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Lawrence Livermore Laboratory

THE ROLE OF COMPUTERS IN QUALITY ASSURANCE
IN THE LLL CRITICALITY SAFETY PROGRAM

Presented by

B. L. Koponen

at the

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MASTER

THE ROLE OF COMPUTERS IN QUALITY ASSURANCE IN THE LLL CRITICALITY SAFETY PROGRAM

BY

B. L. Koponen

SUMMARY

This paper summarizes some of the aspects of computational criticality safety quality assurance that have been emphasized in recent years at LLL. In particular I will discuss (a) computer code changes that have been made that help the criticality analyst reduce the number of errors that he makes and to locate those that he does make and (b) how a computerized "benchmark" data base aids him in the validation of his computational methods.

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Although there are a number of aspects of quality assurance in criticality safety computations, this paper will emphasize two areas that have been of considerable benefit to the LLL Criticality Safety [illegible]

Slide 1

IN RECENT YEARS THE LLL CS PROGRAM HAS BEEN A[illegible] ATTENTION GIVEN TO TWO VITAL [illegible]AS

1. Assurance of input correctness – code improvements
2. Code validation – benchmark library

Our two most [illegible] used criticality [illegible] are "SAN" and "MORSE-C". SAN is an acronym for [illegible] ANISN [illegible] is a version of the MORSE multigroup neutron and gamma-ray Monte Carlo transport code, modified to do only criticality calculations. We have made changes to these codes that help the criticality analyst minimize the number of errors he makes in preparing code input and to easily find the errors that he does make. Some of these changes are mentioned in Slide 2.

Our philosophy has been to make code input as simple as possible since the user is more likely to make errors where code input is complex. The use of mnemonics to identify problem input parameters rather than special characters is helpful, e.g., it is easier to remember the words "Slab", "Cylinder" or "Sphere" than numerical codes such as 1, 2, 3 to represent the three geometries. Other special characters such as $, *, T, to start or terminate arrays were eliminated or replaced by words like "LAST" or "END".

Slide 2

OUR CS CODES HAVE BEEN MODIFIED TO HELP REDUCE AND LOCATE INPUT ERRORS

- Input is simplified
- Mnemonics are used
- Input checking aids were added – mass, density, volume calculations and pictures
- Common problem input parameters standardized

The change in input formats is best displayed by example. Slides 3 and 4 show the input for a simple uranium sphere required for the SAN and ANISN codes. In our opinion, the set-up and checking of the SAN problem is much easier than that for ANISN and consequently less prone to user input errors. Later in this paper I will discuss some of the ways in which SAN was simplified and the limitations imposed upon SAN (e.g., k-calculations only).

Slide 3

SIMPLICITY OF CODE INPUT AND MNEMONICS HELPS IN PROBLEM PREPARATION

Sample "SAN" problem

```
BARE SPHERE
SPHERE REFLECTION VACUUM
1  U235  0  3  0.04480
1  U238  0  3  0.00373 LAST
   8.718 30  1  LAST
END
```

Compare to "ANISN" problem →

Slide 4

COMPLEX CODE INPUT RESULTS IN GREATER CHANCES OF ERROR

Sample "ANISN" Problem

```
BARE SPHERE
1$$ 2 0 0 8 3 1 0 1 244 1 18 3 4 9 3 0 2 3 5R0 7 4R0 15 4R0 1 0 0
2** 22 0.0001 42 1 0 0 0 0 5 0 0001 0 01 0.002 0 75 T
13$$ 108 121 T
3** F1.0 T
4** 24310.0 8.718
8$$ F1
9$$ 3
10$$ 3 3 3
11$$ 0 1 2
 12** 0.0 0.044802 0.0032278
 1** .204 .344 .188  180  090 .014 102
6*                0 0            08330036     .10117273     13775?4      20777348
   .20777348     .13776341       10117273     08330036 7*
  -.9511897     -.7867958      -.5773503     -.2182179     +.2182179    -1.0
  +.7867958     +.9511897  T                                             +.5773503
```

Slide 6

SIMPLICITY OF "SAN" WAS MADE POSSIBLE BY PLACING ON TAPE OR IN CODE SUCH ITEMS AS:

