U.S. Summary Reports on the Status & Progress of Neutronics' Task ID#T16
(Preparation of Neutronic Experiments and Measuring Techniques)

Presented by

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Task Title: Development & Demonstration of Technique for Nuclear Heating Measurements

Task Description

To develop and demonstrate adequate performance of techniques for measuring nuclear heat deposition in materials of ITER neutronics experiments

Task Achievement

U.S. had opted for further development and demonstration of microcalorimetric technique for total nuclear heating measurements. Highlights of the task achievement are as follows:

(1)The original schedule of this task foresaw its completion by December 31, 1993. However, due to late approval of this task by JCT (in December 1993), no experiments could be scheduled. However, the experiments have now been scheduled for April 1994. Also, this task now forms a part of Task ID#16 , entitled *"Preparation of Neutronic Experiments and Measuring Techniques"*.

(2)The preparatory work for the experiments is already underway. This includes scoping heat transfer calculations for probe design, the testing of experimental equipment and data acquisition system etc.

(3)The earlier experimental work done on development of the microcalorimetric technique for total nuclear heating measurements from 1988 through 1993, within the framework of USDOE/JAERI collaborative program, was reviewed and analyzed for directions for the proposed work. Improvements in probe design, instrumentation, and data processing are to be expected in the forthcoming experiments.

Task Title: Direct Nuclear Heating Measurements on Plasma Facing Structural Components

Task Description

The technique for direct nuclear heat deposition measurement is based on the calorimetric method being developed under a previous task ('*Development & Demonstration of Technique for Nuclear Heating Measurements* '). The proposed task shall be carried out in following steps:

(i)Fabricate individual calorimeters of various probe materials of high ITER JCT priority,

(ii)Conduct measurements of nuclear heating in each calorimeter under intense D-T neutron field at FNS (JAERI),

(iii)Validate nuclear data bases through experimental analysis of measured nuclear heating

Task Achievement

(1)This forms a part of Task ID#T16, entitled *"Preparation of Neutronic Experiments and Measuring Techniques"*, which is still awaiting final official approval from JCT.

(2) However, the experiments have already been scheduled for April 1994.

(3)The preparatory work for the experiments is already underway. This includes scoping heat transfer calculations for probe design, the pre-analysis for design of test assemblies, the testing of experimental equipment and data acquisition system etc.,

(4)We have been reviewing our earlier work on total nuclear heating measurements, carried out under USDOE/JAERI collaborative framework for directions for the proposed work. Also, a methodology has been developed to associate a quality factor to a cross-section and response function library based on comparison between calculated and measured nuclear heating rates. This quality factor can be thought of as an embodiment of all factors contributing to discrepancies between the measurements, and the calculations, e.g., neutron and photon spectra, neutron kerma factors, photon production cross-sections, and measurements. Ideal quality factor will be unity.

Task Title: Development and Demonstration of Technique for Measurement of Neutron-Induced Radioactivity in Pulsed Mode

Task Description

(1)Develop and demonstrate the technique for radioactivity measurements in pulsed-operation mode, prior to performing prototypical experiments,

(2)Validate the pulsed-operation related algorithms scheduled to be included in new radioactivity codes FISPACT and RACC which are being developed under a separate task.

Task Achievement

(1)This forms a part of Task ID#T16, entitled *"Preparation of Neutronic Experiments and Measuring Techniques"*, which is still awaiting final official approval from JCT.

(2)The preparatory work for the experiments is already underway. This includes pre-analysis to optimize irradiation, cooling, and counting times, material selection, radioactive products of interest to ITER. Also, we are going to investigate feasibility and desirability of installing pneumatic transport system for extracting irradiated rabbits,

(3)The experiments are tentatively scheduled to be carried out during August through September 1994 period,

(4)We have been reviewing our earlier work on radioactivity measurements, carried out under USDOE/JAERI collaborative framework for directions for the proposed work. Also, a methodology has been developed to associate a quality factor to a radioactivity library based on comparison between calculated and measured isotopic radioactivities. This quality factor can be thought of as an embodiment of all factors contributing to discrepancies between the measurements, and the calculations, e.g., neutron spectrum, activation cross-sections, decay γ yields, and measurements. Ideal quality factor will be unity.

Task Titles: (1)Analysis of Existing Shielding Experiments, (2)Benchmarking of FENDL Library through Analysis of Existing Experiments

Task Description

- Select appropriate shielding experiments that merit analysis based on reference to ITER materials, availability of experimental data, and estimated experimental accuracy.
- Analyze selected experiments and document calculation results and experimental data
- Obtain from JCT the documented results of the other Parties and perform detailed comparative analyses of all results

- Develop methodology for obtaining engineering safety factors from compiled experimental and calculational results

- Generate engineering safety factors for ITER shielding design and document results

