Infrastructure concepts for the interfaces Production-Carrier and Carrier-Terminal for Methane Hydrate Pellets

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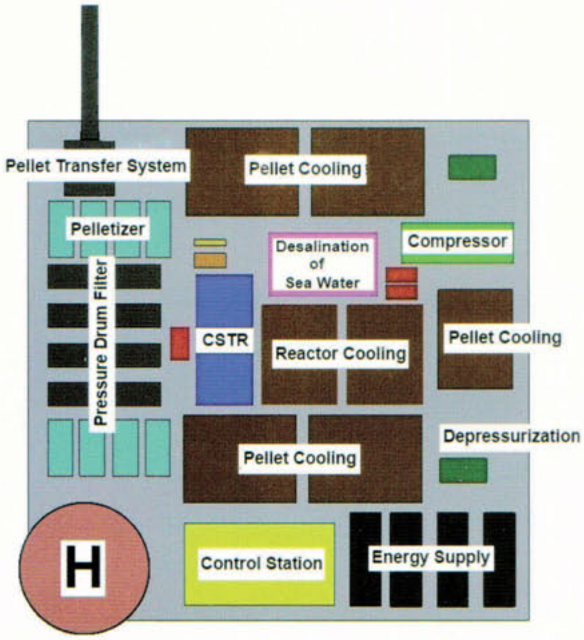
As a scientific partner of the SUGAR B3-subproject the task of the University of Applied Sciences Kiel is the development and conceptual design of the floating production unit at the exploration field and the cargo handling system to transfer methane hydrate pellets from the production to the carrier and from the carrier to the terminal.

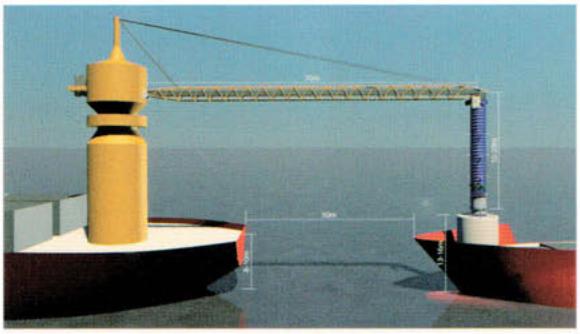
An offshore platform has been dimensioned taking into account the weather and sea conditions at the selected exploration area considering the relevant equipment data for the methane hydrate pellet production process provided by Linde Engineering. This also includes solutions for the short-term storage of produced pellets. Especially the design of the cargo handling system is a technical challenge in order to transfer pellets from the floating production unit to the hydrate pellet carrier designed by the MEYER WERFT.

Based on its wide experience in mechanical engineering and maritime technology the University of Applied Sciences Kiel calculated the relevant data of the semi-submersible offshore platform concerning its stability characteristics to assure a continuous production during different environmental conditions. The relevant data was made available to the MEYER WERFT for the model tests of the platform-carrier-system at the Hamburg Ship Model Basin of the HSVA (Hamburgische Schiffbau - Versuchsanstalt) at realistic sea conditions.

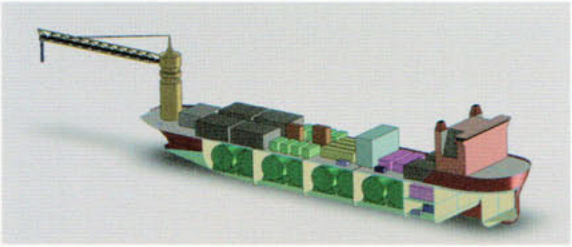
As an alternative solution a constellation FPSO (Floating Production Storage and Offloading) – hydrate pellet carrier has been developed and conceptually designed. In this context the cargo handling system to transfer pellets has also been compiled taking realistic conditions as a basis.



Configuration of the pellet production equipment on the offshore platform.



Cargo handling system FPSO - hydrate pellet carrier.



Developed and conceptually designed FPSO.

