2

Colin D. West[1]

DOSIMETRY ISSUES FOR AN ULTRA-HIGH FLUX BEAM AND MULTIPURPOSE RESEARCH REACTOR DESIGN

REFERENCE: West, C. D., **"Dosimetry Issues for an Ultra-High Flux Beam and Multipurpose Research Reactor Design,"** Reactor Dosimetry ASTM STP 1228, Harry Farrar IV, E. Parvin Lippincott, and John G. Williams, Eds., American Society for Testing and Materials, Philadelphia, 1994.

ABSTRACT: The Advanced Neutron Source is a new user facility for all fields of neutron research, including neutron beam experiments, materials analysis, materials testing, and isotope production. The complement and layout of the experimental facilities have been determined sufficiently, at a conceptual design level, to make reliable cost and schedule estimates. The source of neutrons will be a heavy water reactor, constructed largely of aluminum, with an available thermal neutron flux 5-10 times higher than existing research reactors.

Among the dosimetry issues to be faced are damage prediction and surveillance for component life attainment; measurement of fluence and spectra in regions where both change substantially over a distance of a few centimeters; and characterization and measurement of the radiation field in the research areas around the neutron beam experiments.

KEYWORDS: dosimetry, ultra-high flux beam, research reactor, neutron research

INTRODUCTION

The Advanced Neutron Source (ANS) is designed as a new world-class facility for all fields of neutron research. The neutron source is a 330 MW(f), heavy water cooled and reflected research reactor that has a design based heavily on the successful Oak Ridge High Flux Isotope Reactor (HFIR) and the beam reactor at the Institut Laue-Langevin (ILL) in Grenoble. The technical objectives of the project (Table 1) call for thermal and cold neutron beams of unprecedented flux and, also, first-rate irradiation capabilities.

[1]Project director, Advanced Neutron Source, Oak Ridge National Laboratory, P. O. Box 2009, FEDC, MS-8218, Oak Ridge, TN 37831-8218.

TABLE 1--ANS Project research goals.

- To design and construct the world's highest flux research reactor for neutron scattering
  - Provide 5-10 times the flux of the best existing facilities
- To provide isotope production facilities that are as good as, or better than, HFIR
- To provide materials irradiation facilities that are as good as, or better than, HFIR

DOSIMETRY NEEDS

Figures 1 and 2 illustrate some of the components irradiation facilities in and around the reactor core and reflector tank. Figure 3 shows the layout of neutron beam lines and instruments on the ground floor level. A few other instruments are placed on the second floor of the containment building and are fed by slant beam lines originating in the reflector vessel.

Table 2 lists the major experimental facilities in the baseline ANS conceptual design and their characteristics, and Fig. 4 illustrates the very steep flux and spectrum gradients in some of them. In addition, several reactor components requiring surveillance are listed. Appropriate dosimetry must be provided at these various stations to characterize the irradiation conditions.

TABLE 2--ANS Reactor facilities and components requiring dosimetry measurements.

