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Total Ionization Dose Test Report

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CS249

TOTAL IONIZATION DOSE TEST REPORT

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DOCUMENT CHANGE CONTROL

Edition / Revision	Date	Affected Edition / Revision	Affected Paragraph / Modification
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1. PARTS TRACEABILITY DATA

COMPONENT DESCRIPTION	Ceramic Hermetically Sealed, Radiation Hard Transistor Optocouplers	PART TYPE	CS249
COMPONENT NUMBER	CS249/L2S Option 20	PACKAGE	DIL-6
DATE CODE	1508	MANUFACTURER	ISOCOM LIMITED, GREAT BRITAIN
GENERIC SPECIFICATION	MIL-PRF-19500	ASSEMBLY LOT DIFUSIÓN RUN	I3053 84609021073 & 3821D061111
DETAIL SPECIFICATION	DWG CS249/L2S, Iss.1	AMENDMENT	--

2. TEST CONDITIONS

EVALUATION	X	TEST HOUSE	ALTER TECHNOLOGY TÜV Nord S.A.U. (Seville, Spain)	
ACCEPTANCE DIFUSSION	--	RAD. FACILITY	RADLAB (Seville, Spain)	
ACCEPTANCE LOT	--	RADIATION SOURCE	⁶⁰ Co	ACCEPTANCE LOT --
IRRADIATION TEST	2 Biased OFF 2 Biased ON 1 Unbiased		IRRADIATION UNITS	5 + 1 Control
ANNEALING TEST	2 Biased OFF 2 Biased ON 1 Unbiased		DOSE RATE	31.60 rad (Si)/h
IRRADIATION MEAS.	Remote test.		INTEREST TEST LEVEL	N/Av krad (Si)
RADIATION PLAN	ATN-RP-169 Iss.1		MAXIMUM TEST LEVEL	30 krad (Si)

3. SUMMARY

The results obtained during the irradiation test process show that the samples are sensitive to the cumulative radiation when is tested at ELDR up to an accumulated dose of 30krad (Si). As it can be seen on graphs in Annex, the IC/IF₁ and IC/IF₆ are the most affected parameters and start to be out of limits 20 krad and 30 krad.

After annealing process all parameters are within specification limits.

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4. IRRADIATION TEST FACILITY BACKGROUND

4.1. GAMMA IRRADIATION FACILITY



Figure 4.1-1. Gammabeam® X200 irradiator.

The RADLAB gamma radiation laboratory is based on a Cobalt-60 source placed into a Gammabeam® X200 irradiator. This Cobalt-60 source has photons of 1.17 and 1.33 MeV energies and 403TBq (10893Ci) certified on January, 28th 2013. The facility features meet the requirements for total dose irradiation tests currently demanded by the industry, and applicable standards such as ESCC, MIL-STD or ASTM. The dose rate can be adjusted to the level requested by the customer needs within a wide range, including standard and low window rates specified in ESCC 22900.

Alter Technology is a **DLA Laboratory Suitability** to perform total ionizing dose tests in accordance with **MIL-STD 883 Test Method 1019** and **MIL-STD-750 Test Method 1019**, being the only company outside the USA with this accreditation. Alter Technology is also accredited **ISO/IEC 17025** to perform those tests and, additionally, Total Dose Steady-State Irradiation in accordance with the ESA **ESCC 22900** test method.

ATN has completed a dosimetry inter-comparison exercise with the European Space Agency (**ESA**).

4.2. DOSIMETRY CAPABILITIES

A set of several ionization chambers and electrometers are used to determine the dose rate and allows real time recording. The uniformity of each irradiation area is guaranteed through measurements of relative dose rate in precise profiles.

The specific dosimetry equipment used to this radiation test is specified in the Test equipment identification paragraph

Total Ionization Dose Test Report

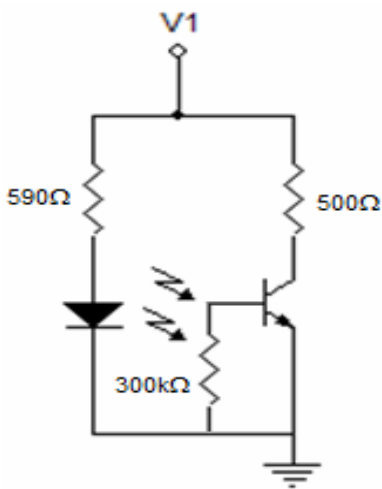
4.3. ENVIRONMENTAL CONDITIONS

Environmental conditions (temperature, pressure and relative humidity) are controlled during the radiation exposures. Dose measurements are compensated against environmental temperature and pressure fluctuations in irradiation room.

4.4. MONITORING

A dedicated data acquisition system is available to record and to monitor online environmental, dosimetical and electrical parameters in real-time. The radiation engineer has complete test overview, with access to all test records all along the test sequence.

5. RADIATION BIAS CIRCUIT



Adjust V1 until $I_F=6\text{mA}$

Figure 5-1. Radiation biased ON circuit.

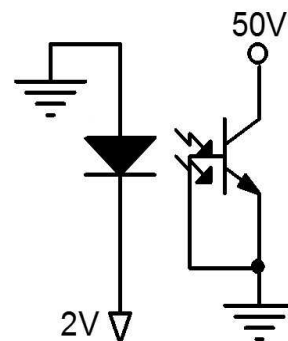


Figure 5-2. Radiation biased OFF circuit.

Notes:

- The pins for the biased ON parts were in accordance with the radiation bias circuit shown in Figure 5-1.
- The pins for the biased OFF parts were in accordance with the radiation bias circuit shown in Figure 5-2.
- The pins for the unbiased parts were short circuited and connected to ground.

Total Ionization Dose Test Report**6. SUMMARY**

Total dose steady-state irradiation test has been carried out on a CS249/L2S Option 20, a Ceramic Hermetically Sealed, Radiation Hard Transistor Optocouplers, manufactured by Isocom Limited. The test was performed until a total accumulated dose of 30 krad(Si) with a dose rate of 31.60 rad(Si)/h. The serial numbers of the samples used are indicated below:

Test S/N	MFR S/N	Usage
R1	15	CONTROL
R2	18	Irradiated, biased ON parts (Figure 5-1)
R3	19	
R4	20	Irradiated, biased OFF parts (Figure 5-2)
R5	21	
R6	22	Irradiated, non-biased parts

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7. RESULTS

The next table shows a summary of the irradiation test results.

	2.5 KRAD	5 KRAD	7.5 KRAD	10 KRAD	15 KRAD	20 KRAD	30 KRAD	ANN24h	ANN168h
V _F	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
I _R	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
I _{CEO}	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IC/IF ₁	PASS	PASS	PASS	PASS	PASS	PASS	NOTE1	NOTE1	PASS
IC/IF ₂	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IC/IF ₃	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IC/IF ₄	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IC/IF ₅	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IC/IF ₆	PASS	PASS	PASS	PASS	PASS	PASS	NOTE1	NOTE1	PASS
V _{CE(SAT)}	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS

NOTE 1: Parameter out of limits

The values measured and graphs with the evolution of the previous parameters during the irradiation and annealing sequence are available in ANNEX.

Total Ionization Dose Test Report**8. CONCLUSION**

The results obtained during the irradiation test process show that the samples are sensitive to the cumulative radiation when is tested at ELDR up to an accumulated dose of 30krad (Si). As it can be seen on graphs in Annex, the IC/IF₁ and IC/IF₆ are the most affected parameters and start to be out of limits 20 krad and 30 krad.

