This is an informal report intended primarily for internal or limited external distribution. (The opinions and conclusions stated are those of the author and may or may not be those of the laboratory.) This report is not to be given additional external distribution or cited in external documents without the consent of the author or LLL Technical Information Department.

UCID - 16682

LAWRENCE LIVERMORE LABORATORY

University of California/Livermore, California

DOES MORSE-L REALLY WORK?

Unclassified

Tom Wilcox

September 14, 1972

MASTER

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

September 14, 1972

MOR-9

MEMORANDUM

TO: Distribution
FROM: T. P. Wilcox
SUBJECT: Does MORSE-L Really Work?

I. Introduction

The question posed by the title is a real question every user must seriously ask before basing his conclusions upon MORSE-L calculations. It is also a question the authors of the code must consider time and time again as their program is made available for others to use. In a general sense, the answer to this question is NO. MORSE-L, with its 15,000 source program cards, is too big a code with too many options to ever be able to be checked in its entirety. In a practical way, however, it is possible to check all the options and then to check all the combinations of options normally used. It is the purpose of this memo to describe to the user the work that has been done to insure the proper operation of MORSE-L.

After checks that are made as a program is being developed, the usual method of insuring correct operation is to run problems the answers to which are known. This is the procedure used here. These problems roughly fall into three catagories:

MASTER

a) Problems to which the answer is known exactly.

These are, for radiation transport problems, at least, very simple cases which have analytic solutions (like those having one neutron velocity, an infinite medium, and only isotropic scattering.) More complex problems do not have analytic answers, unfortunately. This class of problems is poor in that they do not check the multigroup features of the code.

b) Problems which can be, and have been, run using other codes

Physical data is assumed to be known exactly and the output of the tested code is taken to be correct if it agrees with one, or more, of the other codes. This method has its weakness in the fact that the other code could be incorrect or, more usually, that the physical or mathematical methods used in the two codes will produce slightly different solutions.

c) Problems for which there is an experimental measurement of the right answer.

Tests in this group usually end up trying to resolve the question of whether the physical cross section data input to the code or the experiment was in error.

Problems in group a) tend to correct outstanding code errors since the correct answer is known. Problems in group b) then attempt to find errors involving multi-group cross section sets and a more realistic use of the code. Finally, problems in group c) raise the confidence of the user by also checking cross section sets as well as the code's operation. Problems in all three categories should be run when testing a code.

Though such problems are sometimes called test problems, reference problems, or example problems, we will use the currently popular term "benchmark" problem in this memo. Table I lists a dozen such problems which have been run with MORSE-L. The rest of this report will describe these problems and indicate the results obtained. Complete descriptions of each problem are given in the indicated references. The problem output is available from the author.

Table II lists the options available in MORSE-L operation and indicates which of the benchmark problems used each option. It should be noted that three of these items are not tested by the listed problems. Of these, the fission option is used in a pulsed sphere calculation, the infinite absorber has been checked in a problem described in MORSE note 8*, and the adjoint mode has not been tested. Users requiring the adjoint operation should check with the author before attempting to run MORSE-L problems.

*T. Harper, R. Neifer; "MORSE-L --- TORTE Comparisons; " MOR-8;
August 30, 1972.

MORSE note 7** describes the checkout of the source simulation routines in the MORSE-L code. The benchmark problems used here use various source descriptions but no attempt has been made to list these. The above work has adequately covered this phase of operation. In a like manner, the cross section module was checked by the author when first written in both the packed and unpacked mode.

The best check of neutron data in the higher energy range is the LLL Pulsed Sphere work.*** The entire set of these experiments has been run with MORSE-L and will be reported on after some of our neutron cross sections have been updated. In a sense, these represent an additional fifty, or so, benchmark problems.

The twelve benchmark problems were run with the current CDC 6600 version of the code. They will be run with each new version to insure proper code operation in the future.

** J. W. Hudson; "MORSE Source Distributions;" MOR-7; August 10, 1972.

***C. Wong, et. al.; "Livermore Pulsed Sphere Program: Program Summary Through July 1971; "UCRL-51144, RevI; Feb. 10, 1972.

