CONVERSION OF AGS RING TO MODULAR CONSTRUCTION*

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In the original design of the AGS, the magnet was split into 240 separate blocks. This was thought to be a convenient segmentation for manufacture and also allowed for quick replacement of a damaged section. In the years of its construction and operation, magnet blocks have been removed and replaced numerous times on both routine maintenance schedules and in emergencies. The time for quick replacement of a block turns out to be on the order of eight hours. When approaching ring conversion, it was first thought that a magnet module should be able to be removed by a well thought-out combination of special-purpose remote operating tooling and a general-purpose remote manipulator. A careful design study on this approach has convinced us that although this is possible, it is not practical within a reasonable budget. This method also requires that the module design be kept quite uniform, a restriction most experimental people will not accept. There are now in the AGS more special cases than there are standard ones.

With the present radiation levels, it is possible for a man to work in the worst areas of the ring for 20-30 minutes before exceeding his daily limit. It is also true that there are many quiet areas, and it is only necessary to move a few feet away from the source of secondary particles and its downstream cone to decrease the radiation level by a factor of 10 to 100.

Since the protons impinging on an internal target are to be limited to a factor of 4 above the present situation, a new approach has been worked out which we call Rapid Module Replacement. Each magnet module will have its services connected so that a minimum of time need be spent in its removal or reconnection. Some items will come off automatically as the magnet is lifted from its locating pins; others will require a very short time in the radiation area (30 seconds to 3 minutes) for removal.

The water cooling hydrants on the module will be connected to the supply and return headers by means of spring-loaded collars that will automatically disconnect as the magnet is lifted. Small electrical services will be handled in a similar manner.

The buses that supply the bending field power require high pressure contact that cannot be accomplished by a knife switch type connector. Here the force will be developed by a single 1" diam bolt operated by an impact wrench. The mechanism shown in Fig. 1 is so designed that the clamp can be slid into position over the joint and the bolt torqued up in about 30 seconds. It requires, however, that the buses be prealigned on a jig before the module is moved into the radiation area.

A lifting rig that is attached to the magnet with a single lever will probably be used in conjunction with permanently attached studs on the magnet.

The most difficult item to handle on a quick disconnect basis is, of course, the vacuum chamber itself.

In terms of modular construction the key to the chamber design lies in the method of clamping adjacent chambers together. This arrangement affects the actual direction of the final chamber design. The clamping arrangement will essentially be as shown in Fig. 2. Its basic features are as follows:

1. A tapered, coated flange attached to the chamber through flexible, oval bellows.
2. A tapered clamp for quickly engaging or disengaging the flanges and seal.
3. A metal seal, coated with lead and indium.
   a) An integral spacer used to locate the seal as well as to define its lineal force.
   b) A built-in volume for leak detection.

Flange

From the beginning it had been recognized that the traditional bolted flange could not be used. The time involved in its use was far too long to be allowed. After some study it was realized that a tapered flange with some type of clamp was the answer. Because of the small space available in some areas the solution was not simple. Our first efforts led to testing of a fixture and then a rigid, two-piece, single-hinged clamp.

These devices were used to determine whether this method of clamping was effective and if a quick-acting device were feasible. Just about the time that these questions were being answered in the affirmative, another problem was raised. This concerned the question of insulating the chambers from one another. Previously, with rubber O-rings as vacuum seals, this had not been difficult to handle. But now, with the necessity for metal seals, it was a more serious question.

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To solve this problem, the idea was considered of coating one or both of the end flanges with fused vitreous ceramic. The coating consists of an inorganic grit fused onto the flange at 1600°F. This was tried and has been tested with success. The coating is applied at the vacuum sealing surface as well as the pressure surface, and quite satisfactorily holds a vacuum seal as well as mechanically withstanding the pressure. It appears that for our sealing method it will be best to grind the sealing surface in order to obtain an adequate flatness.

The bellows to which the flanges are attached have an important function. They act as springs to retract the flanges when unclamped, thus opening up a small (3/4 in.) space for insertion and/or removal of the seal assembly. This same space also allows clearance for lifting out and returning the entire magnet assembly for maintenance and repair.

Clamp

The clamp is a combination hinged and double-screw type. It is now quite definitely established that we need very little more than 125 pounds per lineal inch of seal to make a leak-tight connection with spring-type metal seals. The clamp we have chosen combines two features of great importance. It is narrow enough to fit into our most confined space and, at the same time, it is wide enough, without being moved, to contact both flanges in the opened position to bring them together.

To insure that the clamp will indeed contact both flanges, it is provided with a small amount of axial movement at the hinge pin. Just above the hinge, as part of the stand, is a platform on which the flanges will rest and slide when clamped and unclamped.

Starting from the clamped position the sequence of operation will be as follows: With an electric or air-driven motor device the clamp halves will be separated a specific amount. The over-center latch will be unlocked and the clamp hinged open. The seal assembly will be removed and protective covers will be slipped on each flange. It is expected that it will be possible to do this in about 30 seconds.

To reclamp, the procedure will be exactly the reverse. However, more care will be required to insert the seal assembly and rejoin the clamp halves. These times, and the procedures themselves, are still to be worked out.

Seal Assembly

It is generally accepted that to effect a vacuum seal all the interstices of the flange surface must be filled to an extent that gas molecules cannot pass through. This can be accomplished in various ways. Two perfectly smooth and flat surfaces by themselves can effect a seal, or a less perfect surface with another material pressed into the roughness can do it. All the elastometers and metal seals do this.

Since we had been concerned about our ability to obtain really high forces with our clamp, gold, silver, copper and aluminum wire had been eliminated from consideration. Lead and indium are soft enough to be used, but present other problems in wire form. Obviously, as small diameter wire they will be difficult to handle, to keep in shape and insert into the seal area. If we make retainers to keep them in position, the wire size will have to increase somewhat and thus, the required lineal pressure would also increase.

Another, more serious, problem is that of "creep." Indium, when put under relatively light pressure, can seal very successfully; when put into a rigid joint design and compressed, however, it slowly creeps away from the flange material and opens up a leak. It is suggested that lead has this same property, but evidence is lacking.

Because of the factors listed above, our thinking had concentrated almost exclusively on coated ring designs. These consist of a ring made of a good strong material such as stainless 304, or 17-4 PH, or Inconel X-750, coated with silver, lead or indium. The seal is effected by compressing the ring to a predetermined height. At this height there is a calculated spring load which forces the softer coating against the flanges, making a tight seal. The spring load keeps the pressure on even if the coating material creeps.

The cross sectional shapes available are many. They include O, C, V, K and double K. Except for the O shape, they have been made for many years as machined seals. Because of their small cross section (less than ¼ in, generally) the amount of compression is small. This requires careful attention to production details, flatness, plating, etc.

Each of our tested seals had a coating of lead and/or indium. The proportions are not final (and may not matter too much), but have been roughly 0.0015 in lead to 0.0005 in indium. Each of the types makes an initial seal at slightly more than 100 lb per lineal inch. It does not matter whether the open area of the seal is turned into the vacuum or out to air.

One important restriction is that the flanges must be quite flat. Since the seal base material is not flexible along its length, any significant variation in flatness can affect the system by losing the required spring pressure. Thus, whereas each ceramic coated flange sealed easily against a flat stainless steel flange, when matched together it was very difficult to seal. When measured, the total variation in flatness of the coated flanges was 0.005 in. This is not bad, but is not good enough for metal seals.

The seal assembly, as shown in Fig. 2, consists of a ring spacer secured to or integral with the seal. The spacer serves two functions.

It limits the compression of the seal to a fixed, calculated amount; in addition, with two pins in the top section it is located on the flange by nesting into two matching slots.

These seals must be handled very carefully when being installed. It is not as important in removing, as they can be stripped and recoated. However, they are reusable a number of times if care is taken.

The spacer is so designed that the volumes between the seal itself and the spacer on both sides are integral. By drilling two holes in the flange aimed at this area we intend to use this volume for leak detection. Helium will be inserted into one hole and flowed through the other hole. It is felt that the clamping of the flanges against the spacer will be sufficiently tight to enable us to check individual joints without flooding the area.

Support

The support for the chamber is supplied at each end of the magnet. Flat aluminum plates are secured to each end of the magnet face. From the plate to the chamber a mix of angles and brackets allows for final adjustment of the position of the chamber. At the upstream end there is allowance for any possible temperature or pressure change in length. Electrical isolation is provided by ceramic bushings.

Since there is a slight pulsing of the magnet pole tips the chamber is secured only to the lower half of the magnet. There is a clearance allowed between the chamber and the pole tips; in addition, in the area within the magnet, the chamber is coated with 0.010 in of sprayed aluminum oxide to insure the electrical isolation.

Pumps

In order to avoid the inevitable pressure gradients between widely spaced pumps it has been decided to use one smaller ion pump of 150 l/s at each chamber. To safeguard the pumps from the effects of radiation they have been placed behind the back leg of the magnet. Due to space considerations it is most convenient to locate them downstream. As a result, each chamber has a four-inch diameter pump-out port on the downstream back-leg side.

The pump itself is secured to a platform attached to the back leg of the magnet. To avoid machining operations on the magnet the attachment is made by clamping to the straps running the length of the magnet.

In order to retain the electrical isolation of the chamber at this point the face of the flange which is bolted to the pump will be coated. The coating is the same ceramic used on the flanges of the chambers.

After a magnet is removed, repaired and replaced in the high radiation area, it is necessary to check its position and make adjustments if necessary. Development is now in progress on a remote theodolite with TV viewing. The instrument will be preleveled and placed on preleveled primary monument pads by hand. Then it will be operated and viewed from a remote location. If adjustments are required, motor drives will be placed on locating guides at the cross slides and jack and the movement will be instituted from the same remote location.

When all these devices have been installed and made to work as well as present tests indicate, the human radiation exposure should be down by a factor of 10 to 100. Greater increase in intensity can only be accommodated by external targeting.

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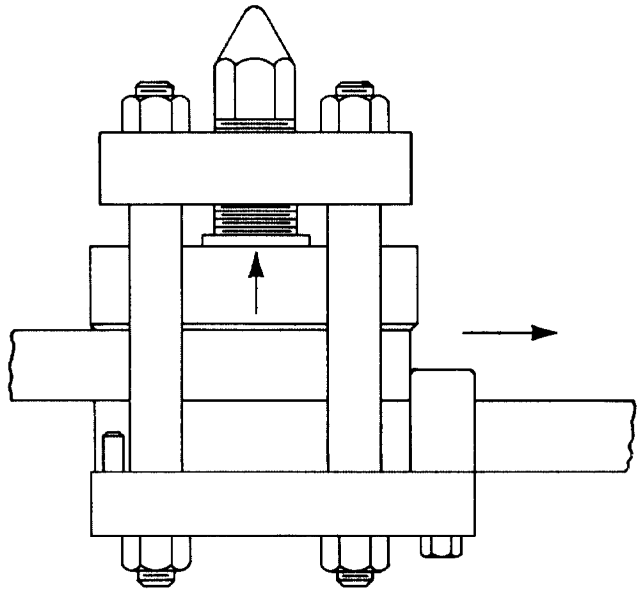

Fig. 1. Bus bar quick disconnect clamp.

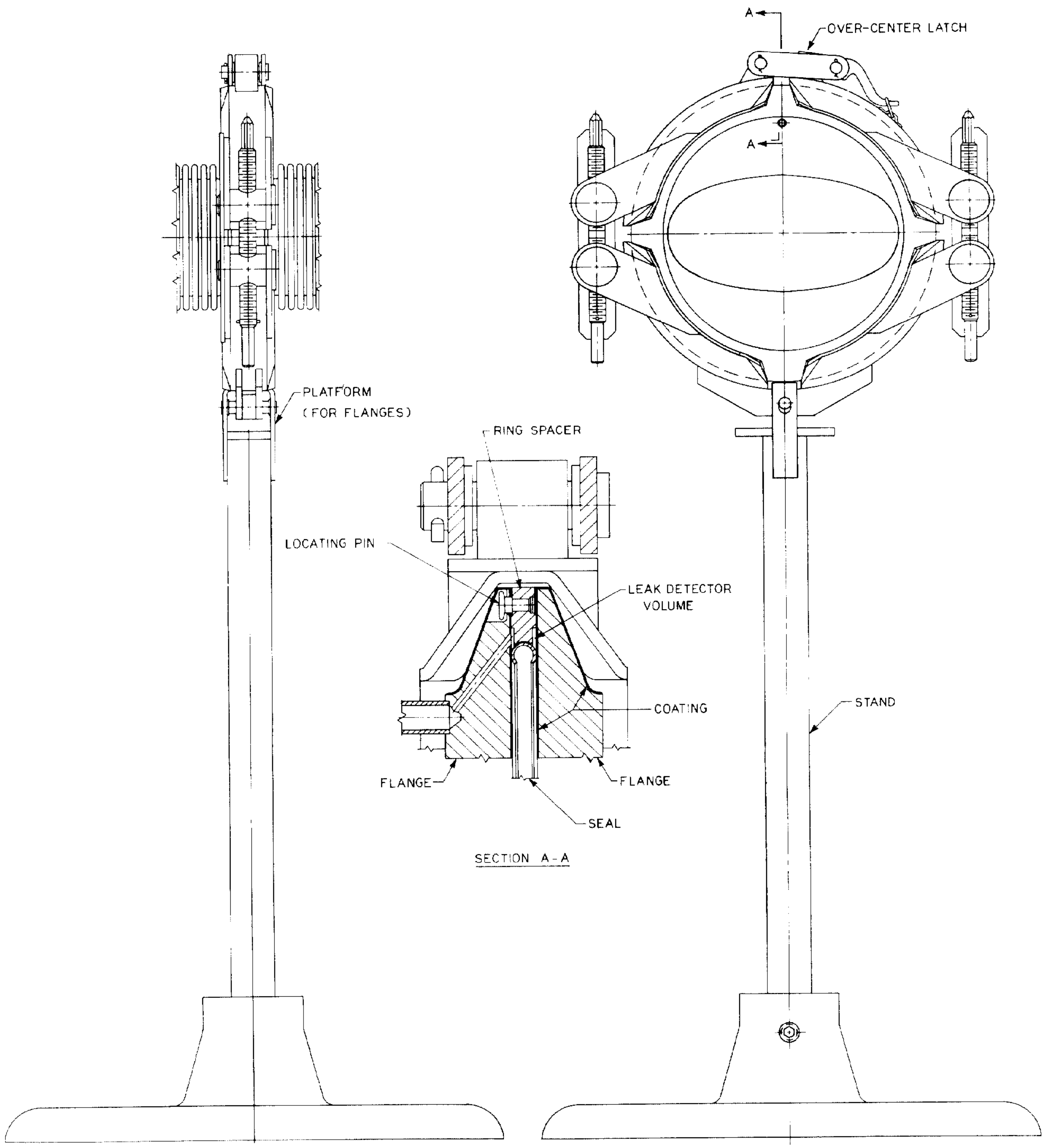

Fig. 2. Chamber clamp assembly.