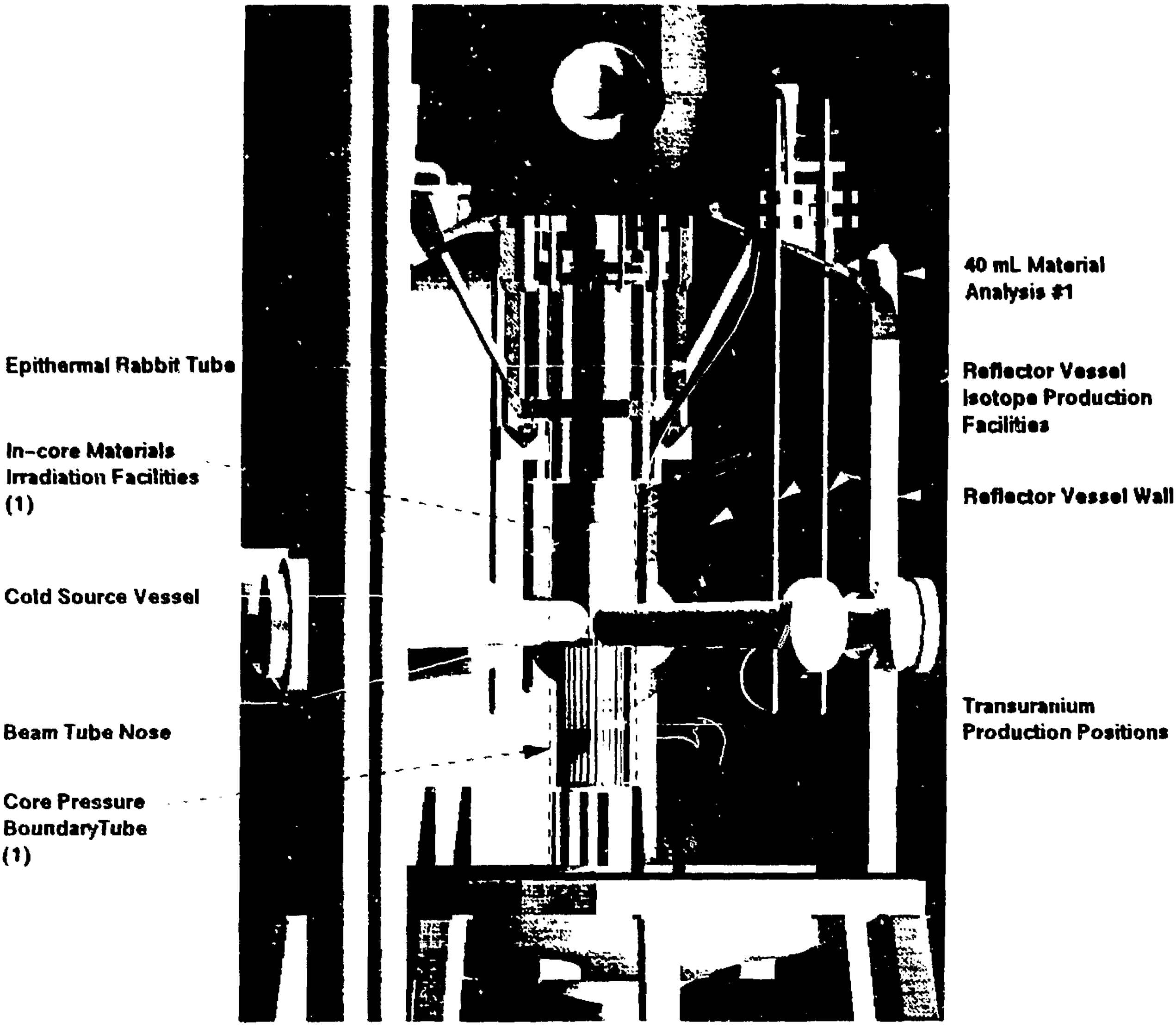
Name (Engineering designation)	Fast flux[a] 10^{19} $m^{-2} \cdot s^{-1}$	Thermal flux[a] 10^{19} $m^{-2} \cdot s^{-1}$	Gamma flux 10^{19} $m^{-2} \cdot s^{-1}$
Fixed irradiation facilities			
In-core materials irradiation facilities	2	4	11
Reflector vessel materials irradiation facilities (SH1, SH2)	0.4	6	6
Transuranium production positions	1.2[b]	4	12

TABLE 2--(continued).

Name (Engineering designation)	Fast flux[a] $10^{19}\ m^{-2}\cdot s^{-1}$	Thermal flux[a] $10^{19}\ m^{-2}\cdot s^{-1}$	Gamma flux $10^{19}\ m^{-2}\cdot s^{-1}$
Reflector vessel isotope production positions (VT-1, VT-2, VT-3, VT-4, HT-1, HT-3, & HT-4)	small	0.9[c]	0.03[c]
Rabbit tubes			
Epithermal isotope production (HT-2)	1.4[b]	6	7
Material analysis 40 mL #1 (PT-1)	small[d]	0.3	0.04
Material analysis 40 mL #2-#5 (PT-2, PT-3, PT-4, PT-5)	small	0.1	0.01
Light water pool rabbit #1 (PF-1)	small	0.05	0.04
Light water pool rabbit #2 (PF-2)	small	0.03	0.04
Components (typical)			
Core pressure boundary tube	1	5	19
Beam tube nose	0.02	7	4
Front face of cold source	0.01	6	5
Reflector tank wall	small	0.2	0.1