The IC/IF₂, IC/IF₃, IC/IF₄ and IC/IF₅ parameters also show a deviation versus accumulative dose although remain within limits during the whole test.

During the annealing process these parameters tend to recover their initial values.

In general, the samples biased OFF and the sample unbiased shows a higher degradation than the samples biased ON.

The rest of the parameters do not show significant deviations versus accumulative dose.

These results are in accordance what it was expected by Alter based on the data provided by previous radiation campaign where it was observed a high degradation in the IC/IF's with the IF low current test conditions.

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9. SCHEDULE

Dose rate rad(Si)/h	Exposure time (h)	Total Dose rad(Si)	Cumulative Dose rad(Si)	Date
--	--	0	0	2015/05/05
31.60	72.73	2298	2298	2015/05/08
31.60	85.37	2698	4996	2015/05/12
31.60	70.07	2214	7210	2015/05/15
31.60	90.66	2865	10075	2015/05/19
31.60	164.22	5189	15264	2015/05/26
31.60	143.73	4542	19806	2015/06/01
31.60	329.24	10404	30210	2015/06/15

Annealing				
Ann24h @25°C	24	--	--	2015/06/16
Ann168h @100°C	168	--	--	2015/06/23

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10. ELECTRICAL MEASUREMENTS SETUP IDENTIFICATION

REF INVENT	DESCRIPTION	CAL. DUE	USAGE
ATN-TJ-EM-162	Test Fixture	N/A	0, 2.5, 5, 7.5, 10, 15, 20, 30krad, ANN24h, ANN168h.
ATN-EM-SW-1082	Test Program	N/A	0, 2.5, 5, 7.5, 10, 15, 20, 30krad, ANN24h, ANN168h.
LE0272.000	Multimeter	2015/09/25	0, 2.5, 5, 7.5, 10, 15, 20, 30krad, ANN24h, ANN168h.
LE0332.000	Power supply	N/A	ANN24h, ANN168h.
LE0340.000	Power supply	N/A	ANN24h, ANN168h.
LE0426.000	Oven	2016/02/12	ANN24h, ANN168h.
LE0723.000	Semic. Parameter Analyzer	2017/03/10	0, 2.5, 5, 7.5, 10, 15, 20, 30krad, ANN24h, ANN168h.
LE1007.003	RAD Probe	2015/11/04	2.5, 5, 7.5, 10, 15, 20, 30krad.
LE1008.000	Electrometer	2015/08/28	2.5, 5, 7.5, 10, 15, 20, 30krad.
LE1009.010	TID Box	N/A	2.5, 5, 7.5, 10, 15, 20, 30krad.
LE1011.004	Power supply	N/A	2.5, 5, 7.5, 10, 15, 20, 30krad.
LE1011.005	Power supply	N/A	2.5, 5, 7.5, 10, 15, 20, 30krad.
LE1011.006	Power supply	N/A	2.5, 5, 7.5, 10, 15, 20, 30krad.

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11. ELECTRICAL MEASUREMENTS TEST CONDITIONS AND LIMITS

Nº	SYMBOL	TEST	CONDITIONS	LIMITS		UNIT
				MIN.	MAX.	
1	V_F	Forward voltage	$I_F=10mA$	0.7	1.8	V
2	I_R	Reverse current	$V_R=3.0V$	--	100	μA
3	I_{CEO}	Collector-Emitter leakage current	$V_{CE}=20V, I_F=0$	--	100	μA
4	IC/IF_1	DC Current transfer ratio	$I_F=1.0mA, V_{CE}=1V$	200	--	%
5	IC/IF_2	DC Current transfer ratio	$I_F=3.0mA, V_{CE}=1V$	200	--	%
6	IC/IF_3	DC Current transfer ratio	$I_F=15.0mA, V_{CE}=1V$	100	--	%
7	IC/IF_4	DC Current transfer ratio	$I_F=10.0mA, V_{CE}=5V$. Note 1.	350	--	%
8	IC/IF_5	DC Current transfer ratio	$I_F=15.0mA, V_{CE}=5V$. Note 1.	100	--	%
9	IC/IF_6	DC Current transfer ratio	$I_F=1.0mA, V_{CE}=15V$	300	--	%
10	$V_{CE(SAT)}$	Collector-Emitter saturation voltage	$I_C=10.0mA, I_F=20mA$	--	0.22	V

- Notes:**
1. Sample and hold pulse is longer than 0.1 seconds. Duty cycle is 10.
 2. The limits included above are included herein for reference purposes only. The degradation of any of these parameters above the limits must not be considered a reason for supplier lot rejection, due to the fact that the aim of this test is to characterize the electrical behaviour of this lot when is submitted to radiation.



