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Design of Integral Shutters for the Beamlines at the Advanced Photon Source

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ABSTRACT

An integral shutter is a device that integrates a white-beam stop, monochromatic-beam (mono-beam) shutters, a safety stop, and a collimator into one assembly to save space in the photon beamline. Various integral shutters have been developed as standard components for the beamlines at the Advanced Photon Source. The integral shutters are designed to be operated in white-beam mode or mono-beam mode. With regard to safety, each mode of operation is secured by locking certain devices in their up or down positions. Some of the components of the integral shutters share designs similar to the front-end shutters or fixed masks. Design details of the integral shutters are presented.

1. Introduction

The 7-GeV Advanced Photon Source (APS) will have completed five insertion device (ID) front ends and 16 bending magnet (BM) front ends by January 1995. A few beamlines will start to operate by March 1995. The integral shutter is a safety device that integrates a white-beam photon stop, a safety stop, a collimator, and double monochromatic-beam (mono-beam) shutters into one assembly. Because the integral shutter is crucial to the safety of downstream personnel and equipment, fail-safe design and the ability to indicate the open and closed positions are critical. An integral shutter has been designed as one of the standard and modular components of the beamlines. The design specifications and detailed engineering drawings are available to the users through the APS design exchange computer network. All the integral shutters covered in this paper are currently being procured by the APS. They will be installed in the APS beamlines at the beginning of 1995.

2. Design Requirements

Integral shutters (IS) are typically placed in the first optics enclosure (FOE) on the beamlines. A typical FOE arrangement is shown schematically in fig. 1. A double-crystal monochromator (DCM) is used to monochromatize the beam. When the DCM is in the mono-beam mode and the two crystals operate properly, the DCM turns the white beam into mono beam. The mono beam is shifted 35 mm above the white beam and is parallel to the white beam. When the DCM is in white-beam mode or in mono-beam mode but the two crystals fail, the white beam stays the same. An IS is placed immediately downstream of the DCM to pass either the mono beam or the white beam in a safe mode to the next experimental station.

The white beam consists of the high-power x-rays and the bremsstrahlung radiation and is considerably more dangerous than the low-power x-ray and synchrotron radiation of the mono beam. The white-beam photon stop is designed to absorbed the high-power x-rays, and the safety stop is designed to block the bremsstrahlung radiation. During the mono-beam mode, both the white-beam photon stop and the safety stop have to be secured in the closed position in case the DCM fails and the mono beam becomes white beam again. Redundant double mono-beam shutters are required to stop the mono beam.

3. Design of the Integral Shutters and Their Application

Figs. 2 through 5 show the designs of four typical integral shutters. In the following, their designs and application are explained. These four designs are the ID IS with movable stops (P4), the ID IS with fixed stops (P5), the BM IS with movable stops (P6), and the BM IS with fixed stops (P7). Shutters P4 and P6 have movable stops that can stop white beam during the mono-beam mode or can allow white beam to pass during white-beam mode. Users of P4 or P6 can use either white beam or mono beam to perform their experiments. Shutters P5 and P7 have fixed stops that always stop the white beam. They are for users who need only mono beam to conduct their experiments.

Shutter P4 consists of seven major parts as shown in fig. 2 (picture shows mono-beam mode). The movable white-beam photon stop (1) is similar to the ID front-end photon shutter [1]. It is a water-cooled photon absorber moved by an air actuator. When the actuator is in the closed position, the cooling surface of the photon absorber makes a 2.5 degree angle with the beam axis to block the white beam. When the actuator moves down to an open position, the photon absorber is level to let the white beam pass.

The movable safety stop and collimator unit (2) has nine pieces of tungsten that are placed in a stainless steel housing. These tungsten blocks form a collimator with a rectangular aperture of 80 mm wide x 18 mm high. A nonrotatable, 39-mm-stroke, triplerod air actuator is used to hold the 300-lb of tungsten blocks and the housing. During the mono-beam mode, the air actuator moves the tungsten blocks up; thus, the mono beam can pass through the aperture, but the bremsstrahlung radiation of the white beam is absorbed by the 200-mm-thick tungsten material. During the white-beam mode, the air actuator moves the tungsten blocks down so that the white beam can pass through the aperture.

