HOW TO EVALUATE AND SELECT AN OZONE GENERATOR

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Awareness of ozone and its applications in India have increased .With more stringent rules with respect to the Environment, Consultants have begun to look to alternate Technologies and have found ozone providing solutions to many of their problems. As this technology is relatively new it becomes very important for Consultants and prospective users to be aware of the intricacies associated with this Technology.

Ozone is a good Technology as long as it is applied well. For successful Ozone applications, four vital aspects are to be borne in mind .They have to be understood, analyzed and than the decision can be taken. Avoid taking buying decisions without having all these figures in front of you. Study thsese information, verify the figures, ask questions and satisfy yourself before you decide. The four aspects to be considered are:

1) **The Ozone Weight to be applied** – the decision is best left to the Manufacturer who will in addition help out the client. If you have a doubt, verify.
2) **The Ozone Concentration** that has to be used and the methods of ozone mass transfer- This will be suggested by the Manufacturer
3) **The Ozone Generator**.- the Hard ware configuration that will determine the success of the project. A good solution must be complemented by a good equipment
4) **Safety Aspects** – Never neglect this aspect. Though ozone is a safe gas when handled well , the equipment uses High power , and needs to have interlocks for protection .The life span of the equipment and maintenance requirement depends upon this factor .Operational safety should also be ensured

In most cases, clients and consultants are often in the dark as to how they go about evaluating ozone systems and the criteria to select the equipment for their applications.
The article will attempt to simplify the process of selections so that the user and the consultant make an informed decision to arrive at the selection. So How do we go about?

1). Consider the Technology First.

Ozone can be produced in 100 ways. There are more than 700 patented ways of ozone production. But commercially three most popular methods are being used.

a) The UV method of ozone production
b) The plate types Corona ozone production
c) The tube types Corona ozone production

a) **The UV OZONE. :** To understand this we need to define the role of Ozone.

ROLE OF OZONATION- AN OVER VIEW

The main purpose of Ozonation is of dual nature. Ozone is expected to perform **both Oxidation and disinfection.** (Oxidation to remove organics and inorganic contaminants and disinfection to kill bacteria etc). Irrespective of the amount of ozone generated per hour, a minimum concentration of at least 1% is required for both oxidation and disinfection.. UV ozone generators cannot generate Ozone at this concentration to perform simultaneous oxidation and disinfection.

CONCENTRATION OF OZONE.

CD OZONE Generators can produce Ozone at a concentration ranging from 1 to 16% w/w compared to 0.1 to 0.001% w/w by UV ozone. This as mentioned is 10 to 1000 times less when compared to CD ozone generators**. The amount of air required for UV Ozone generators is 10 times more than that required for CD units with consequent low Ozone concentrations.**

UV LAMPS USED

Most UV Ozone generators available today use 254 manometers (nm) radiation. 89% of relative spectral energy of UV lamps are at 254 nm, and low of 218 nm. Maximum production of UV ozone occurs at 260 –265 nm. Hence by using 254 nm UV bulbs, it is impossible to produce more than **traces of Ozone.**

MECHANISM OF ACTION

This is the most important difference. The ozone generated by UV ozone is immediately decomposed by UV radiation to form free Hydroxyl radicals. In aqueous solutions these Hydroxyl free radicals (OH+) are very powerful oxidizing agents. But the greatest disadvantage is that the half-life of these Hydroxyl radicals is in the order of MICROSECONDS compared to 22 minutes of Ozone**. Consequently Ozone Generated by UV method cannot be expected to remain in solution for sufficient period of time to provide adequate disinfection, although chemical oxidation can occur.**

It is only recently that UV ozone using 172 nm bulbs was tried. These can produce higher concentration of O^3, but these bulbs have not been described as commercially available nor tested.