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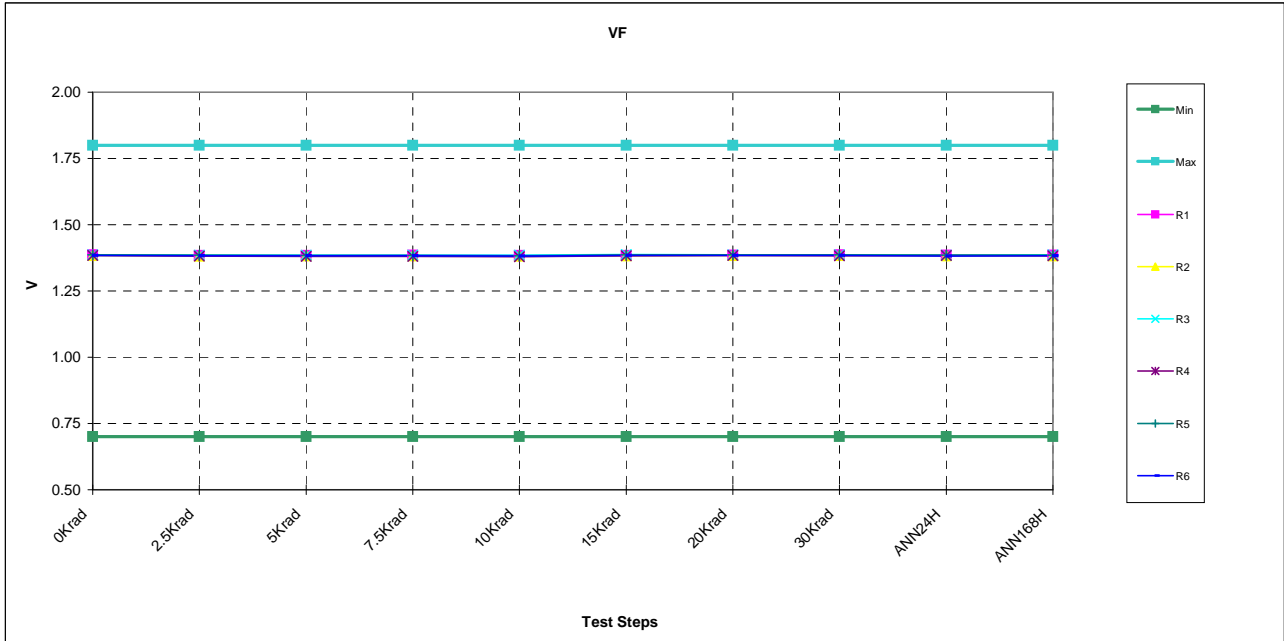
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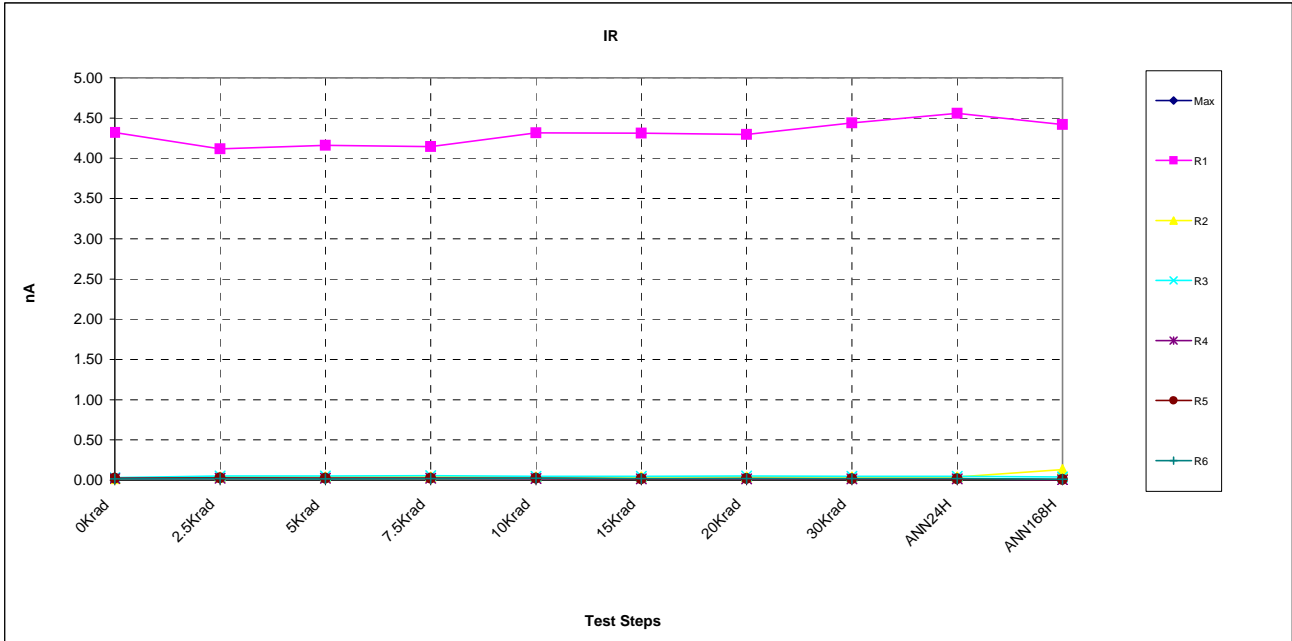
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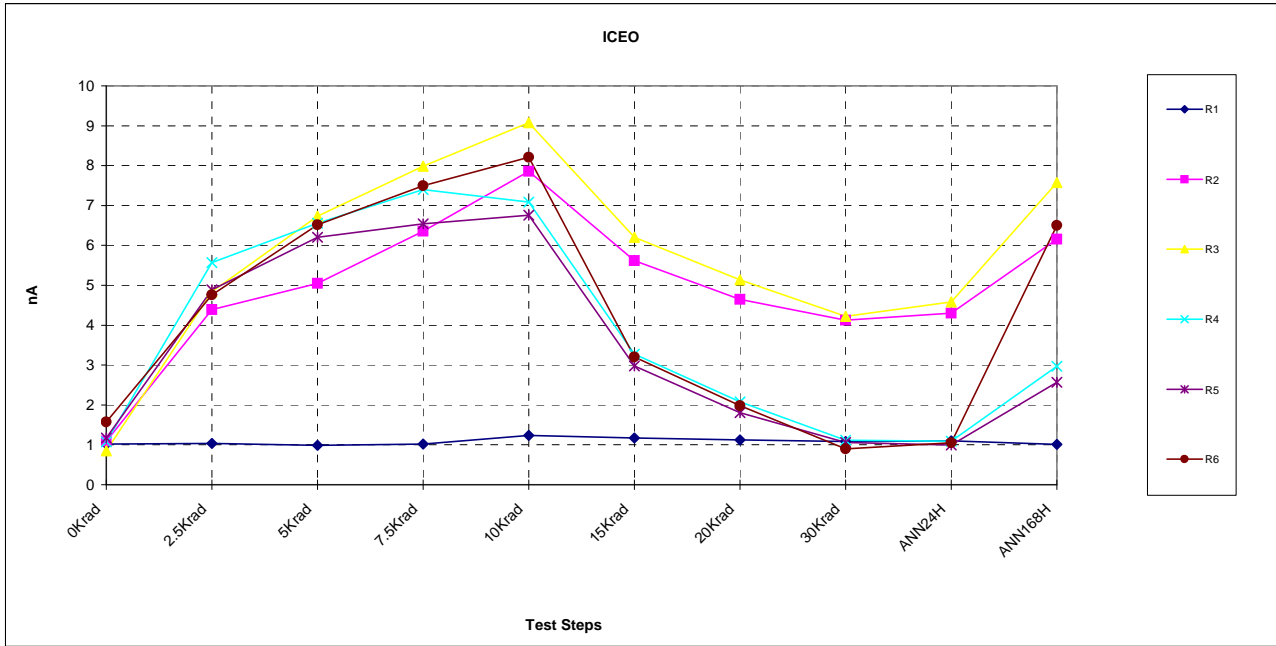
**ANNEX
ELECTRICAL MEASUREMENTS GRAPHS**