The first mono-beam shutter (3) has a tungsten block (133.3 mm wide x 35.6 mm high x 65 mm thick) to absorb the mono beam. An oxygen-free, high conductivity (OFHC) copper rod is used to conduct heat from the tungsten block to an air-cooled fin outside the vacuum chamber. The 33-mm-stroke air actuator that moves the tungsten block has a hollow-rod cylinder for inserting the copper rod. The second mono-beam shutter (4) is similar to the first mono-beam shutter except that the second mono-beam shutter has a 70-mm stroke and a bigger tungsten block (133.3 mm wide x 82.6 mm high x 65 mm thick). The first mono-beam shutter and the second mono-beam shutter are interlocked to close simultaneously to provide redundant protection. In case of power failure or air failure, vacuum force and gravity force will close the mono-beam shutters so that they are fail safe.

The open and closed positions of shutters and stops are indicated by limit switches (5) mounted on the actuators. There are four mechanical limit switches on each actuator to provide redundant signals of both up and down positions for the safety interlock systems. All the air actuators have a magnetic strip on the piston of the air cylinder. Reed switches can be mounted on the tie rods of the air cylinder for additional signals if necessary. A proximity switch (6) will detect the housing of the safety stop and collimator in case the housing falls down, and it will also send a signal to the safety interlock systems.

Kirk-key interlock (7) is required for safety to guarantee that all components of the integral shutters are operating in the proper position during the experiments. During the mono-beam mode, both the white-beam photon stop and the safety stop and collimator are mechanically locked by Kirk-key locking pins in the up position to block the white beam. The Kirk keys cannot be removed from the lock unless both stops are locked in the correct positions. No mono-beam experiment is allowed without removing both keys to assure that users and equipment are always protected from exposure to the dangerous white beam. During the white-beam mode, both the white-beam photon stop and the safety stop and collimator are in the up position to allow white beam to pass. The second mono-beam shutter has to be locked in the up position by Kirk-key lock to prevent the powerful white beam from hitting the tungsten block. Similarly, no white-beam experiment is permitted without removing the Kirk key from the second mono-beam shutter.

Shutter P6 (as shown in fig. 3) consists of seven major parts similar to P4; P6 also operates in exactly the same way as P4. However, P6 is used for a BM beamline instead of an ID beamline. Therefore, P6 has a movable white-beam photon stop (1) for lower power and a movable safety stop and collimator (2) with a wider aperture (120 mm wide). The movable white-beam photon stop is similar to the BM front-end photon shutter [2].

Shutter P5 (as shown in fig. 4) consists of four major parts. The fixed white-beam photon stop (1) is similar to the ID front-end fixed mask. It is a water-cooled photon absorber with an inclined surface of 4.5 degrees to stop the white photon beam all the time. The fixed safety stop and collimator unit (2) always stops the bremsstrahlung radiation, but lets the mono beam pass through its aperture (80 mm wide x 10 mm high). Two mono-beam shutters (3) that are the same as the first mono-beam shutter of P4 are used in P5. No Kirk-keys or proximity switch is needed in P5.

Shutter P7 (as shown in fig. 5) is similar to P5 except that P7 is used for a BM beamline. Therefore, P7 has a lower power, fixed white-beam photon stop (1) and a movable safety stop and collimator (2) with a wider aperture (120 mm wide). The movable white-beam photon stop is similar to the BM front-end fixed mask.

4. Thermal Design

The integral shutters are designed to be installed 31 m from the APS ID or BM sources. The mono-beam shutters are able to absorb 10 W of thermal power of the mono-beam x-ray. The white-beam stops of P4 and P5 are capable of withstanding x-rays of the white beam from a ID source during 7-GeV, 100-mA operation. The white-beam stops of P6 and P7 are able to withstand the x-rays of the white beam from a BM source during 7-GeV, 300-mA operation. Extensive thermal analysis and tests have been performed for the front-end photon shutters [3] and the front-end fixed masks [4]. Since the power density of the photon beam is lower in the beamline than it is in the front end, the integral shutters have a larger safety margin in their thermal design. Regardless, detailed thermal analysis has been done for each device to assure that the design is adequate [see 5,6].

