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VACUUM CONTROL SYSTEM FOR SYNCHROTRON RADIATION BEAM LINES

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The adaptation of electron positron storage rings, used for high energy physics, to synchrotron radiation research increases the vulnerability of the storage ring vacuum. The synchrotron radiation is brought out of the storage ring via a system of vacuum pipes tangential to the circumference of the ring (Fig. 1). These vacuum pipes share a common vacuum with the storage ring. The vacuum pipes that form beam lines intended for X-ray use terminate in thin beryllium windows. Beam lines intended for soft X-ray or ultraviolet radiation use conduct the storage ring vacuum to the experimental sample chamber. The increased length, termination in the beryllium windows rather than steel flanges, and exposure of the storage ring vacuum vessels account for the increase in vulnerability to the vacuum system.

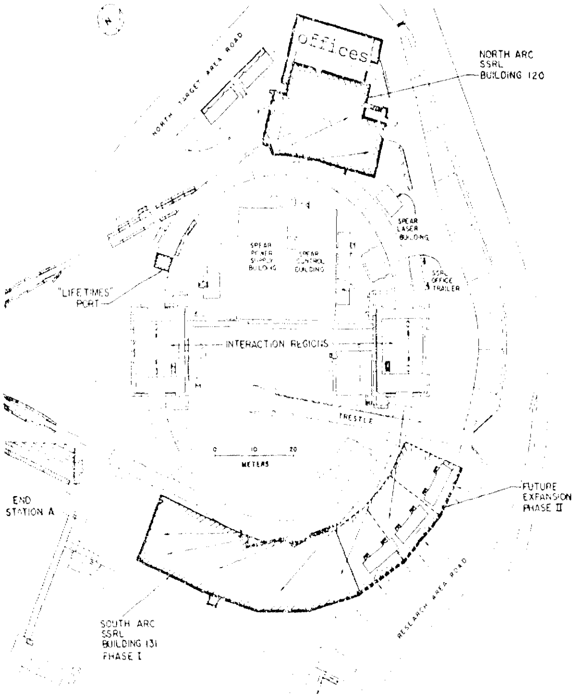
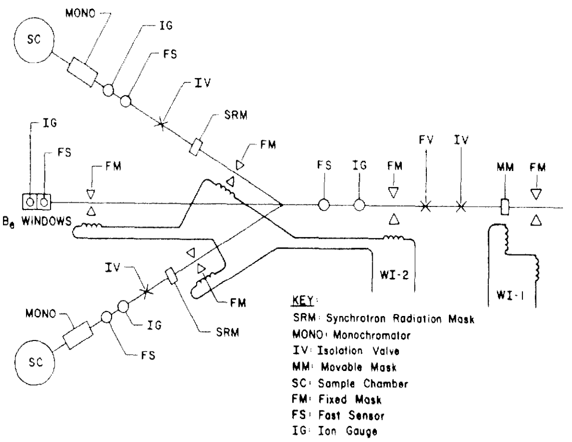


Figure 1. SSRL Beam Lines

A vacuum control system was designed and implemented for the first beam line at the Stanford Synchrotron Radiation Laboratory (SSRL) in 1974. The first beam line consisted of three branches: one X-ray branch and two vacuum ultraviolet branches (VUV)(Fig. 2). The X-ray branch line was further divided downstream of the beryllium windows, but this division is not of interest to the vacuum control system.

The vacuum control system had the following objectives:

1. Minimize the vulnerability of the storage ring vacuum system from the synchrotron radiation beam lines.
2. Allow individual branches of the beam line to function independently of one another.
3. Provide an electrical interface for the opening and closing of the radiation protection system.



KEY:
SRM: Synchrotron Radiation Mask
MONO: Monochromator
IV: Isolation Valve
MM: Movable Mask
SC: Sample Chamber
FM: Fixed Mask
FS: Fast Sensor
IG: Ion Gauge

Figure 2. SSRL Beam Line I

The early stages of design led to the conclusion that there were basically two types of vacuum or cooling water faults. The first type of fault necessitated the "dumping" of the stored beam and the closure of all the vacuum valves. The second type of fault only required the vacuum isolation of the offending beam line or branch line. The former was designated a priority one (Pri 1) fault, the latter, a priority two (Pri 2) fault.

The cooling water flow for the fixed and movable masks is monitored by differential pressure switches. The differential pressure switches are grouped into two circuits.

