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FINAL REPORT PSM 2-2

LOTION 3

(LOw Temperature Irradiation for fusiON)

Dynamic Fracture Toughness Tests of AISI 316 L, TIG and Electron Bean weld specimens irradiated at 315 K

J. Eysermans, J. Van de Velde, JL Puzzolante,
F. Moons, W. Vandermeulen°, W. Hendrix°

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Test Results

Abstract

In the framework of the CEC-DGXII-Fusion NET Technology Programme, precracked AISI 316L base material, TIG Metal Deposit and Electron Beam weld specimens have been irradiated at a temperature of about 350 K, up to 5 dpa.
Instrumented Charpy tests have been performed on irradiated and unirradiated specimens at room temperature. The fracture toughness has been calculated and irradiation hardening is observed. The TIG Metal Deposit and the Electron Beam weld show lower fracture toughness values.

Contents

1. Introduction

In the framework of the CEC-DGXII-Fusion NET Technology Programme, 32 AISI 316L precracked and sidegrooved Charpy test samples have been irradiated at a temperature of about 350 K, up to 5 dpa, in the BR2 materials testing reactor at SCK/CEN, Mol, Belgium.
The irradiation rig was nicknamed LOTION 3: Low Temperature Irradiation for FUsion 3. The AISI 316L specimens were loaded in a basket, cooled by the BR2 primary water (315 K). Irradiation is performed up to a dose of 5 dpa, corresponding to a fast fluence of about 6,5 10^{21} n/cm^2.
In the present report the dynamic fracture toughness values of unirradiated and irradiated specimens are discussed.

2. Neutron irradiation

2.1 Material

The Lotion 3 rig was loaded with 32 Charpy specimens. 16 specimens originated from the plate material, 8 originated from a TIG Metal Deposit, and 8 originated from an Electron Beam joint. The plate material is the CEC-reference material 316L. The plate used for this experience is heat 12879 from Creussot Marrel (1). Table 1 shows the weight percentages of the elements present in the material. For each direction, Transversal-Longitudinal and Transversal-Short, eight samples have been irradiated.
The TIG Metal Deposit material has been provided by the Danish Welding Institute. The specimens fabricated for the LOTION 3 experiment originate from the NET 805-19 production lot. The fabrication and Quality Control of TIG Metal Deposit and Weld report (2) summarizes some important characteristics of this material. The Electron Beam specimens originated from the EB weld joints provided by ECN Petten.

2.2 Test specimens and machining procedure

The specimen is shown in figure 1. The side-grooves are machined after the fatigue crack was introduced in the specimen.
Figure 2 identifies Charpy specimen location in the plate material.
Figure 3 and figure 4 identify the specimen locations in the TIG Metal Deposit and Electron Beam weld joint respectively.
Special care was taken not to heat the material during specimen manufacturing.

2.3 Irradiation rig

The irradiation was carried out in a standard BR2-basket. The specimens were cooled by the BR2 coolant. This temperature is approximately 315 K. The loading scheme of the LOTION 3 irradiation is shown in figure 5.

2.4 Irradiation data

Details on the irradiation history can be found in the Irradiation Report (3). The doses and corresponding dpa values were calculated. The peak dose was $8,1 * 10^{25}$ n/m^2 (E>0,1 MeV), $3,9 * 10^{25}$ n/m^2 (E>1 MeV) or 5,3 dpa. Figure 6 shows the dose distribution over the rig.

3. Fracture toughness tests

3.1 Experimentat details

Instrumented Charpy tests have been performed on precracked specimens in the unirradiated and irradiated condition. All tests have been performed at room temperature and with an impact energy of 359 Joule. A Dynatup instrumented Tinius Olsen impact tester was used for the tests. For each material and orientation, four unirradiated and three irradiated specimens have been tested. The load-time profiles and the experimental parameters measured by the system during all the tests are shown in appendix 1.

3.2 Dynamic fracture toughness calculation

3.2.1 Theory

The fracture toughness of the stainless steel type AISI 316L impact specimens is evaluated using the concept of J-integral (4), because this concept provides an extension of linear elastic fracture mechanics to cases which sustain either small or large-scale plasticity before fracture.

Rice's (4) interpretation of J, leads to the equation

$$J_D = -\frac{1}{B}\frac{dU}{da}$$

where B is the thickness of the specimen and U(a) denotes the potential energy of an elastic body of unit thickness containig a flat surfaced notch of length a. dU/da is the rate of change of potential energy of the cracked elastic body with crack size.
For plain strain conditions the fracture toughness is calculated according to the following relation:

$$K_{J_D} = \sqrt{\frac{J_D \, X \, E}{1 - \vartheta_{pr}^{\,2}}} \qquad [1]$$

where E is Young's modulus, and ϑ_{pr} represents Poisson's ratio.

The J-integral (J_d) is estimated from the energy value E_{TF} according to the relation:

$$J_d = 2 \, E_{TF} / B \, (W - a) \qquad [2]$$

where E_{TF} is the absorbed energy at the estimated fracture load corrected for the elastic energy absorbed by the machine:

$$E_{TF} = E_F - E_m \qquad [3]$$

In this formule, E_F is the absorbed energy at fracture load, and E_m is the elastic energy absorbed by the machine which can be estimated from

$$E_m = (P_f)^2 \, C_m \, / \, 2 \qquad [\,4\,]$$

where P_f is the force for fracture initiation, and C_m is the compliance of the machine. It is assumed that fracture is initiated at load P_f midway between the maximum load (P_m) and the load for general yield P_{GY}, so

$$P_f = (P_m + P_{GY}) \, / \, 2 \qquad [\,5\,]$$

The machine compliance C_m is estimated from

$$C_m = (V_a \, t_e \, / \, P_e) - C_s \qquad [\,6\,]$$

The first term in this equation is the ratio of deflection to load (P_e) on the elastic loading portion of the load record. For fractures before general yielding, $P_e = P_f$. The parameter t_e is the time to reach P_e and V_a is the average velocity at that time.

$$C_s = 72 \, / \, EB \, Y_c + 20 \, / \, EB \qquad [\,7\,]$$

where E is Young's modulus and Y_c is a function of the crack length (a) to specimen width (W) ratio determined by:

$$\begin{aligned} Y_c = \; & 1.8625\,(a/W)^2 - 3.95\,(a/W)^3 + 16.3777\,(a/W)^4 \\ & -37.2277\,(a/W)^5 + 77.554\,(a/W)^6 - 126.8727\,(a/W)^7 \\ & + 172.5325\,(a/W)^8 - 143.964\,(a/W)^9 \\ & + 66.564\,(a/W)^{10} \end{aligned} \qquad [\,8\,]$$

3.2.2 Calculations

Tables 2 and 3 show the calculation of specimen compliance.
First the dimensionless parameter Y_c is calculated by means of formule [8]. The width W of the specimens is 10 mm as shown in figure 1, and the crack length a is measured from the fracture surface after the test was completed.
The specimen compliance is calculated from [7]. The value of Young's modulus is taken from literature (5) and is equal to 193.000 MPa. B is the thickness and is 5 mm as is shown in figure 1.

Table 4 shows the calculation of the fracture load for all tests. Formule [5] is used, and the values for the maximum load P_m and the load for general yield P_{GY} are measured from the load-time profiles in appendix 1.

Table 5 shows the calculation according to formule [6] of the machine compliance for all specimens. The average velocity V_a is measured by the Dynatup system and the time t_e is calculated from the load-time profiles in appendix 1.

The calculation of the dynamic J_d-integral is shown in table 6 for the Electron Beam and TIG Metal Deposit samples, and in table 7 for the Base Material specimens in the Transversal-Short and the Transversal-Longitudinal directions.. First E_{TF}, the absorbed energy at the estimated fracture load corrected for the elastic energy absorbed by the machine has to be calculated according to formule [3].
E_F is the absorbed energy at fracture load and can be calculated from the load-time profiles. E_m is the energy absorbed by the machine and is calculated according to formule [4].

Finally, in table 8 the J-integral Fracture Toughness K_{JD} is calculated according to [1]. Poisson's ratio is taken from Metals Handbook (4) and equal to 0,3.

3.2.3 Results and conclusions

Figure 7 summarizes the results. The blocks show the average Dynamic Fracture Toughness values for the Electron Beam (EB), TIG Metal Deposit (MD) and the Base Material specimens in the Transversal-Short (TS) and the Transversal-Longitudinal (TL) directions in the irradiated and unirradiated condition.
In the unirradiated condition, the obtained results for the TIG Metal Deposit is significantly lower than those obtained for the base material and the Electron Beam Joints. The Dynamic Fracture Toughness of the unirradiated material seems not to be influenced by the orientation since the values for the Transversal-Short (TS) direction and the values for the Transversal-Longitudinal (TL) direction lie within the same scatterband.
The Dynamic Fracture Toughness of the unirradiated Electron Beam joints is comparable with the Dynamic Fracture Toughness of the base material.
In the irradiated condition, the Dynamic Fracture Toughness decreases for all the materials under investigation. The decrease is more pronounced for the base material and the Electron Beam joints than for the TIG Metal Deposit.

References

(1) Technical specification MTG/88/N 052 , G Beurrier, Creussot Marrel Division Le Creuscot Plant, July 29th 1988
(2) NET/ 90 - 805 Fabrication and Quality Control of TIG Metal Deposit and Weld, Palle Aastrup, The Danish Welding Institute, March 1991
(3) Ch. De Raedt, P. Van Mechelen, Fast fluences, dpa values and helium formation in the LOTION 3 experiment in BR2, S.C.K./C.E.N., FT/MOL/94-03, February 1994
(4) K.R. Iyer and R.B. Miclot, Instrumented Charpy Testing for Determination of J-Integral, Instumented Impact Testing, ASTM STP 563, American Society for Testing Materials, 1974, pp. 146-165.
(5) John R. Newby, Metals Handbook Ninth Edition, vol 8, Mechanical Testing, American Society for Metals, 1985

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Element	Weight %
C	0,0188
Cr	17,24
Ni	12,17
Mo	2,308
Ta	0,002
Si	0,35
Mn	1,75
S	0,0006
P	0,0193
B	0,0009
N	0,0733
Co	0,0778
Cu	0,07

Table 1: Composition of the 316L base material in the LOTION 3 irradiation.

	Calculation of specimen compliance				
	Cs= 72 / EB Yc + 20 / EB				
	Yc =	1.8625 (a/W)**2 - 3.95 (a/W)**3 + 16.3777 (a/W)**4			
		-37.2277 (a/W)**5 + 77.554 (a/W)**6 - 126.8727 (a/W)**7			
		+ 172.5325 (a/W)**8 - 143.964 (a/W)**9			
		+ 66.564 (a/W) ** 10			
Specimen	Yc	a (mm)	W (mm)	a/W	
EB1	0.80	5.71	10	0.571	
EB2	1.08	6.18	10	0.618	
EB3	0.97	6.01	10	0.601	
EB4	1.00	6.06	10	0.606	
EB5	1.19	6.32	10	0.632	
EB6	1.13	6.24	10	0.624	
EB7	0.97	6.01	10	0.601	
Specimen	Cs (mm / kN)	E (kN/mm**2)	B (mm)	Yc	
EB1	1.14E-01	193	5	0.796	
EB2	8.96E-02	193	5	1.083	
EB3	9.79E-02	193	5	0.967	
EB4	9.53E-02	193	5	1	
EB5	8.34E-02	193	5	1.191	
EB6	8.69E-02	193	5	1.128	
EB7	9.78E-02	193	5	0.968	
Specimen	Yc	a (mm)	W (mm)	a/W	
MD1	1.08	6.18	10	0.618	
MD2	1.04	6.12	10	0.612	
MD3	1.71	6.84	10	0.684	
MD4	0.44	4.74	10	0.474	
MD5	1.33	6.48	10	0.648	
MD6	1.17	6.3	10	0.63	
MD7	1.65	6.79	10	0.679	
Specimen	Cs (mm / kN)	E (kN/mm**2)	B (mm)	Yc	
MD1	8.98E-02	193	5	1.08	
MD2	9.25E-02	193	5	1.04	
MD3	6.44E-02	193	5	1.71	
MD4	1.90E-01	193	5	0.44	
MD5	7.68E-02	193	5	1.33	
MD6	8.45E-02	193	5	1.17	
MD7	6.59E-02	193	5	1.65	

Table 2: Calculation of specimen compliance for the Electron Beam and TIG Metal Deposit samples.

	Calculation of specimen compliance				
	Cs= 72 / EB Yc + 20 / EB				
	Yc =	1.8625 (a/W)**2 - 3.95 (a/W)**3 + 16.3777 (a/W)**4			
		-37.2277 (a/W)**5 + 77.554 (a/W)**6 - 126.8727 (a/W)**7			
		+ 172.5325 (a/W)**8 - 143.964 (a/W)**9			
		+ 66.564 (a/W) ** 10			
Specimen	Yc	a (mm)	W (mm)	a/W	
TS1	0.96	5.99	10	0.599	
TS2	1.04	6.12	10	0.612	
TS3	1.01	6.08	10	0.608	
TS4	1.04	6.12	10	0.612	
TS5	1.04	6.12	10	0.612	
TS6	0.99	6.05	10	0.605	
TS7	1.04	6.12	10	0.612	
Specimen	Cs (mm / kN)	E (kN/mm**2)	B (mm)	Yc	
TS1	9.84E-02	193	5	0.96	
TS2	9.25E-02	193	5	1.04	
TS3	9.46E-02	193	5	1.01	
TS4	9.25E-02	193	5	1.04	
TS5	9.25E-02	193	5	1.04	
TS6	9.61E-02	193	5	0.99	
TS7	9.25E-02	193	5	1.04	
Specimen	Yc	a (mm)	W (mm)	a/W	
TL1	0.88	5.87	10	0.587	
TL2	1.04	6.12	10	0.612	
TL3	1.14	6.26	10	0.626	
TL4	1.22	6.35	10	0.635	
TL5	0.99	6.05	10	0.605	
TL6	0.99	6.05	10	0.605	
TL7	0.99	6.04	10	0.604	
Specimen	Cs (mm / kN)	E (kN/mm**2)	B (mm)	Yc	
TL1	1.06E-01	193	5	0.88	
TL2	9.25E-02	193	5	1.04	
TL3	8.62E-02	193	5	1.14	
TL4	8.19E-02	193	5	1.22	
TL5	9.61E-02	193	5	0.99	
TL6	9.61E-02	193	5	0.99	
TL7	9.61E-02	193	5	0.99	

Table 3: Calculation of specimen compliance for the Base Material specimens in the Transversal-Short and the Transversal-Longitudinal directions.

	Calculation of fracture load		
	Pf = 0.5 (PGY + Pm)		
Specimen	Pf (kN)	PGY (kN)	Pm (kN)
EB1	2.61	2.15	3.07
EB2	2.38	1.91	2.85
EB3	2.56	2.33	2.79
EB4	2.60	2.32	2.88
EB5	3.54	3.54	3.54
EB6	3.53	3.53	3.53
EB7	3.21	3.21	3.21
MD1	2.59	2.59	2.59
MD2	2.62	2.58	2.66
MD3	2.05	2.05	2.05
MD4	4.26	3.92	4.59
MD5	2.93	2.93	2.93
MD6	3.27	3.18	3.36
MD7	2.26	2.16	2.35
TS1	2.40	2.08	2.72
TS2	2.48	2.24	2.72
TS3	2.46	2.17	2.74
TS4	2.41	2.12	2.69
TS5	3.93	3.81	4.04
TS6	3.50	3.32	3.67
TS7	3.66	3.53	3.78
TL1	2.52	2.31	2.73
TL2	2.39	2.11	2.67
TL3	2.31	1.97	2.65
TL4	2.27	2.04	2.5
TL5	3.14	2.81	3.47
TL6	3.60	3.46	3.74
TL7	3.32	3.15	3.48

Table 4: Calculation of fracture load for the Electron Beam, TIG Metal Deposit and the Base Material specimens in the Transversal-Short and the Transversal-Longitudinal directions.

	Calculation of machine compliance					
	Cm = (Va te / Pe) - Cs					
Specimen	Cm (mm / kN)	Va (m/s)	te (10 -3 s)	Pe (kN)	Cs (mm / kN)	
EB1	4.74E-01	5.12	0.30	2.61	1.14E-01	
EB2	5.56E-01	5.12	0.30	2.38	8.96E-02	
EB3	5.02E-01	5.12	0.30	2.56	9.79E-02	
EB4	4.95E-01	5.12	0.30	2.60	9.53E-02	
EB5	3.41E-03	5.12	0.06	3.54	8.34E-02	
EB6	1.55E-04	5.12	0.06	3.53	8.69E-02	
EB7	5.87E-03	5.12	0.07	3.21	9.78E-02	
MD1	9.03E-03	5.12	0.05	2.59	8.98E-02	
MD2	5.24E-03	5.12	0.05	2.62	9.25E-02	
MD3	3.55E-02	5.12	0.04	2.05	6.44E-02	
MD4	2.00E-03	5.12	0.16	4.26	1.90E-01	
MD5	1.05E-02	5.12	0.05	2.93	7.68E-02	
MD6	9.45E-03	5.12	0.06	3.27	8.45E-02	
MD7	2.02E-03	5.12	0.03	2.26	6.59E-02	
TS1	8.22E-03	5.12	0.05	2.40	9.84E-02	
TS2	4.86E-01	5.12	0.28	2.48	9.25E-02	
TS3	5.30E-01	5.12	0.30	2.46	9.46E-02	
TS4	7.15E-01	5.12	0.38	2.41	9.25E-02	
TS5	1.18E-02	5.12	0.08	3.93	9.25E-02	
TS6	1.23E-01	5.12	0.15	3.50	9.61E-02	
TS7	1.31E-01	5.12	0.16	3.66	9.25E-02	
TL1	4.43E-01	5.12	0.27	2.52	1.06E-01	
TL2	4.43E-01	5.12	0.25	2.39	9.25E-02	
TL3	9.11E-01	5.12	0.45	2.31	8.62E-02	
TL4	7.08E-01	5.12	0.35	2.27	8.19E-02	
TL5	1.74E-03	5.12	0.06	3.14	9.61E-02	
TL6	3.47E-03	5.12	0.07	3.60	9.61E-02	
TL7	1.51E-01	5.12	0.16	3.32	9.61E-02	

Table 5: Calculation of machine compliance for the Electron Beam, TIG Metal Deposit and the Base Material specimens in the Transversal-Short and the Transversal-Longitudinal directions.

	Normalised energy for the calculation of J-Integral								
	Jd = 2 ETF / B (W-a)								
	ETF = EF - Em								
		EF: absorbed energy at fracture load							
		Em: elastic energy absorbed by the machine							
		Em= (Pf)**2 Cm / 2							
Specimen	Jd (J / mm**2)	Cm (mm / kN)	Pf (kN)	Em (J)	EF (J)	ETF (J)	B (mm)	W (mm)	a (mm)
EB1	0.39	4.74E-01	2.61	1.61	5.85	4.23	5	10	5.71
EB2	0.46	5.56E-01	2.38	1.57	6.00	4.42	5	10	6.18
EB3	0.37	5.02E-01	2.56	1.65	5.36	3.71	5	10	6.01
EB4	0.42	4.95E-01	2.60	1.67	5.80	4.12	5	10	6.06
EB5	0.16	3.41E-03	3.54	0.02	1.46	1.44	5	10	6.32
EB6	0.14	1.55E-04	3.53	0.00	1.27	1.27	5	10	6.24
EB7	0.12	5.87E-03	3.21	0.03	1.26	1.23	5	10	6.01
MD1	0.10	9.03E-03	2.59	0.03	1.02	0.98	5	10	6.18
MD2	0.25	5.24E-03	2.62	0.02	2.46	2.44	5	10	6.12
MD3	0.12	3.55E-02	2.05	0.07	1.04	0.97	5	10	6.84
MD4	0.30	2.00E-03	4.26	0.02	4.02	4.00	5	10	4.74
MD5	0.11	1.05E-02	2.93	0.05	0.98	0.93	5	10	6.48
MD6	0.16	9.45E-03	3.27	0.05	1.56	1.51	5	10	6.3
MD7	0.19	2.02E-03	2.26	0.01	1.52	1.51	5	10	6.79

Table 6: Calculation of dynamic J_d-integral for the Electron Beam and TIG Metal Deposit samples.

	Normalised energy for the calculation of J-Integral								
	Jd = 2 ETF / B (W-a)								
	ETF = EF- Em								
		EF: absorbed energy at fracture load							
		Em: elastic energy absorbed by the machine							
		Em= (Pf)**2 Cm / 2							
Specimen	Jd (J / mm**2)	Cm (mm / kN)	Pf (kN)	Em (J)	EF (J)	ETF (J)	B (mm)	W (mm)	a (mm)
TS1	0.54	8.22E-03	2.40	0.02	5.47	5.44	5	10	5.99
TS2	0.42	4.86E-01	2.48	1.49	5.54	4.05	5	10	6.12
TS3	0.50	5.30E-01	2.46	1.60	6.46	4.86	5	10	6.08
TS4	0.40	7.15E-01	2.41	2.08	6.00	3.92	5	10	6.12
TS5	0.18	1.18E-02	3.93	0.09	1.81	1.72	5	10	6.12
TS6	0.09	1.23E-01	3.50	0.76	1.63	0.87	5	10	6.05
TS7	0.15	1.31E-01	3.66	0.88	2.37	1.49	5	10	6.12
TL1	0.34	4.43E-01	2.52	1.41	4.96	3.55	5	10	5.87
TL2	0.39	4.43E-01	2.39	1.27	5.08	3.81	5	10	6.12
TL3	0.35	9.11E-01	2.31	2.43	5.69	3.26	5	10	6.26
TL4	0.40	7.08E-01	2.27	1.82	5.50	3.68	5	10	6.35
TL5	0.19	1.74E-03	3.14	0.01	1.89	1.88	5	10	6.05
TL6	0.21	3.47E-03	3.60	0.02	2.13	2.11	5	10	6.05
TL7	0.12	1.51E-01	3.32	0.83	1.99	1.15	5	10	6.04

Table 7: Calculation of dynamic J_d-integral for the Base Material specimens in the Transversal-Short and the Transversal-Longitudinal directions.

