FIW München & Hanita Coatings

Calibration of the lift-off technique for measuring the internal pressure of fumed silica VIPs

Determination of boundary conditions for the lift-off measurements and processing of measurement raw data

Project outline and cost estimate

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1 Background and Objectives

The foil lift-off technique is the most commonly used method or procedure used by manufacturers to determine the internal pressure of VIPs during and after the production process. It is used for more than a decade now without any evidence or comparison to a ***direct and calibrated measurement method***. In fact, nobody ever showed how close are the liftoff pressure readings to the actual internal pressure.

In addition to the missing comparison of the readings of the measurement equipment, the boundary conditions for the measurement of the internal pressure according to the lift-off technique are not fixed in a standard or in scientific articles. According to FIW and Hanita experiences, there are several influencing factors on the result of the internal pressure measurements.

- Orientation of the specimens and measurement direction of the laser distance device: horizontal orientation vs. vertical orientation of the specimen, implicating the measurement direction horizontal or vertical: from above or from underneath; with or without the gravitation effect on the foil
- Number and technical characteristics of the laser devices
- Speed of evacuation process together with frequency of readings of the distance device
- Number of repetitions of the measurement (compensating expansion of the core and fleece of the VIP with the first round and solving adherence problems of the foil)
- Bearing distance for the VIP and possible restraints of the edges/the foil
- Positioning laser(s) and suction bell
- Compensation of expansion of core and fleece and/or compensation of deflection of the VIP
- Executing the measurement with decreasing or increasing external pressure
- Raw data assessment and derivation of the measurement result (algorithms for reliability and repeatability of results, as a basis for future automation of the measurement)

The purpose of this project is to

1. ***calibrate the readings of the liftoff units against calibrated pressure gauges for the first time and to***
2. ***fix the boundary conditions for the measurement and to***
3. ***describe a reliable procedure for deriving pressure results from the obtained measurement raw data (assessment and algorithm) and to***
4. ***cross-check the above mentioned results with fast methods, such as the Va-Q-Check device.***

2 Aims and benefits for VIPA members

- Higher confidence for manufacturers for their declaration of performance (liability aspects)
- Better accuracy and more experience for the testing method
- Better known relation to real internal pressure (better knowledge on own products)
- Correct values for internal pressure (and pressure increase over time) are the basis for durability calculations on their products
- Pre-normative research: influence the standardization process
- Technical data about equipment and measurement value acquisition (know-how on equipment and algorithms for automation)
- Basis for future development of internal pressure measurement techniques that could be applicable for fiber core panels as well

3 State of the Art

The lift-off technique is used in two versions for measuring the internal pressure of VIPs:

1. The suction bell method on a small section of a VIP envelope
2. The evacuation chamber method on a whole VIP

Both methods make use of one or more laser distance measuring devices that measure the distance to the surface of the foil while constantly evacuating the surrounding - the space under the suction bell for method 1 and the whole evacuation chamber for method 2. The level of vacuum for the pressure compensation method is shown to work in the range from 0.2 to about 100 mbar with membrane type pressure sensors for the range from 0 to 100 mbar.

3.1 Suction bell

The equipment consists of a top and bottom suction bell. In the top suction bell a laser distance meter is implemented. The bottom suction bell is integrated in a mobile table. The standard diameter of the measurement zone of the equipment is 250 mm. For sucking the gauge head to the surface of the vacuum insulation panel (VIP) and executing the measurement according to the pressure compensation method, two different vacuum pumps are installed and used. The first pump is used for sucking the gauge head to the VIP surface and evacuating the vacuum ring seal. Hereby possible existing leakages to the measurement area are mostly compensated. The second pump is used for creating the vacuum in the measurement zone (top and bottom suction bell).

3.2 Vacuum chamber

The system measures internal pressure by using the panel envelope laminate as the measurement membrane. The specimen is placed in a vacuum chamber which is then evacuated. The system records automatically the decreasing pressure surrounding the panel and the displacement of the envelope when the external pressure surrounding the panels approximately gets to the internal

pressure inside the panel. The pressure inside the vacuum chamber at which the envelope starts to move away from the core is considered to be equal to the internal pressure inside the VIP. The proposed project is aimed to find the exact relation between the displacements of the different envelopes to the actual internal pressure of the panels.

