Summary of presentations at the CERN VSC- CE Vacuum Studies Group Teleconference on March 2, 2022

Agenda:

Zoom Teleconference: Mar.2,2022 at 10:00 -12:00 (EDT) 16:00-18:00 (CET)

Co-chaired by P. Chiggiato (CERN) and F. Dylla (LIGO Consultant)

Topic: Updates on on-going studies for UHV and GWO materials and vacuum vessel designs

1. *Introductory remarks*: F. Dylla, P.Chiggiato, R.Weiss

2. *Comparisons on international standards and nomenclature for mild steels*
Dan Henkel, MIT consultant
3. *Updates and plans for on-going outgassing studies of mild steels from members of the CE Vacuum Studies Group* JLab, CWM, NIST
   a.) summary of Feb.17 teleconference on inter-comparisons Fred Dylla
   b.) update on JLab test stand for outgassing measurements Joseph Maniscalco, ODU

4. *Updates on outgassing and surface studies on Silcotek coated steels* Ivo Weavers, CERN

Our next scheduled teleconference is on April 6, 2022 (10:00 EST, 16:00 CET)

This teleconference was the 6th in a series of teleconferences initiated after the January 2019 workshop at the LIGI-Livingston (LA) site on research topics for large UHV systems such as the next generation of GWO.

Notice on use of data: All group members are reminded that data shown during these teleconferences are not to be shared outside of the group or shown publicly without the author's specific permission
This summary is prepared by F.Dylla with the assistance of the presenters. Corrections and possible additions are requested and welcome for an accurate record.

1. Introductory Remarks:

Fred Dylla:

Fred welcomed the group and thanked all participants for their contributions to this informal collaboration and offered our appreciation for Paolo's hosting of these teleconferences and for archiving the group's presentations.

The archive location on the CERN Indico website is the following:

https://indico.cern.ch/category/14657/

Collaboration members desiring access to the site or with material to archive should send a message to Carlo Scarcia at email: carlo.scarcia@cern.ch

Fred noted that the members of the CE Vacuum study group held a teleconference on Feb. 17th to discuss issues that would facilitate the standardization and inter-comparisons of outgassing measurements from several laboratories. He gave a brief summary of this meeting within the agenda below. The informal minutes of this Feb. 17 meeting will be deposited in the archive site.

Paolo Chiggiatto:

Paolo presented a brief update on the plans for formalizing the collaboration between the CERN VSC and the EU's Einstein Telescope (ET) project. The joint activities will include VSC exploring the relevant vacuum technology and surface science for the design of the ET vacuum system including the fabrication, preparation and testing of a prototype vacuum tube segment. Paolo noted that it is desired that this CERN-ET collaboration be extended to include collaboration with the US's Cosmic Explorer (CE) project and the informal collaboration on vacuum issues represented by participants in these teleconferences. As a baseline for the ET design efforts, the vacuum requirements for both Virgo and LIGO will be used.
The proposed vacuum tube designs for this effort are the corrugated thin-walled design with stainless steel presented by Cedric Garion during this collaboration's Feb. 2 teleconference and a UHV-compatible pipeline made of mild steel. Additional designs and wall materials will be considered based on the efforts of the full collaboration.
The content of an MOU between CERN and the ET project has been accepted in principle and the formal document is currently being prepared with a target completion date by the end of March followed by signatures from both parties.

Rai Weiss:

Rai noted that he has deposited a document in the collaboration's archive site that describes the baseline vacuum requirements of LIGO. He observed that these requirements have been met at both LIGO sites since the commissioning of the project. The cost of the as-built and installed 16 km of LIGO beam tubes was $75M USD (in 1994 currency).

The contents of the "LIGO Baseline Directory" in this collaboration's archive is the following:

Files:
LIGO_beam tube summary and baseline.pdf
LIGO beam tube costs 1994 dollars.pdf
CE_vacuum requirements and goals.pdf

Sub directories: backup information
Beam tube baffling
Beam tube alignment
Beam tube residual gas phase fluctuations
Beam tube pumping and outgassing
Beam tube leaks and location
Beam tube fab and installation
Beam tube cleaning and test

2. Comparisons of international standards and nomenclature for mild steels

Dan Henkel, MIT Consultant

The presentation compared several American and European standards for steels and reviewed the history of nomenclature changes over the last fifty years when purchasing steel. Examples were given that demonstrated an inherent level of complexity when defining a type of steel. Despite efforts to unify the standards, there has not been much success in harmonizing them. It is not often that one standard can be directly compared to another. In general, after all the attempts to collect standards from many organizations and simplify, the nomenclature from the 1960s still persists.