	Calculation J-Integral Fracture Toughness			
	KJd = (E Jd / (1 - Vpr ** 2)) ** 0.5			
	Vpr =	Poisson's ration (0,3)		
Specimen	KJd(MPA Vm)	Jd (J / mm**2)	E(kN/mm**2)	Vpr
EB1	289	0.39	193	0.3
EB2	313	0.46	193	0.3
EB3	281	0.37	193	0.3
EB4	298	0.42	193	0.3
EB5	182	0.16	193	0.3
EB6	169	0.14	193	0.3
EB7	162	0.12	193	0.3
MD1	148	0.10	193	0.3
MD2	231	0.25	193	0.3
MD3	161	0.12	193	0.3
MD4	254	0.30	193	0.3
MD5	150	0.11	193	0.3
MD6	186	0.16	193	0.3
MD7	200	0.19	193	0.3
TS1	339	0.54	193	0.3
TS2	297	0.42	193	0.3
TS3	324	0.50	193	0.3
TS4	293	0.40	193	0.3
TS5	194	0.18	193	0.3
TS6	137	0.09	193	0.3
TS7	181	0.15	193	0.3
TL1	270	0.34	193	0.3
TL2	289	0.39	193	0.3
TL3	272	0.35	193	0.3
TL4	292	0.40	193	0.3
TL5	201	0.19	193	0.3
TL6	213	0.21	193	0.3
TL7	157	0.12	193	0.3

Table 8: Calculation of the J-integral Fracture Toughness K_{ID} for the Electron Beam, TIG Metal Deposit and the Base Material specimens in the Transversal-Short and the Transversal-Longitudinal directions.

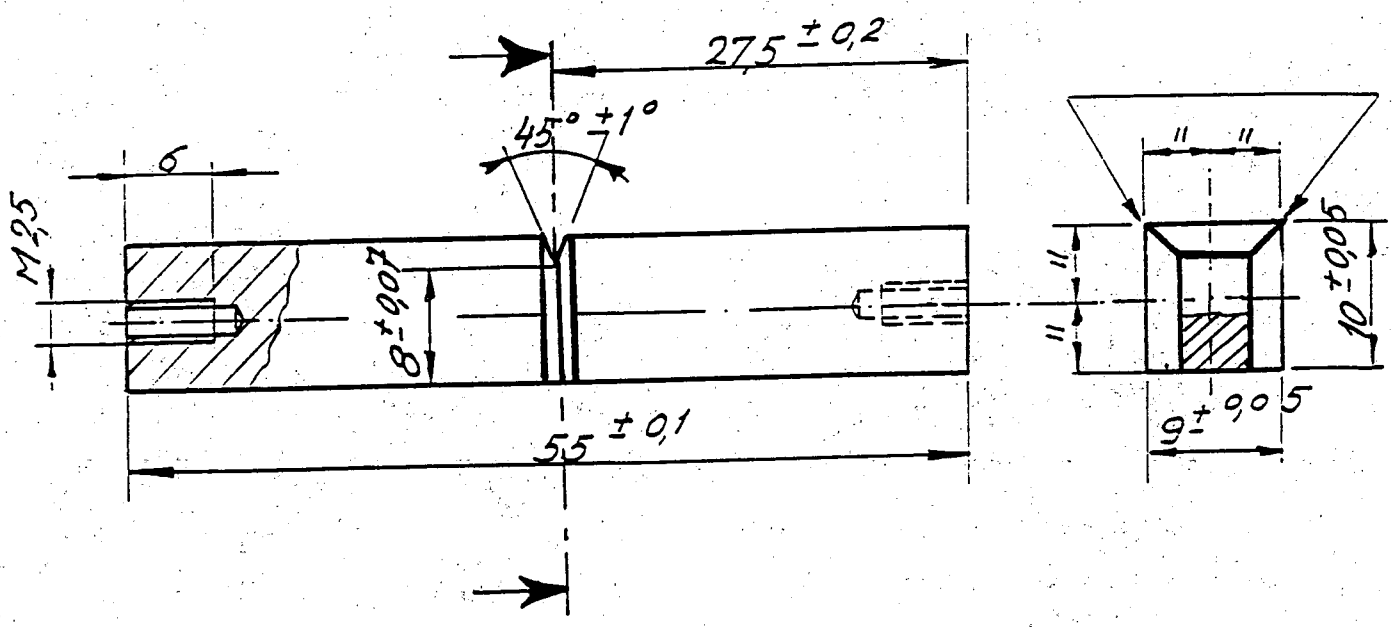


Figure 1: Charpy specimens used in the LOTION 3 experiment

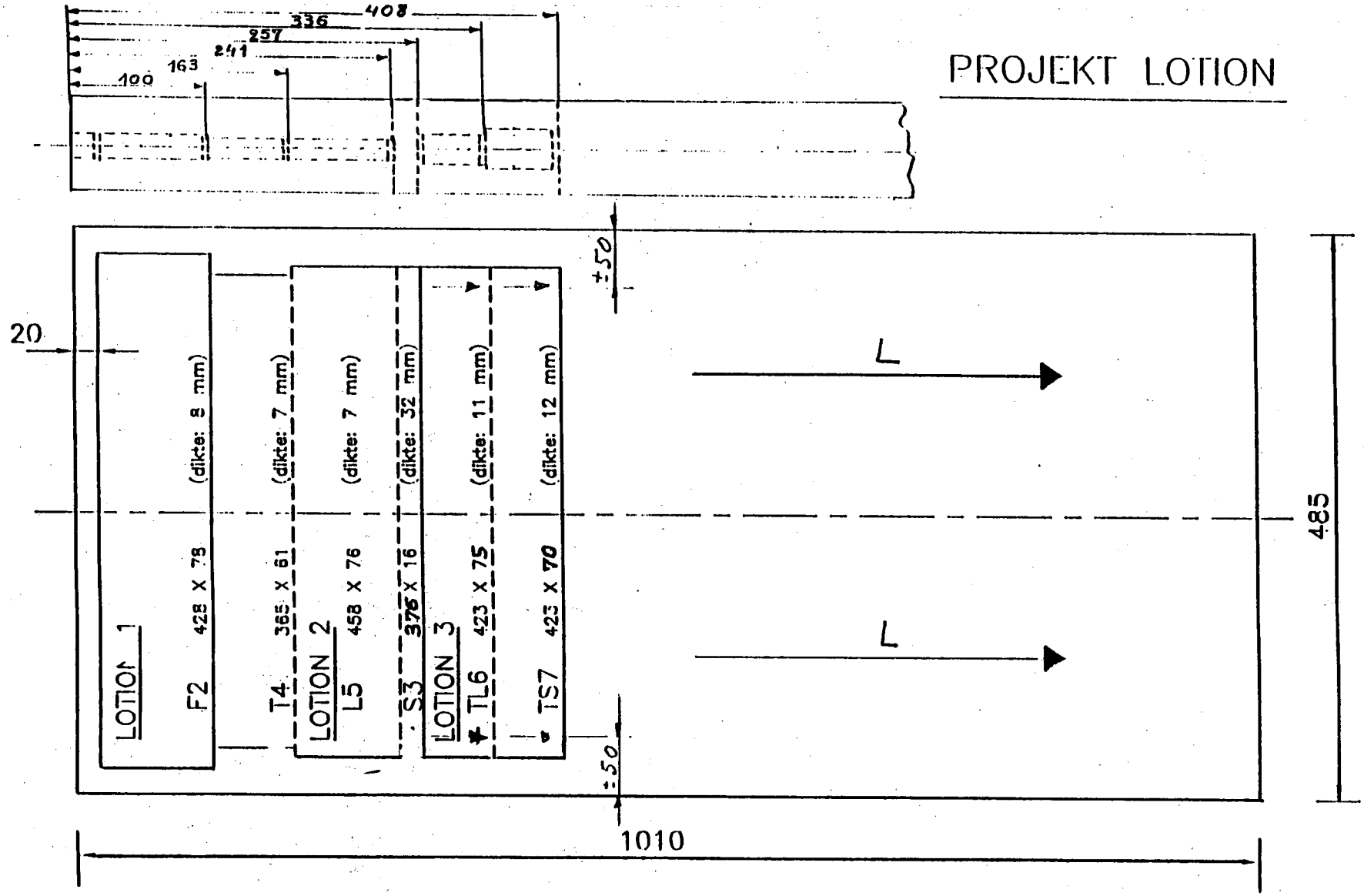


Figure 2: Locations from which the Charpy specimens for the different orientations in the base material originate

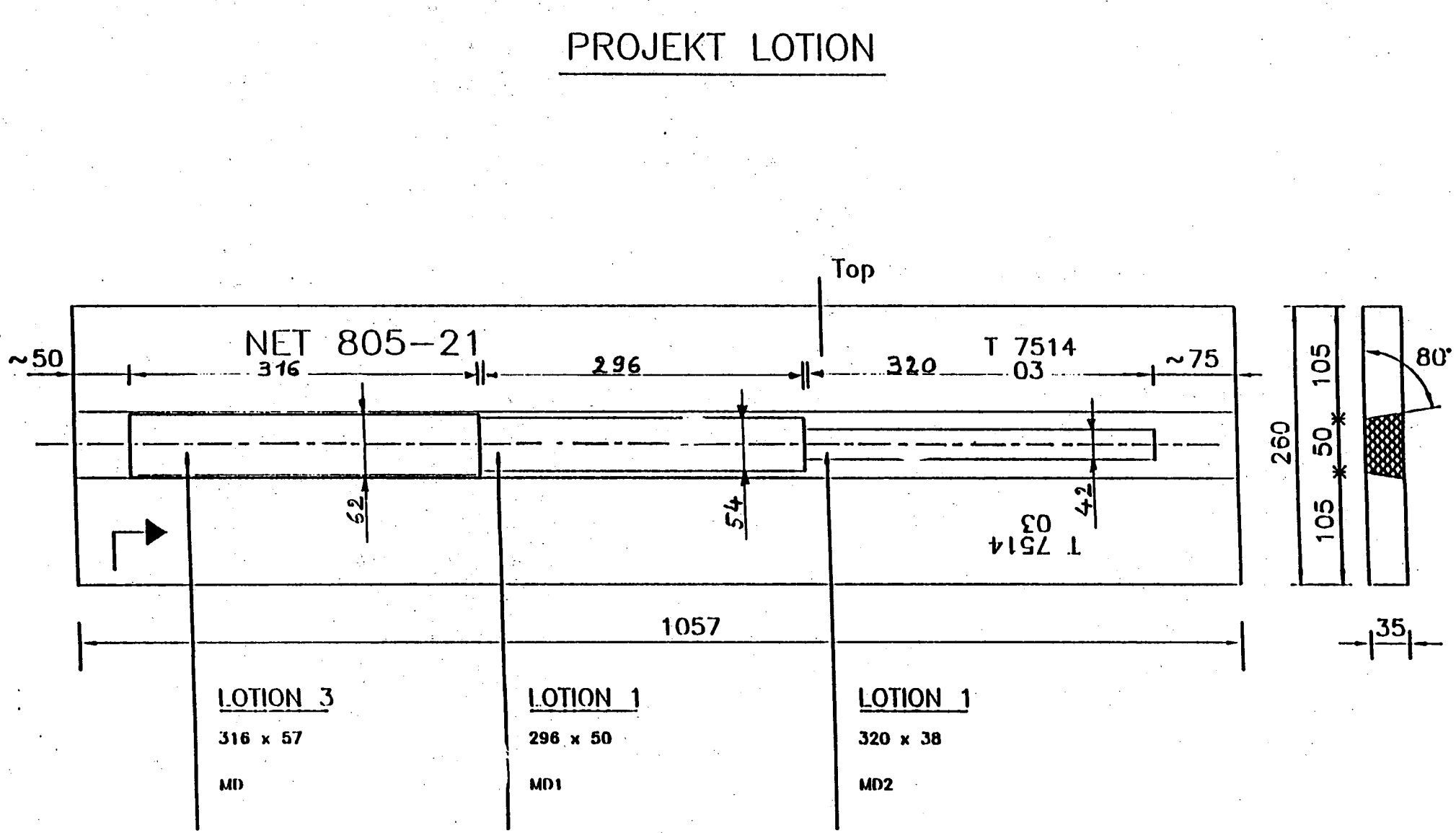
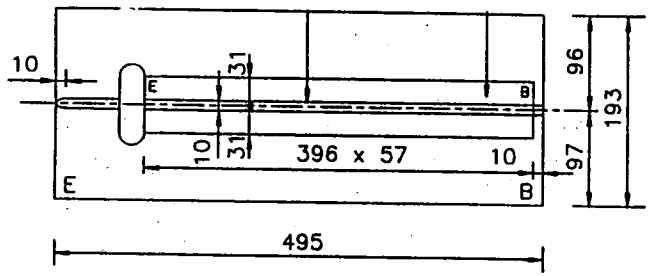
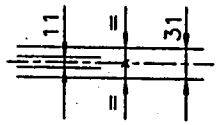


Figure 3: Locations from which the Charpy specimens from the TIG Metal Deposit originate

LOTION 3

Charpy





LOTION 3

Charpy

Impact TL

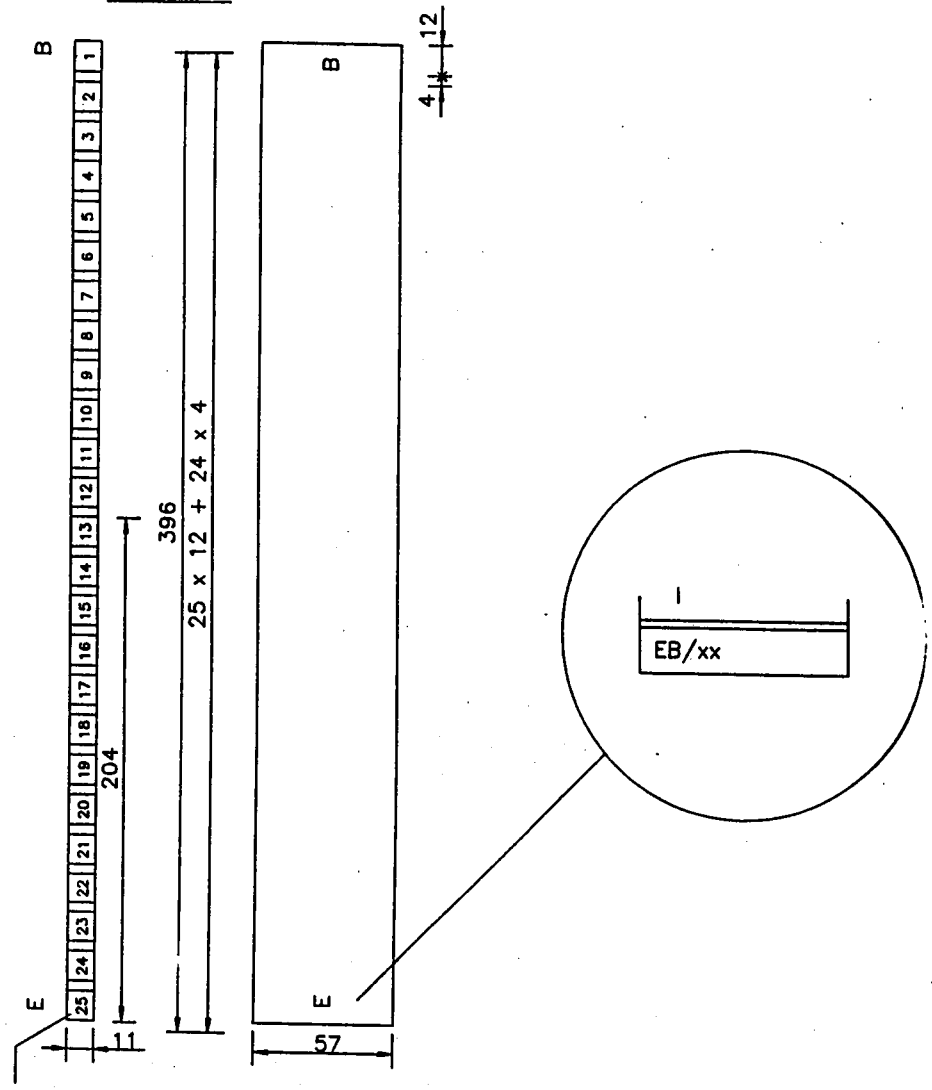


Figure 4: Locations from which the Charpy specimens from the Electron Beam weld joints originate

Specimen holder	Number of specimens	Specimen material and identification			
		MD(1)	EB(1)	TL6(1)	TB7(1)
1	3			12 X 22 32	
2	3		X 16 7 25		
3	4		3 14 / /	/ / 6 21	
4	3			1 17 X 27	
5	3		17 10 19 X		
6	3	13 X -> fluxmonitor 31 40 -> specimen identification			
7	3				X 22 12 27
8	4	9 23 / /			/ / 6 21
9	3	1 17 X 35			
10	3				1 32 17 X

(1) MD : Metal Deposit (Weld filling material)
EB : Electron Beam
TL6/TB7 : Specimen orientation in bulk plate

Figure 5: Loading plan of the LOTION 3 irradiation

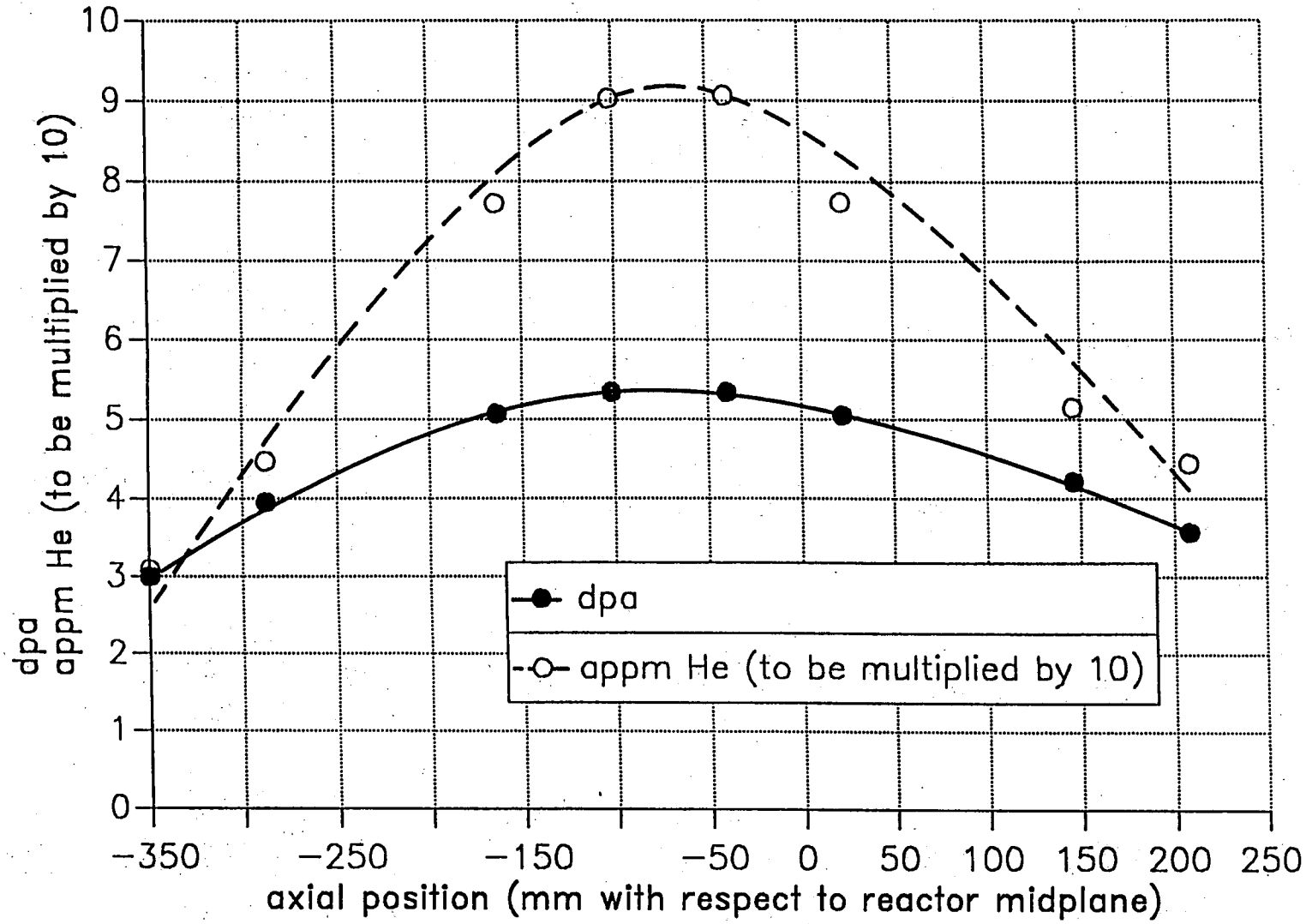


Figure 6: dpa and appm He values in the LOTION 3 experiment as a function of the axial position

