AN OVERVIEW: THE ENVIRONMENTAL IMPACTS OF LNG REGASIFICATION SCHEME FOR SUPPLYING DOMESTIC NATURAL GAS

by

Dwi Anggoro Ismukurnianto

ABSTRACT

In order to supply domestic gas demand which will be in shortage in 2004, especially in West Java where most gas consumers, are located LNG regasification scheme is an alternative technology that may be used for transporting gas from other islands to Java. Under this scheme, the excess capacity from LNG plants in Indonesia can be absorbed especially in low seasonal demand periods, and then the LNG plants' production will be optimized.

During the regasification process of LNG, the seawater will be utilized as the heating medium to vaporize the LNG. Since the temperature of LNG is about –160°C, the seawater will give up heat to the LNG and be cooled to 17°-22°C. The seawater will be chlorinated in order to prevent fouling of the vaporizer tubes by algae and others. The cooled water returned to sea will of course contain a small amount of residual chlorine.

In order to mitigate the impacts, it is important to conduct three-dimensional simulation of seawater dispersed from the system. From the simulation, the water rate and types of vaporizer used are recognized. Open Rack Vaporizer (ORV) is a suitable vaporizer that gives benefits such as low operation cost, simple construction and, easy maintenance, and high reliability and safety.

I. INTRODUCTION

The Oil and Natural Gas Law Number 22 of 2001 has explicitly stated that in order to ensure the availability of oil and natural gas to be used efficiently and effectively, both as fuel and feedstock, it is important to prioritize oil and natural gas for domestic uses. As a consequence, it will increase government income that gives significant contribution for national economy, and develop and strengthen of Indonesia's position in trade and industry activities.

The spirit of the Law is that the Government of Indonesia has considered using natural gas resources effectively and efficiently for domestic purpose because some Indonesian regions have been predicted to suffer becoming shortage of natural gas supply in around 2004. For example in western part of Java (West Java, DKI Jakarta, and Banten Provinces) where about 40% investment has been performed for big industries, this region has been predicted to experience shortage in 2004.

Therefore, it is important to find an alternative way of supplying natural gas by transporting natural gas from other regions to this region. The Government of Indonesia plans to build "*Trans Indonesia Natural Gas Pipelines*" that can transport natural gas between regions. However, this plan has met some obstacles such as unstable social-politic-economic conditions, restriction by Regional Autonomy Law, and high costs needed for building submarine pipeline. Other alternative that has specific characteristics such as lower investment, high flexibility, and investor readiness, is by Liquefied Natural Gas (LNG) regasification scheme.

LNG has been exploited commercially since the late 1950's and early 1960's. The first large-scale trade occurred when British Gas began importing LNG from Algeria in 1964. Since that time, LNG has been established as a major energy commodity. LNG supplies come from countries that have surplus natural gas such as Algeria, Indonesia, Trinidad, Nigeria, Malaysia, Qatar, Oman and Australia. Exporting LNG is a viable economic option when the natural gas users are not near from the producers. The large users of LNG include the USA, Korea and Japan, which derive 94% of their gas as LNG.

Although technically speaking, LNG regasification scheme is one of the most suitable technologies for transporting natural gas among the regions, consideration should also be made from environmental point of view. This paper will highlight the environmental impacts of LNG regasification scheme that would be developed in Indonesia for supplying natural gas for domestic uses. First of all, LNG regasification scheme would be described in order to give an illustration how the scheme works. The second part would discuss the environmental impacts of LNG regasification scheme. After having identified the environmental impacts, it is crucial to describe mitigation action that should be taken. This paper would be end by a conclusion.

II. LNG REGASIFICATION SCHEME

One of the difficulties of getting natural gas from supplier to distributor to user is transportation. Natural gas, normally delivered by pipeline, is not a product suited for overseas export and therefore loses its competitive edge despite an increase in demand. Liquefied natural gas gives natural gas producers and suppliers an alternative to tap into markets that once were out of reach because of transportation limitations. Natural gas, in its normal state, takes up a lot of room and can only be transported through pipelines, which makes it uneconomical to transport over long distances. LNG, however, is 600 times smaller in volume and can be transported long distances by tankers.

