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Research Paper

INITIATION AND ENHANCEMENT OF PRECIPITATION FORMATION BY VORTEX MECHANISM

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The cooling tower can be used to remove heat from various sources such as machinery or heated process material, industrial systems. Cooling tower is used to remove the heat absorbed in the circulating water used in power plants, petroleum refineries, petrochemical plants, natural gas processing plants, food processing plants, semi-conductor plants, and other industrial facilities.

Keywords: Cooling tower, Water treatment, Nozzles

INTRODUCTION

Many alternative technologies have been available for the water treatments which prevent scale and corrosion problems, Bacterial growth in cooling tower systems, and Precipitation enhancing mechanisms. These mechanisms are very effective. It includes two parts (1) a nozzle unit and separation/filtration system. The filtration system used to remove the precipitated calcium carbonate and other suspended solids from the circulating cooling water.

VPEM works on the principle of Controlled Hydrodynamic Cavitations. The technology to be treated is liquid flows with high swirling motion at a high velocity. Due to high swirling motion, along the precipitation pressure drop occurs along the axis which results in drop in pressure resulting in cavitations. Cavitations is the dynamic process in a fluid where micro-sized bubbles form, grow and collapse. When pressure falls below the critical value, cavities are formed in the liquid, when the pressure increases the cavities cannot sustain the surrounding pressure and the bubbles will be collapse at these higher pressures. As the bubbles collapses, the pressure and temperature of the vapor within it increases, resulting in the chemical reaction settling in and it will release CO_2 and other dissolved gases from the solution. By this technology we can

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allow the formation of precipitation of calcium carbonate, and other micro organisms.

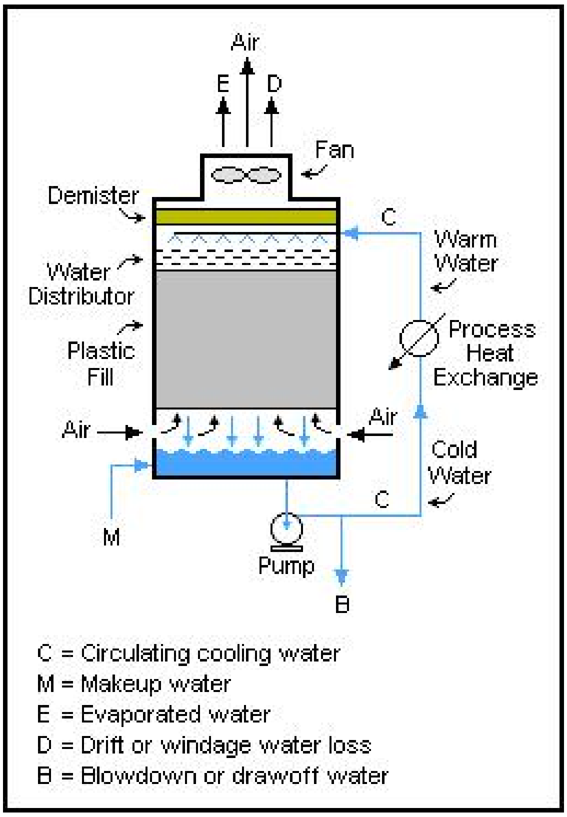
From the above discussion the limitations of cooling the hot water is depending on the environmental conditions such as wet bulb temperature, dry wet bulb temperature and relative humidity. The proposed research work is focused on exploring ways and means to enhance the cooling tower performance. Since water is becoming a scarce commodity reducing the quantity of water evaporation is also an important aspect to be investigated. The usage of advanced materials like polymer composites to replace the wood based packing materials. The severe problem of scaling in the cooling towers is an important problem. The continuous evaporation leads to increase in the dissolved salts concentration. The problem of choking filling material requires frequent replacements. The cost of filling material is 30% of the total cost cooling tower; the maintenance cost is considerable problem for the industry.

- In view of solving this problem, the proposed research work is aimed at (A) Designing the cost effective water treating system, (B) Experimental setup design and fabrication, (C) Experimentation

Overview of Cooling Tower Operation

Cooling towers can generally be classified by use into either HVAC (air-conditioning) or industrial duty. Industrial cooling towers can be used to remove heat from various sources such as machinery or heated process material. The primary use of large, industrial cooling towers is to remove the heat absorbed in the circulating cooling water systems used

Figure 1: Cooling Tower



in power plants, petroleum refineries, petrochemical plants, natural gas processing plants, food processing plants, semi-conductor plants, and other industrial facilities. A cooling system consists of a cooling unit (e.g., cooling tower) and a heat exchanger in Figurebelow. Cool water is pumped from the cooling tower and circulated through a heat exchanger to remove heat (i.e., to cool) from hot process fluids generated in HVAC or other industrial process equipment.