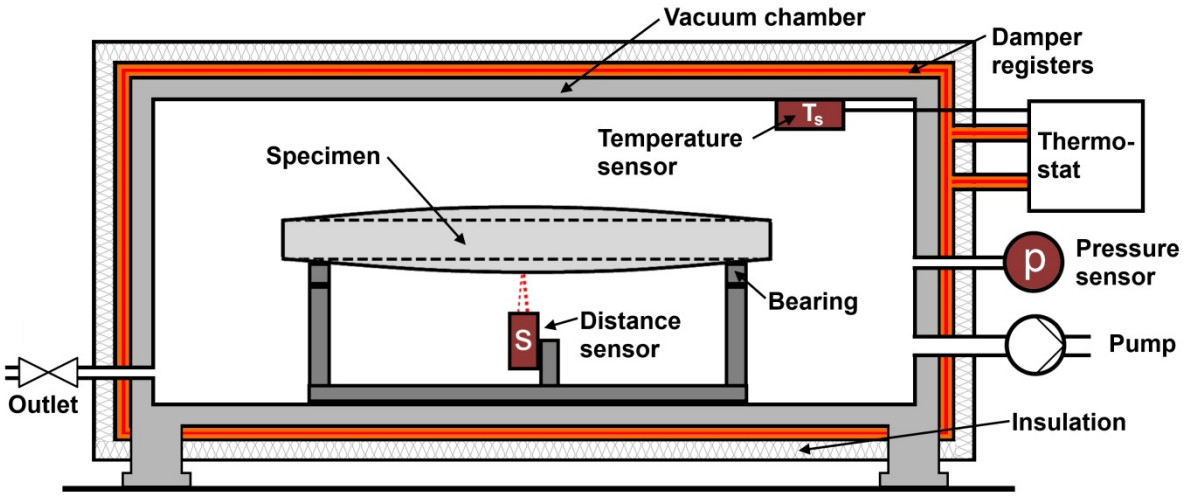

Figure 1: Principal sketch of the measurement device in a vacuum chamber - linear bearings, temperature and distance sensor (laser device)

4 Approach and methodology

4.1 General work program

Hanita will redesign the connector to fit into the FIW vacuum chamber, purchase and build the needed components, instruct FIW how to install the system and how to operate it. Hanita will also be deeply involved in analyzing the calibration test results and in writing the summarizing report.

FIW will select the amount and type of specimens (same procedure for anonymization as for the currently running VIPA compressive strength project can be applied) carry out the very intensive series of calibration tests, analyze the test results together with Hanita and provide a detailed test report including measurement documentation, photos and comments for the standardization process under TC 88 WG 11.

4.2 Calibration of the lift-off technique

The idea is to measure simultaneously the internal pressure of a VIP, the displacement of the envelope and the pressure inside the vacuum chamber. By doing so the exact relation between these 3 measured parameters can be found. It will help to determine in future tests the internal pressure inside the VIPs from the measurements of the pressure inside the evacuated chamber and the displacement of the envelope. This important calibration procedure can be done by connecting a

pressure gauge to the VIP envelope by a leak tight connector invented by Hanita. The result of such procedure will be a correlation relation between the actual internal pressure and the displacement of the envelope when the liftoff procedure is carried out.

The picture below presents the configuration of the proposed calibration system. The internal space of the panel is divided into two parts. The left side contains standard fumed silica board while the right side contains a metal plate that supports the leak tight connector. The 2 arms of the connector allow to evacuate the entire internal volume of the panel and also to measure very accurately the internal pressure in the fumed silica part. This complete unit will be placed inside the vacuum chamber of the liftoff unit and the displacement of the envelope will be detected on the left side of the panel that contains the fumed silica board. The standard connector developed by Hanita should be redesigned in order to fit into the vacuum chamber used at FIW.