FPSO main characteristics:

- Length over all: 208,10 m
- Length between perpendiculars: 200,00 m
- Breadth: 36,00 m
- Height: 20,00 m
- Draught max.: 12,17 m
- Deadweight: 16.650 t
- Tank volume: 20.000 m³ at 100 %
- Engine output: 1 x 8.400 kW
- Speed: 13 kn
- Classification: Germanischer Lloyd (GL)

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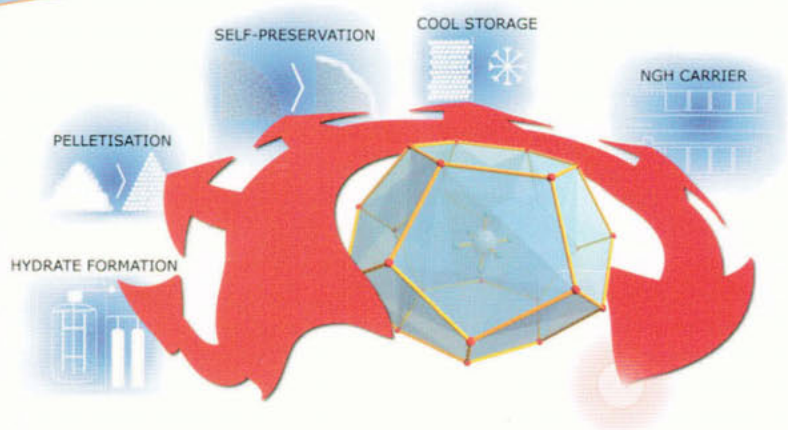
The
Quarterly
Newsletter
SUGAR
Submarine Gashydrate Reservoirs



Transport of gas hydrate towards the shore

SUGAR, from the very beginning, aimed for a comprehensive assessment of marine gas hydrates as a potential energy source over the whole process chain from exploration through exploitation to transport of the produced gas towards the consumer ashore. Given the unusual reservoir characteristics and the fact that the majority of marine gas hydrates are located at the continental slopes, it had to be assessed whether appropriate transport schemes towards the shore exist. Today, a large portion of the known conventional gas reservoirs – known as stranded gas – cannot be used commercially, often because of economical or technological constraints with respect to the transport to the end-user. Thus, subproject B3 addresses the potential transport strategy of gas originating from marine gas hydrate resources.

Though the marine methane hydrate pool is large, the fact that there is no reservoir overpressure as well as the limited knowledge from the Messoyakha gas field observations and permafrost gas production tests (Mallik) suggest that the production rates might be comparably low. Interestingly, for these conditions (low production rates and moderate transport distances), a transport scheme using methane hydrates in pelletized form as transported medium has been proposed in Norway in the mid-nineties and pursued by a consortium in Japan for the last 15 years. The method is known as NGH (Natural Gas Hydrate) transport and has been established on a process development scale, though available information on the process and technical realization is limited. The technology relies on the fact that hydrates appear to show a very slow dissociation rate at relatively mild conditions far out of the stability field. The phenomenon is known as the "self preservation effect", occurring at temperatures slightly below the freezing point of ice. Given the scope of - and expertise within - the SUGAR consortium and the match of the suggested "window of economical advantage" of NGH with the production scenario, B3 focuses on a re-assessment of the technologies needed for a NGH-transport chain for gas originating from marine gas hydrates. In lab-based approaches, a deeper understanding of the underlying process on a microstructural level was aimed for. Polymers have been produced and tested for their potential to further stabilize methane hydrates at ambient pressures. The production plant has been conceptually designed with comprehensive consideration of the technologies available for the different production steps. A carrier for the transport of gas hydrates was designed, including the required containment and cargo handling concept, and addressing risk assessment and safety regulations. Potential infrastructures for the interface between production and carrier at sea have been addressed.

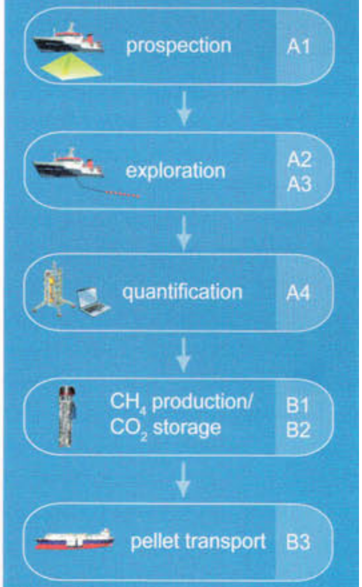
Finally, apart from the technological feasibility, the economical competitiveness will be evaluated relative to competing, partially established technologies.

Enjoy you

Yours,

Prof. Dr. Gregor Rehder

Project Structure


prospection A1
exploration A2 A3
quantification A4
CH_4 production/ CO_2 storage B1 B2
pellet transport B3

SCIENTIFIC GLOBALISATION

In these uncertain economic times, research and development reach out across the globe to create new opportunities and innovative partnerships. Under the heading "High-Tech-Strategy", the German Federal Ministry of Education and Research (BMBF) has launched a second campaign to promote and support individual collaborations between the best research institutes and industrial companies in Germany and India. One of these institutes is IFM-GEOMAR.

