Title
TABLE OF HYPERFINE FIELDS

Authors
Koster, Thomas A.
Shirley, David A.

Publication Date
1970-11-01

Presented at the International Conference on Hyperfine Interactions Detected by Nuclear Radiation, Sept. 6-11, 1970, Rehovot-Jerusalem, Israel

UCRL-20411
Preprint c.2

TABLE OF HYPERFINE FIELDS

Thomas A. Koster and David A. Shirley

November 1970

AEC Contract No. W-7405-eng-48

LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

DISCLAIMER

TABLE OF HYPERFINE FIELDS*

Thomas A. Koster and David A. Shirley

Department of Chemistry and
Lawrence Radiation Laboratory
University of California
Berkeley, California 94720

November 1970

INTRODUCTION

We have updated the Table of Hyperfine Fields from the Proceedings of the first International Conference on Hyperfine Interactions Detected by Nuclear Radiation held at Asilomar in 1967, Hyperfine Structure and Nuclear Radiations, edited by E. Matthias and D. A. Shirley (North-Holland, 1968). Fields are tabulated for substitutional impurities in ferromagnetic iron, cobalt, nickel, and gadolinium. The references listed in column eight are not exhaustive. In general we give the most accurate value reported, and the lowest temperature and lowest concentration values are preferred. Columns two and five are, respectively, the impurity and host elements. Column three gives the isotope number. No special notation is made for excited states: in most cases it is obvious whether an excited state is involved. If two references are cited for a particular entry, one giving the magnitude of the field and the other its sign, the isotope number given in column three is the one used in the magnitude determination. Column four gives the solute concentration in atomic percent: "t" denotes "carrier-free tracer." The absolute temperature is given in column six: "R" denotes room temperature, "He" denotes the liquid helium temperature range, and "0" means either an extrapolation to 0 K or to a measurement below 1 K. The fields appear in column seven. Signs are given explicitely where known,

and errors are given parenthetically. Symbols for methods are: PAC (perturbed angular correlations), NMR (nuclear magnetic resonance), SE (spin echo), M (Mössbauer), NP (nuclear polarization), SH (specific heat).

In some cases values of H_{hf} have been corrected to account for more accurate nuclear moments. No hyperfine anomaly corrections have been attempted, although these must be taken into account for a number of isotopes. Any compilation such as this necessarily involves some degree of subjective judgment on the part of the authors, and we welcome any criticisms, corrections, or additions that its users may have.

Z	El.	A	at.%	Host	T(K)	H_{hf}(kG)	Method	Reference
9	F	19	t	Fe	0	+95.7(5) +32.8(5) +56.9(5)	PAC	BRA67
9	F	19	t	Co	313	35.3(11)	PAC	KLE70
9	F	19	t	Co	0	+59.5(15)	PAC	BRA67
9	F	19	t	Ni	300	+17.8(4) +90.2(14)	PAC	STO68, KLE68A
9	F	19	t	Gd	103	+12.9(4)	PAC	STO68
13	Al	27		Fe	1.4	-55(1)	SE	ASA64, KON67
13	Al	27		Co	1.4	32(1)	SE	ASA64
20	Ca	42	t	Fe	R	-100(9)	PAC	MAR70
20	Ca	42	t	Co	R	-70(15)	PAC	MAR70
20	Ca	42	t	Ni	R	<30	PAC	MAR70
21	Sc	45		Fe		58	NMR	KOI66
21	Sc	44	t	Ni	0	-25.9(3)	PAC	BEN70
23	V	51	1	Fe	77	-87.3	NMR	KOI64, ASA64
23	V	51		Co	1.4	48(1)	SE	ASA64
23	V	51		Ni	1.4	7.5(2)	SE	ASA64
25	Mn	55	1	Fe	0	-226.97	NMR	KOB65, TEM67
25	Mn	55		Co	He	140	NMR	KOB65
25	Mn	55	0.5	Ni	90	-325(1)	NMR	KOB65, KOI63
26	Fe	57		Fe	0	-336.9	NMR	HAN60, BUD61
26	Fe	57	2	Co	4.8	-323	NMR	NAG62, BUD61
26	Fe	57	t	Ni	0	-283(3)	M,PAC	WER61, HOH69
27	Co	59	1	Fe	0	-287.7	M,NMR	DAS60, KOI61

