New Very Small Angle Neutron Scattering (VSANS) Instrument

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Abstract. The design of a new Very Small Angle Neutron Scattering (VSANS) Instrument for use in National Institute of Standards And Technology (NIST) will be discussed. This instrument is similar to a shorter instrument we designed and delivered to ANSTO in Australia called the Bilby SANS instrument. The NIST VSANS and the ANSTO Bilby SANS instruments have very similar dimensions for length and diameter and have similar requirements for internal detector motion, top access port, walkway supports, and ports; however, the Bilby SANS instrument vacuum requirement was lower (7.5x10-5 Torr) and the entire (60,000 pound) vessel was required to move 1.5 meters on external rails with a repeatability of 100 um, which ADC achieved. The NIST VSANS length is 24 meter, internal diameter 2.3 meter with three internal carriages.

The NIST VSANS instrument, which covers the usual SANS range will also allow configuration to cover the range between $q \approx 10^{-4}$ Å^{-1} to 10^{-3} Å^{-1} with a sample beam current of (10^4 neutrons/s). The key requirements are a second position-sensitive detector system having a 1 mm pixel size and a longer sample-detector flight path of 20 m (i.e., a 40 m instrument).

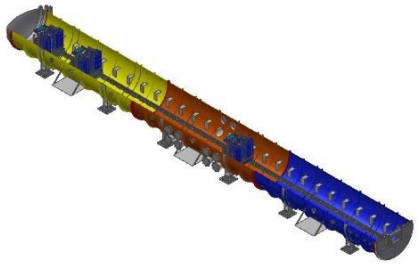

Figure 1. NIST VSANS

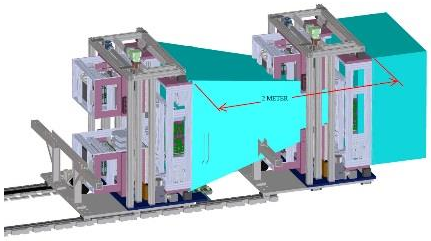

Figure 2. A Pair of Dector Units

1. Introduction

The VSANS instrument, which will cover the usual SANS range, will also allow configuration to cover the range between $q \approx 10^{-4}$ Å^{-1} to 10^{-3} Å^{-1} with a sample beam current of (10^4 neutrons/s). The key requirements are a second position-sensitive detector system having a 1 mm pixel size and a longer sample-detector flight path of 20 m (i.e., a 40 m instrument).

The NIST NCNR VSANS vessel consists of a steel vacuum vessel capable of 1 x 10^{-3} torr. The vessel length is 24000 mm and is built in 3 sections roughly 8000 mm each. The vessel material is 516 steel. Each section is supported on 4 adjustable feet that rest on the floor. Each section must have external ribs designed to withstand the compressive load of the vacuum. Each section is joined to the other at a flange with a captured O-ring on one side and a flat surface on the other. The vessel leak rate is .01 torr/hr. Alignment features accurately join the sections. The front section has a flat aluminum

cover that supports a vacuum gate valve and 4" thick high-density polyethylene (HDPE). The rear section has a domed hatch on an articulated hinge. The first and last sections have manway hatches on the top. Ports are provided for viewing and electrical/air connections to the interior. Two supports for a cable troughs are provided on either side of the vessel. Each section has welded lifting tabs at the top.

The interior of the 3 assembled sections have two welded steps in the bottom that support profile rails. The rails support and guide 3 carriages that travel in-line. A detector cassette mounts to each carriage. The carriages are driven by a pinion gear and motor on a common rack. Each carriage has an absolute encoder. Hard stops and limits are provided for each carriage as well as an anti-collision sensor on each that limits the closest approach between carriages to 2 meters. Cables in cable chains supported by trays are provided for each carriage and detector. Design was based on ASME BPV Section VIII.

2. Key specifications

Key specifications are identified in the chart below which also identifies the ANSTO Bilby SANS vessel requirements and the achievement of each key specification by ADC.

