MARINE ENGINEERING

By

Prof. Abdus Samad

IIT Madras

Lecture63

Desalination

good morning everybody. Today I will start the topic of desalination. desalination is important for your offshore applications. For example, ship or offshore platform, you need desalinated water. long back there was one rhyme: water everywhere, not a drop to drink.

that means the water is there, but you cannot drink it, it is so much salty. if you drink, actually you can die. So you have to reduce the amount of salt content from your water. not only salt, if any bacteria or any other contaminant is there, you have to remove that one, then you can drink or you can use for other purposes. for your ship applications, and offshore platforms applications, there will be maybe boiler systems.

the boiler system needs actually desalinated water or no iron or no salt or no minerals should be there in water. that water will be used for your boiler application. If you are having that content, mineral content or salt content, so that will be getting deposited in your boiler pipes and finally, it will fail. So, whenever you are giving feed water, that makeup water will be coming from your desalination system or filtration system. Now, there will be a

requirement of water for cargo ships or any type of ships or passenger ships or recreational ships but offshore platforms like oil platforms are there so they also need water because engineers will be working for 15 days on off oil industry cases so in that case also they need huge amount of water for their consumption for drinking purpose as well as for day-to-day utilization for cooking purpose for bathing purpose for all many other purposes when you are talking about desalination, so previous days people are used to carry water when they are traveling, but now you have desalination system. So, people are using the newer techniques desalination using thermal or membrane systems. So, membrane system you already know that reverse osmosis based system it will be domestic that water purifier.

So, Aquaguard or many other companies are supplying that water purifier, they are having ROV system, reverse osmosis. Reverse osmosis based system. But some cases like bigger unit if you have then thermal deceleration system also possible or low temperature you create and low pressure you create and you can create more vapor again you condense the vapor.

So, that way you can get desalinated water. Even these days in desert desert area also people are getting desalinated water actually filtrate because they are reducing temperature such a low temperature. that whatever moisture is there in air, so that air moisture will be condensed, it will be collected in a pot. So, in desert area also you can get water because of modern technologies. Now, in this distillation system there will be feed water, that the feed water can come from your sea water, maybe it will be ground water or maybe brackish water, whatever water you get you can purify.

All water is not same in terms of desalination because sea water is having larger amount of salt, but your ground water normal river water they will have lesser amount of salt. So, lesser amount of salt means purifying it will take lesser amount of energy, but if you have very large number of salt like say amount of salt say sea water 35000 or 36000 ppm parts per million. So, in that case your energy requirement will be very high. and when you desalinate you will get two product one will be fresh water for drink or other purposes and will be reject brine. So, this will be having higher salt content, higher salt concentration and this one potable water you can make potable or other uses. Okay. so all your ongoing ship uh cargo ships for long distance or short distance doesn't matter you must have water source there okay and the all the content i have taken from basically different website sources i have collected and i made this slide because you don't have too much time to allocate for this course for this dissonant part in your course so I have collected different portion which will be easy to understand for you so that much content I have given so see what a salt content you see chloride is the maximum portion okay so see what a salinity will be 36,000 ppm parts per million

right and majority is sodium chloride actually sodium and chloride you can see okay and there will be some other salts also so whenever you are desalinating you have to remove all the salts and you have to re you have to reduce your water salt concentration about 500 ppm okay so 36 000 ppm to 500 ppm to bring down in id campus also you are getting water about 500 ppm for your portable or tap water whatever is coming it will be around 500 ppm. And if you have more than 500 ppm, let us say 1000 or more, maybe you can use for clothing and other washing purposes. But for portable drinking purposes, 500 ppm is okay.

But if you are having very low salt concentration, then there will be very much mineral shortage.

that is not suggested actually. Many scientists say that, you know, do not remove completely the mineral part because it is required for your health also. But too much mineral is also not good for your health. So, salt water about 35,000 ppm, 35,000, 36,000 within that range, but normal sea water or river water that will be having 1000, 1500 that much or maybe less also. It is a ground water taking that salt concentration will be much lower also.

Energy consumption will be very high if you are desalinating sea water because larger amount of salt is there. So, it will take more energy to reduce 35,000 to 500, 600 ppm. Desalination process there will be two method basically thermal process and membrane based or RO based system. And 2018 there was 18000 desalination plant operating 150 countries producing 87 million cubic meters of water. And many people think that in next world war will start because of this portable drinking water shortage.