Z	El.	A	at.%	Host	T(K)	H_{hf}(kG)	Method	Reference
27	Co	59		Co[a]	0	-216.0	NMR	ARP59, POR60
27	Co	59		Co[b]	0	-227	NMR	HAR61
27	Co	59	0.59	Ni	0	-120(1)	NMR	BEN62, WES65
28	Ni	61	1	Fe	77	-234.2	NMR,M	STR63A, BUR69, ERI69
28	Ni	61	1	Co	77	188.5	NMR	STR62
28	Ni	61		Ni	4.2	74.8	NMR	STR63B
29	Cu	63	1	Fe	273	-212.7	NMR	KOI62, SAM65
29	Cu	63	1	Co	282	157.5	NMR	KOI62
29	Cu	63		Ni	290	-47.2	NMR	ASA63, WEI60
30	Zn	65	t	Fe	0	-95(15)	NP,PAC	CHI68, INI69
31	Ga	69		Fe	He	110(3)	SE	KON65
31	Ga	69	<2	Co	He	62(1)	SE	KON67
32	Ge	71	5	Fe		+70(3)	PAC	MOR68
32	Ge	71	5	Ni		+33.0(15)	PAC	MOR68
33	As	75		Fe		339.1	NMR	KOI66
34	Se	76	t	Gd		271(68)	PAC	HEE68
39	Y	89		Fe	4.2	+286(5)	SE	KON65, SAM65
40	Zr	91	<2	Co	He	90(2)	SE	KON67
41	Nb	93	<1	Fe		-258	NMR	KOI66, KON67
41	Nb	95	t	Co	0	-189(8)	NP	CAM67
41	Nb	93	<1	Ni	He	-41(1)	SE	KON67
42	Mo	95	<2	Fe	He	-256(5)	SE	KON67
42	Mo	95	<2	Co	He	150(3)	SE	KON67

Z	El.	A	at.%	Host	T(K)	H_{hf}(kG)	Method	Reference
42	Mo	95	t	Ni	328	-29.9(51)	PAC	BON70
42	Mo	100	t	Gd	80	-480(240)	PAC	HEE70, MUR68
43	Tc	96		Fe	0	-298(10)	NP	FOX70
43	Tc	99	<2	Co	R	170(5)	PAC	GER70A
43	Tc	99	<2	Ni	R	-47.8(15)	PAC	GER70A
44	Ru	99	2.3	Fe	4.2	-500(10)	M	KIS66
44	Ru	101	<2	Co	He	415(16)	SE	KON67
44	Ru	99	1	Ni	4.2	-217.20(113)	PAC	SHI68A, SHI68B
44	Ru	104	t	Gd	80	+270(90)	PAC	HEE70, MUR68
45	Rh	100	t	Fe	0	-559.6(16)	NMR	MAT68, KON67
45	Rh	103	<2	Co	He	392(8)	SE	KON67
45	Rh	100	t	Ni	296	-207.1(6)	PAC	KOI70, HOH70
46	Pd	105	<2	Fe	He	-594(12)	SE	AUE66, KON67
46	Pd	105	<2	Co	He	-400(8)	SE	AUE66, KON67
46	Pd	105	<2	Ni	He	-194(4)	SE	AUE66, KON67
46	Pd	106	<0.1	Gd	77	-64(6)	PAC	BOS70
46	Pd	108	t	Gd	80	+350(70)	PAC	MOR68
47	Ag	110	t	Fe	0	-250(6)	NP	KNO70
47	Ag	110	t	Ni	0	-87(8)	NP	EAS66
48	Cd	111		Fe	R	-366(7)	PAC	CIS68, RAG70
48	Cd	111	t	Co	R	268(8)	PAC	HAA70
48	Cd	111	t	Ni	4.2	-68.6(15)	PAC	SHI68A
48	Cd	111	<0.1	Gd	77	-312(9)	PAC	BOS70
50	Sn	119	1	Fe	100	-81(4)	M	BOY60