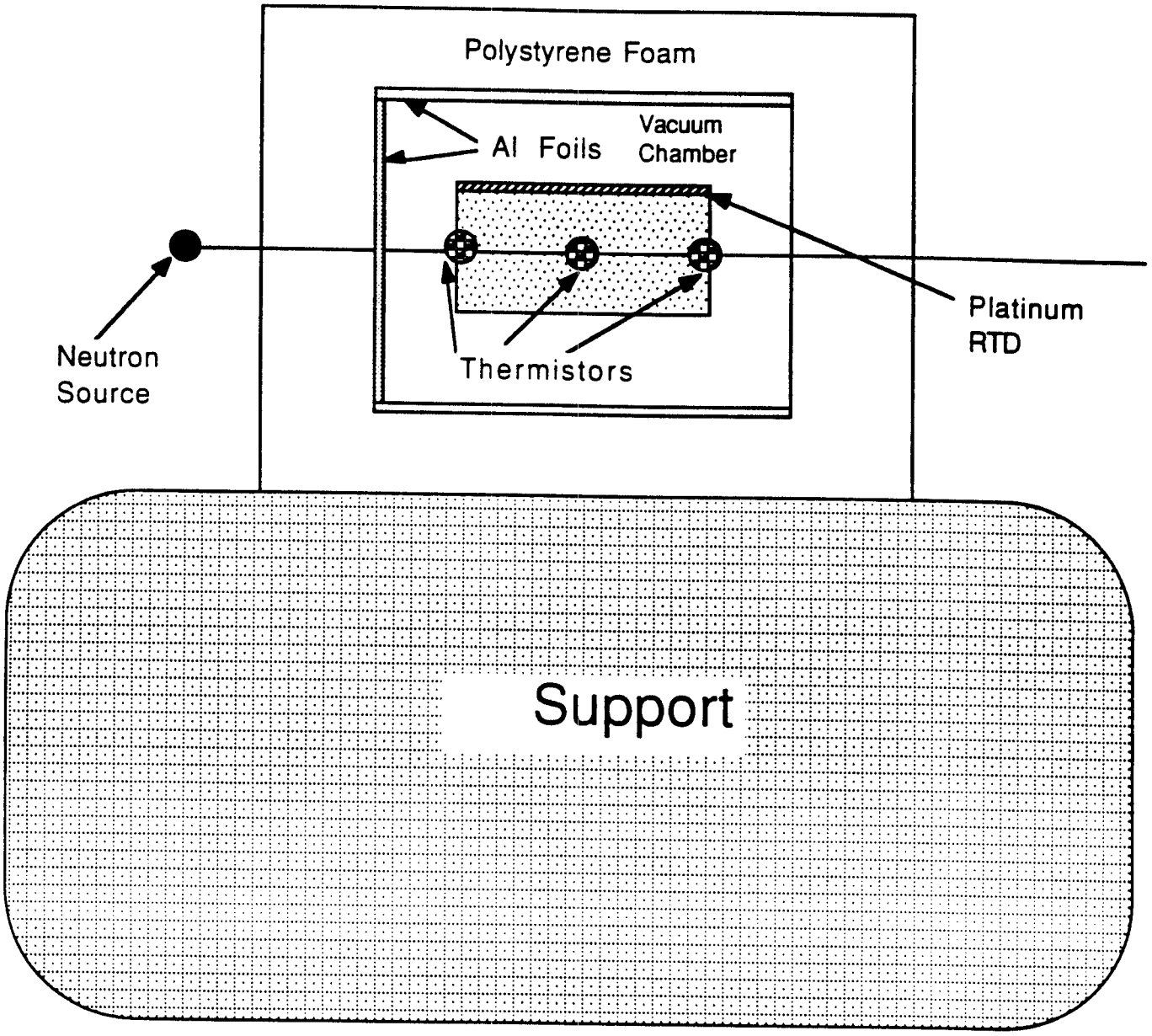
Task Achievement

(1)The original schedule of the task #1 foresaw its completion by December 31, 1993. However, due to late approval of this task by JCT (in December 1993), not much work could be accomplished. As for task#2, it forms a part of Task ID#T16, entitled *"Preparation of Neutronic Experiments and Measuring Techniques"* which is still awaiting final official approval from JCT.

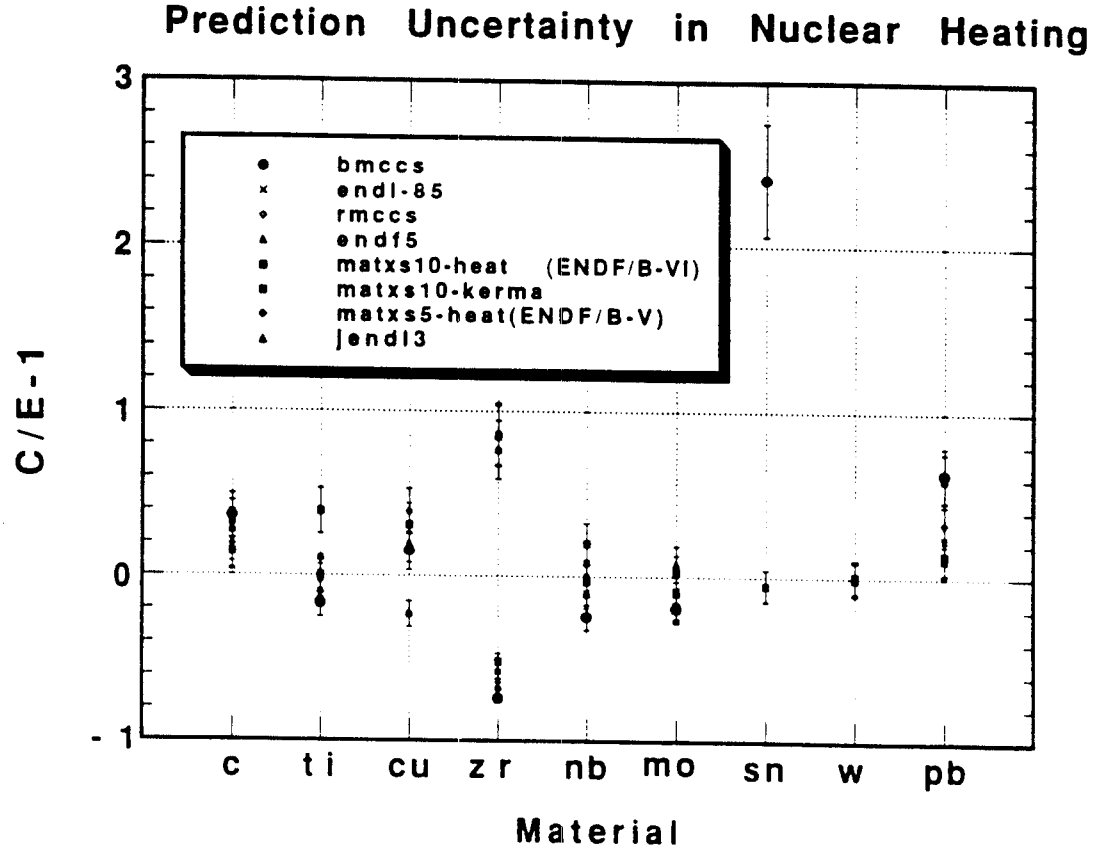
(2)However, preparatory work on selection of relevant existing experiments and development of a methodology for generation of engineering safety factors for ITER was carried out over last year.

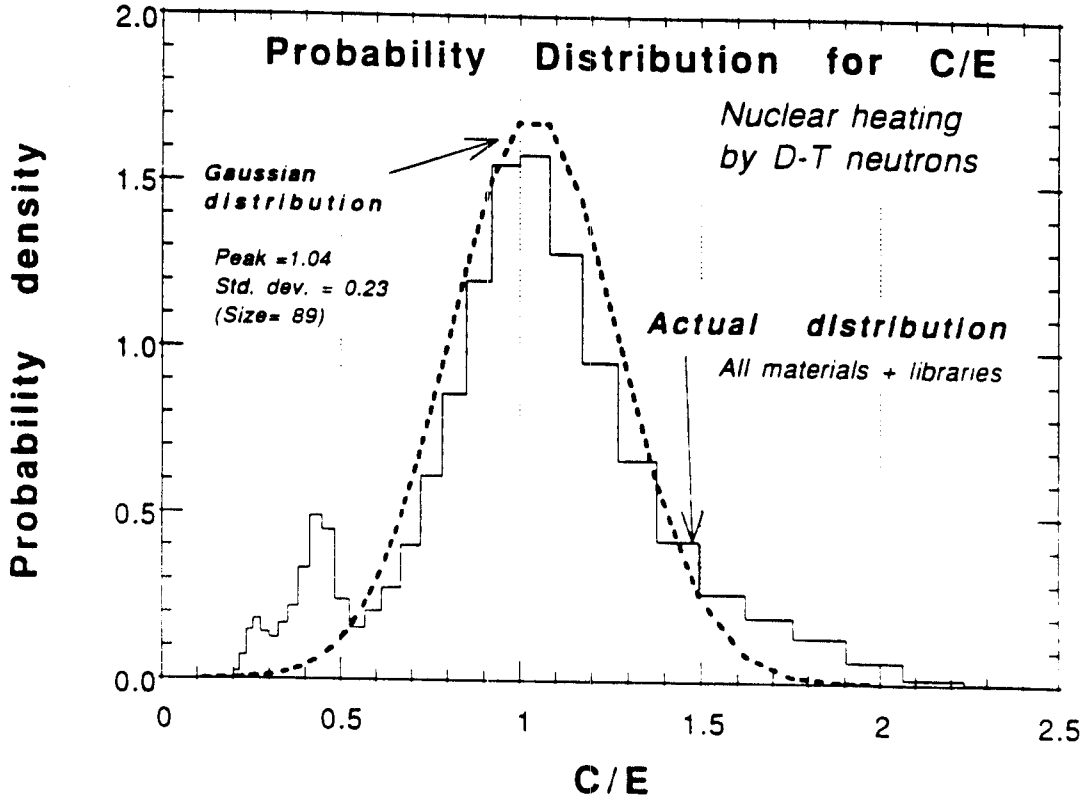
(3)Recently, an informal agreement was reached with FNS, JAERI group on supply of their measured data to U.S. for two shielding experiments conducted recently: (i)1.12 m thick pure stainless steel-316 cylindrical assembly, and (ii)1.12m thick water cooled stainless steel assembly (80% volume stainless steel plus 20% volume water). Once, all experimental details and measured data have been furnished to U.S., the analysis process will be launched.