TABLE I MORSE-L BENCHMARK PROBLEMS

<u>NO.</u>	<u>TYPE</u>	<u>DESCRIPTION</u>
1.	a	Single speed problem - point source in infinite media, $c = 0.3$
2.	a	Single speed problem - point source in infinite media, $c = 0.9$
3.	a	Single speed problem - first collision flux outside a sphere
4.	b	Beam on borated polyethylene slab - coupled n, γ problem
5.	b	Point neutron source in infinite air
6.	b	Point gamma source in infinite water
7.	b,c	Dose rate above a uniform Co^{60} source on air- ground interface
8.	b	Light transmission within a cylindrical guide-- albedo used to simulate light diffusion.
9.	c	Point Co^{60} gamma source outside of a Teflon cylinder.
10.	c	Point Cs^{137} gamma source outside of a Teflon cylinder.
11.	b	BF_3 neutron detector response to incident 14 mev neutrons.
12.	a	Two speed problem to check current estimators.

TABLE II MORSE-L OPTIONS USED IN BENCHMARK PROBLEMS

<u>Option</u>	<u>Problems using option*</u>	<u>Option</u>	<u>Problems using option*</u>
DETECTOR TYPES		DETECTOR BINS	
reaction	4, 11	energy	4, 5, 6, 11
predicted reaction	11	time	1, 2
path length	11	angle	7
boundary crossing	1, 2, 5, 6, 11		
boundary crossing, J	12	RANDOM WALK	
point, ϕ	3, 4, 7, 9, 10, 11	fission	
point, J	12	secondary gamma	4
albedo	8	Russian roulette	1, 2, 3, 4, 7, 9, 10, 11
GEOMETRY		splitting	12
spherical	1, 2, 3, 5, 6, 12	exponential transform	5, 6, 9, 10
general	4, 7, 8, 9, 10, 11	non-leakage	4
w/ interior void	4, 8	energy cut-off	
w/ exterior void	11	neutrons	5
w/ inf. absorber		gammas	6
CROSS SECTIONS		age cut off	2
card input	1, 2, 3, 4, 5, 8, 12	ADJOINT MODE	
tape input	6, 7, 9, 10, 11	ENERGY, VELOCITY, FISSION SPECTRA	
isotropic	1, 2, 12	input on cards	1, 2, 3, 4, 5, 8, 12
anisotropic	3, 4, 5, 6, 9, 10, 11	input from tape	6, 7, 9, 10, 11
negative fix-up			
neutrons	11		
gammas	7, 9, 10		
equivalence table	1, 2, 3, 5, 6, 8		
scattering energy bias	6		

* see previous table for list of problems and problem numbers

II MORSE-L BENCHMARK PROBLEMS ONE AND TWO

Problem Description

An isotropic point source in an infinite homogeneous medium with one-speed cross sections and isotropic scattering. Two different cases are considered; the first has a scattering to total cross section ratio of 0.3 while the second has a ratio of 0.9.

References

- 1) E. A. Straker; W. W. Engle, Jr; P. N. Stevens;
"Some Calculated Milestone Solutions To Time-Dependent Radiation Transport Problems", ORNL-TM-2499; April 1969.
- 2) K. N. Case, F. De Hoffman, G. Placzek; "Introduction to the Theory of Neutron Diffusion, Vol. I"; U.S. Government Printing Office; 1953.

Discussion

The analytic solution to the time independent use is given in reference 2 while numerical solutions to the time dependent case are shown in reference 1. The latter were obtained by use of the time dependent ANISN code and by the Oak Ridge version of MORSE.

Both problems were run with MORSE-L using the spherical geometry option and boundary crossing estimators. Table III indicates the time integrated results vs. the analytic results while Figures 1 through 5 compare the time dependent results. In all cases, the results obtained with MORSE-L seem proper.