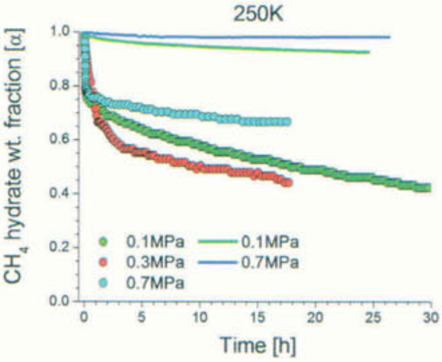
Enhanced process understanding by microstructural and kinetic investigations

One conceivable way to achieve this barrier is to use polymers (or surfactants) to modify the decomposition process so that a tighter ice microstructure and thus stronger ice shielding effect could be achieved by ice recrystallization. Polymers were provided by BASF and were tested for their performance at the University Göttingen, where a fast micro-screening method was developed for this purpose. Methane hydrate was mixed with homogenous polymer powders followed by storage of samples at 268 K at 1 atm over 48 h; these conditions led to a 50% decomposition of a polymer-free gas hydrate sample into ice. These conditions were found to be optimal to test the polymer influence on the stability of gas hydrate. Six samples could be investigated in one run using a custom-built high pressure cell.

The procedure was found to be highly reproducible despite the rather small amount of sample used. A number of different polymers have been investigated. Unfortunately, the screening has not revealed any polymeric structure that enhanced the self-preservation effect; the addition of polymers showed either an indifferent behaviour or even an acceleration of the decomposition process.

Size does matter after all

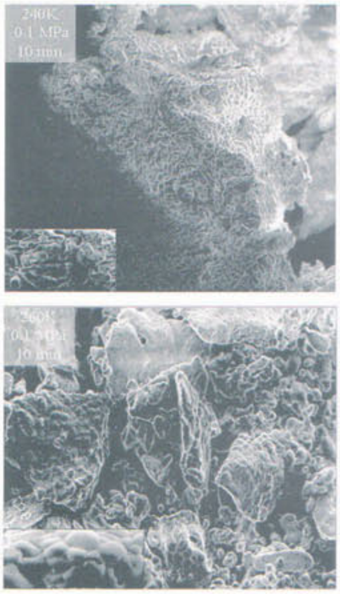
Another peculiar property of the self-preservation we explored is its sensitivity to the particle size (thus surface/volume ratio) of dissociating clathrates. Since it is largely a surface related phenomenon, a certain volume of a clathrate is required to be converted into ice before the anomaly steps in. Therefore larger grains have been found to show a greater degree of preservation than fine powders. This property was used to quickly and efficiently probe the phenomenon using two types of materials: 1) fine CH_4 and NG clathrate powders with a particle size of ~ 250 µm crushed under liquid N_2 and sieved through a set of 200 and 300 µm meshes, 2) undisturbed consolidated clathrate cylinders with a high residual porosity of ~ 40%. In the context of gas transport fine clathrate powders have little application, but due to the relatively high surface area and correspondingly short transformation times, they are an excellent probe for the exploration of dissociation rates. The consolidated cylinders were used as a proxy for gas hydrate pellets. Pressed pellets produced in a technological process are likely to exhibit even greater preservation abilities due to a considerably lower porosity and smaller surface-to-volume ratio. Japanese scientists suggested that the optimal size and shape of clathrates would be a few centimeter large pillow-shaped pellets that offer a good preservation degree, a high packing density and easy handling.



Decomposition kinetics taken at 250K and selected pressures performed with powder (filled circles) and cylindrical (solid lines) samples.

