CAMFIL LABORATORIES – TECH CENTER

Design of a prototype ultrafine dry salt generator

Salt generator prototype Mk. II

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Design of ultrafine salt particle generator Mk. II

General thoughts and design of a new salt generator.

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KEYWORDS	

Abstracts

This report covers the development and design of a new dry salt generator of ultrafine sub-micron salt particles. The generator is based the MK. I prototype that was built as a proof of concept. The idea behind the generator is to recreate the ultrafine salt particles normally found in costal and offshore environments and make lab testing more based on normal outdoor conditions rather than those found in current test standards.

Testing shows that by using this equipment combined with the previously described test method it is possible both to generate ultrafine dry salt particles and to use those to create water bypass. This is done without increasing the pressure drop to the levels normaly required in other commonly used test methods. As this test method is closer to the conditions found in real life. Therefore, it is likely that the failure mechanism created in this test method is closer to that of the failed filters that have been tested in the field than other test methods.

Background

Over the years I have analyzed and tested multiple failed filters from several different manufacturers, one test commonly performed is a so-called water-spray test in which the filters are subjected to a fine water spray to see if the water repellency is adequate or if it has been lowered when comparing to a new filter of the same model. In most cases the water repellency of the filters has been lowered or is completely gone with water penetrating the filter media within seconds.

Questions have been raised as to what causes this behavior as many of the failing filters show high water repellency when they are tested as new filters in different lab tests, even during high pressure drops and high dust loading. Meanwhile the filters that have returned from the field with low water repellency can have low pressure drop and an overall low weight increase. To me this indicates that the current lab standards and test methods are not able to recreate the same failure mechanism as the one occurring out in the field on real installations. Therefore, we set out to create a test method and equipment to create a test that better simulates the real-life conditions and “aging” of the filter.

If the above can be achieved both manufacturers and end users would benefit greatly as this test would highlight flaws in filters that otherwise could go unnoticed in current test methods.

Thoughts & Theory

Current laboratory tests and standards challenges the filters in different ways including combinations dust loading, salt water spraying, high pressure drop etc. These things are done in order to mechanically strain and ultimately break either the filter media or the filter construction. Most tests that include water or salt water spraying rely on high pressure drop to force the water/salt water droplets through the filter media, the high pressure drop is often achieved by dust loading the filter with big particle silica based dusts such as ISO 12103-1 A2 Fine. Meanwhile, when looking at the particle size distribution of outdoor air it is apparent that most particles are a lot smaller than those found in said test dust. When using too big particles most of the particles get stuck on the surface of the media while smaller particles penetrate deeper in to the media and challenges the complete structure of the media. As these small particles penetrate deep into the filter media they might create a bridging effect where they connect the upstream and downstream side of said filter media, possibly breaking the water repellency of the filter media.

Using the same type of particulates in the test as those found outdoor in real life makes the test more credible and challenges the filter in the same way as when exposed to those in real life. It is therefore also important to use particles of the same size distribution in order to find the same failure mechanism.

One of the more challenging particles for a gas turbine filter is salt, specially in offshore and costal environments. In these areas NaCl is present in the air as particles with sizes ranging from as small as 0.01µm to 100µm with 60% of the particles smaller than 0.1µm diameter [1]. Salt is especially challenging as its physical properties allows it to be present in both as liquid as well as solid salt crystals depending on the environment. As sea salt particles are hygroscopic by nature they absorb water while growing both in size and weight as RH increase, as RH gradually decreases the droplet will lose water by evaporation and become “sticky” until it finally at low enough RH returns to a solid particle [2].

As these particles are so challenging both the filter media as well as the gas turbine itself I have decided to focus on these particles to see if I can recreate the phenomenon of reduced water repellency of filter media while at low pressure drop. Sea-salt aerosol also constitute the largest global production rate of aerosol mass [3] and dominate visibility reduction in the clean marine boundary layer.

