Conf-9205116--2

IRRADIATION FACILITIES AT THE ADVANCED NEUTRON SOURCE*

Colin D. West
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831, USA

CONF-9205116--2

DE92 015086

The Advanced Neutron Source is a new, reactor-based facility for all kinds of neutron research proposed for construction at Oak Ridge. It will replace, and greatly out-perform, the aging research reactors at Oak Ridge and Brookhaven. One of the technical objectives for the project is "to provide materials irradiation facilities that are as good as, or better than, the High Flux Isotope Reactor (HFIR)." In practice, the main scientific justification for the new facility lies in the neutron beams that it will produce, which will be an order of magnitude more intense than any available at present. Although the need to optimize the reactor system design for beam production puts some limitations on the irradiation capabilities, the flux at the proposed facilities exceeds the flux available at HFIR; however, the gamma heating rate is also higher, limiting the specimen size that can be accommodated.

The user community, through the National Steering Committee for an Advanced Neutron Source, defined the materials irradiation and isotope production needs and helped to balance the allocation of priorities between different applications of the reactor. The Committee has requested 10 materials irradiation positions — 5 of them instrumented — similar in size to the HFIR target positions (17-mm diam) with a fast flux of at least 1.4×10^{19} $m^{-2}.s^{-1}$. Eight instrumented positions similar to the new removable beryllium positions at the HFIR (48-mm diam) are also requested, with a fast flux of at least 5×10^{18} $m^{-2}.s^{-1}$. The committee also set design goals for the annual transuranic isotope production capability: 1.5 g of ^{252}Cf and 40 μg of ^{254}Es. The present conceptual design contains such facilities and also a number of rabbit tubes in the reflector region, where there is a very large volume of high-thermal flux with very low fast-flux contamination, plus one rabbit tube in a region of high-epithermal flux that is primarily intended for isotope production but could also be used for materials testing.

---

* Prepared by the Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831; operated by Martin Marietta Energy Systems, Inc.,for the U.S. Department of Energy under Contract No. DE-AC05-840R21400.

Introduction

The Advanced Neutron Source (ANS) is a facility, centered around a new 330 MW(f) heavy-water cooled and reflected research reactor, proposed for construction at Oak Ridge. The main scientific justification for the new source is the United States' need for increased capabilities in neutron scattering and other neutron beam research,[1] but the technical objectives of the project also cater for the need to replace the irradiation facilities at the aging High Flux Isotope Reactor - see Table 1 - and to provide other research capabilities to the scientific community.

Irradiation Facilities

Extensive input from the user community (Table 2) has provided the design bases of the various experimental facilities included in the conceptual design of the ANS. These design objectives, and many other requirements relating to the facility performance and safety, are formally documented in the Plant Design Requirements:[2] it is of course necessary to maintain very formal and controlled documentation of any project involving a nuclear reactor.

Table 3, copied from the Plant Design Requirements, lists the many irradiation facilities that the user community has requested. The ANS reactor core is made up of two coaxial elements, of different radii, separated by a small axial gap. Each annular element is made up of involute, aluminum clad fuel plates similar to the High Flux Isotope Reactor (HFIR) at Oak Ridge or to the High Flux Reactor (HFR) at the Institut Laue-Langevin. Such a design combines the short heated length of the HFIR core with the greater neutronic length of the ILL design (Fig. 1). Figure 2 shows the in-core irradiation positions. Because the heavy-water coolant is a relatively poor moderator relatively few neutrons are thermalized in the central hole region, and so the spectrum in the region inside the elements is relatively hard. The very center of the region is occupied by the control rods, but the space immediately above the lower fuel element is available for materials irradiation positions. The space below the upper fuel element has a more epithermal spectrum, being located between the fission neutron source and the thermal flux peak out in the reflector tank. Although the inner positions are primarily intended for materials irradiation testing, and the outer for transuranium isotope production, the uninstrumented materials capsules and the production capsules are interchangeable.

There are three main sets of irradiation facilities in the reflector tank: the six rabbit tubes, the four production positions for isotopes other than the transuranics, and the two large slant facilities, of 52.3-mm internal diameter (46-mm diameter sample capsule), are shown in Figs. 3 and 4.