Cooling Tower Working Principle

In the heat exchanger cooling tower water is warmed as heat is transferred from the hot process fluid to the cooling water. The warmed water then returns back to the cooling tower. In the cooling tower, warmed water is sprayed downward, and air is blown upward with a fan. As the warm water droplets contact the air, some of the water droplets evaporate, and the air absorbs the heat released from this evaporation—thereby lowering the temperature of the remaining water. An outside source of water, commonly referred to as "makeup water," adds more water to the system to make up for evaporation and other water losses. Then the water is re circulated back to the heat exchanging equipment and the process is repeated 1. As this process is repeated, minerals in the re circulated water such as calcium carbonate ($CaCO_3$), iron and silica become concentrated. Calcium Carbonate exists in the form of calcium ($Ca+$) and bicarbonate (HCO_3) ions in water. As the temperature of water increases, the calcium ion precipitates because its solubility decreases with increasing water temperature. When the calcium ion precipitates, it forms an adherent deposit (scale). This scale forms preferentially on hot surfaces as the diffusion of calcium ions is accelerated by the relatively higher temperatures around the heat exchanger surface. The heat exchanger transfers heat less efficiently as the scale builds up. This buildup also blocks water flow in the lines.

Historically, facility operators used chemicals to control conditions in the cooling towers caused by dissolved solids, dissolved gasses, organic compounds, suspended solids and microorganisms in the water. A properly managed chemical treatment program needed to be adjusted, monitored and controlled. In practice this was difficult to accomplish since a properly managed chemical program required constant adjustments due to changes in the system water and make-up water typically, scale formation was inhibited by using acids and threshold inhibitors, including polymers, phosphates, phosphonates or a combination of these chemicals, along with managed cycles of concentration. Anodic, cathodic, or combinational corrosion inhibitors were added to slow down corrosion by forming a protective layer on metal surfaces. Oxidizing and non-oxidizing biocides were added to control the growth of microorganisms.

Cooling Water Problems and Solutions

Water is used in cooling systems as a heat transfer medium and frequently also as the final point to reject heat into the atmosphere by evaporating inside cooling towers. Depending on the quality of available fresh water supply, waterside problems develop in cooling water systems from Scaling, Corrosion, Dirt and dust accumulation, Biological growth.

Any of these problems – or more usually a combination of them – result in costly unscheduled downtime, reduced capacity, increased water usage, high operation and maintenance costs, expensive parts replacements, and acid cleaning operations which reduce the life of the cooling system.

There is no single method of treating cooling water. Selection of water treatment program for a specific system depends on:

1. System design, including system capacity, cooling tower type, basin depth, materials of construction, flow rates, heat transfer rates, temperature drop and associated accessories
2. Water, including makeup water composition/quality, availability of pre-

treatment and assumed cycle of concentration.

3. Contaminants, including process leaks and airborne debris.
4. Wastewater discharge restrictions.
5. Surrounding environment and air quality.

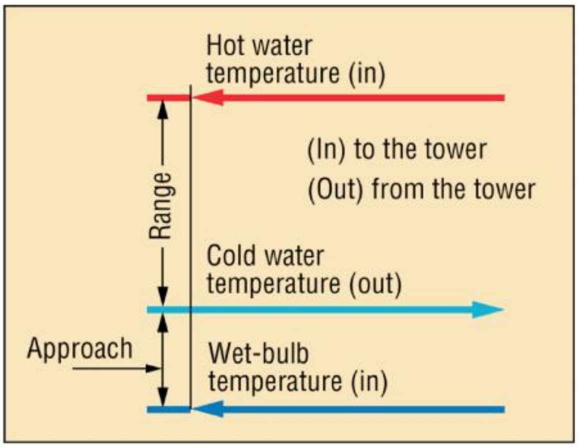
In this course, we will discuss the reasons and means for controlling scale, corrosion and biological fouling.

COOLING TOWER PERFORMANCE

The important parameters, from the point of determining the performance of cooling towers, are:

- "Range" is the difference between the cooling tower water inlet and outlet temperature.
- "Approach" is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature. Although, both range and approach should be monitored, the 'Approach' is a better indicator of cooling tower performance.