TABLE III TIME INTEGRATED FLUENCE - ANALYTIC VS MORSE-L CALCULATIONS

<u>r</u>	<u>$4\pi r^2 \phi$</u> <u>Analytic</u>	<u>$4\pi r^2 \phi$</u> <u>MORSE-L</u>	<u>Calculated-analytic</u> <u>analytic</u>
c=0.3			
0.3	0.8710	0.8687 (.003)*	-.003
0.5	0.7708	0.7683 (.004)	-.003
0.8	0.6277	0.6245 (.005)	-.005
1.0	0.5421	0.5436 (.006)	+.003
1.5	0.3675	0.3666 (.008)	-.002
2.0	0.2441	0.2424 (.010)	+.007
3.0	0.1037	0.1037 (.017)	.000
4.0	0.0427	0.0440 (.020)	+.055
5.0	0.0173	0.0176 (.030)	+.017
6.0	0.0069	0.0072 (.052)	+.044
7.0	0.0028	0.0028 (.079)	-----
8.0	0.0011	0.0011 (.113)	----
9.0	0.0004	0.0004 (.163)	----
10.0	0.0002	0.0002 (.267)	----
c=0.9			
0.3	1.3384	1.3714 (.021)	+.025
0.5	1.5168	1.5003 (.012)	+.011
0.8	1.7130	1.7258 (.017)	+.008
1.0	1.8006	1.7965 (.008)	-.002
1.5	1.8974	1.8807 (.015)	-.009
2.0	1.8660	1.8796 (.013)	+.007
3.0	1.5992	1.6272 (.019)	+.018
4.0	1.2454	1.2411 (.011)	-.004
5.0	0.9158	0.9618 (.032)	+.050
6.0	0.6483	0.5507 (.024)	-.043
7.0	0.4467	0.4379 (.017)	-.020
8.0	0.3018	0.2975 (.017)	-.014
9.0	0.2007	0.2004 (.028)	-.002
10.0	0.1318	0.1296 (.025)	-.017

* .003 is the fractional standard deviation associated with the calculated result.

ORNL-DWG-69-4548

Fig. 1 $4\pi R^2$ flux versus time at 3 mean free paths for non-absorption probability of 0.3. Curve - ANISN, histogram - MORSE, dotted histogram - MORSE -L

ORNL-DWG-69-4549

Fig. 2 $4\pi R^2$ flux versus time at 6 mean free paths for non-absorption probability of 0.3. Curve - ANISN, histogram - MORSE, dotted histogram - MORSE -L

ORNL-DWG-69-4551

Fig. 3 $4\pi R^2$ flux versus time at 3 mean free paths for non-absorption probability of 0.9. Curve - ANISN, histogram - MORSE, dotted histogram - MORSE - L

ORNL-DWG-69-14552

Fig.4 $4\pi R^2$ flux versus time at 6 mean free paths for non-absorption probability of 0.9. Curve - ANISN, histogram - MORSE, dotted histogram - MORSE -L

Fig. 5 $4\pi R^2$ flux versus time at 9 mean free paths for non-absorption probability of 0.9. Curve - ANISN, histogram - MORSE, dotted histogram - MORSE-L

III MORSE-L BENCHMARK PROBLEM THREE

Problem Description

An isotropic point source in the center of a sphere of homogeneous material with one-speed cross sections and isotropic scattering. The total cross section is 1 cm^{-1} , the scattering cross section 0.5 cm^{-1} and the sphere's radius is equal to one cm. The uncollided and first collided flux are to be calculated at a point ten cm. from the sphere's center.

Discussion

This problem was devised to check the point fluence estimator in a situation which approximates the LLL pulsed sphere experiments. The uncollided fluence is given by:

$$\begin{aligned} \phi_0(r) &= \frac{1}{4\pi r^2} e^{-r} & 0 \leq r \leq 1 \\ &= \frac{1}{4\pi r^2} e^{-1} & r > 1 \end{aligned}$$

The first collided fluence can then be written as:

$$\phi_1(r_d) = \int dV \left[\frac{0.5}{4\pi r^2} e^{-r} + \frac{1}{4\pi \rho} e^{-q} \right]$$

where ρ = distance from dV to detector

q = distance thru sphere along ρ

This integral was evaluated by numerical methods for this specific

The MORSE-L problem used spherical geometry and a P_3 expansion of the cross section (in order to avoid the special isotropic scattering routines).

The following results were obtained:

	<u>analytic</u>	<u>MORSE-L</u>	<u>MORSE-L - analytic</u> <u>analytic</u>
uncollided	2.9275×10^{-4}	2.9275×10^{-4} (.0000)	-0-
1st collision	1.0806×10^{-4}	1.0769×10^{-4}	-0.0034
Total	4.0081×10^{-4}	4.0044×10^{-4} (.0012)	-0.0009

IV MORSE-L BENCHMARK PROBLEM FOUR

Problem Description

A monodirectional neutron beam with a U^{235} fission source energy spectrum is normally incident at a point on a borated polyethylene slab of thickness 15.24 cm. Detectors are located 100 meters from the intersection of the uncollided neutron beam and the face of the slab opposite the incident beam. Four detectors, at different angles, are used. Both neutron and secondary gamma fluence are calculated.