1. Ultrafine dry salt generator Mk. II

1.1 Principle

Sea-salt aerosol is produced from bursting bubbles created by white wash and breaking waves from which droplets get ejected. These droplets dry in the wind resulting in ultrafine dry salt particles with sizes down to 0.01µm. To try to replicate this phenomenon and generate these small salt particles the salt generator is built around the principle of bubbling a salt water solution and then drying these droplets in a drying tower to generate dry ultrafine salt particles. For all of the previous testing done be me a 10% (by weight) solution of NaCl in water was used, in future testing it would be interesting to increase this to generate even more dry salt.

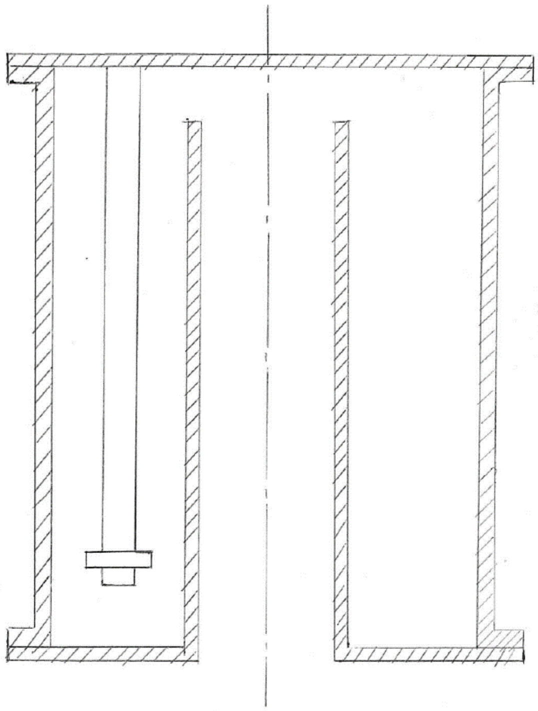


FIGURE 1. LASKIN NOZZLE IN SALT GENERATOR

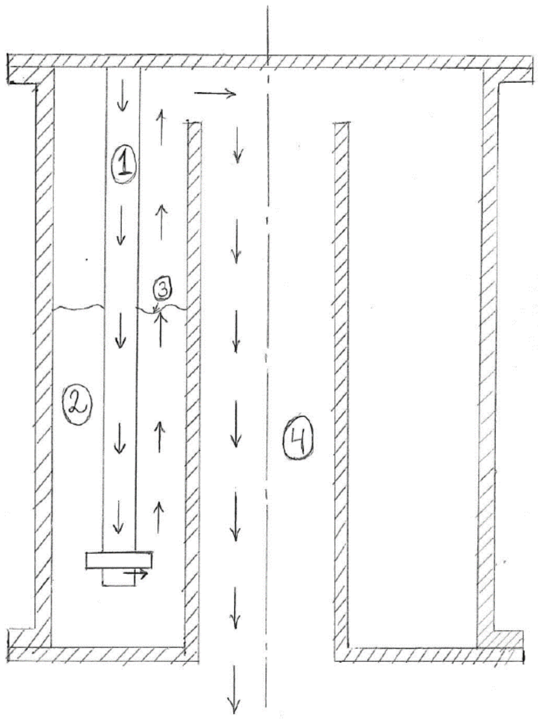


FIGURE 2. WORKING PRINCIPLE OF SALT GENERATOR

1: Compressed air through laskin nozzle
2: Salt water
3: Bubbles bursting creating droplets
4: Exit pipe too air dryer

1.2 Design

1.2.1 Parts

Parts from Jacob: Pipe, blank covers, Quick connect clamps					
Pcs	**Diameter**	**Length**	**Material**	**Artnr**	**Comment**
2	300	200	2mm SS	1203040	
1	300	1000	1mm SS	11303020	
1	100	200	2mm SS	12103130	Push in pipe
1	300-250-140	390	1mm SS	11303288	Branch to connect heater
3	100	-	1mm SS	11103339	90degree bends
1	100-250	200	1mm SS	11003453	Cone piece to connect 90dg bends
1	100	28	1.5mm SS	11103431	Connection flange to testrig
1,1	300,140	-	1.5mm SS		Blank covers for top lid & heater
3	300	-		10303780	Pipe clamp for mounting
1	140	-	1.5mm SS	111437151	Blank cover to fit heater
3,1,1,4	300,250,140,100	-	SS	-	Quick connect pull-ring clamps
Silicone U-seal gaskets will also be needed for each of the pull ring fittings.					

