI; AII	3.0
	AIII; AIV	2.5
Figure 5	BI	3.5
	BII; BIII	2.6
	BIV	1.3
Figure 6	CI	2.4
	CII; CIII	2.4
	CIV	1.8
Figure 7	AII	2.8
	BI	3.5
	CII	2.4
Figure 8	AIV; BIII	2.7
	CIV	1.8

* Increment to be added to or subtracted from the mean value obtained from the appropriate curve, to give upper and lower 95% confidence respectively.

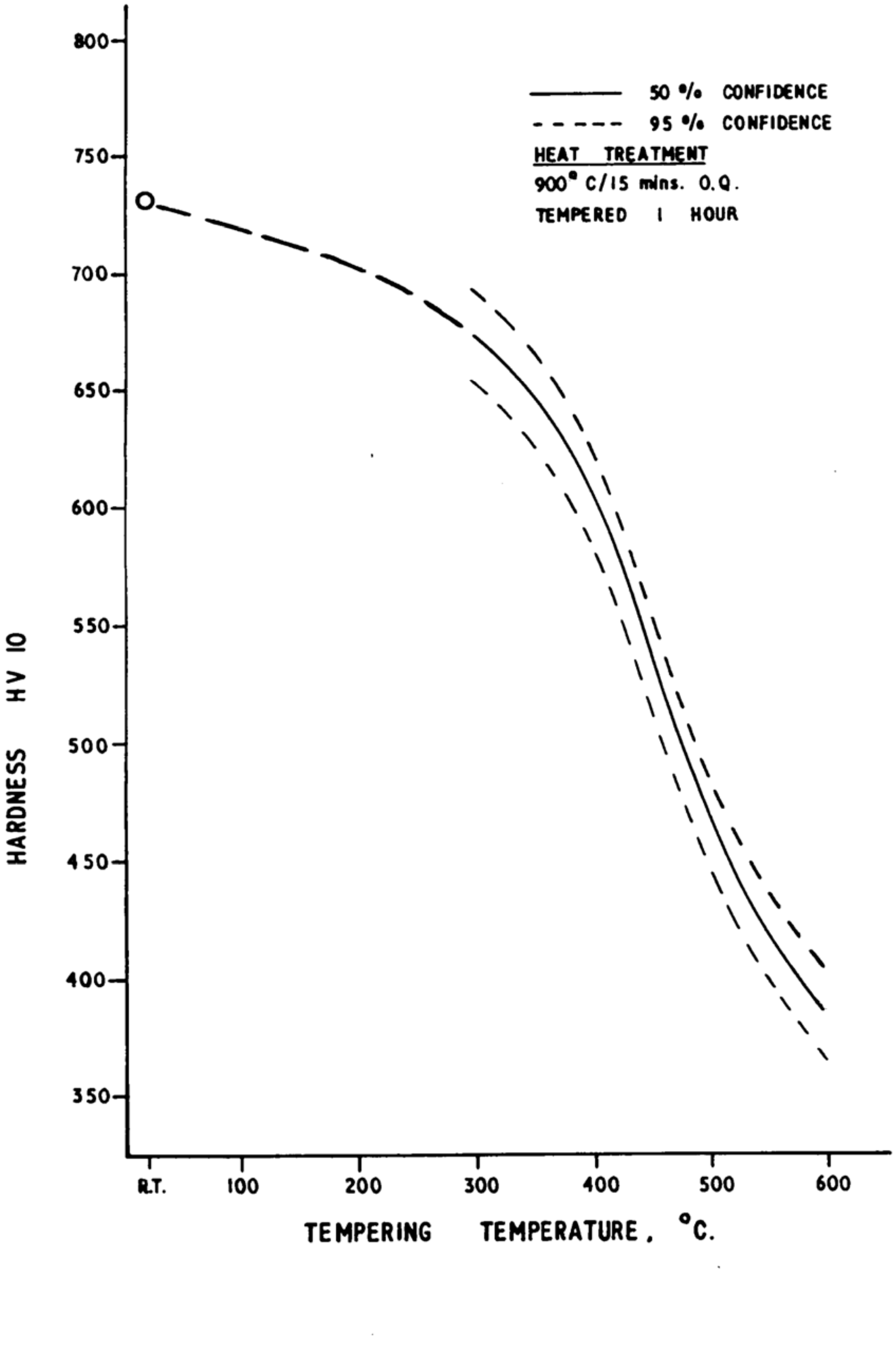

FIG. 1. TEMPERING CURVE DERIVED FOR STEEL A (250 A58)