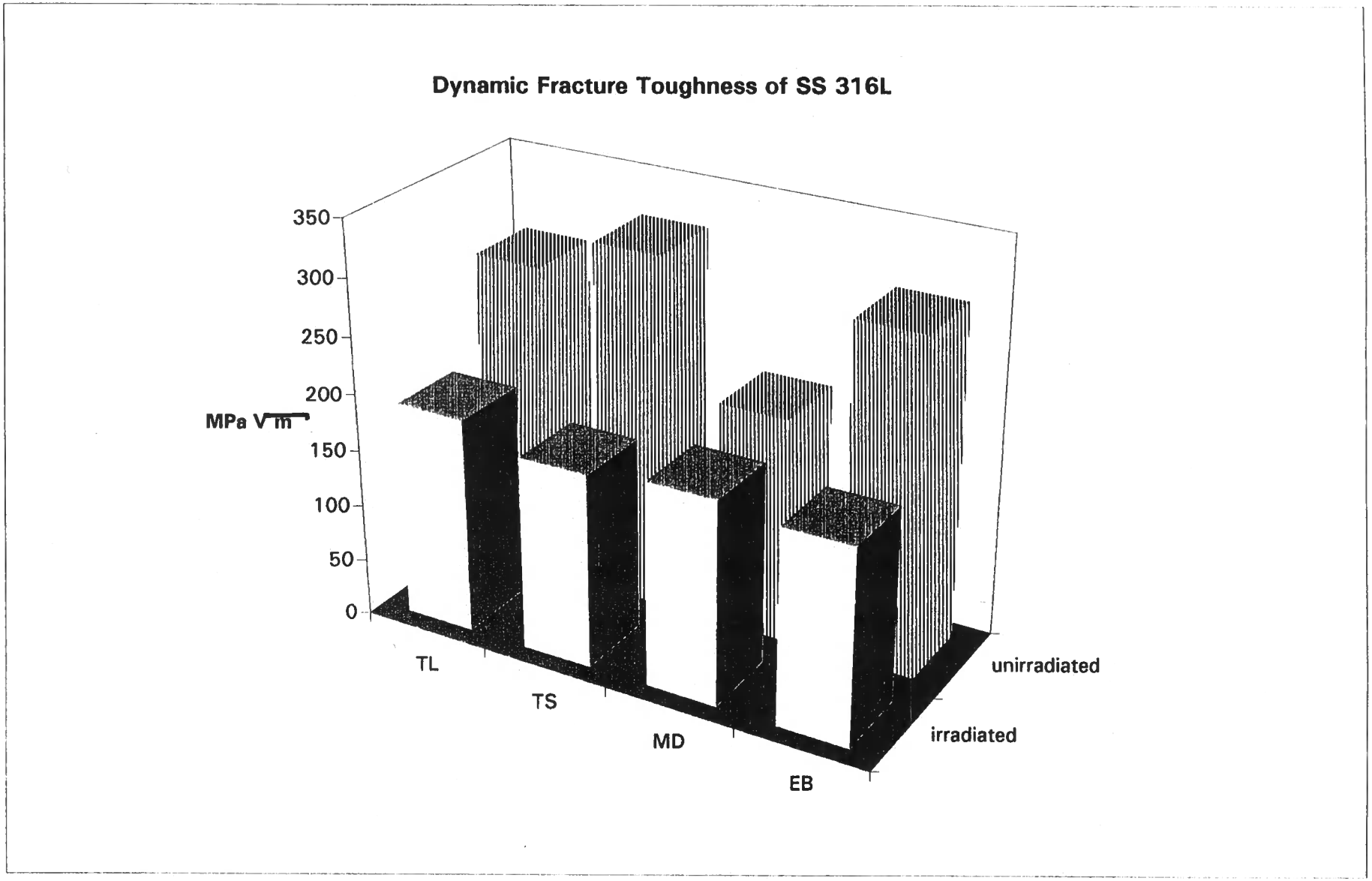
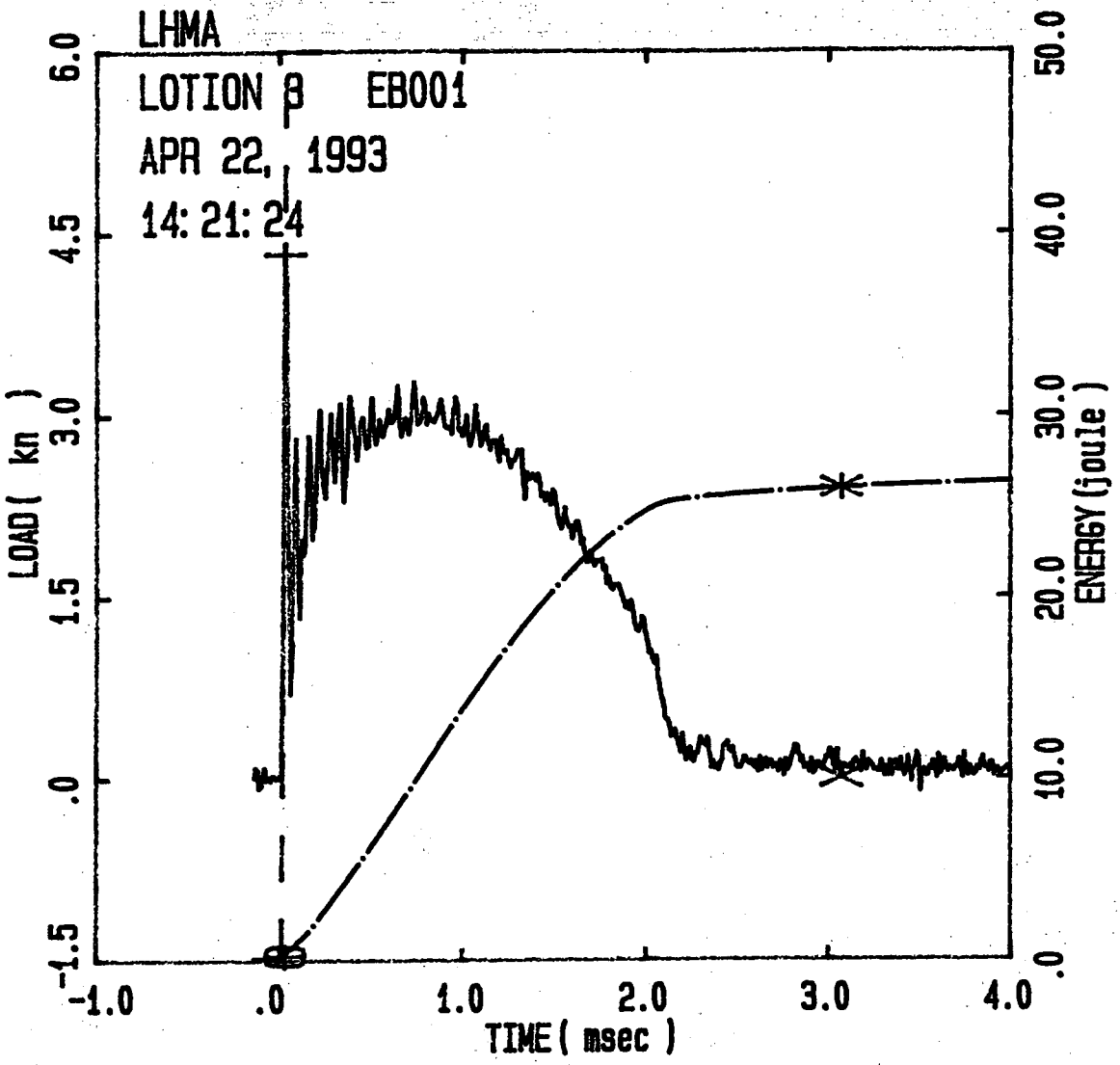


Figure 7: Average Dynamic Fracture Toughness of Stainless Steel 316L The columns show the values for the Electron Beam (EB), TIG Metal Deposit (MD) and the Base Material specimens in the Transversal-Short (TS) and the Transversal-Longitudinal (TL) directions in the irradiated and unirradiated condition.

Appendix 1



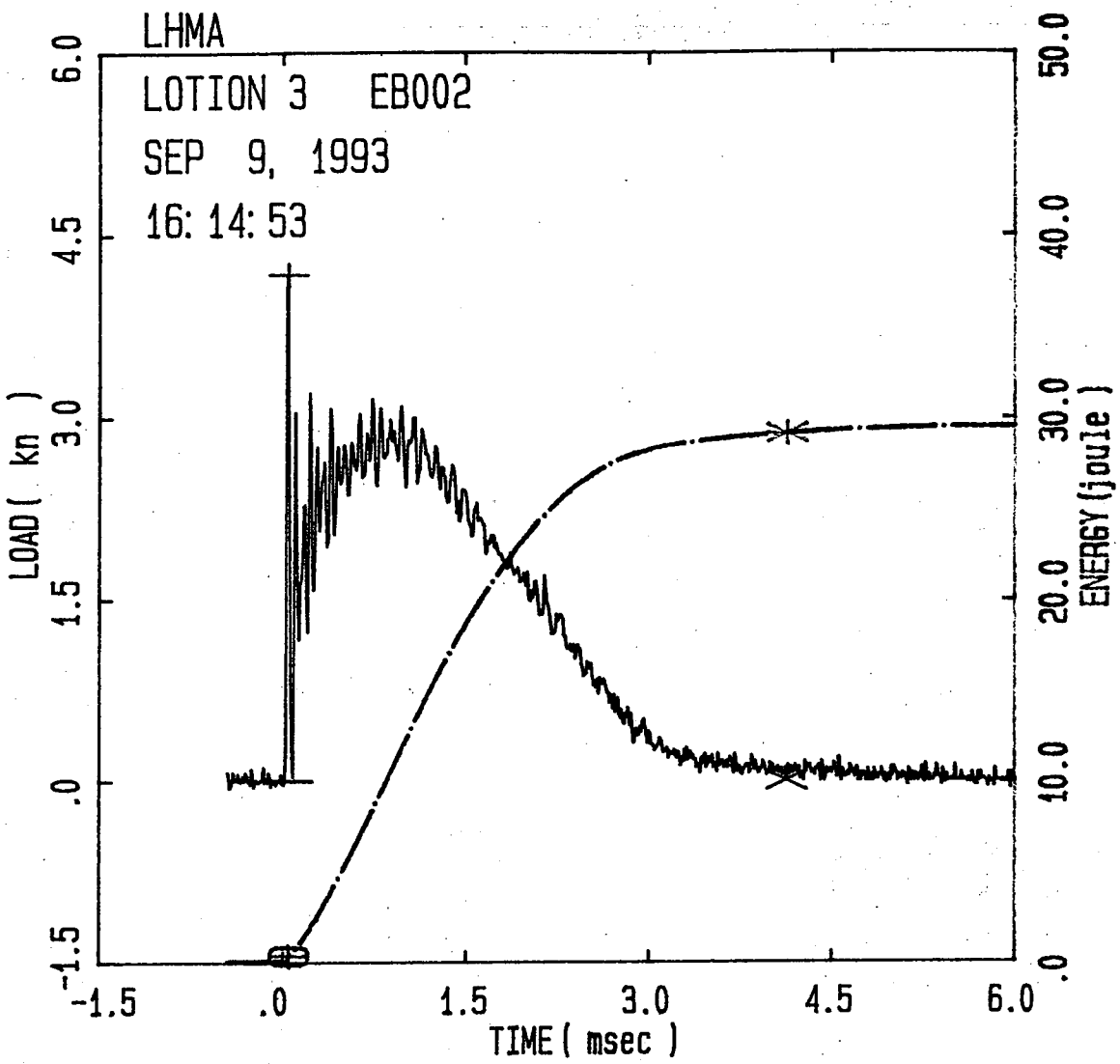
Specimen Id	Temp (c)	Impact Veloc. (m/sec)	Energy (joule)	Time (msec) Max Ld	Time (msec) Total	Load (kn) Max	Energy (joule) MaxId	Energy (joule) Total
LOTION 3 EB001	26.	5.12	357.80	.03	3.07	4.3272	.172	25.990

Filter No.= 2, No Smoothing.
Comments:
LOTION 3 EB 24
E DIAL 24.5 J. ISO TUP 1
FILE 1 NICOLET 75/76 DISK 5

LHMA

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 EB001	26.00	28200.470					
Impact:			5.12			357.80	
Yield:				.03	4.33	.17	.15
Maximum Load:				.03	4.3272	.17	.15
Failure(.00%):				3.07	.00	25.99	15.31
Energy After Max Load:						25.82	
Total Energy:				3.07		25.99	15.31

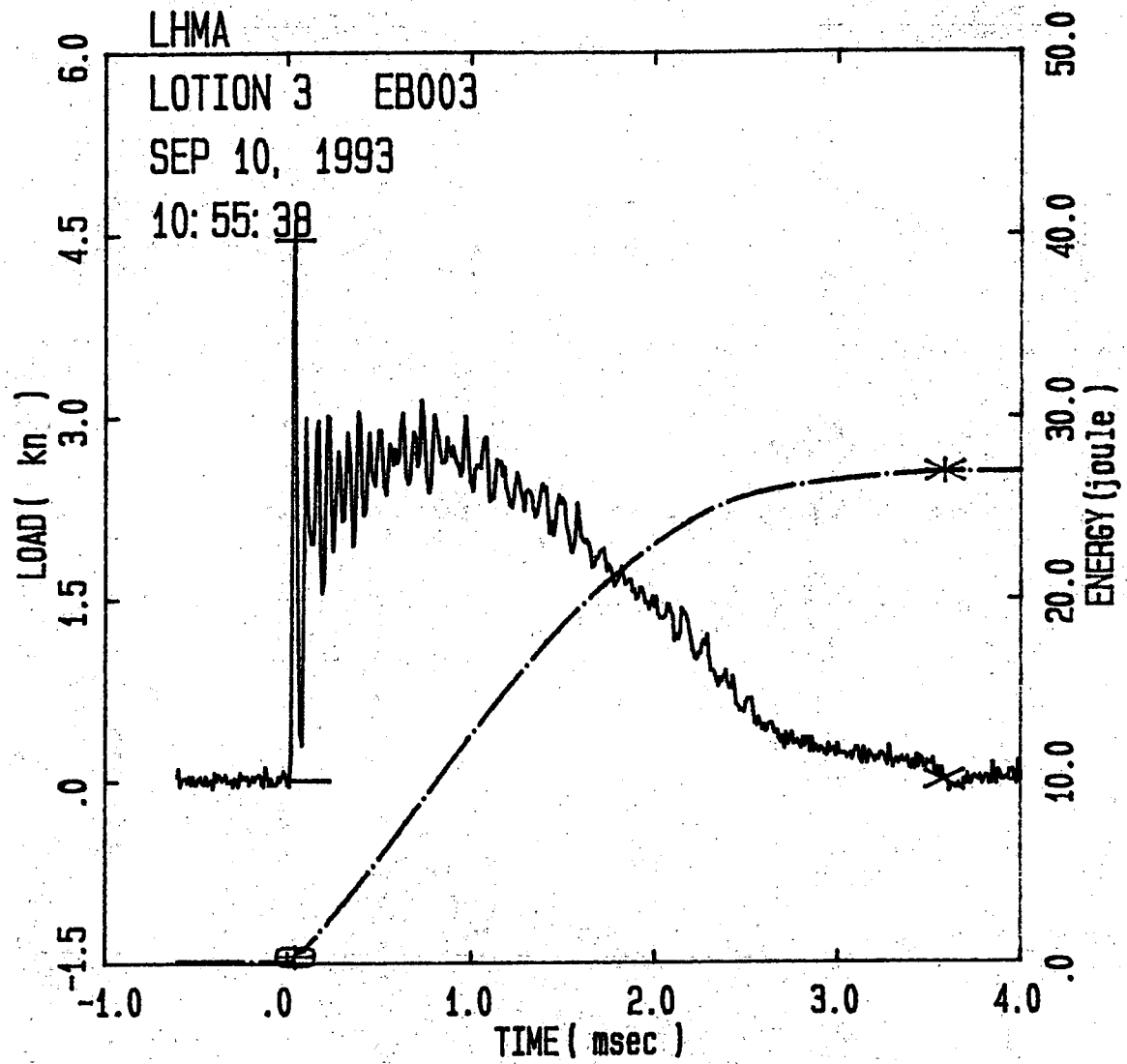
Comments:
LOTION 3 EB 24
E DIAL 25.5 J. ISO TUP 1
FILE 1 NICOLET 75/76 DISK 5



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 EB002 26.50 20435.530							
Impact:			5.12			358.48	
Yield:				.04	4.18	.33	.20
Maximum Load:				.04	4.1848	.33	.20
Failure(.00%):				4.13	.00	29.12	20.54
Energy After Max Load:						28.80	
Total Energy:				4.13		29.12	20.54

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 EB002 26.50 20435.530							
Impact:			5.12			358.48	
Yield:				.04	4.18	.33	.20
Maximum Load:				.04	4.1848	.33	.20
Failure(.00%):				4.13	.00	29.12	20.54
Energy After Max Load:						28.80	
Total Energy:				4.13		29.12	20.54

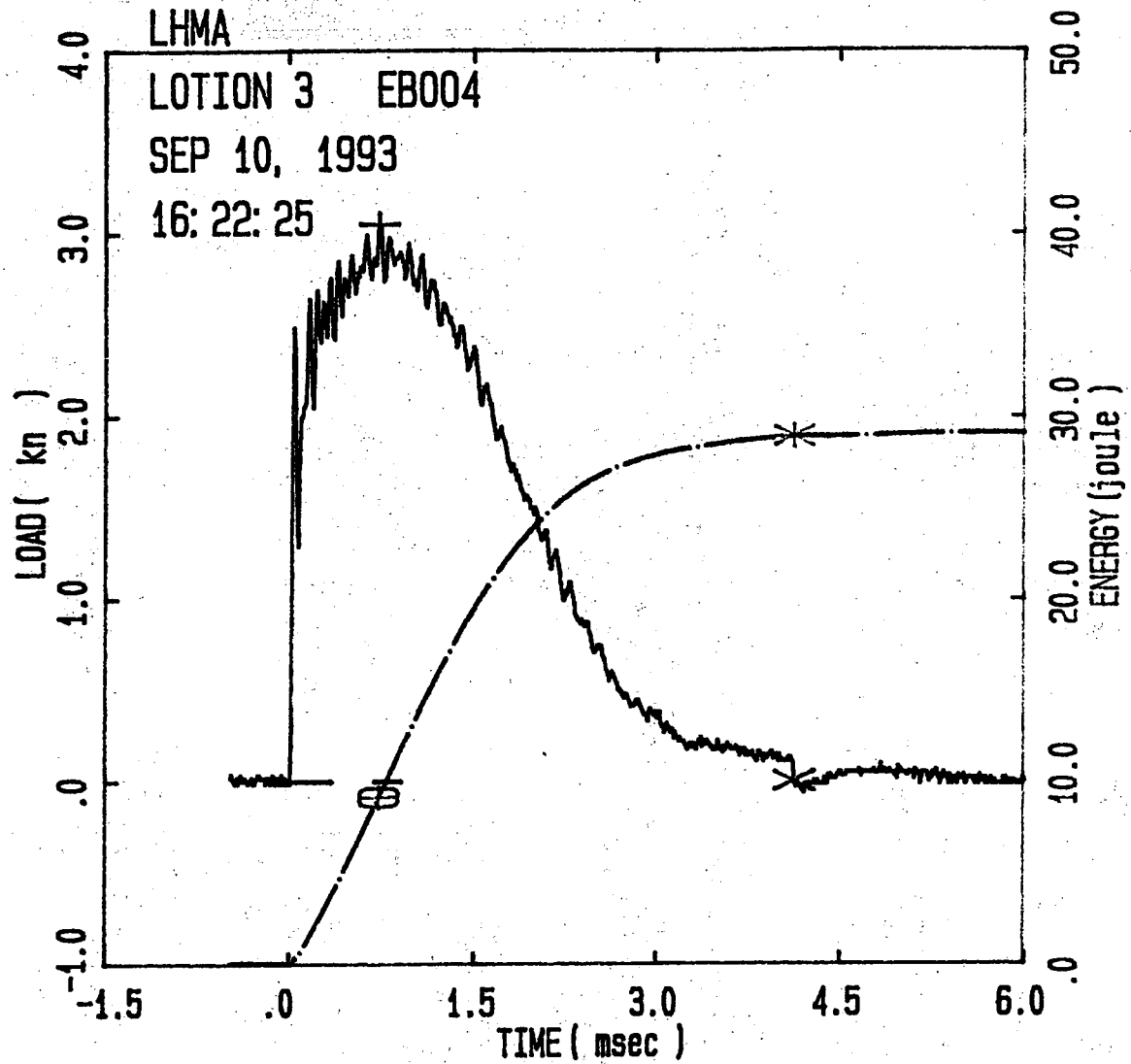
Comments:
ELECTRON BEAM WELDING
SPECIMEN EB 2 UNIRRAD.
DIAL 29 J. ASTM TUP 5
FILE 7 NICOLET NOT CONNECTED
UPSENSITIVITY 10.00 kN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 EB003 25.50 21804.790							
Impact:			5.12			358.48	
Yield:				.04	4.47	.31	.20
Maximum Load:				.04	4.4652	.31	.20
Failure(.00%):				3.58	.00	26.99	17.86
Energy After Max Load:						26.68	
Total Energy:				3.58		26.99	17.86

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 EB003 25.50 21804.790							
Impact:			5.12			358.48	
Yield:				.04	4.47	.31	.20
Maximum Load:				.04	4.4652	.31	.20
Failure(.00%):				3.58	.00	26.99	17.86
Energy After Max Load:						26.68	
Total Energy:				3.58		26.99	17.86

