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HEAVY METAL SHIELDING FOR NEUTRON SOURCES*

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Figure 22 of ICRP Publication 21 (ICRP71) adapted here in Fig. 1 shows the dose equivalent transmission of ^{252}Cf neutrons through lead and polyethylene. The lead transmission is incorrect and could possibly cause unnecessary exposures through its use. This observation is based on our recent measurements of the shielding of heavy metals for neutrons and our calculations using two different computer codes. One of the codes was MORSE (St70) which uses Monte Carlo methods and DLC-37C cross section compilations. The other was ANISN (En67) which uses discrete ordinate methods and DLC-2 cross section data.

Our experimental measurements used a ^{252}Cf source emitting 2.59×10^8 n/sec. The source was placed 3.35 meters above the ground in an aluminum lattice tower in an open area well away from buildings, the detectors were 1.98 meters above the source and the source to detector distance was kept constant. Lead and iron shields were built up around the source in the form of hollow cubes using standard 5.1 cm x 10.2 cm x 20.3 cm bricks. Fluence was measured with a BF_3 counter inside a cylindrical polyethylene shield 6 cm thick with a cadmium outer cover. An Andersson-Braun (An63) detector was used to measure dose equivalent and

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both detectors used scalers for readout. Because of the weight limitations of the tower, we were unable to use shield thicknesses greater than 15.2 cm.

The experimental and calculated transmission of both dose equivalent and fluence are plotted in Figs. 2-4 for lead, iron and tungsten, respectively. No experimental points for tungsten are available. The shielding value of heavy metals for neutrons is largely due to a reduction of the neutron energy through inelastic scattering. Lead and iron show very little attenuation of fluence and tungsten shows only moderate attenuation. It can be seen that the measured fluence transmission for iron and lead is greater than calculated by either MORSE or ANISN. We believe this is because the ^{252}Cf spectrum has approximately 20% of its neutrons above 3 MeV where the response of our moderated BF_3 begins to fall off. As these neutrons pass through the metal shields, their energy is decreased to a region where they are counted more efficiently which makes the measured transmission too high. To a lesser degree, this is also true of the Andersson-Braun detector and the effect seems to be visible for the thicker absorbers.

MORSE and ANISN agree very well for lead and not quite so well for iron and tungsten, presumably due to the different cross sections used. However, the largest discrepancy (~ 50% for dose equivalent transmission through 30.5 cm Fe) is probably not too serious for shielding purposes. It should be observed that for 30 cm of lead, MORSE and ANISN predict ~ 70% transmission of dose equivalent while Fig. 1 would predict about 25%.

Both MORSE and ANISN calculations agree well with the polyethylene attenuation curve in Fig. 1. Recent experimental measurements (Gr 77) up to 10 cm thickness also agree well.

REFERENCES

An63 Andersson I. O. and Braun J., 1963, "A Neutron Rem-Counter with Uniform Sensitivity from 0.025 eV to 10 MeV," Neutron Dosimetry, Vol. 2, pp. 87, IAEA Vienna.

En67 Engle W. H. Jr., 1967, "A One-Dimensional Discrete Ordinates Transport Code with Anisotropic Scattering," ANISN Users Manuel, USAEC-Report K-1693.

Gr77 Griffith R. V., Slaughter D. R., Patterson H. W., Beach J. L., Frank E. G., Rueppel D. W. and Fisher J. C., 1977, "Multi-Technique Characterization of Neutron Fields from Moderated ^{252}Cf and ^{238}Pu Be Sources," UCRL-Preprint 79483.

ICRP71 International Commission on Radiological Protection, 1971, "Data for Protection Against Ionizing Radiation from External Sources: Supplement to ICRP Publication 15," ICRP Publication 21.

St70 Straker E. A., Stevens P. N., Irving D. C. and Cain V. R., 1970, "The MORSE Code - A Multigroup Neutron and Gamma Ray Monte Carlo Transport Code," Oak Ridge National Laboratory, ORNL-CFN-70-2-31.

FIGURE CAPTIONS

1. Broad beam dose equivalent transmission of ^{252}Cf neutrons through slabs of lead and polyethylene. Adapted from ICRP Publication 21 (ICRP71).
2. Measured and calculated dose equivalent and fluence transmission of ^{252}Cf neutrons through lead.
3. Measured and calculated dose equivalent and fluence transmission of ^{252}Cf neutrons through iron.
4. Calculated dose equivalent and fluence transmission of ^{252}Cf neutrons through tungsten.