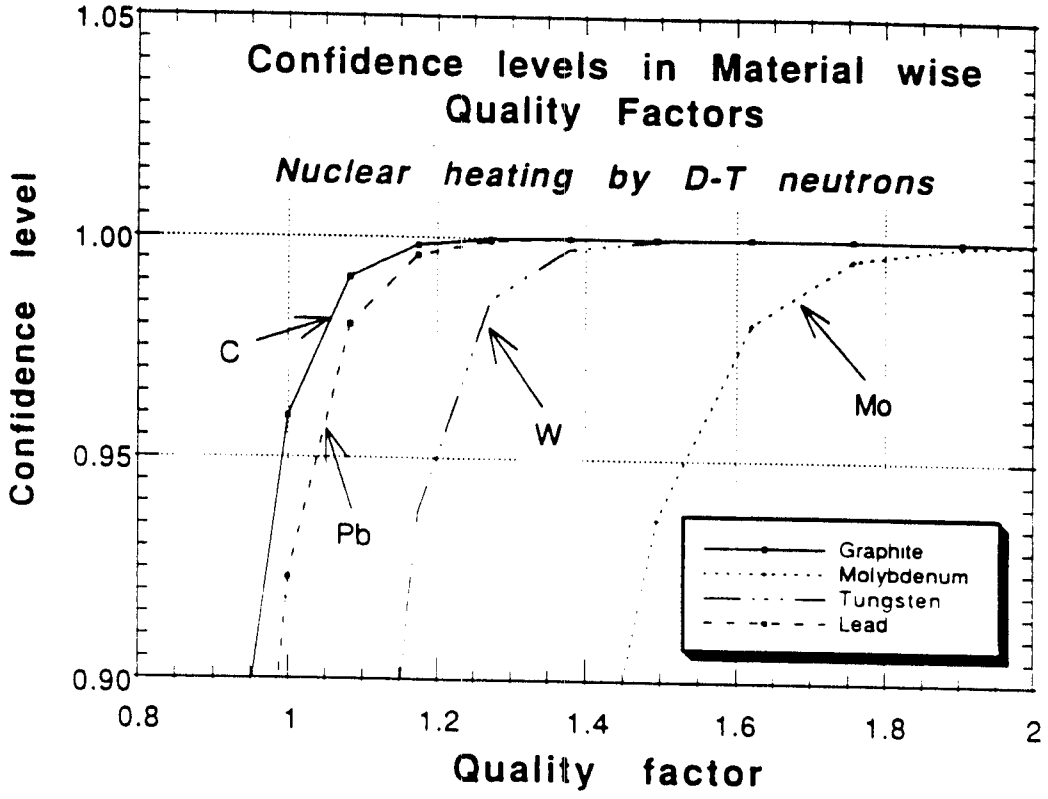
(4)A new methodology was developed to arrive at estimates of design safety factors based on the experimental and analytical results from design -oriented integral experiments. This methodology will be used to obtain design safety factors.