One of the rabbit tubes is designed to place capsules in an epithermal flux region for short irradiations — i.e., less than a full cycle — for transuranic isotope production.

The two large slant facilities, each capable of accepting a 46-mm diameter capsule, are additional materials irradiation testing positions.

There are two rabbit tubes in the light water pool outside the reflector tank, where the spectrum is extremely soft and the neutron flux is still 4×10^{17} $m^{-2}.s^{-1}$ (i.e., 4×10^{13} $cm^{-2}.s^{-1}$).

A gamma irraidation facility will be available in the spent fuel pool.

Conclusion

By virtue of its high power level and unique fuel element configuration the Advanced Neutron Source, although optimized for neutron beam production, will offer powerful and versatile irradiation capabilities.

References

1. "Major Facilities for Materials Research and Related Disciplines," National Research Council, National Academy Press (1984).

2. Advanced Neutron Source Plant Design Requirements, Rev. 2, 8/22/91, ORNL/TM-11625.

Table 1. Project technical objectives

1.	To design and construct the world's highest flux research reactor for neutron scattering
	- 5-to-10 times the flux of the best existing facilities
2.	To provide isotope production facilities that are as good as, or better than, the High Flux Isotope Reactor (HFIR)
3.	To provide materials irradiation facilities that are as good as, or better than, HFIR

Table 2. User community interactions

• National Steering Committee for an Advanced Neutron Source
• ANS/Brookhaven Scattering Workshop
• Californium Workshop
• Goland Subcommittee on Materials Irradiation

Table 3. Irradiation Facilities at the ANS

Parameter[a,b]	Criterion
Materials irradiation	
Small specimens	
Fast flux	≥1.4
Fast:thermal ratio	≥1:2
Total number of positions	10
Number of instrumented positions	5
Damage rate (dpa/y in stainless steel)	≥30
Nuclear heating rate (w/g in stainless steel)	≤54
Axial flux gradient over 200 mm	≤30%
Available diameter (mm)	≥17
Available length (mm)	≥500
Larger specimens[c]	
Fast flux	≥0.5
Fast:thermal ratio	≥1:3
Number of instrumented positions	≥8
Damage rate (dpa/y in stainless steel)	≥8
Nuclear heating rate (w/g in stainless steel)	≤15
Axial flux gradient over 200 mm	≤30%
Available diameter (mm)	≥48
Available length (mm)	≥500
Isotope production	
Transuranium production	
Epithermal flux	≥0.6
Epithermal:thermal ratio	≥1:4
Allowable peak heat flux (MW/m^2)	≥4.0
Total annual production:	
^{252}Cf (g)	1.5
^{254}Es (μg)	40
Other isotopes	
Thermal flux	≥1.7
Number of reflector positions	≥4
Epithermal hydraulic rabbit tube	Epithermal flux peak position
Epithermal:thermal ratio	≥1:4
Allowable peak heat flux (MW/m^2)	≥1.75
Materials analysis	
Activation analysis pneumatic tubes	
40 cm^3 rabbits in reflector	4
1 cm^3 rabbits in reflector	1
Thermal flux at reflector rabbit positions	≥0.2
Heating rate:	
Temperature in a 40 cm^3 high density polyethylene rabbit (°C)	≤120

Table 3. Irradiation Facilities at the ANS (cont'd)

Parameter[a,b]	Criterion
Rabbit tubes in light water pool	2
Thermal flux at light water rabbit positions	≥0.04
Prompt-gamma activation analysis cold neutron stations	
Low-background (multiple beam) guide system	1
Neutron depth profiling	
Number of slant cold beams	1
Gamma irradiation in spent-fuel pool	≥1

Notes:

[a] All fluxes in units of 10^{19} $m^{-2} \cdot s^{-1}$

[b] Neutron spectra are defined as follows: Thermal ≤0.625 eV, 0.625 eV ≤ Epithermal ≥100 eV, Fast >0.1 meV

Sources of neutrons for research are classified as follows: Ultracold <25 μeV, 25 μeV < Very Cold <0.1 meV, 0.1 meV < Cold < 5 meV, 5 meV < Thermal <0.625eV, 0.625 < Hot <1 eV

[c] The large materials irradiation specimens are intended to replace irradiation facilities in the HFIR removable beryllium region. It is unlikely that ANS will be able to meet these goals since the simultaneous requirements of high fast:thermal flux ratio, high fast flux, and low heating rate are intrinsically incompatible with the physics of an undermoderated core.