5. Discussion

The users of the APS beamlines can incorporate one or several of these standard integral shutters in their beamline designs. For example, shutter P4 could be installed in the FOE of an ID beamline followed by P5, which could be installed in the white-beam station immediately downstream. Users can also modify the integral shutters to meet the specific requirements of their beamlines. There are other standard integral shutters that are not covered here. Detailed information about all the standard integral shutters and other standard components is available to the APS users through the APS design exchange computer network.

Acknowledgement

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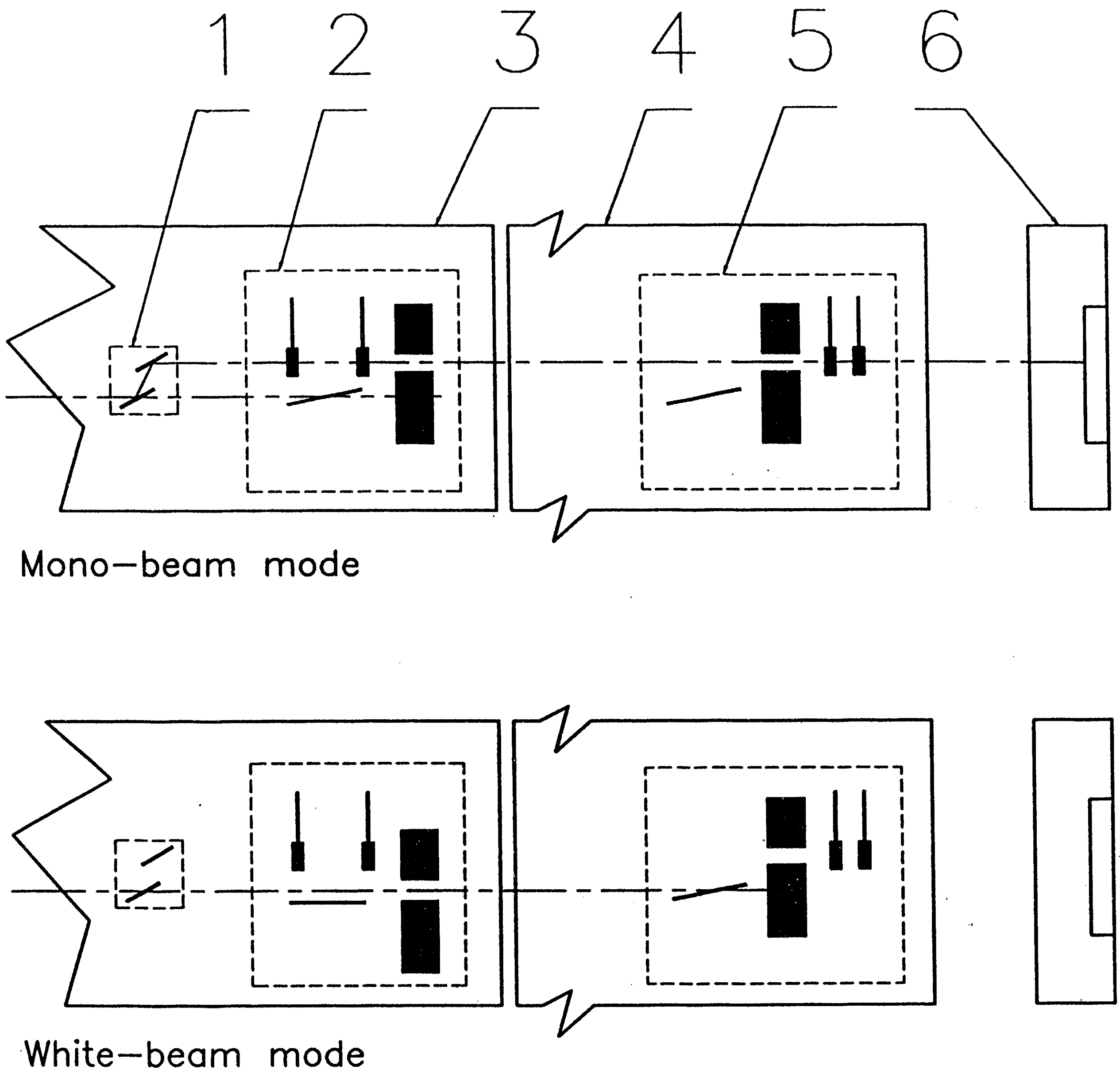