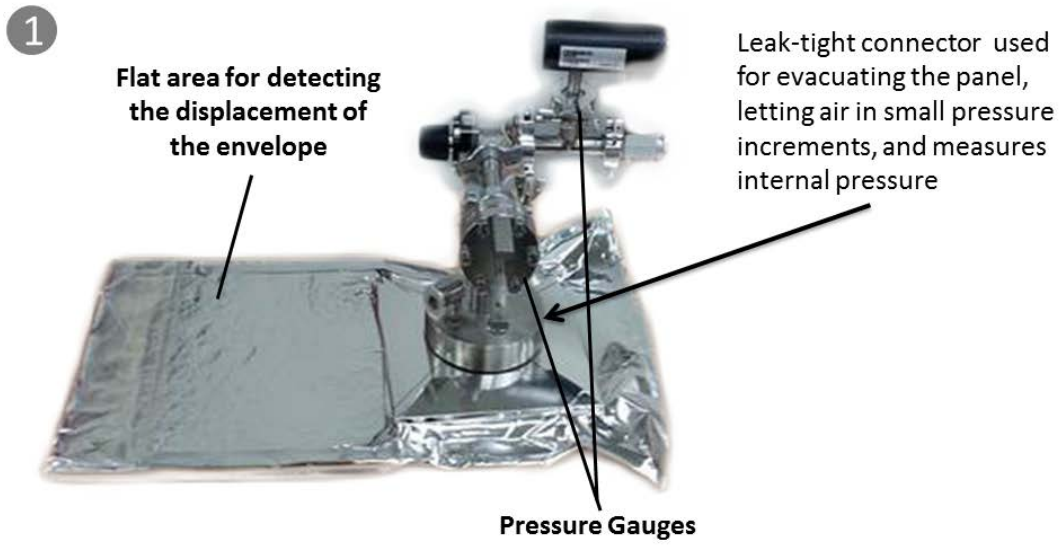

Figure 2: Schematic of the unit to be used for calibrating the liftoff technique

4.3 Investigation of the boundary conditions for the measurement

FIW will check on the relevant influencing factors and develop a concept for correct and reliable measurement results concerning the following boundary conditions:

- Examination of the influence of the type of the bearing (free bearing vs. restrained edges e.g. similar to the suction bell method)
- Definition of the bearings and the bearing distance where the VIP is placed on (e.g. metering section for free bearing similar to area for suction bell?)
- Direction for the distance detection device – measurement with a laser from underneath or from above the specimen? (Vertical bearing of the specimens and horizontal measuring direction is not really useful, as most vacuum chambers are not very high inside)

- Measurement from both directions and correction for the deflection of the panel
- Number of lasers and selection of the correct measurement spots on the specimen
- Number of repetitions for each measurement
- Evacuation speed in mbar/sec
- Pressure limits to prevent damage to the panels
- Pressure increase in between the measurement repetitions - To which level the pressure in the chamber needs to be increased to have independent results for the repetitions?
- Height of the lift-off that is necessary to detect the pressure accurately

4.4 Development of algorithms for data analysis

For the further processing of the distance measurement results into the internal pressure results the basic algorithms for data analysis will be developed. The tangent method and the triangle method will be used. Both methods can be implemented with any adequate script language.

Separate analysis of parts of the measurement data each containing a lift-off sequence between the short-duration ventilations of the vacuum chamber is conducted for both methods. The clipped measurement data is plotted as a function of distance over internal pressure of the vacuum chamber $s(p_{i,c})$. Figure 3 shows the raw measurement data used (one lift-off sequence, $s(p_{i,c})$).