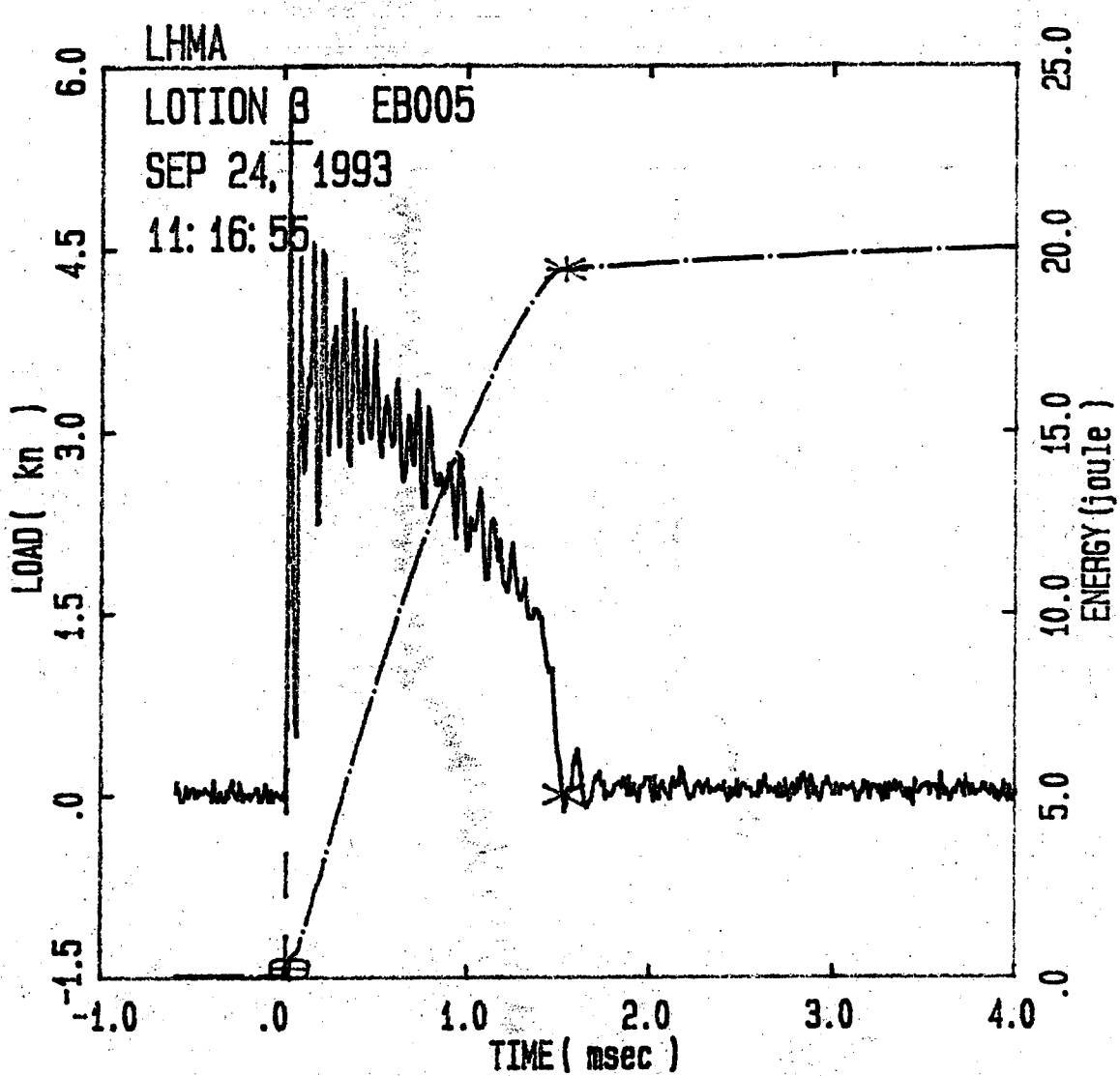
Comments:
ELECTRON BEAM WELDING
SPECIMEN EB 6 UNIRRAD.
E DIAL 27 J. ASTM TYP 5
FILE 11 NICOLET NOT CONNECTED
TUPSENSITIVITY 9.8 kN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 EB004	26.50	821.901					
Impact:		5.12				358.48	
Yield:			.73	3.05		9.14	3.72
Maximum Load:			.73	3.0542		9.14	3.72
Failure(.00%):			4.13	.00		28.93	20.53
Energy After Max Load:						19.79	
Total Energy:			4.13			28.93	20.54

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3	EB004	26.50	821.901				
Impact:			5.12			358.48	
Yield:				.73	3.05	9.14	3.72
Maximum Load:				.73	3.0542	9.14	3.72
Failure(.00%):				4.13	.00	28.93	20.53
Energy After Max Load:						19.79	
Total Energy:				4.13		28.93	20.54

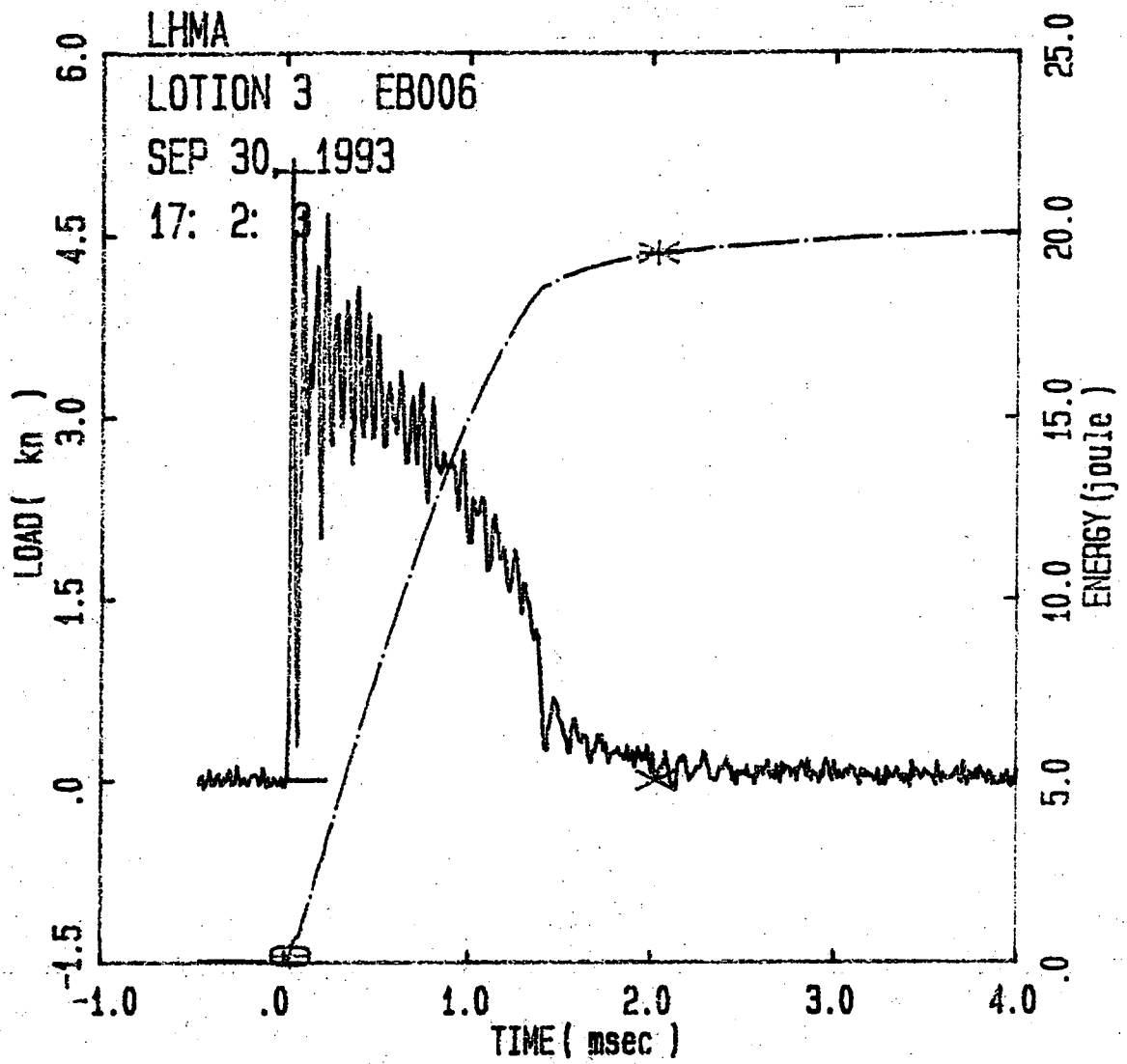
Comments:
ELECTRON BEAM WELDING
SPECIMEN EB 8 UNIRRAD.
DIAL 29 J. ASTM TYP 5
TYPE 15 NICOLET NOT CONNECTED
SENSITIVITY 10.00 KN



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 EB005 26.00 34995.210							
Impact:		5.12				358.48	
Yield:			.03	5.37		.22	.15
Maximum Load:			.03	5.3749		.22	.15
Failure(.00%):			1.53	.00		19.44	7.72
Energy After Max Load:						19.22	
Total Energy:			1.54			19.44	7.76

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 EB005 26.00 34995.210							
Impact:		5.12				358.48	
Yield:			.03	5.37		.22	.15
Maximum Load:			.03	5.3749		.22	.15
Failure(.00%):			1.53	.00		19.44	7.72
Energy After Max Load:						19.22	
Total Energy:			1.54			19.44	7.76

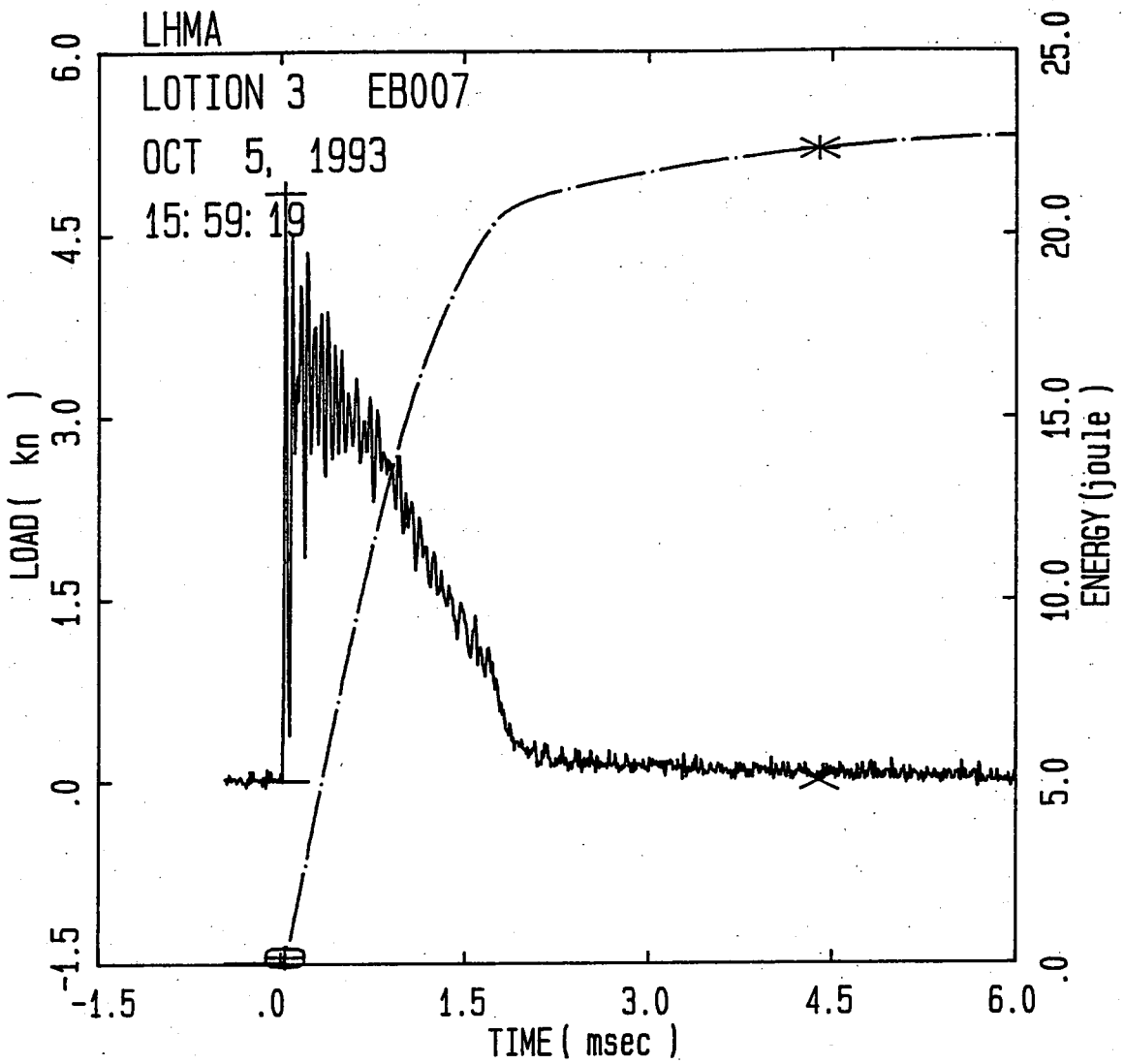
Comments:
ELECTRON BEAM WELDING
SPECIMEN E8/10 IRRAD.
F DIAL 19.5 J. ASTM NO. 5
FILE 18 NICOLET 3/4 DISK 8
TUPSENSITIVITY 10.7 KN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 EB006 26.00 32781.480							
Impact:		5.12				358.48	
Yield:			.03	5.04	.15	.15	
Maximum Load:			.03	5.0350	.15	.15	
Failure(.00%):			2.03	.00	19.51	10.20	
Energy After Max Load:					19.36		
Total Energy:			2.03		19.51	10.20	

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 EB006 26.00 32781.480							
Impact:		5.12				358.48	
Yield:			.03	5.04	.15	.15	
Maximum Load:			.03	5.0350	.15	.15	
Failure(.00%):			2.03	.00	19.51	10.20	
Energy After Max Load:					19.36		
Total Energy:			2.03		19.51	10.20	

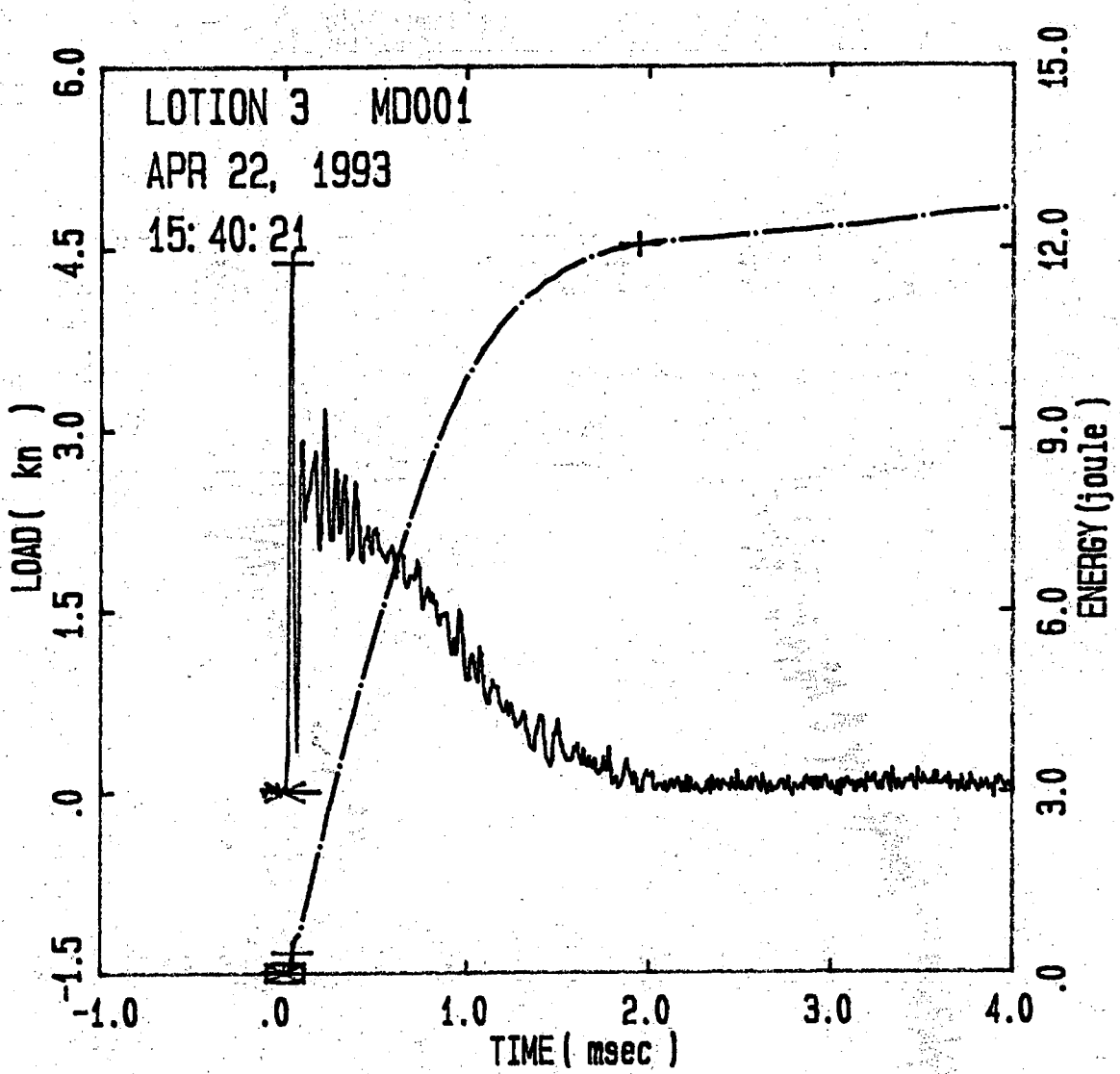
Comments:
ELECTRON BEAM WELDING
SPECIMEN E0/17 IRRAD.
DIAL 19.5 J. ASTM TUP 5
FILE 20 NICOLET 9/10 DISK 8
TUPSENSITIVITY 10.5 KN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 EB007 25.50 31555.250							
Impact:			5.12			358.48	
Yield:				.03	4.85	.16	.15
Maximum Load:				.03	4.8467	.16	.15
Failure(.00%):				4.39	.00	22.33	21.91
Energy After Max Load:						22.17	
Total Energy:				4.39		22.33	21.91

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 EB007 25.50 31555.250							
Impact:			5.12			358.48	
Yield:				.03	4.85	.16	.15
Maximum Load:				.03	4.8467	.16	.15
Failure(.00%):				4.39	.00	22.33	21.91
Energy After Max Load:						22.17	
Total Energy:				4.39		22.33	21.91

Comments:
ELECTRON BEAM WELDING
SPECIMEN EB/19 IRRAD.
F DIAL 22 J. ASTM TUP 5
FILE 21 NICOLET 15/16 DISK 8
TUPSENSITIVITY 9.6 KN.

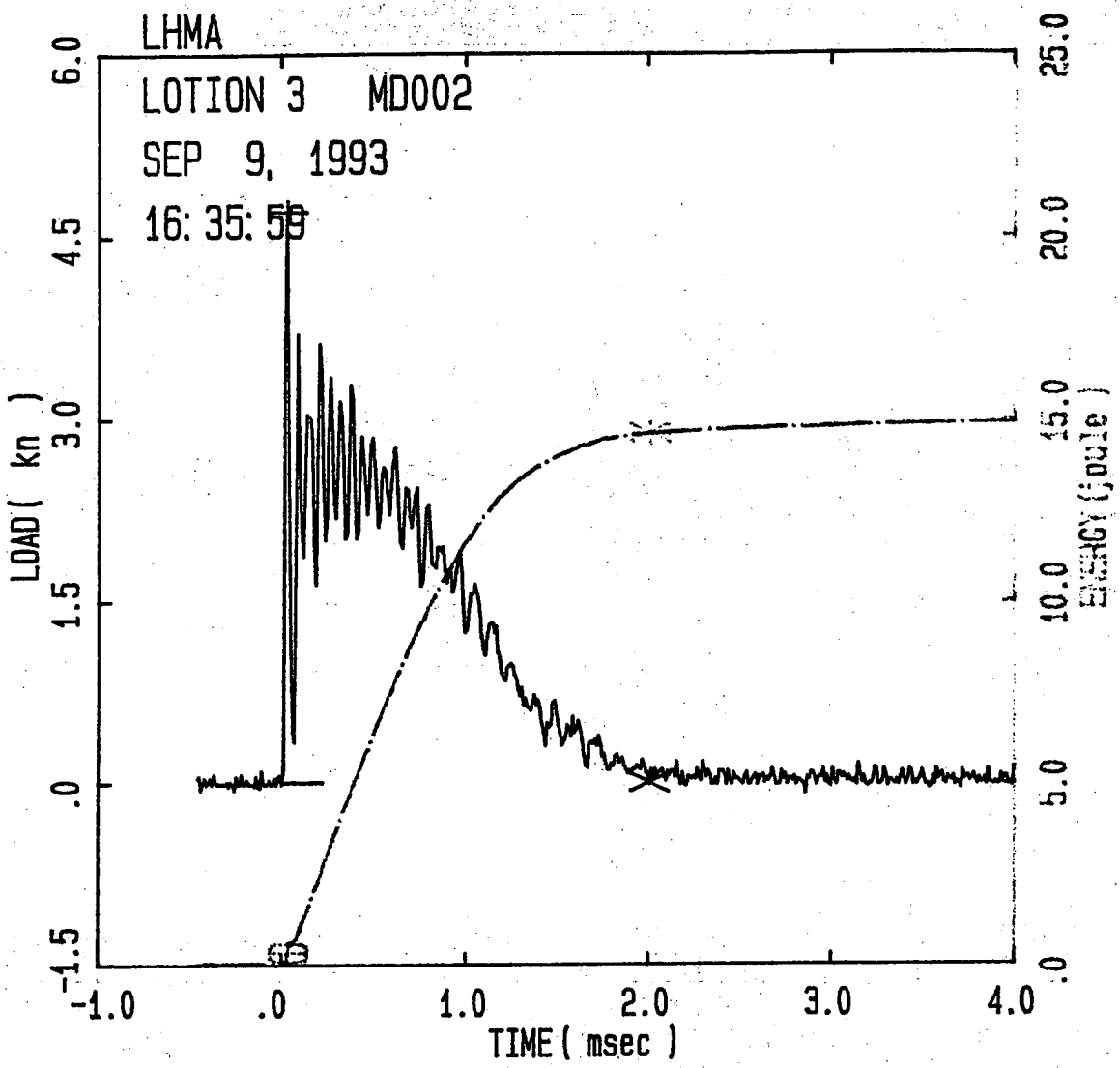


Specimen Id	Temp (c)	Impact Veloc. (m/sec)	Energy (joule)	Time (msec) Max Ld	Time (msec) Total	Load (kn) Max	Energy (joule) MaxId	Energy (joule) Total
LOTION 3 MD001	26.	5.12	357.80	.04	1.94	4.3862	.329	12.072

Filter No.= 2, No Smoothing.
Comments:
LOTION 3 MD 10 ↑
E DIAL 11.5 J. ISO TUP 1
FILE 2 NICOLET 77/78 DISK 5

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 MD001	26.00	.000					
Impact:			5.12			357.80	
Maximum Load:				.04	4.3862	.33	.20
Energy After Max Load:						11.74	
Total Energy:				1.94		12.07	9.81