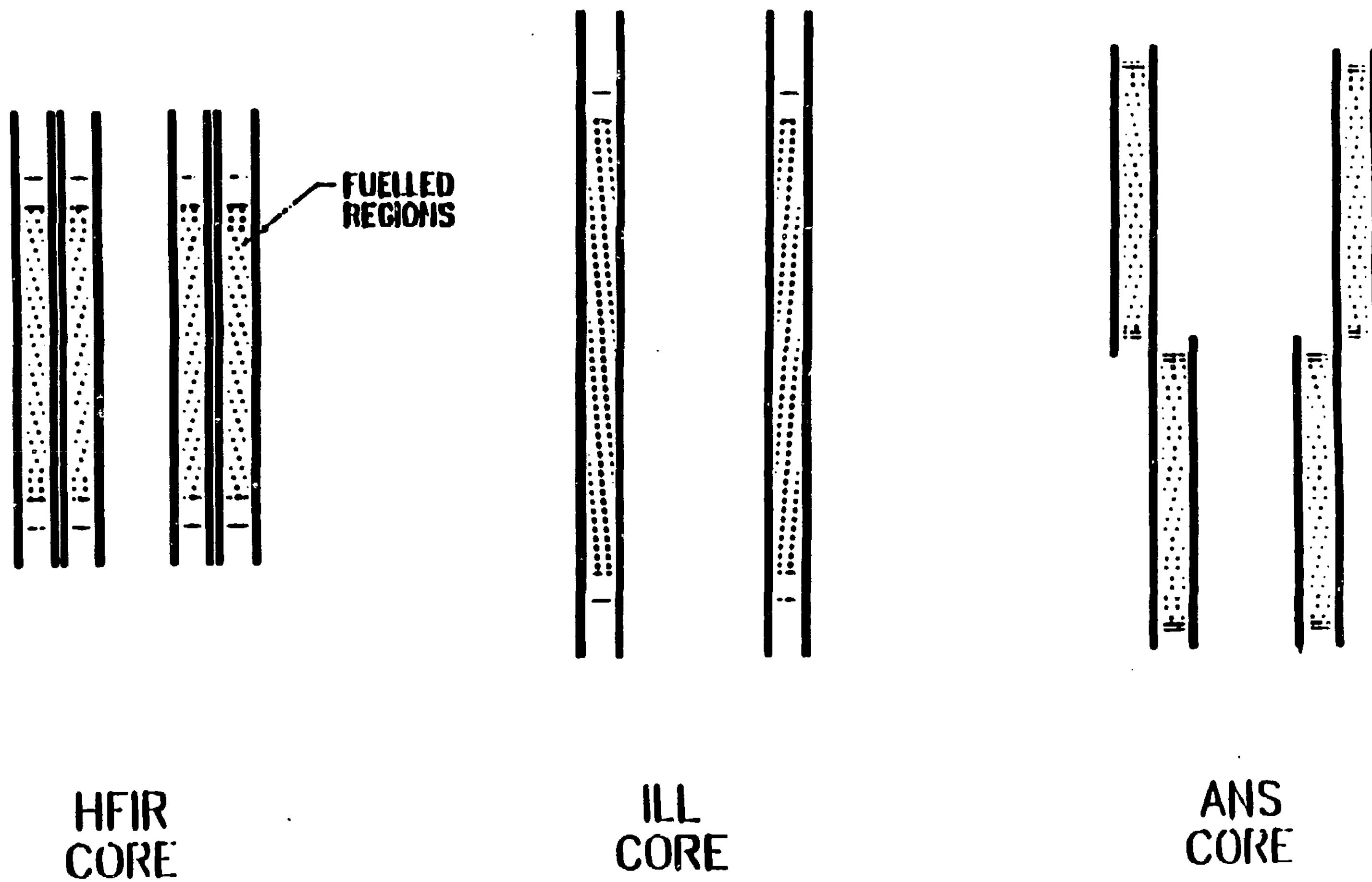

Fig. 1. Scale comparison of HFIR, ILL, and ANS cores