Experimental kitchen

Gas hydrates jealously protect their secrets and a single experimental method is undoubtedly insufficient to understand the complexity of the dissociation process at various p-T conditions in the anomalous preservation region. In subproject B3-1 we have approached these issues by a combination of volumetric (pVT – at the Leibniz Institute for Baltic Sea Research Warnemünde - IOW, and the Geoscience Center of the University of Göttingen - GZG) and X-ray diffraction (XRD – at GZG) methods, supported by cryo field emission electron microscopy of the ice microstructure (cryo FE-SEM - at GZG) and gas chromatography (GC - at IOW). The pVT method (measurement of pressure evolution over time in a constant volume and constant temperature) reveals a complex change in dissociation rates as the ice layer around clathrate particles thickens and recrystallizes as a function of time. The degree of preservation of samples from kinetic runs and these mixed with polymers was obtained from a quantitative phase analysis using cryo-XRD measurements. Phase fractions were established from a full-pattern profile analysis ("Rietveld-refinement") of the obtained powder diffraction data. A portion of clathrate powders "stopped" at various stages of the dissociation were investigated with an ex-situ cryo-SEM using a FEI Quanta 200FEG equipped with a Polaron cryo-stage. Uncoated, partially decomposed clathrate powders were studied at ~ 90 K (cooled with liquid N_2) and a pressure of about 0.1 Pa. In order to minimize the surface damage of the electron beam, a fairly low acceleration voltage of up to 2.5 keV was used. Gas chromatography has proven to be a valuable tool for "quality control" of NG hydrates that are prone to fractionate multi component gases during their formation. The analysis of the gases stranded in the clathrate lattice was subsequently used to calculate the stability field of formed compounds.



Microstructures of surface ice formed on dissociating CH_4 hydrates recovered after 10 min long reaction at ambient pressure and two selected temperatures.

Conceptual design of a methane hydrate pellet production process and overall assessment of a methane hydrate infrastructure for gas transport

State-of-the-art of methane hydrate pellet production technologies exceeding laboratory scale applications is mainly defined by developments carried out in Japan, in particular by Mitsui Engineering and Shipbuilding and partners. Published work on Mitsui's 600 kg/day process development unit in Chiba and the subsequent 2,500 kg/day bench scale unit at Yanai Power Station both motivated and served as main input for own research on methane hydrate pellet production processes, as well as pellet stability and handling issues.

For hydrate production, formation from the liquid phase at 7 °C and 70 bar has been identified as most suitable with regard to reaction rate, formation heat removal and process continuity. As a first product, a 90 wt.% hydrate slurry is assumed, which has to be dewatered prior to pelletization. The pellets are cooled down to -20 °C and finally depressurized to take advantage of the anomalous self preservation effect, i.e. to allow for methane hydrate transportation at moderately low temperatures and atmospheric pressure. According to the literature and SUGAR laboratory results obtained at the Leibniz Institute for Baltic Sea Research Warnemünde, sufficient mechanical strength for sea transportation of pellets and dissociation rates comparable to liquefied natural gas boil-off can be achieved.

From the initial block diagram, operating parameters and fundamental equipment requirements have been derived and the concept has been successively refined. At this stage of the project, qualified external suppliers and manufacturers have been involved to discuss the basic feasibility and new design approaches or to carry out adaptations from related areas of application. As a result, a complete process sequence has been proposed, comprising a continuously stirred tank reactor for hydrate formation, rotary drum type filters for dewatering, horizontal die molding presses for pelletization, pellet cooling in a cold methane gas stream, and depressurization in alternating vessels. In addition to main process equipment, utilities and auxiliaries have also been taken into account, in particular cooling machines and gas turbines for power generation. Relevant equipment data such as physical dimensions, dead and operating weights have been summarized in datasheets and submitted to the University of Applied Sciences Kiel to enable the design and optimization of the mechanical load distribution on an offshore unit hosting the production plant. A special focus has been laid on energy consumption figures and an estimate of the required investment cost.

During the final stage of the project, energy and cost data of the individual work packages within SUGAR B3 will be merged together. The conceptual methane hydrate infrastructure will then be compared to the conventional technologies pipeline and liquefied natural gas transportation, as well as to the not yet established technology of compressed natural gas transportation. In this context, the extensive experience of Linde Engineering in planning, designing and constructing turnkey industrial plants, amongst others for natural gas treatment and liquefaction, is playing a key role. Quantitative criteria for an integral assessment are capital and investment costs and total energy consumption, but qualitative factors such as material handling under rough sea conditions and potential risks will also be taken into account in close cooperation with the SUGAR B3 project partners.

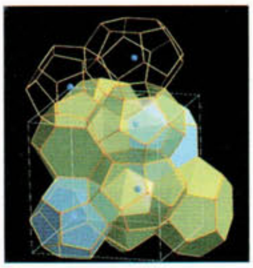
Process sequence for methane hydrate pellet production.

