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Design, construction and erection of seawater intake system to establish a biofouling test facility

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ABSTRACT

Large amount of seawater is used in coastal industries, like power generating plants, desalination plants and aquatic culture farms. A similar requirement exists in Department of Atomic Energy campus at Kalpakkam, Tamil Nadu, India. Seawater in large quantities is required for its nuclear power stations and desalination plants erected on the east coast of Bay of Bengal situated in southern part of India. Such seawater systems have biofouling problems. Hence a seawater intake system has been designed, constructed and erected so that virgin seawater will be available for biofouling studies that was proposed to be carried in a once through flow test facility. A major criterion for the test facility was that continuous supply of seawater should be available at the rate of 160 m^3/h. To meet this requirement, centrifugal pumps were installed at about 150 m away from the shoreline and connected to an intake structure using 600 m long, 355 mm OD, high density polyethylene pipeline laid on the seabed. Details of site selection, options of construction methods, materials selection, pressure drop calculations, sizing of pipes and anchor blocks, stability of intake pipeline, deployment criteria and project cost and planning have been discussed in this paper.

1. Introduction

Many industries in the world, including power plants, use seawater as the ultimate heat sink. Desalination plants also use large amount of seawater for producing potable water. These industries draw seawater using a professionally designed intake system. However, there are many problems related to the usage of seawater on an industrial scale. Seawater contains large number of micro and macro organisms which can settle in the ducts and pipelines of the system and can cause serious biofouling (Al-Juboori and Yusaf, 2012; Matin et al., 2011; Pugh et al., 2003). Problems due to this biofouling are like, reduction in the efficiency of heat exchangers, increase in pressure drop due to friction in flowing systems, clogging of filters and strainers and accelerated localized corrosion. The nuclear power plants situated on the east coast of India also encounter such biofouling related problems (Suresh et al., 1995; Rajagopal et al., 1996). These power plants use seawater from Bay of Bengal in its once-through cooling system and then discharge it back into the sea. In order to study the problems of corrosion and biofouling under seawater conditions and to find suitable solutions which can be practically implemented in the power plants, a Biofouling Test Loop (BFTL) facility has been set up at Bhabha Atomic Research Centre Facilities, Department of Atomic Energy, Kalpakkam, Tamil Nadu state, South India. Experiments related to biofouling and its control, bio-corrosion and environmental effects of condenser discharge etc., are being carried out using this facility. This paper presents information with regard to the technical details on design and construction of the intake system for the facility. Reliability in operation of such intake systems depends on design and site selection. However, there are many inter related factors which make the seawater intake system design highly complex (Colt et al., 2006; Huguenin and Colt, 2002).

1.1. Objective of the project

The objective of the project was to set up a seawater intake system to fulfill the requirement of large quantities of seawater for a once-through seawater flowing experimental facility. The experimental facility has been built to study the settlement of fouling organisms under dynamic seawater conditions and methods of biofouling control. The data generated in this facility is expected to help in designing cooling circuits as well as to prepare operating specifications for existing as well as future power plants and desalination plants expected to be built on the east coast of India.

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1.2. Site selection

The biofouling in a system depends on the nature, types and population of the organisms present in the seawater. The biofouling studies are site specific. Hence the location adjacent to the intake point of the existing power plant on the east coast of India, for which biofouling studies have to be carried out, was chosen as the intake point for the test facility also. This happens to be at around 450 m from the shore line. While selecting a nearest point to the intake of existing power plant, it was also ensured that the intake is away from the out fall of the power plants, desalination plant and municipal outfalls, so that contamination in any form can be avoided (Huguenin and Colt, 2002). It was verified from the bathymetry data that there would be sufficient water depth at the intake location even during lowest sea level (tide) condition.

1.3. Options for construction and selection

The main part of the experimental facility is the seawater intake system. Seawater can be drawn using various methods as explained below:

1. A jetty can be built into the sea upto the intake point. Pumps can be installed on the shore. Suction pipeline can be laid over the jetty. The end of the suction pipe can be run down along with the suction strainer and can be submerged in the sea. In this case the erection of pipeline is relatively easy and can be made intact & secured with the jetty structure. Also there will be a good access to the intake strainer for maintenance. However the height of the jetty shall be such that there is adequate Net Positive Suction Head (NPSH) available in the system. The cost of construction of jetty would be considerably high.
2. A jetty can be built into the sea upto the intake point. Pumps, like submersible or centrifugal type, can be installed at the end of the jetty. Discharge pipeline can be laid over the jetty. In this case the erection of pipeline is relatively easy and can be made intact & secured with the jetty structure. Also there will be a good access to the intake strainer for maintenance.