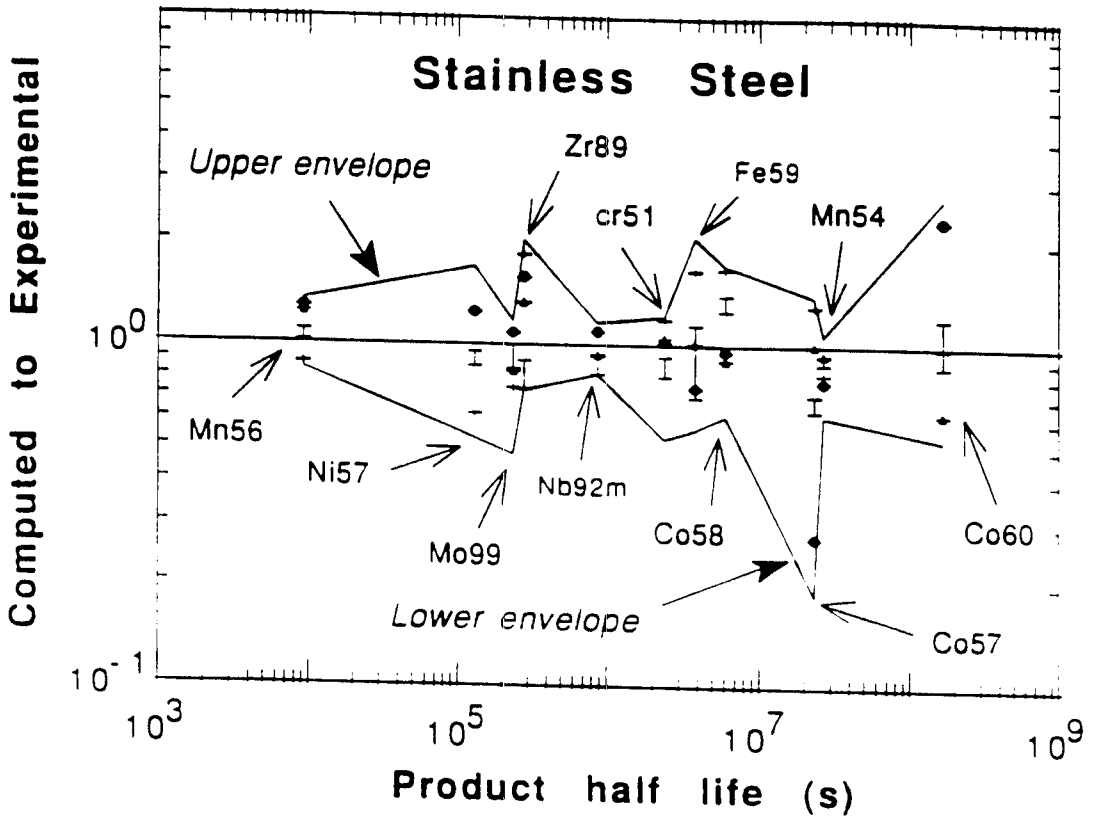


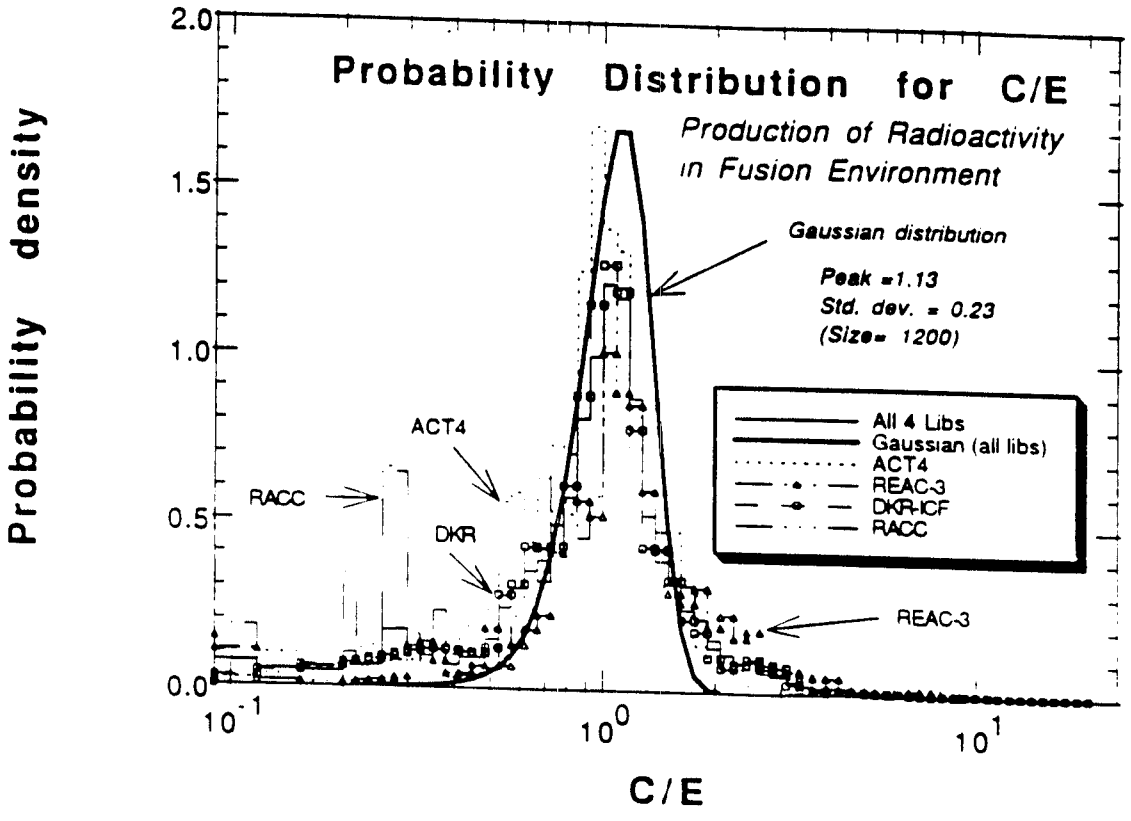
Simplified Picture of Single Probe Calorimeter


Prediction Uncertainty in Nuclear Heating
bmccs
endl-85
rmccs
endf5
matxs10-heat (ENDF/B-VI)
matxs10-kerma
matxs5-heat(ENDF/B-V)
jendl3
C/E-1
3
2
1
0
- 1
c
ti
cu
zr
nb
mo
sn
w
pb
Material


Probability Distribution for C/E
Nuclear heating
by D-T neutrons
Gaussian
distribution
Peak =1.04
Std. dev. = 0.23
(Size= 89)
Actual distribution
All materials + libraries
Probability density
C/E
2.0
1.5
1.0
0.5
0.0
0
0.5
1
1.5
2
2.5


Confidence levels in Material wise Quality Factors
Nuclear heating by D-T neutrons
Confidence level
Quality factor
1.05
1.00
0.95
0.90
0.8
1
1.2
1.4
1.6
1.8
2
C
Pb
W
Mo
Graphite
Molybdenum
Tungsten
Lead


Stainless Steel
Upper envelope
Zr89
Fe59
cr51
Mn54
Mn56
Ni57
Nb92m
Mo99
Co58
Co60
Lower envelope
Co57
Computed to Experimental
10^0
10^{-1}
10^3
10^5
10^7
10^9
Product half life (s)


Probability Distribution for C/E
Production of Radioactivity
in Fusion Environment
Gaussian distribution
Peak =1.13
Std. dev. = 0.23
(Size= 1200)
All 4 Libs
Gaussian (all libs)
ACT4
REAC-3
DKR-ICF
RACC
ACT4
RACC
DKR
REAC-3
2.0
1.5
1.0
0.5
0.0
10^-1
10^0
10^1
Probability density
C/E