- S_n weights and direction cosines
- Cross sections
- Fission spectrum
- Parameters

and restricting calculations to multiplication (k_{eff}) only

FIGURE 1

SAMPLE OF "MORSE-C" INPUT FOR ARRAY OF AQUEOUS URANYL NITRATE SOLUTION CYLINDERS

```
 4001   3X3K3 BARE U(92 6)O2(NO3)2  SOLUTION H/U235=440(ORNL-TM-719) ((ON 206)
BASIC SOT=.003 LAST
 MIX 1 U235 0 3 1.50040-4 1 U238 0 3 1.19900-F 1 N 0 3 3 2406-4
 1 0 0 3 .033850 1 H=H20 0 3 .067440 2 C=ATOMIC 0 3 .03549
 2 H=CH2 0 3 .05679 2 0 0 3 .01420 LAST
GEOMETRY VACUUM 5RP) BOX-X 0 22.73 45 46 68 19 / BOX-Y 0 22 ... 45 46 68 19 /
BOX-Z 0 21.46 42 62 64 38 / ARRAY 27R) /
BOX 1 1 1 SECTOR SOLUTION 1 -1 -3 -5 / SECTOR WALL 2 +1 -3 ... -2 /
SECTOR TOP 2 +5 -6 -2 / SECTOR BOTTOM 2 +3 -4 -2  SECTOR V... 0 +4    -2 /
SECTOR VOID 0 +6 -2 / SECTOR VOID 0 +2 /
SURFACES 1 CYLINDER 5Z 10 9 52 / 2 CYLINDER 5Z 10 10 16 /
 3 PLANE 2Z -8.78044 2Z -10 / 4 PLANE 2Z -9.42044 2Z -10 /
 5 PLANE 2Z 8.78044 2Z 10 / 6 PLANE 2Z 9.42044 2Z 10 /
VOLUME PICTURE 0 10 64 38 0 10 3 68.19 10 22 68 19 10 22 10 68 19 0 13
LAST
END
```

Both the SAN and MORSE-C codes draw pictures of the system being calculated. Slides 8 and 9 show criticality safety models of a system designed to measure the energy dependence of ν in the region 0.5 to 125 eV.[3] The slides show the pictures essentially as drawn by the codes, with the exception of the captions describing the codes and the experiment; also the non-fissile materials in Slide 9 were added later, normally being identified in another part of the SAN output. The user may draw other sections of the system with MORSE-C, including higher magnifications of important details. Figure 3 is an example of how we used the pictures of "Nubar" to illustrate the results of our criticality safety study in an internal LLL memorandum, simply by adding some descriptive material. Such displays also help in quality assurance by aiding independent reviewers determine if the criticality analyst has adequately described the system of interest.

Slide 8

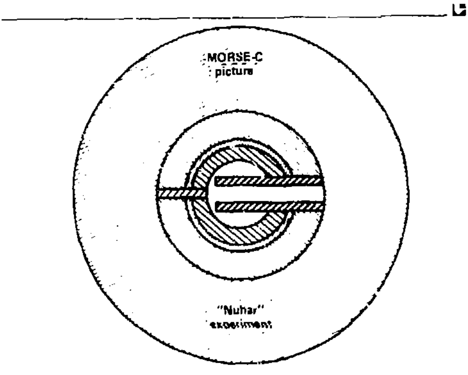
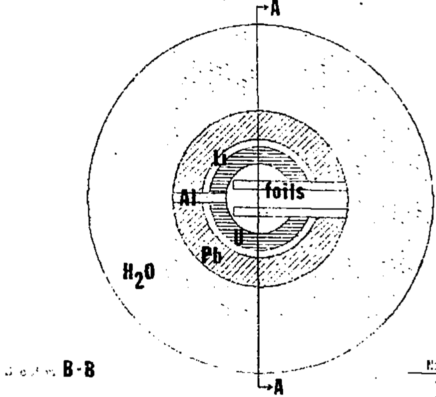


FIGURE 3. Model of NUBAR Experiment Used in MORSE-C Calculations.



