50 PSI Concrete Block Seal

Basic Seal Description: This seal is constructed of fully mortared solid concrete block and is designed to withstand an overpressure of 50 psi from a mine explosion. The seal is 24 inches thick. With no pilaster, the seal is designed for a maximum seal height of 8 feet and a maximum seal width of 20 feet (as measured after site preparation work is completed). With a center pilaster at least 2 feet wide and 4 feet thick, the seal design can be used in entries up to 24 feet wide. The MSHA Seal Approval Number is 50-75.336.1.07.01.0. The mine operator may use this approved seal design provided its installation is approved in the ventilation plan and the mine operator meets the provisions specified in Section 75.336 (b).

The seal is required to be fixed along the roof by the installation of steel angles on each side of the seal. The seal is required to be fixed along the floor and ribs by either bolted angles on each side, or by hitching at least 6 inches into competent floor and rib strata. If the bottom of the seal is fixed by the installation of angles, then the seal can be used in entries up to 8 feet high. If the seal is fixed at the bottom by hitching, then the seal can only be used in entries up to 7.5 feet high.

The solid concrete blocks shall have a minimum compressive strength of 2400 psi and nominal dimensions of 8″ x 8″ x 16″ or 6″ x 8″ x 16″. The joints shall be fully mortared with a mortar having a minimum strength of 1800 psi at 28 days. The seal shall be coated with a suitable sealant. The seal configuration is shown in Figures 1 and 2.

Engineering Design and Analysis: The seal was designed using the Wall Analysis Code (WAC). WAC is a single degree of freedom (SDOF) wall analysis program developed by the U.S. Department of Defense. The WAC program calculates the ultimate wall capacity based on user incorporated assumptions. The analysis was conducted based on the assumed presence of arching action occurring between the roof and floor supports. The program allows hinges to develop at the top and bottom of the wall, as well as at mid-height. Hinge rotations were specified as not to exceed 1 degree. The design calculations are available from MSHA.

Pressure-time curve: The seal was designed considering a rapid loading from a 50-psi pulse as could occur in a mine explosion. The seal calculations consider a 50-psi pulse wave to be reflected off the seal. The pressure-time curve was assumed to be triangular in shape. The load was applied to the seal with instantaneous rise time and 0.3 second duration.

Geologic/Geotechnical Conditions: This seal is designed to be installed with competent roof and floor rock. The design is based on an arching analysis that relies on the strength of the roof and floor to resist the arching thrusts. If the roof and floor rock

are not stronger than the compressive strength of the seal, then the arch cannot properly resist the compressive thrusts. Therefore, it is important for the operator to verify that the roof and floor strata have sufficient strength. If poor ground conditions (e.g., severe cutter roof, floor heave, bedding separation, rib sloughage, etc.) are present, then remediation or an alternate location shall be selected for the seal(s).

Any loose roof, floor or rib material shall be removed prior to seal installation. If the floor at the seal location is soft or weak, or if it may be softened or weakened by water, then such floor material should be removed down to competent rock.

Maximum Allowable Convergence: This seal is designed for areas that will not be subject to significant convergence. The design is generally applicable to areas such as mains or other mine locations not expected to experience gob loading or a significant change in vertical pressure after the seals have been constructed. The seal is built of rigid materials and can fail from buckling or excessive compressive stresses if subjected to significant convergence or squeeze conditions.

Design References: Wall Response to Airblast Loads: The Wall Analysis Code (WAC); TM 5-1300 (NAVFAC P-397, AFR 88-22), "Structures to Resist the Effects of Accidental Explosions," November 1990; and "Methods for Evaluating Explosion Resistant Ventilation Structures," M. J. Sapko, E. S. Weiss, and S. P. Harteis.

Seal Design Table - 50 PSI Concrete Block Seal

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Maximum Entry Dimensions	Thickness of Seal	Specified Minimum Compressive Strength and Size of Solid Concrete Blocks	Mortar	Minimum Anchorage Around Seal Perimeter
8 feet high by 20 feet wide if 6 x 6 x ¾ inch angle used at floor; 7.5 feet high if	24 inches	2400 psi with nominal dimensions of 8″ x 8″ x 16″ or 6″ x 8″ x 16″.	Joints shall be fully mortared with a mortar having a minimum compressive strength of 1800 psi	At roof: 6 x 6 x 3/4 inch angle bolted on both sides. At floor: Either 6 x 6 x 3/4 inch bolted angle, or 6 inch deep hitch.