Z	El.	A	at.%	Host	T(K)	H_{hf}(kG)	Method	Reference
50	Sn	119	1	Co	100	-20.5(15)	M	BOY60
50	Sn	119	1	Ni	100	+18.5(10)	M	BOY60
50	Sn	119	0.2	Gd	4.2	-329(4)	M	GOT69
51	Sb	121	<2	Fe	He	+230	NMR	KOI66, SAM64, STO64, KON67
51	Sb	121	<2	Co	He	187(4)	SE	KON67
51	Sb	121	<2	Ni	He	+94(2)	SE	KON65, KON67
52	Te	125	t	Fe	4.2	+657(20)	M	FRA68
52	Te	125	t	Co	4.2	505(20)	M	FRA68
52	Te	125	t	Ni	4.2	+170(10)	M	FRA68
52	Te	125		Gd	4.2	-229(2)	M	PAS70
52	Te	125	<1	Gd	77	-38(10)	PAC	CRU70
53	I	129	t	Fe	R	1130(40)	M	DEW66
53	I	129	0.3	Gd	4.2	-42(10)	M	PAS70
54	Xe	133	t	Fe	0	1010(40)	NP	DEW69A
55	Cs	133	t	t	4.2	+273(10)	M	DEW69B
56	Ba		t	Fe		-85(14)	PAC	KUG70B
57	La	139	9	Gd	0	70(20)	SH	NIK69
58	Ce	142		Fe	300	-450(290)	PAC	KUG70A
58	Ce	142		Co	300	-306(140)	PAC	KUG70A
58	Ce	142		Ni	300	-94.5(860)	PAC	KUG70A
59	Pr	142	<0.1	Fe	0	825(195)	NP	REI69
60	Nd	148	t	Fe	295	+1680(290)	PAC	GIL66
60	Nd	150	t	Fe	R	+3100(600)	PAC	BOE66

Z	El.	A	at.%	Host	T(K)	H_{hf}(kG)	Method	Reference
60	Nd	148	t	Co	295	+1100(190)	PAC	GIL66
60	Nd	148	t	Ni	295	+107(18)	PAC	GIL66
62	Sm	154	t	Fe	R	+1400(160)	PAC	BOE66
62	Sm	150	t	Co	300	+1119(64)	PAC	MUR67
62	Sm	150	t	Ni	300	+352(13)	PAC	MUR67
62	Sm	150	t	Gd	110	-295(30)	PAC	MUR67
63	Eu	153	t	Fe	R	+750(250)	PAC	BOE66
63	Eu	153		Gd		-290(35)	M	HEN70
64	Gd	156	t	Fe	12	-370(8)	M	RUS70, KLE68B
64	Gd	156	t	Ni	425	-175(45)	PAC	KLE68B
64	Gd	156		Gd	4.2	-305(18)	M	PER68
66	Dy	164	t	Fe	R	-2000(300)	PAC	GRO66
66	Dy	161		Fe	77	-6050(50)	M, PAC	DEW70, GRO66
68	Er	166	t	Fe	R	-2700(400)	PAC	DEU68
70	Yb	170	t	Fe	R	-720(240)	PAC	BOE66
71	Lu	175	t	Fe	R	-483(60)	PAC	DEU66, NIE68
71	Lu	175	0.1	Gd	0	260	PAC	ZMO69
72	Hf	178	1	Fe	4.2	-606(70)	M, PAC	STE69, GER70B
72	Hf	177	0.001	Ni	R	-60(10)	PAC	BRO68
72	Hf	180	t	Gd	77	-304(31)	PAC	MUR69
73	Ta	181	<2	Fe	He	-656(13)	SE, NP	STO65, KON67
73	Ta	181	<2	Ni	He	-98(2)	SE	KON67
74	W	183	<2	Fe	He	-643(13)	SE, PAC	BOE66, KON67