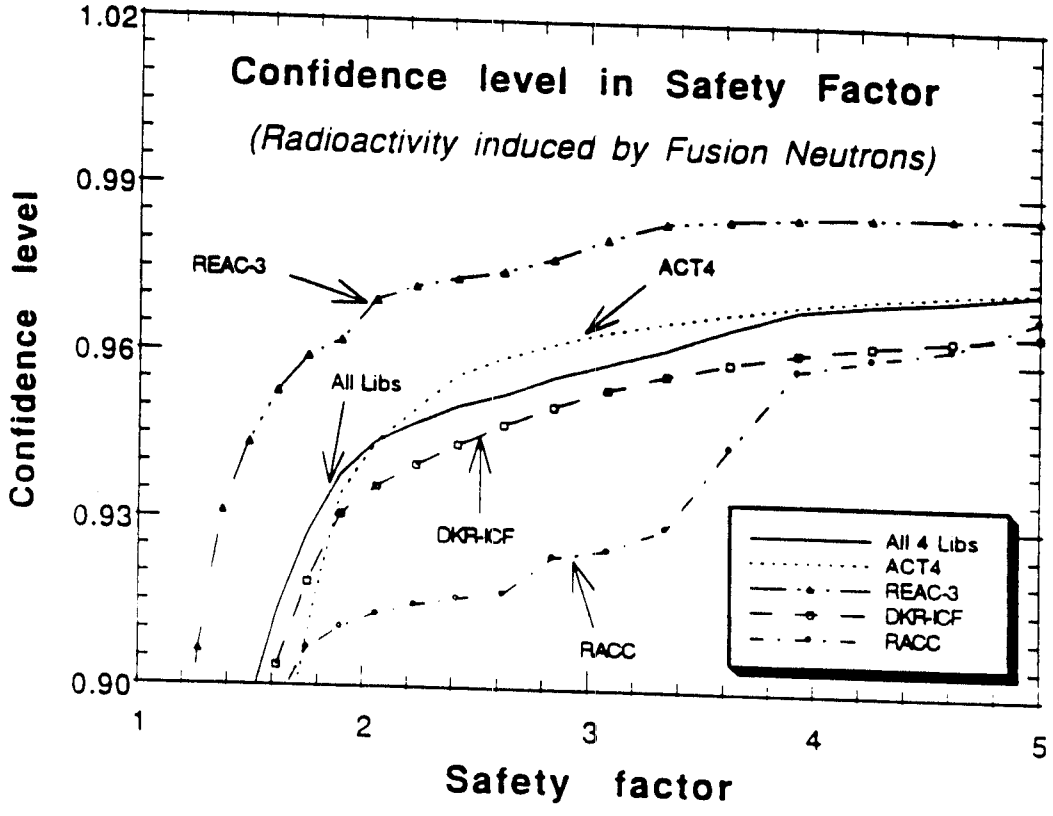
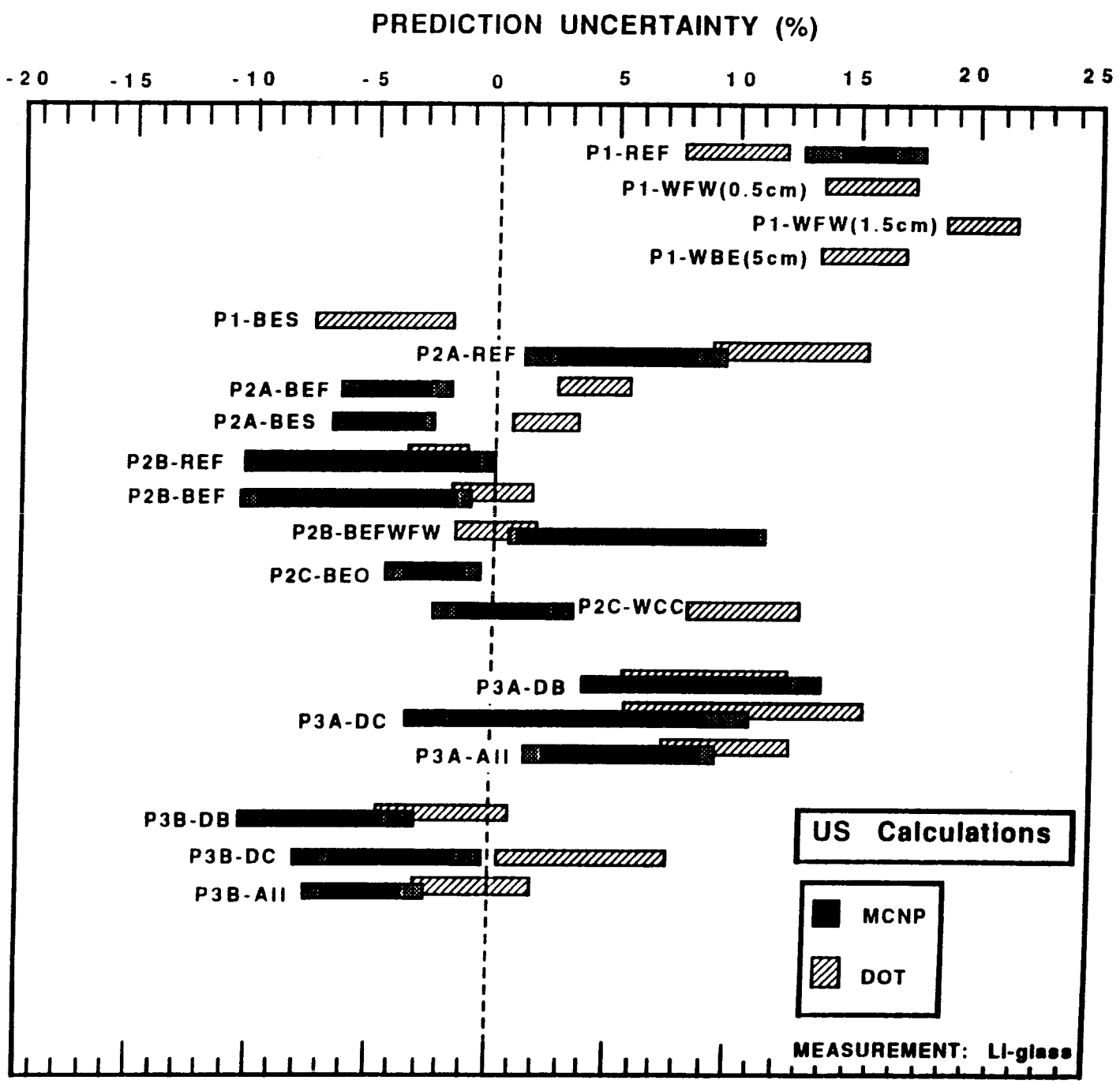
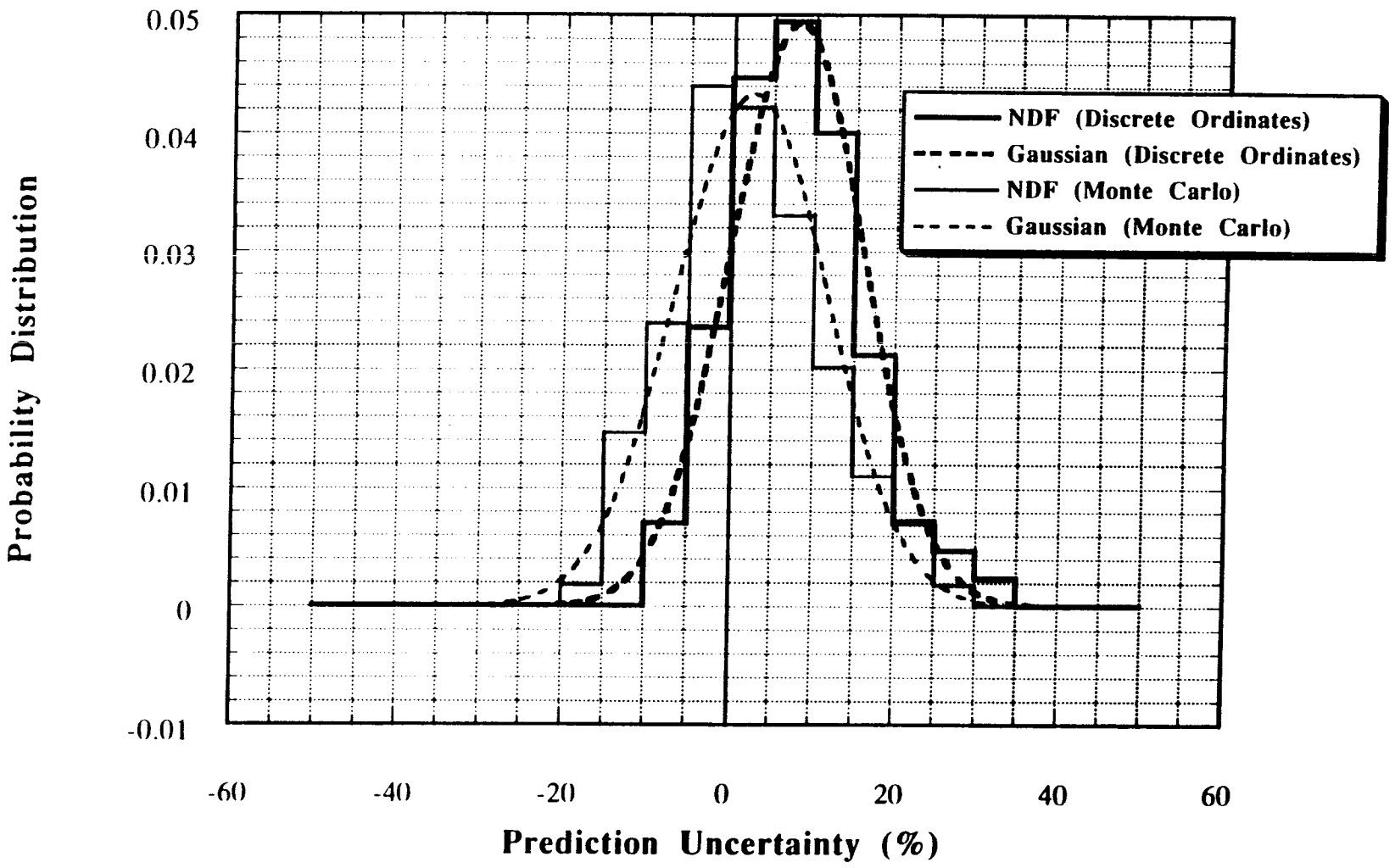