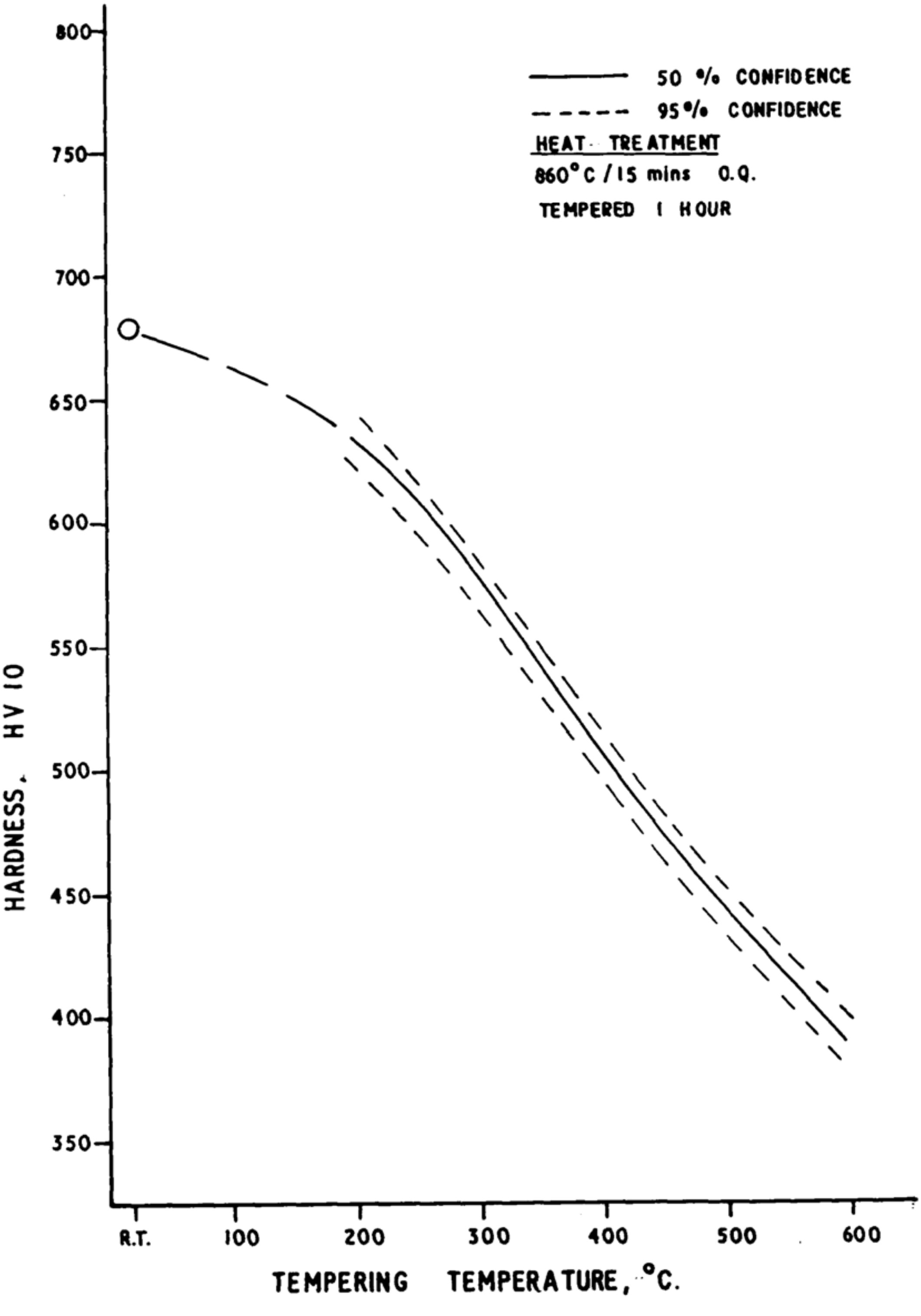

FIG. 2. TEMPERING CURVE DERIVED FOR STEEL B (735A50)