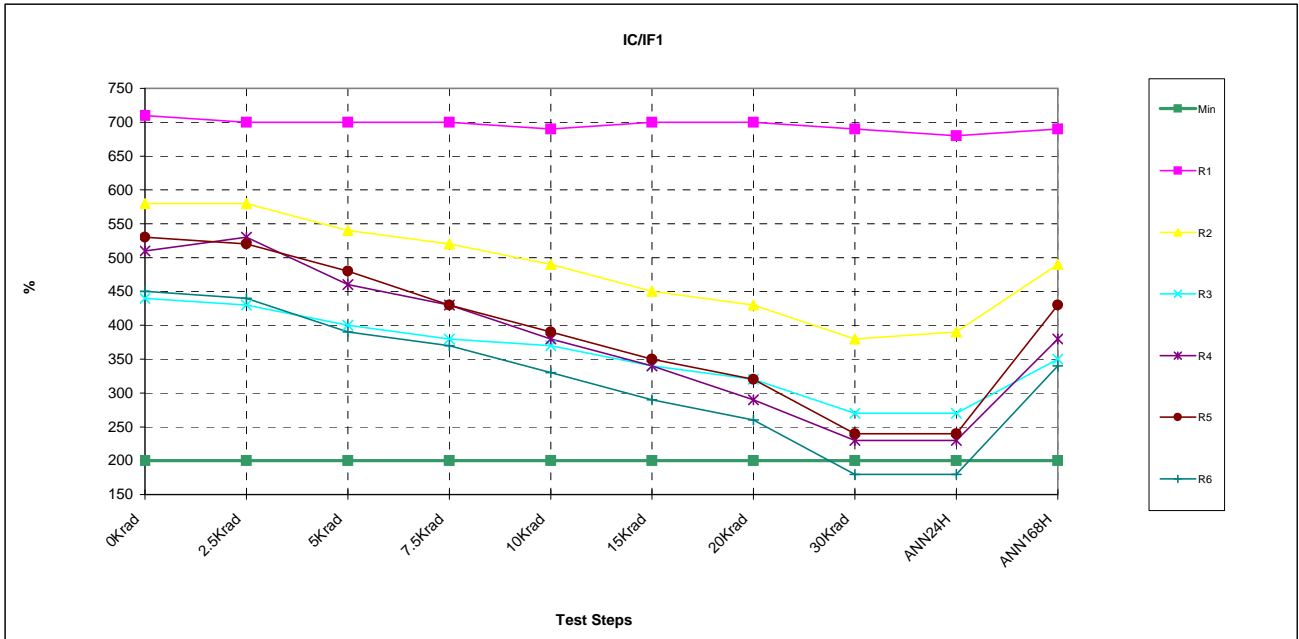
VF	0Krad	2.5Krad	5Krad	7.5Krad	10Krad	15Krad	20Krad	30Krad	ANN24H	ANN168H
Min	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Max	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Unit	V	V	V	V	V	V	V	V	V	V
Control Results										
R1	1.386	1.384	1.385	1.385	1.384	1.384	1.385	1.386	1.385	1.385
Bias ON Results										
R2	1.384	1.382	1.383	1.383	1.381	1.383	1.385	1.384	1.383	1.383
R3	1.386	1.385	1.385	1.385	1.385	1.388	1.387	1.386	1.385	1.386
Statistics bias ON										
min result	1.384	1.382	1.383	1.383	1.381	1.383	1.385	1.384	1.383	1.383
max result	1.386	1.385	1.385	1.385	1.385	1.388	1.387	1.386	1.385	1.386
average	1.385	1.384	1.384	1.384	1.383	1.386	1.386	1.385	1.384	1.385
sigma	0.001	0.002	0.002	0.002	0.003	0.004	0.002	0.001	0.002	0.002
Bias OFF Results										
R4	1.384	1.382	1.381	1.381	1.379	1.383	1.384	1.383	1.384	1.382
R5	1.386	1.385	1.384	1.385	1.383	1.386	1.387	1.386	1.385	1.386
Statistics bias OFF										
min result	1.384	1.382	1.381	1.381	1.379	1.383	1.384	1.383	1.384	1.382
max result	1.386	1.385	1.384	1.385	1.383	1.386	1.387	1.386	1.385	1.386
average	1.385	1.383	1.382	1.383	1.381	1.385	1.385	1.384	1.384	1.384
sigma	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.001	0.002
UNBIASED Results										
R6	1.384	1.383	1.382	1.383	1.382	1.385	1.385	1.384	1.382	1.383



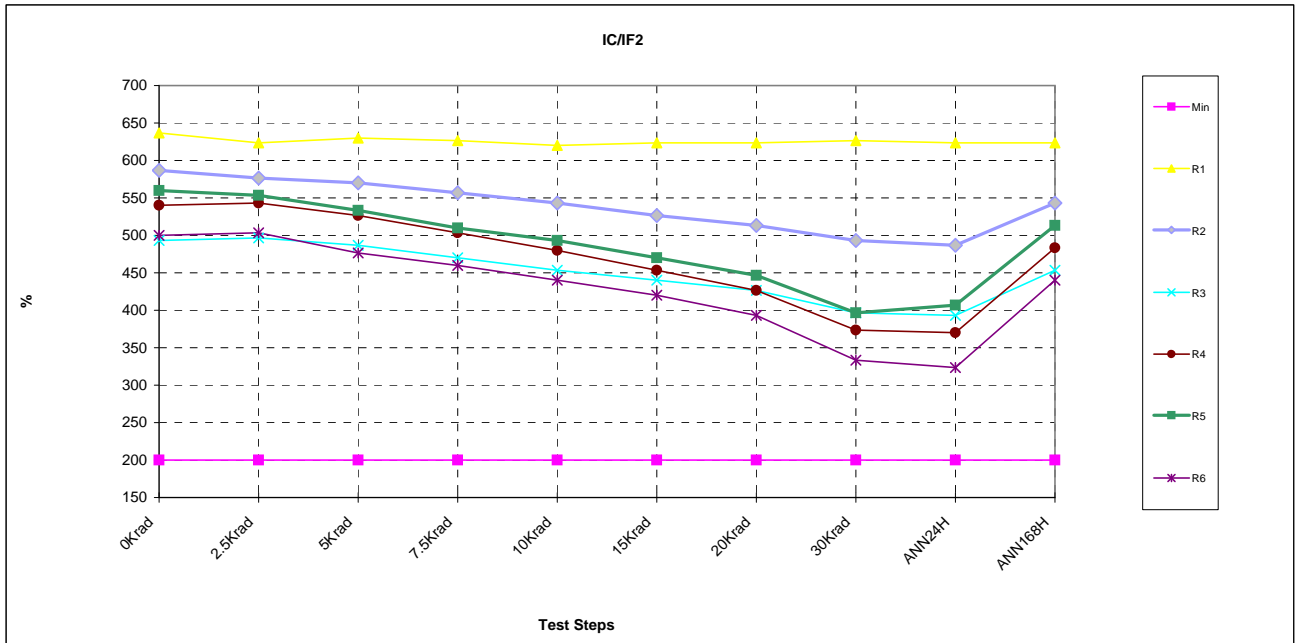
IR	0Krad	2.5Krad	5Krad	7.5Krad	10Krad	15Krad	20Krad	30Krad	ANN24H	ANN168H
Min	----	----	----	----	----	----	----	----	----	----
Max	100000.000	100000.000	100000.000	100000.000	100000.000	100000.000	100000.000	100000.000	100000.000	100000.000
Unit	nA	nA	nA	nA	nA	nA	nA	nA	nA	nA
Control Results										
R1	4.319	4.118	4.162	4.146	4.316	4.311	4.294	4.440	4.560	4.421
Bias ON Results										
R2	0.021	0.041	0.041	0.039	0.041	0.041	0.039	0.039	0.039	0.132
R3	0.031	0.051	0.053	0.057	0.049	0.048	0.051	0.048	0.049	0.041
Statistics bias ON										
min result	0.021	0.041	0.041	0.039	0.041	0.041	0.039	0.039	0.039	0.041
max result	0.031	0.051	0.053	0.057	0.049	0.048	0.051	0.048	0.049	0.132
average	0.026	0.046	0.047	0.048	0.045	0.044	0.045	0.044	0.044	0.086
sigma	0.007	0.007	0.008	0.012	0.006	0.005	0.008	0.006	0.008	0.064
Bias OFF Results										
R4	0.022	0.026	0.023	0.022	0.019	0.017	0.015	0.014	0.015	0.004
R5	0.024	0.027	0.024	0.024	0.024	0.016	0.019	0.014	0.017	0.007
Statistics bias OFF										
min result	0.022	0.026	0.023	0.022	0.019	0.016	0.015	0.014	0.015	0.004
max result	0.024	0.027	0.024	0.024	0.024	0.017	0.019	0.014	0.017	0.007
average	0.023	0.026	0.024	0.023	0.022	0.017	0.017	0.014	0.016	0.005
sigma	0.002	0.001	0.001	0.001	0.003	0.000	0.003	0.000	0.001	0.002
UNBIASED Results										
R6	0.017	0.018	0.018	0.019	0.022	0.019	0.020	0.020	0.019	0.013