Z	El.	A	at.%	Host	T(K)	H_{hf}(kG)	Method	Reference
74	W	183	<2	Co	He	-388(8)	SE, PAC	GIL66, KON67
74	W	184	t	Ni	R	-78(7)[c]	PAC	GIL66
75	Re	185	<2	Fe	He	-760(15)	SE, NP	STO64, KON67
75	Re	185	<2	Ni	He	442(9)	SE	KON67
76	Os	189	1	Fe	4.2	1100(20)	M	PER68
76	Os	189	<2	Co	He	862(17)[d]	SE	KON67
76	Os	189	<2	Ni	He	297(6)[d]	SE	KON67
77	Ir	193	t	Fe	4.2	-1403(20)[e]	M	WAG70
77	Ir	193	t	Co	4.2	-1013(15)[e]	M	WAG70
77	Ir	193	t	Ni	4.2	-464(8)[e]	M	WAG70
78	Pt	195	<2	Fe	He	-1280(26)	SE, NP	STO65, KON67
78	Pt	195	<2	Co	He	830(17)	SE	KON67
78	Pt	195	<2	Ni	He	-340(7)	SE	KON67
78	Pt		t	Gd	77	-780(120)	PAC	HEE70
79	Au	197	<2	Fe	He	-1280(26)	SE, NP	SAM61, KON67
79	Au	197	<2	Co	He	-797(16)	SE, M	GRA64, KON67
79	Au	197	<2	Ni	He	-294(6)	SE, NP	SAM61, GRA64
80	Hg	198	<0.1	Fe		-440(105)	PAC	ZAW69
80	Hg	198	<0.1	Co		-370(78)	PAC	ZAW69
80	Hg	198	<0.1	Ni		-86(22)	PAC	ZAW69
81	Tl	203	<0.02	Fe		-185(70)	PAC	ZAW69
81	Tl	203	<0.02	Co		-90(35)	PAC	ZAW69
82	Pb	204	t	Fe	R	+262(6)	PAC	HAA70, BOW69

Z	El.	A	at.%	Host	T(K)	H_{hf}(kG)	Method	Reference
82	Pb	204	t	Co	R	+262(8)	PAC	HAA70, BOW69
82	Pb	204	t	Ni	R	+135(3)	PAC	HAA70, BOW69
86	Rn	220	t	Fe	R	+950(290)	PAC	ANS70
86	Rn	222	t	Ni	R	+15(3)	PAC	ORR70
88	Ra	224	t	Fe	R	-220(70)[f]	PAC	ANS70A
88	Ra	223	<0.01	Fe		-105(20)	PAC	LEV70
88	Ra	223	<0.01	Co		-80(16)	PAC	LEV70
88	Ra	223	<0.01	Ni		-30(10)	PAC	LEV70
92	U	238	t	Fe	R	-520(155)	PAC	KAU70
93	Np	239	t	Ni	R	+170(40)	PAC	ANS70B
94	Pu			Fe		+620(120)	PAC	DEU70

FOOTNOTES

*Work performed under the auspices of the U. S. Atomic Energy Commission.

(a) Face-centered cubic.

(b) Hexagonal close-packed.

(c) We have corrected the W<u>Ni</u> results given by these authors because their W<u>Fe</u> and W<u>Co</u> results were systematically lower than the NMR values.

(d) Corrected for revised magnetic moment.

(e) Moment corrected for hyperfine anomaly; concentration extrapolated to zero.

(f) Using calculated g-factor.

REFERENCES

ANS70A E. J. Ansaldo and L. Grodzins, "Hyperfine Interactions in Trans-Lead Elements via α - γ PAC," this conference.

ANS70B E. J. Ansaldo and L. Grodzins, Phys. Letters 32B, 479 (1970).

ARP59 V. Arp, D. I. Edmonds, and R. Peterson, Phys. Rev. Letters 3, 212 (1959). The continuous variation of $H_{hf}^{(Co)}$ with composition in Fe-Co alloys and its negative sign for Co in Fe imply a negative sign for Co in Co.

ASA63 K. Asayama, S. Kobayashi, and J. Itoh, J. Phys. Soc. Japan 18, 458 (1963).

ASA64 K. Asayama, M. Kontani, and J. Itoh, J. Phys. Soc. Japan 19, 1984 (1964).

AUE66 K. Auerbach, K. Siepe, J. Witthemper, and H. J. Körner, Phys. Letters 23, 367 (1966).

BEN62 L. H. Bennett and R. L. Streever, Jr., J. Appl. Phys. 33, S1094 (1962).

BEN70 H. C. Benski and C. Hohenemser, "Hyperfine Field of Sc in a Ni Host," this conference.

BOE66 F. Boehm, G. B. Hagemann, and A. Winther, Phys. Letters 21, 217 (1966).

BON70 P. Bond and S. Jha, Phys. Rev.C 2, 1887 (1970).

BOS70 L. Boström, K. Johansson, E. Karlsson, and L.-O. Norlin, "Hyperfine Fields for 5-s-p Elements in Gadolinium," this conference.

