MOISTURE REMOVAL SYSTEMS IN GEOTHERMAL POWER SYSTEMS

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ABSTRACT

This work gives an overview of the various types of moisture removal systems (MRS) used in geothermal steam power plants. It outlines the general description, separation mechanism and performance of each type.

The study shows that the superficial steam velocity is likely to have a major impact on the performance of all MRS.

The inline vortex separator is less effective in removing water entrainment. Demisters and scrubbers are generally used if the water droplets are in micro scale size. However, the actual performance of those types of MRS is unknown due to the lack of published information.

New MRS designs are also being developed and have been tested under geothermal conditions. Although the testing showed that high efficiency has been achieved in the order of 85-99.9 %, none of these technologies are reported to be in commercial use.

Alternative moisture removal technology from other industries including oil and gas, air pollution control and the nuclear industry with reported 99.75 - 99.98% separation efficiency were also investigated. MRS used in steam generation of pressurized water (nuclear) reactors is a good candidate for use in geothermal power systems, it is proposed for future investigations.

1. MOISTURE REMOVAL SYSTEM (MRS) IN GEOTHERMAL DEVELOPMENT

Moisture removal system (MRS) can be divided into two groups (Lee, 1983). The first group involves along the pipeline (scrubbing line) that have a compact design and are relatively low cost (Arifien et al., 2015). The second group involve equipment that is installed at the end of the steam pipe and are comparatively more expensive (e.g. Demisters, Separators and Scrubbers) (Lee, 1983). Figure 1 shows a schematic diagram of a common setup of MRS currently in use for a single flash geothermal power system. In the current design; systems are made up of the separator, scrubbing line, then possibly a wet scrubber or a demister and finally a strainer inside the power house.

Cyclone separators and scrubbing lines were excluded from this work since they were discussed in details by Zarrouk and Purnanto, (2015).

Recent field experience has shown that the current arrangement (Figure 1) may not be ideal as severe turbine damage have been observed due to moisture erosion damage and mineral precipitation (Morris and Robinson, 2015).

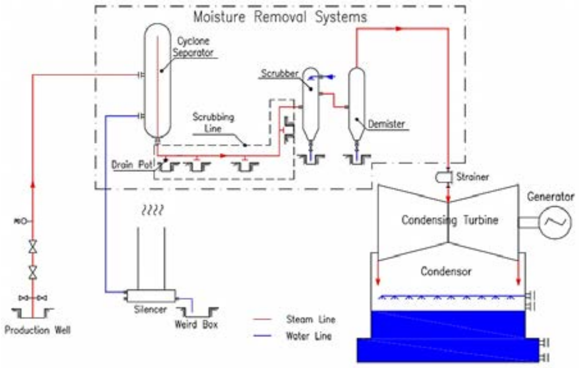

Figure 1: Schematic diagram of a typical MRS for a single flash plant.

1.1 In Line Vortex Separator

The in line vortex separator (ILVS) (Figure 2) also known as the Howden separator, it is a horizontal truncated cone that is usually installed after the HP turbine exhaust to improve steam quality. This is by separating and collecting steam condensates before the steam enters the lower pressure turbine. This is the case in the Wairakei and Ohaaki power plant.

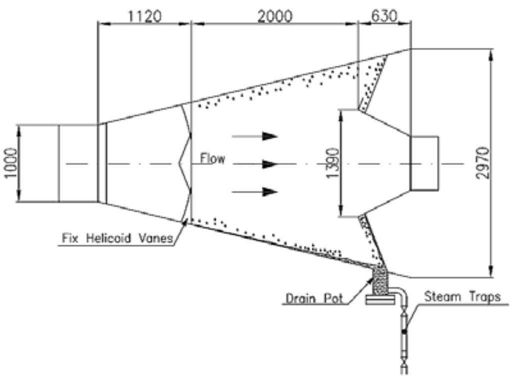

Figure 2: Ohaaki model in line vortex separator (after Lee 1995).

1.1.1 Separation mechanism and efficiency

Although one mechanism may dominate, moisture collection/removal devices rarely operate with a single mechanism. Gravity setting, centrifugal action, impingement and re-entrainment are the common mechanisms involved in separation process of the vortex separator. Interestingly, while the name of vortex separator may indicate that centrifugal action is the prevalent separation mechanism. Laboratory testing showed that gravity and re-entrainment are the dominant mechanism (Lee, 1995). When wet steam enters the ILVS helicoid vanes (placed at the truncated end downstream from the inlet nozzle) it causes the water to be broken into droplets by the flow. The condensates are then drained due to gravity (Figure 2).