No.	Radii (cm)
1	1.550
2	3.175
3	6.101
4	9.002
5	10.272
6	15.307
7	30.310

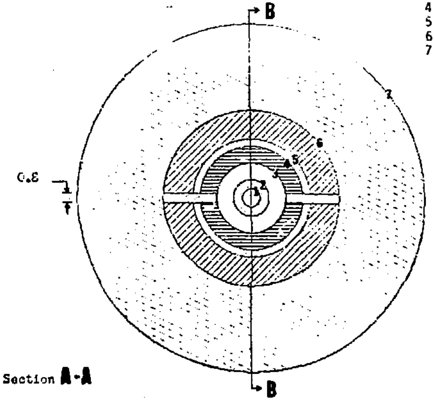
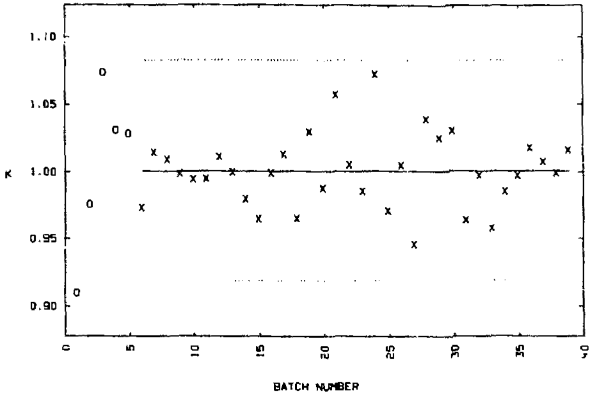


FIGURE 4

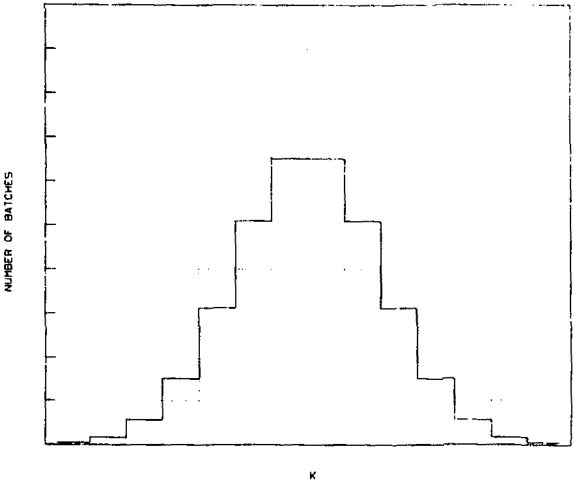
MORSE-C PLOTTING OF INDIVIDUAL BATCH RESULTS



0001-00-02
INDIVIDUAL BATCH MULTIPLICATIONS. SOLID LINE INDICATES AVERAGE VALUE. DOTTED LINES ARE THREE SIGMA LIMITS FOR DISTRIBUTION OF K VALUES.

FIGURE 6

COMPARISON OF MORSE-C RESULTS TO A NORMAL DISTRIBUTION



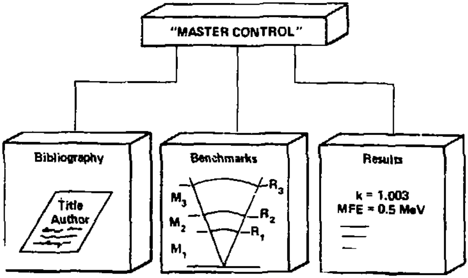
NORMAL DISTRIBUTION OF MULTIPLICATIONS (SOLID LINE) COMPARED TO THAT OBTAINED DURING PROBLEM RUN (DOTTED LINE)

THE W TEST, APPLIED TO THE LAST 34 BATCHES, IS SIGNIFICANT AT THE 75 PERCENT LEVEL.

Slide 12 illustrates how the "MASTER CONTROL"[4] program is used to manage the large amount of data used in our code validation effort. The data base is separated into parts: the bibliographic data base is the source of data describing relevant critical experiments, descriptions of the experiments are entered into the numerical data base, and finally, when the systems have been calculated by our various computational methods, the results of the calculations are entered into the numerical data base. "MASTER CONTROL" performs many useful manipulations of the numerical data such as ordering the benchmarks according to core composition, reflector material, k-effective, median fission energy, etc., and performs calculations such as computing the averages of results, differences of results by various methods, or will punch the data into formats required by codes such as SAN or MORSE-C. Also, it is easy for "MASTER CONTROL" to save the results of these operations as a permanent part of the data base. Some examples of these operations will be given later in this paper.