Fig. 1. Schematic arrangement of a typical IS at the APS (1) DCM, (2) P4, (3) FOE, (4) White—beam station, (5) P5, (6) mono—beam hutch

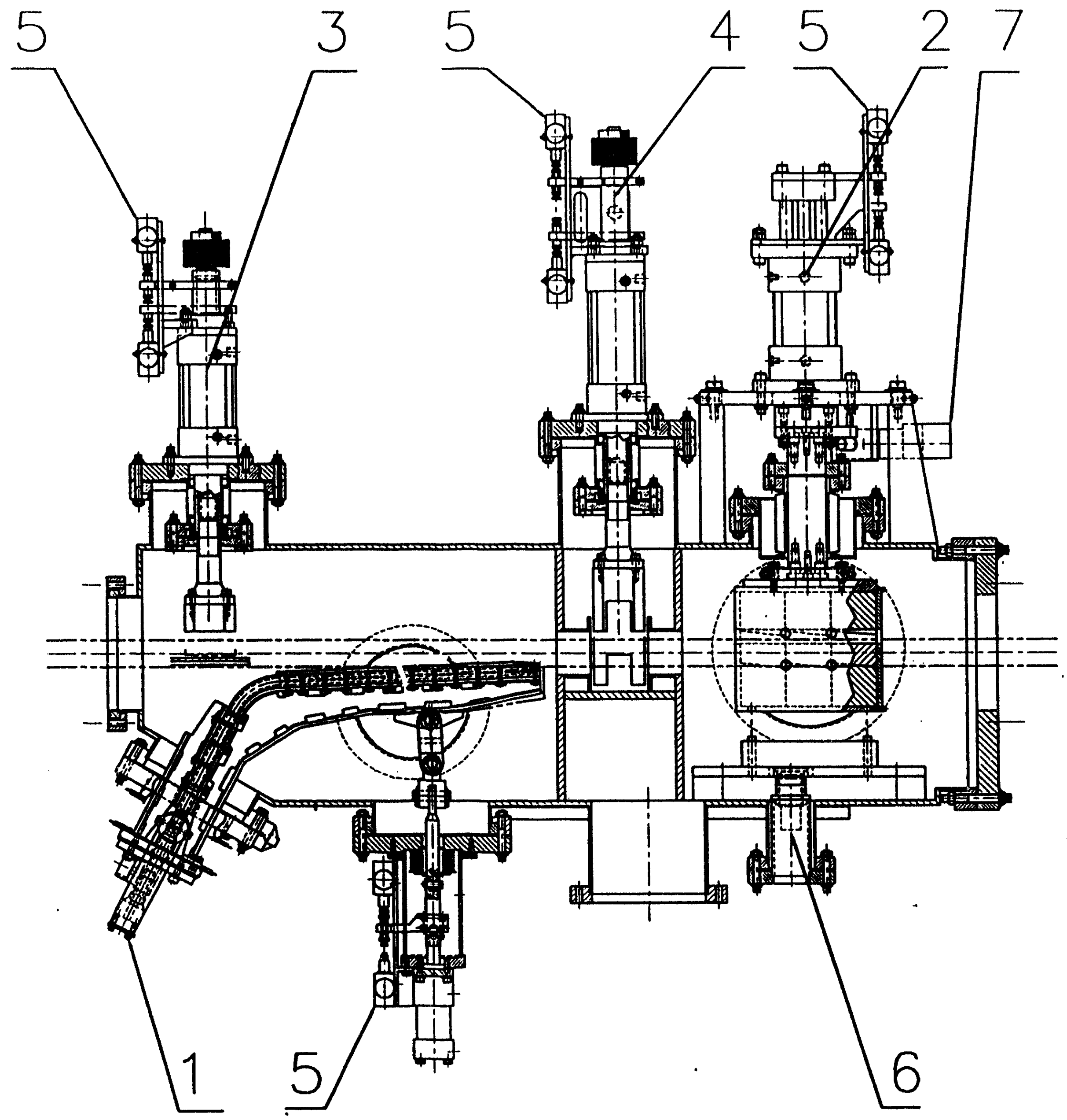

Fig. 2. Shutter P4: (1) movable white-beam photon stop, (2) movable safety-stop and collimator, (3) first mono-beam shutter, (4) second mono-beam shutter, (5) limit switches, (6) proximity switch, (7) Kirk-key interlock