Many people predict. S300 million people are getting water energy requirement 20 to 30 kilowatt hour per meter cube 1970 to 3 kilowatt per meter. the technology improving. amount of water energy requirement to produce certain amount of water is reduced. And you see this 2018 data 18000 now day by day the number of plants increasing.

major plants are there especially in Middle East where dry countries are there, they have lots of money also. So, they can install lots of desalination plant. especially Middle East, Qatar, Kuwait, all Saudi Arabia, they are having large number of desalination plants. Now, if we consider one ROV system, ROV system like you take sea water first, then you remove sand content, then any scaling or any deposition is there you have to do this anti scaling dosing then cartridge filtering then one pump will be there so the pump will be pressurizing water sea water about 60 bar pressure you have to create then only your salt water will be passing through membrane and you will get distilled low salt concentration water okay this is called permeate then after membrane

whatever you are getting one is getting permeate another getting reject ok. Reject means the high salt concentration part. So, that one you are not using you are throwing in the ocean again ok. So, the several processes that if you open any domestic air purification system also will have several systems there will be some sand filter. There will be carbon filtration. There will be UV.

There will be many techniques are there. So, one bacteria killing will be there. Odor or any smell is there. So, that removal charcoal filter will be there. Then your RO filter will be there. Candle. This is a candle actually. This membrane. This is a candle. So, shape will be like this.

Cylindrical shape. They will be putting and water will be entering one side and it will be exiting from other side. and it will be removing all the salts and it will be reducing salt concentration to about 500. So, if you see any RO plant first we are considering RO reverse osmosis plant. it will have few different component you can see this previous slide like you have seawater intake then sand filtration scaling. all the things in short we will discuss.

feed water, a feed pump works, seawater passes through strainer, the pump backwash the sand filter. RO plant operates more than 4 nautical mile away from the shoreline because nearby shoreline there will be lots of debris and contaminant. So, just to avoid that one, a few miles away they will take water and they will be purifying. They can take water from contaminated area also, but problem is that all the mechanical equipment will be getting blocked, clogged. that will be increasing your desalination cost finally, because you have to remove all these filters and you have to replace with a new one or you have to clean, right?

Just to avoid that one, they will take water from mid-side of the ocean instead of coastal side. there will be next sand filtration. it will be removing large suspended solids. very small suspended solids will be captured by your other filters. Sand filters like little bit larger particle, they will be captured.

And sand filter sometime back washing will be there opposite way there will be flowing water and there will be cleaning the sand filtration system. Then there will be anti-scaling dosing. anti-scaling dosing refers to applying anti-scalant chemical actually to prevent the formation and precipitation of mineral salt that cause scaling. scaling means rusting or deposition of metals oxides inside the systems. if it is getting deposited gradually the whole pipeline system or your filtration system will be getting blocked.

So, that is why you should put some anti-scallion dosing or some chemical to avoid scaling. anti-scallions are typically proprietary organic polymers such as polyacrylic carboxylic poly malic acid with molecular weight range 2000 to 10 000 dalton sea water contains springly soluble salt like calcium barium many other salts will be there so that salt should not create any scaling so that is the purpose to make this anti-scaling dosing and now next will be pre-treatment feed so initially you got feed water then you remove bigger

contaminant debris are there, sand removed, anti-scaling dosing you have done. Now, again pre-treated feed water, you have to do pre-treating.

So, large suspended solids with anti-scalant gun, now cartridge filtration. one more level of filtration will be there, that is called cartridge filtration. after that there will be pump. High pressure pump should not get all this contaminant because high pressure pump if they are getting contaminant it will get blocked or clogged. pump is the main part of your system.

a pump will be giving pressure about 60 bar for sea water desalination but for other water desalination pressure requirement will be lower so higher pressure means higher energy consumption okay so 35 000 ppm water you are taking and 60 bar pressure you are creating then you are getting a filtration i mean pure water or portable water okay here they are saying 225 to 375 psi pressure will be created required for brackish water 800 to 1180 psi for seawater. to achieve such high pressure one here axial piston pump normally it will be used. Axial piston pump you can remember pump lecture. So, axial pump means axial pump this is high pressure low flow rate.

Because in this case 60 bar pressure is required. normal centrifugal pump if you are taking then maybe you have to create multiple stages. multiple stages maybe it will be more complex actually. So, to avoid that one they will be taking axial piston pump the reciprocating pump you can remember. So, reciprocating pump will be moving piston moving up and down it will be delivering and it will be delivering at very high pressure.