BOW69 J. D. Bowman and F. C. Zawislak, Nucl. Phys. A138, 90 (1969).

BOY60 A. J. F. Boyle, D. St. P. Bunbury, and C. Edwards, Phys. Rev. Letters 5, 553 (1960).

BRA67 J. Braunsfurth, J. Morgenstern, H. Schmidt, and H. J. Körner, Z. Physik 202, 321 (1967).

BRO68 W. H. Brooker, T. A. McMath, J. Murray, and J. A. Cameron, Can. J. Phys. 46, 1523 (1968).

BUD61 J. I. Budnick, L. J. Bruner, R. J. Blume, and E. L. Boyd, J. Appl. Phys. 32, 1209 (1961).

BUR69 T. J. Burch, J. I. Budnick, and S. Skalski, Phys. Rev. Letters 22, 846 (1969).

CAM67 J. A. Cameron et al., Proc. Phys. Soc. 90, 1089 (1967).

CHI68 O. A. Chilashvili, C. J. Sanctuary, and N. J. Stone, Proceedings of the Eleventh International Conference on Low Temperature Physics, St. Andrews (1968), p. 523.

CIS68 J. I. Cisneros, G. Liljegren, T. Lindqvist, and A. Lopez-Garcia, Arkiv för Fysik 38, 368 (1968).

CRU70 D. W. Cruse, K. Johansson, and E. Karlsson, Nucl. Phys. A154, 369 (1970).

DAS60 J. G. Dash et al., Phys. Rev. Letters 5, 152 (1960).

DEU66 B. I. Deutch, P. Hornshøj, K. Bonde Nielsen, and F. Boehm, Phys. Letters 21, 659 (1966).

DEU68 B. I. Deutch, G. B. Hagemann, K. A. Hagemann, and S. Ogaza, Asilomar†, p. 731.

DEU70 B. I. Deutch, private communication, quoted in ANS70B (1970).

DEW66 H. de Waard and S. A. Drentje, Phys. Letters 20, 38 (1966).

DEW69A H. de Waard and S. A. Drentje, Proc. Roy. Soc. 311, 139 (1969).

DEW69B H. de Waard and S. R. Reintsema, Phys. Letters 29A, 290 (1969).

DEW70 H. de Waard, P. Schurer, P. Inia, L. Niesen, and Y. K. Agarwal, "Mössbauer and Nuclear Orientation Studies on Atoms Implanted In Metals," this conference.

EAS66 W. C. Easley, N. Edelstein, M. P. Klein, D. A. Shirley, and H. H. Wickman, Phys. Rev. 141, 1132 (1966).

ERI69 U. Erich, Z. Physik 227, 25 (1969). The smooth variation of field with concentration implies the sign for the dilute alloy NiFe.

FOX70 R. A. Fox, P. D. Johnston, C. J. Sanctuary, and N. J. Stone, "NO/NMR of ^{110m}Ag and ^{96}Tc in Fe," this conference.

FRA68 R. B. Frankel, J. J. Huntzicker, D. A. Shirley, and N. J. Stone, Phys. Letters 26A, 452 (1968).

GER70A E. Gerdau, H. Winkler, D. Rüter, and J. Braunsfurth, private communication (1970).

GER70B E. Gerdau, F. Sabathil, and W. Müller, private communication (1970).

GIL66 P. Gilad, G. Goldring, R. Kalish, and R. H. Herber, Phys. Rev. 151, 281 (1966).

GOT69 V. Gotthardt, H. S. Möller, and R. L. Mössbauer, Phys. Letters 28A, 480 (1969).

GRA64 R. W. Grant, M. Kaplan, D. A. Keller, and D. A. Shirley, Phys. Rev. 133, A1062 (1964).

GRO66 L. Grodzins, R. Borchers, and G. B. Hagemann, Phys. Letters 21, 214 (1966).

HAA70 H. Haas, private communication (1970).

HAN60 S. S. Hanna, J. Heberle, G. J. Perlow, R. S. Preston, and D. H. Vincent, Phys. Rev. Letters 4, 513 (1960).

HAR61 W. A. Hardy, J. Appl. Phys. 17, 122S (1961).

HEE68 G. M. Heestand, B. Herskind, R. Nord, G. Cohn, and R. Kalish, Bull. Am. Phys. Soc. 13, 126 (1968).

