U. S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
GAITHERSBURG, MD 20899

REPORT OF CALIBRATION

EXRADIN CHAMBER
MODEL A3 SERIAL NUMBER 183

MANUFACTURED BY EXRADIN INC.
LOCKPORT, IL 60441

SUBMITTED BY MARTIN MARIETTA
OAK RIDGE, TN 37831-6501

RECEIVED AT NIST ON 1990 DEC 11

THE CALIBRATION FACTORS GIVEN IN THIS REPORT ARE QUOTIENTS OF THE AIR KERMA AND THE CHARGE GENERATED BY THAT RADIATION IN THE IONIZATION CHAMBER. THE AVERAGE CHARGE USED TO COMPUTE THE CALIBRATION FACTOR IS BASED ON MEASUREMENTS WITH THE WALL OF THE IONIZATION CHAMBER AT THE STATED POLARITY AND POTENTIAL. LEAKAGE CORRECTIONS WERE APPLIED IF NECESSARY. IF THE CHAMBER WAS OPEN TO THE ATMOSPHERE THE MEASUREMENTS WERE NORMALIZED TO ONE STANDARD ATMOSPHERE AND 22 DEGREES CELSIUS. USE OF THE CHAMBER AT OTHER PRESSURES AND TEMPERATURES REQUIRES NORMALIZATION OF THE ION CURRENTS TO THESE REFERENCE CONDITIONS. THE NORMALIZING FACTOR F IS COMPUTED FROM THE FOLLOWING EXPRESSION:

$$F = (273.15 + T) / (295.15 H)$$

WHERE T IS THE TEMPERATURE IN DEGREES CELSIUS, AND
H IS THE PRESSURE EXPRESSED AS A FRACTION OF A STANDARD ATMOSPHERE. (1 STANDARD ATMOSPHERE = 101.325 KILOPASCALS = 1013.25 MILLIBARS = 760 MILLIMETERS OF MERCURY)

THE AIR-KERMA RATE AT THE CALIBRATION POSITION WAS MEASURED BY A FREE-AIR IONIZATION CHAMBER FOR X RADIATION AND BY GRAPHITE CAVITY IONIZATION CHAMBERS FOR COBALT-60 AND CESIUM-137 GAMMA RADIATION. THE GAMMA-RAY AIR-KERMA RATES WERE CORRECTED TO THE DATE OF CALIBRATION, FROM PREVIOUS MEASURED VALUES, BY DECAY CORRECTIONS BASED ON HALF-LIVES OF 5.27 AND 30.0 YEARS, FOR COBALT-60 AND CESIUM-137, RESPECTIVELY.

AIR KERMA IS RELATED TO EXPOSURE BY THE EQUATION

$$K = 2.58E\text{-}04 \, (W/E) \, X / (1-G)$$

WHERE K IS AIR KERMA IN GRAYS (GY)
W/E IS THE MEAN ENERGY PER UNIT CHARGE EXPENDED BY ELECTRONS IN DRY AIR IN JOULES PER COULOMB (J/C)
X IS THE EXPOSURE IN ROENTGENS
G IS THE FRACTION OF THE INITIAL KINETIC ENERGY OF SECONDARY ELECTRONS DISSIPATED IN AIR AS BREMSSTRAHLUNG.

THE FOLLOWING VALUES ARE USED AT NIST: W/E = 33.97 J/C, G = 0.0032 FOR COBALT-60 GAMMA RAYS, G= 0.0016 FOR CESIUM-137 GAMMA RAYS, AND G = 0.0000 FOR X RAYS WITH ENERGY LESS THAN 300 KEV.

TO OBTAIN EXPOSURE IN ROENTGENS, DIVIDE AIR KERMA IN GRAYS BY
8.79E-03 FOR COBALT-60 GAMMA RAYS,
8.78E-03 FOR CESIUM-137 GAMMA RAYS, AND
8.76E-03 FOR X RAYS LESS THAN 300 KEV.