Confidence level in Safety Factor
(Radioactivity induced by Fusion Neutrons)
Confidence level
Safety factor
1.02
0.99
0.96
0.93
0.90
1
2
3
4
5
REAC-3
ACT4
All Libs
DKR-ICF
RACC
All 4 Libs
ACT4
REAC-3
DKR-ICF
RACC

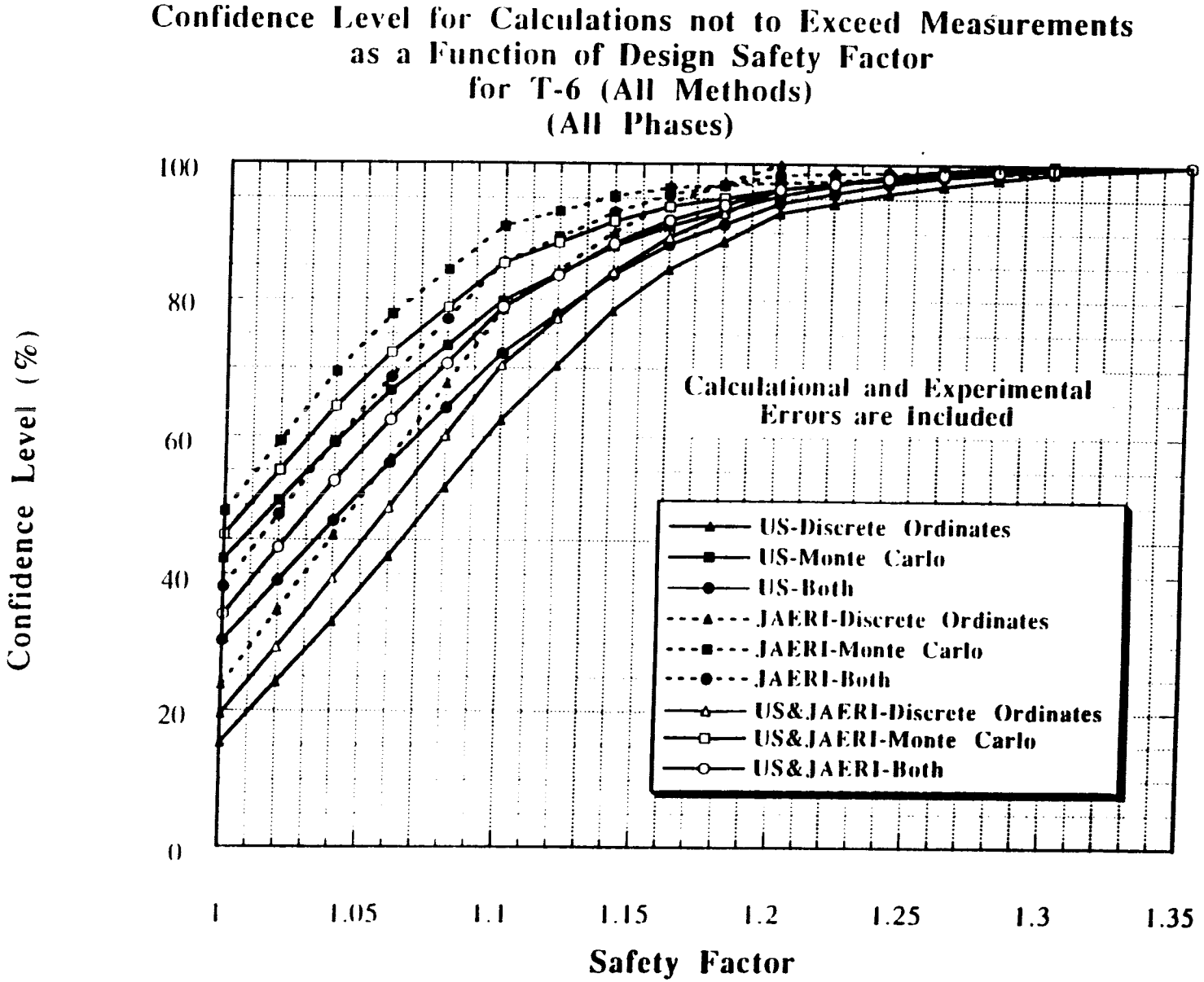
Table (1): Abbreviation for the Experiments Conducted in Phase I through Phase III