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Maximum Entry Dimensions	**Thickness of Seal**	**Specified Minimum Compressive Strength and Size of Solid Concrete Blocks**	**Mortar**	**Minimum Anchorage Around Seal Perimeter**
seal hitched into floor.			such as ASTM C270 Type M or S or Quikrete Blocbond	At ribs: 6 x 6 x 3/4 inch bolted angle or 6 inch deep hitch.
Contact information: For more details on this seal design contact MSHA's Pittsburgh Technical Support Center.				

Material Requirements

Concrete blocks: The concrete blocks shall be solid blocks in accordance with ASTM C90, except that the minimum compressive strength shall be 2400 psi. Block dimensions shall be nominally 8″ x 8″ x 16″ or 6″ x 8″ x 16″. Smaller solid blocks shall only to be used at the top or sides of the seal, where a full-size block will not fit, or as needed to stagger the joints of the seal and pilaster courses.

Perimeter Support: Steel angles shall be 6″ x 6″ x 3/4″, A572 - Grade 50 Steel. The angles shall be install using Grade 75 steel dowels which shall have a minimum diameter of 1-1/8 inch (No. 9). The ends of the dowels shall be threaded to allow the angles to be secured. The dowels shall be spaced on 8 inch centers. The dowels shall be at least 18-inches long.

Mortar: The joints shall be 3/8-inch thick and shall be completely filled with properly mixed mortar. The joint mortar shall conform to ASTM C270 Type S or M mortar. Quikrete BlocBond 1225-51 is also an acceptable mortar and is the only surface bonding mortar permitted to be used as a joint mortar. The surface bonding mortar applied to the seal shall be an MSHA-approved mortar listed as a Suitable Sealant for Mine Ventilation Controls.

Water: Water for mixing the mortar shall be fresh, clean, potable, and free of deleterious amounts of oil, acid, salt, or alkali, except that non-potable water may be used if it meets the requirements of Table 2 in ASTM C94.

Storage Conditions for Construction Materials: Joint and surface mortars shall be stored in weather-tight areas or containers which will exclude moisture and contaminants and keep each material completely separated. Hardened material will be discarded. Concrete block shall be stored in an area that will protect the block from dirt, oil, water and any coating that would interfere with the bond of mortar to the block.

Construction Guidelines

Site preparation: Seals shall be constructed in locations having competent roof, ribs and floor. Prior to seal construction, objects passing through the seal location, such as roof mesh, straps, rails, pipes and wires, shall be safely removed. The ribs, floor, and roof shall be scaled to competent strata prior to placement of the seal. All loose material shall be removed from the seal location for a distance of 3 feet on each side of the seal. Should weak conditions persist, the ribs shall be reinforced by bolting and/or grouting. If the floor strata is weak or soft, or may become weaker or softer from exposure to water, the strata shall be removed at the seal location down to competent rock. After the strata is prepared, keys required for hitching shall be constructed a minimum of 6 inches into the competent strata.

Seals shall be set back at least 10-feet from the nearest corner of any pillar. The seal shall not be located where a geologic feature, such as a fault or open joint would compromise the performance of the seal. Prior to placement of concrete block, the strata and hitches shall be free from dirt, dust, debris, oil, standing or running water, and any unsound material.

Seals shall be provided with supplemental roof support on the inby and outby sides of the seals. The roof support shall consist of a minimum of two cribs, or their equivalent, provided on both the inby and outby sides of the seals.

Prevention of Water Accumulation during Seal Construction: During seal construction, the seal location shall be dry or damp, and there shall be no standing or running water. Standing water shall be pumped or drained from the seal location. Flowing water shall be diverted around the seal location or collected and pumped from a sump to prevent the area of seal construction from becoming wet.

Perimeter Support: In all cases, a 6 x 6 x ¾-inch steel angles shall be installed along the roof in contact with each side of the seal. For ease of handling, the angles can be erected in segments; however each segment shall abut the adjacent segments and shall contain no less than 2 dowels.

The dowels used to attach the angles shall be Grade 75, 1-1/8 inch diameter (No. 9). The dowels shall be at least 18 inches long and spaced on 8-inch centers (Figure 2). The

dowels shall be anchored using resin or mechanical anchors. The dowels shall have treaded ends so that the bolt can be tensioned against the angle. Dome-shaped washers should be used to prevent slippage of the angle. The bolts shall be snug tight to the angle.