Reference

- 1) C. E. Burgart; "Neutron and Gamma-Ray Fluence Transmitted through a slab of Borated Polyethylene - A Milestone Calculation"; ORNL-TM-3517; March 1972.

Discussion

This problem was run by C. E. Burgart with four different codes using the same cross section data. We have merely re-run the problem with MORSE-L. Point fluence detectors were used at the four locations described above and a reaction estimator was used to obtain the total neutron fluence in the slab. The non-leakage option and Russian roulette were used.

The following tables indicate the results obtained by MORSE-L in comparison with the previously calculated results. MORSE (A) and MORSE (S) refer to the ORNL version of MORSE with two slightly different point estimation schemes. MORSE-L approximates MORSE (A).

TABLE IV TOTAL NEUTRON FLUENCE IN 15.24 cm. SLAB

Total Fluence (neutrons cm/ev)

<u>Group</u>	<u>ANISN</u>	<u>DOT</u>	<u>ORNL MORSE</u>	<u>MORSE-L</u>
10	1.55-6*	1.55-6	1.57-6	1.61-6 (.05)
11	2.14-6	2.13-6	2.15-6	2.04-6 (.03)
12	2.94-6	2.93-6	2.94-6	2.97-6 (.03)
13	4.73-6	4.68-6	4.69-6	4.60-6 (.02)
14	1.93-5	1.91-5	1.97-5	1.90-5 (.02)
15	3.03-4	2.98-4	3.09-4	3.01-4 (.02)
16	1.60-3	1.57-3	1.59-3	1.59-3 (.02)
17	6.86-3	6.74-3	6.77-3	6.69-3 (.02)
18	1.91-2	1.87-2	1.91-2	1.93-2 (.02)
19	4.70-2	4.61-2	4.82-2	4.52-2 (.02)
20 <	1.09-1	1.07-1	1.10-1	1.07-1 (.03)
21	1.97-1	1.93-1	1.94-1	1.91-1 (.03)
22	2.03-1	1.99-1	2.00-1	1.95-1 (.02)

* read as 1.55×10^{-6}

TABLE V PARTICLE FLUENCE FOR THE 15.24 cm SLAB

Detector Number	1	2	3	4
Cosine	0.98561	0.89632	0.73218	0.14447
Angle	9.7°	26.3°	42.9°	81.7°
Neutron Fluence (neutrons /cm ² - source neutron)				
ANISN	3.57 -10	2.74-10	1.86-10	1.20-11
DOT-SPACETRAN	3.54-10	2.58-10	1.37-10	0.97-11
MORSE (A)	3.72-10 (.04)	2.85-10 (.05)	1.69-10 (.06)	1.08-11 (.16)
MORSE (S)	3.60-10 (.03)	2.72-10 (.03)	1.59-10 (.04)	1.06-11 (.11)
O6R	3.60-10 (.04)	2.69-10 (.05)	1.55-10 (.07)	0.91-11 (.21)
MORSE-L	3.80-10 (.04)	2.93-10 (.04)	1.78-10 (.05)	1.34-11 (.11)
Gamma-Ray Fluence (photons /cm ² - source neutron)				
ANISN	8.86-10	8.31-10	7.06-10	9.29-11
DOT-SPACETRAN	8.46-10	7.94-10	6.41-10	6.93-11
MORSE (A)	8.45-10 (.04)	7.93-10 (.04)	6.75-10 (.04)	9.27-11 (.06)
MORSE (S)	8.87-10 (.03)	8.30-10 (.03)	7.08-10 (.03)	9.66-11 (.05)
O6R-OGRE	9.31-10 (.04)	8.69-10 (.04)	7.34-10 (.04)	9.72-11 (.10)
MORSE-L	8.52-10 (.03)	7.97-10 (.03)	6.78-10 (.03)	9.28-11 (.04)

TABLE VI FRACTIONAL DIFFERENCES COMPARED TO ANISN RESULTS

Detector Number

Neutron Fluence

DOT-SPACETRAN	-0.01	-0.06	-0.26	-0.19
MORSE (A)	-0.01 (.04)*	+0.04 (.05)	-0.09 (.06)	-0.10 (.16)
MORSE (B)	+0.01 (.03)	-0.01 (.03)	-0.15 (.04)	-0.12 (.11)
O6R	+0.01 (.04)	-0.02 (.05)	-0.17 (.07)	-0.24 (.21)
MORSE -L	+0.06 (.04)	+0.07 (.04)	-0.04 (.05)	+0.12 (.11)