In-Core Irradiation Facilities

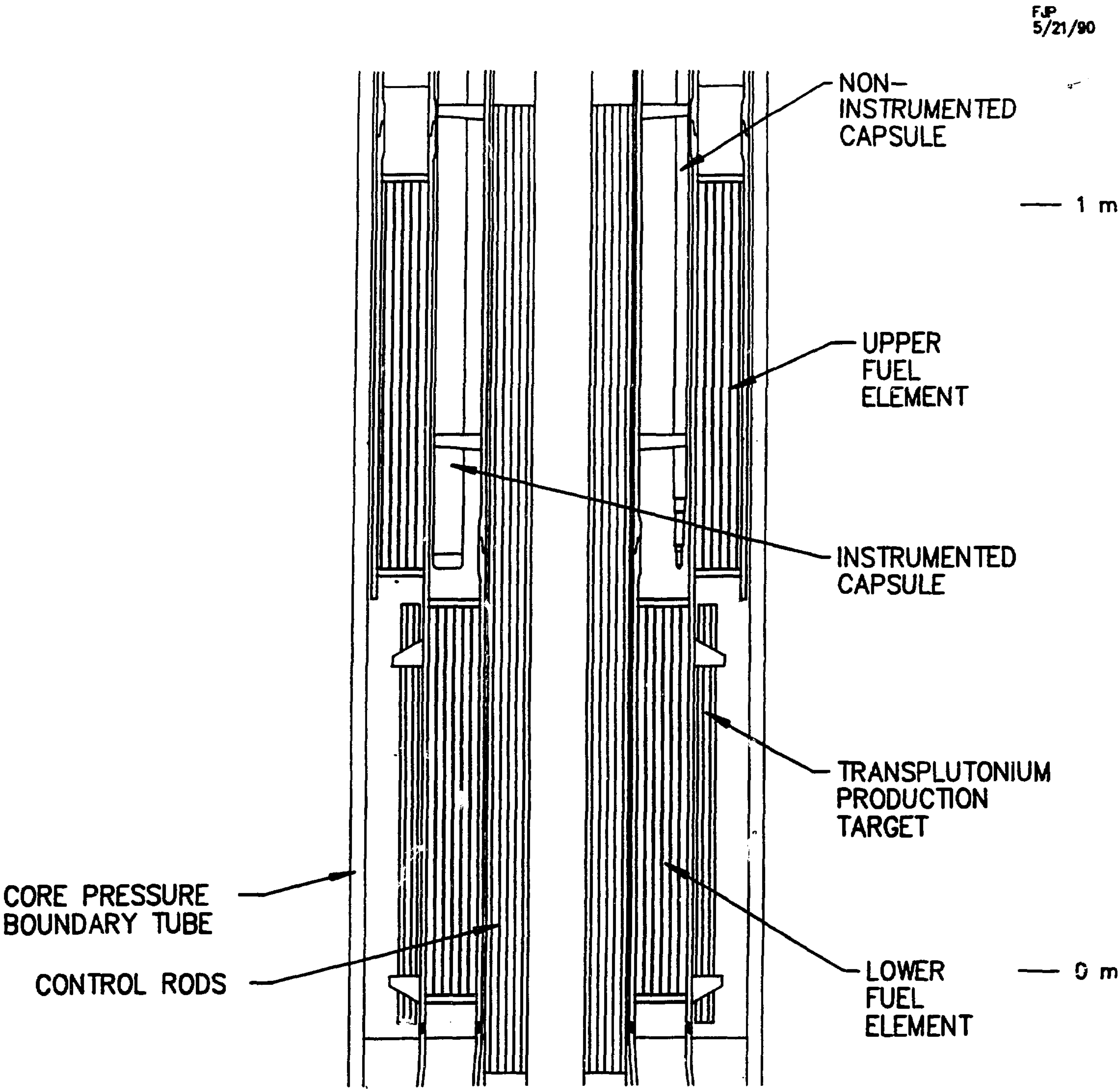

Figure 2