The angles shall be in full contact with the face of the seal and the strata or the spaces shall be filled with mortar. If a seal contains a pilaster, the angle should also butt up against the inby and outby faces of the pilaster.

Along the floor and ribs, the seal can be either fixed by installation of angles or the seal shall be hitched at least 6 inches into competent floor strata and ribs. A floor angles shall be installed using the same bolting requirements as the roof angles. The rib angles shall be installed with the same size bolts, but the spacing can be increased to 16-inch center-to-center spacing.

Hitching: In lieu of installing angles along the floor, the seal can be hitched at least 6 inches into competent floor rock. Similarly, an option to installing steel angle along the ribs is to hitch the seal at least 6 inches into solid rib. Where there is any question about the strength of the floor or rib material, the depth of the hitch shall be increased to 12 inches or more.

The floor and rib hitches shall be squared off (see figure below) and shall not be rounded or bowl shaped. The area between the seal blocks and the limits of the hitches shall be completely filled with compacted concrete or joint mortar. If necessary, forms shall be used along the rib so that the gap between the block and rib is completely filled. In excavating hitches, only enough material shall be removed to create sufficient room to allow the blocks to be positioned and properly mortared into place. If roof or floor rock is exposed in the rib, then the hitch shall extend through the rock layers such that the ends of the seal are fully hitched for the entire height of the seal. Only mortar or concrete, no extraneous materials, shall be used to fill the gaps between the seal blocks and the surrounding strata.

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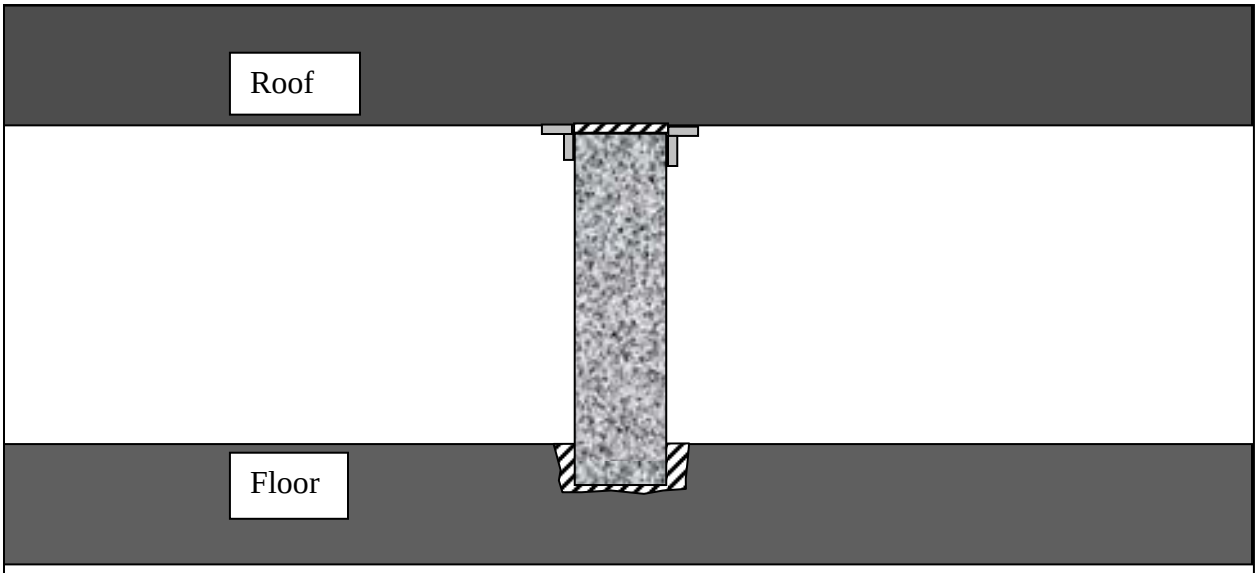

Simplified profile illustration of how floor hitch shall be squared off and backfilled with compacted mortar or concrete (hatched area) to at least the floor level. The same requirements apply to rib hitches.

Block Placement: The block shall be laid in a transverse pattern and courses alternated such that the vertical joints are staggered as shown in Figure 3. In staggering the vertical joints, blocks shall be offset by at least one-fourth of the dimension of the block.