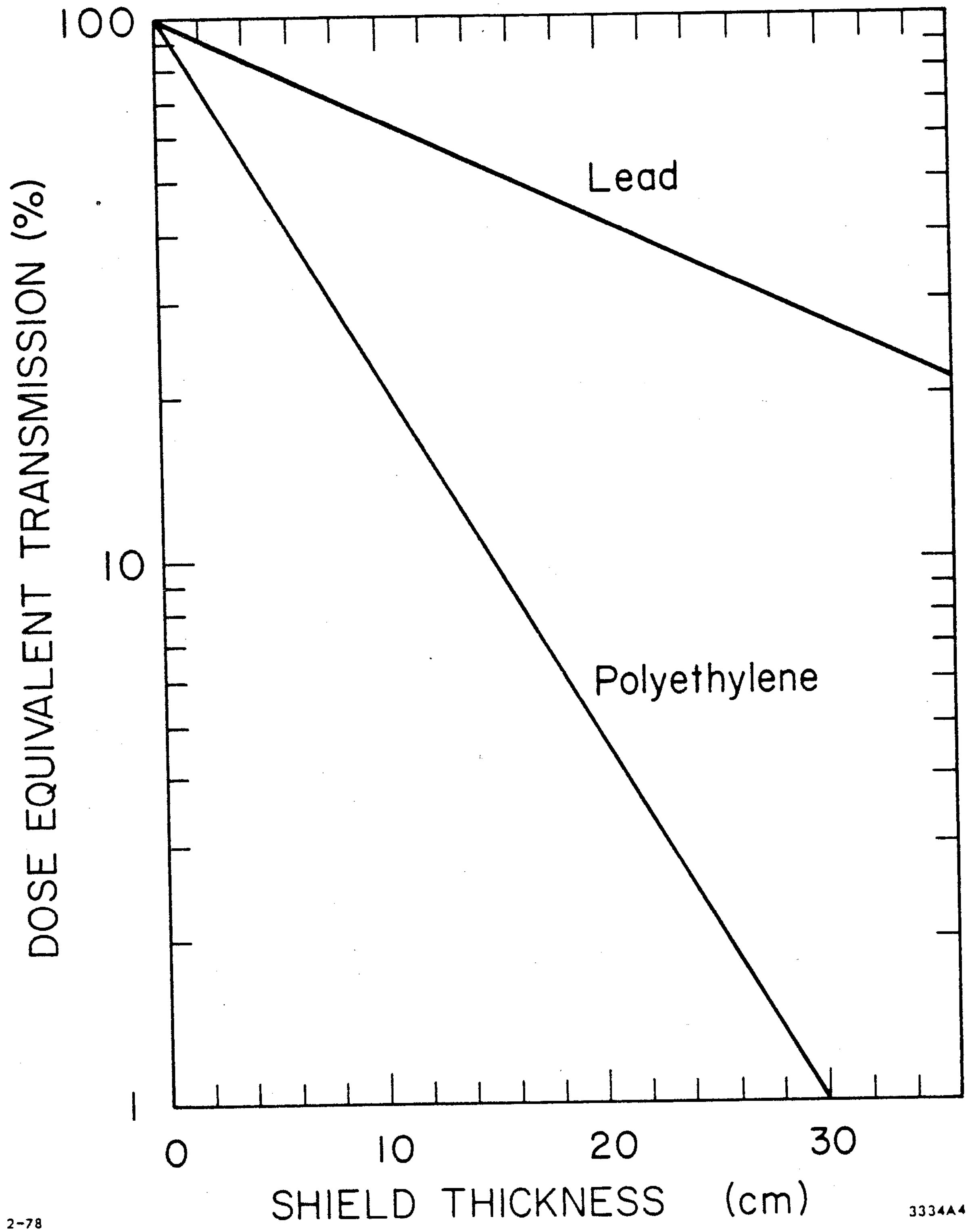

100
10
1
Lead
Polyethylene
DOSE EQUIVALENT TRANSMISSION (%)
0
10
20
30
SHIELD THICKNESS (cm)
2-78
3334A4

