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# PRELIMINARY CONSIDERATIONS OF AN INTENSE SLOW POSITRON FACILITY BASED ON A $^{78}$KR LOOP IN THE HIGH FLUX ISOTOPES REACTOR

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## INTRODUCTION

Suggestions have been made to the National Steering Committee for the Advanced Neutron Source (ANS) by Mills (1) that provisions be made to install a high intensity slow positron facility, based on a $^{78}$Kr loop, that would be available to the general community of scientists interested in this field. The flux of thermal neutrons calculated for the ANS is 5 E+15 sec$^{-1}$ cm$^{-2}$, which Mills has estimated will produce a 5 mm beam of slow positrons having a current of about 1 E+12 sec$^{-1}$. The intensity of such a beam will be at least 3 orders of magnitude greater than those presently available. The construction of the ANS is not anticipated to be complete until the year 2000. In order to properly plan the design of the ANS, strong considerations are being given to a proof-of-principle experiment, using the presently available High Flux Isotopes Reactor, to test the $^{78}$Kr loop technique. The positron current from the HFIR facility is expected to be about 1 E+10 sec$^{-1}$, which is 2 orders of magnitude greater than any other available. If the experiment succeeds, a very valuable facility will be established, and important information will be generated on how the ANS should be designed.

## A PRELIMINARY DESIGN FOR A $^{78}$KR SLOW POSITRON LOOP

The sketch in Figure 1 shows a preliminary concept for a Kr loop facility in the HFIR. Krypton gas will be introduced into a cylinder located in the beryllium neutron reflector outside the reactor core. The gas will be irradiated for about 100 hrs (half life of $^{79}$Kr is 35.0 hr) to achieve saturated activity. The gas will then be condensed inside a cup cooled to 6° K. Neon gas will be condensed on the Kr layer as a moderator. The slow positron beam coming out of the cup will be put through Soa lens optics and then brightness enhanced. The voltages on the cup, Soa lens elements, and brightness enhancement film will probably be similar to those suggested by Canter et al. (2). After initial brightness enhancement the positron beam can be manipulated for whatever spectroscopic purposes desired. In an additional paper included in these proceedings the authors make suggestions for how it can be used for microanalysis of materials.

Note that the overall dimensions of the source cup and its associated optics in Figure 1 are rather large. One concludes that the scale of the source cup and the Soa optics must follow the following rule:

$$\text{length (or width) of optical element} = \text{const.} * W * (c/f)^{1/2}$$

W = Width of the mouth of Kr cup    c = desired positron current

f = thermal neutron flux





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The activated krypton must be condensed as a thin film. The thickness of the film will be constant, independent of the total mass of Kr; therefore the area of the cup must be directly proportional to the mass of Kr. Thus the linear dimensions of the cup and the associated optics must scale as the square root of the total mass of condensed krypton, which is proportional to the desired positron current. The mass of krypton required to produce a given positron current is inversely proportional to the slow neutron flux of the reactor.

In Figure 1 a condensation cup with an inside diameter of 6 cm, length of 12 cm, is considered. This is based on the estimate by Mills (1) that a Kr thickness of 160 um should be used. Our group is in the process of making a Monte Carlo calculation of the optimum Kr thickness. In order to keep spherical aberration to a reasonable level, the inside diameter of the first Soa lens element has been set at 12 cm, twice that of the cup. The lengths and widths of the rest of the Soa system are proportional to those of the first lens. About 0.1 mole of $^{78}$Kr is required to coat the inside of the cup in Figure 1. It will be necessary to use enriched $^{78}$Kr. The price of 99% $^{78}$Kr is $15,500 per STP liter.

The highest flux of neutrons presently available in one of the permanent beryllium irradiation facilities in the HFIR is about 4 E+14 $sec^{-1}$ $cm^{-2}$. The specific positron emission of the condensed Kr layer is directly proportional to the neutron flux in the reactor. The ANS will be higher in flux by about a factor of 10. Mills (1) has estimated that the size of the krypton cup necessary to produce a slow positron current of 1 E+12 $sec^{-1}$ is 12.5 cm x 25 cm. This will require that the size of the Soa lens be slightly greater than twice that shown in Figure 1; perhaps a bit unwieldy. Mills is presently considering experiments with Ne moderator configurations for which the mouth of the cup can be made smaller (3). This is highly desirable in order to keep the dimensions of the facility to a manageable size.

Figure 2 shows the location of the Kr loop facility in the HFIR. There is adequate room for large add-on equipment such as ACAR. The neutron scattering facility of the HFIR is on the floor immediately below the Kr site. There should be no interference between the Kr loop and the other experiments being conducted at the HFIR.

## ANTICIPATED PROBLEMS

The krypton loop facility appears to be feasible, but it is not without foreseeable problems. These can be overcome with proper planning.

Mills has estimated that the positron source cup of the ANS facility will have a heat load of 3-5 Watts (1), depending upon the amount of Kr that is activated. Helium refrigerators should be able to handle this. There will be no appreciable temperature gradient across the Kr film.