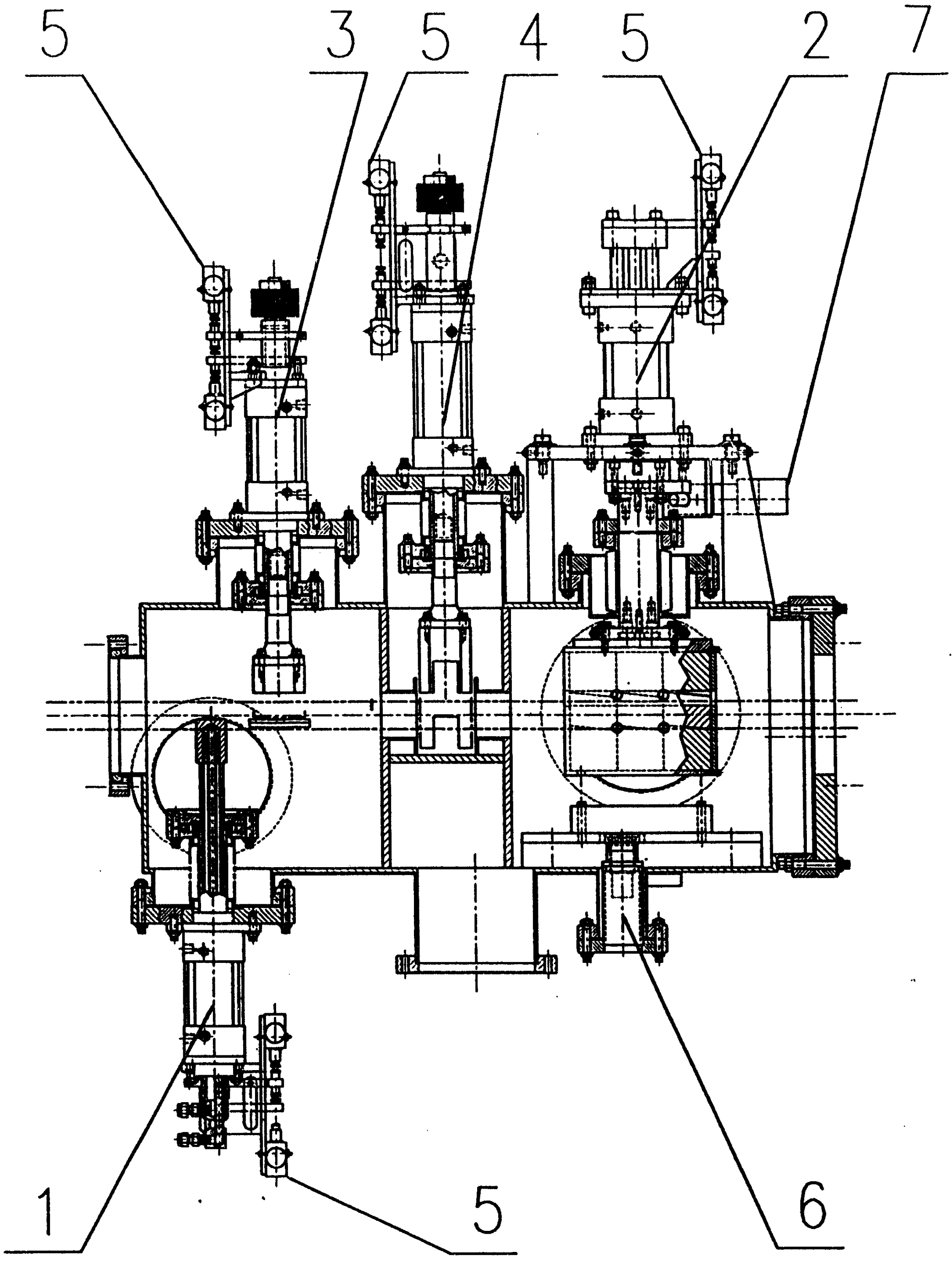

Fig. 3. Shutter P6: (1) movable white–beam photon stop, (2) movable safety stop and collimator, (3) first mono–beam shutter, (4) second mono–beam shutter, (5) limit switches, (6) proximity switch, (7) Kirk–key interlock