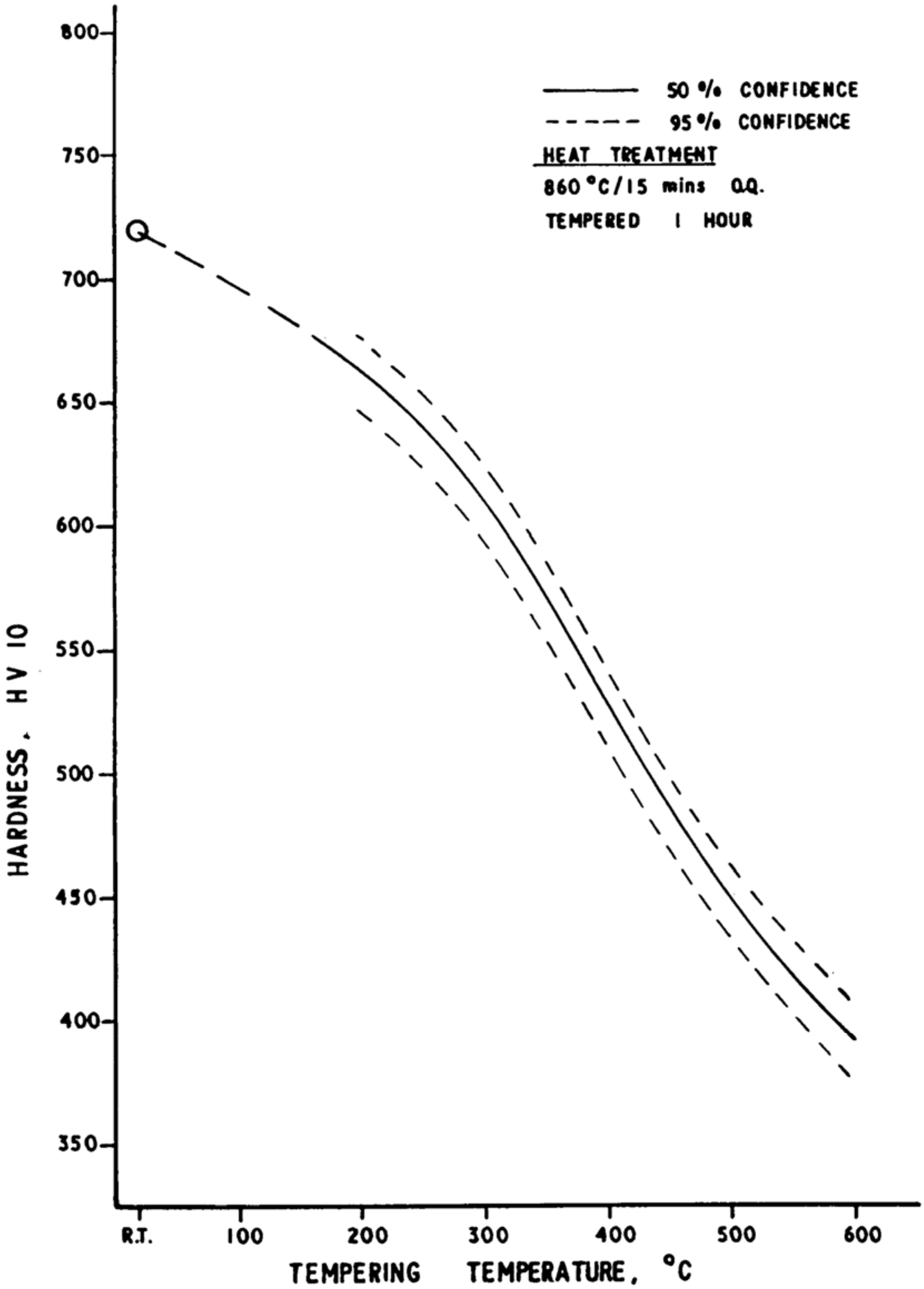

FIG. 3. TEMPERING CURVE DERIVED FOR STEEL C. (805 A60)