Contamination of the Ne moderator may be a problem, even with an extremely clean vacuum environment. It will be possible to flash the contaminated Ne away by heating from 6° K to higher temperatures and then recondensing the Ne.

It is not known whether or not the Ne moderator will withstand the radiation damage imposed by intense positron sources. If radiation damage becomes a problem, it may be possible to eliminate it by periodic annealing of the Ne film.

Causing the Kr film to condense exclusively inside the source cup, and not on the outside also, will possibly present a problem. It may be necessary to use special protocols for cooling the inside of the cup to lower temperatures than the outside.

The activated Kr will transmute to Br which may cause vacuum contamination problems. Although a small amount chemically, the bromine might corrode the metal surfaces of the inside of the vacuum system, causing moisture collection and subsequent outgassing. Special gettering procedures will be necessary to keep the vacuum system free of Br contamination.

Radiation safety is of utmost concern. The possibility of vacuum accidents, from broken feedthrus, or improper operating procedures, must be taken into account, and the capacity for handling such emergencies must be built into the facility. A preliminary review by ORNL health physicists indicates that there is not unreasonable hazard. Since $^{79}$Kr is inert chemically, its toxicity and environmental retention factors are reduced in severity. Its daughter product, $^{79}$Br, is a stable isotope.

## CONCLUSIONS

The suggestion that a $^{78}$Kr loop in a nuclear reactor be used as a basis for a high intensity slow positron facility is sufficiently valid to warrant a proof-of-principle experiment. Results of such an experiment will have a profound impact on the design of the Advanced Neutron Source. The anticipated current of slow positrons is higher than that of any source presently available in the world.

## REFERENCES

1. A. P. Mills, Jr., "Suitability of $^{79}$Kr as a Reactor-based Source of Slow Positrons", to be published.

2. K. F. Canter, P. H. Lippel, W. S. Crane and A. P. Mills, Jr., Positrons in Solids, Surfaces, and Atoms: A Symposium in Honor of the 60th Birthday of Steven Berko (World Scientific, 1986)