[a]End-of-cycle.
[b]Epithermal flux.
[c]Typical.
[d]"Small" means $\sim 10^{14}$ or less.

The 48 beam instruments will attract more than 1000 users a year to carry out experiments lasting from a few days to a few weeks, and the users' environment must be characterized and protected. Neutrons are scattered from samples placed in the beams, and the intensity of the scattered neutron patterns are measured as a function of the sample orientation. In other words, the very nature of the experiments means that the scattered irradiation field is changing in an unpredictable way



Reflector Vessel Components and Experiment Facilities Positions

Fig. 1 (1) The dashed arrow indicates that the component is located here but not shown.

Material Analysis Locations

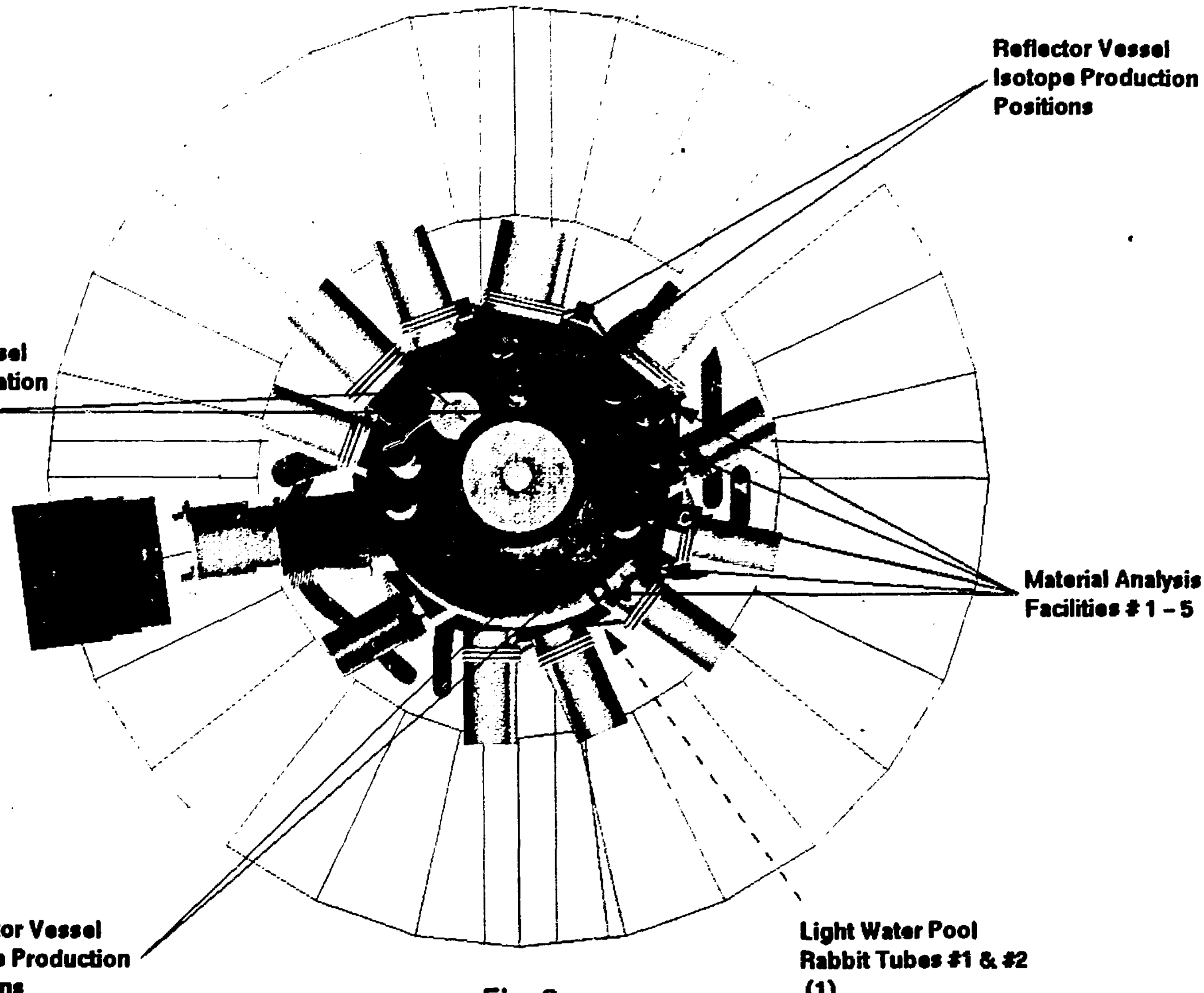


Fig. 2

(1) The dashed arrow indicates that the component is located here but not shown.

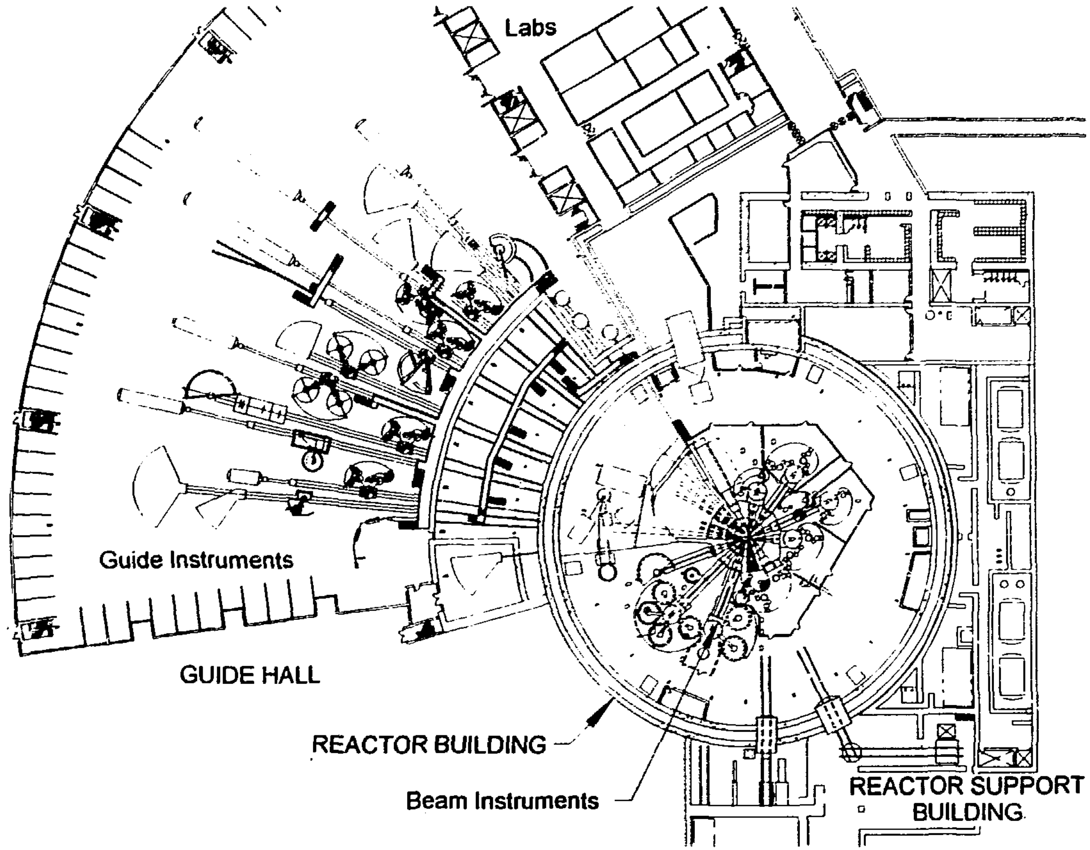


Fig. 3--Ground floor beam lines and instruments.