HEE70 G. M. Heestand, P. Hvelplund, B. Skaali, and B. Herskind, Phys. Rev., to be published (1970).

HEN70 W. Henning, G. Bähre, and P. Kienle, "On the Magnetic Field and Charge Density of Conduction Electrons at Nuclei in Rare Earth Metals," this conference.

HOH69 C. Hohenemser, R. Reno, H. C. Benski, and J. Lehr, Phys. Rev. 184, 298 (1969).

HOH70 C. Hohenemser, private communication (1970).

INI69 P. Inia, Y. K. Agarwal, and H. de Waard, Phys. Rev. 188, 605 (1969).

KAU70 E. N. Kaufmann, H. P. Lie, and D. E. Murnick, "Implantation Perturbed Angular Correlation Studies in ^{238}U in Iron" in Nuclear Reactions Induced by Heavy Ions, ed. by R. Bock and W. R. Hering, (North-Holland, 1970), p. 424.

KIS66 O. C. Kistner, Phys. Rev. 144, 1022 (1966).

KLE68A O. Klepper and H. Spehl, Z. Physik 215, 17 (1968).

KLE68B O. Klepper, H. Spehl, and N. Wertz, Z. Physik 217, 425 (1968).

KLE70 O. Klepper and F. Bosch, "Hyperfine Field of ^{19}F Ions Implanted into a Cubic Cobalt Lattice," this conference.

KNO70 T. F. Knott, H. R. Andrews, E. J. Cohen, F. M. Pipkin, and D. C. Santry, Phys. Rev. Letters 25, 543 (1970).

KOB65 S. Kobayoshi et al. (private communication, cited in KON65).

KOI61 Y. Koi, A. Tsujimura, T. Hihara, and T. Kushida, J. Phys. Soc. Japan 16, 1040 (1961).

KOI62 Y. Koi, A. Tsujimura, T. Hihara, and T. Kushida, J. Phys. Soc. Japan 17, Suppl. B-I, 96 (1962).

KOI63 Y. Koi and A. Tsujimura, J. Phys. Soc. Japan 18, 1347 (1963).

KOI64 Y. Koi, A. Tsujimura, and T. Hihara, J. Phys. Soc. Japan 19, 1493 (1964).

KOI66 Y. Koi, private communication, 1966.

KOI70 S. Koički, T. A. Koster, R. Pollak, D. Quitmann, and D. A. Shirley, Phys. Letters 32B, 351 (1970).

KON65 M. Kontani, K. Asayama, and J. Itoh, J. Phys. Soc. Japan 20, 1737 (1965).

KON67 M. Kontani and J. Itoh, J. Phys. Soc. Japan 22, 345 (1967).

KUG70A H. W. Kugel, T. Polga, R. Kalish, and R. R. Borchers, "The Hyperfine Magnetic Interaction of the First (2^+) State of ^{142}Ce in Iron, Cobalt, and Nickel," this conference.

KUG70B H. W. Kugel, T. Polga, R. Kalish, and R. R. Borchers, Phys. Letters 32B, 463 (1970).

LEV70 M. Levanoni and F. C. Zawislak, Phys. Rev. C 2, 672 (1970).

MAR70 M. Marmor, S. Cochavi, and D. B. Fossan, Phys. Rev. Letters 25, 1033 (1970).

MAT68 E. Matthias, D. A. Shirley, N. Edelstein, H. J. Körner, and B. A. Olsen, Asilomar †, p. 878.

MOR68 J. Morgenstern, J. W. Schmidt, G. Flügge, and H. Schmidt, Phys. Letters 27B, 370 (1968).

MUR67 D. E. Murnick, L. Grodzins, J. D. Bronson, B. Herskind, and R. R. Borchers, Phys. Rev. 163, 254 (1967).

MUR68 D. Murnick, L. Grodzins, R. Kalish, R. R. Borchers, J. Bronson, and B. Herskind, Asilomar †, p. 503.

MUR69 D. E. Murnick, S. Hüfner, and B. Herskind, Z. Physik 226, 175 (1969).

NAG62 D. Nagle et al., Phys. Rev. 125, 490 (1962).

NIE68 K. Bonde Nielsen and B. I. Deutch, Asilomar †, p. 727.

TECHNICAL INFORMATION DIVISION
LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720