Slide 12

A COMPUTER PROGRAM IS ALSO USED TO MANAGE THE LARGE AMOUNT OF DATA NEEDED FOR CODE VALIDATION



Slide 15

PORTION OF THE AUTHOR CONCORDANCE

ARNOLD, M. J.				
740	INGRAM, G. / ABSALOM, R. M. / ARNOLD, M. J. / BAKER, A. R.	63-10-00	AEEW-R315	THE FIRST CORE OF ZEBRA
760	ADAMSON, J. / ABSALOM, R. M. / ARNOLD, M. J. / BAKER, A. R. / BROOMFIELD, A. M. / FURNEAUX, D. / INGRAM, G. / PATTENDEN, S. K. / PATTERSON, C. R. / STEVENSON, J. M.	65-10-00	AEEW-R461	THE THIRD CORE OF ZEBRA
ARNOLD, W. H.				
198	ARNOLD, W. H. /	59-11-00	YAEC-152	CRITICAL MASSES AND LATTICE PARAMETERS OF WATER-URANIUM DIOXIDE CRITICAL EXPERIMENTS A COMPARISON OF THEORY AND EXPERIMENT
ARONSON, A. L.				
1907	PALMEDO, P. F. / LUDEWIG, H. / ARONSON, A. L.	70-06-00	TANSAO, 13, 253-254	EFFECT OF HYDROGEN CONTENT OF GRAPHITE IN FAST CRITICAL EXPERIMENTS
ARTHUR, M. G.				
109	SCHUSKE, C. L. / ARTHUR, M. G. / SMITH, D. F.	56-08-06	RFP-0066	NEUTRON MULTIPLICATION MEASUREMENTS ON ORALLOY SLABS IMMERSED IN SOLUTIONS PART 1
110	SCHUSKE, C. L. / ARTHUR, M. G. / SMITH, D. F.	56-10-15	RFP-0069	NEUTRON MULTIPLICATION MEASUREMENTS ON ORALLOY SLABS IMMERSED IN SOLUTION PART-2
1113	SCHUSKE, C. L. / ARTHUR, M. G. / GOODWIN, A. / HICKEL, A. N. / SMITH, D. F.	57-11-27	RFP-0089	SUBCRITICAL MEASUREMENTS ON PARALLELEPIPEDS CONTAINING URANIUM 235 AND SALT [illegible]
ARTEM'EV, G. YA				
432	LYTECYMNSKI, A. I. / KOCHNEVSOB, V. A. / APISTOV, G. YA. / MOGILNYER, A. I. / PAUPHILOV, U. A. / STEPOVSKIY, V. M. / CHUCHNOV, L. A.	61-08-00	IAEA-VIENNA-1961 327-343	EXPERIMENTAL STUDIES OF SOME OF THE PHYSICAL FEATURES OF [illegible] MODERATED INTERMEDIATE [illegible]
ASAOKA, R.				
1893	ASAOKA, R.	71-07-00	EUR-4625	ANALYSIS OF CRITICAL EXPERIMENTS ON THE [illegible]

Slide 17 illustrates how the computerization of the benchmark data has helped in our code validation. Computer storage of the data provides an easily accessible file of experiments that were selected to provide a basis for comprehensive testing of computational methods. In many cases, the originators of the data have been contacted for additional information and clarification. When changes are made in the codes or cross sections it is not difficult to assess the effects of these changes and re-enter the results into the data base. "MASTER CONTROL" aids in the evaluation by displaying results in ways that may indicate trends that might not be evident from a single validation point. Slide 18 lists some of the possible ways of displaying "benchmark" results and Figure 7 is an example.

Slide 17

COMPUTERIZATION OF BENCHMARK DATA HAS SIMPLIFIED CODE VALIDATION PROVIDING:

- Archival storage of selected experiments
- Rapid access to data
- Evaluation of new cross section data or calculational methods
- Display of results that may indicate trends not evident from a single validation point

Slide 18

"MASTER CONTROL" ASSISTS IN THE INTERPRETATION OF "BENCHMARK" RESULTS BY ORDERED DISPLAYS OF:

- Sources of data
- Core materials
- Reflectors
- Median fission energies
- k's
- Codes or cross section treatments

In Slide 19 I have entered the area of speculation, but I expect that the question would be asked, so I prepared the slide presenting our best estimate of when a publication will be available. As long as new experiments are being done, the bibliographic data base will not be complete, but we plan to cut off additions long enough to publish what we have, and do later updates of new measurements and measurements that were inadvertently omitted in the present work. Work on the numerical data base has been pre-empted by our desire to complete the bibliography but, hopefully, a publication can be prepared in the coming year.

Slide 19

WHEN WILL THE BENCHMARK LIBRARY BE READY FOR PUBLICATION?

- Bibliography — we hope this summer, with periodic updating to follow
- Numerical — about 170 experiments are included but the variety of materials and geometries is limited — perhaps a version can be published within a year

REFERENCES

1. W. W. Engle, "A Users's Manual for ANISN", K-1693, Oak Ridge Plant, Union Carbide Corporation Nuclear Division (1967).

2. E. A. Straker, P. N. Stevens, D. C. Irving, and V. R. Cain, "The MORSE Code -- A Multigroup Neutron and Gamma-Ray Monte Carlo Transport Code", ORNL-4585, Oak Ridge National Laboratory (1970).