Figure 2: Range and Approach



- Cooling tower effectiveness (in percentage) is the ratio of range, to the ideal range, i.e., difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is = Range/(Range + Approach).
- Cooling capacity is the heat rejected in kCal/hr or TR, given as product of mass flow rate of water, specific heat and temperature difference.
- Evaporation loss is the water quantity evaporated for cooling duty and, theoretically, for every 10, 00,000 kCal heat rejected, evaporation quantity works out to 1.8 m^3.

  An empirical relation used often is:

  *Evaporation Loss (m^3/hr) = 0.00085 x 1.8 x circulation rate (m^3/hr) x (T1 – T2).

  T1 – T2 = Temp difference between inlet and outlet water.

  *Source: Perry's Chemical Engineers Handbook (Page: 12-17).
- Cycles of concentration (C.O.C) is the ratio of dissolved solids in circulating water to the dissolved solids in makeup water.
- Blow down losses depend upon cycles of concentration and the evaporation losses and is given by relation:

  Blow Down = Evaporation Loss/(C.O.C. – 1).
- Liquid/Gas (L/G) ratio, of a cooling tower is the ratio between the water and the air mass flow rates. Against design values, seasonal variations require adjustment and tuning of water and air flow rates to get the best cooling tower effectiveness through

measures like water box loading changes, blade angle adjustments.

Thermodynamics also dictate that the heat removed from the water must be equal to the heat absorbed by the surrounding air:

where:

L/G = liquid to gas mass flow ratio (kg/kg)

T1 = hot water temperature (°C)

T2 = cold water temperature (°C)

h2 = enthalpy of air-water vapour mixture at exhaust wet-bulb temperature (°C)

h1 = enthalpy of air-water vapour mixture at inlet wet-bulb temperature (°C)

Factors Affecting Cooling Tower Performance

Capacity

Heat dissipation (in kCal/hour) and circulated flow rate (m^3/hr) are not sufficient to understand cooling tower performance. Other factors, which we will see, must be stated along with flow rate m^3/hr.

Range

Range is determined not by the cooling tower, but by the process it is serving. The range at the exchanger is determined entirely by the heat load and the water circulation rate through the exchanger and on to the cooling water.

Range °C = Heat Load in kcals/hour/Water Circulation Rate in LPH

Thus, Range is a function of the heat load and the flow circulated through the system.

L(T1 – T2) = G(h2 – h1); L = (h2 – h1)G/T1 – T2

Cooling towers are usually specified to cool a certain flow rate from one temperature to another temperature at a certain wet bulb temperature. For example, the cooling tower might be specified to cool 4540 m^3/hr from 48.9 °C to 32.2 °C at 26.7 °C wet bulb temperature.

Heat Load

The heat load imposed on a cooling tower is determined by the process being served. The degree of cooling required is controlled by the desired operating temperature level of the process. In most cases, a low operating temperature is desirable to increase process efficiency or to improve the quality or quantity of the product. In some applications (e.g., internal combustion engines), however, high operating temperatures are desirable. The size and cost of the cooling tower is proportional to the heat load. If heat load calculations are low undersized equipment will be purchased. If the calculated load is high, oversize and more costly, equipment will result. Process heat loads may vary considerably depending upon the process involved. Determination of accurate process heat loads can become very complex but proper consideration can produce satisfactory results. On the other hand, air conditioning and refrigeration heat loads can be determined with greater accuracy.

Formation of Calcium Carbonate Without Chemicals

The hard water contains a large amount of calcium in the form of relatively soluble calcium hydrogen carbonate $Ca(HCO_3)^2$, therefore in water calcium carbonate Ca_2^+ and bicarbonate HCO_3^- ions are present. When water is heated carbon dioxide CO_2(g) evolves and raise the solid calcium carbonate $CaCO_3$(s):

$Ca_2 + (aq) + 2(HCO^-_3)(aq) \rightleftharpoons CaCO_3(S) + CO_2(aq) + H_2O(l) \longrightarrow CaCO_3(s) + CO_2(g) + H_2O(l)$

The resulting calcium carbonate $CaCO_3$ (Calcite polymorph) is heat-insulating and is therefore is effected for the heat transfer in a heating element. The above reaction is actually a compilation of two equilibrium reactions.