Before the LNG can not be supplied into the gas transmission network it must be converted back to a gas; this process called regasification or vaporization. Based on its physical characteristic, LNG is a suitable means for transporting and storing natural gas due to the location of the natural gas reserves are usually far from potential users. It is difficult to transport natural gas by any other means, such as pipeline that is not economically feasible due to the relatively low energy content per unit volume.

Natural gas transportation in LNG form will be economically feasible. The study conducted by Hidayati et al. in Suharyono H. (2000) showed the comparison between natural gas transportation pipeline and LNG tanker, where the latter case includes conversion from natural gas to LNG. In this study, the comparison was made for natural gas transportation from East Kalimantan to East Java by using 40 inch pipeline and LNG transportation by using 125.000 m^3 LNG tanker to deliver 1.4 million ton LNG per year. The results showed that for 1,000 km distance, transportation cost of the pipeline was equal to that of LNG tanker, i.e. USD 1.5/MMBTU. If the distance is less than 1,000 km, the pipeline transportation cost will be lower than the LNG tanker transportation cost. The situation will be the opposite if the distance is more than 1,000 km.

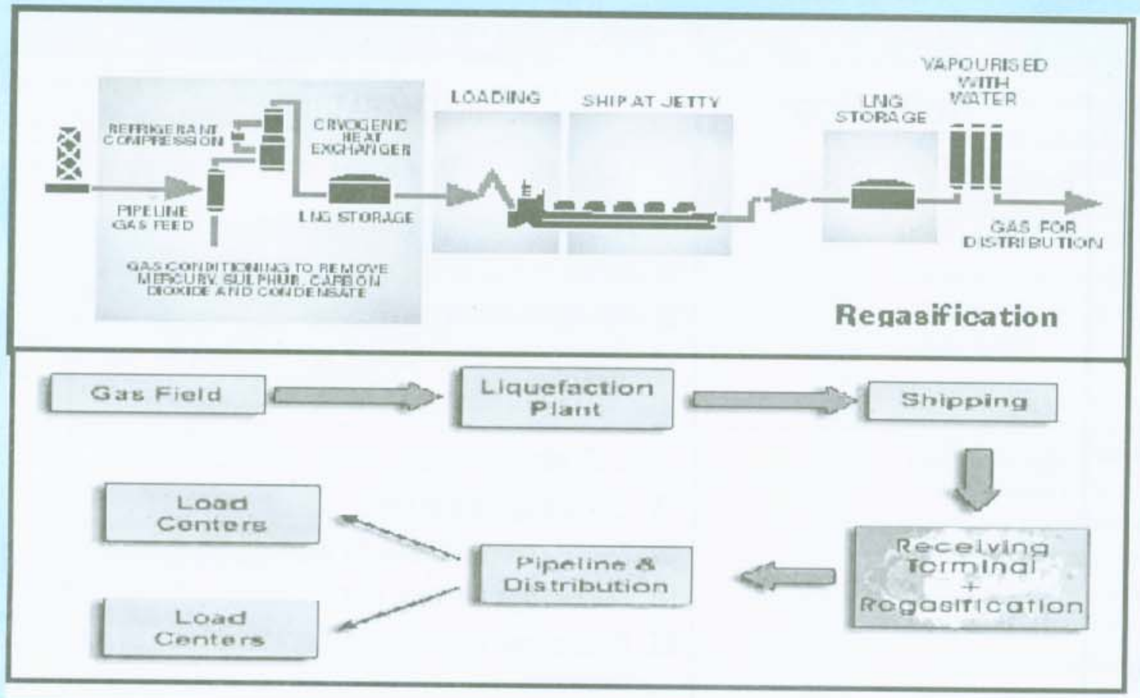
The sources of LNG may be obtained from the existing LNG Plants such as LNG Arun, Bontang, Tangguh, etc. LNG will be stored in the receiving terminal before being regasified to be natural gas. Natural gas can then be transported to natural consumer anytime needed. By using the LNG regasification scheme, the excess capacity from the existing LNG Plants can be absorbed, especially in low seasonal demand periods.

