CHARA TECHNICAL REPORT

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Plan for Commissioning of the CHARA Vacuum System

S.T. Ridgway

ABSTRACT: Following extensive experimentation, we now have the equipment and procedures for complete commissioning of the CHARA Vacuum system and for subsequent maintenance. These are described here. Appendices contain information about the vacuum sub-system volume, needed for performance evaluation, and current information about pump speeds, pressures and the vacuum performance.

1. INTRODUCTION

The CHARA Vacuum System has come along slowly, owing to decisions at design and fabrication time to greatly economize in this area. The most important such decision was obtaining the vacuum boxes without leak checking by the vendor (to save fabrication costs) and the decision to not leak check them before installation (owing to lack of personnel and test facilities). Finding a low-cost approach to debugging and maintaining the vacuum system has been pursued somewhat leisurely, again owing to lack of available technical staff. As of this writing, the exploratory, planning and test work has been completed, and the final steps toward commissioning can be laid out and scheduled with confidence.

2. COMMISSIONING

Here is a list of the commissioning tasks. The largest task, leak checking of the 48 vacuum boxes, can be accomplished in from 1 to 3 months, depending on the availability of the lead person assigned to the task.

A. Complete leak checking of all vacuum boxes

The procedures for economical leak checking of the vacuum boxes in-place are now established and the equipment is on hand.

* Center for High Angular Resolution Astronomy, Georgia State University, Atlanta, GA 30303, USA
Tel: (404) 651-2932, Fax: (404) 651-1389, Anon FTP: chara.gsu.edu, website: www.chara.gsu.edu/CHARA

Of the 42 vacuum boxes to check, approximately 8 have been checked at this time, although a thorough system check-out will probably cover all 48. The estimated time required is approximately 1 day/box. (As an example, in recent tests, 4 boxes were adequately checked in 3 days. However, this required working long hours.) Since much of the time is waiting for the volume to pump down, or for helium to clear from the system, it may be more practical to schedule the testing at approximately 2-3 work days per box at 0.2-0.3 effort. At this cadence, each telescope line will have to be closed for of order one month, and the complete task would require approximately 6 months. The staffing required is one vacuum/mechanical specialist to carry out the tests and repairs, supported by two additional people for approximately 1 day every month for removal and replacement of vacuum tubes.

The procedure would be as follows. A time would be selected when a telescope could be out of operation for an appropriate duration. On the first day, approximately 7 of the vacuum tube lengths would be removed and placed in the aisle. Then in sequence, the leak detector would be attached to each vacuum box. The box would be pumped down and alternately leak checked and repaired until performance was satisfactory. The allowance of three days is important because the testing process can flood the box and the laboratory with helium, which must then clear in order to allow a sensitive test. It may be necessary to ventilate the laboratory to reduce the clearing time.

The goal of the test and repair cycle is to have each box pumping to below 40 microbars, to eliminate all leaks detected at that level, and remaining below 1000 microbars for a minimum of 7 days.

The procedure is described in additional detail below.

B. Complete computer interface of vacuum gauges

The gauges are all installed and the cabling had been run to the computer area. The A-D converter has been acquired. Monitoring software is needed (note added: software completed).

At the present, the gauges are read with a hand-held unit that can be moved from one gauge to another. This is an undesirable method. The gauges are delicate and can be damaged by repeated plugging and unplugging of the readout cable. The gauges cost about $350 each (Balzers TPR 260).

Access to the vacuum information will be needed around the OPLE Lab. A wireless laptop or PDA would be useful.

C. Completion of Vacuum System and Building

1. Install temperature sensor in Pump House.

The vacuum pumps are rather reliable and do not require frequent intervention. The main operational concern is the temperature in the Pump Building. If the temperature is low, the pumps will not start. When the pumps are running, the temperature in the (insulated) building will rise high enough to cause damage or to cause automatic shutdown of the pumps, unless the forced ventilation is running. The ventilation could be off because the person who started the pump forgot to turn it on, or it could fail. A temperature sensor should be installed with remote access through the computer, for both automatic and remote manual use.

2. Vibration isolate vacuum pumps

At present, the vacuum pump vibrations appear to disturb interferometric operations. The evidence is actually fragmentary as other vibration sources, some identified and some not, also are an intermittent factor.

It is not difficult to achieve substantial vibration isolation of the vacuum pumps.

The Leybold RUVAC D65B weighs 177 pounds and runs at 1800 RPM. The Leybold RUVAC 501 weights 285 pounds and runs at 3600 RPB. The two are in a common frame, with a total system weight of about 500 pounds.