WHY CONCENTRATION OF OZONE IS SO IMPORTANT

The solubility of Ozone in water is only partial and is governed by Henrys Law (the solubility of the gas in water is directly proportional to its partial pressure in the gas phase) . Consideration of Henrys Law lead to the obvious conclusion that the higher the Ozone concentration the greater will be the solubility of ozone in water. **The more ozone is dissolved in water the more effective it is as a disinfectant**. It is therefore very clear

that Ozone generated through UV radiation, not much of Ozone is available in the water for both Oxidation and disinfection. The following table explains:

Table ref. STOVER et al 1986

Temperature Deg. Cel	GAS PHASE OZONE CONCENTRATION (% w/w)					
	0.001% UV-254 nm	0.1% UV 185 nm	1% CD	1.2% CD	2%	3% CD
	EQUILIBRIUM OZONE WATER SOLUBILITY mg/liter					
5 Deg Cel	0.007	0.74	7.39	11.09	14.79	22.18
25 Deg Cel.	0.004	0.35	3.53	5.29	7.05	10.58
30 Deg Cel	0.003	0.27	2.7	4.04	5.39	8.09

SOLUBILITY OF OZONE IN WATER (in mg/liter)
AS GENERATED BY UV VS CORONA DISCHARGE

CHICKS LAW FACTOR : The disinfection process of ozone is governed by Chicks law . This law follows the CT Factor more commonly known as Contact time factor. Just as antibiotics used in Chemotherapy have specific doses for different strains of Bacteria , and the minimum Inhibitory concentration of that particular antibiotic in the blood will decide on the efficacy of the antibiotic, Ozone also has different CT factors for bacteria / virus etc. Therefore for effective Ozonation, CT levels are to be maintained if full benefits are to be achieved. Therefore the concentration/ and time factor is the most important in ozone disinfection, both of which are not achievable with UV ozone.
Air-borne Bacteria/ virus are more easily destroyed by ozone than water borne organisms. This is the precise reason why for air treatment ozone requirement is so very low.

b) Plate type Corona Technology -
The plate type Technology was first developed by the Russians and have now been considered out dated . All over the world this plate type Technology has been supercede by the tube technology due to the following reasons:

The plates are usually connected to the high voltage wires by means of alloy solder. During the course of the CD formation, the system is at a very high-energy state and resulting also in significantly high temperature. This combination creates weakness in the solder and together with the reaction with the ozone produced at the critical phase , the joints break-up within a short time causing generator failure.

The other factor is that when air is passed through the parallel plates, the small width of the space between the plates would increase the resistance to the airflow that only a portion of the air (supplied by a weak force fan) is available for Ozone production

It is a known fact that metals can accumulate dust because of electrostatic conditions. Even with the best of filters, if one examines the air conditioning duct after months of operation, heavy dust build-up could be observed. This dust build-up attracts moisture on the corona plate .The dust also accumulates. This will result in failure of the cell if they are not cleaned regularly. The maintenance of the plate is very cumbersome and risky

The plate types of generators allow air to pass between two or more parallel plates with alternating negative and positive charges. The corona between the plates will generate the Ozone. Where the application uses Air as feed gas the pre treatment of the feed gas becomes very vital . Air quality must be at least Minus 60 degrees Dew Point to prevent formation of Nitrous oxides due to ozone reactions with moisture and Nitrogen present in the air , This may not be a problem in very small-scale applications but becomes a very big factor large applications.

With the plate method of production it is not possible to make any changes in the production of Ozone or modifications of Ozone after production to rectify this. The fresh air introduction in large applications could contain significant moisture to dissolve the gases and from nitric acids which may in the course of time attack the metal plates.

How ever this problem of Nitrous acid formation can be avoided in plate type systems by using oxygen as feed gas. So for applications where air feed is sufficient, plate type technologies are found to be expensive

c.) The Tube Type Corona Technology

By far the most common and the most widely used. This is the latest technology and the most reliable technology. The technology consists of a di-electric that could be glass /SS combination or Ceramic. Air /Oxygen as feed gas is passed through the minute gap between the di electric and high voltage applied. The ionization of oxygen takes place within this gap and ozone is formed.