A laboratory scale model was used by Lee (1995) to test the performance of the in line vortex separator for the Ohaaki power plant. It was designed based on an upsized version of the Wairakei ILVS (private communications with K. C. Lee). The laboratory result (using air and water) showed that separation efficiency decreases with the increasing air flow rate (Figure 3). Figure 3 showed that, the lowest separation efficiency was 75 % with the high flow rate and low inlet wetness condition. The highest efficiency achieved was 95% for low air flow rate and higher inlet wetness condition, showing that efficiency decreases down to 75% with an increase of Vsg > 28 m/s.

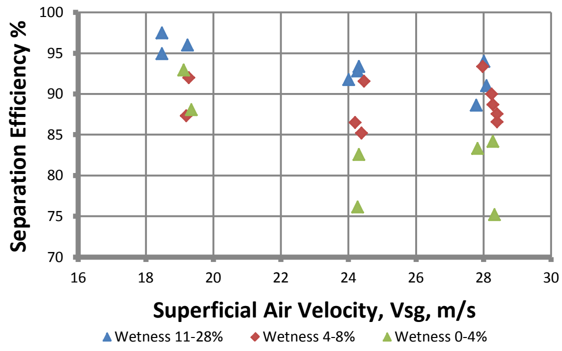

Figure 3: Separation efficiency vs superficial inlet air velocity (Vsg) (after Lee 1995).

The experiment also showed that the inlet wetness has more influence on the separation efficiency than the superficial air velocity as illustrated in Figure 4. For Vsg < 20 m/s, the efficiency is relatively stable at around 88% to 98% for different inlet wetness. The efficiency varies from 75% to 95% with the increase of wetness for Vsg > 20 m/s and dryness > 96% (Figure 4).

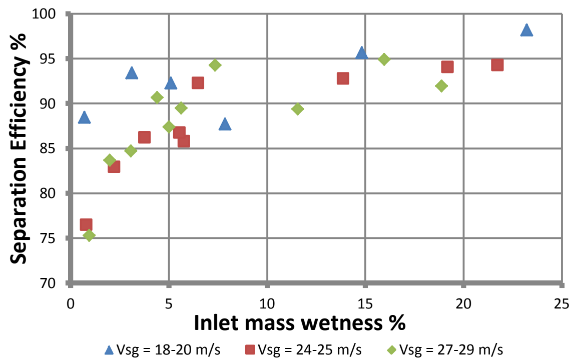

Figure 4: Inlet mass wetness vs separation efficiency (after Lee 1995).

Lee (1995) showed that the net pressure drop across the separator varies between 24 Pa/D and 35 Pa/D. Lee (1995) concluded that helicoid vanes increase pressure drop across the separator. Removing this element not only would decrease the pressure drop by up to 350 Pa for the model separator but it also increases separator efficiency.

The ILVS has not been used in New Zealand after it was implemented in Ohaaki power plant in the late 1980's. This is possibly related to its low moisture removal efficiency. It is likely that increasing the ILVS size used in Ohaaki have affected the separation efficiency.

1.2 Demisters (Mist Eliminators)

Demisters are commonly used as the last line of defense before the steam inters the power station (Figure 1). The main function of the demister is to capture any carried over liquid droplets in the steam (Adiprana et al., 2010). The term "scrubber" is used interchangeably with "demister" at times when describing moisture removal equipment. Scrubbers are normally referred to when water is sprayed into the steam to improve its purity (Morris and Mroczek, 2015). Open literature on detailed design of scrubbers and demisters is very limited. Demisters can be installed in the same vessel inside scrubber or it can be in a dedicated vessel (Figure 1).

Fabian, (1993) highlighted several essential factors which need to be addressed when selecting the demister:

- The targeted droplet sizes which must be removed.
- Maximum pressure drop that can be permitted.
- Susceptibility of plugging if solids are present.
- Liquid handling capability.
- Installation, whether mist eliminator can be installed inside existing equipment or stand alone as a dedicated vessel.
- The availability of the demister's construction material.
- Cost of mist eliminator itself and other supporting utilities.

Impingement type is the most widely used of mist eliminators (Arnold and Stewart, 2008) and in general the separation mechanisms of this type of demister are as follow:

- **Inertial Impaction**
  Liquid droplet with a size range of 1-10 μm has sufficient momentum to break through the streamline and hit the mist eliminator. This inertial impaction is the most important mechanism in the operation of the mist eliminator.
- **Direct inception**
  Liquid droplet with smaller size (0.3 – 1.0 μm) will flow through the streamline. However, when the particle streamline distance is close enough to the target, the particle can be collected on the surface of the target. The mechanism works well when the mist eliminator has small pores/mesh.
- **Diffusion**
  Random Brownian motion can cause small particles to move and strike a target to be collected. This mechanism is driven by high concentration gradient and low fluid velocity.