Reaction 1: the carbonate-bicarbonate equilibrium

HCO_3^- ions react with itself (HCO_3^- is amphoteric) according to the following chemical equilibrium:

$$HCO_3^- + HCO_3^- \rightleftharpoons H_2CO_3 + CO_3^{2-}$$

The formed H_2CO_3 is unstable and breaks down into CO_2 carbon dioxide and H_2O water. By heating the water, the solubility of carbon dioxide in the water decreases and disappears from the water. The above chemical equilibrium CO_2 disappears, and ensures that new CO_2 is formed: the chemical equilibrium shifts to the right (according to the principle of Le Chatelier). Because by replenishing CO_2 there is also CO_3^{2-} formed, which does not disappear from the reaction, the concentration of CO_3^{2-} ions is increased.

Reaction 2: The solubility equilibrium of calcium carbonate

The presence of Ca^{2+} ions will react with the now largely present, of CO_3^{2-} ions to calcium carbonate (lime scale):

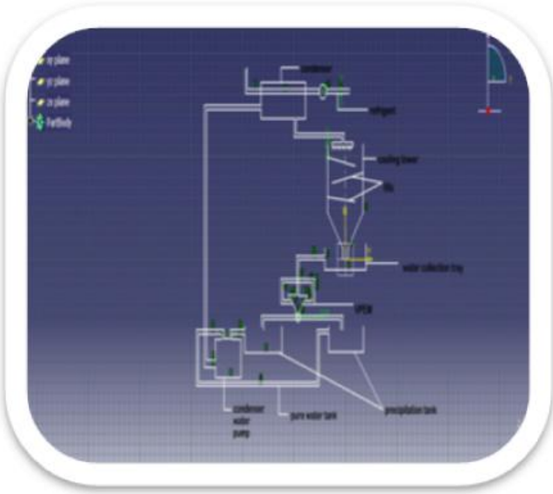
$$Ca^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow CaCO_3(s)$$

Since calcium carbonate is insoluble in water, this equilibrium moves strongly to the right.

VPEM WORKS ON CONTROLLED HYDRODYNAMIC CAVITATION

As illustrated below, the VRTX technology system is tangential treatment. It includes two parts: 1) a nozzle unit, and 2) filtration system.

Figure 3: Schematic Diagram of a Modern Cooling Tower with VPEM Mechanism



Schematic Diagram of a Modern Cooling Tower with VPEM Mechanism

The filtration system is used to remove the precipitated calcium carbonate and other suspended solids from the circulating cooling water.

The system works on the principle of Controlled Hydrodynamic Cavitation (CHC). This hydrodynamic cavitation is referred byEvaluation of Non Chemical Treatment technologies for Cooling Towers at Select California Facilities *et al.* (February 2009).

In turbulent liquid s, and at high velocity, hydrodynamic cavitation will occur. Cavitation is the dynamic process in a fluid where micro-sized bubbles form, grow, and collapse. When pressure decreases to a low values, cavities are formed in the liquid. When pressure increases, the cavities cannot sustain the surrounding pressure, and consequently, collapse creating localized points of extreme high pressure and temperature. As the bubble collapses, the pressure and temperature of the vapour within it increases. The bubble will eventually collapse to a minute fraction of its original size, at which point the gas within dissipates into the surrounding liquid via a rather violent mechanism, which releases a significant amount of energy in the form of an acoustic shock-wave and as visible light. At the point of total collapse, the temperature of the vapor within the bubble may be several thousand Kelvin, and the pressure several hundred atmospheres. Resulting in the chemical reaction settling in and will release CO_2 and other dissolved gases from the solution. By this technology we can allow the formation of precipitation of calcium carbonate, and other microorganisms.

Inside VPEM Mechanism

The Inlet: If the water enters at the middle of the top hits the water around the inside of the spout. The patented nozzle forces the water in to three Dimensional motions. It gives a circular motion before the area ends up in the Vortex.

Vortex Chamber: In the vortex chamber the water rotating around the flow axis. Because of that it forces the water exit the outside of the vortex chamber.

Out Side: The vortex area made of reliable environmentally friendly materials to ensure the stability and desired shape.

Inside: If the water rubs against the vortex surface, electrons are drawn which create a positive field. And these particles of water are extracted at the surface and accumulate at the centre of the vortex.

The Vortex: When the water flows through the vertex chamber, i.e., reducing are of the nozzle, there it forces the water to spin faster, so that a vacuum pressure is generated at the centre of the vortex. By the forces that occur on the water, it breaks the structure of water.