ON 1986 JAN 01 THE AIR-KERMA RATES OF THE NIST STANDARDS WERE REDUCED TO TAKE INTO ACCOUNT CHANGES IN THE HUMIDITY CORRECTION, AND THE ENERGY-ABSORPTION COEFFICIENT AND STOPPING-POWER RATIOS. LABORATORIES WITH INSTRUMENTS CALIBRATED PRIOR TO 1986 JAN 01 CAN BRING THEIR INSTRUMENTS INTO AGREEMENT WITH THE NEW AIR-KERMA RATES BY REDUCING THE EARLIER CALIBRATION FACTORS BY THE FOLLOWING CHANGES IN PERCENT:

60CO	137CS	X RAYS
-1.1	-0.8	-0.2

NO CORRECTION IS MADE FOR THE EFFECT OF WATER VAPOR ON THE INSTRUMENT BEING CALIBRATED, SINCE IT IS ASSUMED THAT BOTH THE CALIBRATION AND THE USE OF THAT INSTRUMENT TAKE PLACE IN AIR WITH A RELATIVE HUMIDITY BETWEEN 10% AND 70%, WHERE THE HUMIDITY CORRECTION IS NEARLY CONSTANT.

THE OVERALL UNCERTAINTY OF THE CALIBRATION DESCRIBED IN THIS REPORT IS 1%, OF WHICH 0.7% IS ASSIGNED TO THE UNCERTAINTY IN THE AIR-KERMA RATE OF THE NIST BEAM. THE OVERALL UNCERTAINTY WAS FORMED BY TAKING TWO TIMES THE QUADRATIC SUM OF THE STANDARD DEVIATIONS OF THE MEAN FOR COMPONENT UNCERTAINTIES OBTAINED FROM REPLICATE DETERMINATIONS, AND ASSUMED APPROXIMATIONS OF STANDARD DEVIATIONS FOR ALL OTHER UNCERTAINTY COMPONENTS; IT IS CONSIDERED TO HAVE THE APPROXIMATE SIGNIFICANCE OF A 95% CONFIDENCE LIMIT. DETAILS OF THE UNCERTAINTY ANALYSIS ARE GIVEN IN: LAMPERTI, P.J., LOFTUS, T.P., AND LOEVINGER, R., "CALIBRATION OF X-RAY AND GAMMA-RAY MEASURING INSTRUMENTS AT THE NATIONAL BUREAU OF STANDARDS", NBS SPECIAL PUBLICATION 250-16 (1987).

THE CALIBRATION FACTOR IS GIVEN TO FOUR DIGITS TO PREVENT ROUNDING ERRORS UP TO 0.5 PERCENT WHEN THE FIRST DIGIT IS UNITY.

INFORMATION ON TECHNICAL ASPECTS OF THIS REPORT MAY BE OBTAINED FROM P. J. LAMPERTI, RADIATION PHYSICS C214, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, GAITHERSBURG, MD 20899, (301) 975-5591.

REPORT REVIEWED BY PJ

REPORT APPROVED BY BERT M. COURSEY

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NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY REPORT OF CALIBRATION

MARTIN MARIETTA
OAK RIDGE, TN 37831-6501

EXRADIN CHAMBER
MODEL A3 SERIAL NUMBER 183
OPEN TO THE ATMOSPHERE WHEN TESTED
WALL POTENTIAL WAS -300 VOLTS WITH RESPECT TO INNER ELECTRODE

BEAM CODE	HALF-VALUE LAYER AL (MM)	CU (MM)	CALIBRATION FACTOR 22 DEG C AND 1 ATM	DIST (M)	BEAM SIZE (MM)	AIR-KERMA RATE (GY/S)
137CS		10.8	*8.372E+06 GY/C	0.87	S 64	8.0E-04

DURING CALIBRATION THE CAVITY WAS POSITIONED IN THE CENTER OF THE BEAM WITH THE STEM PERPENDICULAR TO THE BEAM DIRECTION. THE HV WIRE FACED THE SOURCE OF RADIATION.

3.E-15 AMPERES WAS THE LEAKAGE CURRENT MEASURED BEFORE CALIBRATION.

1.008 WAS THE RATIO OF THE CURRENT MEASURED FOR FULL COLLECTION POTENTIAL TO THE CURRENT FOR HALF COLLECTION POTENTIAL FOR A CURRENT OF 5.1E-11 AMPERES. A DETAILED SATURATION STUDY WAS NOT CARRIED OUT AND NO CORRECTION FOR LACK OF SATURATION WAS APPLIED TO THE DATA.