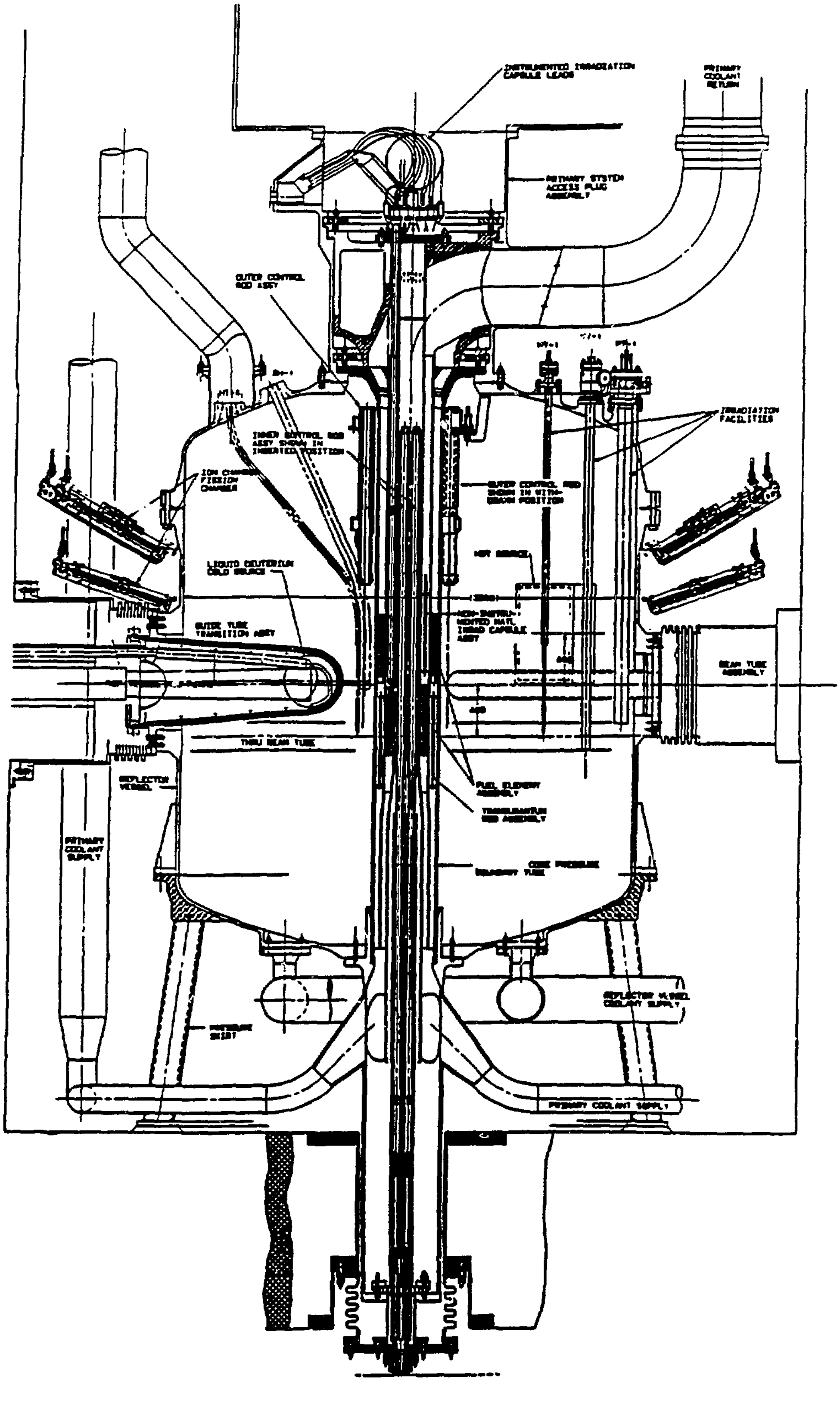

Fig. 3. Side view of reflector tank irradiation facilities