All cooling water downstream of the first movable mask forms one circuit, (Fig. 2), Water Interlock 2 (WI 2). This will generate a priority two (Pri 2) fault in the event of a cooling water failure. This failure will close the first movable mask, thus shielding all the water cooled surfaces downstream from the synchrotron radiation. The Pri 2 fault thus generated also closes the vacuum partitioning valves. The valve closure is superfluous for this mode of failure, but greatly simplifies the design.

The cooling water for the first movable mask and the fixed mask just upstream are grouped together to form an interlock circuit, Water Interlock 1 (WI 1). The failure of this cooling water will generate a Pri 1 fault causing the stored beam to be "dumped" and all vacuum valves to close.

The beam line is segmented by vacuum valves (Fig. 2). Each segment is instrumented with a nude Bayard-Alpert ionization gauge and a "fast sensor". The ionization gauge is read by a commercially available controller-power supply unit. The process control channel of the controller is used to generate a high pressure alarm signal. The ionization gauge and associated controller have a response time of >1 second. The "fast sensor" is a unit developed at SLAC and consists of a fine stainless wire (.015" diameter and 7.5" long) suspended in the vacuum. The wire is kept at a potential of one thousand volts. At pressures of 10^{-4} torr or less, no current flows between the wire and the grounded vacuum vessel. Should the pressure rise above 10^{-3} torr, current begins to flow between

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the wire and the vacuum vessel. The detection of this current is used to generate a high pressure alarm. The potential on the wire must be removed upon detection of the discharge current before the current increases and destroys the wire. Ionization gauges are used to monitor pressures in the appropriate beam line segments and generate an alarm at a high pressure (4×10^{-7} torr) due to slowly rising pressure. The "fast sensor" senses rapid rises in pressure in its associated beam line segment and sends an alarm to the control logic at a pressure of 3×10^{-3} torr.

The control system logic is so configured that should a vacuum fault occur in a segment that can "see" into the storage ring, a Pri 1 fault is generated. If the offending segment does not have a direct path to the storage ring, i.e., a partitioning valve is closed, a Pri 2 fault is generated.

The vacuum isolation valves used to partition the beam line are large aperture gate valves with metal to metal sealing surfaces. These valves have closing time of >2 seconds. Close to the storage ring a fast acting valve is installed. This valve, along with its associated electronics, has a closure time of 50 milliseconds. This valve does not form a perfect vacuum seal (with 1 atm. across the valve the leak rate is 1 torr liter per second) but it does minimize the gas load into the storage ring in the event of a vacuum accident. The fast valve is activiated by a Pri 1 fault condition.

There is one inconsistency in the formation of beam line segments by vacuum valves. The space between the thin beryllium windows is evacuated and instrumented in the same fashion as a vacuum segment formed by vacuum valves. Sensors located in the space between the beryllium windows are logically connected to perform the same function as the instrumentation of the vacuum segment downstream of the first vacuum valve.

The vacuum control system allows the opening and closing of vacuum valves and their appropriate synchrotron radiation masks as long as the pressure on both sides of the vacuum valves is in the proper range. The VUV branches use the vacuum valves and synchrotron radiation masks that partition them into segments as radiation stoppers for the personnel protection system. The logic circuit on the vacuum control system is so arranged as to allow the vacuum system sensors or the personnel protection system to close the valves and masks.

The placement of the vacuum systems operating controls, vacuum displays and their interconnection is dominated by the symbiotic relationship between the SPEAR storage ring and SSRL. Each experimental station is equipped with a display panel that indicates the position of valves, masks, and status of ionization gauges and fast sensors. The display panel is also fitted with an emergency off button that will issue a Pri 1 fault.

The control panel, located in the SPEAR control room, is equipped with a series of LED's that memorize the fault condition until cleared separately. This feature facilitates the diagnosis of transient faults. The logic itself is constructed of TTL 7400 series integrated circuits interconnected via standard wire wrap techniques. The time domain of the logic is suitable for lower speed logic elements such as relays.

SSRL now has four beam lines with multiple branches, each with an independent vacuum control system. Consideration is now being given to a centralized control system for existing and future beam lines. The system under study would have each beam line under the control of a micro-processor. The micro-processors would be linked to a mini-computer. This system has the attractive features of flexibility and low cost expansion.

Acknowledgments

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