DEFENSE NUCLEAR FACILITIES SAFETY BOARD

February 7, 1997

MEMORANDUM FOR: G. W. Cunningham, Technical Director

FROM: J. Kent Fortenberry / Joe Sanders

SUBJECT: SRS Activity Report for Week Ending February 7, 1997

Joe Sanders attended a 5-day accelerator design class this week.

Recommendation 96-1 / Safety Resolution Spending for ITP - The following information addresses questions raised earlier this week regarding funding for 96-1 related activities at SRS. In summary, the Recommendation 96-1 / safety resolution related FY97 funding for ITP is coming from the funds that were originally designated to support full ITP operation. The one exception to this is about $545,000 from EM-50 for development of a fluidic sampler (not specifically related to 96-1). Full operation of ITP is expected in FY98 and funding should remain about $60 million. The following cost figures are estimates, and the percentages assigned to 96-1 include all benzene related activities, not just activities specifically driven by the 96-1 Implementation Plan.

	Total FY97 funds (Millions)	**% 96-1**	**Total 96-1 funds (Millions)**
Operations / Maintenance	19.7	10%	1.9
Cost Project (inerting sys)	13.3	90%	12.0
Control Management	0.5	25%	0.1
Engineering	10.4	75%	7.8
Facility Support	3.8	50%	1.9
Work Control	2.4	50%	1.2
SRTC/Chemistry	4.1	90%	3.7
Training & Procedures	3.8	75%	2.9
CE/GPP Projects	2.9	10%	0.3
Site Overhead	6.0		3.1
Total	66.9		34.9

FY98 Budget Proposal - DOE-SR announced the proposed FY98 budget this week. In summary, total cost of operations ($1,507 million in FY97) is reduced by 118 million to $1,389 million for FY98 and could result in a reduction of 1400 to 1500 workers. The proposed budget claims continued progress on commitments to the DNFSB to stabilize and safety store nuclear materials, but notes that some work delays may occur. Work activity specific to nuclear materials stabilization / canyon operations include operation of F-Canyon, FB-Line, and H-Canyon. HB- Line operation is not specifically identified. Pu-239 scrap processing (originally

scoped as an HB- Line activity) is included, but is not assigned to a facility.

HB-Line Deinventory - DOE-SR has directed WSRC to proceed with plans to deinventory the HB-Line Vault. This deinventory is meant to reduce to safeguards cost associated with the HB- Line facility, and perhaps to position the facility for deactivation. There is some uncertainty as to whether a safeguards cost reduction can actually be achieved by transferring material to the 235F vault. In addition, some Pu-238 material might be removed from HB-Line before being properly dispositioned in HB-Line, the only remaining Pu-238 facility at SRS. The deinventory includes the following:

Pu-238 oxide (18 containers) - ship to LANL (already completed)
Pu-238 Lab samples (2 containers) - calcine in HB-Line Phase III and ship to LANL
Pu-242 oxide (47 containers) - ship to LANL
Pu-238 mixed with Np, Zr, Th, etc. (13 containers) - repackage and send to 235F vault
Pu-238 low assay (39 containers) - repackage and send to 235F vault

For Pu-238 material to be stored in the 235F vault, the EP-60 inner containers will be repackaged into new EP-61 weld-sealed containers. There is no weight-loss data for the Pu-238 mixed with Np, Zr, Th, etc. or the Pu-238 low assay material, and so the moisture content is indeterminate. Assumptions must be made about maximum moisture and hence maximum pressure buildup during storage. HB-Line is currently completing stabilization of Pu-242 solutions. Preparations would then begin to either stabilize Pu-239 scrap or deactivate the facility (see FY98 Budget Proposal). Prior to deinventory and possible deactivation, the HB-Line facility will be used to calcine the Pu-238 Lab samples and repackage for shipment to LANL. However, the Pu-238 mixed with Np, Zr, Th, etc. and the Pu-238 low assay material will not be calcined prior to repackaging and storage in the 235F vault. In addition, there is no final disposition for the Pu-238 material being sent to 235F.