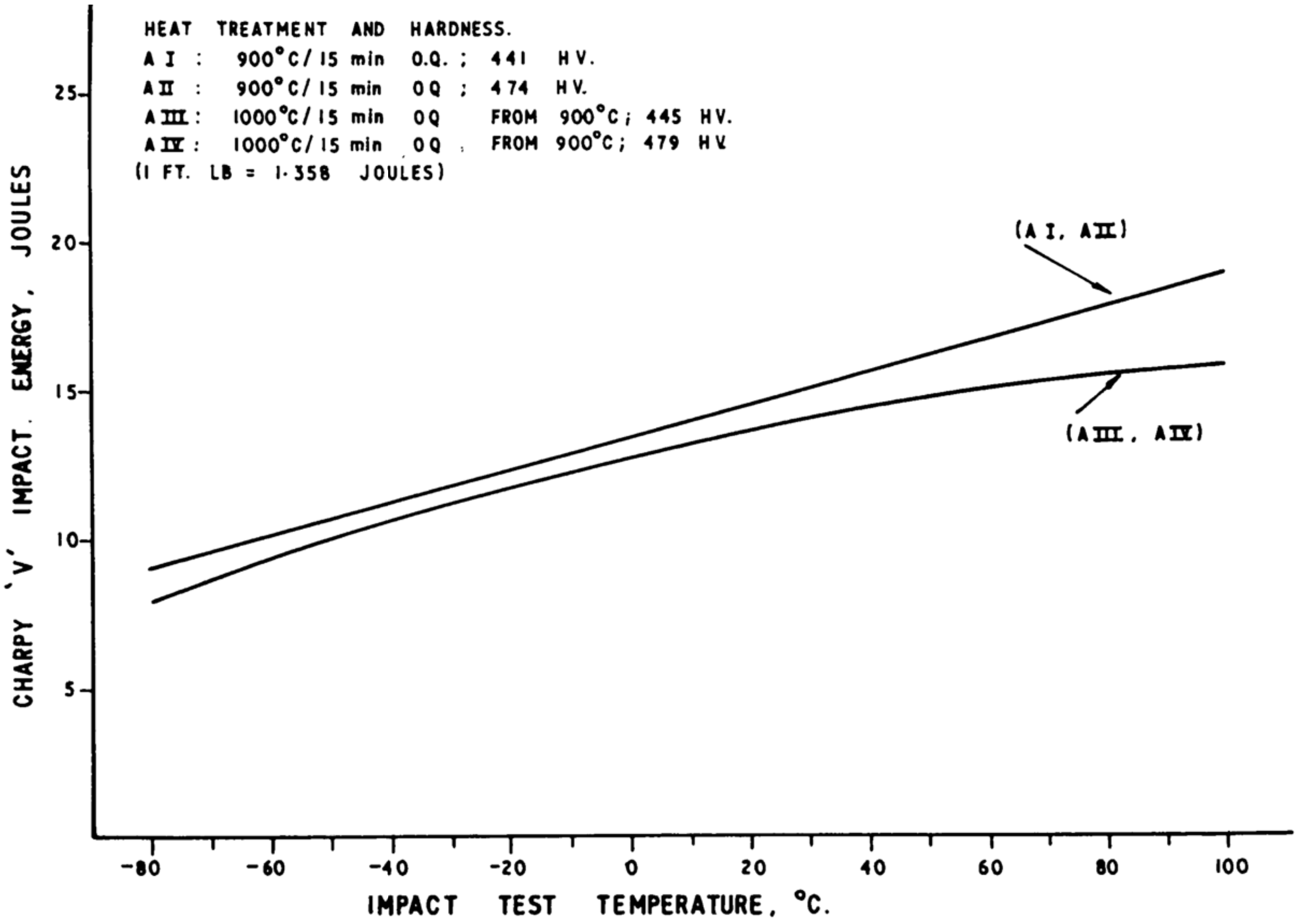

FIG. 4. IMPACT TRANSITION CURVES FOR STEEL A (250 A58)