Mesh and vane demisters are the two basic types of impingement mist eliminator which are commonly in use (Fabian, 1993; Swanborn, 1988).

1.2.1 Mesh demister (Knit screen)

Mesh demister is regularly used where a higher overall percentage removal of liquid is required and the droplet size to be removed is relatively small, down to 1.0 μm (Towler and Sinnott, 2013). The mesh consists of multiple layers of blankets. Each blanket formed by asymmetrical interlocking loops of wire. Knitted steel wire has a diameter ranging from 0.1 – 0.28 mm and void fraction (ratio of void volume with wire mesh volume) typically within 0.95-0.99 (Fabian, 1993). Stainless steel pads around 100 mm thick having density of 150 kg/m^3 are frequently used (Bahadori, 2014).

The mesh demister works through the principle that as steam passes through a wire mesh. The gas phase flow through the outer round shape of the wire while the heavier water droplets will not be able to make the turns around the wire perimeter and gets impinged on the wire as shown in Figure 5. As the droplets impinge on the wire, water films get formed around the wire and run down through mesh pad to the underside of the pad. At this point, the water films become integrated into large droplets that fall down to the collection part of the demister. Figure 6 shows typical arrangements of mesh demister. This design is used at the Ohaaki condenser outlet and non-condensable gas intercoolers, experience show that they are prone to sulpher deposition clogging (communications with Chris Morris).

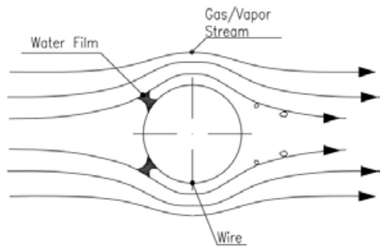

Figure 5: Separation principal of wire mesh demister (after Swanborn 1988).

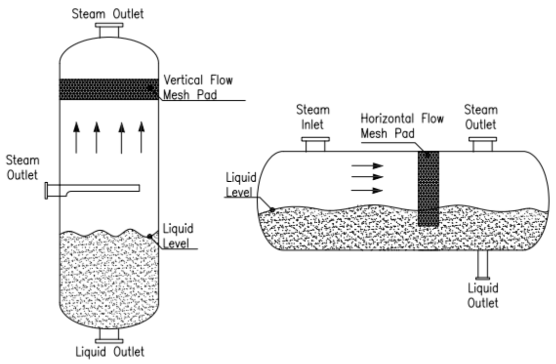

Figure 6: Typical arrangements of vertical and horizontal flow mesh demister (after Swanborn 1988).

1.2.2 Vane type demister

Vane-type demisters consist of series of narrowly spaced uniformly tortuous plates (also known as Z-plates) positioned in parallel to the direction of the steam flow. In doing so, the steam is forced to make considerably sharp turns through the spacing between plates (Figure 7). The space between plates is typically in the range of 5.0 - 75 mm (Fabian, 1993). This type of demisters has almost the same separation performance as wire mesh demister but it is better in terms of plugging and cleaning (Bahadori, 2014). The vane-type demister can be used up to pressures of 75~100 bar and a maximum allowable velocity inside the vane decreases with an increase in pressure (Swanborn, 1988). Chevron shape mist eliminator is the most popular design of the vane type demisters (Fabian, 1993). Poihipi, Gunung Salak and Te Mihi geothermal power plants are a few examples of geothermal power plants which use these types of demister (Adiprana et al., 2010; Morris, 2007). The entrained moisture will impinge on the plate since it cannot follow the changes in direction. The liquid which is formed from this process can be routed into down-comer pipes and flows directly to a liquid reservoir at the bottom of the demister vessel as in the wire mesh demister. Figure 7 demonstrates the separation principle of vane type demister, showing that the gas is forced to make considerably sharp turns through the spacing between plates.

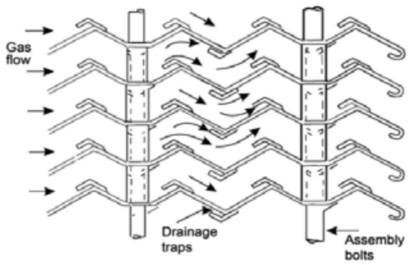

Figure 7: Vane demister separation principle (from Bahadori 2014).

Figure 8 shows a simple schematic diagram of the vane type demister at the Poihipi geothermal power plant, New Zealand (Morris, 2007).