Gamma-Ray Fluence

DOT-SPACETRAN	-0.05	-0.04	-0.09	-0.26
MORSE (A)	-0.05 (.04)	-0.05 (.04)	-0.04 (.04)	-0.00 (.06)
MORSE (B)	+0.00 (.03)	-0.00 (.03)	+0.00 (.03)	+0.04 (.05)
O6R-OGRE	+0.05 (.04)	+0.05 (.04)	+0.04 (.04)	+0.05 (.10)
MORSE -L	-0.04 (.03)	-0.04 (.03)	-0.04 (.03)	-0.00 (.04)

*This entry indicates that MORSE (A) yielded an answer 1% lower than ANISN and that the MORSE (A) results had a fractional standard deviation of 4%.

V MORSE-L BENCHMARK PROBLEM FIVE

Problem Description

A point neutron source with a fission energy spectrum is located in an infinite homogeneous air medium. The neutron flux is calculated as a function of distance from the source and as a function of neutron energy.

Reference

- 1) A. E. Profio (editor); "Shielding Benchmark Problems"; ORNL-RSIC-25 (ANS-SD-9); Supplement 1; August 1970.

Discussion

This is shielding Benchmark Problem 3.0 submitted by E. A. Straker of ORNL. This problem is also given out with the ORNL version of MORSE as an example problem.

The MORSE-L results for this problem were plotted on the curves of reference 1 as dots in the center of a circle. These figures are attached. It should be noted that the MONTE CARLO results on these plots are the result of 05R calculations. The MORSE-L results should be the same as the plotted solid line (ANISN). Within the statistical error of the calculations, there is good agreement.

Fig. 6 $4\pi R^2$ Dose Versus Range.
 x - Monte Carlo — Discrete Ordinates
 ⊙ MORSE-L

FISSION SOURCE

ORNL-DWG 69-3411

Fig. 7 $4\pi R^2$ Fast Fluence Versus Range.
 x - Monte Carlo — Discrete Ordinates
 o MORSE-L

Fig. 8 $4\pi R^2$ Fluence Versus Range for Neutrons in the 12.2-15 MeV Energy Interval. $\times$ - Monte Carlo — Discrete Ordinates $\odot$ MORSE-L

FISSION SOURCE

ORNL-DWG 69-3413

Fig. 9 $4\pi R^2$ Fluence Versus Range for Neutrons in the 8.18-12.2 MeV Energy Interval. x - Monte Carlo — Discrete Ordinates
⊙ MORSE-L

Fig. 10 $4\pi R^2$ Fluence Versus Range for Neutrons in the 6.36-8.18 MeV Energy Interval. x - Monte Carlo — Discrete Ordinates

⊙ MORSE-L

Fig. 11 $4\pi R^2$ Fluence Versus Range for Neutrons in the 4.06-6.36 MeV Energy Interval. x - Monte Carlo — Discrete Ordinates

⊙ MORSE-L

Fig. 12 $4\pi R^2$ Fluence Versus Range for Neutrons in the 2.35-4.00 MeV Energy Interval. x - Monte Carlo — Discrete Ordinates
 ⊙ MORSE-L

FISSION SOURCE

ORNL-DWG 69-3417

Fig. 13 $4\pi R^2$ Fluence Versus Range for Neutrons in the 1.108-2.35 MeV Energy Interval. x - Monte Carlo — Discrete Ordinates.

⊙ MORSE-L

Fig. 14 $4\pi R^2$ Fluence Versus Range for Neutrons in the 0.111-1.108 MeV Energy Interval. x - Monte Carlo — Discrete Ordinates

⊙ MORSE-L

VI MORSE-L BENCHMARK PROBLEM SIX

Problem Description

A point gamma source with an initial energy between 9.45 and 10 MEV located in an infinite water medium. The differential energy spectra is to be calculated at points which correspond, approximately, to 1, 2, 4, 7, 10, 15, and 20 mean free paths from the original source.

Reference

- 1) H. Goldstein, J. E. Wilkins, Jr.; "Calculation of the Penetration of Gamma Rays;" NYO-3075; June 1954.