An inexpensive vibration isolation unit would be the Longwood Elastomers Series 300 style 318 cylindircal mounted isolator. Each unit, operating in shear, has a capacity of 200 pounds and isolates in two axes in shear and 1 axis in compression. The isolation in shear will be approximately 90% at 1800 RPM and 95% at 3600 RPM. It can be installed so that the shear isolation is vertical and in the direction toward the beam combining building. The isolation in compression will be 81% at 1800 RPM and 93% at 3600 RPM. This axis can be oriented parallel to the beam combining building.

Installation is simple. The unit consists of a cylinder with bolt holes on each end. It can be attached to the end of the vacuum system frame, and the opposite end of the isolators attached to a piece of steel angle. This will raise the system by 3-4 inches. To accommodate this motion, the unit can be moved several feet further from the manifold pipe, and the intervening gap carried through a plastic hose.

The specified Longwood unit is not available in small quantities from the manufacturer. Similar products found elsewhere are not similarly documented and may not be suitable.

A more aggressive solution is available, using damped spring mountings, eg from eservice@sdp-si.com. With a natural frequency of approximately 5 Hz, the isolation at 1800 RPM (30 Hz) will be 95%, and at 3600 RPM (60 Hz) 98%. A plan for vibration isolation with spring mounts is given below.

3. Exhaust

In spite of the oil mist recuperator and the oil mist eliminator, the vacuum pumps will, over the course of their life, put a considerable number of quarts of oil out in the exhaust. Unless these are vented, they will continue to soak the inside of the pump building.

The exhaust should be vented to the exterior. The amount of oil emitted, at low density, will be very dilute, similar to a gas-powered chain saw, and is unlikely to be a greater environmental hazard.

D. Update vacuum equipment maintenance procedure

1. Vacuum pumps.

We already have a maintenance procedure for the vacuum pumps. This involves regular checking of the oil levels.

The RUVAC users manual recommends an oil change after 500 hours of use, and then every 3000 hours of use. Estimating pumping 2 hours per day, CHARA would accumulate only 700 hours of use per year. In this case, and because CHARA cycles the pump from atmospheric to operating pressure frequently, the oil should be regularly tested for neutralisation value according to DIN 51 558. If the neutralisation value excedes 2, the oil should be changed.

The TRIVAC oil should be changed after 100 hours, and then every 2000-3000 hours. Again, under CHARA usage patterns, oil should be changed when the neutralisation value exceeds 2, if the viscosity at 25C exceeds 300 mPas, or if the oil appears darkened.

The neutralization test is not difficult, but involves maintaining a supply of chemicals and apparatus which must be cleaned and stored. For CHARA purposes, it may be best to settle on an annual oil change as sufficient even if not necessary.

2. Beam Transport Tube Seals

The beam tube seals should be monitored every 6 months (more often if problems are suspected or detected) for drift of the tube seals or of the tubes.

3. Seal and Tube Integrity and Vacuum Quality

The rubber seals, both indoors and outdoors, are fastened with hose clamps, as are the sections of plastic tube which are utilized in the vacuum system in several places (End Boxes, Periscope Boxes, Manifold interface, Pump interface). The hose clamps tend to loosen due to plastic flow of the material. At present, it appears that they should be tightened every 6 months. It has been confirmed that important leaks occur if the clamps on the plastic hose are not regularly tightened – the hose is exceptionally stiff, and the vacuum integrity can only be maintained with very tight clamps.

E. Initiate automatic logging of vacuum system performance and maintenance

When the computer interface is completed, monitoring, logging and diagnostics should be implemented.

Under normal operation, the telescope beam lines will be isolated from each other and from the manifold, hence readouts are needed for each line, plus the manifold. For monitoring, readouts should be updated perhaps every second. It will be necessary to access this from throughout the lab. Logging could reasonably be enabled for every minute, producing an archive of about 5 MB per year (note added: automatic logging operational).

Diagnostics should be available, at least as an optional display at the observing console. One useful information would be "time to pressure" extrapolating the current pressure rise to predict when the pressure will hit a specified limit.

Various options for units could be considered. Atmospheres (standard) seems the most intuitive for non-specialists, as it is fairly obvious that a pressure around 0.001 atm is satisfactory for most purposes.

3. VACUUM BOX COMMISSIONING LEAK-CHECK PROCEDURES

The main test system is a CEC helium leak detector (model 24-120B) with a Dupont 24-038 roughing system, both in good condition. Local service is available. (The observatory also has a Veeco helium leak detector (MS-9AB) - however, this unit is in poor condition and service is not locally available.)