Standards from organizations such as AISI, SAE and UNS classify steel by composition only. Examples are 1020, 4130 and 304L. In contrast, ASTM and the EN standards were each developed for specific applications such as seamless pipe (A519) and structural steel (A36). The standards are comprehensive, covering composition, mechanical properties, test methods and size/shape tolerances. Thus, 1020 is included as a grade of A36 but A36 does not have to be 1020.

Certifications sheets for steels used to make vacuum system equipment for outgassing studies were gathered from the five labs and compared in the table below. Welspun is a pipe manufacturing facility that typically uses API X65 steel for transmission line pipe. Carbon is just above the upper limit for low carbon steel (<0.25) and manganese is high (1.40) to provide strength, stiffness and weldability. The closest material to Welspun is the E355C used by CERN. Although the W&M and NIST materials have lower manganese, it was recommended that they continue to use these materials for current outgassing studies until they can be upgraded to match transmission line pipe steel.

ASTM	Type/Gr	UNS	EN	C	Mn	P max	S max	Si	Cr	Ni	Mo	Cu
					W&M							
A36	Plate	G10200	C22	0.18-0.23	0.30-0.60	0.040	0.050					
					CERN							
A656	50	K12447	S355J2+AR	0.22	1.60	0.035	0.035	0.55		0.30		
A572	50	K12447	S355J2+N	0.22	1.60	0.035	0.035	0.55		0.30		
A516	70+N	K02700	P355N	0.31	0.85-1.20	0.035	0.04	0.15-0.30				
A519	1524	G15240	E355C	0.19-0.25	1.35-1.65	0.040	0.050					
					NIST							
A36	Plate	G10220	S235JR	0.20	0.85	0.009	0.002	0.18	0.09	0.11	0.03	0.27
A36	Plate	G10220	S235JR	0.20	0.86	0.012	0.008	0.15	0.18	0.09	0.03	0.26
A36	Plate	G10220	S235JR	0.20	0.76	0.012	0.006	0.04	0.06	0.03	0.01	0.04
					Welspun							
API X65	PSL2			0.26	1.40	0.04	0.05	0.45				

3a. Discussion of means of standardizing outgassing measurements of water from mild steels

Fred Dylla, MIT consultant

On Feb. 17, members of the CE Vacuum Study Group held a teleconference to standardize procedures for preparing samples and measurement techniques for inter-lab comparisons of outgassing and surface characterization of mild steels. The full minutes of the discussion are archived on the collaboration's Indico site.

We discussed the necessity of standardizing the choice of material (for the mild steels under study), the cleaning and preparation procedures being used, the definition of some type of standard air exposure after initial pump-down, and subsequent recording and analysis of data in order to enhance inter-lab comparisons of the data among the CE Vacuum Group and our collaborators at CERN.

We agreed on the following:

1. **Cleaning procedures**: all groups would use a cleaning procedure that was documented to remove the grease that was typically applied to mild steels to minimize rusting during shipment, plus removal of the usual adventitious carbon contaminants.

2. **Chamber (or sample collection) treatment** prior to outgassing measurements:
   a.)prebake of the chamber to 100-150C for approximately 24 hrs to remove atmospheric H_2O.
   b.)pump-down to a base pressure of less than 1×10^{-7} torr.

3. **Exposure of the chamber to a "standard humid air" exposure**. For the purposes of these measurements (comparison of mild steels and treated steels to existing measurements of stainless steels), a standard air exposure would be exposure to laboratory quality air at nominal 1 atm pressure with a measured relative humidity in the range of 40-50% for a period of approximately a 1hr.