Accelerator Production of Tritium (APT) - A draft of the Conceptual Design Report (CDR) has been developed by LANL. A technical review of the CDR is currently being performed by Burns & Roe/General Atomic (B&R/GA); B&R/GA was awarded the contract to perform the preliminary and final design. The CDR will be submitted to DOE for review in April. Based partially on the results of its review, DOE will provide FY98 funding of approximately $200M, the lion's share of which will go for continued research, development, and demonstration (RD&D), but will also provide for beginning preliminary design. At the end of FY98, the Secretary of Energy will select either APT or commercial light water reactor irradiation of target rods to support future tritium production. If APT is not selected as the primary production system, the current intent is to continue funding through FY00 to complete RD&D and final design, and then to put the design on the shelf. However, it is dubious whether the project would receive funding in the remaining years (approximately $200M in FY99 and FY00) to achieve this. A general description of the current APT conceptual design is attached.

Board Members

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

February 9, 1997

MEMORANDUM FOR: G. W. Cunningham, Technical Director

COPIES Board Members

FROM: Joe Sanders

SUBJECT: Description of the 'Accelerator to Produce Tritium' (APT) Conceptual Design

1. Overall Process Description: The overall design requirement for APT is to be operable by 2007 and to provide a maximum production rate of 3 kilograms of tritium per year. Figure 1 provides a general schematic of the proposed superconducting linear proton accelerator. Protons supplied from an ionization chamber will be accelerated to 1700 MeV in a linear accelerator and enter the Target/Blanket System. Figure 2 provides a general schematic of the proposed Target/Blanket System. The highly energetic protons strike the target material, tungsten, and undergo a spallation nuclear reaction. In the spallation reaction, the proton effectively strikes the nucleus of the tungsten atom, 'shattering' it, resulting in the emission of a cloud of protons, neutrons and other particles (i.e, a smaller nucleus). Some of the resulting protons and neutrons are energetic enough (>100 MeV) to cause additional spallation reactions. On average, nearly 58 high-energy neutrons are produced from each incident 1700 MeV proton. The resultant energetic neutrons are moderated using heavy water (D_2O) and are then 'captured' by helium-3 nuclei (which have a very high capture cross-section for low energy neutrons) producing tritium as follows:

$${}_{2}^{3}He + {}_{0}^{1}N \longrightarrow {}_{1}^{3}T + {}_{1}^{1}H$$

The helium-3 gas containing a small amount of tritium will flow through the target assembly continuously, undergoing neutron capture. Once out of the core, the mixture will flow through a palladium-silver diffusion bed which will strip out and collect the tritium before recycling the helium-3 back to the core.

The proton beam will have an intensity of 0.1 amperes (6.2E17 protons per second) and an power of 170MW. In order to produce 3 kg/yr, a capacity factor of approximately 72% will need to be achieved. Of the 170 MW beam power, approximately 130 MW of heat will be produced in the Target/Blanket system, requiring substantial heat removal systems; the remaining 40 MW are converted to mass from the spallation of the tungsten nucleus. The proposed facility design will require approximately 420 MW of electrical power, the vast majority of which will be used to accelerate the proton beam. South Carolina Electric & Gas (SCE&G), with whom SRS is currently required to purchase power, will be able to supply this load. However, the rate at which the grid load can be increased to or decreased from full power is limited (requiring 10's of minutes) which may mandate additional design considerations. The overall design and construction cost for APT is estimated to be $3 - 4 billion.

2. Facility System Description

Target/Blanket Assembly: As shown in figure 2, the continuous proton beam enters the Target/Blanket Assembly through the beam entrance window. Redundant target assemblies will be utilized to improve overall facility availability, and are described in figure 3. The purpose of the beam entrance window is to form an integral barrier between the target/blanket cavity atmosphere (kept at 1 torr) and the accelerator atmosphere (kept at a hard vacuum of approximately 1/1000 torr). Approximately 630 KW of power will be deposited into the window, thus requiring active cooling. The window will be constructed of Inconel-718 and will include channels for cooling water.

After passing through the window, the proton beam will strike the solid tungsten spallation target. Tungsten was chosen as the primary target over lead, which is better from a neutronics standpoint, because of lead's chemical toxicity (which would require disposal as mixed waste) and low melting point. D2O will be used as the primary moderator/coolant for the stainless steel-clad tunsten targets; light water will not be used for cooling in this region due to its high neutron-capture cross-section which would significantly reduce the tritium production rate. The neutrons will then be captured by the helium-3 gas circulating through aluminum tubes. An outer lead blanket will be used to reflect/scatter neutrons which have not been captured; a very small proportion of the neutrons will have enough energy to result in lead nuclei spallation. A significant amount of iron will serve as the vessel structure and provide shielding. Of the 130MW of heat generated in the blanket assembly, approximately half is deposited in the tungsten targets and will be removed by the D2O coolant. The remaining heat will be generated in the helium-3 tubes and lead blanket/reflector modules. This heat will be removed by light water passing through cooling channels in the lead.