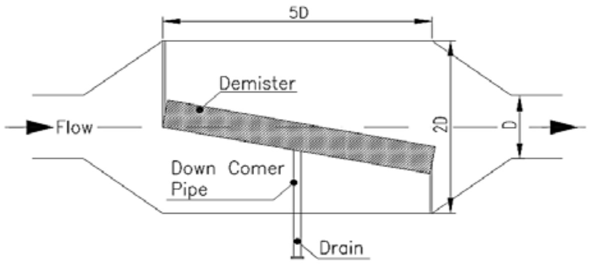

Figure 8. Plan view of the Poihipi vane type demister (after Morris, 2007).

Experience showed that the size of demister and demister holders need to be assessed carefully (Adiprana et al., 2010; Morris, 2007). When droplets hit the demister plate they will cause vibration. The larger the size of demister, the more serious vibration becomes thus it will increase the stress in the contact point with the assembly points (Figure 8). Adiprana et al. (2010) reported that although there was not significant damage on the demister vane plate, severe surface erosion-corrosion on the demister elements holder can be seen clearly when inspecting the demister. However, our experience showed the opposite behavior to those reported by Adiprana et al. (2010).

2 ALTERNATIVE TECHNOLOGY FOR MOISTURE REMOVAL SYSTEMS

2.2 Scrubbers

The function of this device is not only to remove any remaining liquid carry over but also to clean the steam from any dissolved minerals. In general there are two types of scrubbing based on absorbent type, wet scrubbing and dry scrubbing *(Wang et al., 2004).* Although the types of the scrubbers are not clearly reported in the literature, some geothermal power plants use the term scrubber for moisture removal.

2.2.1 Wet Scrubbing

Water is the most common absorbent liquid in wet scrubbing (Morris and Mroczek, 2015; Wang et al., 2004). However, in special circumstances a relatively non-volatile liquid may be used as the absorbent. In geothermal power developments, clean and deoxygenated water is used as absorbent liquid to prevent contaminants introduced to the systems and also to prevent oxidation corrosion. There are several types of wet scrubbers in use in geothermal applications. However, only the Venturi type has been reported to have been tested in geothermal condition (Figure 9).

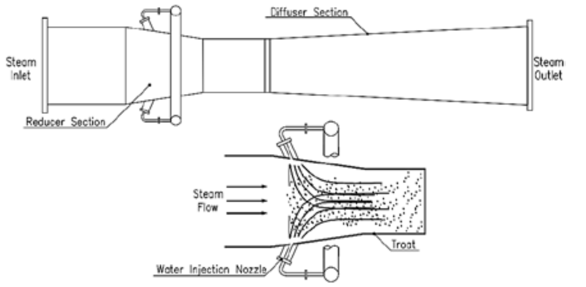

Figure 9: Typical Venturi scrubber (after Hibara et al., 1990)

Venturi scrubber generally has removal efficiency at around 80-90 % for particles greater than 2 μm and usually used for washing low pH steam. The basic principle of this scrubber is that as the gas enters the Venturi area, the Venturi effect increases gas velocity. This high velocity is where the absorbent liquid is sprayed. The high-velocity gas forces the liquid to atomize into small droplets, which offer a large total surface area into which the particulate matter (PM) absorbs. The gas then returns close to its initial velocity after passing through the Venturi section. At this lower velocity, the scrubbing liquid agglomerates back into the bulk liquid phase, containing the PM.

2.2.2 Dry Scrubbing

The basic principle of dry scrubbing systems is adsorbing or absorbing impurities by using an agent followed by separation of the spent agent (Fisher and Jung, 1996; Hirtz et al., 2002). Primarily all dry scrubbers have a chemical injection zone followed by a reaction zone where the pollutant in the gas are treated/reacts with the dry alkali and a precipitator of fabric filter as a device to remove residual particulate matters (PM). In dry scrubbing system (DSS) a dry powder or semidry slurry can also be used as absorbent; depending on the requirements (Wang et al., 2004).

Using DSS technology in the geothermal applications can lead to maximum amount of mass and energy retrained for power generation because quenching or steam condensation is relatively negligible (Hirtz et al., 2002). There are two common types of DSS that being investigate for geothermal application; DSS absorbent and adsorbent (Hirtz et al., 2002). However, none of these methods have been reported in commercial use.

2.3 Boundary layer inline scrubber (BLISS)

BLISS is classified as polishing separator for moderate amount of liquid and entrained solid. Even though BLISS is considered a multi-positional device, it is a horizontal inline centrifugal separator which utilizes the pipeline as part of the separation process. This design feature is believed to greatly reduce material and installation cost of separators (Jung and Wai, 2000). Figure 8, shows that BLISS consists of spin generator, vessel shell, perforated liner/section and drain pot. Figure 8 show that the spin generator forces the liquid droplets towards the walls.