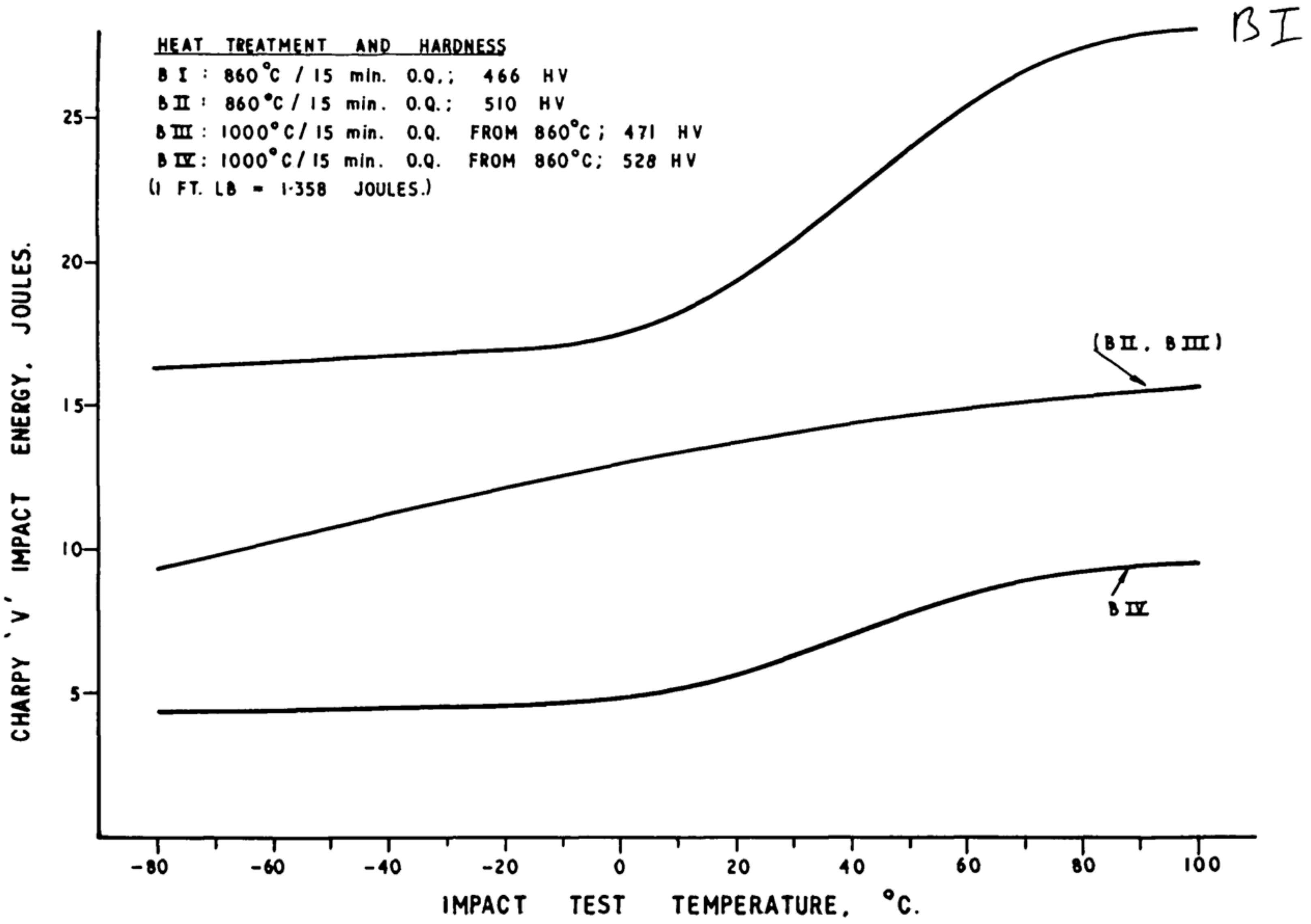

FIG. 5. IMPACT TRANSITION CURVES FOR STEEL B (735A50)