Optimization of the "Self-Preservation" effect:

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

BASF The Chemical Company

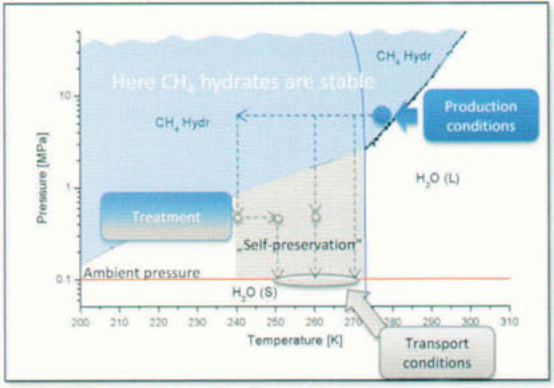
Gas hydrates (clathrate hydrates, clathrates) containing methane are not only a promising future source of energy. These ice-like crystalline solids can also serve as a potential gas container built merely from water molecules organized in the form of a 3D network of cages. This particular arrangement allows for a relatively high packing of gas molecules that reaches on average 165 m³ of gas per 1 m³ of solid at standard temperature and pressure (STP). On this basis synthetic clathrates of methane or natural gas (NG) are considered to be an interesting alternative to conventional gas storage/transport technologies, in particular for smaller, dispersed sources (e.g. from natural gas hydrate deposits) where the application of conventional technologies is still too costly to be applied.



Cage-like structure sI of CH_4 hydrate.

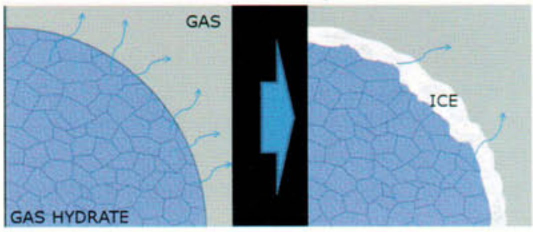
Every rose has its thorn

Even if liquid water, as basic component of the clathrate structures, is readily accessible for technological processes, the produced gas hydrates are a fairly challenging material. Clathrate cages require elevated pressures and/or lower temperatures for their formation and, in principle, also for their storage. If these conditions are not met, gas hydrates start to disintegrate into their basic components. Thus, at first sight gas hydrates are very unlikely to be able to compete with already well established storage/ transport technologies like compressed natural gas (CNG) or liquefied natural gas (LNG) - was it not for an unusual phenomenon called self-preservation - allowing gas hydrates to persist at much milder conditions outside their thermodynamic conditions of stability even for a period of a few weeks.



Examples of possible pathways of CH_4 hydrate treatment from the production to the transportation step.

In order to apply this phenomenon in an industrial process clathrates produced from liquid water and gas at +4 °C and 6 MPa would have to be cooled down to the desired temperature and decompressed within the so-called self preservation region. This phenomenon, known also as the self preservation, describes a meta-stable state in which destabilized clathrates undergo a dissociation process orders of magnitude slower than expected. The anomaly has been found exclusively at temperatures below the melting point of ice, mostly in the range between 242 K and 271 K. For what is known about the mechanism, it appears very likely that self-preservation is related to the accumulation of ice at the surface of gas hydrates. This ice layer, formed in an initial decomposition process, eventually leads to the so-called "ice shielding effect" by hindering the out-diffusion of gas molecules. These remain at the internal gas hydrate – ice interface increasing locally the chemical activity of the gas phase, and thus bringing the gas hydrate back into their field of stability at the interface.



Schematic dissociation of gas hydrates in the "self-preservation" region where the protective ice film is formed.

Why ice is not all the same?

Any technical application of self preservation calls for a full control of the process. Yet, it has been found that the phenomenon appears to have a variable strength depending on the dissociation pressure and temperature as well as the chemical composition of the gas. Consequently, even if anomalous preservation is present, the boil-off of gas (by a slow permeation of the ice layer) is difficult to predict. Our investigations suggest that the microstructure of the formed ice plays a pivotal role. It turned out that flat, large ice crystals tightly enveloping clathrate particles create a more efficient protection than aggregates of small, loosely arranged crystals. Could the production of ice with their specific properties be fully mastered one could gain full control of the dissociation rates. From our experiments we see that this may indeed be the key to a controlled self-preservation, but to prove the usefulness of this property, additional tests on hydrates technically manufactured under „close to reality" conditions are indispensible.

Can polymers improve the self-preservation of clathrates?