In order to give clear picture of LNG regasification scheme, Figure 1 shows the LNG chain where LNG regasification scheme is a part of the chain.

LNG is transported from LNG plants to LNG receiving terminal. The receiving terminal is the point where the LNG regasification process activity begins. In the receiving terminal, LNG can be converted directly into gas or LNG can be transferred into LNG storage tank depending on LNG regasification scheme used. If LNG is directly converted, LNG is pumped at a pressure of 1,100 psig from LNG tanker, and then LNG is converted into gas phase through a vaporization process. LNG can also be transferred into the storage tank before being converted into the gas phase.

During the vaporization process, seawater is utilized as the heating medium to vaporize the LNG. Seawater at its normal prevailing temperature of approximately 27°C will be pumped to LNG vaporizers. LNG at approximately -160°C (-256°F) temperature will flow through the vaporizer tubes, while water flows over the outside of the tubes. The water will give up heat to the LNG and be cooled that depends on water circulation rates, and hence the liquid phase LNG is converted into the gas phase. The cooled water will continuously be returned back to sea. Gas will then be delivered to the customer through the existing gas processing, transmission and distribution facilities. In addition, water supplied to the vaporizer will be chlorinated to prevent fouling of the vaporizer tubes by algae and others. The cool water returned to sea will contain a small amount of residual chlorine.

LNG is stored in special cryogenic tanks. Typical LNG tanks have two walls separated by heavy insulation: an outer wall of reinforced concrete lined with carbon steel and an inner wall of nickel steel. The tanks are



Source: Sawchuck, J and Mark Howard (2001)

Figure 1
LNG chain

designed to withstand earthquakes and very high winds. They are also surrounded by a diked system to collect LNG in the event of a leak or spill. LNG tanks are very big – 100,000 cubic meters is common. At the LNG facility in Trinidad, the tanks are about 45 meters high and 72 meters in diameter – taking up about a football field.

LNG regasification technology can be classified into two types, as summarized in Table 1. The choice of LNG regasification technology is made by considering its characteristics and economic evaluation.

III. ENVIRONMENTAL ISSUE OF LNG REGASIFICATION SCHEME

The main environmental issues of LNG regasification scheme are due to the cooled water dispersion and residual chlorine discharged from LNG regasification facilities.

A. *Seawater*

The environmental baseline condition of seawater shows that seawater temperature would be in normal condition for a tropical water area, and ranges from 27.6° C to 28.7° C. Its variation at different depth from season to season is generally small due to homogeneous waters. Maximum difference is about 0.1°C.

Seawater temperature is generally lower at the West season and East season because of strong blast of wind at those seasons that may affect intensive evaporation on the seawater surface. For this evaporation, the nature absorbs a lot of heat from the water mass, so that the temperature may decrease. Moreover, the wind that blows during these two seasons comes from high latitude area with cold climate. This factor may strongly affect the decrease of seawater temperature.

During transition period of the season, evaporation is usually low due to weak blast of wind and uncertainty direction. Moreover, the water surface is quiet and the heating process of seawater on the surface takes place well. As a result, during this period seawater temperature would be in maximum condition.

As described above that the seawater will be returned back into the sea after being circulated in the vaporizer. Its temperature will decline since the water will give up heat to the LNG and be cooled that depending on water circulation rates. The cooled water pro-

Table 1
LNG regasification technology

NO	TECHNOLOGY	CHARACTERISTICS
1.	Floating Production Storage Offshore (FPSO)	☑ Moveable ☑ Needs LNG barge and regasification unit ☑ Utilize marginal gas well ☑ Needs cryogenic tank for storing LNG ☑ Natural gas is not stored, but it should be directly delivered
2.	Terminal LNG	☑ LNG jetty ☑ Unloading/loading LNG ☑ Needs cryogenic tank for storing LNG ☑ Needs regasification unit ☑ Natural gas is not stored, but it should be directly delivered

Source: *BP Indonesia (2001)*

duced from the scheme would affect living process and organism distribution in the marine environment.