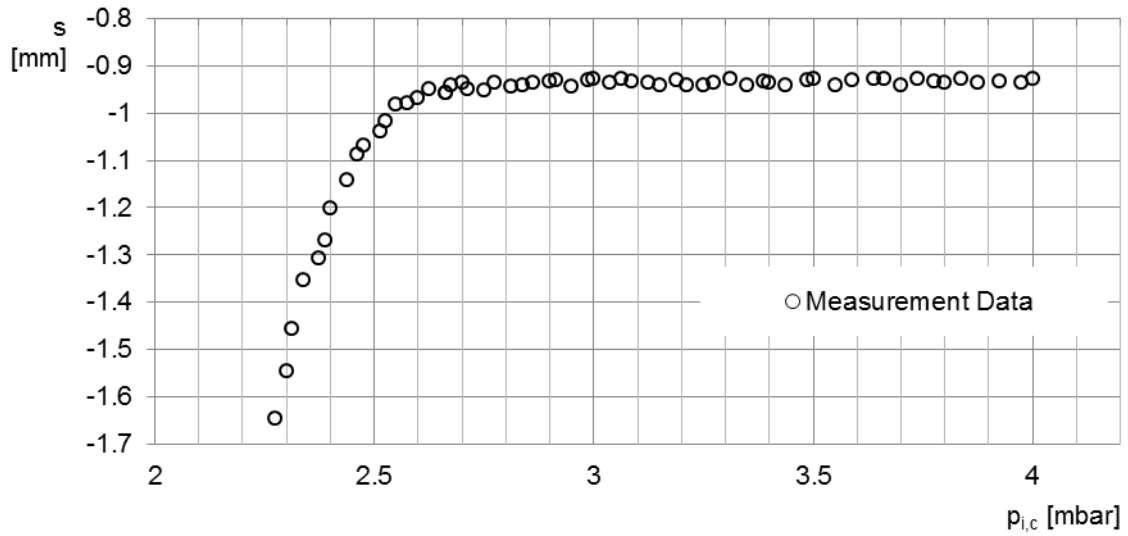

Figure 3 Exemplary measurement data $s(p_{i,c})$ determined on a VIP with 15 mm thickness, sample rate 1 Hz

4.4.1 Implementation of the “tangent method” for data analysis

To find the linear sectors of the two tangent lines a linear regression analysis of the measurement data starting with two data points (values of pressure and displacement) and increasing the included data point by point is conducted. This is done from the beginning of the data/sequence onwards for

tangent A and from the end of the data backwards for tangent B. Then the quality of the tangents is checked with the RSS (root sum square) method.

4.4.2 Investigation of a new method for data analysis – "triangle method"

An alternative method is being developed by FIW at the moment. It is based on the analysis of each lift-off sequence with the triangle method. A polyline consisting of all measurement points can be closed easily to a shape that can be basically described as a triangle with a rounded tip representing the bent transition zone. Therefore the first and the last measurement points have to be connected (Figure 4).