Other parts: Heater, nozzles etc.					
Pcs	**Type**	**Manufacturer**	**Model**	**Artnr**	**Comment**
Choose one	Heater	Leister	LHS 21S PREMIUM 2kW	139.909	Heater without internal fan. Use combines with fan of choice.
	Heater	Leister	HOTWIND SYSTEM 2300W	140.096	Heater with internal fan and LCD, possibility to connect temp probe.
Opt.	Temp probe	Leister	-	106.956	Temp probe for HOTWIND. Makes it possible to set temperature
Opt.	Flange connector	Leister	-	125.317	Push-fit flange for HOTWIND
6	Nozzles	-	Laskin	-	Laskin nozzles for aerosol generation. Dimensions described below. Use stainless steel.
Various pipe parts, fittings, compressed air tubes, connectors etc. will not be specified at this moment and can be chosen by personal preference.					

1.2.2 Aerosol generator

The generator consists of two 200mm long pipes with a 3mm thick disc of stainless steel welded between them in order to make it watertight, the upper 200mm holds the saltwater and the lower 200mm connects to the rest of the drying tower with a Quick connect clamp so the generator can be easily cleaned. In the center of the disc a hole needs to be cut and the exit pipe to the dryer need to be welded in from below. See illustration below.

In the event that one salt generator would not be enough it would be fairly easy to assemble a second generator and drying tower and connect to the same heater and generate twice the amount.