As having been explained above, the seawater that comes to the vaporizer will be chlorinated to prevent fouling of the vaporizer tubes by algae and other aquatic biota growth. Therefore, the water that is returned back into the sea will of course contains residual chlorine. Although only a small amount of residual chlorine discharged from the scheme, it is important to look at the impact on the organism living in the marine environment as chlorine functions also as a biocide.

From a study by BP Indonesia [2], it can be recognized that the concentration of residual chlorine decreases as of the distance from the discharge point increases as seen in Figure 2. It also can be said that the environmental impact of residual chlorine discharged from the scheme seems to be localized and self-decay process will occur during the operation.

B. *Biology*

From marine biology viewpoints, water temperature is an important factor in controlling living process and organism distribution in the marine environment. The impact of water temperature on the aquatic biota is discussed in accordance with the growth requirement for each aquatic biota. The standard, decree of Environmental Minister No. 02/MENLH/I/1988, has strictly stated that the water temperature should be in normal temperature that is dependent on the location.

The impact of temperature on aquatic biota would be very much determined by the thermal differential (DT) between the intake and the discharge seawater. Indeed, the smaller thermal differentials result in minimum impact on aquatic life. It is expected that the temperature drops of about 4° - 6° C can probably be tolerated by the aquatic life.

The growth of phytoplankton, for example, is a function of temperature, light intensity, and other environmental factors. Table 2 shows the water temperature required for phytoplankton growth. It inreases with temperature. Optimum temperatures are generally between 20° and 25°C, but thermophilic strain of Chlorella and *Anacystis nidulans* grow best at about 40°C.

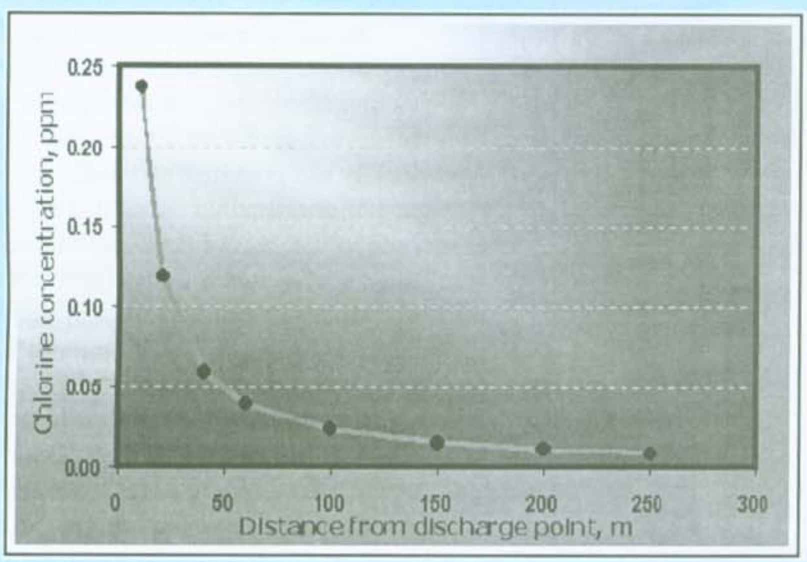
In general the biological impact of cooled seawater discharged from the LNG regasification scheme can be illustrated as seen Figure 3. From the figure, it can be said that if the water is discharged horizontally, and then organisms called "plankton" will be affected. The further impact is the disturbance of food chain in the aquatic due to the plankton is primary producer that produces a kind of food for consumers. Moreover, the plankton community is usually much more than other community in the aquatic environment. In other words, the impacts that may occur are probably wider.

If the water is discharged vertically, the effects that may occur are probably narrower since the discharge point is only a few meters from the surface while organisms called "benthos" live at the bottom of the sea. Other component that may be affected by the cooled water discharged from the LNG regasification scheme is fish. The optimal water temperature for many fishes to live is between 25° and 35° C. Therefore, water temperature is a sensitive environmental factor that needs to be taken into account since several sea fishes are sensitive to the change of water temperature.