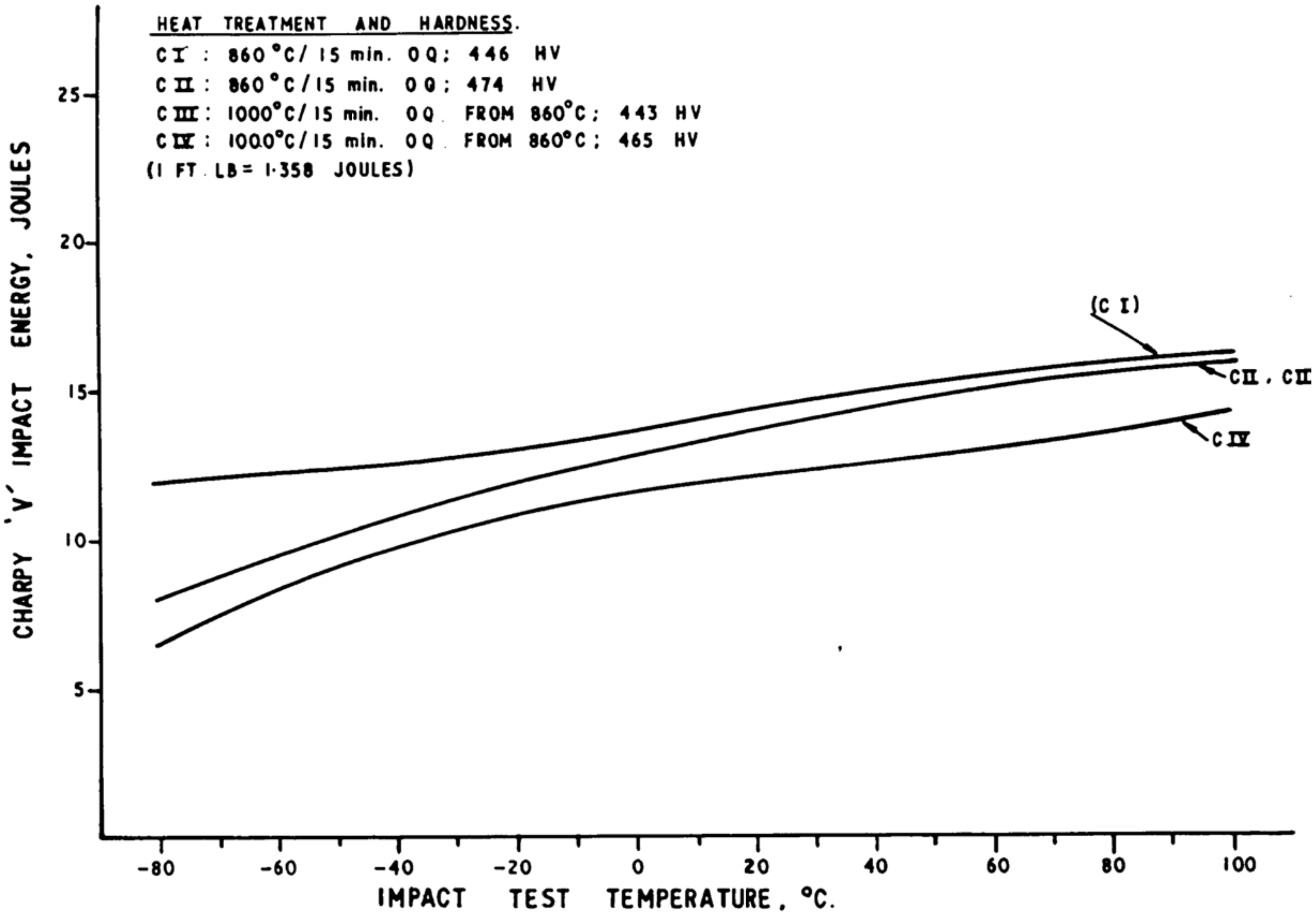

FIG. 6. IMPACT TRANSITION CURVES FOR STEEL C. (805 A60)