Enhancing self-preservation essentially means to stabilize an ice structure on the surface of gas hydrate particles, providing a permeation barrier to the out-diffusion of gas molecules emerging from the decomposing hydrate.

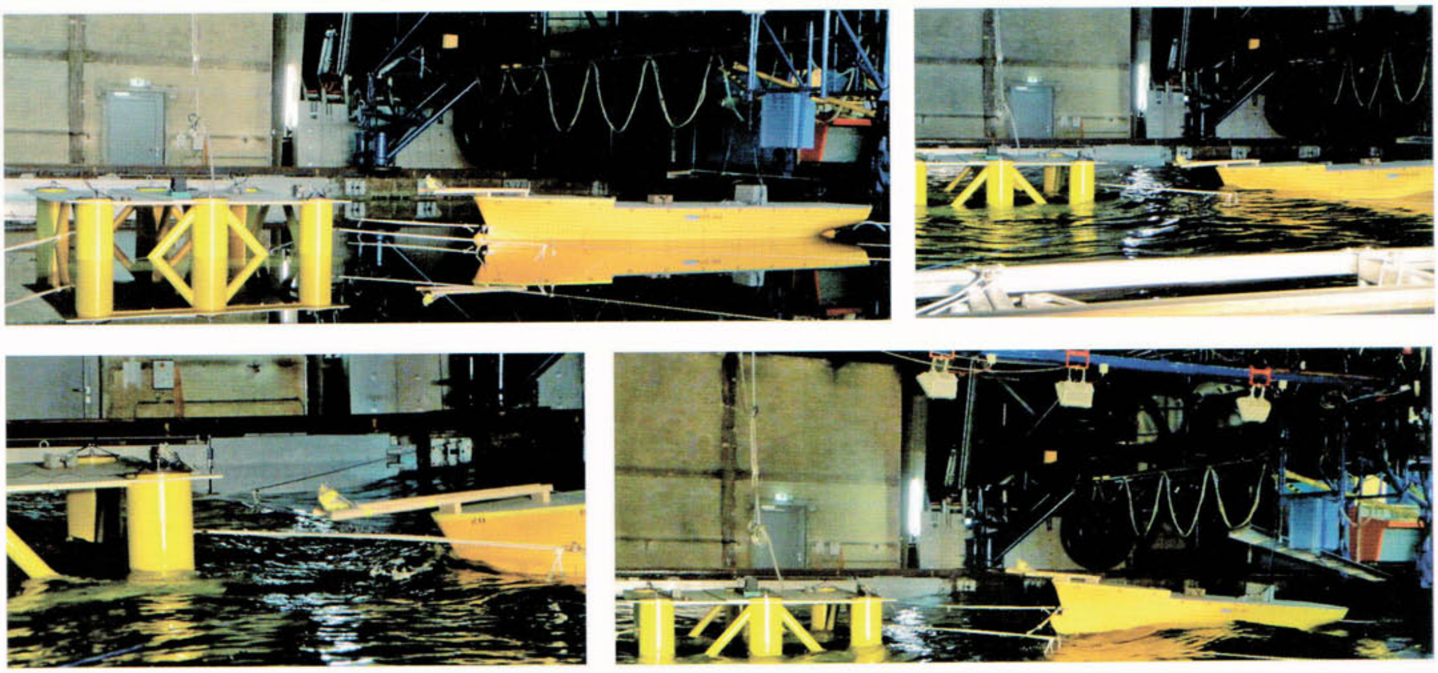
Development of a Methane Hydrate Pellet Carrier and its Containment System

The Task

Based on MEYER WERFT experiences in the design and building of special ships, in particular with tankers for the transportation of gas, the MEYER WERFT was asked in the beginning of 2010 to join as partner in the research project SUGAR to develop a Methane Hydrate Pellet Carrier, including the required containment system, with a loading capacity of 20.000 m³.

The pellet carrier is one link in the long process chain, starting with the exploration and the extraction via the production of pellets and the transportation to the shore-based terminals to the further processing for commercial use. The pellet carrier has to receive the methane hydrate pellets, which are produced offshore on a floating production unit (design by the University of Applied Sciences Kiel) and transferred by the production unit's own infrastructure to the pellet carrier, safely transport the gas hydrates to a terminal, and deliver the pellets with the ship-based cargo handling plant to the terminal. During the loading process, production unit and pellet carrier have to be positioned close to each other using their own effective propulsion and dynamic positioning system (DP).