The testing procedure requires in turn isolating each of the vacuum boxers. This is achieved by removing sections of vacuum tubing on each side of the box, and inserting temporary plugs, at least one of which has an access valve for pumping and testing. As a special case, it is not convenient to remove the vacuum tube from the End Boxes, so on each line, the End Box, the adjacent POP box, and the connecting tube, are isolated as a unit.

The Dupont roughing pump has marginal capacity for roughing of the vacuum boxes. There are several options. One is to use a section of hose to connect the volume under test to another vacuum line, and use the main pump for initial evacuation. This has been tried and works well, though it does require additional reconfiguration and coordination. . In the case of the End Box plus POP Box, which is the largest volume that would be tested in this way, the initial pressure when the Dupont roughing pump was connected was 1000 microbar, and the roughing pump easily took it down to 30 microbar over a period of several hours (after the larger leaks were repaired) allowing a sensitive leak check. Another option is to exchange the 5 cfm roughing pump for a 16 cfm model (the largest that will conveniently fit into the system configuration). In any event, if the Dupont pump is used for roughing, it should be exhausted to the outside, as significant oil mist will be discharged, even through the de-misting filter.

Testing of Turning Box, Periscope and Beam Transport Tubes

For East and West lines, the following procedure is suggested. Isolate the Turning Box by removing tube sections on each side, and use the 8" blank plug and valve plug to close the volume. Use the Leak Check system to test the volume. (This is a large volume to evacuate with the Dupont pump. If the Dupont roughing pump is used, its exhaust should be exhausted outside. Alternatively, use a second valve plug and a tube to pre-evacuate the Box with the main pump.)

Leave the telescope side plug in place. Remove the 12" tube section east of the Periscope Box, and close the volume with a valved plug. Use the main pump to pre-evacuate the volume, and then test with the Leak Tester through the valved plug.

Now reconnect the beam transport tube to the Turning Box and using the main pump, check the vacuum performance out to the telescope.

If needed, follow up with maintenance of the outside tube seals.

For the south lines, the following procedure is recommended. Remove a section of 8" tube outside the OPLE building and close the line with an 8" blank plug. Remove the 12" tube section east of the Periscope Box and close the volume with a valved plug. Use the main pump to pre-evacuate the volume, and the Leak Tester to check the Turning Box and the Periscope Box.

Testing of POP Boxes and End Boxes

For each of POP Boxes 1-3, remove the sections of 12" tube on each side. Close one side with a 12" blank plug and the other with a 12" valved plug (however, the valve will not be required). Put the valved test port on the POP access flange. Evacuate with the Leak Check roughing pump and test with the Leak Test unit.

It is not convenient to isolate the POP4 and the End Boxes separately. Instead, remove the section of 12" tube west of POP4. Put a blank 12" plug on the west tube joint of POP4. Install the Periscope box valved test port. The Leak Test Roughing Pump cannot evacuate this volume. On a separate, available telescope line, install the valved test port plate on its POP4. Use a hose to connect the other line to the line under test, and use the main pump to evacuate the POP4+End Box through the other telescope POP line. Remove the tube and test the POP4 with the Leak Tester attached to the valved 12" plug. Then test the End Box through the valved access port.

4. LEAK TESTING AFTER COMMISSIONING

After commissioning, all of the vacuum system will be nominally tight. From time to time, leaks will occur. It will be necessary to have a test protocol to isolate and fix these leaks.

A logging system should be set up to keep track of all access to the vacuum space. This log will show which access ports may be suspect for o-ring problems.

Problems will also occur with repaired leaks losing their integrity - this is inevitable since many leaks have been sealed with epoxy which is brittle and does not have a resilient bond on some surfaces.

Starting with a leaking system, a plug should be introduced into the system to approximately isolate the inside from the outside systems. The East and West lines can be conveniently isolated on either side of the Turning Box, to test mostly inside, and east of the Periscope Box to test mostly outside. The South lines can be isolated conveniently outside the OPLE, to test mostly inside, and east of the Periscope Box to test mostly outside.

Most leaks will be inside, and the subsequent effort will involve successive breaks in the line (by pulling 12" tube sections, to test further and further east). When the problem is narrowed to a single box, it will be isolated as in the commissioning, probably according to the plan above.

4. PUMP VIBRATION ISOLATION

Isolation is accomplished with a mounting providing a low resonant frequency for the given weight. A suitable spring mounting appears to be model no. A10Z31-2461 from Stock Drive Products / Sterling Instrument (www.sdp-si.com, email eservice@sdp-si.com, 819-8900X491, Fax: 516-326-8827).