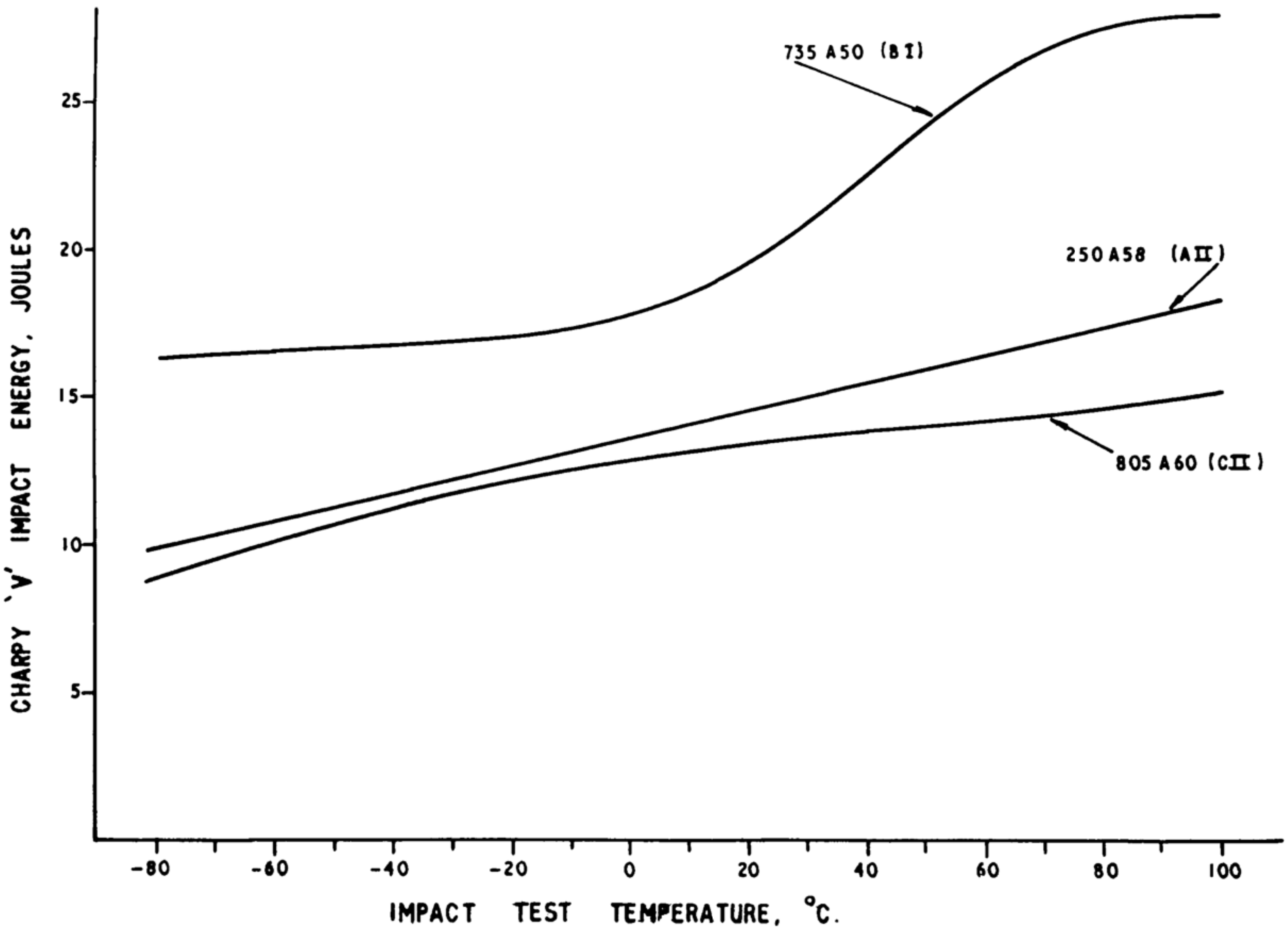

FIG. 7. IMPACT TRANSITION CURVES FOR STEELS HEAT TREATED AT 900°C. (STEEL A) AND 860°C. (STEELS B AND C) TO A HARDNESS IN THE RANGE 465 – 475 HV.