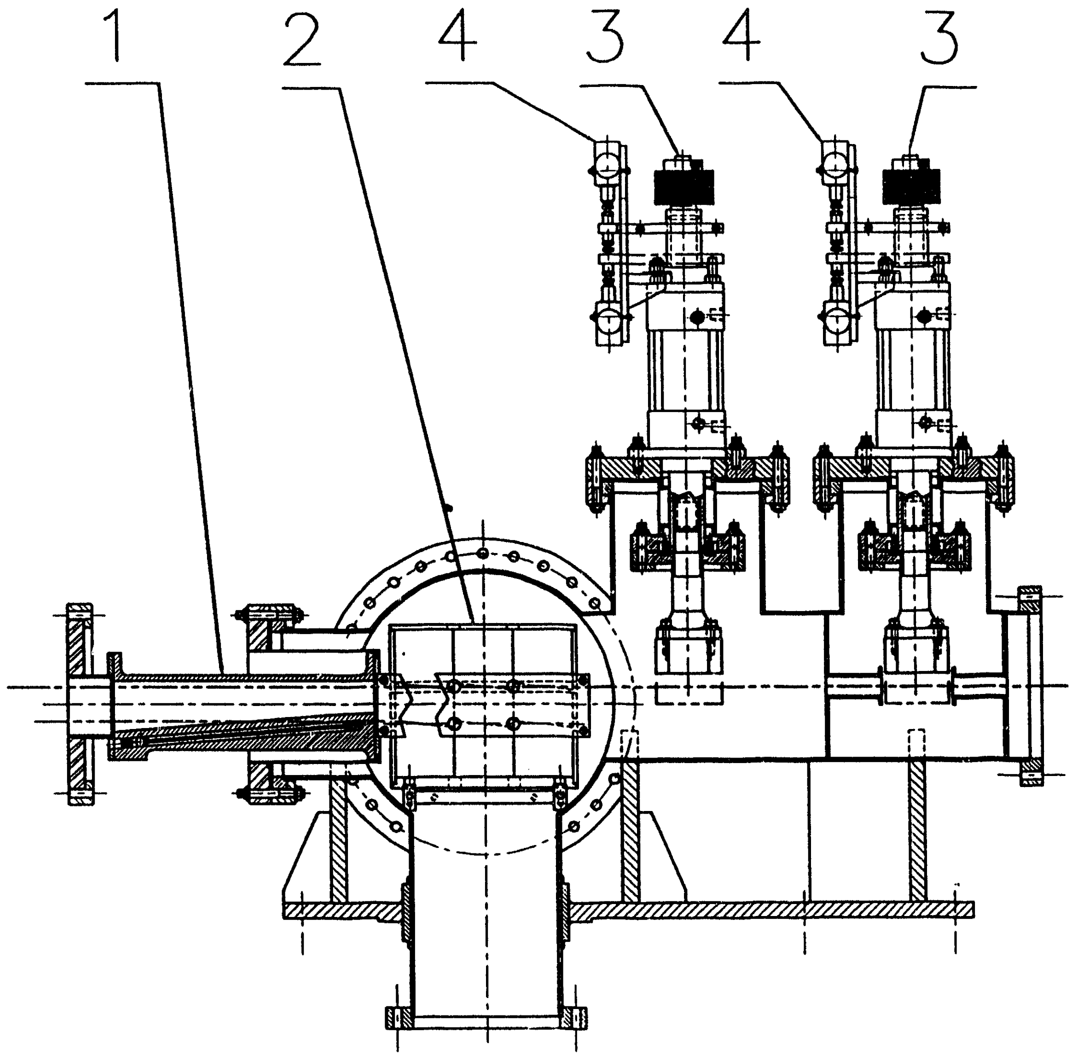

Fig. 4. Shutter P5: (1) fixed white–beam photon stop, (2) fixed safety stop and collimator, (3) first mono–beam shutter, (4) limit switches.