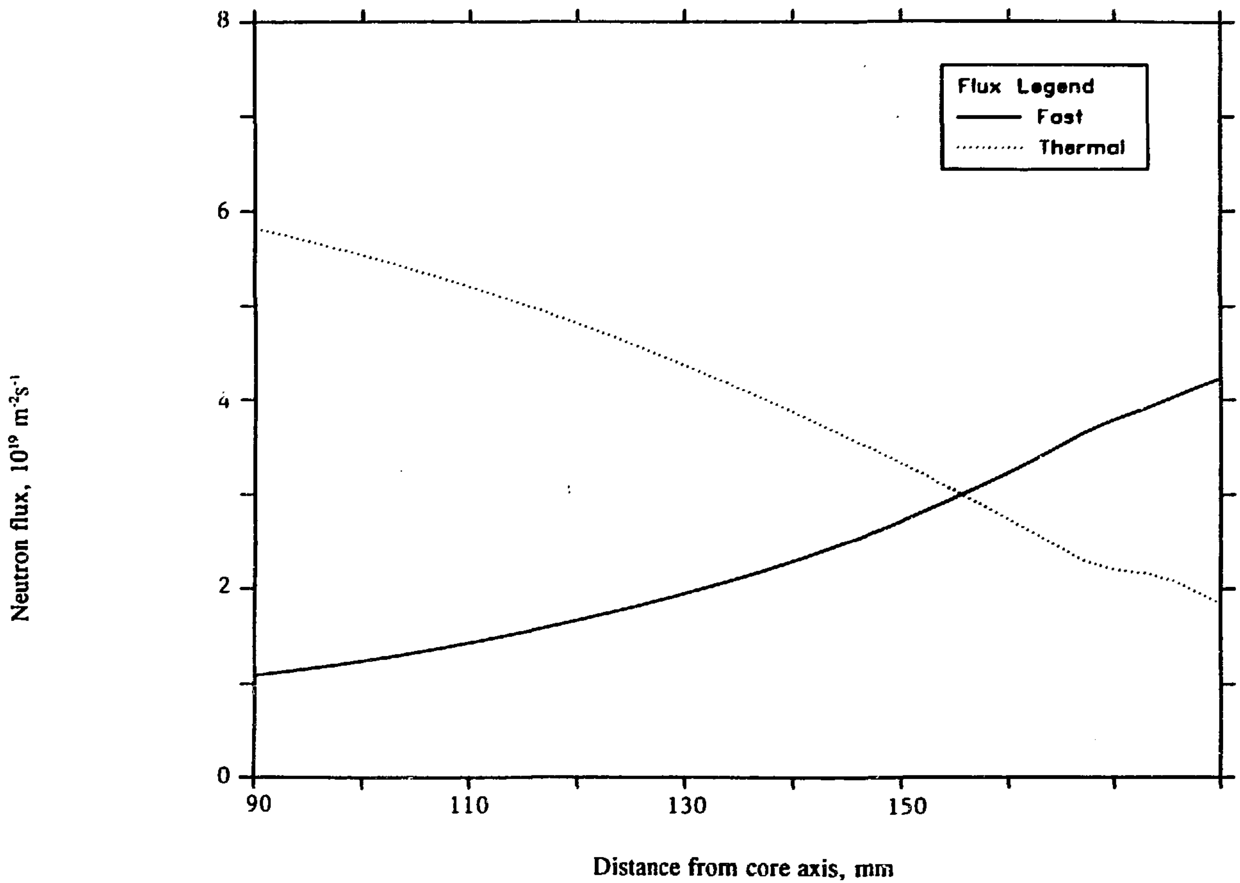


Fig. 4--Fast and thermal flux variation in the region set aside for irradiation facilities inboard of the upper fuel element.

on a very short (seconds or minutes) time scale. Of course, shielding and safety interlocks will be provided, but dosimetry will obviously be a key part of the health physics program.