The first course of blocks shall be placed on a straight, uniform, and solid foundation. The floor (or bottom of the floor hitch) shall be leveled or a concrete footer constructed to provide a suitable seal foundation. A concrete footer does not change the requirement for installation of a floor angle or the use of a floor hitch. The 6-inch hitch depth shall not be reduced by the footer.

Compressible material, such as wood, shall not be placed in the space between the top course of blocks and the roof. Such material would deform under lateral seal loading and prevent the development of internal arching action, which requires a rigid contact between the seal and the roof strata. A few wedges, however, can be placed at the roof if necessary to stabilize the seal during construction.

Mortaring: Mortar shall be mixed with suitable quality water and in the amount specified by the mortar manufacturer's recommendations.

The first course of blocks shall be laid in a properly mixed mortar layer that is not thinner than 1/4 inch or thicker than 1 inch. This mortar layer shall not be used to compensate for the level or roughness of the floor or hitch.

Joint mortar shall be mixed to a uniform consistency and then applied to the surface of each block. Mortar shall not be applied by using a thin or runny mixture and allowing the mortar to flow into spaces between the blocks. The mortar must be mixed to the manufacturer's recommendations. All the vertical and horizontal joints shall be fully-filled with mortar that is nominally 3/8-inch thick and shall not be less than ¼ inch or greater than ½ inch. The entire joint between adjacent blocks must be filled with mortar. The joint thickness between blocks shall not exceed ½ inch nor be less than ¼ inch (ACI 530.1-99/ASCE 6-99/TMS 602-99, "Specification for Masonry Structures"). Concrete masonry units shall not be wetted before joint mortar application. Rock dust, water, dirt or debris shall not to be mixed into the joint mortar, and shall not be coating the block when the mortar is placed.

The space between the top surface of the blocks and the mine roof or the side surface or the blocks and the mine rib needs to be fully packed with mortar or concrete so that there is complete and rigid contact between the seal and the strata between the angles.

Surface mortar shall be applied to the seal and shall be MSHA approved as a Suitable Sealant for Mine Ventilation Controls. The mortar shall be mixed and placed using the quantity of water and thickness specified by the mortar manufacturer. The concrete block shall be prepared in accordance with the surface mortar manufacturer's recommendations. If the block is to be wetted for the surface coating, care shall be taken not to disturb or washout any joint mortar that may not be set.

If the temperature during seal construction is below 40 degrees, measures shall be taken, such as use of a protective enclosure, to ensure that the air temperature at the seal is kept above 50 degrees for at least 72 hours.

Quality Control Requirements

The person certifying the seal construction shall be knowledgeable about seal requirements and shall be responsible for overseeing seal construction to ensure that site selection and preparation are acceptable, the hitching/anchorage is adequate, and good construction practices are followed with acceptable tolerances. Table 1 shows the tolerance requirements specified by ACI 530.1-99/ASCE 6-99/TMS 602-99, "Specification for Masonry Structures" and can be used as a guide for acceptable construction. The certifying person shall ensure that the seal design is re-evaluated by a professional engineer in the event conditions are encountered during seal construction that do not permit the seal to be constructed according to these guidelines.

Table 1: Guidelines for concrete block seal construction tolerances.

Variation from Level (bed joints and top of wall :	+1/4 inch in 10 feet
	+1/2 inch maximum
Variation from plumb :	+1/4 inch in 10 feet
	+3/8 inch in 20 feet
	+1/2 inch maximum
True to Line :	+1/4 inch in 10 feet
	+3/8 inch in 20 feet
	+1/2 inch maximum

Storage, transportation, and mixing of all seal materials shall be according to the manufacturer's specifications. Materials shall not be used beyond the manufacturer's specified shelf life. Mortar shall be stored in a dry environment. A visual check of the material shall be made before use. Bagged material shall be relatively soft and loose, indicating limited exposure to moisture. Any hard material shall be discarded.

The person certifying the seal construction shall take the action required to certify that the seal was constructed to the specifications required of the seal design.

Site Preparation: The person certifying the seal construction shall ensure that site preparation complies with the construction guidelines.

Perimeter Support: The person certifying the seal construction shall ensure that the dowels used to install the steel angles have proper size and spacing, and that the angles are tight against the seal and strata.

Block Placement: The person certifying the seal construction shall ensure that the blocks are laid in a transverse pattern with all joints fully mortared and with staggered vertical joints. The certifying person should also verify that the blocks meet the minimum compressive strength requirement.

Mortar: The person certifying the seal construction shall assure that the mortar conforms to the material requirements, and is proportioned and mixed in accordance with the manufacturer's recommendations.