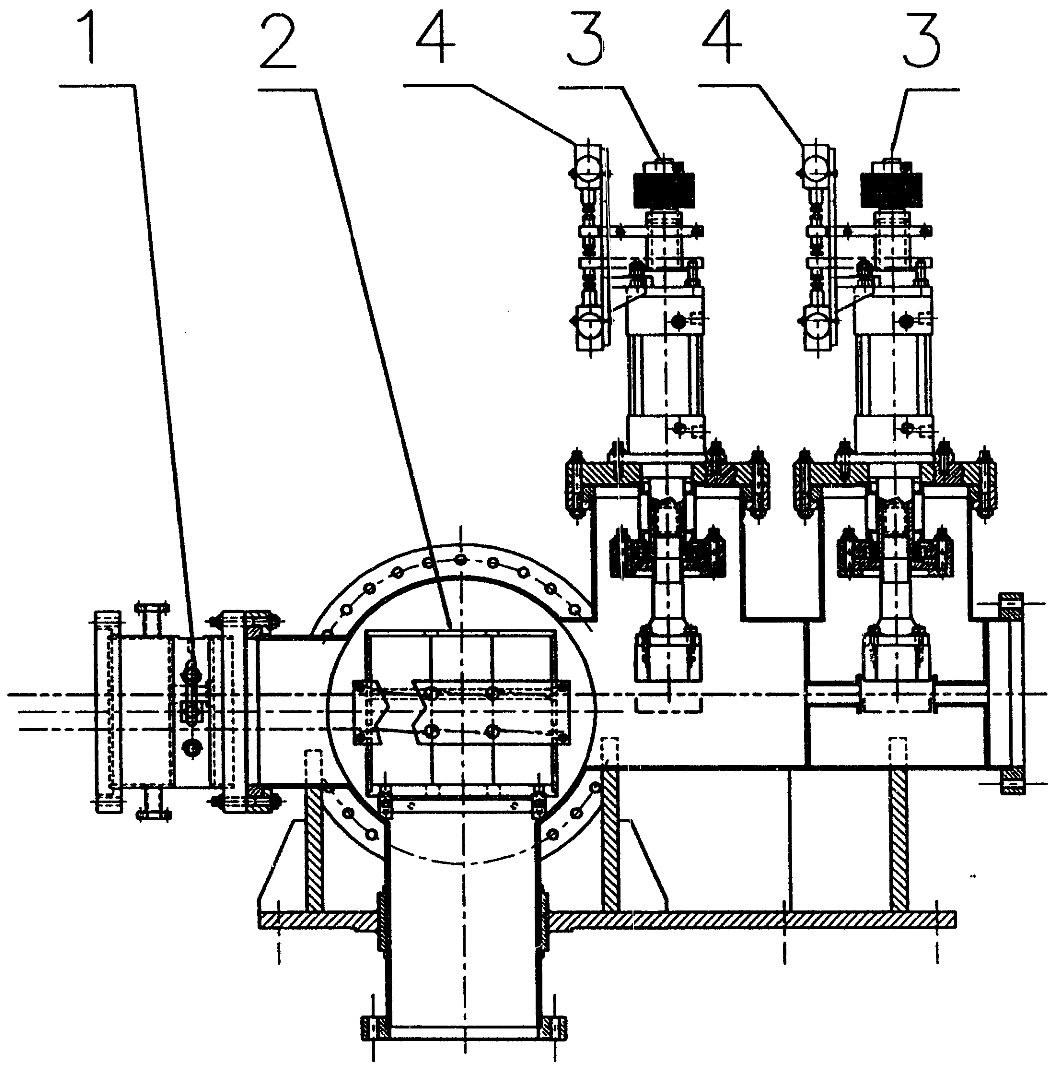

Fig. 5. Shutter P7: (1) fixed white–beam photon stop, (2) fixed safety stop and collimator, (3) first mono–beam shutter, (4) limit switches.

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