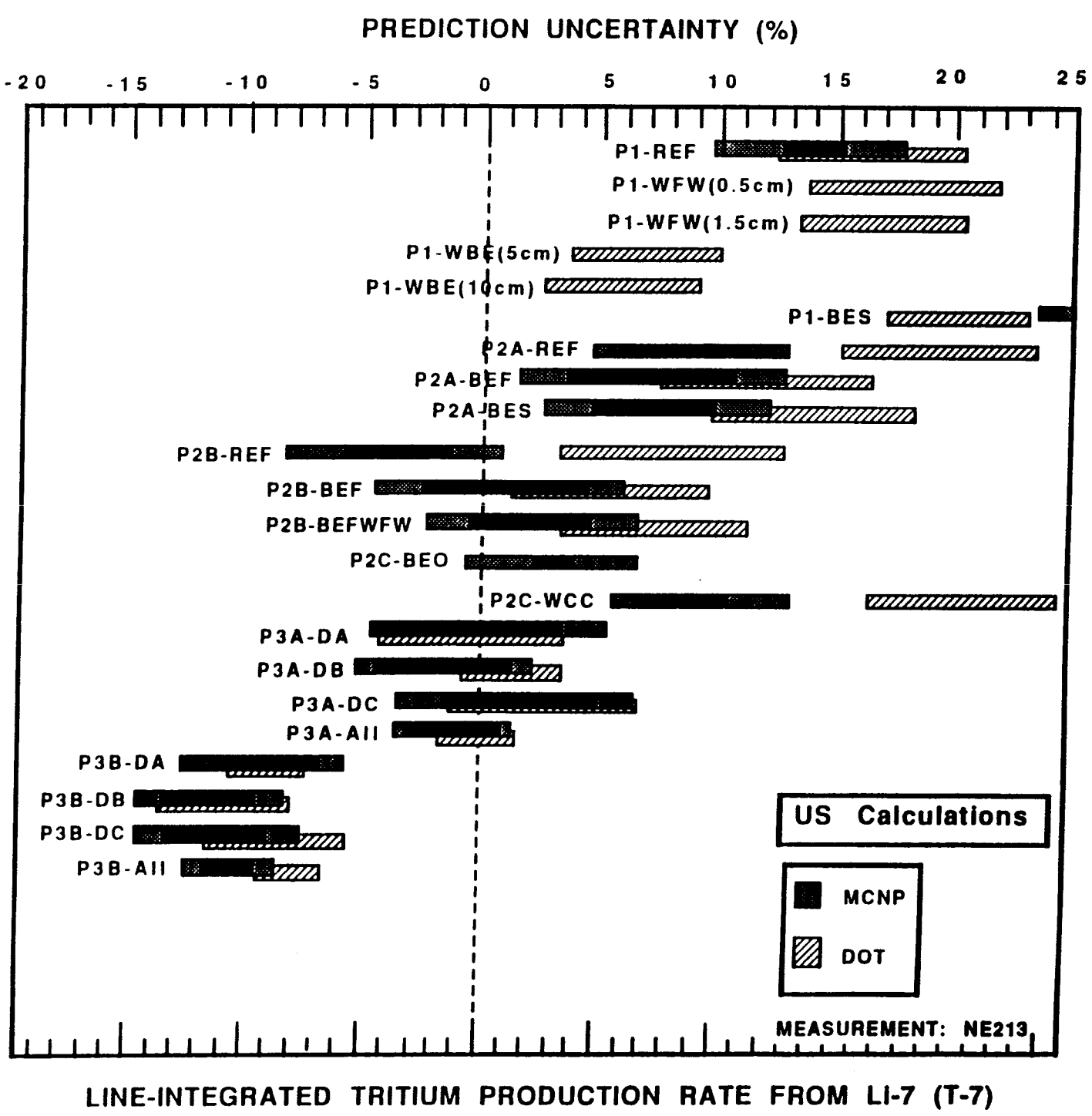
Phase	Experiment /Case	Abbreviation
I	Reference Experiment	P1-REF
I	First Wall Experiment-FW=0.5 cm	P1-WFW(0.5)
I	First Wall Experiment-FW=1.5 cm	P1-WFW(1.5)
I	Beryllium Experiment-Be=5 cm	P1-WBE(5 cm)
I	Beryllium Experiment-Be=10 cm	P1-WBE(10 cm)
IIA	Reference Experiment	P2A-REF
IIA	Beryllium Front Experiment	P2A-BEF
IIA	Beryllium-Sandwiched Experiment	P2ABES
IIB	Reference Experiment	P2B-REF
IIB	Beryllium Front Experiment	P2B-BEF
IIB	Beryllium Front With First Wall Expt.	P2B-BEFWFW
IIC	Water Coolant Channel Experiment	P2C-WCC
IIC	Beryllium Edge-On Experiment	P2C-BEO
IIIA	Reference Experiment-Drawer A	P3A-DA
IIIA	Reference Experiment-Drawer B	P3A-DB
IIIA	Reference Experiment-Drawer C	P3A-DC
IIIA	Reference Experiment-Drawer A&B&C	P3A-All
IIIB	Armore Experiment-Drawer A	P3B-DA
IIIB	Armore Experiment-Drawer B	P3B-DB
IIIB	Armore Experiment-Drawer C	P3B-DC
IIIB	Armore Experiment-Drawer A&B&C	P3B-All
IIIC	Large Opening Experiment-Drawer A	P3C-DA
IIIC	Large Opening Experiment-Drawer B	P3C-DB
IIIC	Large Opening Experiment-Drawer C	P3C-DC
IIIC	Large Opening Experiment-Drawer D	P3C-DD
IIIC	Large Opening Expt.-Drawer A&B&C	P3C-All


PREDICTION UNCERTAINTY (%)
-20
-15
-10
-5
0
5
10
15
20
25
P1-REF
P1-WFW(0.5cm)
P1-WFW(1.5cm)
P1-WBE(5cm)
P1-BES
P2A-REF
P2A-BEF
P2A-BES
P2B-REF
P2B-BEF
P2B-BEFWFW
P2C-BEO
P2C-WCC
P3A-DB
P3A-DC
P3A-All
P3B-DB
P3B-DC
P3B-All
US Calculations
MCNP
DOT
MEASUREMENT: LI-glass
LINE-INTEGRATED TRITIUM PRODUCTION RATE FROM LI-6 (T-6)

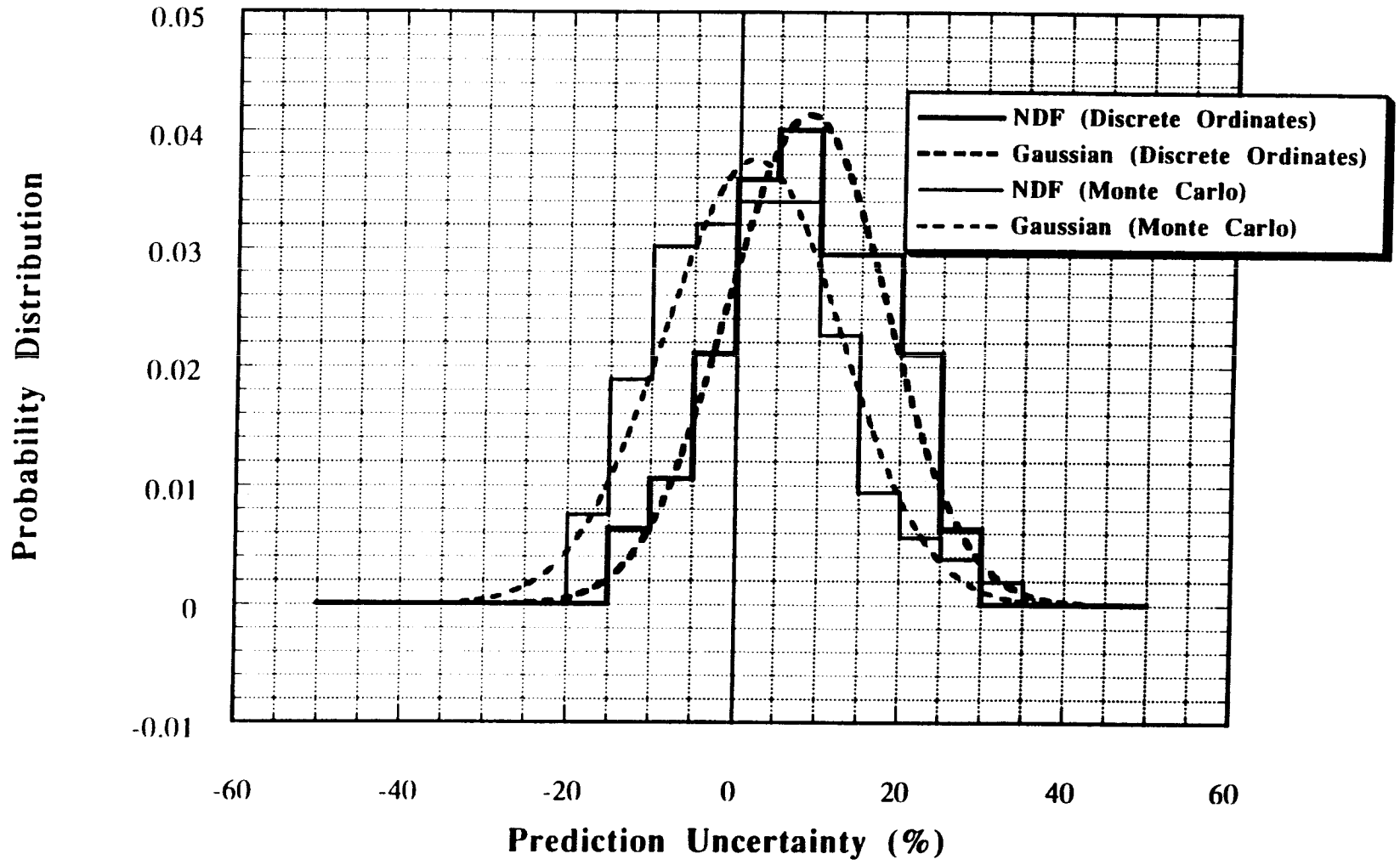
Gaussian Distribution that Approximates the Normalized Distribution Function, NDF, of the Prediction Uncertainties in T-6 (US Calculations, All Measuring Methods, All Phases)