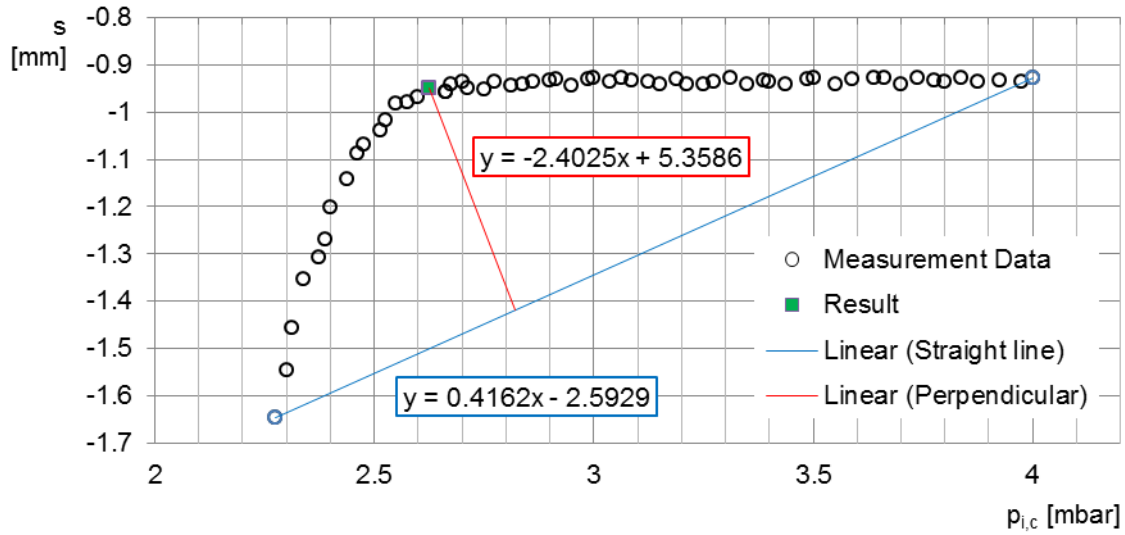

Figure 4 Utilization of the triangle method on exemplary real measurement data

Both methods will be investigated and their algorithms will be described that they could be used in an automation by the VIPA members on their factory production control.

4.5 Technical specifications

All necessary technical specifications for the equipment will be documented and listed for VIPA. The members should be able to perform reliable measurements on their own products after the end of the project.

4.6 Further validations

Validation of existing company specific fast methods can be done with low additional effort if planned properly before the start of the research work. Within this approach the existing fast method "Va-Q-Check" will be investigated on several tested panels, as it is the best known fast method on the market.

5 Discussion and outcome

The main outcome of this project will be a report on how to calibrate liftoff systems and several calibration curves for different types of envelopes. The report will also contain detailed instruction how to preform correctly the liftoff procedure. For example how to correlate accurately the displacement of the envelope to the exact pressure inside the VIP.

The final report will also include recommendations on important parameters such as boundary conditions for the measurement (e.g. distance and type of bearings where the VIP is placed on), number of repetitions required, how to further process and average the results, the speed of evacuation and many more technical details. It will also contain the algorithms that the VIPA members could use for automating the process in their own labs.

If company specific methods are cross-checked, the results will be presented in a separate test report.

6 Cost estimation and time schedule

In order to be able to carry out the investigation properly, an amount of ***€ 25,000-(net)***

FIW - ***€ 14,500***
Hanita - ***€ 10,500***

will be necessary for the above mentioned program. Of course we are flexible to adjust the investigation program to the needs of the VIPA members. The investigations can be carried out starting May / June 2016. Time required to carry out the study is 8 months.

The validation of company specific methods will be done on the basis of the necessary additional effort (hourly basis). This effort will only be small if we know it before the start of the research work or even before ordering the panels from different manufacturers.

6.1 Terms of Payment

- 50 % at the start of the project
- 40 % after submitting the final research report
- 10 % after completion of the evaluation of the final report

6.2 Time Schedule

	May 16	June 16	July 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16
Start	May 1st							
Organization specimens								
Setting up equipment								
Testing								
Evaluation								
Conclusion and Report								Dec 31st
Progress report to VIPA			July 31st			Oct 31st		

Project runtime: May 2016 – Dec 2016
Sampling of material: to be defined by VIPA technical working group (e.g. similar to compressive strength project)
Final report: December 2016

6.3 Further conditions

6.3.1 Review

After submitting the final report VIPA has 2 weeks for review. Requested changes or comments will be applied to the report by FIW / Hanita within reasonable time, not exceeding one month. After completion of this evaluation the second half of the payment is due.

6.3.2 Delays

If the deadline of December 31st cannot be met by FIW / Hanita, a discount of 500 € for every month of delay will be granted. This term is only valid for delays caused by FIW / Hanita. If force majeure delays are occurring FIW / Hanita can request for extension of the project without granting aforementioned discount.

6.3.3 Termination

If severe breaches of the terms and conditions of this contract occur the contract can be terminated. Possible payments can be reimbursed.

6.4 Arbitration clause

German law will be applicable to this contract. In the event of a dispute between parties that cannot be resolved through good faith negotiation, the dispute will be resolved under the arbitration of the registered Court of Amtsgericht München, VR 1925.
VAT-ID-No.: DE 129 515 824

FIW Munich & Hanita Coatings
Thursday, April 07, 2016

Christoph Sprengard

Yoash Carmi