The quantity of ozone formed with is Technology depends on the Technology used to generate High voltage .Ozone can be formed at concentrations between 6-16 % using this Technology. Most of the large ozone companies around the world use this technology and have continuing research to improve and make the technology more economical and better efficiency. For very large applications this technology provides the most economical way to produce ozone. Ozone produced by this method can be anywhere up to 40% more economical when compared to the plate type Corona ozone Systems

2) Consider the running costs of ozone generator
The variable factors of ozone production can be classified into:

1) Feed Gas - Choice of feed Gas – Air Or Oxygen
2) Energy -Power consumption for ozone production
3) Cooling system – Air cooled or water Cooled ozone generators
4) Maintenance costs of the ozone system

The first three forms what is known as the THREE PILLARS OF OZONE GENERATION

CHOICE OF FEED GAS

The choice of feed gas will determine the running cost of the ozone system. Whether to use Air or Oxygen as feed gas will depend on the application needs. Applications that need high concentration ozone will require the use of oxygen as feed gas. This is because as Air Contains only around 19% oxygen, the concentration of ozone produced with air will never exceed 3% w/w , whereas with oxygen a concentration of upto16 % can be used . Some of the High concentration applications are : Paper and Pulp (12%) , Textile Effluent Treatment for COD and Color Reduction (7-10%) , Waste water Treatment for Disinfection (3- 6 %) , Waste water Treatment for COD reduction (6%). ,STP (3-6%) Ozonolysis (6%). Other applications such as potable water treatment, Process water, and municipal water treatment are normally at concentrations obtained through using Air as feed gas though in some special cases oxygen is also recommended .Chemical reactions of ozone are not governed by ozone concentrations. Choice of right concentrations will however help in ozone mass transfer (cost of application) and help reduce cost of accessories .

Air as feed gas: When air is used as feed gas, the cost of application determined

1) Capital costs of air compressor, Air driers and filters
2) Running costs of air compressors and air driers
3) Maintenance costs of air compressor systems
4) Costs of ozone mass transfer

While using Air as feed gas, one should remember that the size of the ozone systems would also be large. The cost of ozone mass transfer will affect the cost of application. Due to the volume of the gas involved in such applications, the hydro-injector system, the diffuser systems, the injector pumps have all to be sized accordingly, affecting the over all capital costs.

The technology of the ozone generating system will also determine the volume of air required for a specified ozone production. Good ozone generators require less air for producing the same weight of ozone, thereby bringing about a lower capital and subsequent running costs.

Oxygen as Feed Gas

Oxygen is expensive unlike air. Therefore while determining the feed gas for ozone generation this must be kept in mind. Using oxygen means, using a smaller ozone generator (reduced capital costs) since the same ozone generator can produce nearly double the quantity of ozone. The overall costs of ozone mass transfer devices will also be lower since relatively lower volume of gas is being used

However the lower capital costs of ozone generator can be offset by the cost of the oxygen system. This is where the ozone generation technology assumes a great role .Imported ozone systems scores over here as they require 25-30% lesser oxygen to produce the same weight of ozone when compared to non standard equipments

When oxygen is considered the choice can be using oxygen by LOX (liquid oxygen supplied in tanks @ Rs 8- 12 per kg of oxygen) , or oxygen produced through PSA (pressure swing- Investments costs plus oxygen production cost up to Rs 5 per Kg) . The choice between the two will depend on the local costs of liquid oxygen when compared to the investment, running and maintenance costs of a PSA system

When using oxygen as feed gas, the question of concentration arises. By using oxygen the concentration of Ozone obtained would be anywhere from 6-14%. Selecting a particular concentration would depend on the following factors

1. The application requirement
2. The local costs of power – the higher the concentration required, the more power would be required to produce ozone, but the requirement of oxygen will also be less. Lower concentration will involve lower power demand, but higher oxygen demand. So the total running costs have to be compared and the best alternative selected

POWER CONSUMPTION OF OZONE SYSTEM

Ozone production is a consequence of high voltage applied across a dielectric. The energy splits the oxygen molecules to atoms that recombine to form some ozone .Therefore along with oxygen requirement; power is also an important consideration. Research has been done for more than decades to produce ozone with lower power. Today very good technologies are available that produce ozone with lower power. A good ozone generator should be able to produce 1 gram of ozone with about 8 watt of power or less . Such ozone systems normally use medium frequency from 800 Hz to 1000 Hz..The higher the power applied, the more ozone is produced and the smaller the sizes of the equipment .Ozone generators using mains frequency have a very high power demand.

Ozone produced from Air may require up to 15 Watts per gram of ozone as the power costs of air compression has to be included in the cost of ozone production.

COOLING SYSTEM.