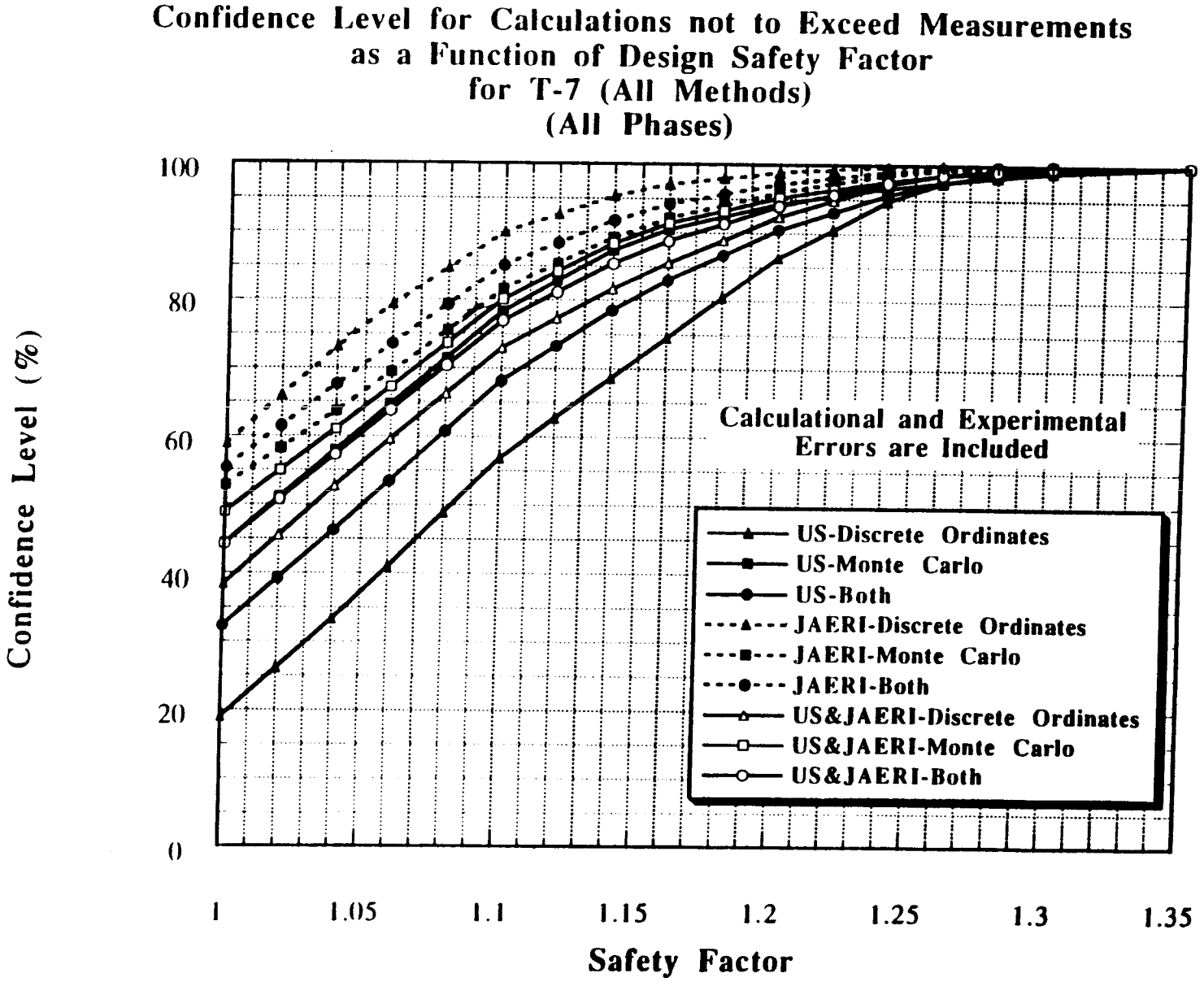



Confidence Level for Calculations not to Exceed Measurements
as a Function of Design Safety Factor
for T-6 (All Methods)
(All Phases)
Confidence Level (%)
100
80
60
40
20
0
1
1.05
1.1
1.15
1.2
1.25
1.3
1.35
Safety Factor
Calculational and Experimental
Errors are Included
US-Discrete Ordinates
US-Monte Carlo
US-Both
JAERI-Discrete Ordinates
JAERI-Monte Carlo
JAERI-Both
US&JAERI-Discrete Ordinates
US&JAERI-Monte Carlo
US&JAERI-Both


PREDICTION UNCERTAINTY (%)
-20
-15
-10
-5
0
5
10
15
20
25
P1-REF
P1-WFW(0.5cm)
P1-WFW(1.5cm)
P1-WBE(5cm)
P1-WBE(10cm)
P1-BES
P2A-REF
P2A-BEF
P2A-BES
P2B-REF
P2B-BEF
P2B-BEFWFW
P2C-BEO
P2C-WCC
P3A-DA
P3A-DB
P3A-DC
P3A-All
P3B-DA
P3B-DB
P3B-DC
P3B-All
US Calculations
MCNP
DOT
MEASUREMENT: NE213
LINE-INTEGRATED TRITIUM PRODUCTION RATE FROM LI-7 (T-7)

Gaussian Distribution that Approximates the Normalized Distribution Function, NDF, of the Prediction Uncertainties in T-7 (US Calculations, All Measuring Methods, All Phases)




Confidence Level for Calculations not to Exceed Measurements
as a Function of Design Safety Factor
for T-7 (All Methods)
(All Phases)
Confidence Level (%)
100
80
60
40
20
0
1
1.05
1.1
1.15
1.2
1.25
1.3
1.35
Safety Factor
Calculational and Experimental
Errors are Included
US-Discrete Ordinates
US-Monte Carlo
US-Both
JAERI-Discrete Ordinates
JAERI-Monte Carlo
JAERI-Both
US&JAERI-Discrete Ordinates
US&JAERI-Monte Carlo
US&JAERI-Both