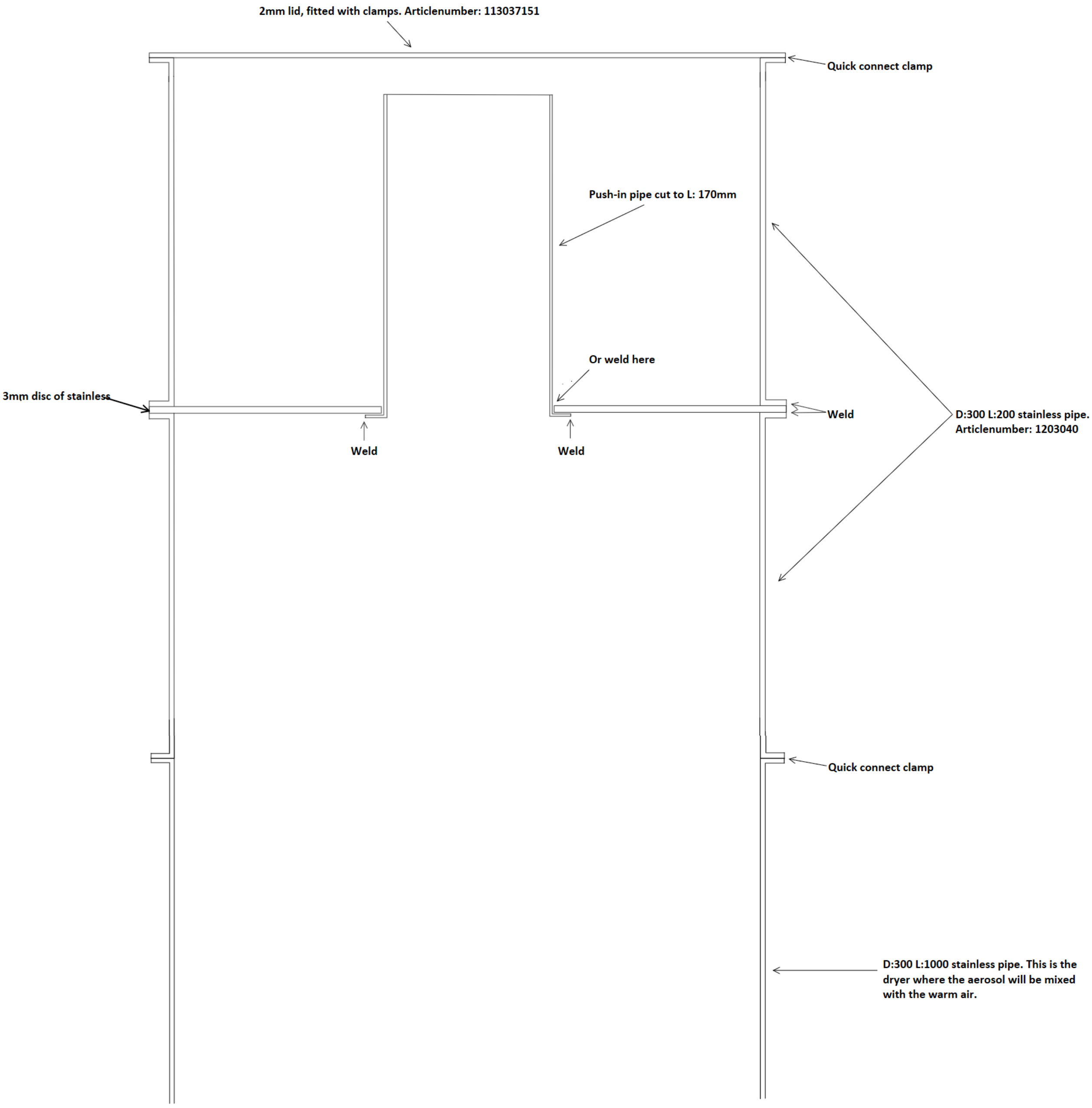


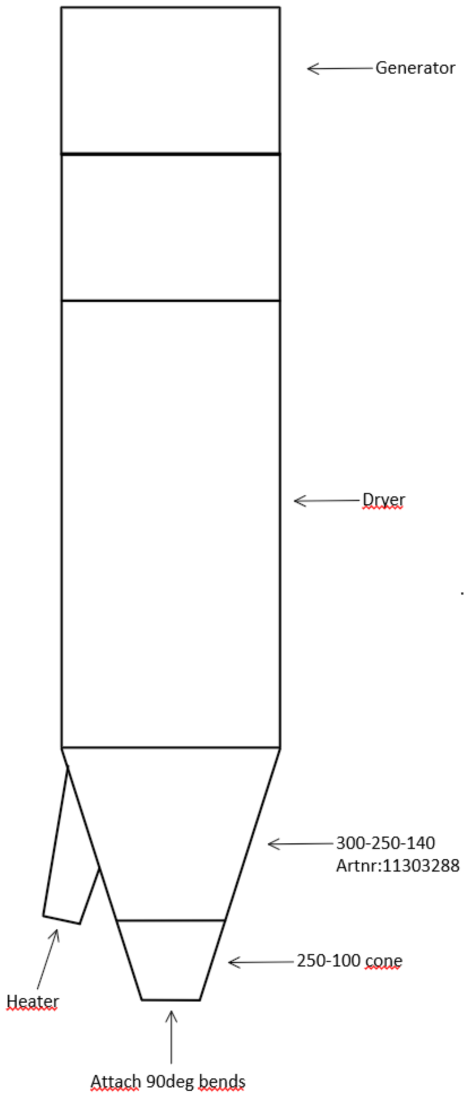
FIGURE 3. CUT-AWAY VIEW OF SALT GENERATOR

1.2.3 Laskin nozzles

Machine 6 laskin nozzles out of stainless steel using dimensions below, drawings will be provided later. Save approx. 2mm of material at the bottom of the nozzle, the other end can be cut short and then be internally threaded. Or left long and externally threaded.

FIGURE 4. DIMENSIONS OF LASKIN NOZZLE

1.2.4 Assembly



Assemble the pipe parts according to the sketch to the left, use silicone U-seal between each of the fittings that use the Quick connect clamps.

Take the Ø300mm blank cover and drill 6 holes evenly displaced and 50mm in from the outer edge. Use pipe couplings and compressed air couplings to fit a laskin nozzle in each of the 6 holes. Leave approximately 10mm between the nozzle and the bottom of the container.

Attach the heater to the 140mm blank cover, if using the HOTWIND then drill a hole in the blank cover and fit the push-fit flange by welding or using sealant.