The concept would utilize a metal plate interface between the spring mounts and the pump. The supports can be mounted to the plate in the shop, and the pump moved onto the plate and clamped to the plate.

It is also necessary to isolate the manifold connection. This can be done with plastic tubing. The tubing is flexible in bending but stiff in compression, so it is necessary to have at least one bend. Figure 1 below illustrates this concept.

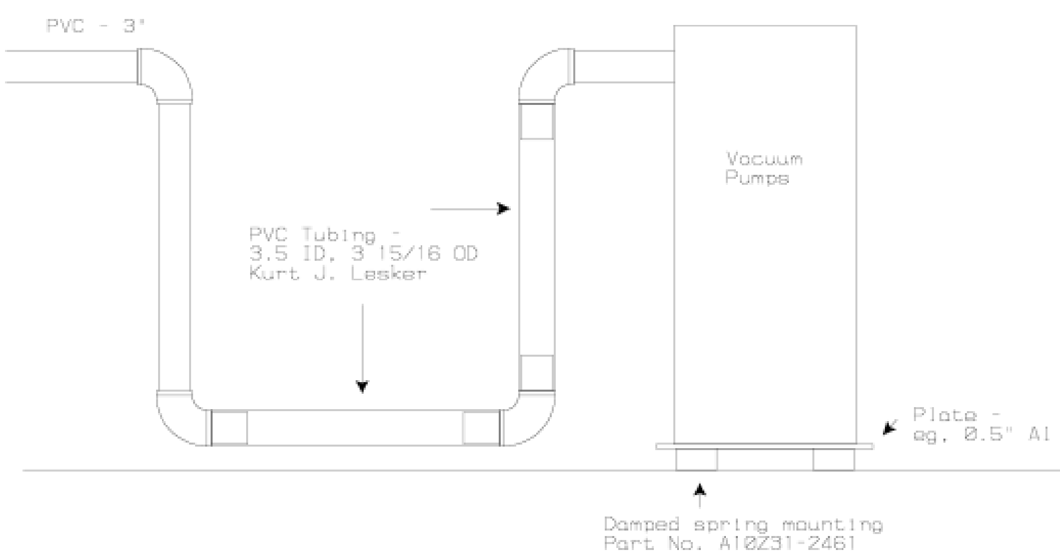


Figure 1. Main vacuum pump vibration isolation.

5. EQUIPMENT ADDITIONS OR IMPROVEMENTS

Although the minimum complement of equipment is available, several items mentioned above should be added for convenience or other reasons. First, a custom End Box port is needed with a vacuum valve, for test access. The Dupont roughing pump (5 cfm) should be replaced with a larger model (16 cfm). A cold trap should be added to the roughing line, to reduce possible contamination from the pump. A long exhaust hose should be added to vent the exhaust outside the laboratory (particularly important if the roughing pump is used to evacuate the boxes from atmospheric pressure).

6. APPENDIX A – VACUUM SYSTEM VOLUMES, PUMP RATES AND LEAK RATES

Sub-system volumes

The vacuum system consists of six lines, one for each telescope. Each line contains a length of beam transport tubing, which differs in length from line to line, from the telescope coude area to the OPLE building. Within the OPLE building, the light continues through a series of vacuum boxes, each containing optics and in some cases mechanisms.

The volume of various system components is needed to estimate or interpret pumping speeds and leak rates, for example. Component volumes are collected in Table 1.

Turning Box	6.4 FT3
POP Box	3.1
Periscope Box	3.0
End Box	2.9
POP4+End Box+ Joining tube	45.6
20’ Length of POP Tube	14.4
Manifold	5.3
S1 beam tube	183
S2 beam tube	152
W1 beam tube	132
W2 beam tube	34
E1 beam tube	186
E2 beam tube	126
Total System Not including manifold	1877

Table 1. Vacuum component volumes. Note that the box volumes include the extensions which connect to input and output tubes, hence are appropriate for isolated pumping of these units.

The total volumes of the lines are collected in Table 2.

	S1	S2	W1	W2	E1	E2	Total
Cubic Feet	361	329	309	211	363	303	1877
Liters	10212	9319	8751	5976	10276	8573	53107

Table 2. Total volume of the various telescope lines, and of the total system (not including the manifold).

The beam transport and POP lines are made up of aluminum tubes with flexible rubber sleeve joints. The vacuum boxes are made from carbon steel pipe, plated with low-phosphorus nickel.

The lines are pumped through a PVC manifold (including PVC valves). The pump is a two-stage system consisting of a Roots Blower backed with a rotary vane pump.