3. R. E. Howe, and T. W. Phillips, "Prompt Fission Neutrons from eV Resonances in ^{235}U: Measurement and Correlation with other Fission Properties", Phys. Rev. C, 13, 195-205 (1976).

4. V. E. Hampel and J. R. Wade "MASTER CONTROL -- A Unifying Free-Form Data Storage and Data Retrieval System for Dissimilar Data Bases", Proceedings of the ASIS 32nd Annual Meeting, San Francisco, California, (1969) Vol. 6, pp. 159-74.

BLK/gh

The SAN code was designed to be used from an interactive terminal (teletype, television monitor, etc.). It was thus necessary to keep the input as simple as possible and make the code fast running. We noticed that the majority of our ANISN problems were being run in a somewhat "standard" fashion - k-calculations, fixed S_n constants, group size, fission spectrum, convergence parameters, etc. We decided, therefore, to make our interactive version one in which many of these items were fixed and stored in the code or on tape. There was a loss of flexibility in SAN, but we still have ANISN available for the occasional searches, source problems, etc., that we need. (Incidently, we have also made changes in ANISN such as the mnemonic input format that help to make ANISN easier to input and check.) Slide 5 and 6 outline the changes in SAN.

I do not wish to spend an excessive amount of time in the oral presentation on this subject so I will not include comparable examples for MORSE-C, but for the written paper I show an example of the MORSE-C input for a 3x3x3 array of solution cylinders, a fairly complex system (Figure 1). The reader may compare this format to the KENO input format if he wishes. In MORSE-C the Monte-Carlo parameters such as neutrons per batch, standard deviation termination, etc., have been fixed at preselected values, but the user has the option of overriding these if he wishes. In the example of Figure 1, I chose to change the standard deviation termination from its preselected value of 0.005 to 0.003 (card no. 2 of Figure 1).

Slide 5

WHAT LED TO THE DEVELOPMENT OF "SAN"?

- **Interactive version required simple input**
- **Most of our "ANISN" calculations were being done with "standard" input parameters**
- **Many items being required by user input can be kept in code or on tape**

The output of our criticality codes was also modified to help the user insure that his problem was properly described. (Slide 7) a table of atomic weights is attached to the cross section library permitting the codes to compute the physical densities of the materials requested by the user. It is then a simple matter for the SAN code to compute the volumes and masses of the materials used in the problem. In the general geometry MORSE-C, a special Monte-Carlo subroutine was programmed to compute volumes of the various regions, with some statistical uncertainty in the results. Figure 2 illustrates a MORSE-C volume and mass calculation.

Slide 7

AT THE SAME TIME CODE INPUT WAS SIMPLIFIED, CODE OUTPUT WAS IMPROVED

These changes were designed to

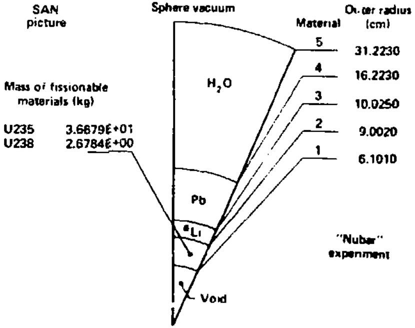
- **Help the user ensure that the problem was what he intended**
- **Display pictures of the geometry in detail and to scale**
- **Display calculated output as plots rather than columns of numbers**

FIGURE 2

SAMPLE OF MORSE-C VOLUME AND MASS CALCULATION

REGION NO	VOLUME CM**3	VOLUME STD DEV	VOLUME FSD	MASS ISOTOPE	MASS KG	MASS STD DEV
1	6.00E+03	1.90E+01	0.0038	U235	2.93E-01	1.11E-03
				U238	2.27E-02	8.99E-05
				N	3.77E-02	1.43E-04
				O	4.30E+00	1.70E-02
				H*H2O	5.64E-01	2.14E-03
				TOTAL	5.41E+00	2.05E-02
2	8.97E+02	3.13E+00	0.0045	C*ATOMIC	4.94E-01	2.22E-03
				H*CH2	8.83E-02	2.97E-04
				C	2.83E-01	1.18E-03
				TOTAL	8.23E-01	3.69E-03
2	2.18E+02	6.72E+00	0.0308	C*ATOMIC	1.34E-01	4.78E-03
				H*CH2	2.07E-02	8.39E-04
				O	8.22E-02	2.94E-03
				TOTAL	2.57E-01	7.93E-03
2	2.12E+02	6.81E+00	0.0312	C*ATOMIC	1.50E-01	4.88E-03
				H*CH2	2.02E-02	8.29E-04
				O	8.01E-02	2.49E-03
				TOTAL	2.50E-01	7.80E-03
0	4.20E+02	9.15E+00	0.0218	VOID	0	0
0	4.22E+02	9.21E+00	0.0218	VOID	0	0
0	4.12E+03	1.59E-01	0.0039	VOID	C	0