Accelerator: As shown in figure 1, acceleration of protons to such a high energy (1700 MeV which corresponds to a particle speed of 93% of the speed of light) requires an elaborate accelerator. The acceleration necessarily occurs using several different subsystems due to their efficiencies at accelerating the protons over differing energy regimes. For the proposed design of APT, the source protons are produced simultaneously in two equivalent lines. These two proton beams are then combined (at 20 MeV) into a single beam which is then accelerated up to maximum energy. The proposed final acceleration stage which takes the proton from 217 to 1700 MeV, and consumes between 80 - 90% of the facility power, will incorporate superconductivity using liquid helium. The entire accelerating region will require a ¾-mile long tunnel. The proton beam will then be magnetically deflected into one of two redundant target stations, as depicted in figure 3. By using two target stations, the overall facility availability can be greatly enhanced. The major subsystems of the accelerator are described in more detail below.

Ion Source - Protons are produced in an ionization chamber. In this chamber, extremely low pressure (1/1000 torr) hydrogen gas is heated using microwaves causing the hydrogen atoms to ionize; ionization occurs at a temperature of approximately 100,000oC. The protons are then extracted from the chamber using a strong electric field. The energy of the protons in the exiting beam is approximately 75 KeV.

Radio Frequency Quadrupole (RFQ) - The proton beam is ?bunched' and accelerated from 75 KeV to 7 MeV in the RFQ. This is achieved by exciting the device at its electrical resonant frequency, 350 MHz, using four klystrons. A klystron is a device which emits a high frequency signal, which for this high frequency is known as radio frequency (RF). The electric field established in the RFQ provides the time-dependent motive force to accelerate the positely-charged protons. Additionally, the characteristics of the induced electric field causes the continuous proton stream to form bunches spaced at 2.86 nanoseconds (inverse of the frequency).

Coupled-Cavity Drift Tube Linear Accelerator Subsystem (CCDTL) - The first stage of the CCDTL accelerates the proton beam from 7 to 20 MeV. As shown in figure 1, these two proton beams are then combined. This is achieved by purposefully combining the 350 MHZ beams such that they are 180o out-of-phase with each other. The result is a beam consisting of proton bunches separated by 1.43 nanoseconds (700 MHz). This beam is then accelerated to 100 MeV in the second stage of the CCDTL. Like the RFQ, the CCDTL device is excited at its resonant natural frequency, using klystrons. This device also takes advantage of the sinusoidal variation in the electrical field to accelerate the proton bunch while the electric field is positive and to allow the protons to drift at constant velocity by shielding the electric field when it is negative. Thus, one can picture the CCDTL providing alternating shielded and unshielded regions which get progressively longer as the bunches achieve higher velocities such that they remain in-phase with the frequency of the electric field.

Coupled-Cavity Linear Accelerator Subsystem (CCL) - The CCL accelerates the proton beam from 100 to 217 MeV. The operating methodology of the CCL is much the same as CCDTL except that the electrical field is created in localized, alternating regions such that shielding is not required to prevent proton deceleration when the field is negative.

Superconducting Radio Frequency Cavities (SCRF) - The SCRF accelerates the proton beam from 217 to

1700 MeV. This section of the accelerator imparts most of the energy (88%), taking up most of its ¾-mile length and consuming most of its electrical power. The SCRF is very similar to the CCL with the difference being that the cavities are backfilled with liquid helium in order to maintain their temperature very near absolute zero. By using a superconducting material (niobium), RF losses due to the inherent electrical resistance of the cavity structure, through which the electrical fields are established, are greatly diminished. While room temperature acceleration could be used for this section, utilizing superconductivity reduces the overall electrical consumption by over 20% (>100MW). However, a large amount of thermal insulating material will be required.

FOR A COPY OF THE FOLLOWING FIGURES CONTACT DNFSB LIBRARY AT 1-800-788-4016

Figure 1: Superconducting Linear Proton Accelerator

Figure 2: Target/Blanket System

Figure 3: Dual Target Stations (for availability)