Other Requirements

Air Sampling Pipes: Two gas sampling pipes will be installed in each seal. The sampling pipes may be metallic, such as copper, provided the pipes are properly grounded. The inby ends of the two pipes shall be approximately 12 inches from the

roof. The pipes shall be supported by hangers or on cribbing. The sampling pipes shall be ½-in diameter.

One sampling pipe shall extend approximately 15 feet into the sealed area. The other sampling pipe shall extend into the center of the first connecting crosscut inby the seal. Each sampling pipe shall be equipped with a shut-off valve, rated at a strength to withstand a 50 psi overpressure, and appropriate fittings for taking gas samples.

Water Drainage System: A water drainage system shall be installed during seal construction in the lowest elevation seal(s) of the set. This seal is not designed to impound water other than to a minimal, unavoidable depth. The actual size and number of pipes shall be based on the anticipated maximum flow rate at the seal location. The pipes used shall be corrosion resistant and have equivalent strength properties of a schedule 80 smooth wall steel pipe *(240 psi internal pressure rating*). If more than one drainage pipe is installed in the seal, the horizontal distance between the pipes shall not be less than 3 feet. Mortar shall be packed tightly around the pipe(s) with no voids. Pipes shall be installed as low as practical to minimize the depth of water against the seal.

Pipe sections shall be joined in accordance with the pipe manufacturer's installation recommendations. Pipe joints and couplers shall have resistance to internal pressure which is equivalent to the pressure rating for a schedule 80 smooth wall steel pipe.

The drainage system shall be equipped to prevent the exchange of air through the pipe(s). A water trap and valve will be installed on the outby side of each drainage pipe. The valve and its connections shall have blast resistance equivalent to a schedule 80 smooth wall steel pipe. The valve shall be installed on the inby side of the water trap. Water traps shall be U-shaped and the vertical depth of the U shall be large enough that a sufficient quantity of water can be maintained in the trap to prevent evaporation prior to the scheduled periodic examination. The U-portion of the water trap shall be recessed into the mine floor to minimize the depth of water against the seal and to strengthen its blast resistance.

The water drainage system shall be checked weekly and used to ensure that water, other than for a few inches of depth, is not being impounded by the seal. If water adversely affects the floor or ribs to the point where the function of the seal is jeopardized, then remedial measures, such as grouting, shall be taken. If impoundment of more than a few inches of water cannot be avoided, then the structure needs to be redesigned to take water impoundment into account or a water diversion or pumping system needs to be installed.

A low weir(s) or catchment, no more than 12 inches high, shall be constructed across the entry inby the seal to trap sediment and debris that may clog the drainage pipe(s).

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Air Leakage: Seals shall be installed at least 10 feet from the corner of any pillar to reduce air leakage around the seal. The seal will be coated with an approved sealant to a thickness of at least 1/8 inch. The mortar shall be compacted in the space between the blocks and the roof and ribs. If necessary to prevent leakage, the perimeter of the seal will be grouted after the seal cures.

Fire Resistance/Flame Spread Index: The seal is constructed of solid concrete blocks and mortar.

Time Required for Seal to Reach Design Strength: Mortar is typically considered to reach its intended strength after 28 days. During the curing period, the atmosphere behind the seal must be monitored daily or frequently enough to allow a trend to be determined. The atmosphere in the sealed area must be maintained inert as specified in 75.335(b)(3) until the seals reach their intended strength. The purpose of this sampling is to provide the mine operator with information about the conditions behind the seals and to provide a measure of how well the seals are functioning. Fluctuations in the methane content may be an indication of seal leakage that must be addressed by locating and treating leaks. The information from monitoring is intended to allow the operator to know the conditions behind the seals so that when conditions dictate, appropriate safety measures can be taken. The protocol in the ventilation plan must include measures to be taken and actions that will be followed during the curing period.