Due to the harsh environmental conditions in the planned area of operation (e.g. continental slope in the North Atlantic) and an envisaged all year operation, MEYER WERFT worked closely together with specialists of HSVA (Hamburgische Schiffbau-Versuchsanstalt), the Technical University Berlin and with specialists from the nautical side (e.g. captains, pilots etc.) in order to take into consideration the possible weather impact on both vessels during joined, non-independent operation. Consequently, HSVA was subcontracted by MEYER WERFT to carry out relevant model tests to get realistic figures of the sea-keeping characteristics of the vessels in bad weather. The model test results indicate that the behaviour of the vessels in bad weather doesn't permit a continuous cargo handling, which means that the loading of the pellet carrier will have to stop for a certain while. Based on the necessity that the production unit must have sufficient capacity to store the produced pellets while loading is not possible, it was decided within the group of project partners to concentrate on a FPSO design for the production system rather than the previously investigated semi-submersible platform design.



Testing the behaviour of the Pellet Carrier versus the behaviour of the Floating Production Unit during different sea states in the North Atlantic.

Development of a Methane Hydrate Pellet Carrier and its Containment System

The Carrier

For the design of the Pellet Carrier, good seakeeping capabilities as well as good stationkeeping capabilities have to be taken into consideration. In order to achieve acceptable results, effective and powerful propulsion is mandatory, together with a taylor-made dynamic positioning system. This assures that a safe loading quite close, but with controlled distance to the unit (in the so-called "tandem configuration") is possible in reasonable weather conditions.

Pellet Carriers main characteristics:

- Length overall: 176,60 m
- Length between perpendiculars: 166,00 m
- Breadth: 30,60 m
- Height: 16,90 m
- Draught max.: 8,40 m
- Deadweight: 16.650 t
- Tank volume: 20.000 m^3 at 100%
- Engine output: 4x 3.000 kW
- Speed: 16 kn, at 9.000 kW
- Classification: Germanischer Lloyd (GL)

Containment System

A special Cargo Containment System with a complex cargo-handling plant has to be designed for a safe loading of the gas hydrate pellet cargo. The containment system consists of eight cylindrical cargo tanks, each with an intake of 2.500 m^3. These tanks are arranged in four insulated and cooled cargo holds/compartments and connected to a specially designed cargo-handling plant that will distribute the pellet cargo in the containment system with a high degree of redundancy. The development of the cargo handling system was subcontracted to companies specialized in the field of bulk cargo handling and designed in detail together with the MEYER WERFT. The handling system consists of a chain conveyor system with a capacity of approximately 160 m^3/h. The complete containment system, including the cargohandling facility, is laid out and designed for a temperature of -20 °C as well as a pressure of 2 bar. These conditions are vital to stabilize the pellet cargo and keep the pellets in the necessary structure for an effective transportation, and have to be kept during the loading process as well as during transportation to the terminal and discharge. The IGC (International Gas Code) was taken into consideration.

Side view of the Pellet Carrier (NGH-Carrier) specially designed by MEYER WERFT for the transportation of gas hydrate pellet cargo.

Example of a similar sized LPG/Ethylen Carrier, designed and built at MEYER WERFT in 2010.

Safety and Risk Analysis of Methane Hydrate Transport at Sea

The gas hydrate carrier developed and designed by MEYER WERFT within the SUGAR project represents a new concept for the transport of methane compared with the existing technologies LNG and CNG. Therefore no rules for the construction of these ships exist at present. But how to evaluate such novel technologies like in other industries, in the maritime industry risk-based approaches are increasingly applied for the evaluation of novel ship designs, such as the NGH carrier, that challenge the existing regulatory framework, i.e. regulations of the International Maritime Organisation (IMO) and classification rules. Risk analysis is used to determine the risk level of the ship or its systems in order to evaluate that the novel designs achieve at least the same safety level as already established technology. The process of risk analysis is shown in Figure 1. The core steps of a risk analysis are the Hazard Identification (HazId) (step 1) and the quantitative analysis (step 2).

The evaluation of the risk can either be done by comparing against an explicit acceptance criterion (a value), an implicit acceptance criterion (derived from a reference design that complies with existing regulations/rules) or by making the risk ALARP (As Low As Reasonably Practicable).

In the latter case risk mitigating measures so-called risk control options, are systematically identified (step 3) and evaluated with respect to their cost effectiveness (step 4).