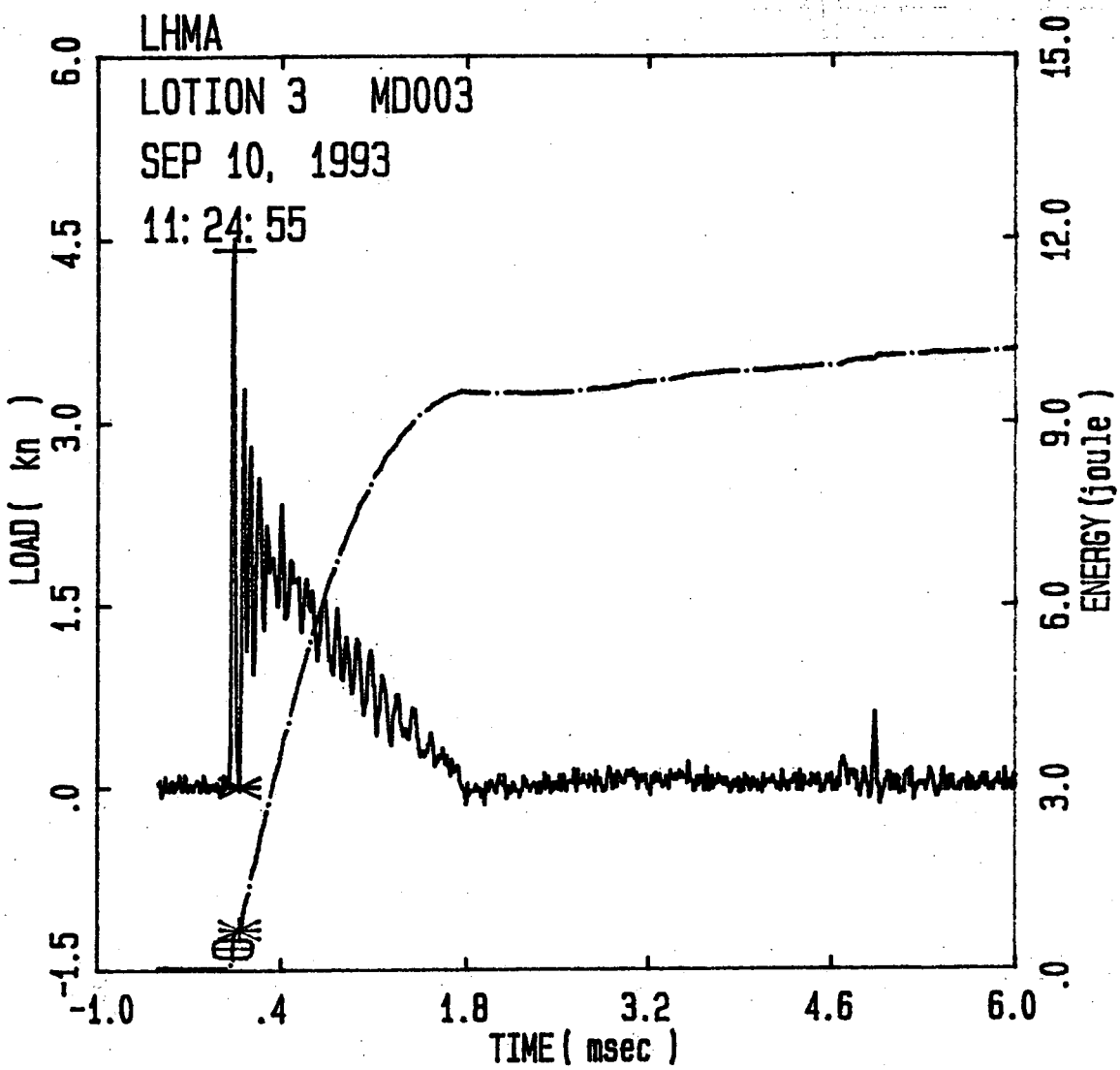
Comments:
LOTION 3 MD 10
E DIAL 12.5 J. ISO TUP 1
FILE 2 NICOLET 77/78 DISK 5
Friction 13



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 MD002	26.50	30690.160					
Impact:			5.12			358.48	
Yield:				.03	4.71	.31	.15
Maximum Load:				.03	4.7134	.31	.15
Failure(.00%):				2.01	.00	14.61	10.14
Energy After Max Load:						14.30	
Total Energy:				2.01		14.61	10.15

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
OTION 3 MØØ2	26.5Ø	3Ø69Ø.16Ø					
Impact:			5.12			358.48	
Yield:				.Ø3	4.71	.31	.15
Maximum Load:				.Ø3	4.7134	.31	.15
Failure(.ØØ%):				2.Ø1	.ØØ	14.61	1Ø.14
Energy After Max Load:						14.3Ø	
Total Energy:				2.Ø1		14.61	1Ø.15

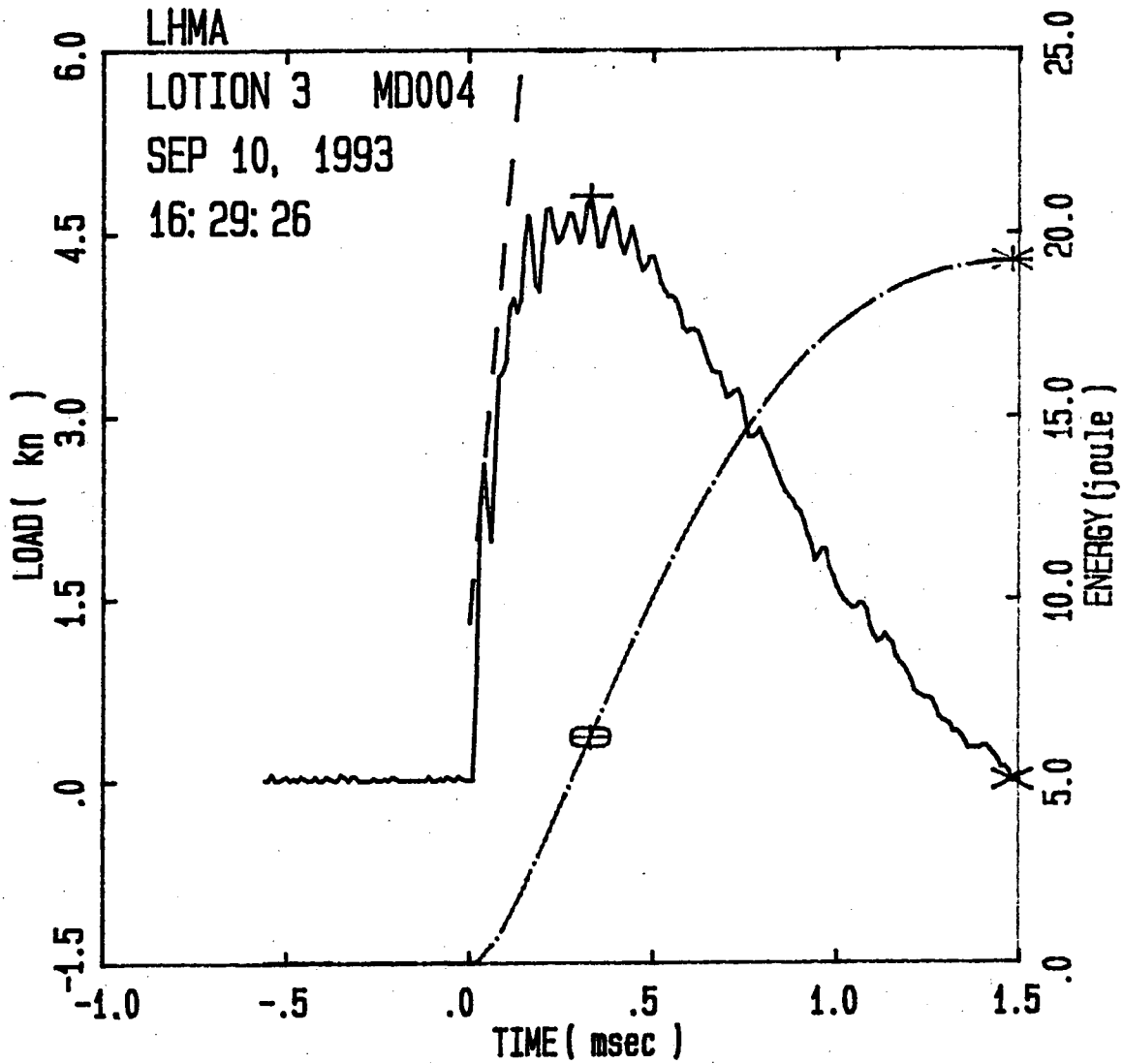
omments:
ETAL DEPOSIT WELDING UNIRRAD.
PECIMEN MD/8
DIAL 14.5 J. ASTM TUP 5
IE 8 NICOLET NOT CONNECTED
UPSENSITIVITY 9.7 KN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 MD003 26.00 21588.140							
Impact:			5.12			358.48	
Yield:				.04	4.42	.34	.20
Maximum Load:				.04	4.4208	.34	.20
Failure(.00%):				.09	.00	.66	.45
Energy After Max Load:						.32	
Total Energy:				.09		.66	.46

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 MD003 26.00 21588.140							
Impact:			5.12			358.48	
Yield:				.04	4.42	.34	.20
Maximum Load:				.04	4.4208	.34	.20
Failure(.00%):				.09	.00	.66	.45
Energy After Max Load:						.32	
Total Energy:				.09		.66	.46

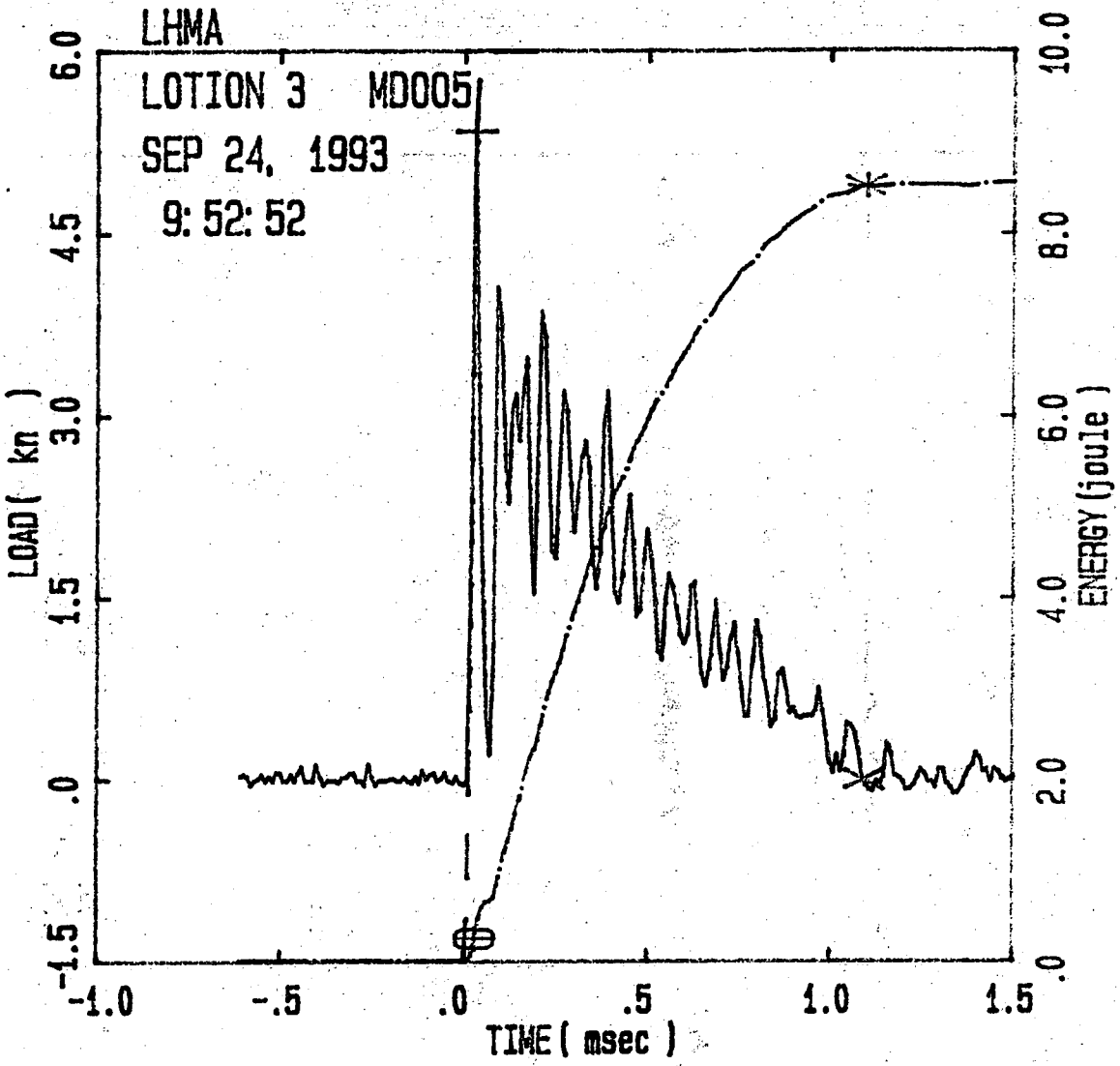
Comments:
METAL DEPOSIT WELDING UNIRRAD.
SPECIMEN MD/22 1
DIAL 9 3. ASTM TUP 5
FILE 12 NICOLET NOT CONNECTED
UPSENSITIVITY 10.00 KN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 MD004	26.50	7130.103					
Impact:			5.12			358.48	
Yield:				.33	4.80	6.21	1.68
Maximum Load:				.33	4.7982	6.21	1.68
Failure(.00%):				1.48	.00	19.25	7.45
Energy After Max Load:						13.04	
Total Energy:				1.48		19.25	7.45

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 MD004	26.50	7130.103					
Impact:			5.12			358.48	
Yield:				.33	4.80	6.21	1.68
Maximum Load:				.33	4.7982	6.21	1.68
Failure(.00%):				1.48	.00	19.25	7.45
Energy After Max Load:						13.04	
Total Energy:				1.48		19.25	7.45

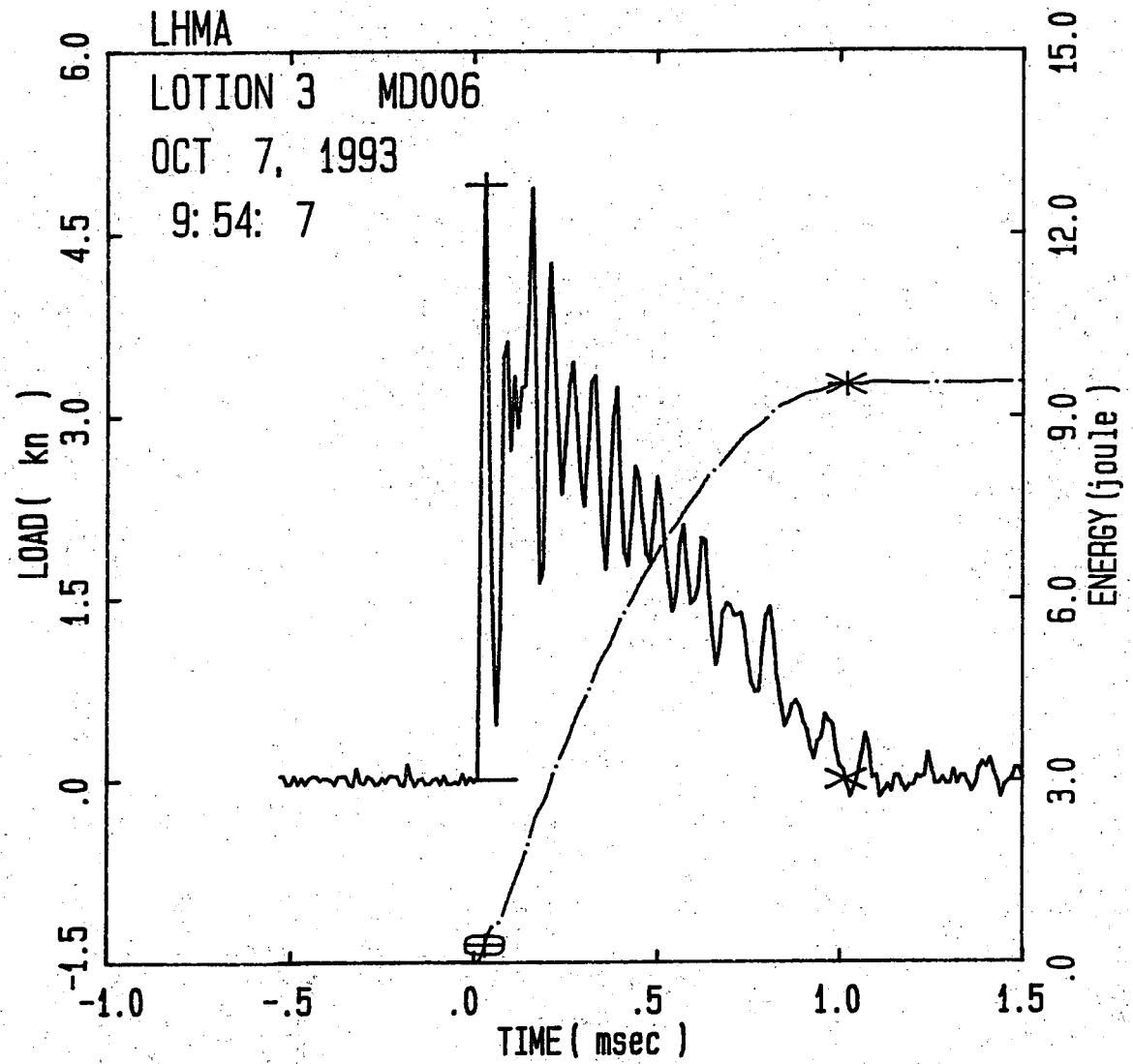
Comments:
METAL DEPOSIT WELDING UNIRRAD.
SPECIMEN MD/24
DIAL 19 3. ASTM TUP 5
FILE 16 NICOLET NO SIGNAL
UPSENSITIVITY 9.8 kN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 MD005 26.00 34739.270							
Impact:		5.12				358.48	
Yield:			.03	5.34		.24	.15
Maximum Load:			.03	5.3355		.24	.15
Failure(.00%):			1.09	.00		8.52	5.56
Energy After Max Load:						8.27	
Total Energy:			1.10			8.52	5.59

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 MD005 26.00 34739.270							
Impact:		5.12				358.48	
Yield:			.03	5.34		.24	.15
Maximum Load:			.03	5.3355		.24	.15
Failure(.00%):			1.09	.00		8.52	5.56
Energy After Max Load:						8.27	
Total Energy:			1.10			8.52	5.59

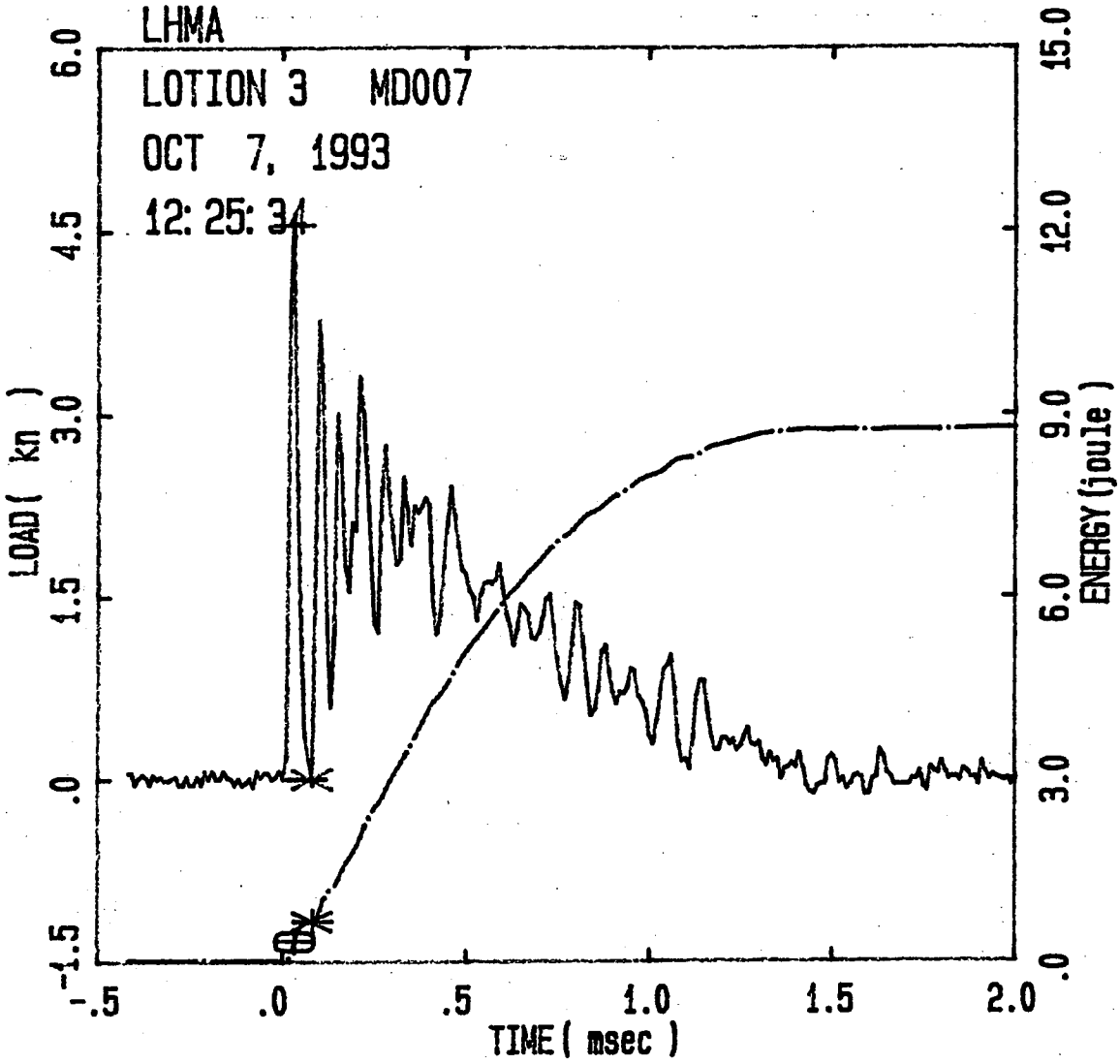
Comments:
METAL DEPOSIT WELDING IRRAD.
SPECIMEN MD/13
DIAL 8.5 J. ASTM EP 5
FILE 17 NICOLET 1/2 DISK 8
HIPSENSITIVITY 10.5 kN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 MD006 24.00 31962.600							
Impact:		5.12				358.48	
Yield:				.03	4.91	.28	.15
Maximum Load:				.03	4.9090	.28	.15
Failure(.00%):				1.02	.00	9.52	5.16
Energy After Max Load:						9.24	
Total Energy:				1.02		9.52	5.18