Vacuum Column: The micro and nanobubbles float towards the centre of the vertex, i.e., towards the middle and connect the bubbles with other bubbles and may not return to their initial positions. The positive changed particles moves to the centre of vortex.

EXPERIMENTAL SETUP FOR NOZZLE 1

Water Re-circulated for 3½ hrs

Water is allowed to the tangential holes of a nozzle so, it enters in to the vortex chamber, there the controlled hydro dynamic cavitation

Figure 4a: Hyperpolic Structure of Nozzle-1

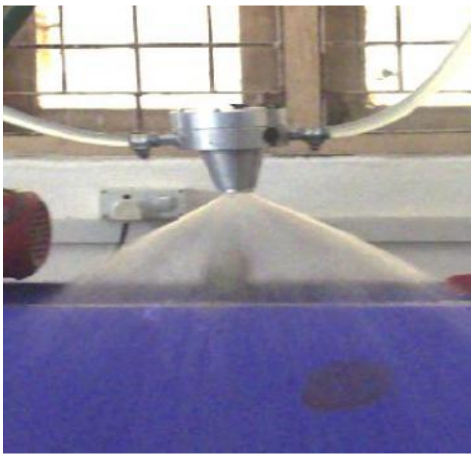
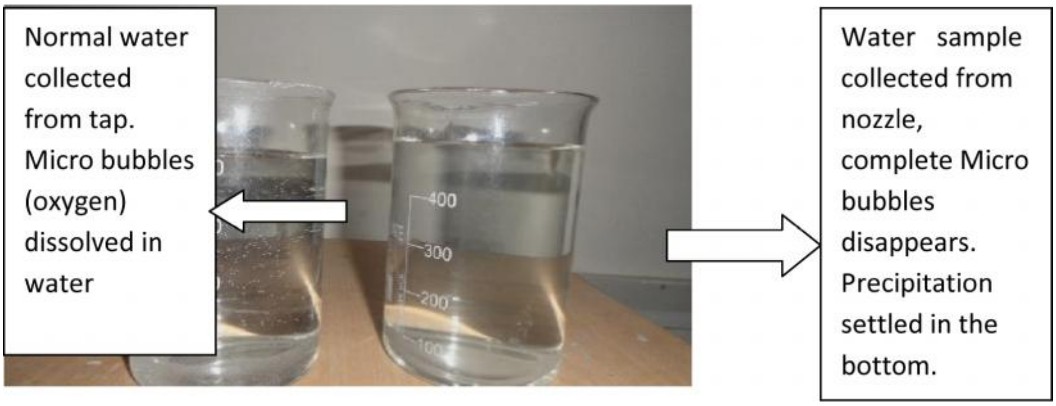


Figure 4b: Sample Water Collection



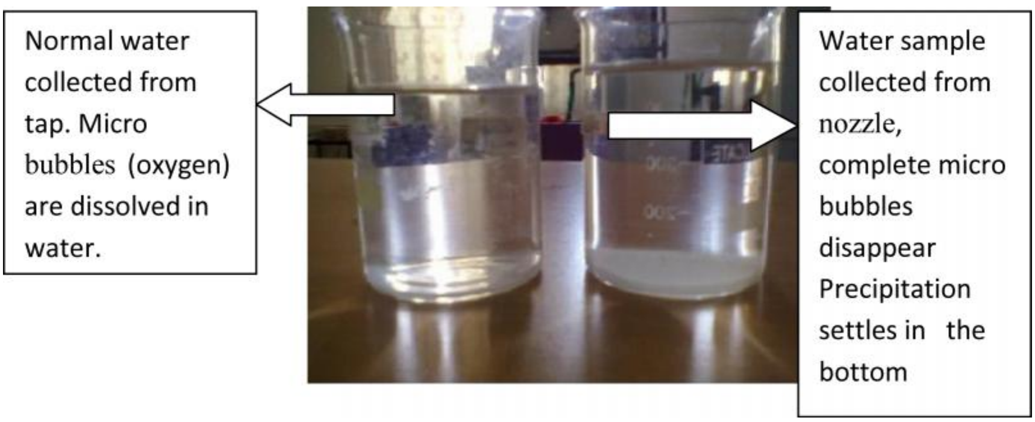
mechanism is followed and continuous supply of water is re circulated in to the nozzle. In this experiment the water is re-circulated for three and half hours. The experimental set up as shown in the figures.