During ozone production, lots of heat is produced. The heat produced have to be removed as and when it is generated to avoid loss of ozone due to heat. Most ozone generators have cooling/chilled water circuits for their di-electric to remove this heat. Small applications that require small ozone generators – up to 20 grams are normally air cooled. It is the larger ozone systems that require cooling/chilled water circuits. The amount of chilled/cooling water required will depend on the heat load. This is where technology plays an important part. Sophisticated technologies are available today where the heat generated during ozone production is limited, thereby requiring low chilled water requirement. Ozone systems are also available that can use cooling water form 6 Degrees Centigrade to 30 Degrees centigrade with little or no loss of ozone produced. The more the chilled water required, the lower the temperature required, the higher will be the investment costs of the chiller system, and the higher will be the running costs. For very high ozone production -50 kilos per hour and above, this becomes a crucial factor to determine the cost of ozone production and clients have opted for vapor adsorption based chilled water system where the power requirements are low compared to the conventional screw chiller type

Maintenance Costs of Ozone Systems

These are normally missed by the client.. Ozone generators require periodical maintenance .Maintenance costs can be very high sometimes

.The Di electrics are most often the culprits . Di electrics are exposed to High voltage and heat. The electrical stress often produces failures that require change in di electrics. The cost of this change can affect the maintenance costs, the machine down time and low productivity. Longevity of the cells is often linked to the construction of the tubular cells and the Technology used. Few German machines guarantee di electrics for 10 years by virtue of their construction and Technology used . The breakdown voltage of the di electrics should be at least 75% more than the voltage applied across the dielectrics .This will ensure that the glass of the di electric withstands the electrical stress involved and prevent failures

The other components such as transformers, inverters, chokes, may also come in for maintenance if the quality of these are not up to the mark.

Ozone produced by Air has maintenance problems with the Air Compressors and achieving the required dew point of the feed gas. More often the loss of production can be due to this factor.

Plate type ozone generators are more problematic to maintain. Because the corona plates offer a large surface area, they are more proned for dust accumulation, attacks by nitrous acid formation, and subsequent cell failures. It is precisely for this reason that this technology has become obsolete favoring the tube technology instead.

SAFETY INTERLOCKS

For all Industrial applications this is an important consideration. The entire system must be considered SAFE including operations. The presence of safety interlocks can protect the equipment, as well as the operator

Look out for the following safety features

1) protection against High and low pressures of feed gas
2) protection against high cooling water temperatures
3) protection against High transformer temperatures
4) protection against Ozone and oxygen leaks
5) protection against Door open operation
6) Requirement of off- gas treatment – Ozone Destructors

The ozone generator must provide a PLC (man machine interphase) that will automatically shut down the system for Total protection. This will also help in easy identification of faults.

Example: The following example will demonstrate that higher investments on equipments offering better Technology will more than be offset by lower running and maintenance costs .

Let us assume that the client requires a total of 2000 grams of ozone for a particular application. The application also warrants an ozone concentration of 7% w/w

Apart form consideration of the Technology, the quality of the Equipment, the Credibility of the Manufacturer, the availability of fast Service response, guarantees including power consumption , oxygen consumption , ozone production, the following calculations can help the client make a decision.

Let us assume that the client has a choice of selecting imported Equipment (say W) and a local equipment (say M) He will work out the running costs between Equipment W and the equipment M on the following basis

Cost of Equipment W : Rs 6500000 Cost of Equipment M : 4500000

a) Power Consumption for 2 Kg : W 15.2 KW M : 20.8 KW Savings : 294,000 Rs per annum (@ Rs 6 per KW)

b) Oxygen requirement for 2 Kg: W 22 nM3 M : 32nM3
(for 7% concentration) Savings: 876,000 Rs per annum (@ Rs 10 per M3 of O2)

c) Cooling water Requirement: W 2.4 M3 per hour M: 10 M3 per hour (savings on energy and capital costs)

The client invests Rs 2 Million more by selecting Equipment W. However he spends in excess of Rs 1 Million every year by way of running costs. This apart has expenses involved in maintenance, loss in production due to long machine downtime.

It now becomes easier for the client to choose the equipment he wants.

Conclusion: This article tends to provide some intrinsic details concerning ozone equipment and its performance. By evaluating the system based on these factors, the end user will be confident that he has made a right decision and he would get the results he wants.

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A CONTAINERISED OZONE SYSTEM IN A PULP MILL