In addition to the dosimetry required to carry out the ANS research functions, our holistic approach includes two programs--one to ensure safe operation of the reactor and its associated facilities, including the heavy water detritiation and upgrade plant, and one to detect and characterize any environmental releases. Table 3 lists the places and operations outside the reactor requiring a dosimetry program.

TABLE 3--Dosimetry at ANS "away from the reactor."

Beams, guides, and instruments	Beam transport--characteristics of collimated, transported, polarized, and filtered beams; leakage from beam transport systems
	Monochromator--characteristics of radiation scattered from or transmitted through crystal; bulk shielding; leakage path of monochromator shield
	Sample and analyzer crystals--scattered and transmitted radiation
	Access control and general area dosimetry
Primary and reflector heavy water	^{16}N, tritium, and other heavy water activation products
	Activated erosion products, corrosion products, and other flow-entrained materials
	Potential fission product contamination, including core failure scenarios
Spent fuel, irradiated targets, and irradiated reactor components	Prediction of source terms
	Shielding, heating, radiation transport, and criticality safety in refueling stack and tunnel
	Shielding, criticality safety, and heating in refueling cell and transfer locks
	Shielding and criticality safety in spent fuel pools, target handling pool and cells, and containment transfer locks
	Shielding and contamination control in cask loading and segmentation areas
Heavy and light water cleanup systems	Normal and emergency system source terms
	Shielding and contamination control during handling of filter cartridges and resins
	Deuteration and dedeuteration

TABLE 3--(continued).

Plant waste systems	Identification and inventory assessments in all waste systems
	Shielding
	Effluent monitoring
	Integration into site monitoring network
Detritiation and upgrade facility	Tritium monitoring (general)
	Process tritium dosimetry
	Control of other radioactive contaminants
Ventilation systems	Filter monitoring
	Contamination control at filter stations and in ductwork
	Dry ventilation systems, tritium and heavy water recovery
	Stack monitoring
	Integration into site monitoring network
General health physics	Personnel dosimetry
	Tritium bioassay program
	Area and portal monitors
	Routine and special surveys
	ALARA and work permits

With the completion of a conceptual design for the ANS last year, there are sufficient design information and analyses of the neutron and gamma spectra around the core (although more are still needed) to begin planning for the ANS dosimetry programs. The advice and guidance of the community is eagerly sought.

Table 4 lists our preliminary thinking about some of the dosimetry techniques that might be used for the reactor and experimental facilities. Once again, we would appreciate the advice of the community.

TABLE 4--Proposed dosimetry techniques for ANS.[a]

Neutron detectors

Radioactivation monitors (RMs)

TABLE 4 (continued).

Solid state track recorders (SSTRs)
Helium accumulation fluence monitors (HAFMs)
Bonner sphere spectrometers
Neutron spectrometers (proton-recoil detector, NE-213 scintillator, Stilbene scintillator)
Tissue equivalent proportional counter (TEPC)
HE-3 spectrometer
Multisphere spectrometers (lithium iodide detectors with polyethylene spheres)

Gamma detectors

Thermoluminescent dosimeters (TLDs)
High purity germanium (Hp Ge) and lithium drifted germanium detectors

[a]This tentative list of dosimetry techniques for the various ANS facilities and operations discussed earlier was kindly provided by F. B. Kam.

CONCLUSION

ANS will require carefully designed dosimetry programs to measure (1) the neutron flux and spectrum in very high flux regions with very steep gradients in and around the core; (2) the radiation environment around the neutron beam experiments, which will change during the course of those experiments; (3) the radiation environment encountered by the operators of the reactor and its support facilities; (4) the flux and spectrum experienced by certain reactor system components; and (5) environmental monitoring outside the reactor buildings. Planning for these programs is just beginning.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the help received from, inter alia, E. E. Alston, F. B. Kam, F. J. Peretz, D. L. Selby, B. R. Smith, and B. A. Worley.