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MODULAR TYPE QUICK SPLICING METHOD FOR TPS BEAMLINE RADIATION SHIELDING HUTCH

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Abstract

The synchrotron light source is transported to the experimental station through a beamline with specified optics, such as mask, mirror, slit, monochromator. Generally, standard beamline should use solid materials (stainless steel, tungsten, lead, and PE) to block bremsstrahlung and synchrotron radiations, even the neutron. The radiation-shielded hutch surrounds the peripheral area of the beamline with iron and lead panels. It requires blocking the scattering radiation to protect the person against radiation hazards. A modularized radiation shielding hutch includes the frame, wall, and ceiling cover that can assemble on-site through splicing. This method could greatly shorten the installation. Besides, we designed the modular ceiling cover units with a quick mounting/opening function to easily enable the maintenance and installation of large optical components. The details of the concept design for the fixed-point radiation shielding hutch in the TPS beamline are also reported that includes the configurations of the radiation shielding wall panels, frames, and pipes/cables arrangements.

INTRODUCTION

Since 2016, Taiwan Photon Source (TPS) has built 15 beamlines that entail radiation shielding hutches. These beamlines in the high-energy synchrotron radiation accelerator require fast and efficient construction of a safe shielded hutch structure. The design details of the radiation shielding hutch are described in this report. The amount of radiation caused by the relative distance between the scattering conditions of each optical component and the radiation shielding wall is obtained through calculation after confirming the full beamline design. The specifications of the material and thickness of the minimum required shielding walls are obtained by the analysis results of the simulation. Then, using the materials safer than the simulation results to configure and build the radiation shielding hutch in the limited beamline area. These safe materials components are made by iron and lead plates to block scattered radiation. The design in this report also considers wall panels, beams, columns, and pipeline entrances, even the exit doors. The previous Taiwan Light Source (TLS) and European Synchrotron Radiation Facility (ESRF) radiation shielding hutches were designed to use accessory overlapping lead plates to avoid radiation leakage [1]. The installation of wall panels and the protection methods for overlapping parts are more cumbersome and time-consuming. The fixed overlapping parts are arranged on the wall panels to simplify and increase the efficiency of construction. The joints of the wall panels for the installation are overlapped by 37.5 mm. Moreover, the wall panels must be embedded in the ground cement 30 mm to avoid radiation leakage. Thus, only a few bolts can be fixed and installed. The splicing construction method in this design can effectively shorten the on-site installation time. The hutch design is equipped with a detachable ceiling, which is more convenient for subsequent installation and maintenance.

RADIATION SHIELDING

There are two major radiation sources to be considered in the beamline shielding design, the high energy bremsstrahlung, and high intensity synchrotron. Bremsstrahlung originated from interactions between electron particles and residual gas molecules, known as the gas bremsstrahlung, is the dominant component for the shielding design of collimator and stopper inside the beamline hutches. In TPS, the photon energy of primary bremsstrahlung is sufficiently high to introduce a photonuclear reaction that neutrons can be generated from the heavy metal shielding elements intercepting the energetic bremsstrahlung. Therefore, neutron shielding using polyethylene is applied around the collimator and stopper to ensure the dose intensity outside the hutch boundary is within the NSRRC design dose limit of 0.5 μSv/h. As shown in Fig. 1 is the dose distribution of gamma and neutron on the top view by FLUKA [2] simulation of gas bremsstrahlung from TPS (3GeV, 500mA, 1ntorr air pressure) straight section of 7 m air path hitting a lead collimator and terminated by a tungsten stopper (10 cm in height, 10 cm in width, 30 cm in thickness). The gamma dose rate at 1 meter from the scattering collimator or stopper is less than 0.1 μSv/h without hutch shielding taken into consideration. However, the neutron dose rate 1meter away from the shielding material is high than the allowable dose rate of 0.5 μSv/h which requires proper neutron shielding on these lead blocks and tungsten stoppers.

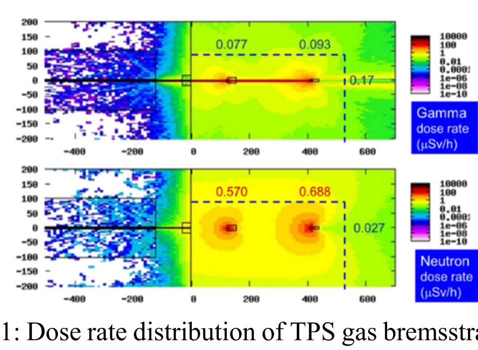

Figure 1: Dose rate distribution of TPS gas bremsstrahlung interaction with shielding collimator and stopper.