Contact Information: Stanley J. Michalek, Mine Safety and Health Administration, Pittsburgh Safety and Health Technology Center, Cochrans Mill Road, Pittsburgh, PA. 15236. Phone: 412-386- 6974

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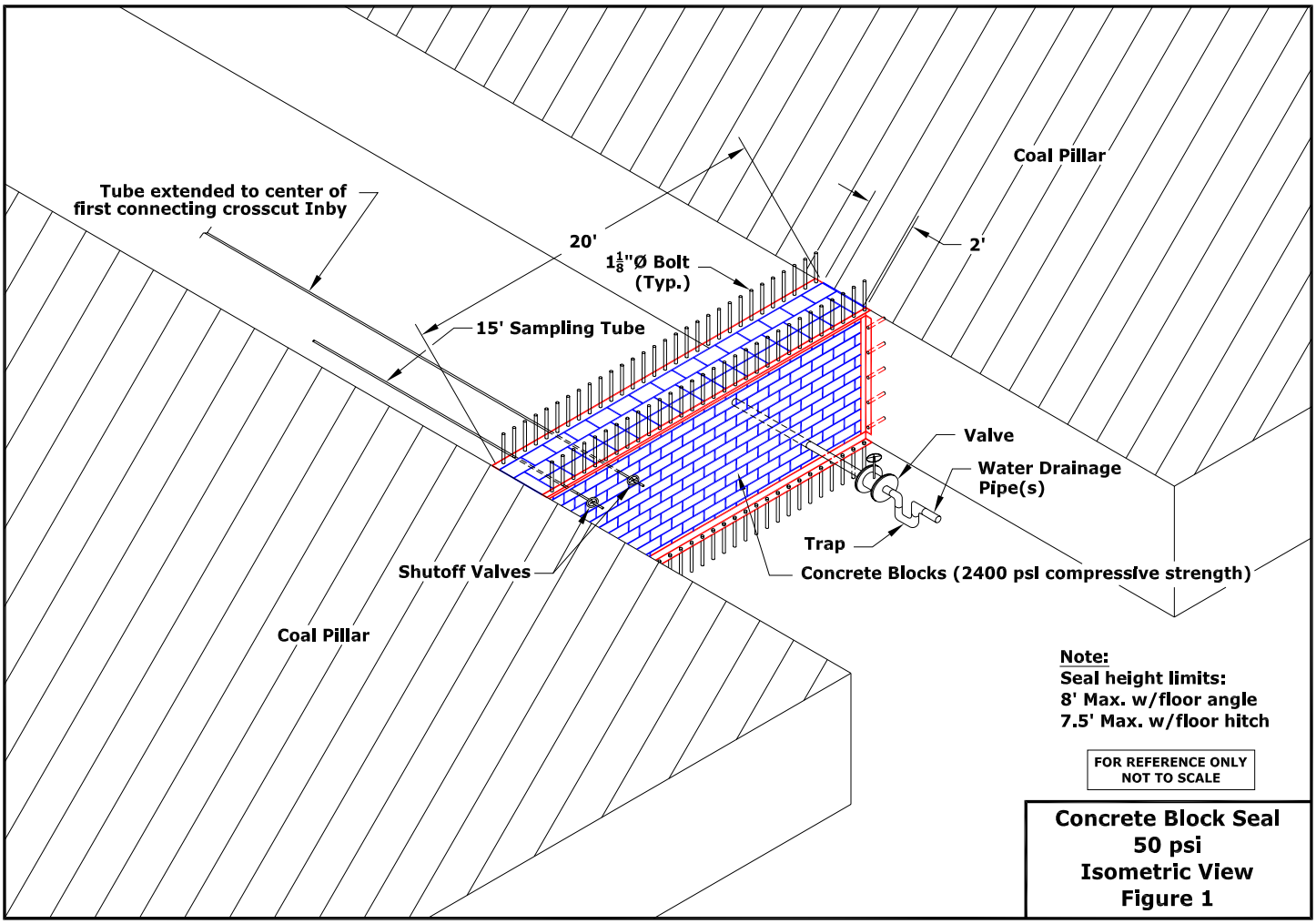