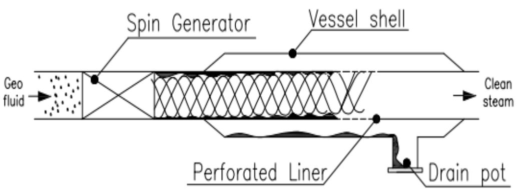

Figure 8: The BLISS separator (after Jung and Wai 2000).

2.3.1 Separation mechanism, performance and development

Jung and Wai (2000*)* used an air water experimental model to test the performance of different designs (classes) of the BLISS. The result indicates that the maximum liquid removal efficiency was approximately at 85% (Figure 9). Figure 9 shows that B class has a better performance and that performance of the BLISS is greatly affected by inlet quality.

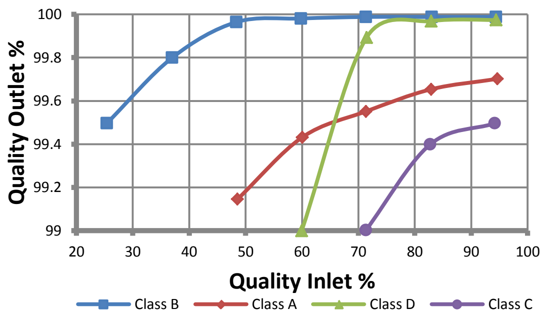

Figure 9: Performance test of four different designs of the BLISS (after Jung and Wai 2000).

The BLISS is relatively similar in principle to the ILVS (Figure 2) and has not been in commercial use in geothermal power development (Zarrouk and Purnanto, 2014).

2.4 Diverging Separator

Diverging Vortex Separator (DVS) is designed to address problems that have been reported after the field trials at the Salton Sea geothermal field between 1972 and 1975 (Schilling, 1983). The main aim of this separator design is to achieve a very clean steam separation from highly saline geothermal brines. Several separator characteristics such as inlet velocity, liquid phase, co-current flow and maintenance aspect were considered in design process. The flow-wise diverging vortex (Figure 12) was introduced in order to minimize brine carry over by decreasing the relative steam to brine velocity and take advantage of the Coanda effect to remove the brine from the vessel *(Schilling, 1981).* Figure 10 illustrates DVS general design.

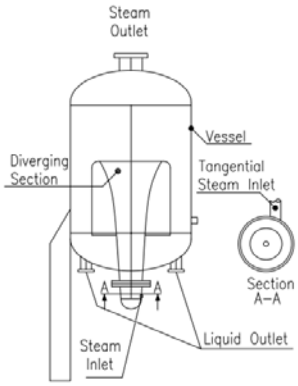

Figure 10: Diverging separator general arrangement (after Schilling 1983).

2.4.1 Separation mechanism, performance and development

Steam enters into the separator in a tangential manner. Since the vessel has a circular cross section, the fluid is forced into a vortex field with a centrifugal acceleration thus the fluid whirls around the center axis of the separator (Figure 11) (Schilling, 1983). Total flow of steam and brine moves co-currently upward thought the vessel up to a certain height until vertical velocity component is nearly 0.3 m/s. At this whirl velocity it is still possible for brine to travel upward. The Coanda effect and vessel surface causes the brine flow to turn away from the steam flow (Schilling, 1981). Meanwhile, the steam flow continues in the upward direction and exhausts from the outlet nozzle.

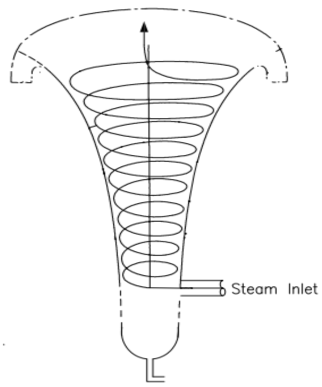

Figure 11: Flow through flow wise diverging vortex area (after Schilling 1983).

Field test of several sizes of separator and vessel were conducted to measure the performance of this design. Schilling (1981) reported that the separator efficiency was around 99.998 % (Figure 14) at well head condition in the Salton Sea geothermal field. Although the result indicates that DVS could be a viable alternative to existing technology, there is no further development and/or report on its application in commercial development.