3. A. P. Mills, Jr.; Ray trace calculations are in progress to determine optimum moderator configuration.

## DISCLAIMER

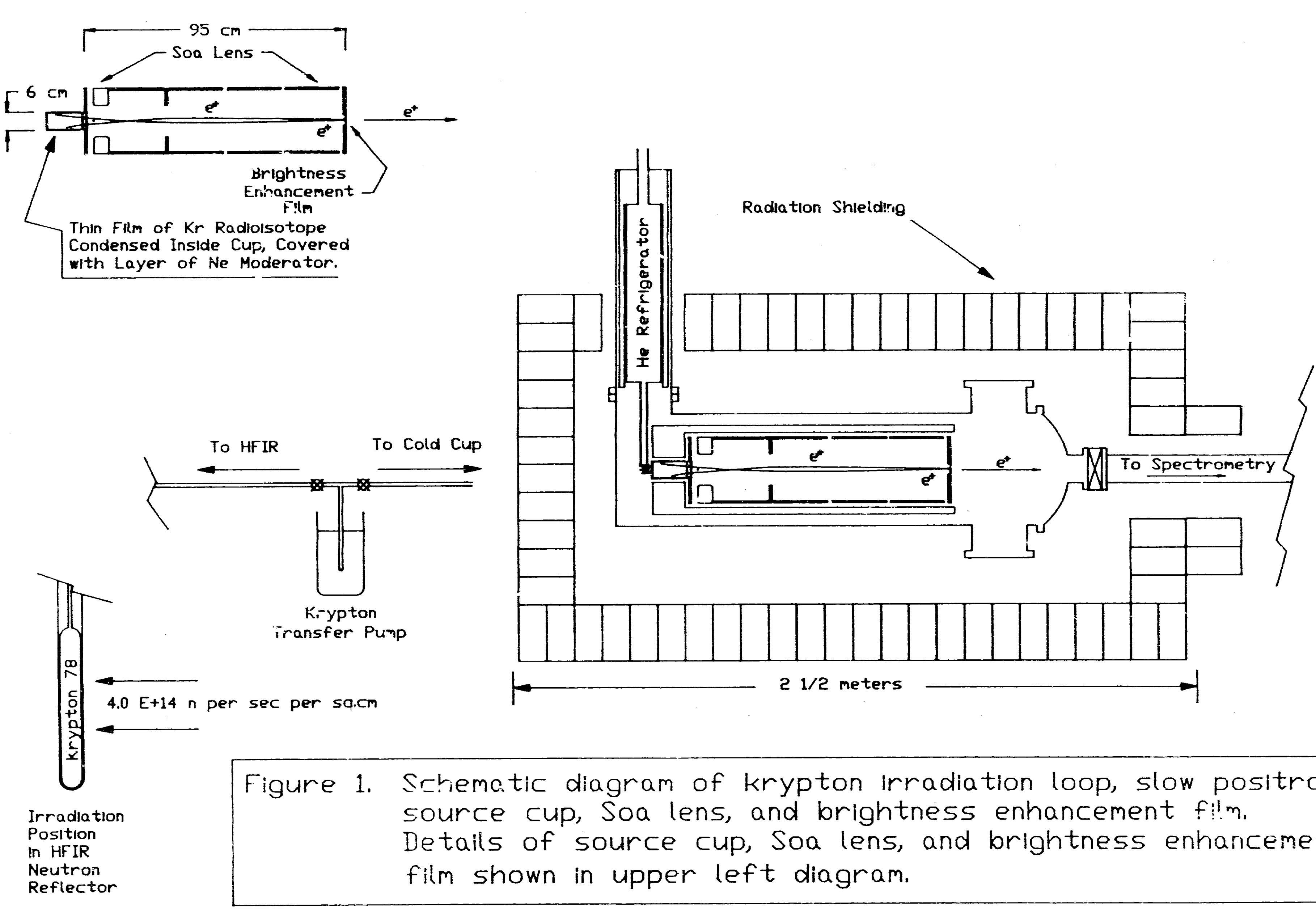


Figure 1. Schematic diagram of krypton irradiation loop, slow positron source cup, Soa lens, and brightness enhancement film. Details of source cup, Soa lens, and brightness enhancement film shown in upper left diagram.

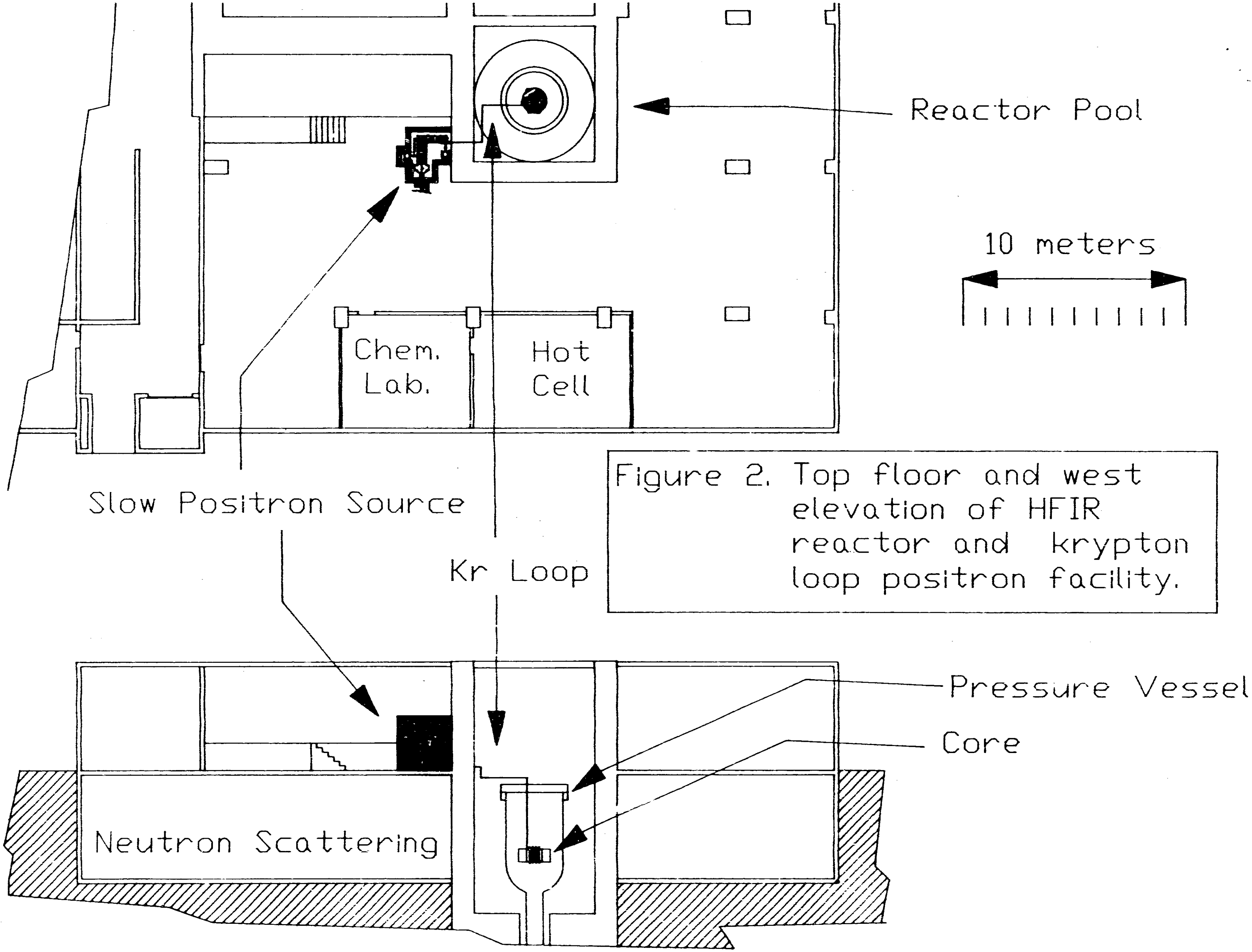


Figure 2. Top floor and west elevation of HFIR reactor and krypton loop positron facility.

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