Table 2
The effect of temperature on the phytoplankton growh

No	Class of Phytoplankton	Temperature (°C)
1.	*Chlorophyceae*	10 – 39
2.	*Xanthophyceae*	15 – 30
3.	*Chrysophyceae*	18 – 20
4.	*Bacillariophyceae*	18 – 25
5.	*Dinophyceae*	18 – 20
6.	*Myxophyceae*	25 – 41

Source: *Fogg. G.E. (1965)*



Source: *BP Indonesia (2002)*

Figure 2
Dilution of residual chlorine at distance X

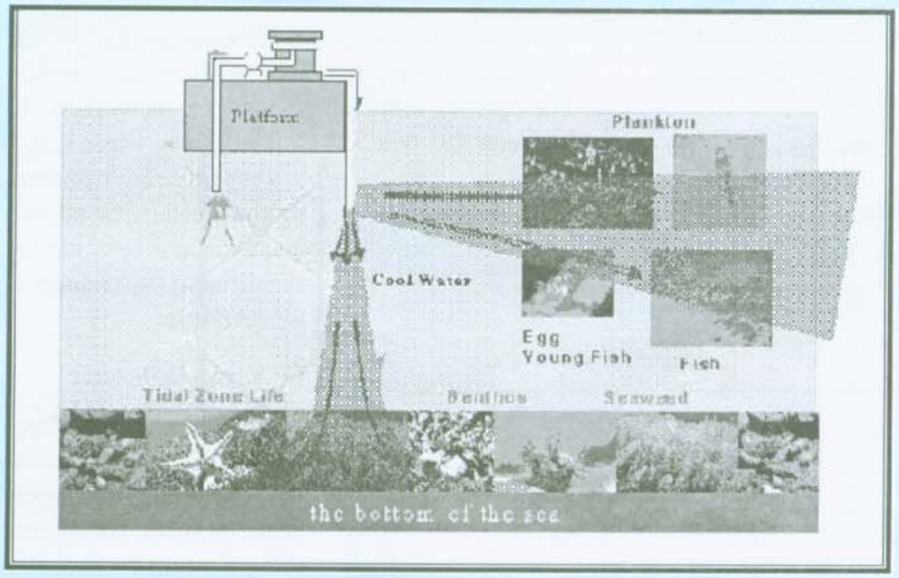
C. *Socio-Economic*

There would be a socio-economic impact of the cooled seawater although first, second and third degrees socio-economic impact might be expected coming from the overall LNG regasification scheme.

The primary socio-economic impact can be seen from the perception that may appear during the construction of LNG regasification facilities. It could give significant primary impact if a small number of local people expected to get involved in the construction process. Failure to realize such an opportunity would cause an unexpected negative impact instead of positive socio-economic impact to occur.

The perception can also be related to water pollution that might be already in the seawater for quite some time. The operation of LNG regasification facilities could posibbly generate negative social perceptions and this might be so appearing during the period of public hearing that is required by national EIA (AMDAL) Law.

Existing economic activities in the coastal zone may be found in the form of fish embankment



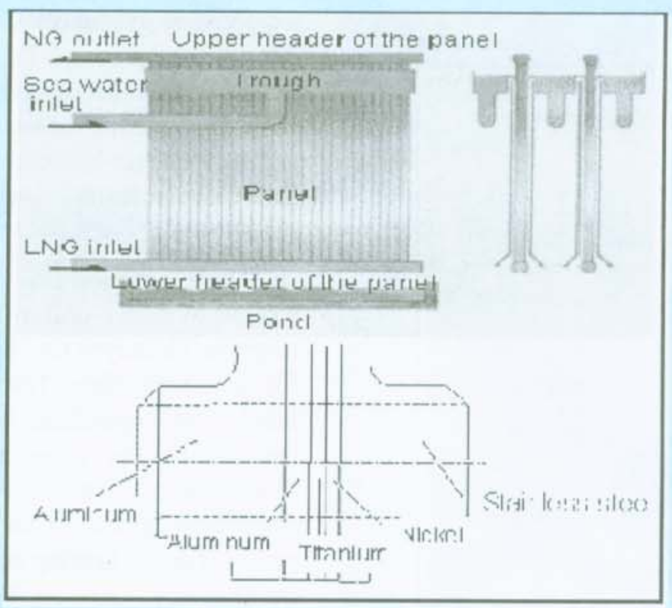
Souce: *BP Indonesia (2002)*

Figure 3
An illustration of biological impacts

or fish caging. Such an activity may be expected to grow along with a growing population and decreasing benefit of traditional offshore fishing. When seawater population getting worse, either unrelated or directly related to the LNG regasification activities and eventually bringing influence up to the seashore, then the economic activities in the coastal zone will certainly be impacted.