Discussion

This problem attempts to duplicate one of the classic moments calculations of Goldstein and Wilkins. A high energy source in a light element was chosen to test the ability of MORSE-L to follow the Compton scattering process.

Reference 1) gives results for a 10 MEV source in water. The closest that we can duplicate this is with a source in group 1 of the 30 group gamma library. Since the original work did not include the gammas produced in the pair production process, no valid comparison can be made below 0.51 MEV. The cross sections used in MORSE-L are not identical to those used in reference 1, therefore, it cannot be expected that the two results will be identical.

Figure 15 indicates the MORSE-L results compared with the Goldstein - Wilkins results.

KE SEMI-LOGARITHMIC 359-63G
 KEUFFEL & ESSER CO. MADE IN U.S.A.
 2 CYCLES X 140 DIVISIONS
 Differential Energy Spectra,
 $4\pi r^2 \epsilon N_0 \Gamma I_0$

Figure 15 Differential Energy Spectra for a gamma source in water.
 Smooth curves - 10 MEV source from Goldstein and Wilkins.
 Histogram - 9.45 to 10 MEV source as calculated by MORSE-L

VII MORSE-L BENCHMARK PROBLEM SEVEN

Problem Description

This problem calculates the gamma-ray dose three feet above a uniform plane source of Co^{60} on an air-ground interface.

Reference

- 1) A. E. Profio (editor); "Shielding Benchmark Problems";
ORNL-RSEC-25 (ANS-SD-9); Supplement 1; August 1970.

Discussion

This is shielding benchmark problem 4.0 submitted by C. W. Garrett of Radiation Research Associates. It represents a standard civil defense problem which simulates a fallout field. This problem has been solved by a number of investigators both analytically and experimentally.

The problem was solved using the MORSE-L code and the LLL 35 group gamma cross section library in a manner similar to that described in reference 1). The exact analytic solution for the uncollided kerma (dose) rate is 1.140×10^{-7} . MORSE-L gave $(1.13 \pm .01) \times 10^{-7}$. The total kerma rate has been expressed in terms of the dose buildup factor - i.e. the total kerma rate divided by the uncollided rate. Table VII lists our results as well as those of others. The references to the listed results have been omitted in the table but may be found in reference 1.

Figure 16 indicates the angular distribution of the kerma rate. The MORSE-L results agree with the other calculations and experiments within the monte carlo statistics.

TABLE VII EXPERIMENTAL AND CALCULATED BUILD-UP FACTORS

<u>Investigator</u>	<u>Method</u>	<u>Buildup Factor</u>	<u>Notes</u>
Rexroad & Schmake; 1960	experiment	1.25	ionization chamber
Schlemn, et al; 1959	experiment	1.15	GM tube
		1.38	Film Pack
Plummer & Miller; 1963	experiment	1.15	ionization chamber
Spencer; 1962	moments	1.21	
Berger; 1957	moments	1.22	
Hubbell, Clark, Buchanan; 1962	moments	1.23	
Berger; 1967	moments	$1.21^{+.01}$	
Berger; 1957	MONTE CARLO	1.22	
Marcum; 1965	MONTE CARLO	1.16	
French; 1967	MONTE CARLO	1.18	
Garrett; 1968	MONTE CARLO	$1.21^{+.02}$	
Kalos; 1968	MONTE CARLO	1.20	
	MORSE-L	$1.23^{+.02}$	

Shielding Benchmark Problem 4.0

ORNL-DWG 69-2123

Fig. 16 Kerma Angular Distribution
For MORSE-L BENCHMARK PROBLEM SEVEN.
MORSE -L RESULTS PLOTTED AS A HISTOGRAM.

VIII MORSE-L BENCHMARK PROBLEM EIGHT

Problem Description

This problem calculates light transmission (by diffusion) within a cylindrical guide. The source is considered to be uniformly distributed on a disk at one end of the cylinder and is given a Lambertian (cosine) angular distribution. The guide contains a vacuum and the diffusion on its walls is simulated by the use of the albedo option. The problem calculates the outgoing current on the cylinder's walls as a function of distance from the source.

References

- 1) D. C. Ward; "MONTE CARLO Calculations of the Light Diffusion Study"; DAG-71-80; Sept. 1971.

Discussion

The problem shown here is one of a number run during the summer of 1971 in order to simulate the experimental work done in L-Division's Light Diffusion Study. This particular problem received additional attention in order to check out the accuracy of the simple monte carlo program written at that time.