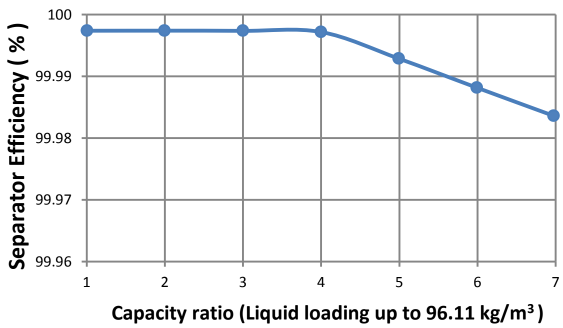

Figure 12: DVS performance characteristic (after Schilling 1983).

3 ALTERNATIVE MRS TECHNOLOGY FROM OTHERS INDUSTRIES

3.2 Demister design from the oil and gas industry

Two types of mist extractors are commonly used in series in the oil and gas industry (Amistco, 2004; Bothamley and Campbell, 2013). The most commonly used configuration of mist extractor is a combination of mesh and vane mist eliminator (Bothamley and Campbell, 2013). This could be a combination of either; mesh followed by vane or vane followed by mesh. The mesh pad will act as an agglomerator or coalescer, converting the entrainment droplet size distribution to larger size when mounting a mesh pad upstream of the vane unit. These droplets are commonly well above the lower limit of the vane unit thus it is easier to remove. On the other hand, mounting a mesh pad downstream of the vane unit will increase the liquid loading and solid handling of the mesh pad. Under these circumstances, the vane unit will act as a shield for the mesh pad from the heavy mist load.

3.3 Scrubber design form air pollutants control industry

3.3.1 Packaged Tower Scrubbing

A packaged tower scrubbing is mainly used to absorb pollutants present in the gas (air) stream when extremely high removal efficiency of a pollutants is required, typically 99% (Wang, et al., 2004). This design uses countercurrent flow of the gas and liquid. The package bed contains packing which may either be randomly dumped or structured, depending on the initial condition as shown in Figure 13. The purpose of the packing is to promote gas–liquid contact so that the pollutants will be removed from the gas stream and absorbed into the liquid stream. Distribution of absorbent liquid onto the packed bed is equally important to ensure adequate wetting of the packing. The presence of mist eliminator above the packing forces the droplets to coalesce from the gas stream so that only a clean and dry gas phase passes through the scrubber.

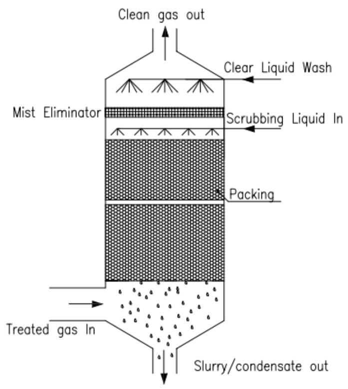

Figure 13: Typical package tower scrubbing *(*after Wang, et al. 2004).

3.3.2 Tray Tower Scrubbing

In tray tower scrubbing, numerous trays are used in this application (Figure 16). Bubble cap, perforated and valve types are the different trays commonly used in air pollutant control industry. The trays have certain openings per tower to provide specified open area for the treated gas to flow. Similar to the packing in packaged tower scrubbing, with counter current flow, the trays are the place where high gas-liquid contact occurs.

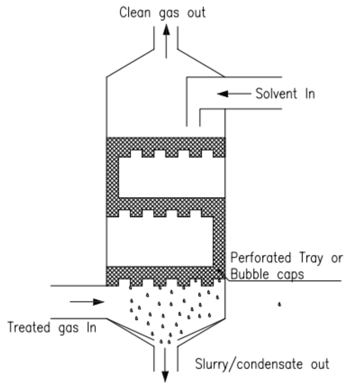

Figure 14: Typical package tower scrubbing (after Wang, Pereira et al. 2004).

3.4 Steam moisture removal system (MRS) from nuclear industry

The nuclear industry has developed moisture removal system (MRS) for steam generators in pressurized water reactors for more than four decades (Fournier et al., 2009; Green and Hetsroni, 1995). This technology maybe more appropriate as an alternative method because it is almost similar in process (liquid-vapor) to moisture removal devices used in the geothermal industry. MRS is commonly installed in the upper part of nuclear steam generator and consists of two mist extractors (Figure 15). The early designs of MRS has a standard warranty for moisture removal efficiency not less than 99.75% while the more recent design is within the range of 99.9% - 99.98% (Fadda et al., 2010; Fournier et al., 2009; Green and Hetsroni, 1995; Nakao et al., 1998; Nishida et al., 2004).