The second degree socio-economic impact will therefore probably occur due to the economic benefits of existing fish embankment could be decreasing after LNG regasification activities run, and with the absence of a comprehensive environmental management therapy such a negative impact would be getting worsen and socio-economic distress may appear serious as time goes by.

Tertiary socio-economic impact may occur as a result of secondary physical and chemical impacts. For example, degrading mangrove greenbelt in particular would intensify salt intrusion and underground water pollution up into the well of each household in the coastal zone and this could induce social unrest and trigger social upheaval. Degrading traditional values and customs along with growing criminality could totally be intensified within communities in the affected nearby seashore due to several reasons, but people might consider the construction of LNG regasification facilities as being the prime cause of all.

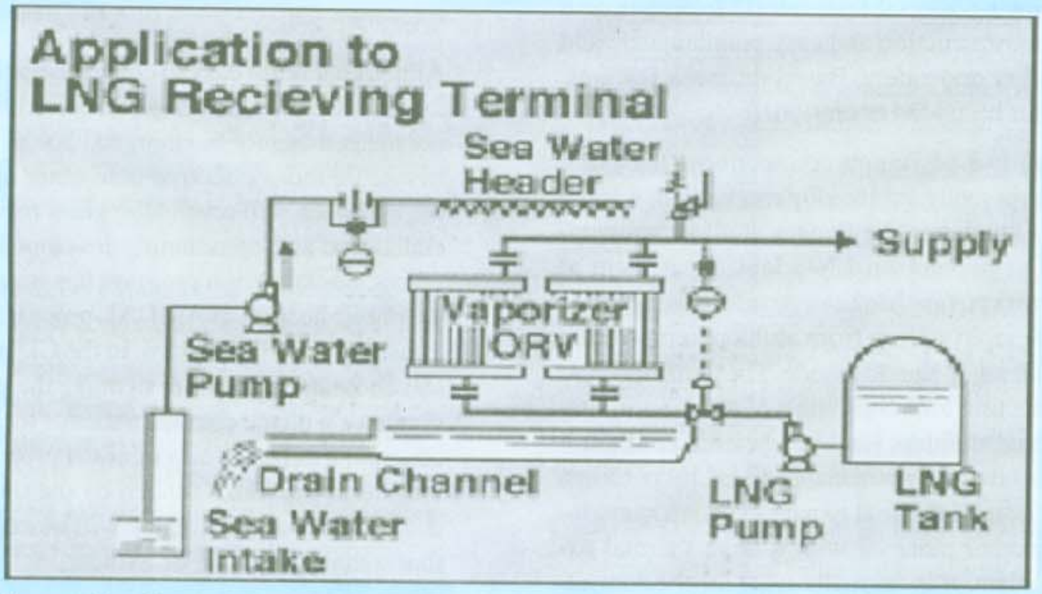


Souce: *Sumitomo precision products and Tokyo Gas.*

Figure 4
ORV conceptional flow and transition joint used

IV. ENVIRONMENTAL MANAGEMENT

Environmental management would be conducted in order to mitigate the environ-



Souce: *Tokyo Gas (2003)*

Figure 5
The application of OVR in the LNG receiving terminal

mental impacts of cooled seawater and residual chlorine. The action would be focused on both of them and socio-economic impacts.