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Synchrotron radiation with extremely high photon flux will pose a significant scattering dose on the hutch surface which becomes the primary factor in determining the hutch shielding. Hutch shielding for TPS 19 A beamline utilizes STAC8 [3] code developed by SPring8 for the calculation of dose distribution on the hutch surface from synchrotron scattering at major optics components. The layout of TPS 19 A hutch as shown in Fig. 2 with Double Crystal Monochromator (DCM) at 25m from the source point which is at the end of insertion device IU22 with a maximum magnetic force of 0.72 T at a minimum gap opening of 7 mm is assumed the major scatter of white light in the optics hutch. The results of dose distribution with respect to the scattering angle from DCM is shown in Fig. 3 where maximum dose after hutch shielding of 2 mm of lead and 6mm of iron at 60 to 80 degree of scattering angle is less than NSRRC allowable dose rate of 0.5 μSv/h.

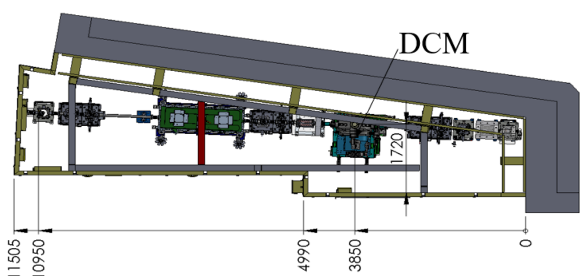

Figure 2: The layout of optics hutch of TPS 19 A beamline.

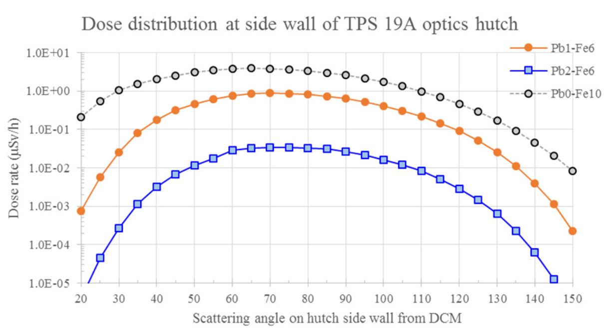

Figure 3: The dose distribution of synchrotron scattering on the side wall of TPS 19 A optics hutch.

HUTCH DESIGN

The selected material and wall thickness of the radiation shielding hutch can result from the above calculation. The design of the combined edges of each component must overlap when coupling shielding materials. The entrance of the pipeline or wires must not be able to see through the interior. The radiation should attenuate by multiple reflections to reach the background value. The following section will introduce the design and details of the main structure, shielding panels, and pipeline entrance.

The main structure is composed of a wall-mounted column, as Fig. 4 shown, and a floor-standing column. The columns are based on 150×150 mm H-Beam with a thickness of 10 mm steel and assembled/fastened with high-tension screws. The anchorage depth of the main structure reinforcing the wall is 200 mm. The overall structure of the H-Beam connect is shown in Fig. 5. The structural system can withstand a lateral force of 0.4 G or more by the simulation analysis results.

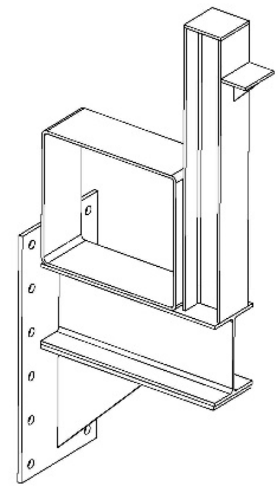

Figure 4: wall-mounted columns.

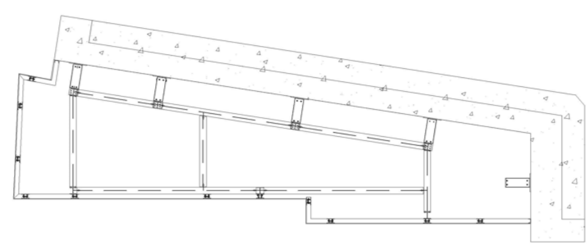

Figure 5: structure of the H-Beam connects.

Fig. 6 shows that the radiation shielding wall panel adopts modular design and splicing construction demonstration. The standard panel size is 1 m (W)× 3.45 m (H). The channel steel is used to strengthen the structural rigidity of the wallboards. The lead-containing panel is composed of a Fe- Pb-Fe sandwich structure. Besides, the lead sheet of the overlapped board is hidden on the inner side. Both sides overlap each other by 37.5 mm to ensure that there is no gap between the lead sheets. The wall panel assembly uses this splicing method as the top inset of Fig. 6 shown. The overlap parts should weld to the unilateral wall panel. The panel assembly with this splicing method can reduce the installation process. The joints of the roof installation must overlap the roof and sidewall panels, as shown in Fig. 7. Using a sandwich method to form an L-shape can prevent radiation leakage. The ground concrete joint is constructed by embedding 30 mm into the ground, as shown in Fig. 8.