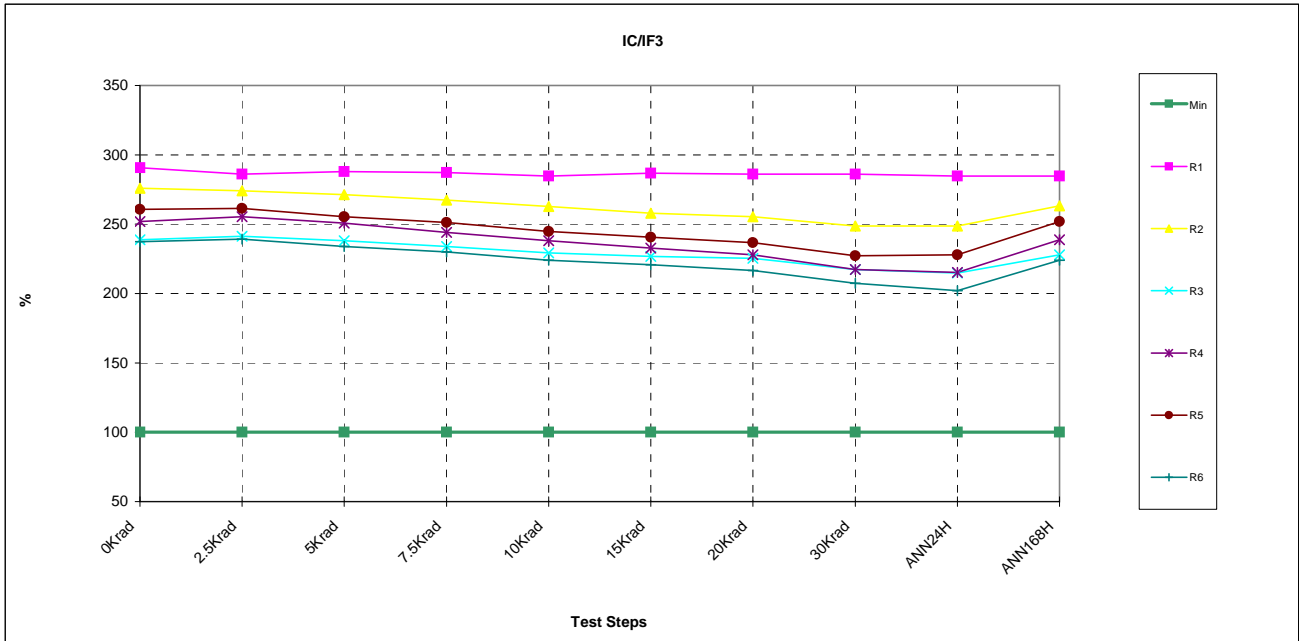
ICEO	0Krad	2.5Krad	5Krad	7.5Krad	10Krad	15Krad	20Krad	30Krad	ANN24H	ANN168H
Min	-	-	-	-	-	-	-	-	-	-
Max	100000.000	100000.000	100000.000	100000.000	100000.000	100000.000	100000.000	100000.000	100000.000	100000.000
Unit	nA	nA	nA	nA	nA	nA	nA	nA	nA	nA
Control Results										
R1	1.020	1.034	0.990	1.015	1.233	1.175	1.124	1.087	1.098	1.012
Bias ON Results										
R2	1.089	4.386	5.047	6.356	7.859	5.620	4.648	4.122	4.302	6.153
R3	0.850	4.836	6.735	7.985	9.077	6.204	5.135	4.221	4.579	7.580
Statistics bias ON										
min result	0.850	4.386	5.047	6.356	7.859	5.620	4.648	4.122	4.302	6.153
max result	1.089	4.836	6.735	7.985	9.077	6.204	5.135	4.221	4.579	7.580
average	0.970	4.611	5.891	7.171	8.468	5.912	4.892	4.171	4.441	6.866
sigma	0.169	0.318	1.194	1.152	0.861	0.413	0.344	0.070	0.196	1.009
Bias OFF Results										
R4	1.073	5.568	6.554	7.398	7.088	3.275	2.082	1.115	1.095	2.966
R5	1.169	4.886	6.201	6.540	6.755	2.979	1.808	1.057	0.992	2.565
Statistics bias OFF										
min result	1.073	4.886	6.201	6.540	6.755	2.979	1.808	1.057	0.992	2.565
max result	1.169	5.568	6.554	7.398	7.088	3.275	2.082	1.115	1.095	2.966
average	1.121	5.227	6.377	6.969	6.921	3.127	1.945	1.086	1.043	2.765
sigma	0.068	0.483	0.250	0.607	0.236	0.209	0.194	0.041	0.073	0.283
UNBIASED Results										
R6	1.572	4.757	6.519	7.500	8.214	3.202	1.982	0.901	1.049	6.505



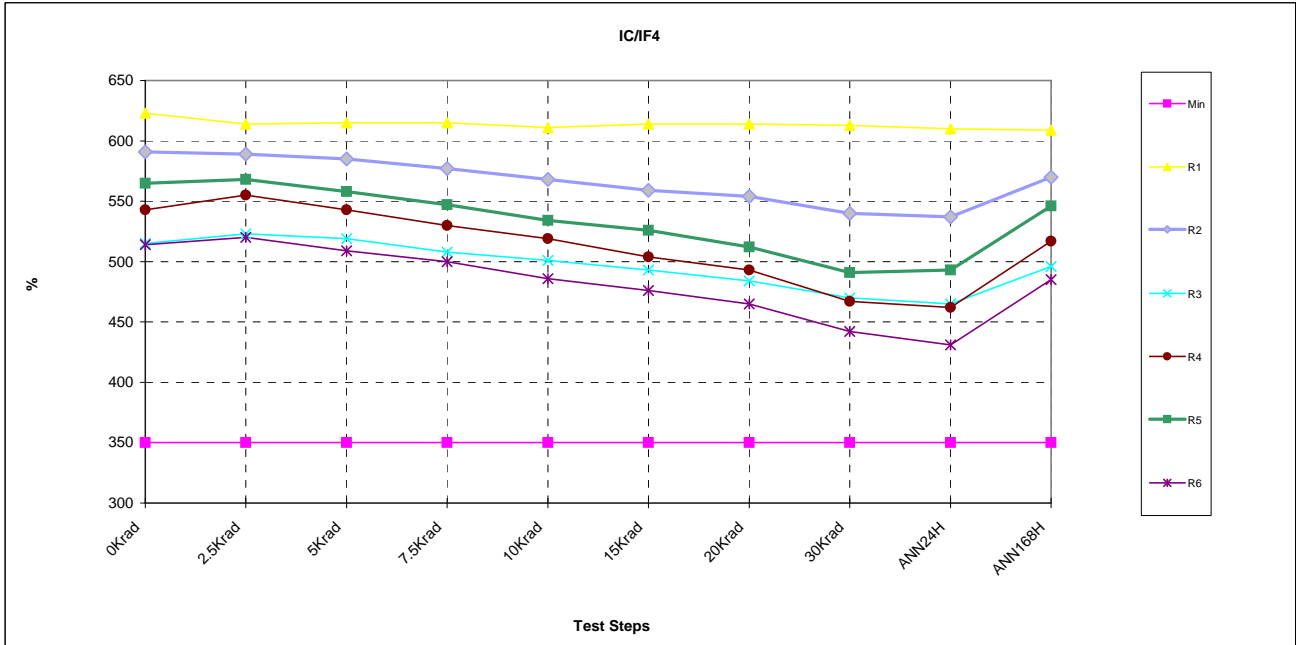
IC/IF1	0Krad	2.5Krad	5Krad	7.5Krad	10Krad	15Krad	20Krad	30Krad	ANN24H	ANN168H
Min	200	200	200	200	200	200	200	200	200	200
Max	--	--	--	--	--	--	--	--	--	--
Unit	%	%	%	%	%	%	%	%	%	%
Control Results										
R1	710.00	700.00	700.00	700.00	690.00	700.00	700.00	690.00	680.00	690.00
Bias ON Results										
R2	580.00	580.00	540.00	520.00	490.00	450.00	430.00	380.00	390.00	490.00
R3	440.00	430.00	400.00	380.00	370.00	340.00	320.00	270.00	270.00	350.00
Statistics bias ON										
min result	440.00	430.00	400.00	380.00	370.00	340.00	320.00	270.00	270.00	350.00
max result	580.00	580.00	540.00	520.00	490.00	450.00	430.00	380.00	390.00	490.00
average	510.00	505.00	470.00	450.00	430.00	395.00	375.00	325.00	330.00	420.00
sigma	98.99	106.07	98.99	98.99	84.85	77.78	77.78	77.78	84.85	98.99
Bias OFF Results										
R4	510.00	530.00	460.00	430.00	380.00	340.00	290.00	230.00	230.00	380.00
R5	530.00	520.00	480.00	430.00	390.00	350.00	320.00	240.00	240.00	430.00
Statistics bias OFF										
min result	510.00	520.00	460.00	430.00	380.00	340.00	290.00	230.00	230.00	380.00
max result	530.00	530.00	480.00	430.00	390.00	350.00	320.00	240.00	240.00	430.00
average	520.00	525.00	470.00	430.00	385.00	345.00	305.00	235.00	235.00	405.00
sigma	14.14	7.07	14.14	0.00	7.07	7.07	21.21	7.07	7.07	35.36
UNBIASED Results										
R6	450.00	440.00	390.00	370.00	330.00	290.00	260.00	180.00	180.00	340.00