* THE CHAMBER WALL THICKNESS WAS INCREASED FOR THIS BEAM QUALITY BY ADDITION OF THE SHELL SUPPLIED WITH THE CHAMBER.

CHECKED BY P. Lamperti

EXPLANATION OF CHAMBER CALIBRATION TABLE

THE BEAM CODE IDENTIFIES IMPORTANT BEAM PARAMETERS. FOR X RADIATION THERE ARE FOUR GROUPS. THE LETTERS L, M, H, AND S STAND FOR LIGHT, MODERATE, HEAVY, AND SPECIAL FILTRATION, RESPECTIVELY, AND THE NUMBER FOLLOWING THE LETTER IS THE CONSTANT POTENTIAL ACROSS THE X-RAY TUBE. FOR GAMMA RADIATION THE BEAM CODE IDENTIFIES THE RADIONUCLIDE.

THE HALF-VALUE LAYERS IN ALUMINUM AND IN COPPER HAVE BEEN DETERMINED BY A FREE-AIR CHAMBER FOR X RADIATION. THE CU HVLS FOR 60CO AND 137CS ARE CALCULATED. THE CALIBRATION FACTORS OR CORRECTION FACTORS ARE LISTED IN ORDER OF INCREASING AL HVL WITHIN EACH GROUP.

THE CALIBRATION FACTOR OR CORRECTION FACTOR IS DEFINED ON THE FIRST PAGE OF THIS REPORT. IF THE CHAMBER WAS OPEN TO THE ATMOSPHERE, THE FACTOR HAS BEEN NORMALIZED TO THE TEMPERATURE AND PRESSURE SHOWN AT THE TOP OF THE COLUMN. WHEN THE ENTRY IS A CALIBRATION FACTOR, IT IS IN SPECIAL UNITS (GRAYS PER COULOMB). WHEN THE ENTRY IS A CORRECTION FACTOR, IT IS DIMENSIONLESS. IF THE CORRECTION FACTOR IS FOLLOWED BY A NUMBER, THE NUMBER GIVES THE APPROXIMATE PERCENT OF FULL-SCALE ELECTROMETER READING AT WHICH THE CALIBRATION WAS PERFORMED.

THE DISTANCE SHOWN IS THAT BETWEEN THE RADIATION SOURCE AND THE DETECTOR CENTER OR THE REFERENCE LINE. FOR THIN-WINDOW CHAMBERS WITH NO REFERENCE LINE, THE WINDOW SURFACE IS THE PLANE OF REFERENCE.

THE BEAM SIZE IS THE PERPENDICULAR DISTANCE FROM THE CENTER LINE OF THE CALIBRATION BEAM TO THE 50 PERCENT INTENSITY LINE. FOR CIRCULAR FIELDS THE LETTER C PRECEDES THE DIMENSION. FOR SQUARE FIELDS THE LETTER S PRECEDES THE DIMENSION, AND THE CHAMBER AXIS IS PERPENDICULAR TO A SIDE OF THE SQUARE. IF NO LETTER PRECEDES THE DIMENSION, A SPECIAL FIELD WAS USED AND ITS DIMENSIONS ARE GIVEN IN A NOTE AT THE BOTTOM OF THE TABLE.

THE AIR-KERMA RATE AT WHICH THE CALIBRATION WAS PERFORMED IS GIVEN IN THE LAST COLUMN. IF THE CHAMBER IS USED TO MEASURE AN AIR-KERMA RATE THAT IS SIGNIFICANTLY DIFFERENT FROM THAT USED FOR THE CALIBRATION IT MAY BE NECESSARY TO CORRECT FOR RECOMBINATION LOSS.

THE EFFECTIVE ENERGY IS GIVEN ON THE NEXT PAGE OF THIS REPORT FOR THOSE BEAMS FOR WHICH IT IS BELIEVED TO BE A MEANINGFUL CHARACTERIZATION OF THE BEAM QUALITY. FOR GAMMA RADIATION THE EFFECTIVE ENERGY IS THE PHOTON ENERGY.

FOR X RADIATION THE EFFECTIVE ENERGY IS COMPUTED FROM GOOD-GEOMETRY COPPER ATTENUATION DATA. THE INITIAL SLOPE OF THE ATTENUATION CURVE IS USED TO DETERMINE AN ATTENUATION COEFFICIENT, AND THE PHOTON ENERGY ASSOCIATED WITH THIS COEFFICIENT IS THE "EFFECTIVE ENERGY".
THE ENERGY VS ATTENUATION-COEFFICIENT DATA USED FOR THIS PURPOSE ARE TAKEN FROM J. H. HUBBELL, INT. J. APPL. RADIAT. ISOT. 33, 1269 (1982). FOR BEAM CODES H50 TO H300, THE EFFECTIVE ENERGY IS WELL REPRESENTED BY (EFFECTIVE ENERGY) = 0.861V - 6.1, WHERE V IS THE CONSTANT POTENTIAL IN KILOVOLTS.

CONVENTIONAL CALIBRATION CONDITIONS FOR X- AND GAMMA-RAY MEASURING INSTRUMENTS

BEAM CODE	ADDED FILTER AL (MM)	CU (MM)	SN (MM)	PB (MM)	HALF-VALUE LAYER AL (MM)	CU (MM)	HOMOGENEITY COEFFICIENT AL	CU	EFFECT. ENERGY (KEV)	DIS-TANCE (CM)	EXPOSURE RATE MIN. (MICRO-GY/S)	MAX. (MILLI-GY/S)
L10	0				0.029		79			25	0.01	15.
L15	0				0.050		74			25	0.01	37.
L20	0				0.071		76			50	0.01	29.
L30	0.265				0.22		60			50	0.01	3.5
L40	0.50				0.49		57			50	0.01	3.5
L50	0.639				0.75		58			50	0.01	3.5
L80	1.284				1.83		58			50	0.01	3.5
L100	1.978				2.8		59			50	0.01	3.5
M20	0.230				0.152		79			50	0.01	4.4
M30	0.50				0.36		64			50	0.01	2.6
M40	0.786				0.73		66			50	0.01	3.5
M50	1.021				1.02	0.032	66	62		50	0.01	3.5
M60	1.51				1.68	0.052	68	64			7.0	1.7
M100	5.0				5.0	0.20	72	55			8.8	2.6
M150	5.0	0.25			10.2	0.67	87	62			8.8	3.5
M200	4.1	1.12			14.9	1.69	95	69			8.8	2.6
M250	5.0	3.2			18.5	3.2	98	86			8.8	1.7
M300	4.0		6.5		22	5.3	100	97			4.4	0.70
H10	0.105				0.148		89			25	0.01	0.026
H15	0.500				0.152		87			25	0.01	0.026
H20	1.021				0.36		88			50	0.01	0.026
H30	4.13				1.23	0.038	93	94		50	0.01	0.026
H40	4.05	0.26			2.9	0.093	94	95		50	0.01	0.026
H50	4.0			0.10	4.2	0.142	92	90	38		2.6	0.57
H60	4.0	0.61			6.0	0.24	94	89	46		0.18	0.044
H100	4.0	5.2			13.5	1.14	100	94	80		0.05	0.017
H150	4.0	4.0	1.51		17.0	2.5	100	95	120		0.26	0.087
H200	4.0	0.60	4.16	0.77	19.8	4.1	100	99	166		0.18	0.052
H250	4.0	0.60	1.04	2.72	22	5.2	100	98	211		0.26	0.044
H300	4.1		3.0	5.0	23	6.2	99	98	252		0.35	0.026
S75	1.504				1.86		63			50	0.01	3.5
S60	4.0				2.8	0.089	75	70			2.6	0.52
137CS						10.8			662		13.	0.87
60CO						14.9			1250		13.	22.

FOR THE X-RAY BEAM CODES, THE LETTER INDICATES LIGHT, MODERATE, HEAVY, AND SPECIAL FILTRATION, AND THE NUMBER IS THE CONSTANT POTENTIAL IN KILOVOLTS.

THE INHERENT FILTRATION IS APPROXIMATELY
1.0 MM BE FOR BEAM CODES L10-L100, M20-M50, H10-H40, AND S75; AND
3.0 MM BE FOR BEAM CODES M60-M300, H50-H300, AND S60.

THE HALF-VALUE LAYERS FOR 137CS AND 60CO ARE CALCULATED.
THE HOMOGENEITY COEFFICIENT IS TAKEN AS 100(1ST HVL/2ND HVL).