Fig. 1

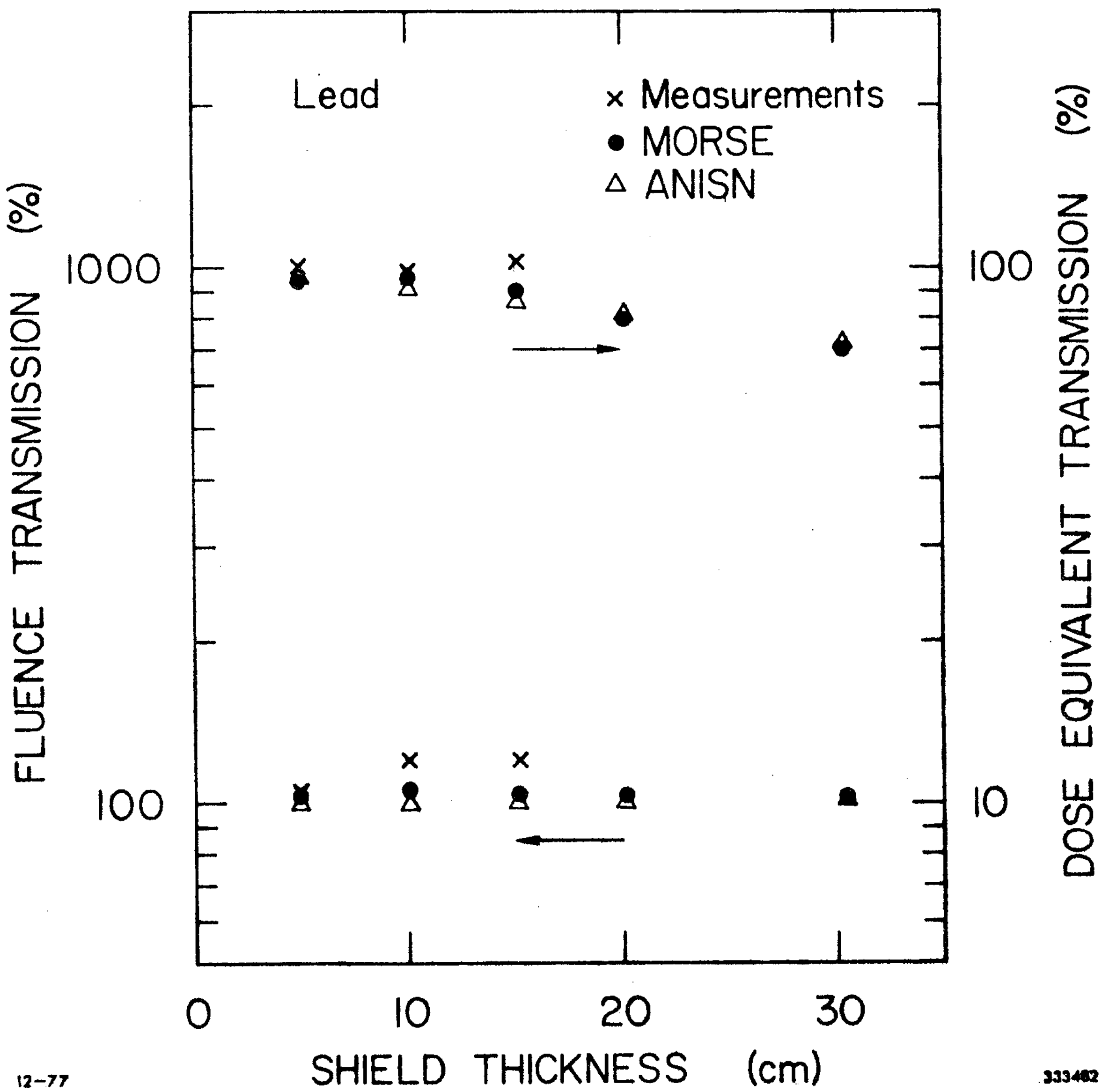

Lead
× Measurements
● MORSE
△ ANISN
FLUENCE TRANSMISSION (%)
1000
100
DOSE EQUIVALENT TRANSMISSION (%)
100
10
0
10
20
30
SHIELD THICKNESS (cm)
12-77
333482