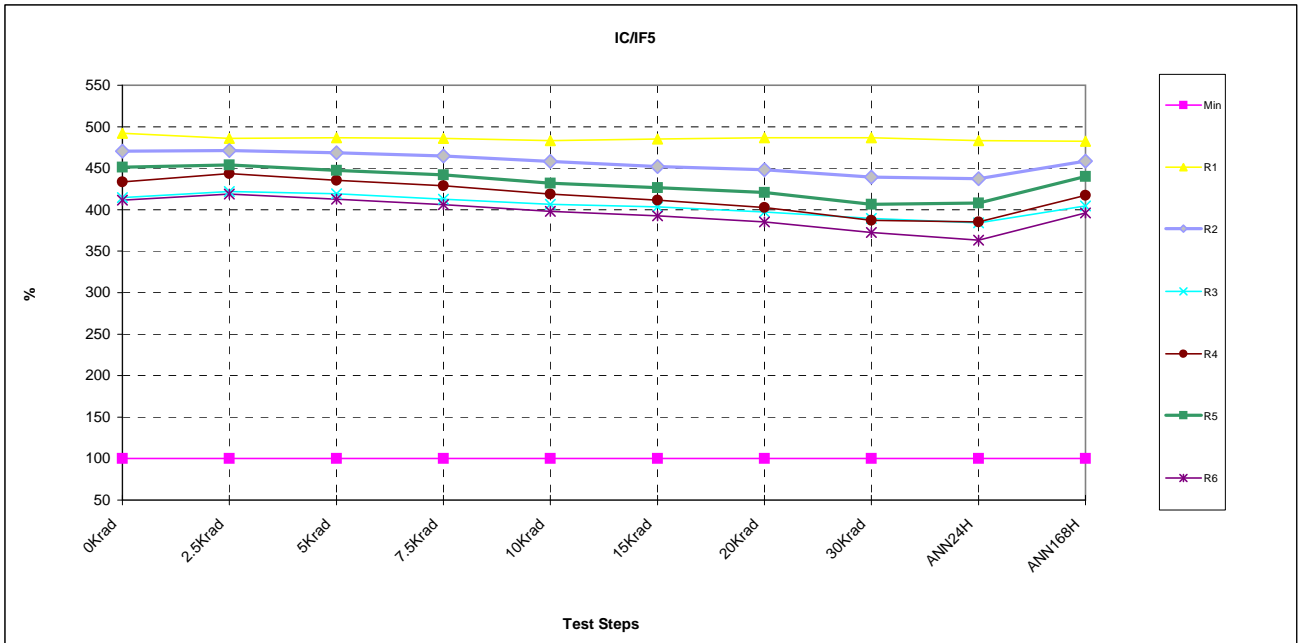
IC/IF2	0Krad	2.5Krad	5Krad	7.5Krad	10Krad	15Krad	20Krad	30Krad	ANN24H	ANN168H
Min	200	200	200	200	200	200	200	200	200	200
Max	--	--	--	--	--	--	--	--	--	--
Unit	%	%	%	%	%	%	%	%	%	%
Control Results										
R1	636.67	623.33	630.00	626.67	620.00	623.33	623.33	626.67	623.33	623.33
Bias ON Results										
R2	586.67	576.67	570.00	556.67	543.33	526.67	513.33	493.33	486.67	543.33
R3	493.33	496.67	486.67	470.00	453.33	440.00	426.67	396.67	393.33	453.33
Statistics bias ON										
min result	493.33	496.67	486.67	470.00	453.33	440.00	426.67	396.67	393.33	453.33
max result	586.67	576.67	570.00	556.67	543.33	526.67	513.33	493.33	486.67	543.33
average	540.00	536.67	528.33	513.33	498.33	483.33	470.00	445.00	440.00	498.33
sigma	66.00	56.57	58.93	61.28	63.64	61.28	61.28	68.35	66.00	63.64
Bias OFF Results										
R4	540.00	543.33	526.67	503.33	480.00	453.33	426.67	373.33	370.00	483.33
R5	560.00	553.33	533.33	510.00	493.33	470.00	446.67	396.67	406.67	513.33
Statistics bias OFF										
min result	540.00	543.33	526.67	503.33	480.00	453.33	426.67	373.33	370.00	483.33
max result	560.00	553.33	533.33	510.00	493.33	470.00	446.67	396.67	406.67	513.33
average	550.00	548.33	530.00	506.67	486.67	461.67	436.67	385.00	388.33	498.33
sigma	14.14	7.07	4.71	4.71	9.43	11.79	14.14	16.50	25.93	21.21
UNBIASED Results										
R6	500.00	503.33	476.67	460.00	440.00	420.00	393.33	333.33	323.33	440.00