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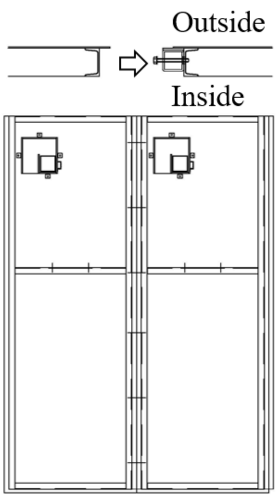

Figure 6: shielding wall panels.

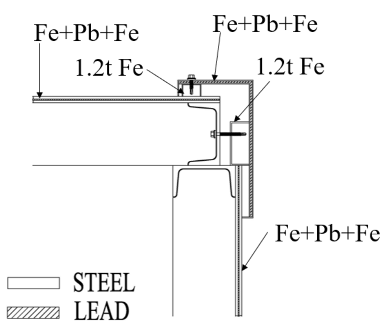

Figure 7: structure of the roof joints outside the hutch.

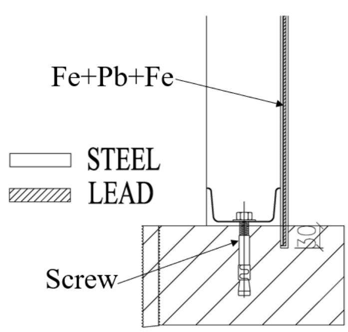

Figure 8: ground-entry type, to prevent radiation leakage.

As shown in Fig. 9, the ceiling of the radiation shielding hutch is designed to be quick-detachable. The hutch ceiling can be lifted after the L-shaped radiation shield is removed. The large optical components can be hung from the ceiling in/out of the radiation shielding hutch for installation and maintenance. As Fig. 10 shown, the side-mounted pipeline or wire entrance of the radiation shielding hutch is designed on the shielding wall panel. It not only uses a circuitous path to avoid radiation leakage but also can connect to the internal cable tray on the same side to arrange the pipelines. This design makes the pipelines tidier and improves the aesthetics of the overall appearance. Due to the demands of various entrances of radiation shielding hutch, there are three commonly used pipeline entrances, such as double-port, single-port, and duct type. The material used in this side-mounted pipeline entrance is the same as the wall panel.

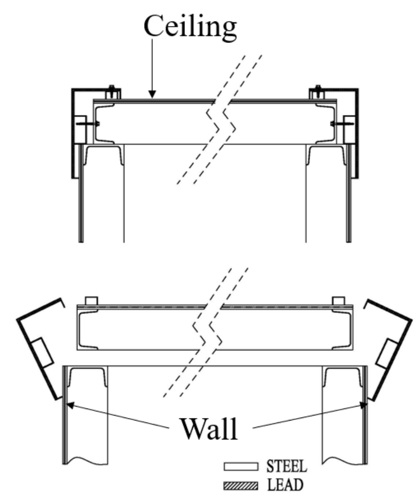

Figure 9: Side view of ceiling quick-release parts.

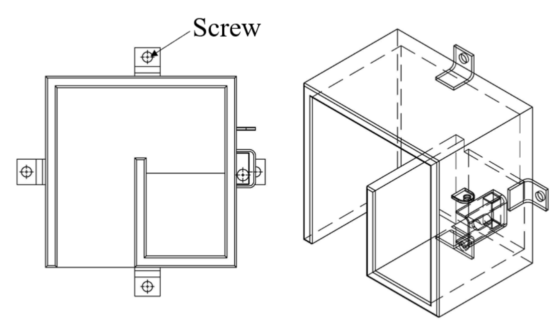

Figure 10: side-mounted pipeline/wire entrance part.

CONCLUSION

The beamline shielding design deploys fixed-position collimators and stoppers made of tungsten, lead, and PE located at the vicinity of the beam path to attenuate bremsstrahlung and its secondary by-product, the neutrons. The Fe-Pb-Fe sandwich structure panel is used for the modularized radiation shielding hutch by the calculation of the thickness. Quick splicing modular designs do not require on-site production of components. The detachable ceiling design can solve the problem of installation and maintenance of large optical elements. The assembly process can save time compared to the previous design. This radiation shielding hutch design has been used in TPS can reduce the radiation value outside the shielded house to 0.5 μSv/h.

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