Slide 9



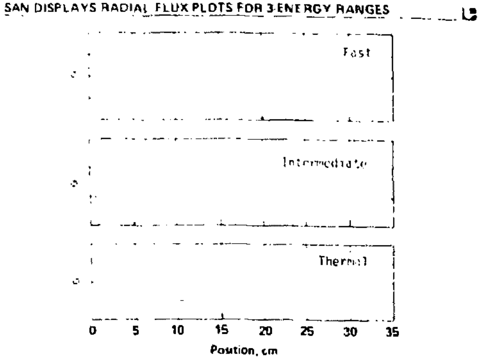
We have also been aided by the other visual displays of SAN and MORSE-C. SAN displays the radial neutron flux integrated over three energy groups - fast, intermediate, and thermal (Slide 10). For problems with 92 neutron energy groups, which we run routinely, the integrated flux plots are more helpful than 92 separate plots or long tables of numbers. SAN also displays the fraction

$$\int_0^E \nu\Sigma_f\phi(E)dE \Big/ \int_0^\infty \nu\Sigma_f\phi(E)dE$$

vs. energy, from which we get the median energy of neutrons causing fissions (median fission energy). This is a helpful characterization of the spectrum of the system. SAN also plots the energy-dependent spectra for each of the spatial regions and plots the leakage spectra.

In addition to spectra plots, MORSE-C plots the history of the batch calculations. Figure 4 illustrates the plotting of the individual batch results and Figure 5 shows the averages. These plots help us to determine if the problem has settled. MORSE-C plots the batch averages "backwards", i.e., by eliminating all batches previous to the one at which the average is to be calculated. This type of averaging shows the effect of the initial source for cases where a sufficient number of the early batches have not been discarded, and how many batches should be discarded in such a case.

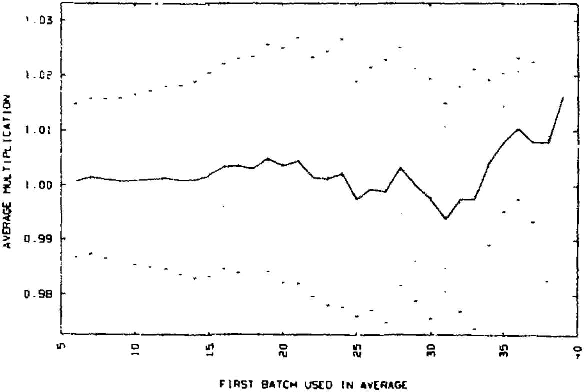
Slide 10



MORSE-C also tells the user how his batch results compare to a normal distribution. Figure 6 illustrates this plotting for the "Nuber Experiment".

FIGURE 5

MORSE-C PLOTS BATCH AVERAGES FROM LAST TOWARDS FIRST



0001-00-02
AVERAGE MULTIPLICATION CALCULATED USING THE LAST N BATCHES. INDICATED ERROR IS THREE TIMES STANDARD DEVIATION OF ESTIMATE OF K.

The second part of this talk considers code validation. ANSI standard N16.9* states that "...the limits may be derived from calculations made by a method shown to be valid by comparison with experimental data...". Slide 11 lists three aspects of code validation. The second item is not strictly a part of a formal code validation scheme, but is helpful in code validation. For example, if the results of calculations for identical systems with discrete ordinates and Monte-Carlo codes are in significant disagreement, a bug may be present in one of the codes; however, even if they agree they may both be in error due to a common defect. Thus it is essential that validation include calculations for experimental systems.

<u>Slide 11</u>

A SECOND VITAL AREA OF COMPUTATIONAL QA IS IN CODE VALIDATION

- **Code performance checks**
- **Comparison of codes**
- **Integral tests of the program and data by calculation of experimental systems — "benchmarks"**

Slide 13 displays some of the features of the bibliographic data base. We have selected only documents that pertain to experimental measurements, omitting criticality safety calculations or "survey calculations". Some documents containing calculations of critical experiments are included. The data base includes sufficient infomation to identify the documents and includes abstracts to help us decide if a document is useful before we inspect the full-text report. Various indices, listings, concordances, or on-line searches help us select "benchmark" data. Slides 14-16 illustrate some of the bibliographic operations. Slide 16 shows a portion of a concordance on "sites". These arrays were added to the data base to identify the location and program of the experimental work regardless of the origin of the report, e.g., if a report is issued at LLL discussing experiments done at LASL, the site description will still be that of the LASL program.