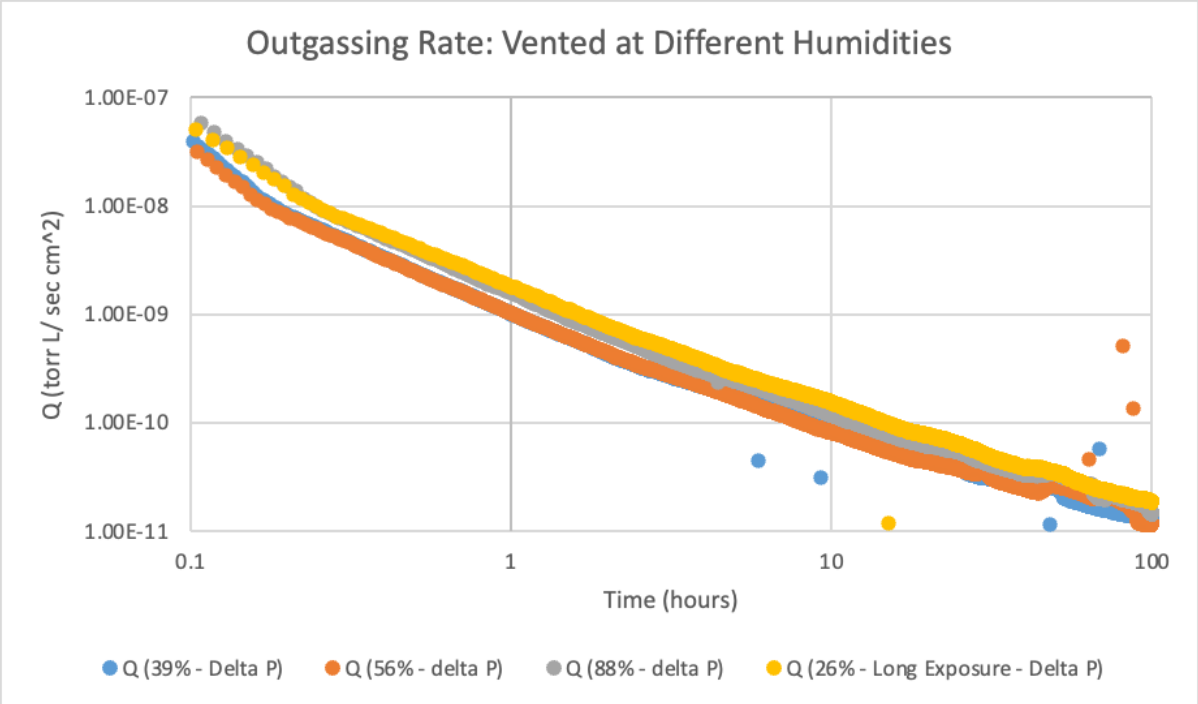
4. **Outgassing measurement**: measure the $P(H_2O)$ versus time for at least 100 hrs after starting measurements.

5. **Material choice for mild steels**: for now continue measurements on the alloy that each group presently has on hand, which is A36 plate stock (type 1020 and 1022) being used at W&M and NIST.

3b. Update on mild steel outgassing measurements at Jefferson Lab

Joseph Maniscalco, ODU and JLab

Changes were made to the test apparatus used to study hydrogen outgassing of low carbon steel (AISI 1020). Specifically, the spinning rotor gauge was replaced with a broad range gauge (combination cold cathode and Pirani) and an orifice was installed between the test pipe and right-angle valve leading to a turbo pump cart. Throughput measurements of water outgassing rate were performed for air backfills with a range of humidity and exposure times. The pump down plots show the familiar power law dependence, $Q(t) = Q_{1h}/t^{\alpha}$ with α for each measurement ~ 1. After evaluating properties of the new gauge, the JLab team plans to measure pump down times for the pipe sample at different ambient temperatures. A similar set of measurements will be performed with a 316L stainless steel tube sample for comparison.

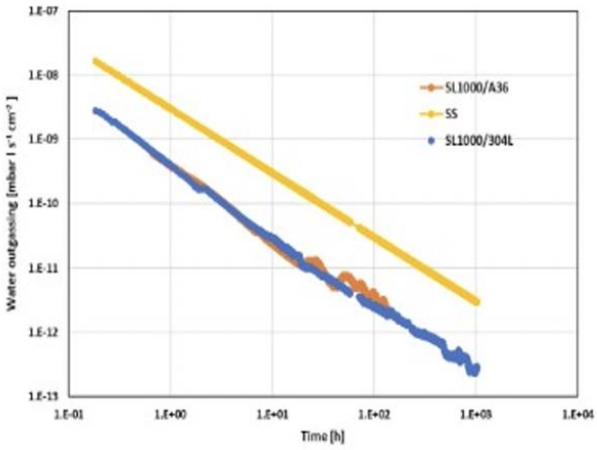


4. Updates on outgassing and surface studies at CERN on Silcotek coated mild steel

Ivo Weavers, CERN

A second pump down showed a standard 1/t behavior which confirmed the outgassing rate of the SL1000 coating measured previously (approx.. 2.5 10^-11 mbarls-1cm-2).
The TDS measurement resulted in a similar peak at approximately 575C but no second peak as with the coated stainless samples.
SEM images showed a large amount of particulates on the surface which are not acceptable for a GWD.

SL1000 on mild steel – Pumpdown 2



S_{eff} for water = 2.88 l/s
Sample Area = 67360 cm^2

(samples removed for accumulation measurement)

Time [h]	Water outgassing [mbar l s^{-1} cm^{-2}]
1	$3.95\ 10^{-10}$
10	$2.31\ 10^{-11}$
100	$3.58\ 10^{-12}$

SL1000 on Stainless Steel
Q = $2.5\ 10^{-11}$ mbar l s^{-1} cm^{-2} at 10 hours