Table 1. NIST VSANS and ANSTO Bilby Spec Comparison

Specification	**NIST VSANS**	**ANSTO Bilby**	**Achieved on Bilby**
Length	24,000 mm	20,020 mm	20025 mm
Diameter	2300 mm	2300 mm	2300 mm
Vacuum	1 x 10^{-3} Torr	7.5 x 10^{-5} Torr	7.5 x 10^{-5} Torr
Vessel Straightness	+/- 12 mm	+/- 10 mm	+3, -7.5 mm
Leak Rate	.01 Torr/hr	.000075 Torr/hr	.00002 Torr/hr
Carriage Load	800 Kg	2000 Kg	2000 Kg
Carriage Travel	17,400 mm Max (Mid)	18,800 mm	18,800 mm
Carriage XY Deviation	+/- 2 mm	+/- 1 mm	+/- .7 mm
Adjustment Vertical	+/- 25 mm	+/- 10 mm	+/- 10 mm
Adjustment Lateral	+/- 25 mm	+/- 20 mm	+/- 20 mm
Adjustment Axial	+/- 25 mm	1.5 meters	1.5 meters
Codes	ASME BPV Section VII	AS 1210	ASME BPV Section VII, AS 1210
Material	Steel 516	Stainless Steel 304	Stainless Steel 304
Sections	3	3	3
Rear Hinge	Yes	Yes	Articulated
O-Rings	Buna- N	Buna- N	Buna- N
Walkway Support	2000 lbs./tab	250 kg/m2	7300 lbs. Centrally located on Section
Manway Hatch	# TBD, 66 cm 3 sections	x1, 120 cm Diameter	x1 Central Section

3. Straightness of Travel

The straightness of travel for each detector is the most important spec and possibly the hardest to achieve. Vessel straightness, roundness, compression deflection, are not as important as the straightness requirement of the internal steps and the adjustability of the rails to make the travel of the center of the detectors parallel to the centerline of the vessel. ADC has devised a method for adjusting

and supporting the rails on the internal step for the much heavier Bilby detectors for ANSTO. In addition, the ***entire*** 64,000 pound Bilby chamber moved on external rails 1.5 meters. The Bilby vessel movement feature placed constrains on the support of each section that can be greatly improved on the NIST VSANS vessel (which does not move).

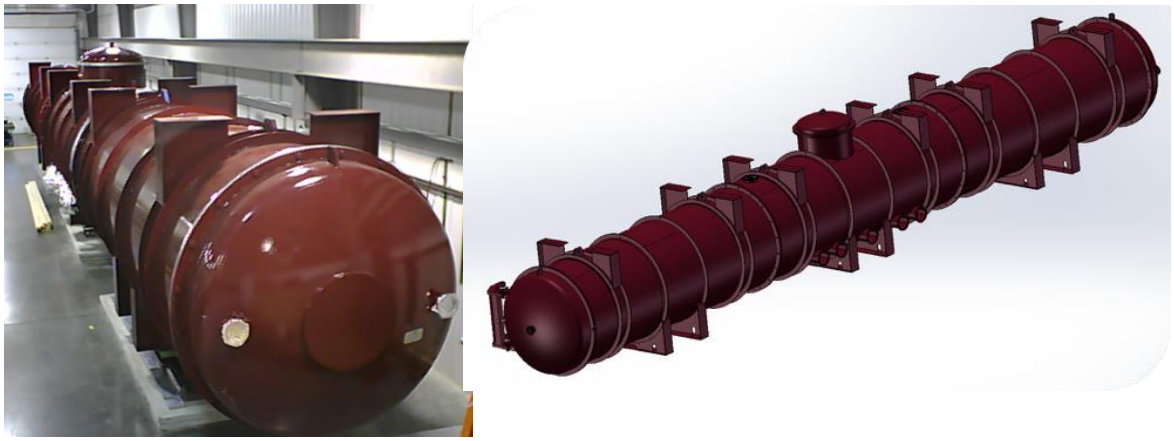

Figure 3. ANSTO Bilby SANS Vessel

ADC designed the step for maximum stiffness by using thick solid 304 SS material to prevent deflection of the rails as the detector is moved. The steps ran the full length of each section and were machined in one piece as can be seen in Figure 4 below. They were stitch welded to the shell to limit warp. For the NIST VSANS, access is provided in the vertical step for paint access under the step.

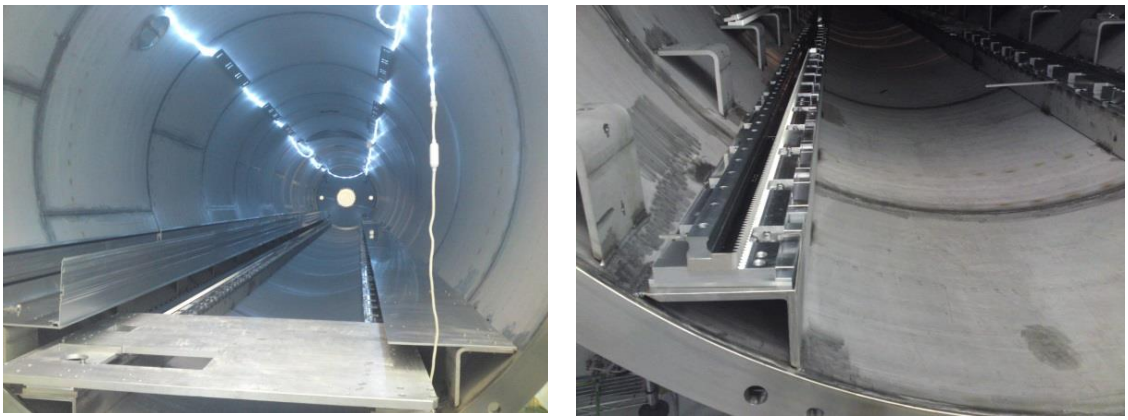

Figure 4. ADC's Rail Shimming Design

ADC used a laser to measure the error in the steps (down to 10 um) and thereby calculate the thickness of the shim plates. The vertical error was corrected to +/- 0.35 mm as shown in the chart below in Figure 5.