Slide 13

THE BIBLIOGRAPHIC D.B. IS THE SOURCE OF THE "BENCHMARKS" INCLUDING:

- ~1060 documents
- Authors, titles, dates, abstracts, sites, etc.
- Concordances on (1) sites (2) authors (3) titles and abstracts
- On-line searching

Slide 14

LISTING OF A PORTION OF THE DATA IN THE BIBLIOGRAPHIC DATA BASE

LLL BIBLIOGRAPHY OF CRITICAL EXPERIMENTS

65 ID-NUMBER ID-NUMBER 65

AUTHOR	MAGNUSON D W
TITLE	CRITICAL EXPERIMENTS WITH ENRICHED URANIUM METAL, POLYETHYLENE, PLEXIGLAS AND TEFLON MIXTURES
REPORT NUMBER	ORNL-TM-2382
DATE PUBLISHED	68-02-00
NSA NUMBER	22 18283

ABSTRACT

[illegible]

Slide 16

PORTION OF THE SITE CONCORDANCE

POLAND ANNA CRITICAL ASSEMBLY

1536	DABROWSKI, C. + MALEWSKI, S.	NUKLEONIKA, 18, 472-494	73-00-00	ANALYSIS OF THE PHYSICAL PARAMETERS OF THE ANNA CRITICAL [illegible]
1549	[illegible]	NUKLEONIKA, 19, 563-574	74-00-00	FAST THERMAL CRITICAL ASSEMBLY [illegible] ANNA [illegible]
1811	DABROWSKI, CYRYL + MALEWSKI, STEFAN	INR-1289	71-00-00	PHYSICAL AND GEOMETRICAL PARAMETERS OF ANNA CRITICAL ASSEMBLIES, PART I

POLAND ANNA CRITICAL ASSEMBLY - CALCULATIONS

1931	MALEWSKI, S. DABROWSKI, C.	INR-1456 9A/PR A	73-00-00	PHYSICAL AND GEOMETRICAL PARAMETERS OF ANNA CRITICAL ASSEMBLIES, P[illegible] 2

ROCKY FLATS BORATED PLUTONIUM METAL CYLINDERS

1[illegible]1	BIDINGER, G. H. + SCHUSKE, C. L. + SMITH, D. F.	RFP 02[illegible]	60-07-07	NUCLEAR SAFETY EXPERIMENTS ON PLUTONIUM AND ENRICHED URANIUM HYDROGEN MODERATED ASSEMBLIES CONTAINING BORON
3[illegible]	GOODWIN, A. JR. SCHUSKE, C. L.	JAAB[illegible] 15 120-129	61-00-00	PLEXIGLAS AND GRAPHITE MODERATED PLUTONIUM ASSEMBLIES

ROCKY FLATS BORON/STAINLESS STEEL PLATES

195	SCHUSKE, C. L. BIDINGER, G. H.	RFP 0245	61-06-00	NUCLEAR SAFETY MEASUREMENTS ON SYSTEMS CONTAINING BORON AND ENRICHED URANIUM
494	ROTHE, R. E.	NSENAO, 35, 257-276	69-02-00	CRITICAL MEASUREMENT ON AN ENRICHED URANIUM SOLUTION SYSTEM
904	ROTHE, R. E.	CONF 680909, 096-107	68-09-23	THE INTERACTION BETWEEN POISONED AND UNPOISONED ELEMENTS IN A [illegible] CELL ARRAY
1355	ROTHE, R. E.	TANSAO, 19, 187-188	74-00-00	CRITICALITY OF PERIODICALLY BORON POISONED ENRICHED-URANIUM SOLUTION SYSTEMS
1559	ROTHE, R. E. + ALVAREZ, D. L. + CLARK, H. E.	NUTYBB 25, 502-516	75-03-00	THE CRITICALITY OF PERIODICALLY BORON POISONED URANIUM SOLUTION SYSTEMS