In this option, if centrifugal pumps have to be installed over the jetty, the structure must be more robust than the option-1 and hence would be relatively more expensive. However, if submersible pumps are used, relatively simple jetty would be sufficient. Though maintenance cost of submersible pump would be comparatively high the advantage with this option is that in case of failure of pump, we can replace and deploy with a spare pump, which can be readily stored (Colt et al., 2006).

1. Constructing a tunnel under the sea to have a gravity flow of seawater into a deep fore bay/well located on the shore. The seawater collected in the well is pumped out for usage. This system is relatively simple but is cost involving and is suitable for huge volumetric flow only. In this option, a simple jetty structure may also be required to have access to the off-shore intake well and to carry out bside-ciding at the intake point to control biofouling in the tunnel. On a whole this option is expensive as both underground tunnel and jetty structure construction have to be carried out. However, the operational cost would be relatively low.
2. Constructing a canal and drawing seawater using pumps. This system is suitable for high flow and will be cheaper compared to all the above options. However, the canal needs frequent maintenance, which is the main cost incurring component. Hence the operational cost is high.
3. Constructing beach wells (Voutchkov, 2005). Water drawn from the beach wells will have low salinity, low dissolved oxygen and also reduced levels of silt, organic contamination, aquatic micro organisms etc. Hence, systems using sea water from beach wells will have relatively less biofouling. The disadvantage in this option is that the maintenance of the system is costly. Besides, the beach wells could be constructed only under certain favorable geological condition and the construction of these could have some environmental impact. This option can be most suitable for systems like desalination plants of smaller capacities. However, this option is not suitable for our project as we need representative seawater that is being used by the existing plants to study about the biofouling and its control.
4. Deploying a long pipeline in the sea, mostly made of flexible materials like HDPE, and connecting it to a pump on the shore. Designing the system is simple but erection is relatively a difficult process. Cost is also comparatively cheaper. However, access to the suction strainer block will be difficult.

The expected completion period of the proposed experiments in the facility is around 4 years. Hence the capital cost of the project must be suitably fixed. Considering the cost effectiveness for a very short duration of usage, the option-6 was chosen.

2. Design and construction of the intake system

The seawater intake system draws seawater directly from the sea and discharges into a main seawater sump which has a capacity of around 40 m^3. The total flow of seawater required for various experiments was calculated as 160 m^3/h and the system was accordingly designed. The suction pipeline consists of HDPE pipes and a centrifugal type of pump, which has 100% standby, situated in an onshore pump room. Measuring from the sea bed at the location of intake suction strainer block, the low sea level is 5 m and high sea level is 6.7 m. The average height of the site (floor level in the laboratory), from the same datum as above, is 11 m. The seawater pumps have been installed in a pit constructed in the pump room such that the center line of pump suction is around 3.5 m above the low seawater level at this shore location. Since there is a suction lift and as we cannot have any foot valve/check valve at the end of the suction pipe (in the sea), during startup, the suction line needs to be primed. The priming is done by operating water ring type vacuum pump, which also has 100% standby. The water is drawn through a suction strainer located in the pump room to filter out any silt that is expected to be drawn along with the seawater. The system has ball and butterfly type valves located at various points in the piping system, which are either used for isolation or for controlling the flow.

2.1. Selection of material of construction

For the piping, materials like hot dip galvanized iron or duplex stainless steel could be chosen as they have very good strength. But these materials could corrode over a period of time besides having high cost. Also the metal pipes are heavy and do not have flexibility that is required for deploying them into the sea. Moreover when the pipe rests on the uneven sea bed, the pipe has to adjust to its contour, which is not possible with the metal pipes. Materials like polyvinyl chloride (PVC), fiber reinforced plastic (FRP) and low density polyethylene could also be chosen, but these materials have relatively very low strength and due to the low wall thickness of pipes that are commercially available, these pipes cannot take large bending loads, which are expected to be subjected during deployment. Moreover PVC has very less resistance toward embrittlement due to solar UV radiation exposure. Hence high density polyethylene, HDPE (IS 4984, 2006; Janson, 1996) was chosen as the material for seawater intake system pipeline. This material has good resistance to corrosion and resistance to solar UV radiation.