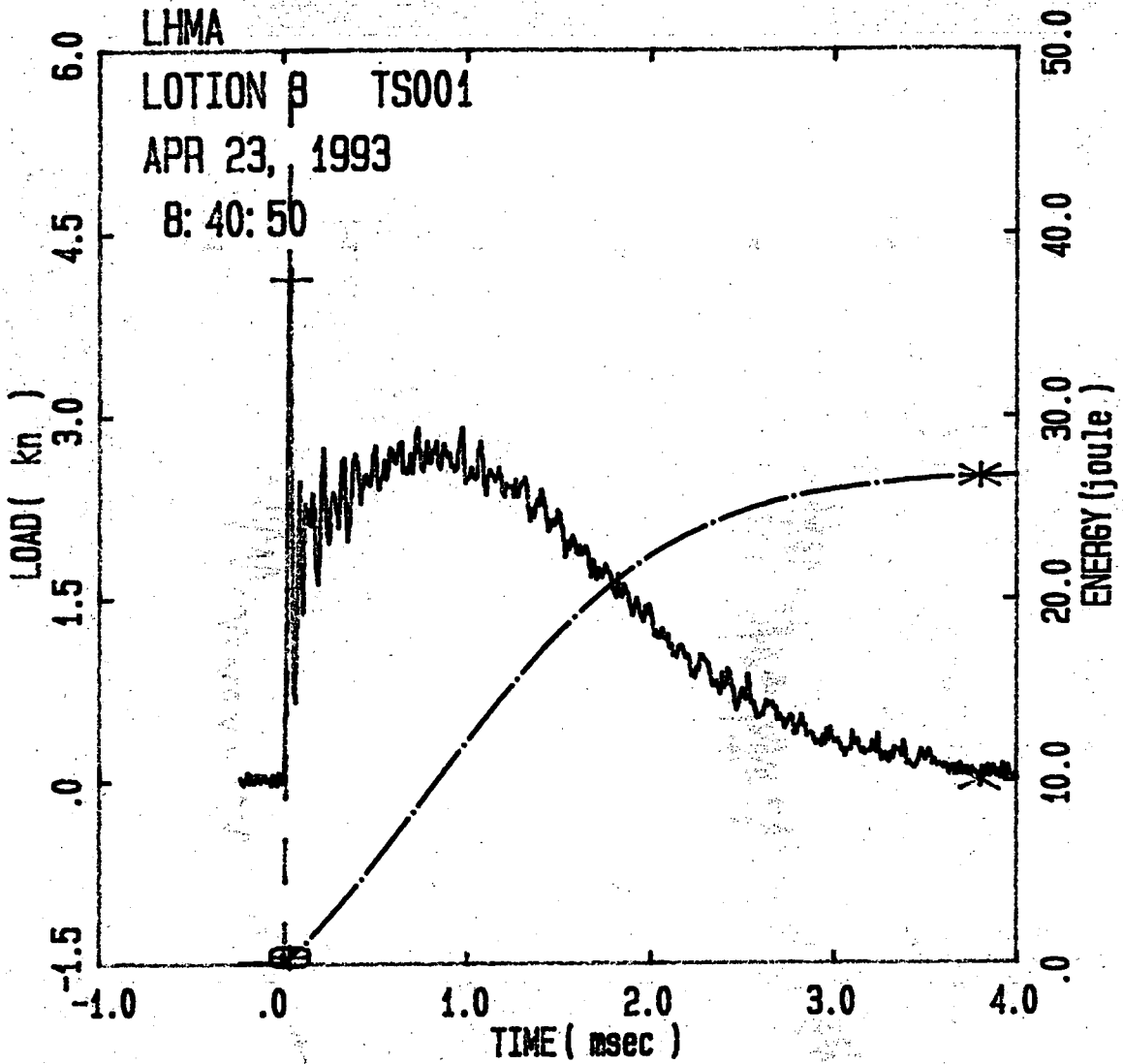
Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 MD006 24.00 31962.600							
Impact:		5.12				358.48	
Yield:				.03	4.91	.28	.15
Maximum Load:				.03	4.9090	.28	.15
Failure(.00%):				1.02	.00	9.52	5.16
Energy After Max Load:						9.24	
Total Energy:				1.02		9.52	5.18

Comments:
METAL DEPOSIT WELDING IRRAD.
SPECIMEN MD/31
E DIAL 9.5 J. ASTM TUP 5
FILE 24 NICOLET 21/22 DISK 8
TUPSENSITIVITY 9.9 kN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 MD007	25.50	29329.400					
Impact:			5.18			366.85	
Yield:				.03	4.56	.32	.16
Maximum Load:				.03	4.5567	.32	.16
Failure(.00%):				.08	.00	.65	.40
Energy After Max Load:						.33	
Total Energy:				.08		.66	.41
Y:			5.17	.09	1.99	.71	.47
M:			5.17	.11	3.19	1.03	.57
U:			5.17	.11	3.19	1.03	.57
A:			5.12	1.42	.10	8.74	7.30
T:			5.12	1.42	.10	8.74	7.30

Comments:
METAL DEPOSIT WELDING IRRAD.
SPECIMEN MD/40
E DIAL 8 J. ASTM TUP 5
FILE 26 NICOLET 25/26 DISK 8
TUPSENSITIVITY 10.00 kN.

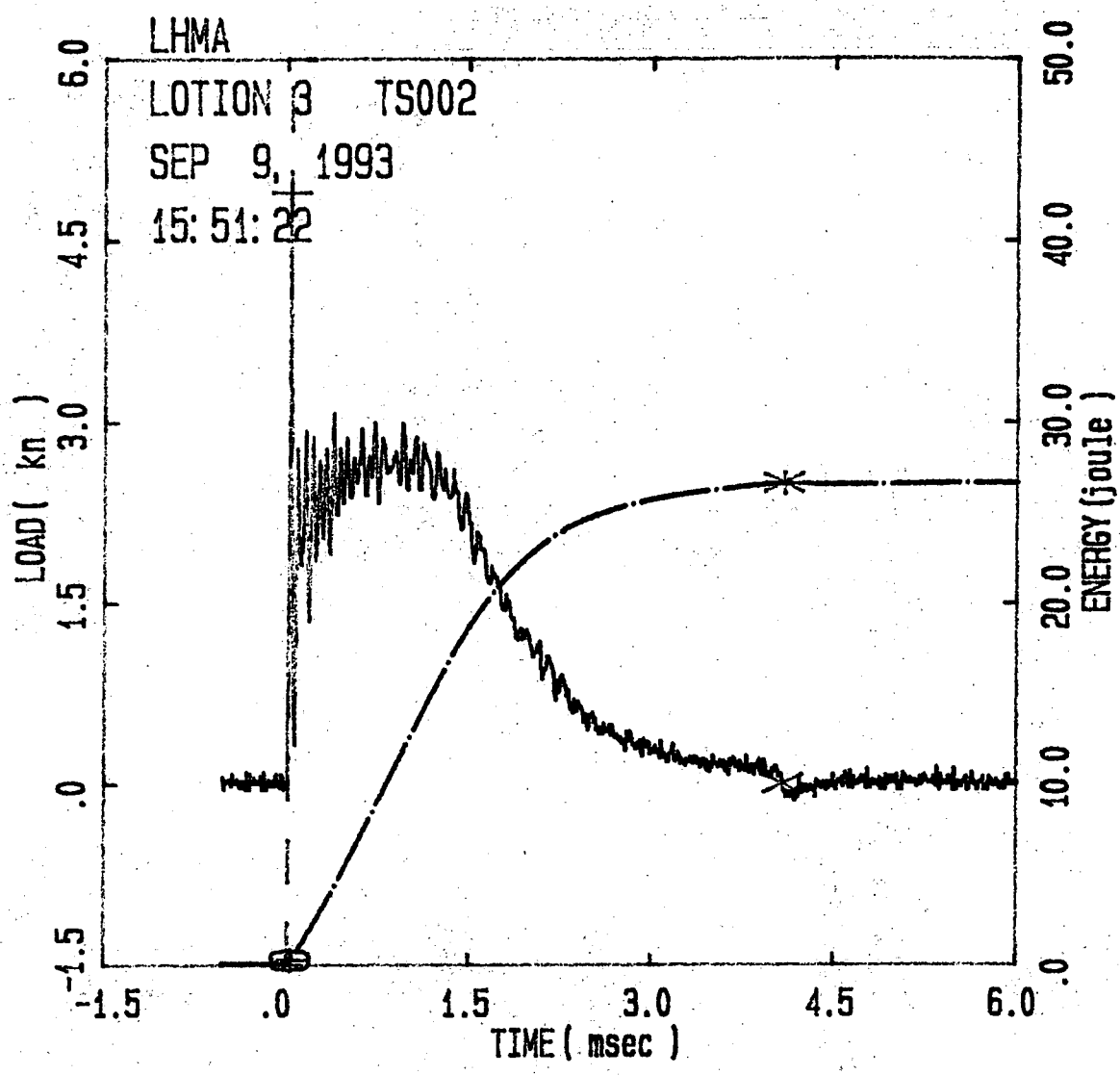


Specimen Id	Temp (c)	Impact Veloc. (m/sec)	Energy (joule)	Time (msec) Max Ld	Time (msec) Total	Load (kn) Max	Energy (joule) Maxld	Energy (joule) Total
LOTION 3 TS001	26.	5.12	357.80	.04	3.80	4.1206	.347	26.720

Filter No.= 2, No Smoothing.
Comments:
LOTION 3 TS 7/8 ↓
E DIAL 26 J. ISO TUP 1
FILE 4 NICOLET 81/82 DISK 5

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TS001	25.50	33380.460					
Impact:			5.12			357.80	
Yield:				.04	4.12	.35	.20
Maximum Load:				.04	4.1206	.35	.20
Failure(.00%):				3.79	.00	26.72	18.91
Energy After Max Load:						26.37	
Total Energy:				3.80		26.72	18.93

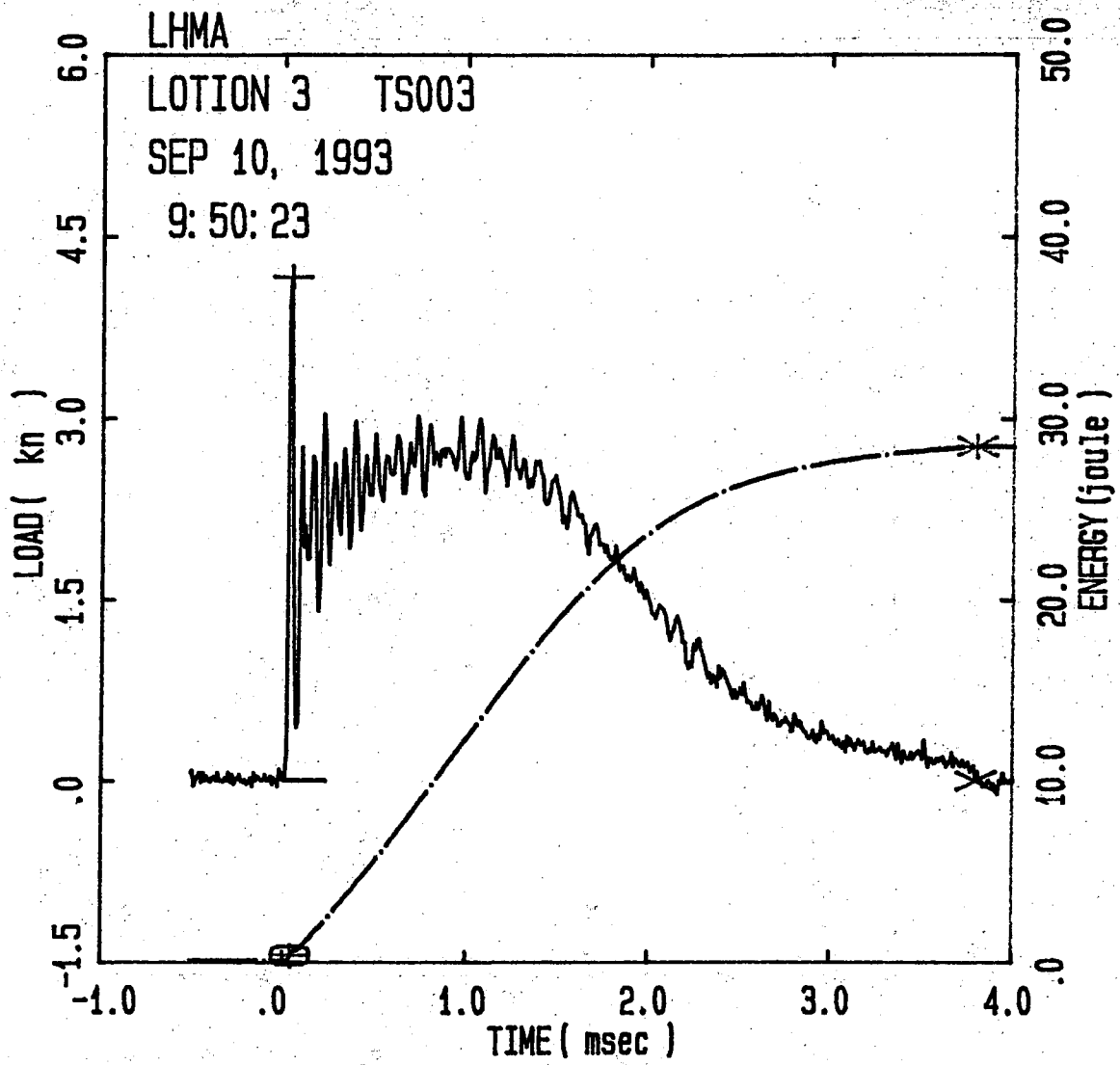
Comments:
OTION 3 TS 7/8↓
E DIAL 27 J. ISO TUP 1
ILE 4 NICOLET 81/82 DISK 5
Friction 13



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TS002 26.50 31840.770							
Impact:		5.12				358.48	
Yield:			.03	4.89	.22	.15	
Maximum Load:			.03	4.8904	.22	.15	
Failure(.00%):			4.08	.00	26.62	20.35	
Energy After Max Load:					26.40		
Total Energy:			4.09		26.62	20.38	

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TS002 26.50 31840.770							
Impact:		5.12				358.48	
Yield:			.03	4.89	.22	.15	
Maximum Load:			.03	4.8904	.22	.15	
Failure(.00%):			4.08	.00	26.62	20.35	
Energy After Max Load:					26.40		
Total Energy:			4.09		26.62	20.38	

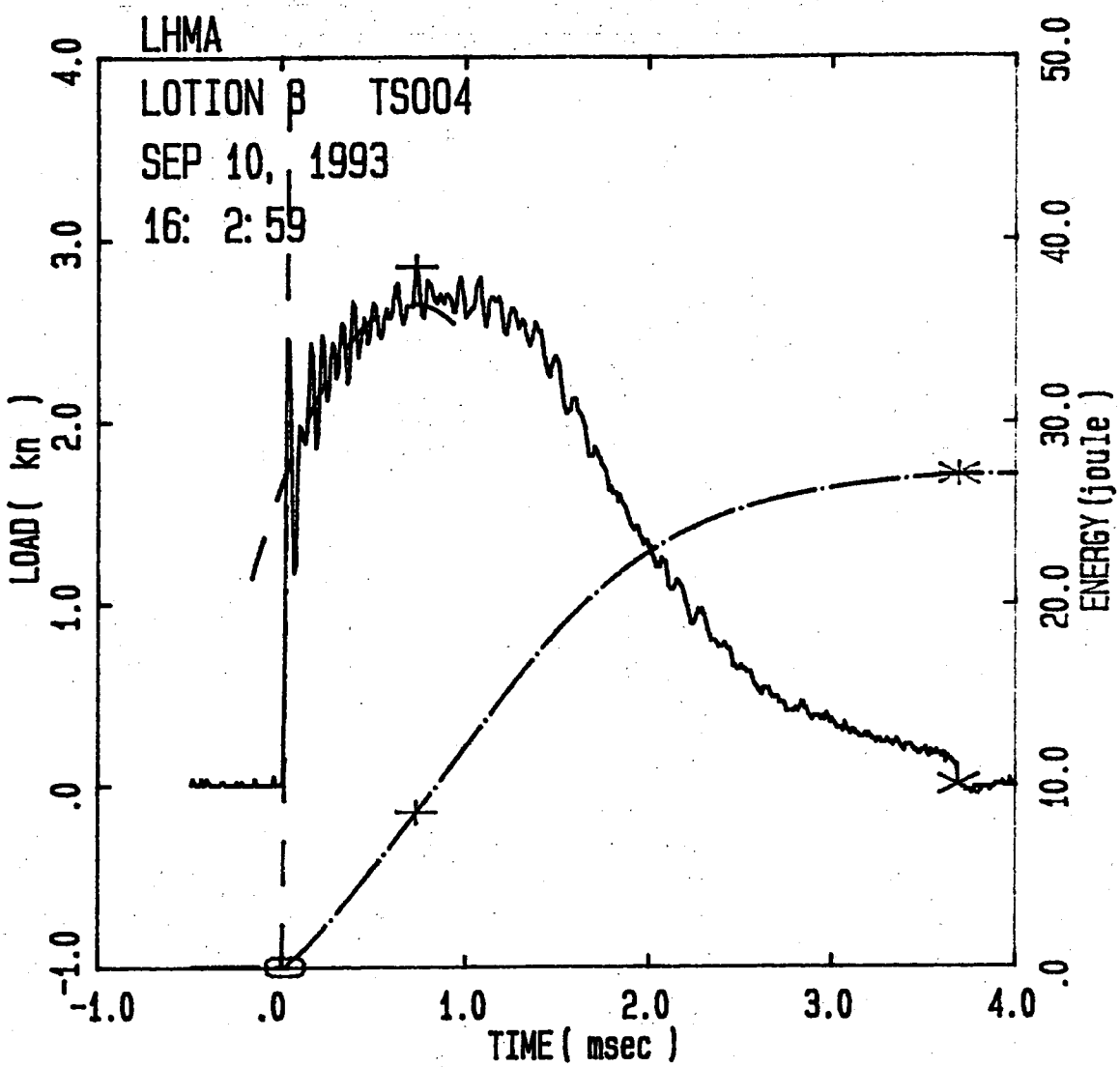
Comments:
BASE MATERIAL 2 UNIRRAD.
SPECIMEN TS 7/7
F DIAL 26.5 J. ASTM TUP 5
FILE 6 NICOLET NOT CONNECTED
UPSENSITIVITY 9.8 kN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TS003 25.50 20367.240							
Impact:		5.12				358.48	
Yield:			.04	4.17	.32	.20	
Maximum Load:			.04	4.1708	.32	.20	
Failure(.00%):			3.80	.00	28.49	18.93	
Energy After Max Load:					28.17		
Total Energy:			3.80		28.49	18.93	

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TS003 25.50 20367.240							
Impact:		5.12				358.48	
Yield:			.04	4.17		.32	.20
Maximum Load:			.04	4.1708		.32	.20
Failure(.00%):			3.80	.00		28.49	18.93
Energy After Max Load:						28.17	
Total Energy:			3.80			28.49	18.93

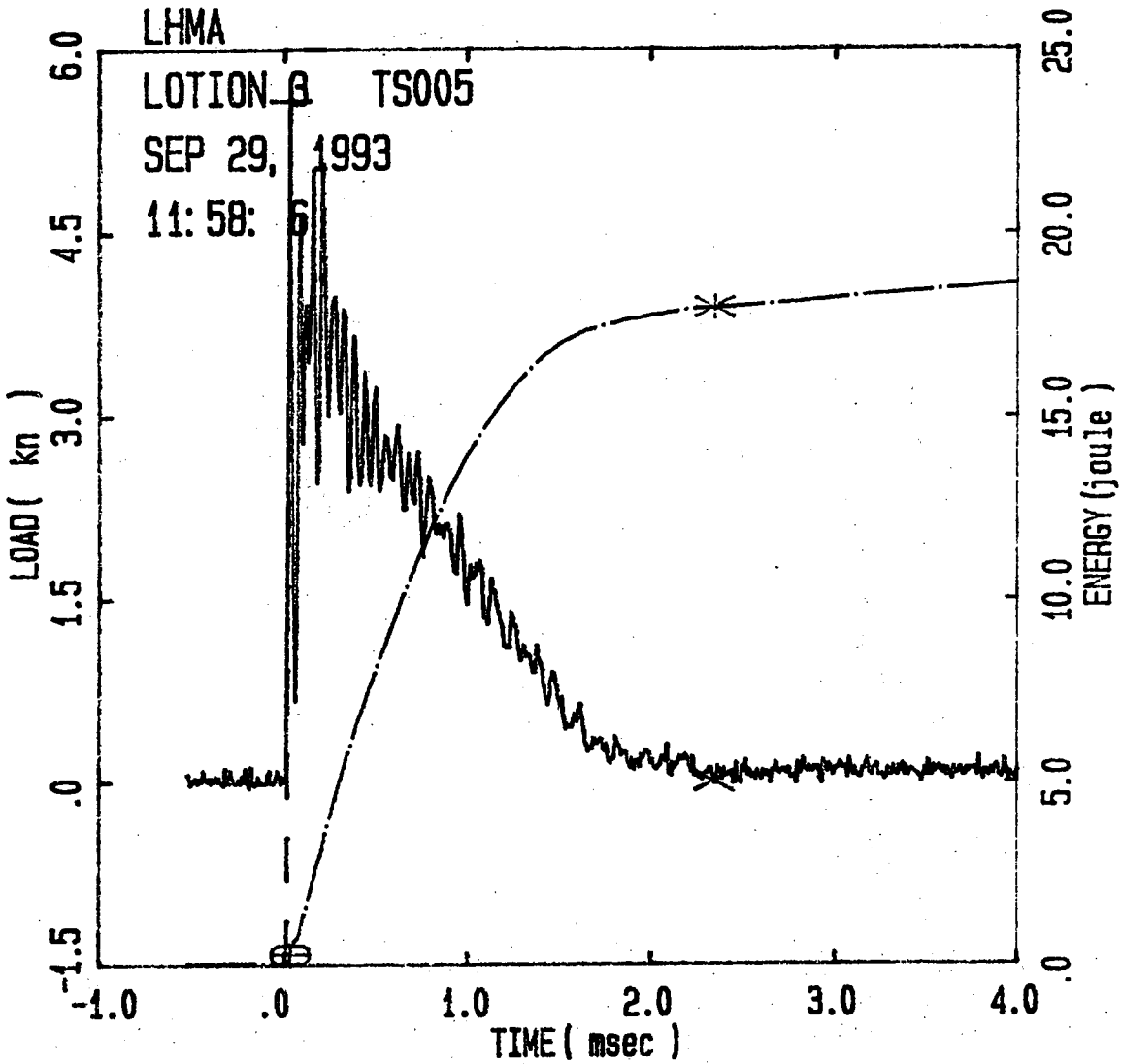
Comments:
BASE MATERIAL 2 UNIRRAD.
SPECIMEN IS 7/10
DIAL 28.5 J. ASIM TUP 5
FILE 10 NICOLET NOT CONNECTED
UPSENSITIVITY 9.6 KN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TS004	26.50	7308.136					
Impact:			5.12			358.48	
Yield:				.02	.75	.02	.10
Maximum Load:				.73	2.8531	8.51	3.72
Failure(.00%):				3.69	.00	27.15	18.40
Energy After Max Load:						18.64	
Total Energy:				3.69		27.15	18.40

pecimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
OTION 3 TS004	26.50	7308.136					
Impact:			5.12			358.48	
Yield:				.02	.75	.02	.10
Maximum Load:				.73	2.8531	8.51	3.72
Failure(.00%):				3.69	.00	27.15	18.40
Energy After Max Load:						18.64	
Total Energy:				3.69		27.15	18.40