Table VIII indicates the first collision current obtained analytically, from reference 1), and from MORSE-L. The reference 1) solution was obtained with 200,000 source particles but no statistical

uncertainty is available. The MORSE-L problem used 20,000 source particles. The results of MORSE-L are within the stated uncertainty with the exception of the first position. At this position, the w-test indicates that the results are not to be believed. The results for all collisions are indicated in the same table. These give a better comparison since the statistical variations are smaller.

The MORSE-L problem simulated the Lambertian albedo by an input table. The problem has been run using the built in cosine albedo. The results are similar except that less running time was required.

TABLE VIII RESULTS OBTAINED FOR THE LIGHT DIFFUSION PROBLEM

Position		Outgoing Albedo Current				
		First Collision			All Collisions	
<u>Z Min</u>	<u>Z max</u>	<u>Analytic</u>	<u>DAG-71-80</u>	<u>MORSE-L</u>	<u>DAG-71-80</u>	<u>MORSE-L</u>
8	10	8.93×10^{-2}	8.84×10^{-2}	9.09×10^{-2} (.028)*	4.79×10^{-1}	4.88×10^{-1} (.013)**
18	20	1.87×10^{-2}	1.81×10^{-2}	1.96×10^{-2} (.062)	2.94×10^{-1}	2.99×10^{-1} (.015)
28	30	6.18×10^{-3}	6.10×10^{-3}	6.34×10^{-3} (.116)	1.82×10^{-1}	1.82×10^{-1} (.018)
38	40	2.70×10^{-3}	2.69×10^{-3}	2.79×10^{-3} (.185)	1.16×10^{-1}	1.20×10^{-1} (.023)
48	50	1.40×10^{-3}	1.63×10^{-3}	1.18×10^{-3} (.260)	7.52×10^{-2}	7.78×10^{-2} (.034)
58	60	8.13×10^{-4}	8.77×10^{-4}	4.18×10^{-4} (.350)	4.91×10^{-2}	4.60×10^{-2} (.022)
68	70	5.13×10^{-4}	5.50×10^{-4}	5.57×10^{-4} (.334)	3.20×10^{-2}	3.04×10^{-2} (.034)
78	80	3.44×10^{-4}	3.34×10^{-4}	4.87×10^{-4} (.429)	1.93×10^{-2}	2.00×10^{-2} (.049)
88	90	2.41×10^{-4}	2.92×10^{-4}	2.79×10^{-4} (.585)	1.16×10^{-2}	1.27×10^{-2} (.060)

* The value indicated in parenthesis is the fractional standard deviation

** W-test was zero

IX MORSE-L BENCHMARK PROBLEMS NINE AND TEN

Problem Description

A point gamma source is located in air external to, and on the axis of, a cylinder of teflon. The energy absorption build-up factor is calculated for points down the axis of the cylinder. Problem 9 used a Co^{60} source while problem 10 used a Cs^{137} source.

References

- 1) E. Goldberg, et, al.; "Experiments to Test Validity of SORS-G MONTE CARLO Code: I - Au^{198} and Cs^{137} "; UCIR-121; May 1967.
- 2) E. Goldberg, et. al.; "Experiments to Test Validity of SORS-G MONTE CARLO Code"; UCIR-368; Jan. 1969.

Discussion

These calculations simulate experiments performed by E-Division. The energy absorption was measured by thermoluminescent dosimeters placed into the center of teflon disks which were then stacked to form the cylinder. The uncollided absorption was measured by a TLD external to the teflon cylinder. The cylinder was encased in a mild steel can with a hole cut out of the forward end. The references above describe the experiment in more detail (note; figure 3 of reference 1) shows the proper experimental set-up while figure 1 of this reference indicates additional lead collimation not used to obtain the data indicated here.) The cylinder is nominally 27.7 cm

in diameter and 34.3 cm long. The cylinder is small enough in diameter that it may not be considered as an infinite plane.

The Co^{60} source was simulated by one 1.17 and one 1.33 MEV gamma per disintegration. No attenuation associated with this source was considered. The Cs^{137} source which emits a single gamma at 0.661 MEV had a steel jacket and a finite absorption associated with the CsCl contained within it. It was necessary in this case to calculate the leakage spectrum from the source before calculating the attenuation in the teflon.