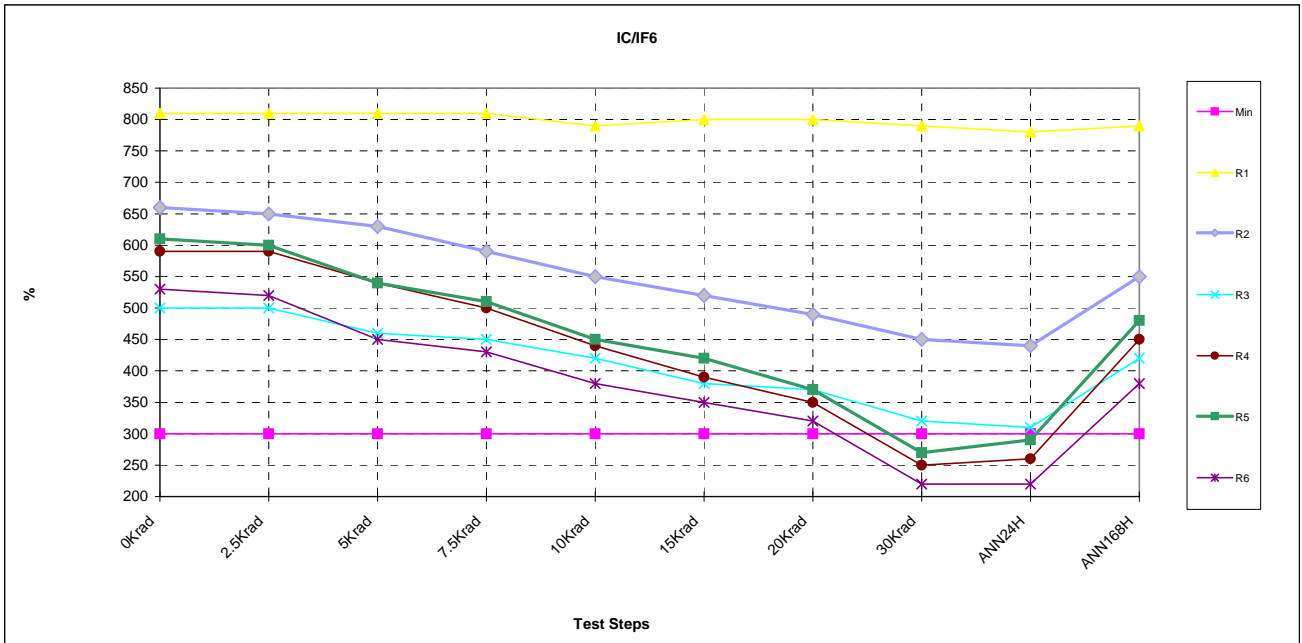
IC/IF3	0Krad	2.5Krad	5Krad	7.5Krad	10Krad	15Krad	20Krad	30Krad	ANN24H	ANN168H
Min	100	100	100	100	100	100	100	100	100	100
Max	--	--	--	--	--	--	--	--	--	--
Unit	%	%	%	%	%	%	%	%	%	%
Control Results										
R1	290.67	286.00	288.00	287.33	284.67	286.67	286.00	286.00	284.67	284.67
Bias ON Results										
R2	276.00	274.00	271.33	267.33	262.67	258.00	255.33	248.67	248.67	263.33
R3	238.67	241.33	238.00	234.00	229.33	226.67	225.33	217.33	214.67	228.00
Statistics bias ON										
min result	238.67	241.33	238.00	234.00	229.33	226.67	225.33	217.33	214.67	228.00
max result	276.00	274.00	271.33	267.33	262.67	258.00	255.33	248.67	248.67	263.33
average	257.33	257.67	254.67	250.67	246.00	242.33	240.33	233.00	231.67	245.67
sigma	26.40	23.10	23.57	23.57	23.57	22.16	21.21	22.16	24.04	24.98
Bias OFF Results										
R4	252.00	255.33	250.67	244.00	238.00	232.67	228.00	217.33	215.33	238.67
R5	260.67	261.33	255.33	251.33	244.67	240.67	236.67	227.33	228.00	252.00
Statistics bias OFF										
min result	252.00	255.33	250.67	244.00	238.00	232.67	228.00	217.33	215.33	238.67
max result	260.67	261.33	255.33	251.33	244.67	240.67	236.67	227.33	228.00	252.00
average	256.33	258.33	253.00	247.67	241.33	236.67	232.33	222.33	221.67	245.33
sigma	6.13	4.24	3.30	5.19	4.71	5.66	6.13	7.07	8.96	9.43
UNBIASED Results										
R6	237.33	239.33	234.00	230.00	224.00	220.67	216.67	207.33	202.00	224.00



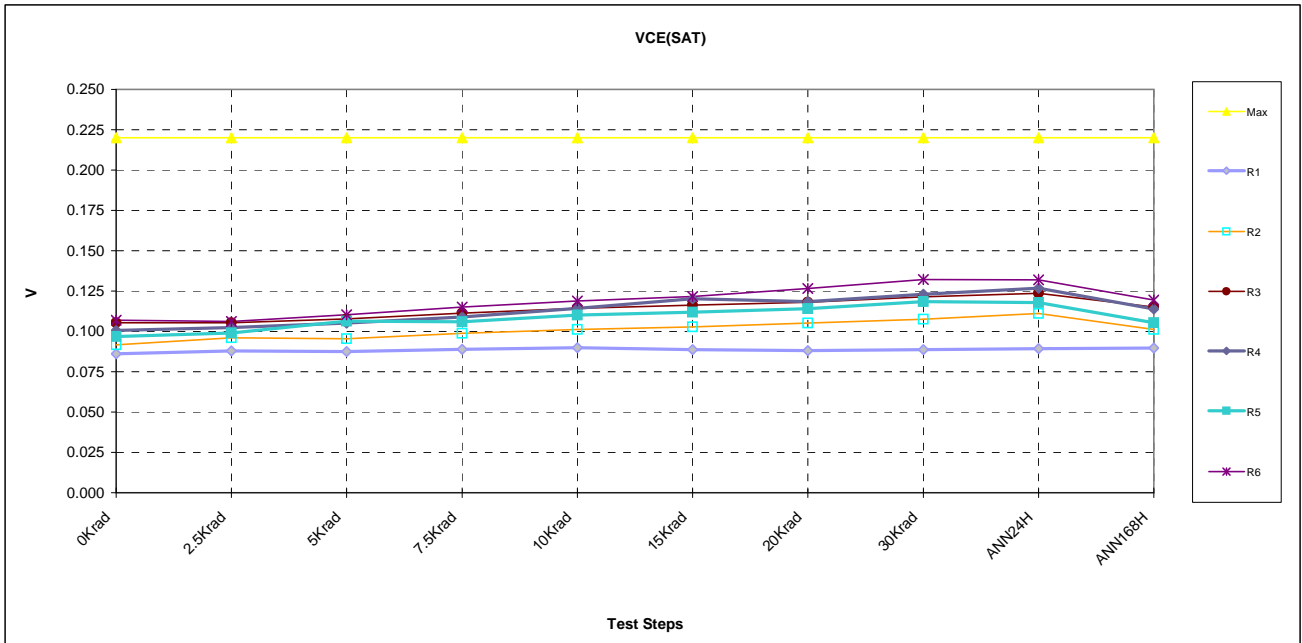
IC/IF4	0Krad	2.5Krad	5Krad	7.5Krad	10Krad	15Krad	20Krad	30Krad	ANN24H	ANN168H
Min	350	350	350	350	350	350	350	350	350	350
Max	--	--	--	--	--	--	--	--	--	--
Unit	%	%	%	%	%	%	%	%	%	%
Control Results										
R1	623.00	614.00	615.00	615.00	611.00	614.00	614.00	613.00	610.00	609.00
Bias ON Results										
R2	591.00	589.00	585.00	577.00	568.00	559.00	554.00	540.00	537.00	570.00
R3	515.00	523.00	519.00	508.00	501.00	493.00	484.00	470.00	465.00	496.00
Statistics bias ON										
min result	515.00	523.00	519.00	508.00	501.00	493.00	484.00	470.00	465.00	496.00
max result	591.00	589.00	585.00	577.00	568.00	559.00	554.00	540.00	537.00	570.00
average	553.00	556.00	552.00	542.50	534.50	526.00	519.00	505.00	501.00	533.00
sigma	53.74	46.67	46.67	48.79	47.38	46.67	49.50	49.50	50.91	52.33
Bias OFF Results										
R4	543.00	555.00	543.00	530.00	519.00	504.00	493.00	467.00	462.00	517.00
R5	565.00	568.00	558.00	547.00	534.00	526.00	512.00	491.00	493.00	546.00
Statistics bias OFF										
min result	543.00	555.00	543.00	530.00	519.00	504.00	493.00	467.00	462.00	517.00
max result	565.00	568.00	558.00	547.00	534.00	526.00	512.00	491.00	493.00	546.00
average	554.00	561.50	550.50	538.50	526.50	515.00	502.50	479.00	477.50	531.50
sigma	15.56	9.19	10.61	12.02	10.61	15.56	13.44	16.97	21.92	20.51
UNBIASED Results										
R6	514.00	520.00	509.00	500.00	486.00	476.00	465.00	442.00	431.00	485.00



IC/IF5	0Krad	2.5Krad	5Krad	7.5Krad	10Krad	15Krad	20Krad	30Krad	ANN24H	ANN168H
Min	100	100	100	100	100	100	100	100	100	100
Max	--	--	--	--	--	--	--	--	--	--
Unit	%	%	%	%	%	%	%	%	%	%
Control Results										
R1	492.00	486.00	486.67	486.00	483.33	485.33	486.67	486.67	483.33	482.67
Bias ON Results										
R2	470.67	471.33	468.67	464.67	458.00	452.00	448.00	439.33	437.33	458.67
R3	414.67	422.00	419.33	412.67	406.67	403.33	397.33	389.33	384.00	404.67
Statistics bias ON										
min result	414.67	422.00	419.33	412.67	406.67	403.33	397.33	389.33	384.00	404.67
max result	470.67	471.33	468.67	464.67	458.00	452.00	448.00	439.33	437.33	458.67
average	442.67	446.67	444.00	438.67	432.33	427.67	422.67	414.33	410.67	431.67
sigma	39.60	34.88	34.88	36.77	36.30	34.41	35.83	35.36	37.71	38.18
Bias OFF Results										
R4	433.33	443.33	435.33	428.67	418.67	411.33	402.67	387.33	385.33	417.33
R5	451.33	454.00	447.33	442.00	432.00	426.67	420.67	406.67	408.00	440.00
Statistics bias OFF										
min result	433.33	443.33	435.33	428.67	418.67	411.33	402.67	387.33	385.33	417.33
max result	451.33	454.00	447.33	442.00	432.00	426.67	420.67	406.67	408.00	440.00
average	442.33	448.67	441.33	435.33	425.33	419.00	411.67	397.00	396.67	428.67
sigma	12.73	7.54	8.49	9.43	9.43	10.84	12.73	13.67	16.03	16.03
UNBIASED Results										
R6	411.33	418.67	412.67	406.00	398.00	392.67	385.33	372.67	363.33	396.00



IC/IF6	0Krad	2.5Krad	5Krad	7.5Krad	10Krad	15Krad	20Krad	30Krad	ANN24H	ANN168H
Min	300	300	300	300	300	300	300	300	300	300
Max	--	--	--	--	--	--	--	--	--	--
Unit	%	%	%	%	%	%	%	%	%	%
Control Results										
R1	810.00	810.00	810.00	810.00	790.00	800.00	800.00	790.00	780.00	790.00
Bias ON Results										
R2	660.00	650.00	630.00	590.00	550.00	520.00	490.00	450.00	440.00	550.00
R3	500.00	500.00	460.00	450.00	420.00	380.00	370.00	320.00	310.00	420.00
Statistics bias ON										
min result	500.00	500.00	460.00	450.00	420.00	380.00	370.00	320.00	310.00	420.00
max result	660.00	650.00	630.00	590.00	550.00	520.00	490.00	450.00	440.00	550.00
average	580.00	575.00	545.00	520.00	485.00	450.00	430.00	385.00	375.00	485.00
sigma	113.14	106.07	120.21	98.99	91.92	98.99	84.85	91.92	91.92	91.92
Bias OFF Results										
R4	590.00	590.00	540.00	500.00	440.00	390.00	350.00	250.00	260.00	450.00
R5	610.00	600.00	540.00	510.00	450.00	420.00	370.00	270.00	290.00	480.00
Statistics bias OFF										
min result	590.00	590.00	540.00	500.00	440.00	390.00	350.00	250.00	260.00	450.00
max result	610.00	600.00	540.00	510.00	450.00	420.00	370.00	270.00	290.00	480.00
average	600.00	595.00	540.00	505.00	445.00	405.00	360.00	260.00	275.00	465.00
sigma	14.14	7.07	0.00	7.07	7.07	21.21	14.14	14.14	21.21	21.21
UNBIASED Results										
R6	530.000	520.000	450.000	430.000	380.000	350.000	320.000	220.000	220.000	380.000



VCE(SAT)	0Krad	2.5Krad	5Krad	7.5Krad	10Krad	15Krad	20Krad	30Krad	ANN24H	ANN168H
Min	--	--	--	--	--	--	--	--	--	--
Max	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Unit	V	V	V	V	V	V	V	V	V	V
Control Results										
R1	0.086	0.088	0.088	0.089	0.090	0.089	0.088	0.089	0.089	0.090
Bias ON Results										
R2	0.092	0.096	0.096	0.099	0.101	0.103	0.105	0.108	0.111	0.101
R3	0.105	0.105	0.108	0.111	0.114	0.116	0.118	0.122	0.124	0.115
Statistics bias ON										
min result	0.092	0.096	0.096	0.099	0.101	0.103	0.105	0.108	0.111	0.101
max result	0.105	0.105	0.108	0.111	0.114	0.116	0.118	0.122	0.124	0.115
average	0.099	0.101	0.102	0.105	0.108	0.110	0.112	0.115	0.117	0.108
sigma	0.010	0.007	0.009	0.009	0.009	0.009	0.009	0.010	0.009	0.010
Bias OFF Results										
R4	0.101	0.102	0.105	0.109	0.114	0.120	0.118	0.123	0.127	0.114
R5	0.097	0.099	0.106	0.106	0.110	0.112	0.114	0.119	0.118	0.105
Statistics bias OFF										
min result	0.097	0.099	0.105	0.106	0.110	0.112	0.114	0.119	0.118	0.105
max result	0.101	0.102	0.106	0.109	0.114	0.120	0.118	0.123	0.127	0.114
average	0.099	0.101	0.106	0.107	0.112	0.116	0.116	0.121	0.122	0.110
sigma	0.003	0.002	0.001	0.002	0.003	0.006	0.003	0.003	0.006	0.006
UNBIASED Results										
R6	0.107	0.106	0.110	0.115	0.119	0.122	0.127	0.132	0.132	0.120