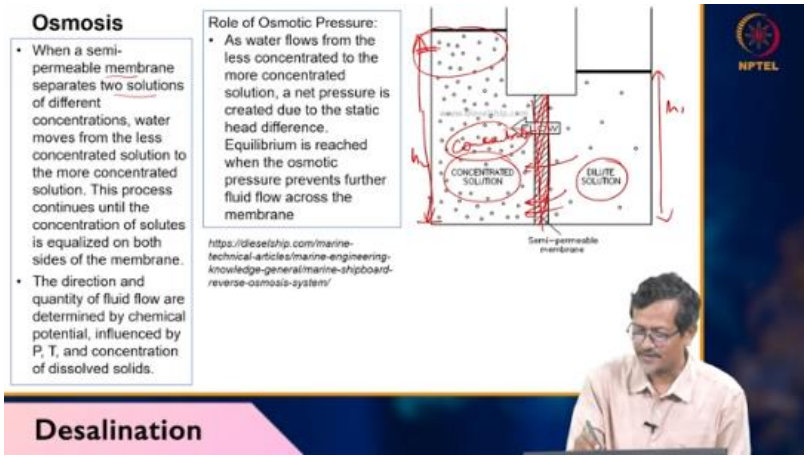
But the axial piston pump property is that it will be delivered at a lower flow rate. But centrifugal pump if you are using, a centrifugal pump will give giving higher flow rate, but the pressure will be lower. So, that will be difficult to handle because then again space consumption, the total space requirement will be larger. So, small amount of fluid you are pumping at higher pressure and positive displacement, these are called positive displacement pump. Positive displacement pump.

pump okay so positive displacement pumps are there axial pump diaphragm pump scroll pump so uh several other types of pumps also there okay progressive gravity pump is there screw pump is there okay uh so normally piston pump is very common with very simple in construction like injection syringe taking certain fluid and delivering okay Now, reverse osmosis when you are talking about then you should know what is osmosis first. So, osmosis when a semi-permeable membrane separates two solution of different

concentration. So, you can see this one semi-permeable membrane picture and this is dilute solution and this is concentrated. This is concentrated solution.

The dilute solution will be passing the membrane. It will be going to concentrated solution. And the pressure, this height will be larger than this height. This is H1. This is H2. So, H2 will be larger than H1 because of the semipermeable membrane. So, this actually this technology is used for your one ocean energy conversion system.

So, because you got higher head here, this water you collect and you pass through this one through a pump or turbine. if you can pass through this turbine you can run you can get some electricity actually so then how you get this salt different or the different concentrated water river water will have low salt concentration sea water have high salt salt concentration now when river is mating ocean you put one membrane and you create certain structure like this so that where sea water side is there so their level will be increasing And river side water level will be lower. So, higher level when you got you put that water through one pipe one turbine you get electricity. So, that technology also people are trying to develop from sea water to energy. Because river is salt concentration is lower sea water salt concentration is higher.



2 salt concentration when you are mixing and salt concentration water having membrane inside one higher level another lower level you are getting energy ok. So this phenomena is happening because of osmosis process. It is called osmosis. this is called semi-permeable membrane. The term semi-permeable means it will be allowing certain amount of salt or fluid to restrict certain amount to allow.

So, this process, you see this one, water moves from less concentration solution to more concentration solution. This process continues until the concentrated solution is equalized

in both side membrane. continuously this low density fluid will be moving, water will be moving through this one. The direction and quantity of fluid are determined by chemical potential influenced by pressure, temperature and concentration of the dissolved solids. role of osmotic pressures as water flows from the less concentration to the more concentration solution a net pressure is created due to the static head difference ok.