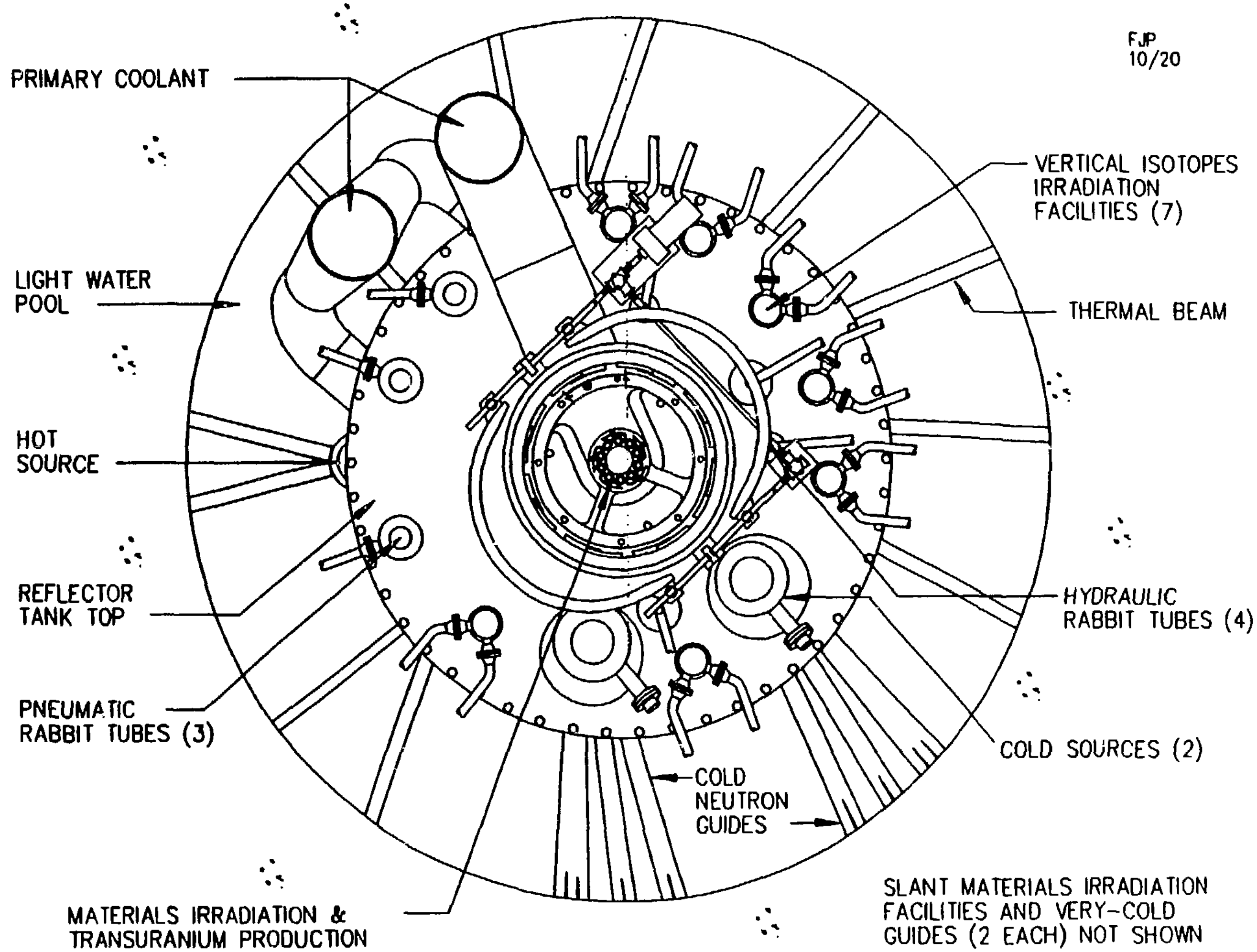

Fig. 4. Plan view of reflector tank irradiation facility access points