Water Re-circulated for 7 hrs

In this experiment the water is re-circulated 7 hours and then the samples of water are collected. In these samples all the gas bubbles are collapsed after some time the dissolved salts are settled at the bottom of the glass container. The experimental set up is as shown in the figures.

Figure 5a: Hyperbolic Structure of Nozzle (7 hrs Re-circulated)

Figure 5b: Samples of Water (7 hours Re-circulating Water)



EXPERIMENTAL SETUP FOR NOZZLE 2

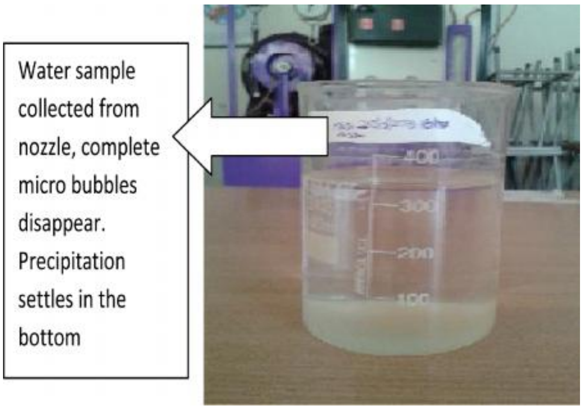
Modified Nozzle Dimensions

Inlet of nozzle Diameter	=	76 mm
Water Inlet Diameter	=	30 mm
Length of Nozzle	=	75 mm
Out Nozzle Diameter	=	12 mm
Cover Plate Diameter	=	76 mm
Height of the Cover Plate	=	50 mm
Hole of Nozzle Diameter	=	8 mm

Water Re-circulated for 6 hrs

In this experiment the water is re-circulated 6 hour then collected the samples of water in these sample all the gas bubbles are collapsed after some time the dissolved salts are settled at the bottom of the glass beakers. The experimental set up as shown in the figures.

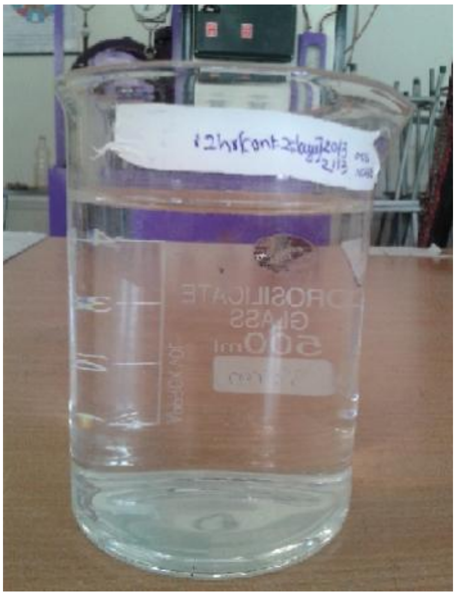
Figure 6: Modified Nozzle Samples of Water (6 hours Re-circulating Water)



Water Re-circulated for 12 hrs

In this experiment the water is re-circulated 12 hour then collected the samples of water in these sample all the gas bubbles are collapsed after some time the dissolved salts are settled at the bottom of the glass beakers. The experimental set up as shown in the figures.

Figure 7: Modified Nozzle Sample of Water (12 hours Re-circulating Water)



CONCLUSION

- Hydrodynamic cavitations working effectively and cone formation confirms this effect.Volume flow rate of flow variation is manifested in and let cone angle variation measurements are being taken.
- For 3 ½ hr duration after water flows through vortex tube mechanism dissolved gases escape and due to partial pressure created along the axis of the vortex tube. $CaCO_3$ formed and settled for 6hr duration of water re-circulated through in vortex tube for 6 hrs, 9 ml EDTA is consumed and 396.4 ppm $CaCO_3$ is formed. $CaCO_3$ formed and settled for 7 hr duration of water re-circulated through in vortex tube for 7 hrs, 7.3 ml EDTA is consumed and 321.565 ppm $CaCO_3$ is formed.

- $CaCO_3$ formed and settled for 12 hr duration of water re-circulated through in vortex tube for 12 hrs, 9.1 ml EDTA is consumed and 400.08 ppm $CaCO_3$ is formed.

It is confirmed that 7 to 8 hrs of re-circulation through vortex tube will separate the maximum amount of $CaCO_3$.

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