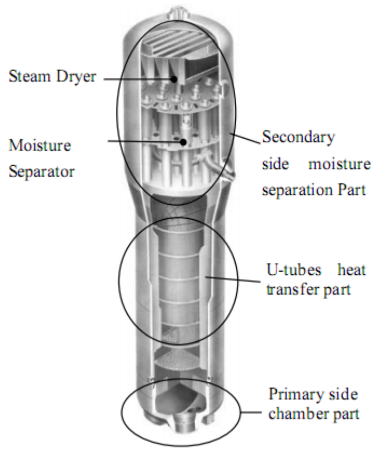

Figure 15: Nuclear steam generator (from Nishida, Mizutani et al. 2004).

3.4.1 Primary Separator

The first stage of MRS is the primary separator which consists of multiple-centrifugal swirl vane columns (swirl demister) or axial-flow cyclones. This configuration allows the demister to handle large quantities of liquid loading at acceptable pressure drop. The swirl vanes are designed as shown in Figure 16 to avoid vibration that may cause damage to the downstream components of the plant. The swirl vane basically consists of a fixed swirl generation device in the inlet section and a separation section with discharges for gas and liquid at the top outlet. Centrifugal effect caused by swirl vane allows the steam to move upwards, while forcing the separated water out of the system. In most types of swirl vanes, the liquid is drained through an annulus in between the cyclone walls while the gas exits from the top. This primary separation system improves steam quality from approximately 80% to 90% (Nishida et al., 2004).

Field measurement tests and computation fluid dynamics (CFD) analysis proved that outlet steam wetness from the separator was within the range of 0.1%-0.037% (Fadda et al., 2010; Fournier et al., 2009).

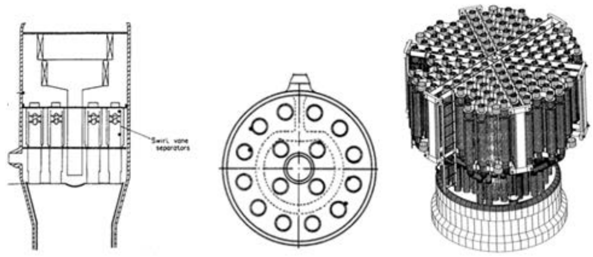

Figure 16: Swirl vanes/axial-flow cyclone configuration (from Kolev, 2009).

Similar to other types of demisters, knowhow on the detailed design of this type of demister is restricted to the manufacturers and developers. Austrheim (2006); Bothamley and Campbell (2013) proposed practical equations which can be used to estimate droplet removal efficiency of an individual swirl vane as follows:

$$\eta_{clyc} = 1 - exp\left[-8 \times Stk_{cycl}\frac{L_{cycl}}{D_{cycl}tan^2\alpha}\right] \quad (1)$$

$$Stk_{cycl} = \frac{(\rho_l - \rho_s){d_p}^2 V_{s,cycl}}{18\mu_s D_{cycle}} \quad (2)$$

$$V_{st,cycl} = K\left(\frac{\rho_l - \rho_s}{\rho_s}\right)^{0.5} \quad (3)$$

where:

η_{clyc} Axial flow Cyclone separation efficiency (m),
Stk_{cycl} Cyclone stokes number,
L_{cycl} Cyclone length (m),
D_{cycl} Cyclone diameter (m),
α Cyclone inlet swirl angle (degree),
ρ_l Liquid density (kg/m^3),
ρ_s Steam density (kg/m^3),
d_p Droplet diameter (m),
$V_{st,cycl}$ Superficial steam velocity through a bundle of cyclones (m/s),
μ_s Steam dynamic viscosity (kg/ms),
K Sounder-brown coefficient (m/s).

Swirl vanes spacing is usually expressed as a function of cyclone diameter (D_{cycl}) and is correlated to K value. Thus, the number of swirl vane required can be formulated as follows:

$$n_{cycl} = \frac{4 \times A_v}{c \times \pi\, {D_{cycl}}^2} \quad (4)$$

where

n_{cycl} Number of cyclone,
A_v Vessel Cross section area (m^2),
c Constant.

The operating principle of the swirl vanes is effectively similar to that of the ILVS and the BLISS separators. However, the likely reason for its high removal efficiency is related to the small/compact size of the individual swirl vane. However, this should result in high pressure drop.

3.4.2 Secondary Separator

At the second stage, a number of vanes (chevron type or corrugated shaped) are carefully arranged in several banks to form a secondary separator (Figure 17) that is commonly called steam dryer in nuclear engineering industry. The vanes bank is typically installed within a frame and the frame is a function of flow rates, properties of the steam and water that is being removed (Fadda et al., 2010*).* If steam passes through this secondary separator with a wetness of roughly 10%, then it will exit the system with a wetness of the range of 0.1% to 0.02% (Fadda et al., 2010; Fournier et al., 2009; Nakao et al., 1998).