FIGURE 7

SAMPLE LISTING OF A PORTION OF THE BENCHMARK DATA BASE
--ORDERED BY DIFFERENCE BETWEEN SAN AND MORSE-C RESULTS

IDN	CORE	REFLEC TOR	REFL. THICK.	MFF (MEV)	SAN 920RP	MORC 920RP	DK
100003	PU-D	W	4.699	1.14E+00	0.9942	0.9832	-.0110
480002	PU-A	BE	13.004	9.43E-01	0.9919	0.9828	-.0091
360003	PU-D	C	3.830	1.17E+00	1.0007	0.9933	-.0074
30003	U-235	C	9.982	1.05E+00	1.0049	0.9953	-.0063
380002	PU-D	TI	0.000	1.27E+00	0.9872	0.9822	-.0050
470002	PU-A	BE	20.967	8.80E-01	0.9619	0.9570	-.0049
230002	U-233	U	2.302	1.23E+00	0.9855	0.9816	-.0039
320006	U-235	C	10.160	8.42E-01	1.0015	0.9976	-.0039
200003	U-233	BE	11.766	5.98E-01	0.9987	0.9953	-.0034
310003	U-235	CU	10.561	7.74E-01	1.0178	1.0147	-.0031
270004	U-235			9.92E-01	1.0028	1.0001	-.0027
440101	U-233	BE	3.264	6.15E-01	1.0061	1.0039	-.0022
420003	U-235	BE	9.268	6.09E-01	1.0040	1.0021	-.0019
430003	U-233	BE	5.440	7.29E-01	1.0064	1.0046	-.0018
490002	PU-A	BE	6.167	1.03E+00	1.0001	0.9984	-.0017
340003	[illegible] Pu-D	U	1.950	1.34E+00	0.9922	0.9905	-.0017
500002	PU-A	BE	5.222	1.11E+00	1.0028	1.0012	-.0016
570001	VERA11	U	33.000	7.64E-01	0.9745	0.9734	-.0014
80003	PU-D			1.45E+00	0.9955	0.9951	-.0004
560001	JEZEEEL			1.37E+00	0.9917	0.9917	0.0000
240003	U-233	W	2.430	1.10E+00	0.9818	0.9819	0.0001
180003	U-233	BE	4.145	9.89E-01	0.9915	0.9921	0.0006
40003	U-235	U	4.4[illegible]	1.00E+00	1.0083	1.0095	0.0012
90002	PU-D:U-235			1.25E+00	0.9997	1.0012	0.0015
50002	U-235	U	1.705	9.91E-01	1.0039	1.0055	0.0016
450003	U-235	BE	2.222	8.65E-01	1.0027	1.0047	0.0020
60403	PU-D			1.35E+00	0.9978	0.9998	0.0020
390003	PU-D	U	8.730	1.40E+00	0.9957	0.9980	0.0023
190003	U-235	W	5.080	8.18E-01	1.0028	1.0054	0.0026
150004	U-235	BE	4.690	7.59E-01	1.0094	1.0126	0.0032
140004	U-235	W	10.180	7.28E-01	1.0009	1.0042	0.0033
400002	PU-D	BE	5.230	1.06E+00	1.0019	1.0062	0.0044
210002	U-233 U-238			1.05E+00	1.0041	1.0090	0.0049
460002	PU-A	BE	31.954	8.62E-01	0.9945	0.9999	0.0054
250002	U-233	BE	2.045	1.09E+00	0.9865	0.9922	0.0057
220002	U-233 U-235			1.20E+00	0.9864	0.9924	0.0060
280002	U-238	U	19.914	1.06E+00	0.9853	0.9915	0.0063
10002	U-235			9.94E-01	1.0005	1.0070	0.0065
20003	U-235	U	18.009	1.06E+00	1.0003	1.0071	0.0068
110002	PU-D	BE	3.688	1.13E+00	1.0028	1.0101	0.0073
290002	U-23[illegible]5	NI	4.240	8.83E-01	1.0144	1.0217	0.0073
70003	PU-D	U	4.128	1.36E+00	1.0000	1.0085	0.0085
410101	U-233	BE	20.268	4.54E-01	0.9818	0.9909	0.0091
590001	ZEBRA3	U	30.500	6.68E-01	0.97[illegible]	0.9812	0.0108

If time permits, the talk will be ended with a slide summarizing the two areas of emphasis of this talk, hoping that perhaps some of this information has been of interest to the audience. (Slide 20).

Slide 20

TWO AREAS OF EMPHASIS HAVE BEEN OF HELP TO OUR CS QA PROGRAM

These are

1. Simplification of input and improvement of output of criticality safety codes

2. Use of computers in managing the data needed in code validation