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### VIT = Vacuum Insulated Tubing Important Manufacturing Qualifications and Recommended Quality Control Steps for any Purchaser

There are five (5) important specifications and/or manufacturing procedures (we call qualifications) Buyers might want to understand during the decision process for the purchase of VIT. We list qualifications for the OTSI product and leave an open column for reply from other Insulated Tubing providers<sup>1</sup>:

Qualification Detail	OTSI	Other
<p><b><u>Bake-Out (Temperature Programmed Desorption Cycle):</u></b> This is a 15-24 hour process whereby a completely assembled joint of VIT is placed into an oven and baked at increasing temperatures over time to <u>desorb</u> and <u>mechanically pump</u> gas molecules trapped in the matrix structure of the steel inner and outer tubing.<sup>ii</sup></p>	Yes	?
<p><b><u>Controlled activation of Getter:</u></b> Getter <u>must be activated at pressures below 1-Torr<sup>iii</sup></u> to avoid contamination of the Getter surface and the chance of forming a Passivation layer blocking the sorption of gas molecules. If Getter is activated in the well during the 1st steam cycle manufacturer should provide technical detail confirming how &lt;1Torr annulus pressure is guaranteed: Especially in the case where the manufacturer does not have a Bake-out of the completely assembled VIT joint and when the completed joint has been in storage for a period of time (perhaps +6 months of storage)</p>	Yes Activation at less than 10-15 Milli-Torr (0.01 to 0.015 Torr)	?
<p><b><u>Quantity of Getter installed into each joint:</u></b> Manufacturers not using a Bake-out will have substantially higher Getter quantities to compensate for outgassing and all manufactures should be prepared to tell Buyer both the quantity of Getter installed and the volume of gas they intend to sorb from outgassing.</p>	Yes >450 grams	?
<p><b><u>Number of Radiation Barriers:</u></b> Heat flux from the injections string to the casing and overbearing formation is mostly radiation. This being the case, the insulation system is optimized with multiple reflective barriers each being separated by an insulating material. Each manufacturer should tell the Buyer the number of reflective barriers and demonstrate that each radiation layer has an appropriate insulating barrier between layers to avoid conduction heat transfer.</p>	Yes 7-layers of AL foil each separated by ceramic paper or fiberglass cloth	?
<p><b><u>Qualification of Raw Materials for Vacuum Duty:</u></b> The manufacturer should provide the technical data sheet to confirm multilayered insulation system raw materials are manufactured for vacuum duty.</p>	Yes Data Sheets upon request	?



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- i See OTSI Specification for VIT.
  - ii See Temperature Programmed Desorption Cycle (Bake-out).
  - iii One (1) Torr = 1/760 of one standard atmosphere of pressure or ~133.3 Pa. The High Vacuum pressure for Insulated Tubing (VIT) will be in the range  $1 \times 10^{-1}$  to  $1 \times 10^{-7}$  Pa.

Table of pressures for Vacuum Systems (target range for activation of Getter):

<b>% Vacuum</b>	<b>Torr (mm Mercury)</b>	<b>Micron</b>	<b>psia, (lb/in<sup>2</sup> abs)</b>	<b>Inches Mercury Absolute</b>	<b>Inches Mercury Gauge</b>	<b>kPa abs</b>	
99.999	0.01	10	0.000193	0.000394	29.9196		0.0013



**Recommended quality control steps for the Petroleum Engineer having responsibility for specifying and Purchasing Insulated Tubing**

1. Traceability of raw materials. Company shall have an internal system for traceability of Material Test Reports and Conformance reports on all raw materials used.
2. Inspection of welding procedures and welder qualifications.
3. Calibration records for all equipment used in the manufacturing operation:
  - a. Welding equipment.
  - b. Post weld heat treatment equipment.
  - c. Control of ambient temperature and humidity in the manufacturing space.
  - d. Leak detection equipment at the Bakeout oven.
  - e. Oven temperature controls.
  - f. K-Value checking equipment (thermocouples).
  - g. Thread gauging equipment.
4. Raw material storage. Adequate temperature and humidity control.
5. Confirm the insulating raw materials are manufactured for vacuum service and insulating materials are without binders or other contamination that will outgas into the evacuated annulus.
6. Joints shall have a unique serial number for traceability.
7. Confirm the OD of the inner tube and the ID of the outer tube are cleaned by suitable method to remove mill scale, oils, and other contamination prior to assembly.
8. General cleanliness of the tubing assembly area and procedures used to assure joints are assembled in a clean manner.
9. Observe welding and prestress operations.
10. Examine records for the Programmed Temperature Desorption Cycle and Getter Activation (Bakeout cycle). Confirm Getter activation is within manufacturers specifications and activation is within the specified time & temperature limit to become 90-100% effective.
11. Observe K-Value testing.
12. Observe threading operation.