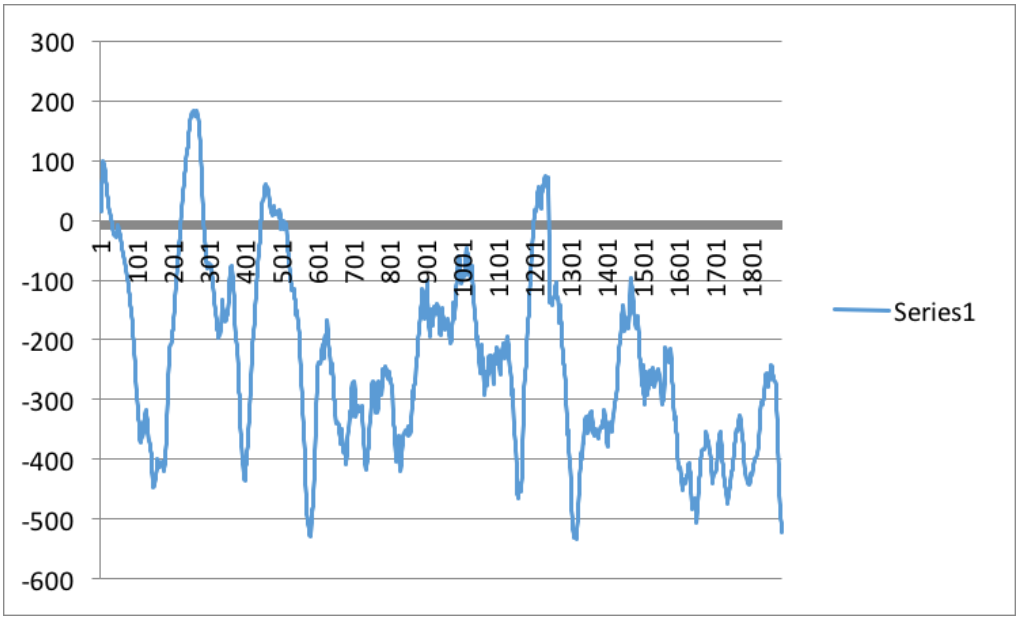

Figure 5. Bilby Vertical Rail Error

4. Vessel Material

The Bilby SANS vessel was constructed of 304 stainless steel and was unpainted inside to achieve 7.5 x 10^{-5} Torr. The NIST VSANS vessel is constructed of carbon steel (516) and is painted inside and out; however, the vacuum requirement is 1 x 10^{-3} Torr. Carbon steel is stronger than stainless and a thinner shell may be possible which reduces the weight. The Bilby vessel had a thick shell and was reinforced with a double shell at key locations such as at the lifting tabs. Bilby was designed so that lifting would not permanently deform the shape of the vessel (primarily the internal steps) and so that a 250 pound man on the catwalk would not affect the experiment if one was in progress.

5. Detector Motion System

The motion system for the detectors consists of 3 carriages that are driven on the same rack and guidance rails. Each carriage is driven by a pinion gear attached to a gear box and stepper motor. An absolute rotary encoder is mounted to a separate pinion gear on each carriage to encode the position. Two profile rails are provided on steps welded to the bottom of the vessel shell. The motor and gearbox are sized to provide .1 m/s^2 accel/decel on 800 Kg payload while resisting the IGUS cable chain load and bearing truck friction. Top speed of 200 mm/sec (7.9 inches/sec) can be achieved.

IGUS chains and trays are provided for each carriage and convey the cables and hoses necessary for the detector as well as the carriage motor and encoder.

6. References

[1] The 30 m Small-Angle Neutron Scattering Instruments at the National Institute of Standards and Technology; *J. Appl. Cryst*. (1998). **31**, 430-445
[2] D33—a third small-angle neutron scattering instrument at the Institut Laue Langevin; IOP PUBLISHING *Meas. Sci. Technol*. **19** (2008) 034007 (8pp)
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[4] The Neutron Beam Expansion Program at the Bragg Institute; International Workshop on Neutron Optics and Detectors (NOP&D 2013) *Journal of Physics*: Conference Series 528 (2014) 012026