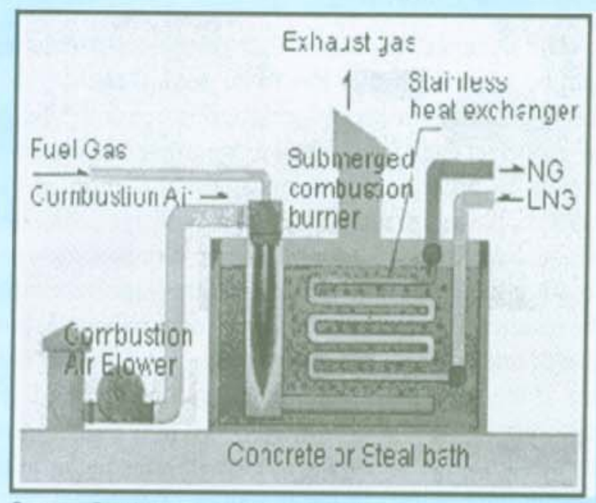
A. *Cooled Seawater*

Cooled seawater discharged from LNG regasification facilities is a key issue that will affect the environmental component. First of all, in order to localize the environmental impact, the water discharge method has to be decided. Horizontal water discharge method may affect the aquatic biota that lives on the surface water such as plankton and fishes. Vertical water discharge method could disturb the aquatic biota that lives at the bottom of the sea such as benthos and fishes. A horizontal seawater discharge method toward offshore is recommended, as the cooled seawater will be dispersed within short mixing region from the discharge point.

From technology point of view, it is possible to conduct three-dimensional dispersion simulation in order to determine the water temperature discharged from the facilities so that it is suitable for living organisms in the marine environment. From the simulation, it can be decided what types of vaporizer to be used for the LNG regasification scheme, and water circulation rate can be determined in order to decide thermal differential between the intake and the discharge points.

LNG Vaporizer is designed to re-gasify LNG by heat exchange and mainly made by aluminum alloys, and the connecting pipes are made of stainless steel. There are two basic types of vaporizer, one is "Open Rack Vaporizer (ORV)" and the other "Submerged Combustion Vaporizer (SMV)".

ORV utilizes seawater as heat source. Seawater down flows on the outside surface of the aluminum heat



Souce: *Sumitomo precision products*

Figure 6
SMV conceptional flow

exchanger panel and vaporizes LNG inside of the panel. ORV has following special features: 1) low operation cost; 2) simple construction and easy maintenance; and 3) high reliability and safety. Based on these features, ORV is used for base load operation.

Due to the use of flange connections, the ORV needed to be kept ready (in standby mode) with a small flow of LNG to maintain the flanges at a low temperature in order to prevent an LNG leak from there at startup. A transition joint has been developed in 1985 in order to enable rapid startup from ambient temperature without maintaining in standby mode. The transition joint is a pipe-connecting tool consisting of aluminum, titanium, nickel, and stainless steel in a layered configuration. This structure absorbs thermal stress by putting a material with a small thermal expansion coefficient together with another material with a large thermal expansion coefficient. It is normally used for the connection between the vaporizer and piping, and greatly contributes to improvement of operation and maintenance, as seen in Figure 4, while Figure 5 shows the application of ORV in the LNG receiving terminal.

Submerged Combustion Vaporizer (SMV) uses hot water heated by the submerged combustion burner to vaporize LNG in the stainless tube heat exchanger. SMV has following special features: 1) Low facility cost; 2) Quick startup; and 3)Wide allowable load fluctuation. Based on these features, SMV is applied to mainly the vaporizer for emergency or peak shaving operation, but it is also used as a base load vaporizer in an inland area.

B. *Residual Chlorine*

The standard stipulates that residual chlorine discharged to the seawater has to be zero. Residual chlorine is produced from chlorination process to prevent the vaporizer tube from fouling due to marine organism growth. In order to obtain optimum condition of heat transfer process, small concentration of hypochlorite is introduced to inhibit the growth of micro-organisms which would reduce heat transfer rates on the vaporizer tubes. The residual chlorine produced may disturb aquatic biota growth and further effect on marine food web. Therefore, if the use of hypochlorite cannot be avoided, it is important to use it intermittently, as it may cause immunity syndrome to the unwanted micro-organisms, while intermittent use will certainly reduce operational costs.