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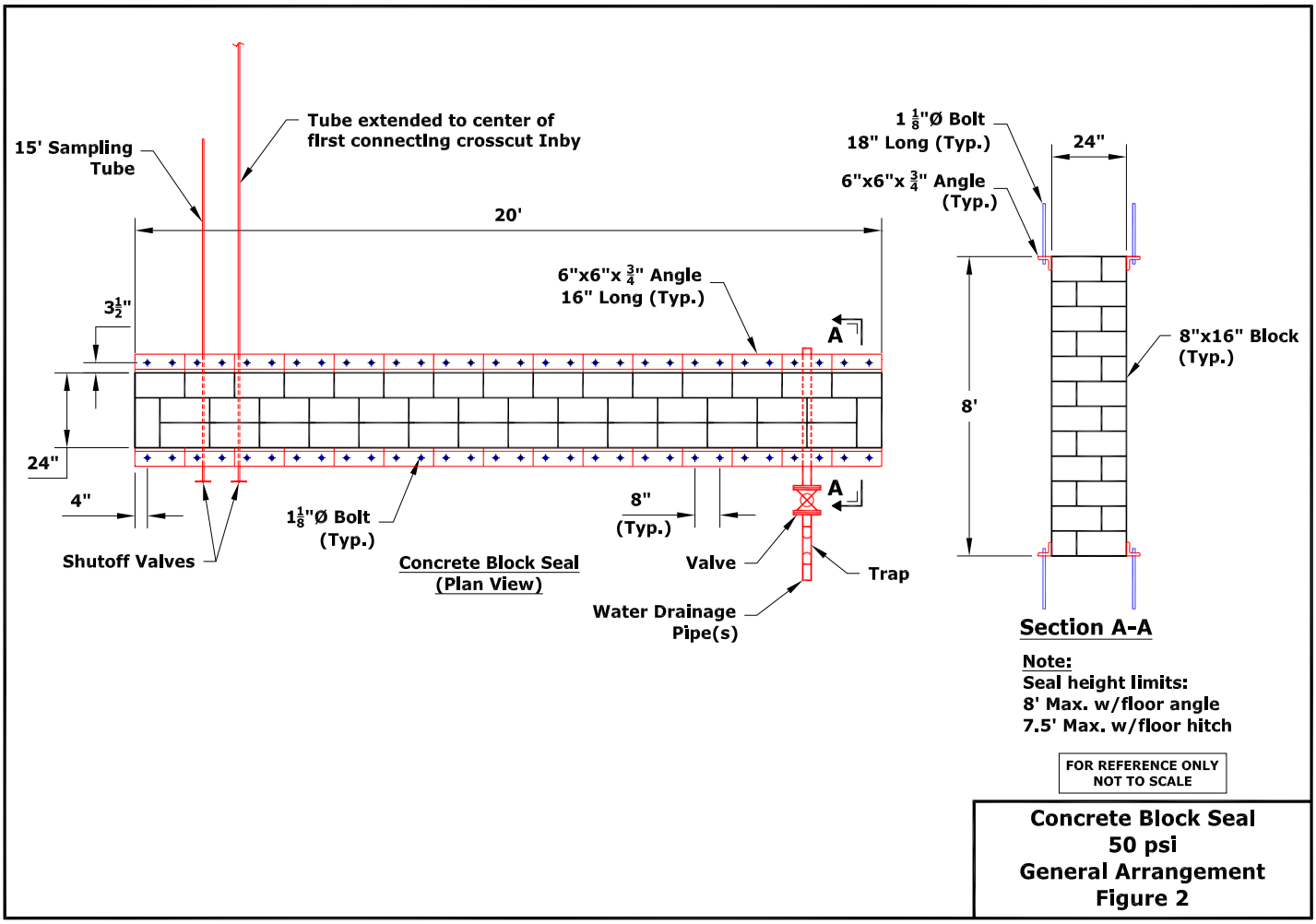

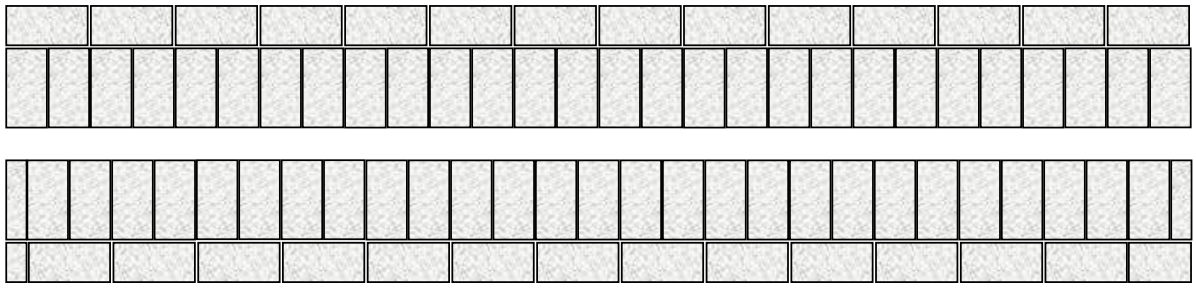

Figure 3 – Illustration of block pattern for alternate courses (in plan view) to stagger vertical joints.