Fig. 2

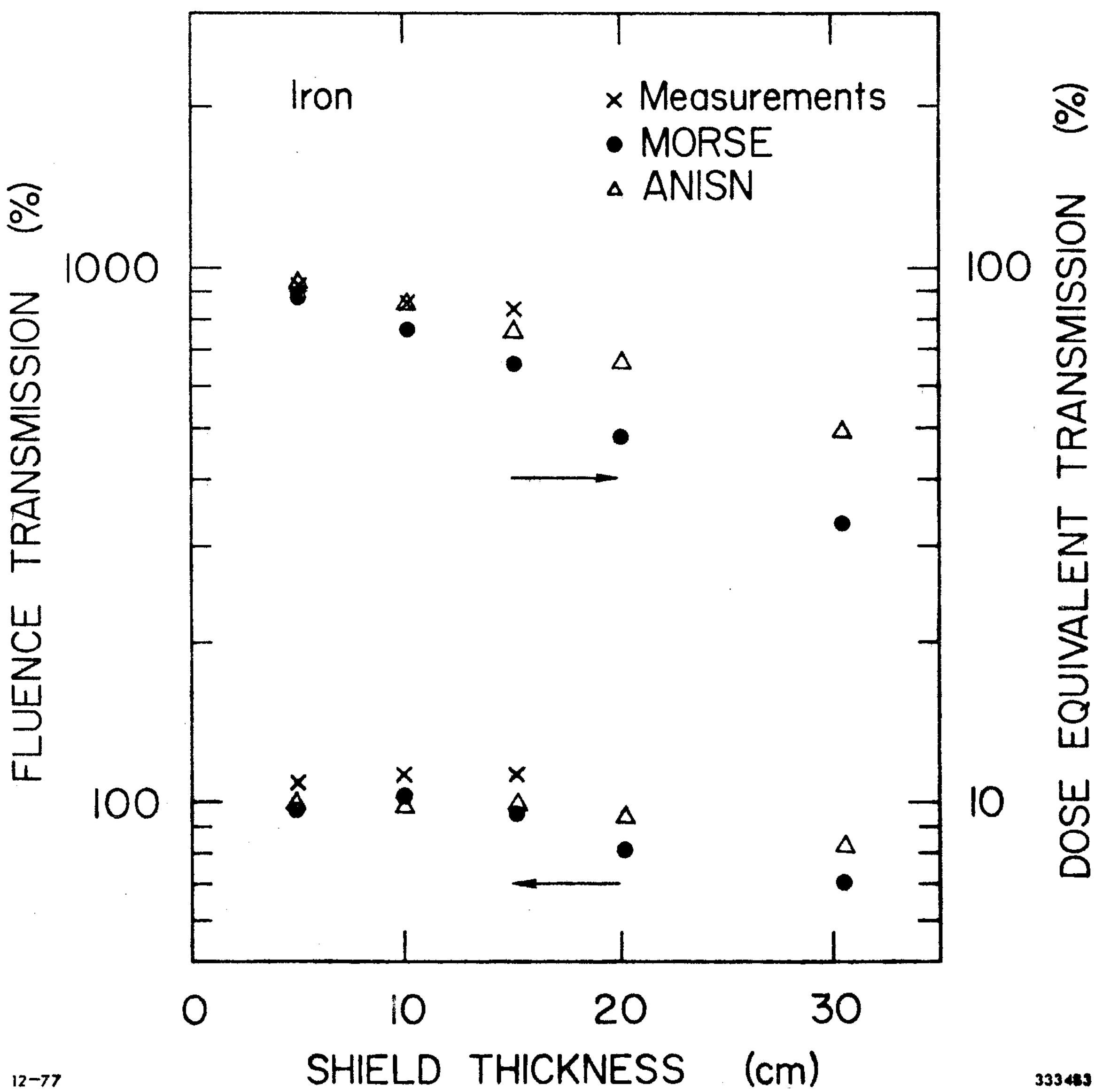
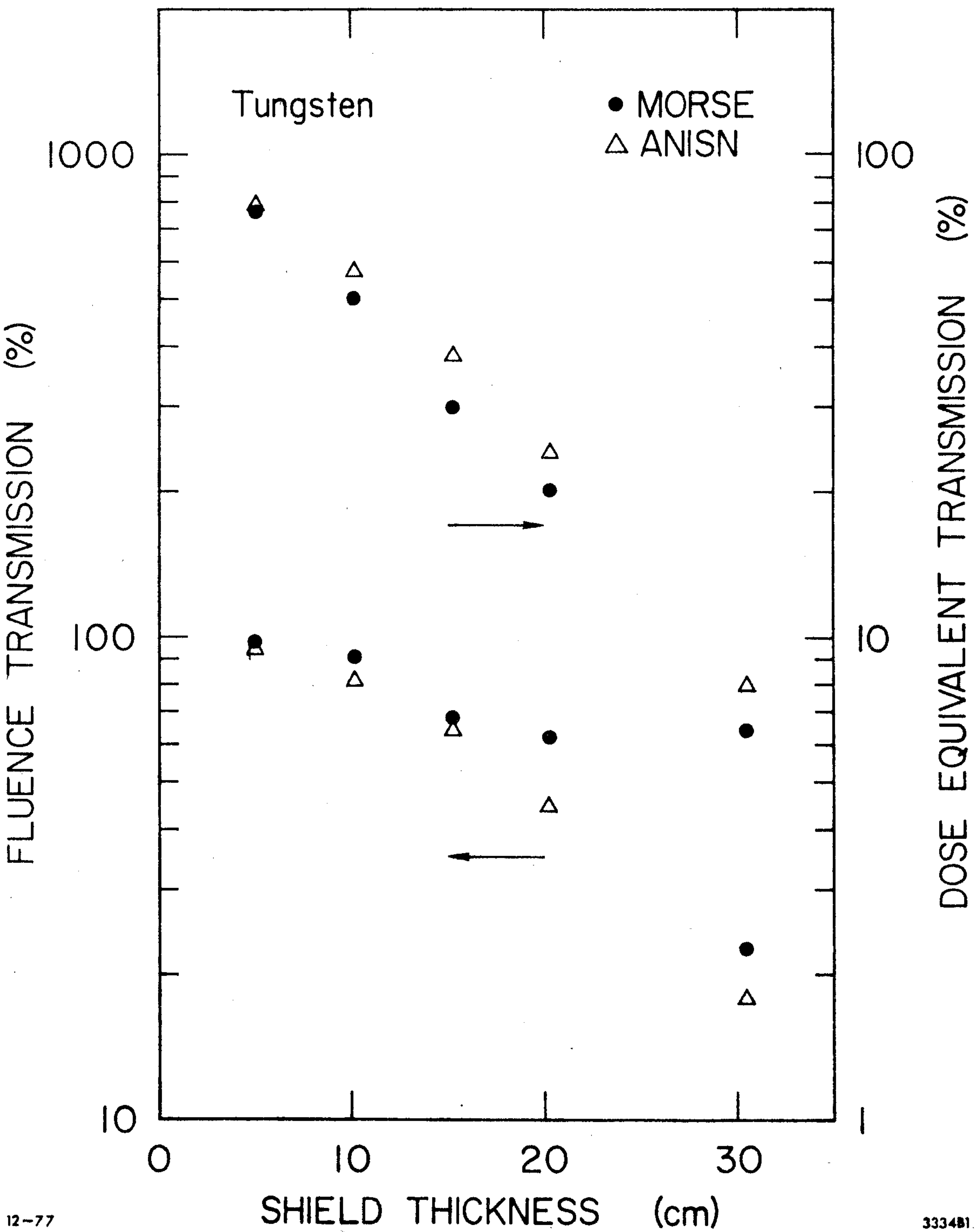

Iron
× Measurements
● MORSE
△ ANISN
FLUENCE TRANSMISSION (%)
DOSE EQUIVALENT TRANSMISSION (%)
1000
100
100
10
0
10
20
30
SHIELD THICKNESS (cm)
12-77
333483

Fig. 3


Tungsten
● MORSE
△ ANISN
1000
100
10
100
10
1
FLUENCE TRANSMISSION (%)
DOSE EQUIVALENT TRANSMISSION (%)
0
10
20
30
SHIELD THICKNESS (cm)
12-77
333481
Fig. 4