Pump Performance

In practice, the Main Vacuum Pump system achieves pressures of 0.18 Torr (2e-5 atm) when pumping on the PVC manifold alone. The manifold has a leak rate of 5 liters/hour, so the pump is operating at 250 m3/hour. The Roots pump is specified to have a maximum pump rate of 505 m3/hour. Considering the manifold geometry, we are probably getting near the maximum available pump speed. We don't really know the ultimate pressure with this pump system, but it is certainly below the achieved 2e-5 atm.

The pump typically can bring a single vacuum line to near its current leak-limited pressure within about 40 minutes.

Manifold

The manifold has a leak of 5 liters/hour, which is smaller than the leak rates in the telescope lines, so it is not a performance-limiting factor at present. It will be limitation after the lines have been fully serviced - if the manifold leak is a leak to outside the vacuum system. However, the manifold has been leak checked without finding this leak. It may be a leak through one of the PVC valves, in which case it would not be important when all lines are evacuated. This remains to be ascertained.

PVC Valves

PVC valves were selected for the cost advantage ($250 vs $2000). The valves are designed for irrigation systems, but the design is valid for vacuum systems (ball style). One valve was purchased and tested and found to be leak free at a very satisfactory level. The valves installed have never been individually tested. Leak checks, however, have not shown any indication of leaks. The valves can be overhauled (balls lubricated, or even replaced).

Vacuum Line Performance

The vacuum lines are in a continual state of maintenance, both for detection and correction of leaks, and because it is regularly necessary to open the vacuum system for alignment or replacement of optics and upgrades of control and of alignment targets.

Table 3 shows the lowest achieved pressure in each line, the current achieved pressure, the current leak rate, and the current pressure 8 hours after the line closed at its minimum pressure.

	S1	S2	W1	W2	E1	E2
Best achieved P in atm	.00075			.0002	.0004	.00067
Current achieved P in atm	.00075			.0002	.0004	.00067
Current leak liters per hour	156			20	57	66
Current P atm after 12 hours	.19			.042	.068	.094

Table 3. Current vacuum performance of the telescope lines when isolated and pumped individually.

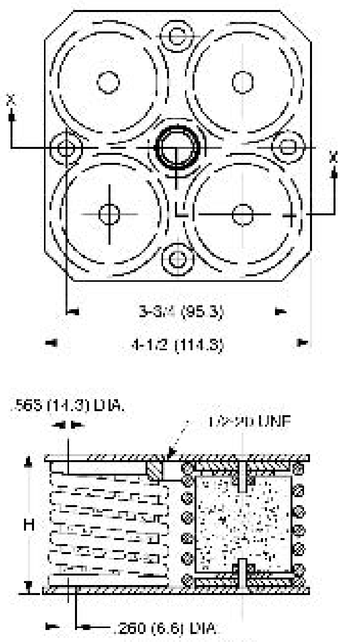
It is clear that there is considerable variety between lines, and that there is significant work to do in leak detection and repair. For comparison, note that the achieved leak rate for the POP4-End Box pair plus joining pipe was 2 liters per week! Extending this performance to the entire system, the pressures would rise to only .006 atm after a week. This is not a limit, as the leak checking can still be pushed several orders of magnitude more sensitive.

7. APPENDIX B – PUMP ISOLATION SPRINGS

Vibration & Shock Mount Product Finder

INCH **Damped Spring Mountings – To 750 lbs.**

■ CORROSIVE ENVIRONMENT ■ STAINLESS STEEL MESH
■ FOR LOADS OF 150 TO 750 POUNDS



SECTION X-X

CHARACTERISTICS
Lateral to vertical stiffness approximately 1:1.
Elastic Limit corresponds to a maximum load in compression of .012 oz. and radially .007 oz.
Damping factor c/co 0.15 to 0.20.

APPLICATIONS
- HEAVY LOADS
- COMPRESSORS
- PUMPS
- GRAIN VIBRATORS

MOUNTING
Must be loaded vertically through its axis.

MATERIAL: **Mounting Plates** – Mild Steel, Painted
Springs – High-Tensile Steel; Phosphated, Dyed Black
Isolator – Knitted Stainless Steel Mesh
TEMPERATURE: -94°F to +347°F (-70°C to +175°C)

Catalog Number*	Static Load				Natural Frequency Hz	H - Height			
	lbs.		kg			Free		Max. Load	
						in.	mm	in.	mm
A10Z31-2461	150	260	60	118	4 – 4-1/2	3.0	76.2	2.376	60.4
A10Z31-2462	250	450	113	205					
A10Z31-2463	440	750	200	340					

*To be discontinued when present stock is depleted.

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