C. *Socio-Economic Impacts*

In order to change public perception on the operation of LNG regasification scheme, it is important to consider the following approaches:

1. Social Approach

   Although it is not easy to change negative perception to positive one on LNG regasification activities, it does not mean it cannot be changed. Social approach will in fact be more effective than other approach since the approach will reach "the grass root" through socialization and community development (CD) programs. Socialization program has been started since the public hearing of AMDAL process, and then continued by the CD program. in the CD program, all of stakeholders sit together to make the program in accordance with the characteristics of local society. The program can be in form of crash program, short and long-term programs funded by the owner. By using these programs, the society will be kept informed so that social unrest can be avoided.

2. Institution Approach

   Socialization and CD programs can also be prepared and conducted by the local authorities including Local Government. Either Provincial or Kabupaten level, the local authorities usually have programs for local society in surrounding LNG regasification facilities. The program can further be discussed with all of stakeholders, and then be implemented through the local authorities. The programs will be successfully implemented if all parties have goodwill for improving social prosperity.

V. CONCLUSION

From the discussion above, the following conclusion can be obtained:

1. LNG regasification scheme is a suitable option for delivering natural gas from the sources to certain areas. It is more economical if the distance is more than 1,000 km. Moreover, when natural gas is turned into LNG its volume shrinks by a factor of six hundred.
2. The source of LNG can be obtained from the existing LNG plants in which the excess capacity can be absorbed in the domestic market, especially in low seasonal export demand periods.
3. The main environmental issues of LNG regasification scheme are cooled seawater dispersed and residual chlorine. Both of these will affect aquatic biota and living process in the marine environment and may further affect the socio-economic condition of local society.

4. The environmental management that should be taken into account in order to mitigate the impacts are as follows:

   a. Water discharge method will determine the environmental impacts occurred. Recommended method is to use horizontal water discharge method toward offshore in order to minimize the impacts.

   b. Conduct three-dimensional simulation to obtain water circulation rate and determine types of vaporizer used.

   c. Open Rack Vaporizer (ORV) is one type of vaporizer that can be used for re-gasify LNG as the vaporizer is designed to use seawater with the features: low operation cost, simple construction and easy maintenance, and high reliability and safety.

   d. Residual chlorine impacts can be minimized by using intermittent injection of hypochlorite. Intermittent method can also reduce operational cost.

   e. Socio-economic impacts can be minimized by using social and institution approaches. Social approach can be more effective than other approach as this approach will reach "the grass root" of the local society.

REFERENCES

1. BP Indonesia, 2001. *Studi Kelayakan Proyek Regasifikasi LNG Untuk Memenuhi Kebutuhan Gas di Jawa* (Feasibility Study on LNG Regasification Project for Supplying Natural Gas to Java Island). Cooperation between BP Indonesia and Research and Development Center for Oil and Gas Technology "LEMIGAS", Jakarta.
2. BP Indonesia, 2002. Environmental and Ecological Assessment of Cooled Sea Water Discharge From LNG Regasification. Cooperation between BP Indonesia and Research and Development Center for Oil and Gas Technology "LEMIGAS", Jakarta.
3. Ergconsultancy, 2002. LNG Chain. http://www.ergconsultancy.com/ the_lng_chain_tyo.html.
4. Fogg, G.E. 1965. Alga Culture and Phytoplankton Ecology, 2nd ed., University of Wisconsin Press, USA.
5. Kobe Steel, Ltd. (2003). ORV (Open Rack Vaporizer). Kobe Steel, Ltd. Japan. http://www.kobelco.co.jp/eneka/p01/orve.htm
6. Sawchuck, J. and Mark Howard. 2001. A Gas Economy Brief: The LNG Chain. Beyond Petroleum, www.bpgaseconomy.com.
7. Suharyono, H., Ph.D. 2000. Domestic LNG Utilization. Proceedings of the Sixth AEESEAP Triennial Conference, Kuta, Bali, Indonesia.
8. Sumitomo Precision Products, 2003. LNG Vaporizer. http://www.spp.co.jp/ English/jigyou/ekika-e.html.
9. Tokyo Gas, 2003. Open Rack LNG Vaporizer. Tokyo Gas Co., Ltd. http://www.tokyo-gas.co.jp/techno/stp/02a8_e.html. •