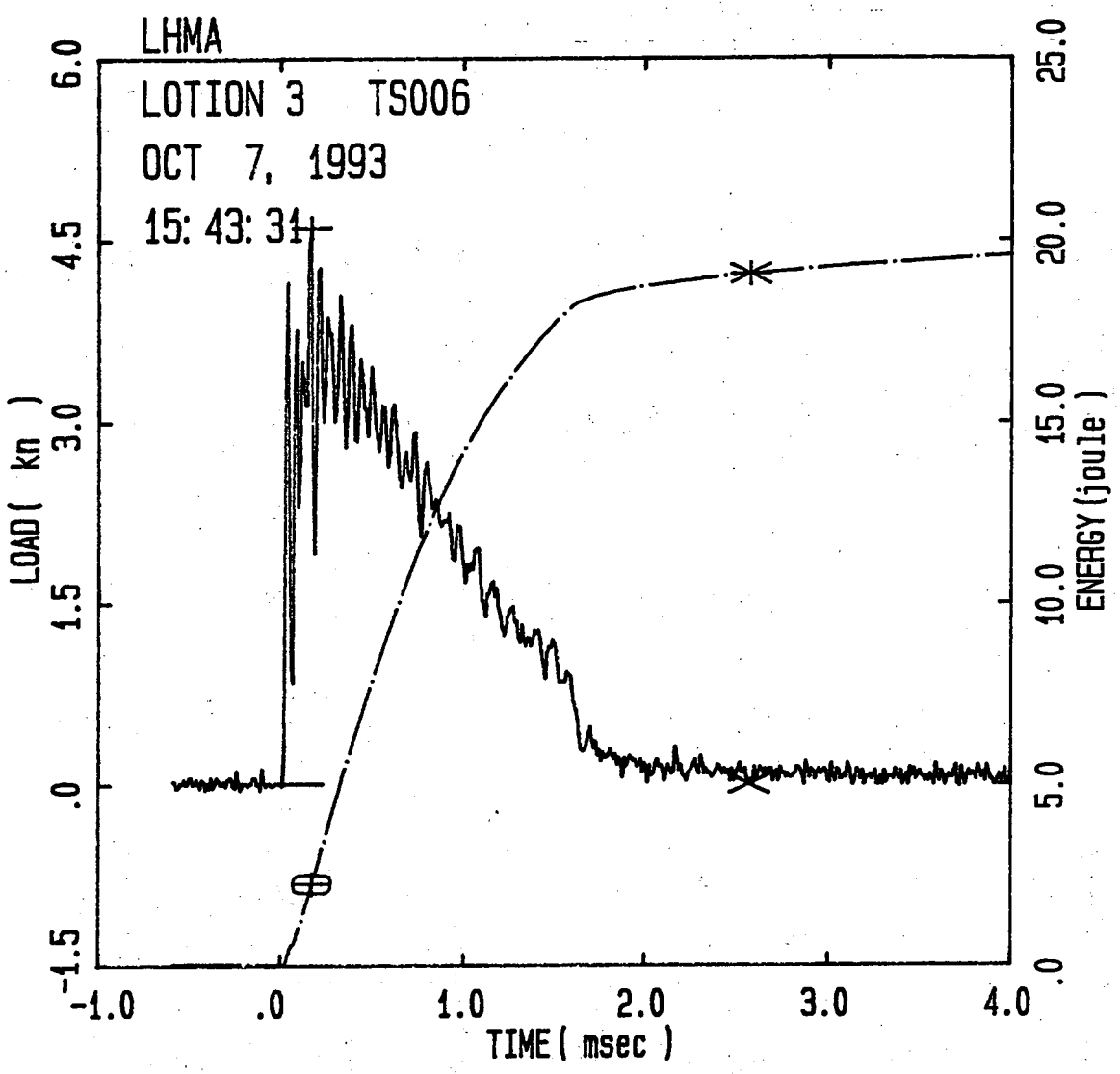
Comments:
BASE MATERIAL 2 UNIRRAD.
SPECIMEN TS 7/11
DIAL 27 I. ASTM TUP 5
FILE 14 NICOLET NOT CONNECTED
TUPSENSITIVITY 9.9 KN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TS005 23.50 36298.490							
Impact:		5.12				358.48	
Yield:			.03	5.57	.25		.15
Maximum Load:			.03	5.5750	.25		.15
Failure(.00%):			2.35	.00	17.98		11.80
Energy After Max Load:					17.73		
Total Energy:			2.35		17.98		11.81

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TS005 23.50 36298.490							
Impact:		5.12				358.48	
Yield:			.03	5.57	.25		.15
Maximum Load:			.03	5.5750	.25		.15
Failure(.00%):			2.35	.00	17.98		11.80
Energy After Max Load:					17.73		
Total Energy:			2.35		17.98		11.81

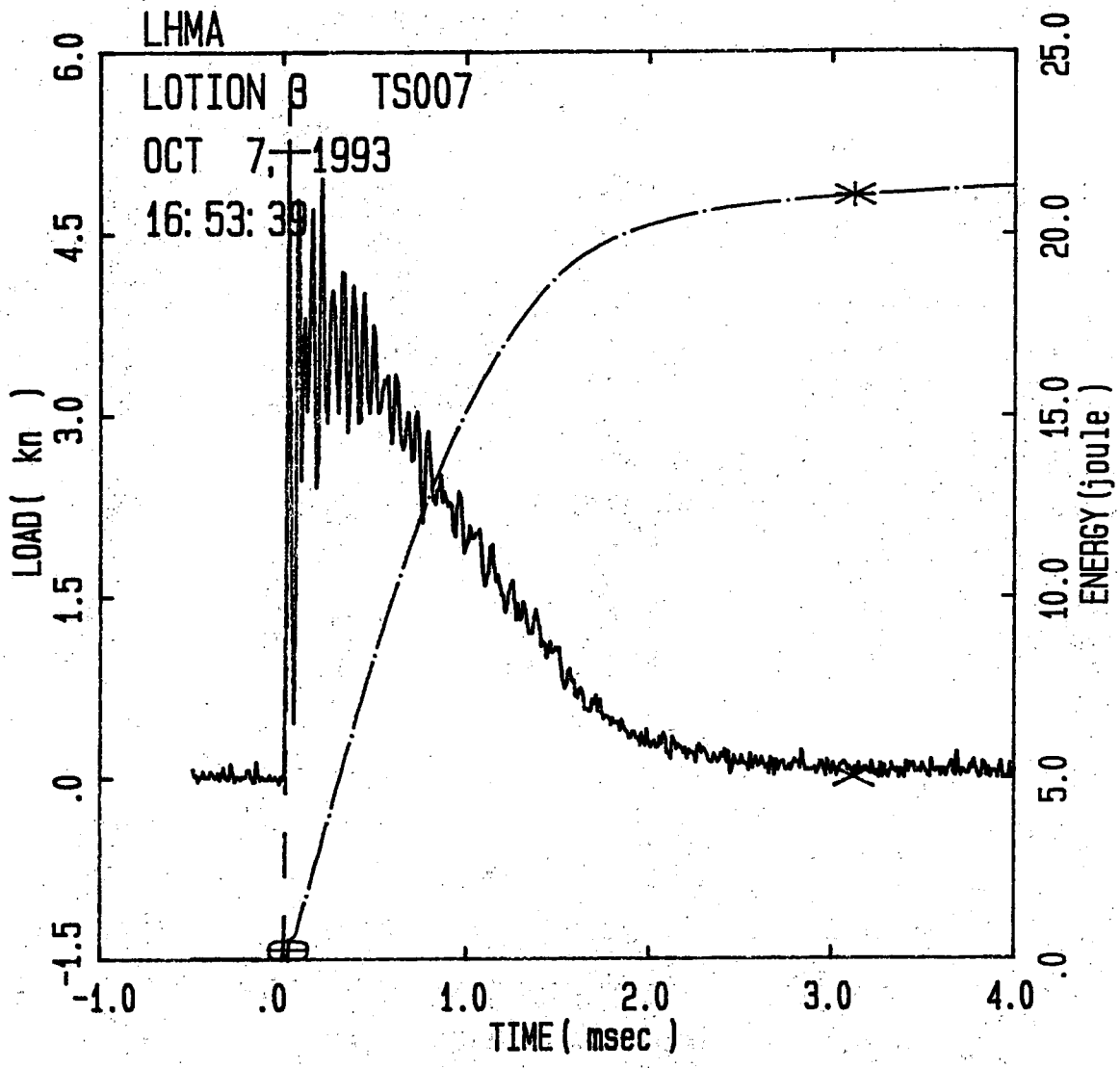
Comments:
BASE MATERIAL 2 IRRAD.
SPECIMEN TS 7/12
DIAL 18 J. ASTM TUP 5
FILE 19 NICOLET 5/6 DISK 8
TUPSENSITIVITY 10.4 KN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TS006 26.00 5300.316							
Impact:		5.12				358.48	
Yield:			.17	4.61	2.24		.87
Maximum Load:			.17	4.6077	2.24		.87
Failure(.00%):			2.57	.00	19.07		12.90
Energy After Max Load:					16.84		
Total Energy:			2.57		19.07		12.90

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TS006 26.00 5300.316							
Impact:		5.12				358.48	
Yield:			.17	4.61	2.24		.87
Maximum Load:			.17	4.6077	2.24		.87
Failure(.00%):			2.57	.00	19.07		12.90
Energy After Max Load:					16.84		
Total Energy:			2.57		19.07		12.90

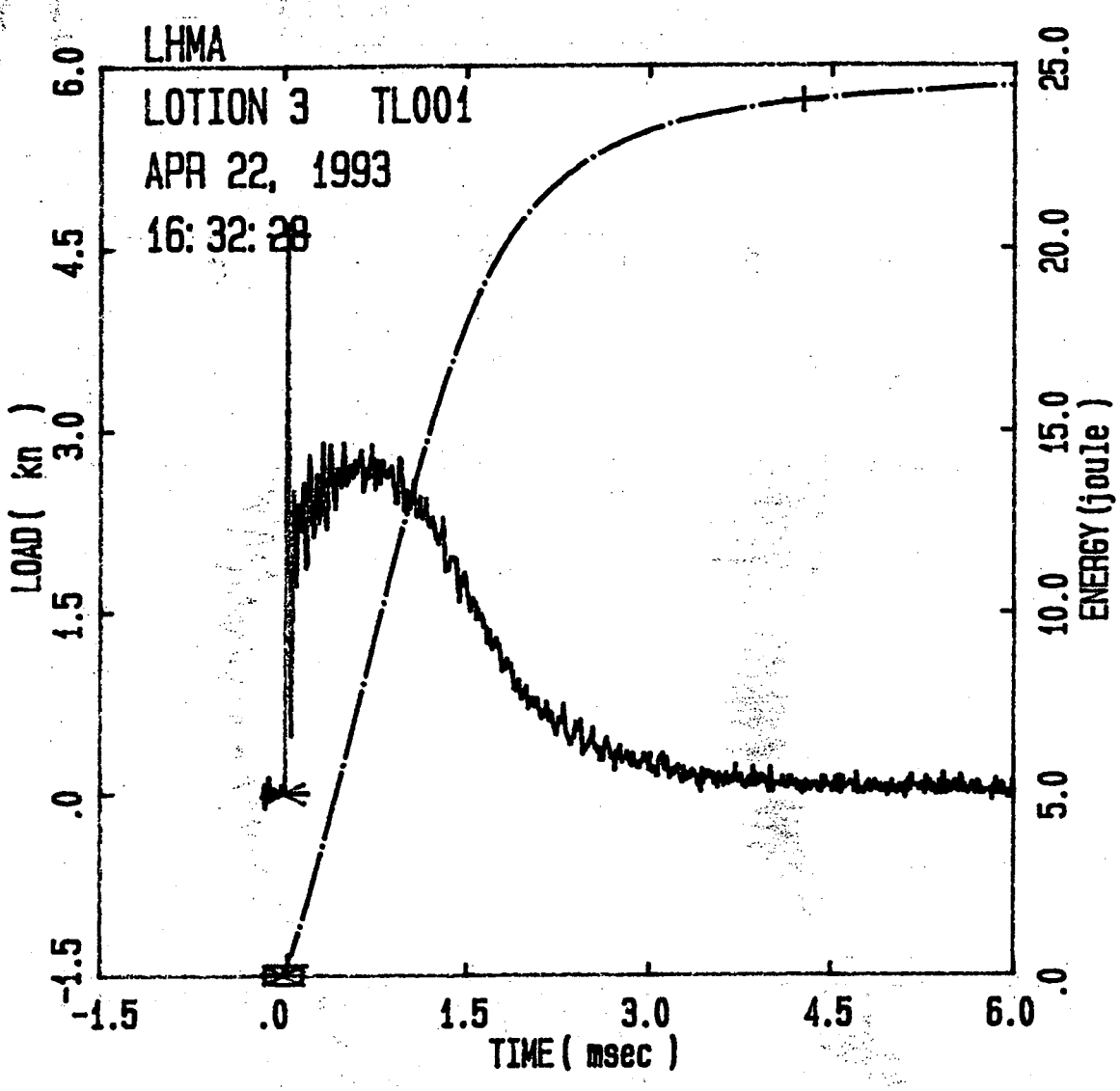
Comments:
BASE MATERIAL 2 IRRAD.
SPECIMEN TS 7/22
E DIAL 19 J. ASTM TUP 5
FILE 27 NICOLET 27/28 DISK 8
TUPSENSITIVITY 9.5 kN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TS007 26.00 33718.260							
Impact:		5.12				358.48	
Yield:				.03	5.18	.24	.15
Maximum Load:				.03	5.1787	.24	.15
Failure(.00%):				3.12	.00	21.06	15.61
Energy After Max Load:						20.82	
Total Energy:				3.12		21.06	15.61

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TS007 26.00 33718.260							
Impact:		5.12				358.48	
Yield:				.03	5.18	.24	.15
Maximum Load:				.03	5.1787	.24	.15
Failure(.00%):				3.12	.00	21.06	15.61
Energy After Max Load:						20.82	
Total Energy:				3.12		21.06	15.61

Comments:
BASE MATERIAL 2 IRRAD.
SPECIMEN TS 7/27
E DIAL 21 J. ASTM TUP 5
FILE 28 NICOLET 29/30 DISK 8
TUPSENSITIVITY 9.9 kN.

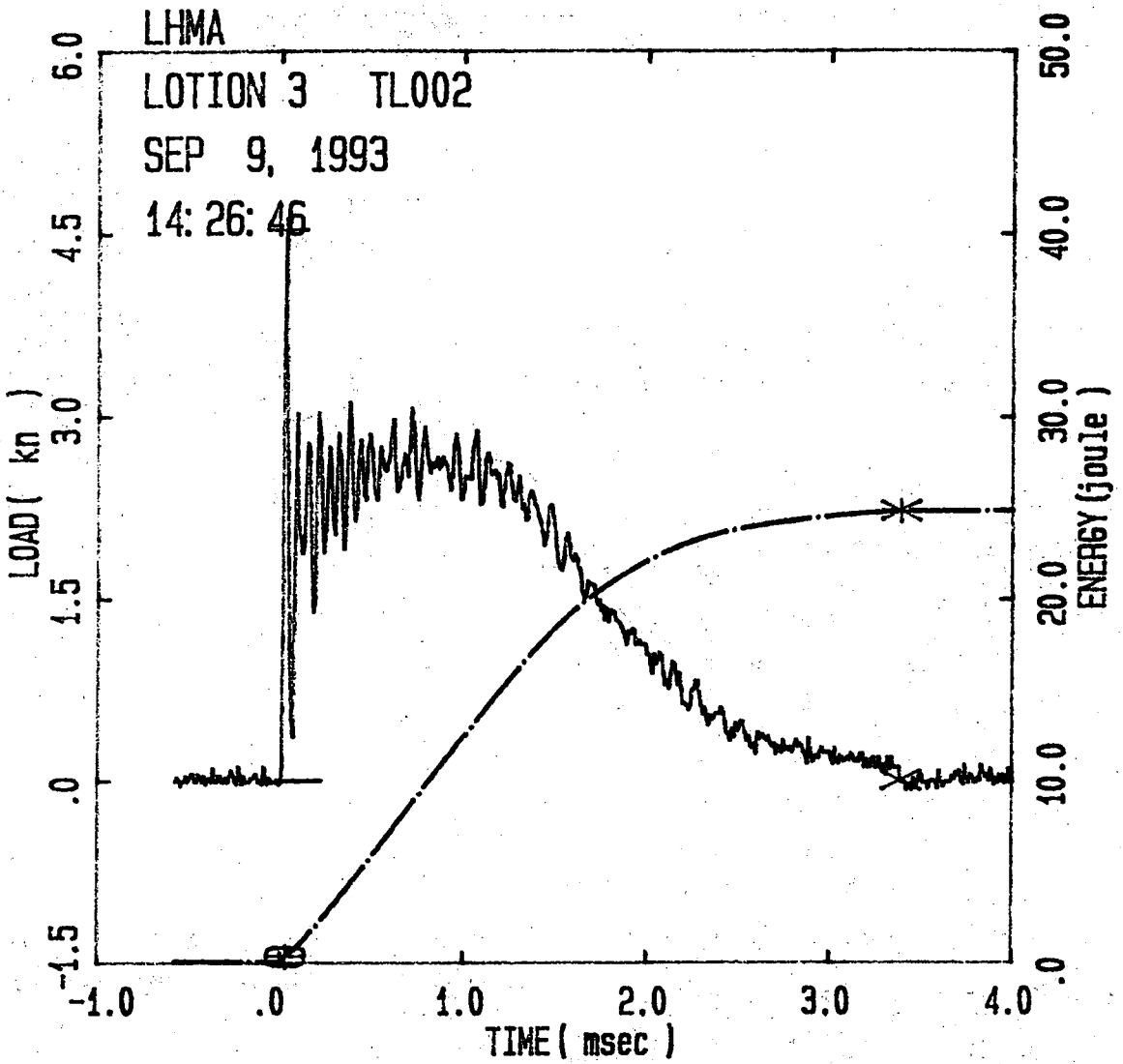


Specimen Id	Temp (c)	Impact Veloc. (m/sec)	Energy (joule)	Time (msec) Max Ld	Time (msec) Total	Load (kn) Max	Energy (joule) MaxId	Energy (joule) Total
LOTION 3 TL001	26.	5.12	357.80	.03	4.26	4.6209	.249	24.045

Filter No.= 2, No Smoothing.
Comments:
LOTION 3 TL 6/13 /
E DIAL 23 J. ISO TUP 1
FILE 3 NICOLET 79/80 DISK 5

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TL001	26.00	.000					
Impact:			5.12			357.80	
Maximum Load:				.03	4.6209	.25	.15
Energy After Max Load:						23.80	
Total Energy:				4.26		24.04	21.24

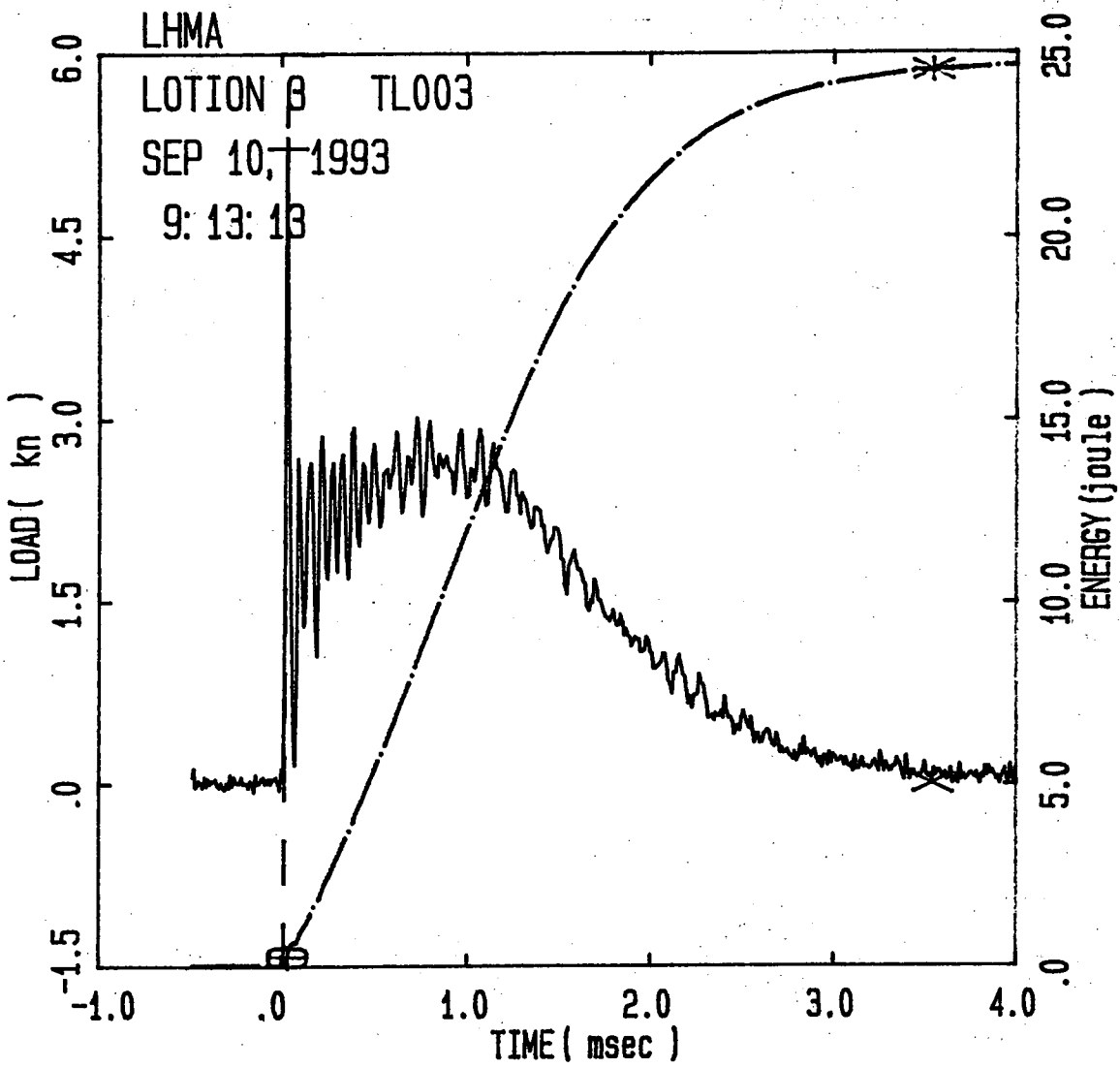
Comments:
LOTION 3 TL 6/13
E DIAL 24 J. ISO TUP 1
FILE 3 NICOLET 79/80 DISK 5
FRICTION 13