As with other inertia impaction mist extractors based on K value (Sounders-Brown) is the most common method for sizing vane demister (Bothamley and Campbell, 2013; Fabian, Cusack, et al., 1993). This empirical method primarily based on the estimation of an allowable gas velocity to achieve the required degree of droplet separation as follows:

$$V_{s,vane} = K\left(\frac{\rho_l - \rho_s}{\rho_s}\right)^{0.5} \quad (5)$$

where :

$V_{s,vane}$ Superficial gas velocity (m/s),
K Sounder-Brown coefficient.

The maximum velocity is then used to calculate the diameter D of the vessel for the actual gas volume rate:

$$V_s = \frac{Q_s}{A_v} = \frac{Q_s}{\frac{\pi \times D^2}{4}} \rightarrow D = \sqrt{\frac{4 \times Q_s}{\pi \times V_s}} \quad (6)$$

where:

V_s Steam velocity (m/s),
Q_s Steam volumetric flow rate (m^3/s),
D Vessel diameter (m).

Substituting V_s (Eq. 6) with $V_{s,vane}$ from Eq. (5) gives:

$$D = \sqrt{\frac{4 \times Q_s}{\pi \times K\left(\frac{\rho_l - \rho_s}{\rho_s}\right)^{0.5}}} \quad (7)$$

A practical approach which can be used to quantify droplet capture efficiency of a vane type demister is as follow (Bothamley and Campbell, 2013).

$$\eta_{vane} = 1 - exp\left[\frac{-(\rho_l - \rho_s){d_p}^2 V_{s,vane} n\theta}{515.7\mu_s b cos^2\theta}\right] \quad (8)$$

where:

η_{vane} Vane demister separation efficiency (%),
n Number of bends,
θ Bend angle degree,
μ_s Viscosity of gas (cP),
b Vane spacing (m).

3.3.3. Potential Application

Based on the long history of successful implementation in the nuclear industry, an alternative demister with swirl vanes and vane type cloud prove be an optimum option. To improve the overall effectiveness of the MRS, a combination of wet scrubbing, scrubbing line and a demister design from nuclear industry may prove to give the solution to the problems discussed by Morris and Robinson (2015). The idea of this configuration is to install wet scrubber close to separator and uses nuclear MRS systems as final separation device with scrubbing line of about 500 meters long (Arifien et al., 2015) in between (Figure 17). By installing the wet scrubber close to the separator, the purification process can start at early stages to help in the removal of most of the carried over minerals. Any remaining minerals, liquid carry over and the generated condensates from the wet scrubber will be handled by scrubbing line. A demister with combined swirl vanes and vane type will polish the steam to the acceptable steam quality (dryness fraction) > 99.5% (Morris and Robinson, 2015) (99.75 - 99.98%) quality before entering the turbine house.

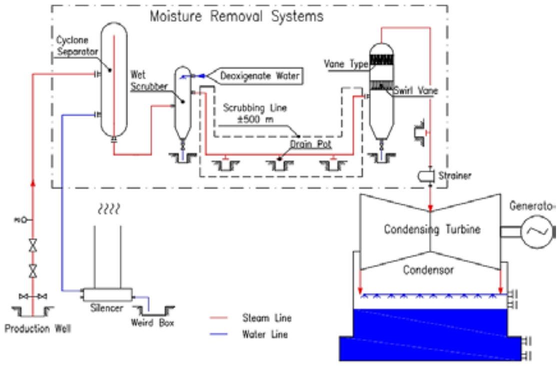

Figure 17: Proposed configuration of the MRS.

4 CONCLUSION

A review of existing MRS currently in use shows that:

- There is limited published information on the design and operation of MRS.
- Inlet mass wetness is a more dominant parameter affecting the inline (ILVS and BLISS) separators performance rather than the superficial steam velocity.
- Mesh demister has better performance compared to vane demisters. However, mesh demisters cannot operate in high pressures and plugs quickly.
- 99.998 % is the maximum moister removal efficiency was reported when testing diverging separator.

The review MRS in other industries (oil and gas, air pollution and nuclear industry) shows that the nuclear industry's MSR to be more applicable to the geothermal plants conditions.

Adopting proven technology from the nuclear industry may be the solution to improve the performance of current design of demisters. It will likely reduce the uncertainty of a totally new moisture removal system design. It is similar in process to geothermal (liquid-vapour) conditions and has proven/reported performance of 99.75-99.98%. Although further investigation is required, the proposed moisture removal system (Figure 17) is likely to give a better overall separation efficiency than the current configuration (Figure 1).

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