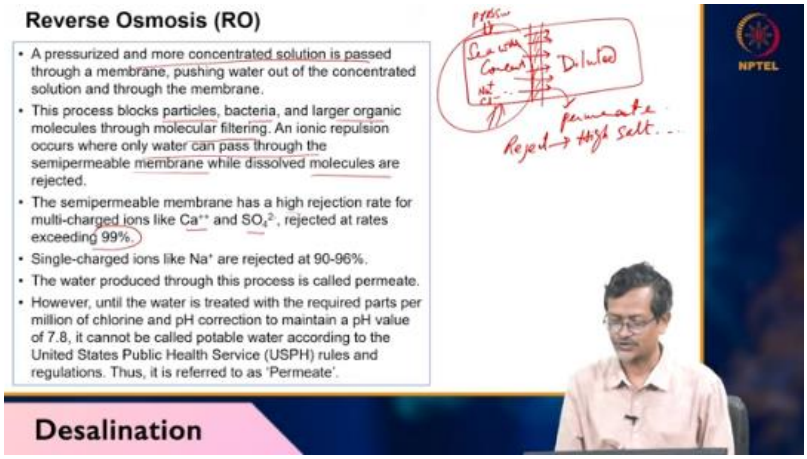
So, you can see this is the net pressure ok. So, h rho g you can calculate how much pressure is created. Equilibrium is reached when the osmotic pressure prevents further fluid flow across. So, this h rho g it will be increasing increasing after certain time that pressure will be forcing back so that's why there there will be some equilibrium in between so then reverse osmosis will be opposite how it is happening a pressurized and more concentrated solution is passed through a membrane so now we have membrane we have concentrated solution we have diluted solution a low concentration solution and diluted okay so

in this case concentrated solution will be passing certain amount of fluid to dilute the solution okay so this is maybe sea water and you create very high pressure so at high pressure the salts na cl all the salts will not move through this membrane only water will be flowing through this one so only certain amount of salt may be going based on your separation your membrane efficiency this process blocks particles bacteria large organic molecule through molecular filtering and ionic repulsion occurs when only water can pass through the semi permeable membrane while dissolved molecules are rejected okay so salt whatever salt is there that will be rejected by this membrane And this salt seawater side concentration gradually be increasing because water part going to diluted section, but salt part is remaining. this part will have more salt concentration. gradually the salt concentration will be increasing.

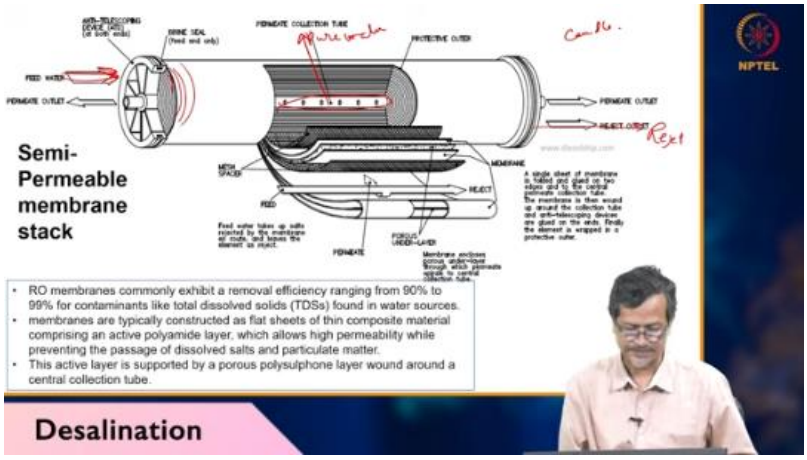
you have to remove that also to increase your system performance. So, semipermeable membrane has a high rejection rate for multi charge ion like calcium, sulphate, the reject rate exceeding 99 percent reject rate means the water you are rejecting ok. The water produced through this process is called permeate. So, whatever water you got permeate, permeate and whatever rejected fluid it will have low high salt concentration.

high salt concentration to be there and the how much the high higher than the actual ocean water whatever you used okay so however until the water is treated with required parts per million of chlorine and ph also should be maintained whenever disorienting ph you have to maintain you have to remove bacterias you have to remove salt then only you can use for your shipping applications Here one picture of semi-permeable membrane or candle

you can say in domestic that water purifier, aqua guard or many companies are there. they will be saying candle. candle means you are giving feed water and feed water will be going through this all this layers. Then inside here you can see lots of holes are there.



You are collecting pure water here. you are collecting pure water here. And your reject is going here, the rejected water. So, it is flowing through several layers of your membrane, then you are getting water. So, RO membranes commonly exhibit removal efficiency ranging 90% to 99% for contaminants like total dissolved solid.



So, that solid they say total dissolves or TDS. normally the technical person when they will be coming for servicing this etc. What is the TDS? So, they say total dissolved solid how much is there? Now, what is semi-permeable membrane?

So, semi-permeable membrane or selectively permeable membrane they say a membrane capable of permitting passing certain substance which while hindering others. water they are allowing but salt not allowing. That is why this is semi permeable. This property of

selective permeability is determined by factors such as molecular size, charge and other intrinsic properties.

In process like osmosis and ribosomosis, a semi-permeable membrane allows the passage of water molecules while impeding the solid. here one picture I have copied from this component.