Use the 90° bends to make it easier to fit the generator to the testrig.

Optional: Build a support structure/cage around the complete salt generator to aid in mounting the generator and to prevent anyone from touching the potentially hot pipes. I will be using aluminum profiles and some perforated stainless steel sheets to make a nice structure around everything and use the clamps with Artnr: 10303780 to attach the dryer to the structure.

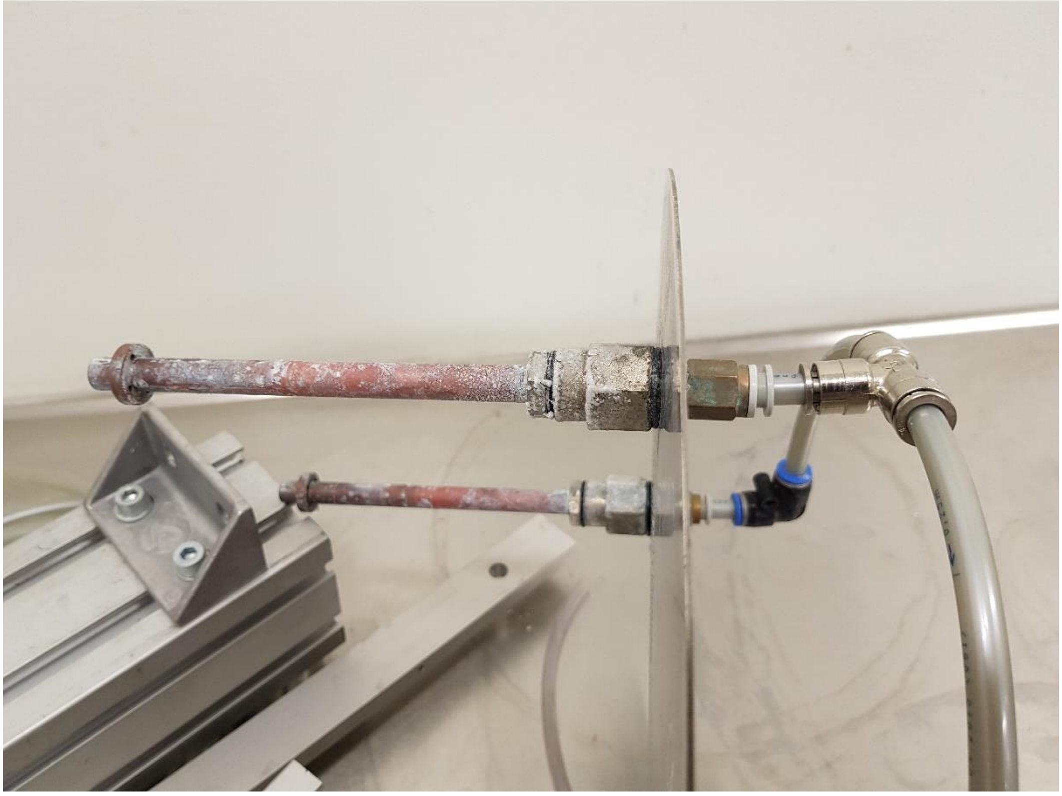


FIGURE 5. ATTACHED LASKIN NOZZLES TO TOP LID SHOWING CONNECTORS ETC. MK.II SHOULD BE STAINLESS.

FIGURE 6. SALT WATER CONTAINER WITH EXIT PIPE IN THE MIDDLE. PIPE CUT TO 170MM.

[1] Clarke, A. D., S. R. Owens, and J. Zhou (2006), An ultrafine sea-salt flux from breaking waves: Implications for cloud condensation nuclei in the remote marine atmosphere, J. Geophys. Res., 111, D06202, doi:10.1029/2005JD006565.

[2] Thermodynamic and optical properties of sea salt aerosols. I. N. TangA, . C. Tridico1 ,a ndK . H. Fung

[3] Warneck, P. (1988), Chemistry of the Natural Atmosphere, Int. Geophys.. Ser., vol. 41, 757 pp., Elsevier, New York.