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TL002	26.50	29574.570					
Impact:			5.12			358.48	
Yield:				.03	4.54	.30	.15
Maximum Load:				.03	4.5421	.30	.15
Failure(.00%):				3.39	.00	24.86	16.94
Energy After Max Load:						24.55	
Total Energy:				3.39		24.86	16.94

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TL002	26.50	29574.570					
Impact:			5.12			358.48	
Yield:				.03	4.54	.30	.15
Maximum Load:				.03	4.5421	.30	.15
Failure(.00%):				3.39	.00	24.86	16.94
Energy After Max Load:						24.55	
Total Energy:				3.39		24.86	16.94

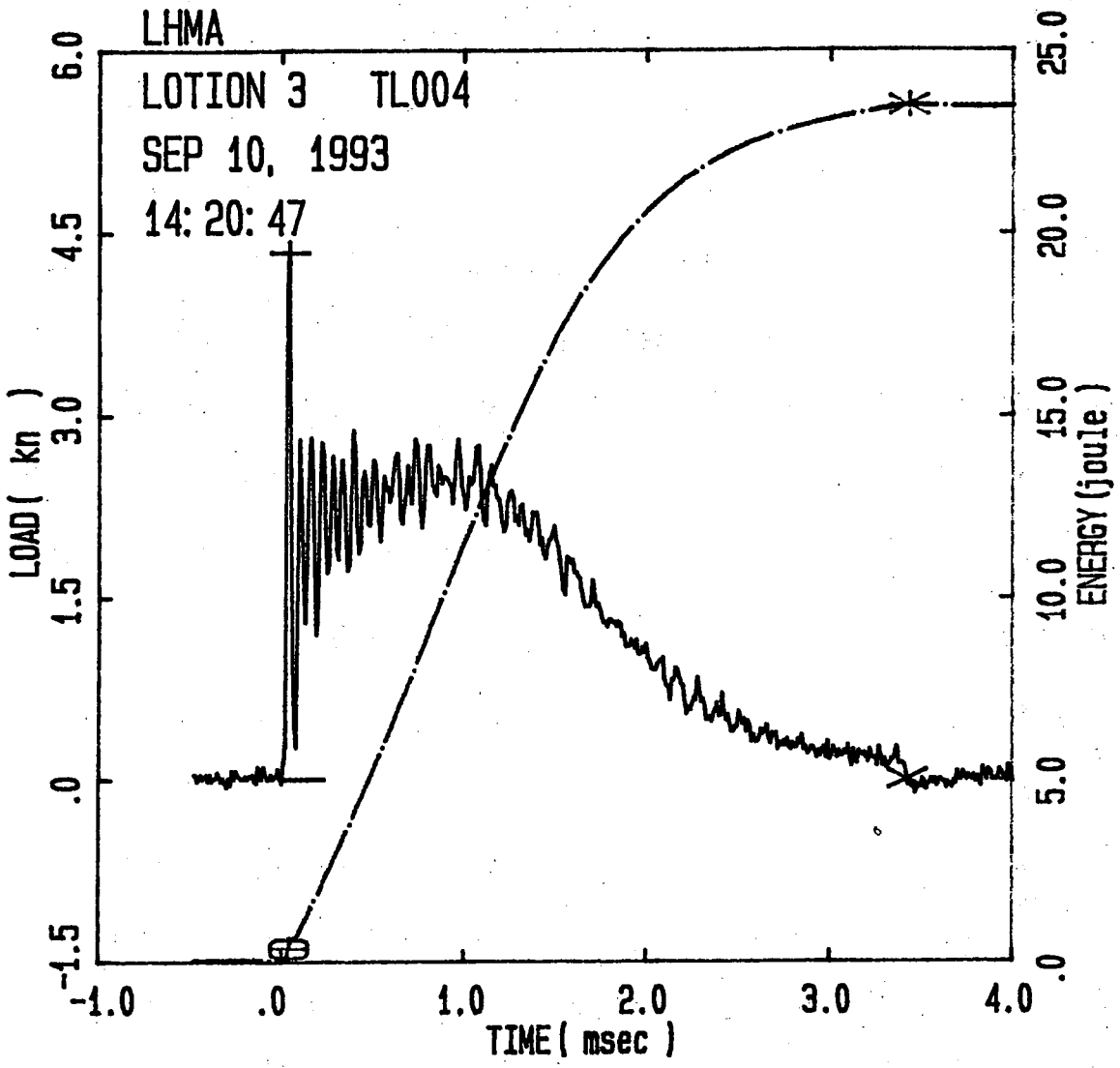
Comments:
BASE MATERIAL 1 UNIRRAD.
SPECIMEN TL 6/7
E DIAL 24.5 J. ASTM TUP 5
FILE 5 NICOLET NUT CONNECTED
UPSENSITIVITY 9.9 KN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TL003 25.50 33968.390							
Impact:			5.12			358.48	
Yield:				.03	5.22	.23	.15
Maximum Load:				.03	5.2171	.23	.15
Failure(.00%):				3.54	.00	24.53	17.69
Energy After Max Load:						24.30	
Total Energy:				3.54		24.53	17.69

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TL003 25.50 33968.390							
Impact:			5.12			358.48	
Yield:				.03	5.22	.23	.15
Maximum Load:				.03	5.2171	.23	.15
Failure(.00%):				3.54	.00	24.53	17.69
Energy After Max Load:						24.30	
Total Energy:				3.54		24.53	17.69

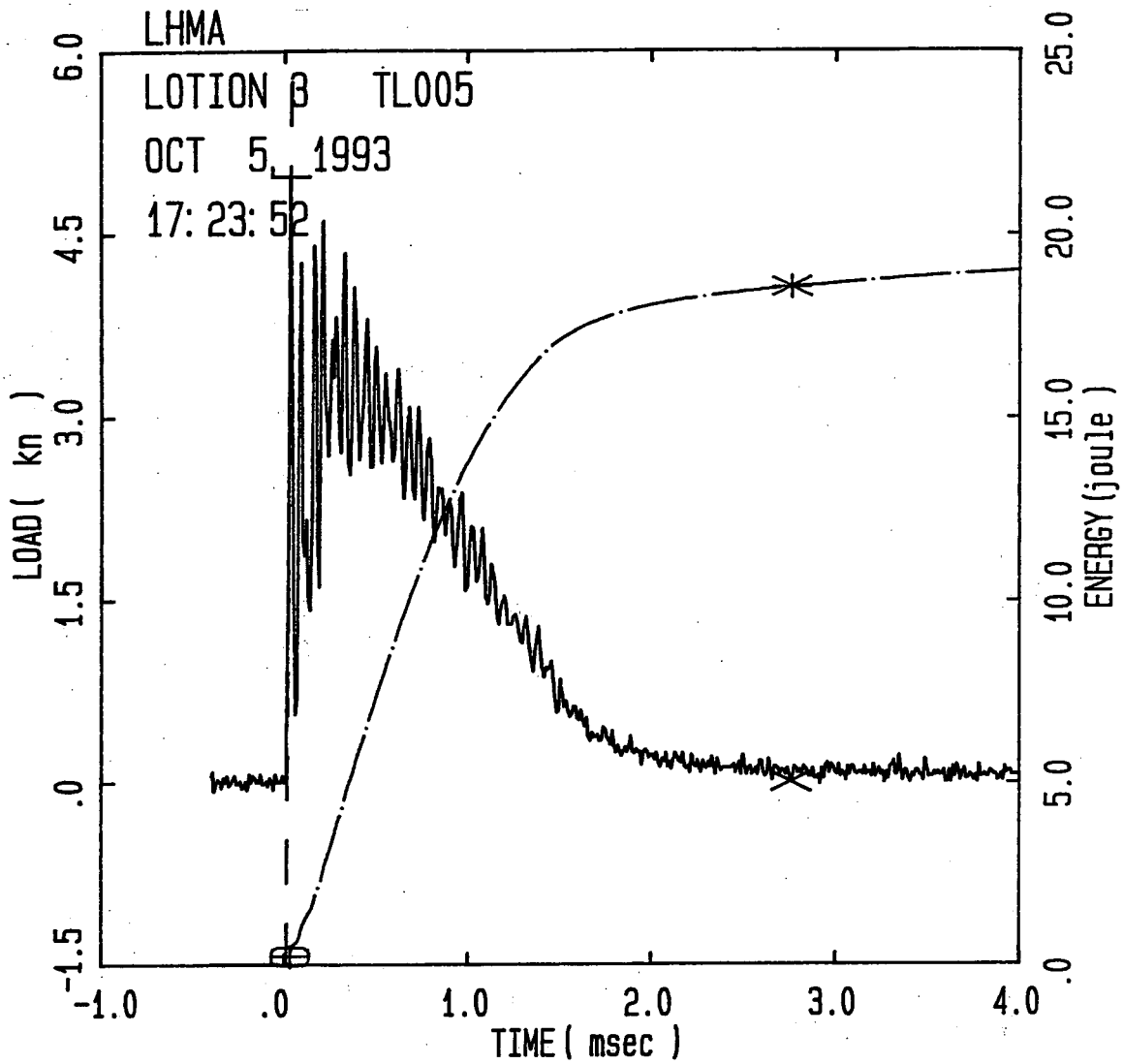
Comments:
BASE MATERIAL 1 UNIRRAD.
SPECIMEN TL 6/14
E DIAL 24 J. ASTM TUP 5
FILE 9 NICOLET NOT CONNECTED
TUPSENSITIVITY 10.6 KN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TL004 26.50 21212.140							
Impact:		5.12				358.48	
Yield:			.04	4.34	.33		.20
Maximum Load:			.04	4.3438	.33		.20
Failure(.00%):			3.42	.00	23.48		17.14
Energy After Max Load:					23.15		
Total Energy:			3.43		23.48		17.17

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
OTION 3 TL004 26.50 21212.140							
Impact:			5.12			358.48	
Yield:				.04	4.34	.33	.20
Maximum Load:				.04	4.3438	.33	.20
Failure(.00%):				3.42	.00	23.48	17.14
Energy After Max Load:						23.15	
Total Energy:				3.43		23.48	17.17

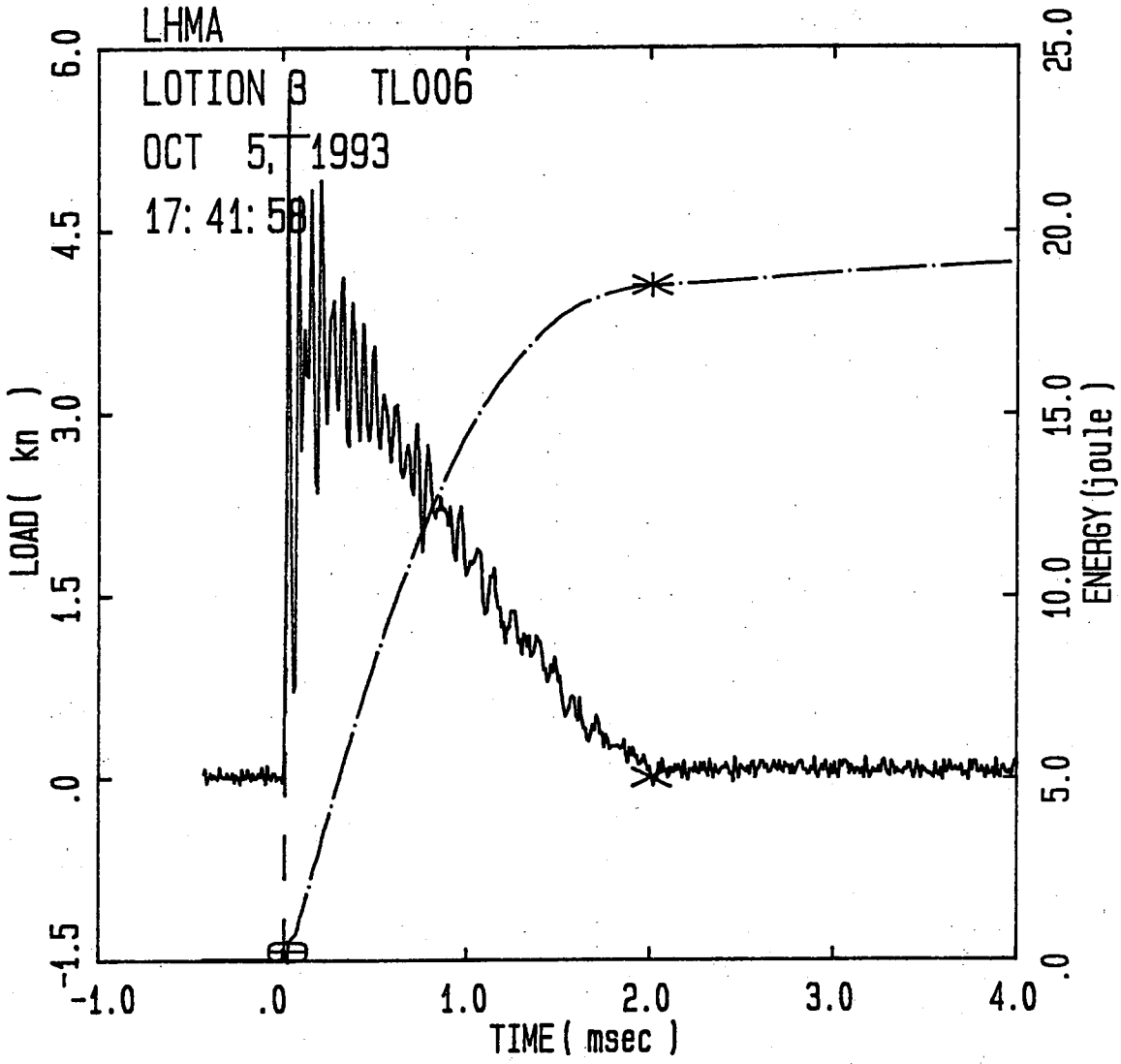
omments:
ASE MATERIAL 1 UNIRRAD.
PECIMEN TL 6/16
DIAL 23.5 J. ASTM TUP 5
ILE 13 NICOLET NOT CONNECTED
UPSENSITIVITY 10.4 kN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TL005 25.50 32336.410							
Impact:			5.12			358.48	
Yield:				.03	4.97	.22	.15
Maximum Load:				.03	4.9665	.22	.15
Failure(.00%):				2.76	.00	18.58	13.86
Energy After Max Load:						18.36	
Total Energy:				2.76		18.58	13.86

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TL005 25.50 32336.410							
Impact:			5.12			358.48	
Yield:				.03	4.97	.22	.15
Maximum Load:				.03	4.9665	.22	.15
Failure(.00%):				2.76	.00	18.58	13.86
Energy After Max Load:						18.36	
Total Energy:				2.76		18.58	13.86

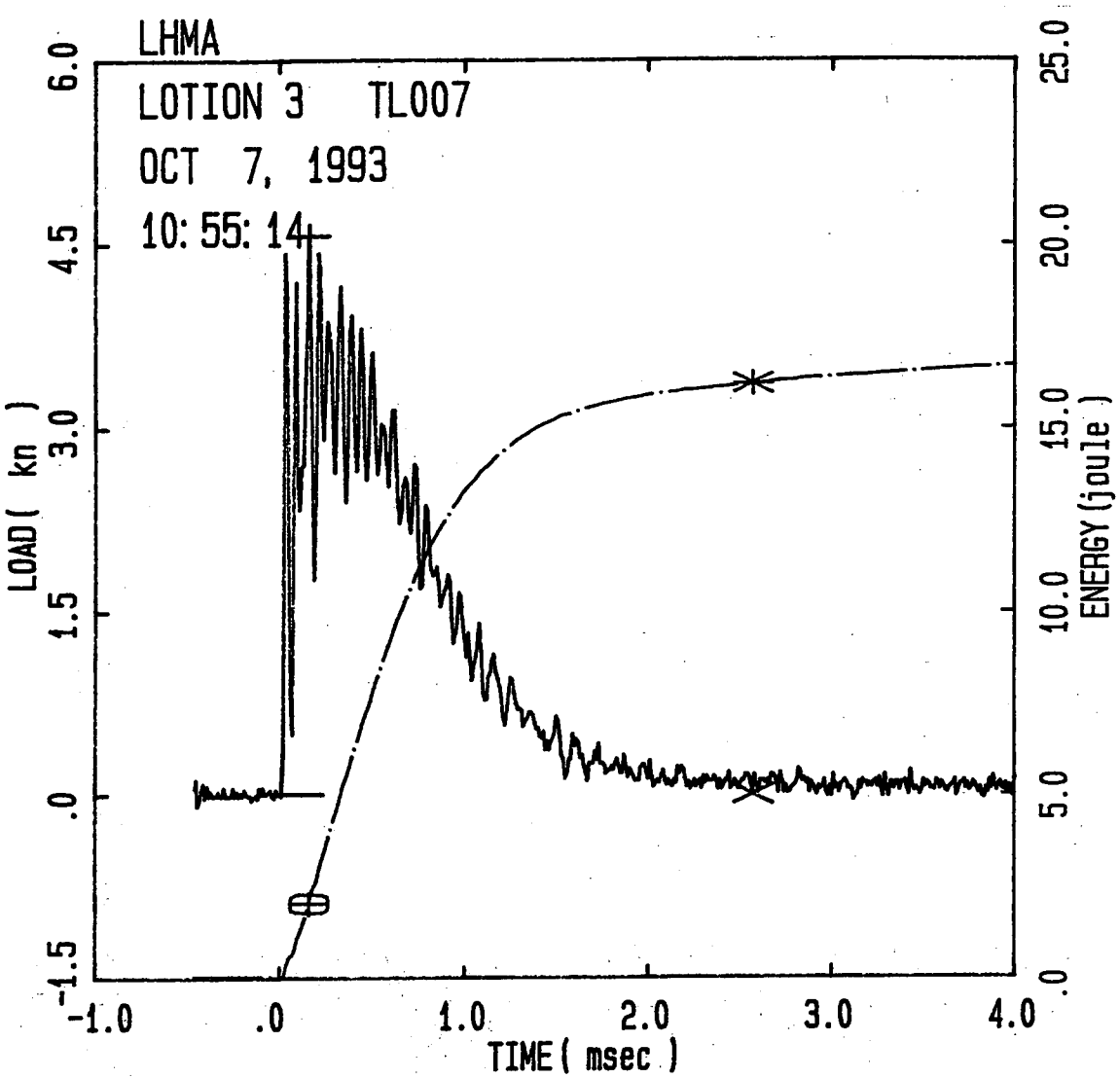
Comments:
BASE MATERIAL 1 IRRAD.
SPECIMEN TL 6/1
F DIAL 18.5 ASTM TUP 5
FILE 22 NICOLET 17/18 DISK 8
TUPSENSITIVITY 9.7 kN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TL006	25.50	34377.990					
Impact:			5.12			358.27	
Yield:				.03	5.28	.23	.15
Maximum Load:				.03	5.2785	.23	.15
Failure(.00%):				2.01	.00	18.52	10.11
Energy After Max Load:						18.29	
Total Energy:				2.01		18.52	10.11

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TL006	25.50	34377.990					
Impact:			5.12			358.27	
Yield:				.03	5.28	.23	.15
Maximum Load:				.03	5.2785	.23	.15
Failure(.00%):				2.01	.00	18.52	10.11
Energy After Max Load:						18.29	
Total Energy:				2.01		18.52	10.11

Comments:
BASE MATERIAL 1 IKRAD.
SPECIMEN TL 6/27
DIAL 18.5 J. ASTM TUP 5
FILE 23 NICOLET 19/20 DISK 8
TUPSENSITIVITY 10.00 kN.



Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TL007	25.00	5595.486					
Impact:		5.12				358.45	
Yield:			.16	4.58	2.01		.82
Maximum Load:			.16	4.5783	2.01		.82
Failure(.00%):			2.57	.00	16.22		12.93
Energy After Max Load:					14.22		
Total Energy:			2.57		16.22		12.93

Specimen Id.	Temperature c	Slope n/mm	Velocity m/sec	Time msec	Load kn	Energy joule	Deflect mm
LOTION 3 TL007	25.00	5875.600					
Impact:		5.12				358.45	
Yield:			.16	4.81		2.11	.82
Maximum Load:			.16	4.8073		2.11	.82
Failure(.00%):			2.57	.00		17.03	12.92
Energy After Max Load:						14.92	
Total Energy:			2.57			17.03	12.92

Comments:
BASE MATERIAL 1 IRRAD.
SPECIMEN TL 6/17
2 DIA 1" I. ASTM TUP 5
FILE 55 NICOLET 23/24 DISK 8
SUPERSENSITIVITY 10.5 KN.