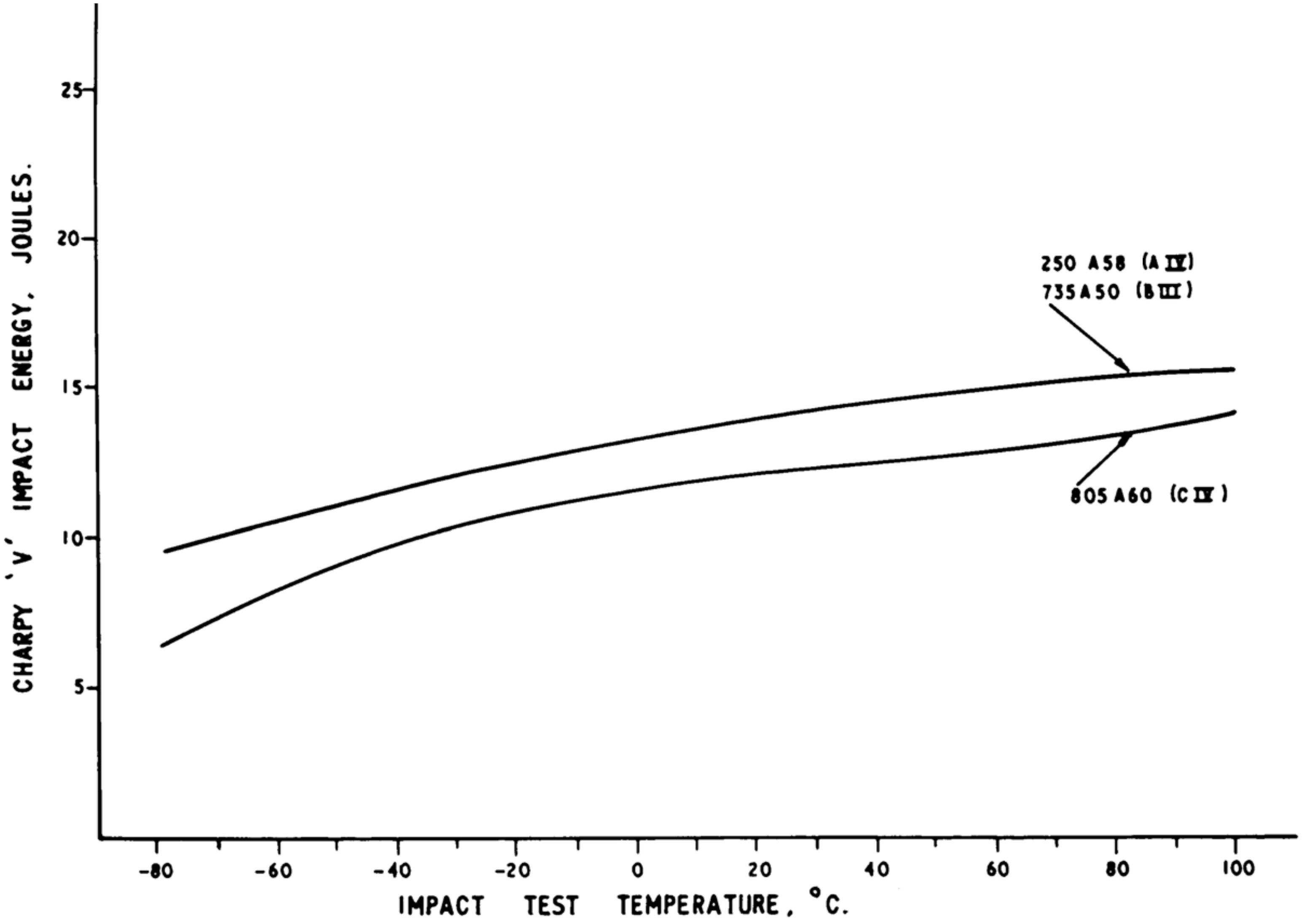

FIG. 8. IMPACT TRANSITION CURVES FOR STEELS HEAT TREATED AT 1000°C. TO A HARDNESS IN THE RANGE 465 - 480 HV.