Point fluence estimators were used in both problems. This technique does not allow an estimate to be made of the statistical accuracy obtained. Figures 17 and 18 present the results obtained experimentally as well as the calculated points. The Co^{60} source problem was run approximately twice as long as the Cs^{137} problem. Neither problem has produced good answers at the far end of the teflon. This could be corrected by additional running time. Results closer to the source seem to be valid, however.

Figure 17 Experimental and calculated build up for Co^{60} source.
 Dots are experimental measurements; solid line represents best fit while dotted line approximates 90% confidence limits to experiment; X's indicate MORSE-L calculated points

Figure 18 Experimental and calculated build up for Cs^{137} source.
Dots are experimental measurements; solid line represents best fit while dotted line approximates 90% confidence limits to experiment; X's indicate MORSE-L calculated points

MORSE-L BENCHMARK PROBLEM ELEVEN

Problem Description

BF_3 gas is contained in a cylinder two inches in diameter and two inches high. This cylinder is surrounded by one inch of CH_2 . An incident beam of 14 MEV neutrons hits one end of the cylinder. The number of protons formed from neutron reactions in the B^{10} are to be calculated.

Discussion

This problem does not represent a real detector but was devised from data on hand to test the different flux estimators available within MORSE-L. At neutron energies above 20 KEV, the BF_3 gas has a very low cross section and all detector types should produce similar results (the reaction type will have poor statistics).

The reaction, predicted reaction, and path length estimators were used to estimate the flux within the BF_3 . The boundary crossing estimator calculated the average flux on the outside of the BF_3 cylinder (a correction was made to the calculated uncollided flux in this case since this part of the calculation was not simulated correctly by the set-up used in this problem). The point flux estimator evaluated the flux at the center of the cylinder.

Table IX contains the results obtained for this problem. There is no indication from these values, or from the additional data contained in the problem output, that the various detector types are not functioning correctly.

TABLE IX RESULTS OBTAINED FOR PROBLEM #11

Estimator type	protons produced per incident neutron	
	<u>neutron reactions > 20 KEV</u>	<u>all neutron reactions</u>
reaction	1.28×10^{-5} (.15)*	1.83×10^{-3} (.042)
predicted reaction	1.55×10^{-5} (.01)	1.72×10^{-3} (.037)
path length	1.55×10^{-5} (.01)	1.86×10^{-3} (.037)
boundary crossing	1.59×10^{-5} (.01)	1.93×10^{-3} (.045)
point	1.59×10^{-5} (.04)	2.15×10^{-3} (.104)

*The value in parenthesis is the fractional standard deviation associated with the calculated result.

XI MORSE-L BENCHMARK PROBLEM TWELVE

Problem Description

A point source in the middle of a sphere formed of dummy material.

Discussion

This problem was put together in order to check the two current estimators available in MORSE-L. The correct currents in the problem can be calculated knowing the source and absorption within the problem. A two energy group problem was established so that the splitting option could also be checked.

The correct results for three spherical surfaces with the problem are given below followed by the results of the boundary crossing current estimator:

	<u>Source less absorption</u>	<u>calculated current</u>
1)	.71340	.71340
2)	.65665	.65665
3)	.62162	.62162

At the outside of the sphere, the calculated currents were:

boundary crossing	0.6216	(.002)
point estimator	0.6209	(.002)

TPW:rt

Distribution

C. Anderson

D. Buchla

P. Brown

G. Canfield

J. Carothers

W. Collins

W. Cooper

R. Da Roza

N. Davies

W. Dickinson

R. Doyas

I. Eccles

R. Ellis

E. Farley

J. Ferguson

J. Fleck, Jr.

H. Francis

R. Geil

W. Grayson

P. Giles

C. Groseclose

D. Hanner

T. Harper

L. Hilton

R. Howe

R. Howerton

J. Hudson

R. Jones

B. Koponen

J. Lee

W. Loewe

G. Maenchen

J. Mallett

S. Matthews

W. McMaster

E. Mendelsohn

G. Miller

J. Mogford

L. Moon

J. Morton

E. McCauley

R. Neifert

N. Parker

S. Perkins

E. Plechaty

C. Prevo

A. Profio

C. Reinhardt

L. Richards

P. Robinson

J. Ruminer

J. Shearer

G. Tiresill

A. Toor

J. Watson

T. Wilcox

TID File, L-9 (2)

NOTICE

"This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights."