	<p style="text-align: center;">Proposal to SLAT: Slot length adjustments due to vacuum considerations</p>	date: 2012-10-12
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Issue 1: Slot space between adjacent cryomodules, short slot

In the high-beta section, there are two different kinds of inter module slots: (i) a long one called LWU (linac warm unit), housing quadrupoles, vacuum pumps and beam instrumentation and (ii) a short one combining the two 4-cavity cryomodules into one 8-cavity string.

The short inter module slot has a length of 300mm and contains flanges and a bellow. The beam line gate valves are located in the cryomodule slot. A preliminary assessment of this space has been made and found to be acceptable. The cryomodules should use manual valves with metal sealed gates, since their mode of operation will be “open and forget” and they will only be used during cryomodule installation or removal. One of the two valves adjacent to the short inter-module slot will be required to include a pumping port, mounted in the main valve body, to which a valve will be installed to allow the interspace between the cryomodules to be pumped out and leak tested before the valves on the cryomodules are opened.

A preliminary estimate of the space required for installation of the warm section is computed as follows:

Bellows length of about 200mm required to provide about ± 20 mm travel needed to make a clean connection, plus 2 flanges and 2 blanks appx. 80mm, thus a total length of around 280mm will be required.


This length is the absolute minimum, since this space will also be needed to permit the installation of a temporary cleanroom where the clean connections between the warm section and cryomodules can be made.

Issue 2: Increasing slot length of cryomodules to allow the installation of double beam line gate valves

The current design incorporates a single valve at either end of each cryomodule.

It is proposed to increase the number of valves to two at each end of a cryomodule that faces an LWU. Only at the end of the high beta cryomodules that face a short connection slot, would the number of valves be one (unchanged). The proposed change would improve installation and maintainability and increase operability and reliability of the cryomodules and the intermediate warm sections (LWU).

The use of metal sealed valves could normally be recommended for this purpose; however, particulate generation resulting from the opening and closing actions of the valves could lead to a generation of particles which, when transported into the cavities, lead to a potential reduction in cavity performance due to field emission. The use of elastomer sealed valves has the advantage of minimizing or eliminating particulate generation; however, elastomers are subject to radiation damage. After 10 to 15 years of operation at the CEBAF facility at JLab failure of the Viton gate seals has been experienced. These valves, which are used in the same application as at ESS, are no longer sealing when exposed to air. The Viton seals are failing from radiation as well as taking a permanent set over time due to sealing pressure, or a combination of both. The choice of valve configuration and sealing material used will influence how the valves will be used not only during operation but also during installation and maintenance periods. The selection made will have a significant impact on the operability and reliability of the accelerator and therefore the whole facility.

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From an operational point of view it would be recommend that the valves be closed when accelerator operations are suspended, i.e. during a shut down, or as the result of certain situations arising during machine operation in order to reduce the risk of potential contamination of the cavities. Some examples of these situations are:

- during a maintenance period, whether for hours or for an extended period of time as a result of operator/ technician error or an accident where a window is broken causing an inadvertent venting of the machine;
- responding to the closing of a fast valve, triggered by a rising pressure within the accelerator;
- inadvertent venting of the machine due to equipment failure or a loss-of-beam incident.

Closing the valves in these events will help safeguard the cavities. This is a similar strategy that has been adopted by SNS.

Assuming that on average, a maintenance cycle occurs weekly, 20 years of operation of the machine will result in around 1000 valve cycles; a significant number when there is a potential for the generation of metal particles by metal sealed valves. The use of elastomer sealed valves significantly reduces this potential but the radiation damage to the elastomer needs to be addressed. One option would be to implement a preventative maintenance program that would replace the gate seals on a regular basis e.g. every 10 years. However, in this case a second valve would need to be installed to avoid having to vent the adjacent cavities during this maintenance.

With the proposed double valve arrangement a manually operated, metal sealed, gate valve would be installed as the innermost valve, i.e. closest to the cryomodule, and a pneumatically operated, elastomeric sealed, valve on the outside. One of the two valves will need to include a pumping port, mounted in the main valve body to allow the space between the valves to be evacuated or vented as needed. Since the innermost valve is manually operated the opportunity may exist to mount it inside the cryomodule, potentially reducing overall slot length. The use of EDPM elastomers, which have an improved resistance to radiation compared to Viton, should be considered.


Some of the advantages and disadvantages of the using a single or double valve arrangement with consideration to valve style, material selection and operation are summarized in the table below.

Conclusion:

The beam line gate valves at the extremities of the cryomodules serve the purpose of isolating the cavities in the respective cryomodule from the rest of the beam line, both during installation and removal as well as during maintenance periods.

Metal sealed valves will generate particulates each time they're actuated. These particulates can decrease cavity performance by introducing field emission sites. Therefore, the number of valve cycles needs to be restricted. This in turn will preclude routine maintenance of beam line equipment. Having only metal sealed valve is therefore not an option.

The use of elastomer sealed valves overcomes the concern of particulate generation thus allowing the valves to be closed routinely during maintenance and other events that could occur on the accelerator. This higher allowable duty cycle would allow pneumatic operation of this valve.

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However, elastomer seal replacement will be required about every 10 years due to radiation damage. Changing the elastomer gate seals requires venting to atmosphere of the sections adjacent to the valve. This means that such a valve must not be placed closest to the cavities, as venting those would likely have a significant impact on their cleanliness. The consequences on availability and performance of the accelerator are not acceptable.

The configuration proposed would use a manually operated, metal sealed, gate valve closest to the cavities. This valve would essentially be limited to opening, following installation of the cryomodule, and one full cycle during maintenance of the elastomer sealed valve. The outer valve would be a pneumatically operated, elastomer sealed gate valve with an essentially unlimited duty cycle allowing valve operation to be integrated into the overall operation and protection of the machine.

This proposed configuration will add the length of a beam line gate valve to each end of a cryomodule that faces an LWU, although the integration of the second valve into the vacuum enclosure of the cryomodule might reduce the impact on the slot length.

Considering a gate valve with an installed length of 80 mm, this would lead to a maximum total increase in length of the cold linac of 7 m.

Issue 3: Allocation of sufficient slot length for the installation of the Low Energy Differential Pumping (LEDP) and High Energy Differential Pumping (HEDP) sections

The LEDP and HEDP will be incorporated into the LWU design as special LWU's with one unit located at the entrance to the first spoke cavity and the other located after the last high β cavity. At this time the slot space currently assigned for these units appears reasonable but needs to be confirmed by the vacuum group.



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Comparison Between Single and Double Valve Installations

Activity	Advantage	Neutral	Disadvantage
Single Valve Installation, Option for metal or elastomer gate seal and manual or pneumatic valve actuation.			
Manually operated gate valve with metal sealed gate.	<ul style="list-style-type: none"> Limited particulate generation due to infrequent valve closures. Gate seal not affected by radiation. 		<ul style="list-style-type: none"> Valves cannot be readily closed to protect cavities while accelerator maintenance is performed. Individual cavities may not be protected in the event of loss of vacuum event. Valves cannot be closed remotely.
Manually operated gate valve with elastomer sealed gate.	<ul style="list-style-type: none"> Negligible particulate generation due to elastomer gate seal and infrequent valve closures. 		<ul style="list-style-type: none"> Valves cannot be readily closed to protect cavities while accelerator maintenance is performed. Individual cavities may not be protected in the event of loss of vacuum event. Valves cannot be closed remotely. Gate seal affected by radiation. Radiation damage to gate seal will require changing of seal about every 10 years. Cavity will require to be vented when gate seal changed.
Pneumatically operated gate valve with metal sealed gate.	<ul style="list-style-type: none"> Valves can be readily closed to protect cavities while accelerator maintenance is performed. Individual cavities can be protected in the event of loss of vacuum event by closing valves. Valves can be closed remotely. 		<ul style="list-style-type: none"> Significant particle generation can be expected due to frequent valve closures.
Pneumatically operated gate valve with elastomer sealed gate.	<ul style="list-style-type: none"> Negligible particulate generation can be expected due to elastomer gate 		<ul style="list-style-type: none"> Gate seal affected by radiation. Radiation damage to gate seal will require changing seal



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	<p>seal even with frequent valve closures.</p> <ul style="list-style-type: none"> • Valves can be readily closed to protect cavities while accelerator maintenance is performed. • Individual cavities can be protected in the event of loss of vacuum event by closing valves. • Valves can be closed remotely. 		<p>about every 10 years. Cavity will require to be vented when gate seal changed.</p>
<p>During installation, applicable to both metal and elastomer sealed gate valves.</p> <p>Cryomodules are delivered under vacuum with valves closed. Clean connections are made between cryomodules and LWU and LWU evacuate and leak tested before valves are opened.</p>		<ul style="list-style-type: none"> • With the cryomodules and LWU under vacuum and pressure balanced across the cryomodule isolation valves. When the valves are opened the probability of particulate transport into cavity will be low. 	<ul style="list-style-type: none"> • Particulates will be generated if metal sealed valves are used when valves are opened.
<p>During installation, applicable to both metal and elastomer sealed gate valves.</p> <p>Cryomodules are delivered at atmospheric pressure with valves closed. Clean connections are made between cryomodules and LWU and valves are opened. Adjacent cryomodules and LWU are evacuated together before leak test.</p>			<ul style="list-style-type: none"> • Particulates will be generated if metal sealed valves are used when valves are opened. • Cryomodules and LWU evacuate together with a high probability of particulates being transported into the cavities due to turbulence in the flow during pump down.



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<p>During change out of cryomodule or LWU removal, both metal and elastomer sealed gate valves.</p> <p>The cryomodule isolation valves are closed and the LWU vented. The beam line clean connections are disconnected and the isolation valves of the cryomodules and ends of the LWU are blanked.</p> <p>For cryomodule replacement see previous comments "during installation"</p> <p>For LWU replacement, the sequence will be the same as for the cryomodule supplied under vacuum.</p>		<ul style="list-style-type: none"> • With the cryomodules and LWU under vacuum and pressure balanced across the cryomodule isolation valves. When the valves are opened the probability of particulate transport into cavity will be low. 	<ul style="list-style-type: none"> • Cryomodules and LWU evacuate together with a high probability of particulates being transported into the cavities due to turbulence in the flow during pump down.
<p>Installation/ change out of beam instrumentation or vacuum equipment installed on LWU.</p> <p>Vent LWU to effect change out equipment.</p> <p>Following replacement the sequence will be the same as for the cryomodule supplied at atmospheric pressure.</p>		<ul style="list-style-type: none"> • Particulate will be generated during a change out of beam instrumentation or vacuum equipment. Connections must be made clean. • Same as during installation regarding pressure balance across valve and cryomodule under vacuum. 	<ul style="list-style-type: none"> • Additional particulates generated during valve operation if metal sealed gate valves used.
<p>Replacement of elastomer gate seals.</p> <p>Both cryomodule and LWU will need to be vented. A clean removal/ installation of the valve will need to be made.</p> <p>Following valve replacement the sequence will be the same as for installation with the cryomodule supplied at atmospheric pressure.</p>			<ul style="list-style-type: none"> • Potential for particulates to be generated during valve change. • Cryomodules and LWU evacuate together with a high probability of particulates being transported into the cavities due to turbulence in the flow during pump down.



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<p>During installation. Cryomodules are delivered at atmospheric pressure with the inner and outer valves closed. Clean connections are made between cryomodules and LWU and evacuate and leak tested. The interspace between the valves is evacuated and leak tested. The LWU and interspace between the valves is vented and the valves opened. The cryomodules and LWU are evacuated.</p>			<ul style="list-style-type: none"> • Limited particulate generation as metal sealed valve opened. • Cryomodules and LWU evacuate together with a high probability of particulates being transported into the cavities due to turbulence in the flow during pump down.
<p>During change out of cryomodule or LWU. Close manual valves to maintain cryomodule under vacuum. LWU can be maintained clean by purging while connection with cryomodule is broken and subsequently being blanked. Proceed as for cryomodule delivered under vacuum with the inner and outer valves closed.</p>		<ul style="list-style-type: none"> • With the cryomodules and LWU under vacuum and pressure balanced across the cryomodule isolation valves. When the valves are opened the probability of particulate transport into cavity will be low. 	<ul style="list-style-type: none"> • Limited particulate generation as metal sealed valve opened.
<p>Installation/ change out of beam instrumentation or vacuum equipment installed on LWU. Vent LWU to effect change out of equipment. Following replacement the sequence will be the same as for installation of the cryomodules supplied at under vacuum.</p>		<ul style="list-style-type: none"> • With the cryomodules and LWU under vacuum and pressure balanced across the cryomodule isolation valves, when the valves are opened the probability of particulate transport into cavity will be low. 	<ul style="list-style-type: none"> • Limited particulate generation as metal sealed valve opened. • Particulates generated during change out of beam instrumentation or vacuum equipment.



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Replacement of elastomer gate seals.
Close inner valves and open outer valves.
Vent LWU and maintain under a slight
purge. Close outer valve and remove
valve assembly from body and replace.
Terminate purge on LWU evacuate and
leak test. Open inner valve.

- With the cryomodule and LWU under vacuum and pressure balanced across the cryomodule isolation valves, when the valves are opened the probability of particulate transport into cavity will be low.

- Particulates generated during valve replacement.
- Limited particulate generation as metal sealed valve is closed and opened.

Clean connection: the connection is made in a portable clean room to minimize the potential for contamination to the cryomodule on the mating of the connecting flanges.