It allows to draw a balance between the various technical and operational issues, including the human element, and between safety and costs. The core of an FSA is a risk analysis (Figure 1) consisting of the Hazard Identification (HazId) (step 1) and the risk analysis with identification of risk mitigating measures (risk control options) (step 2 and 3).

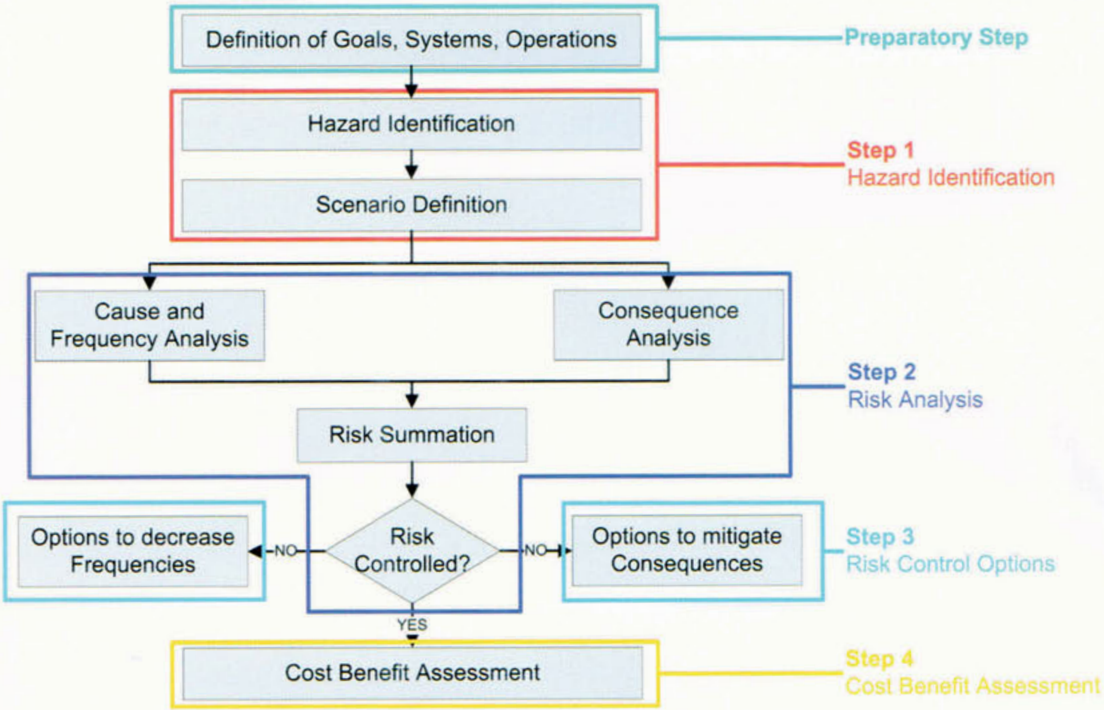


Figure 1: Steps of a risk analysis.

Safety and Risk Analysis of Methane Hydrate Transport at Sea

In the SUGAR subproject B3 GL's task is the safety evaluation of the novel gas hydrate carrier, the aim of GL's work is to support and assess the development under risk aspects to ensure that the risk level for the newly developed concept is as low as it is for existing competing concepts (e.g. LNG Carrier that transport natural gas at low temperatures in liquid state).

The HazId is carried out by the systematic approach of Failure Modes, Effects and Criticality Analyses (FMECA). During several meetings experts discuss potential failures of a system or process, their causes and their effects. Frequencies of failures are estimated and consequences for human safety, for environment and for property (ship and cargo) are quantified. In order to rank the hazards identified, the Risk Index (RI) was used, that provides benefits compared to the risk priority number. Apart from serving as a ranking criterion, the RI can also be applied in further analyses, e.g. for the purpose of comparing different designs.

So far FMECA meetings have taken place to discuss the sea voyage of the vessel; potential failures discussed were e.g. leakage of cargo tanks and insulation failures caused by collisions or material failures, pressure rise in cargo tanks caused by insulation failures, problems of the cooling plant or machinery failures resulting in minor consumption of boil off gas. The evaluation of the meetings is still ongoing.

Further activities are focused on the development of the risk model. The risk model will be designed as an Event Tree (ET). For the time being it is planned to develop ETs for the accident categories collision and grounding. An ET is a graphical representation of the logic model that identifies and quantifies the possible outcomes following an initiating event. The basis of an Event Tree is a high level event sequence. An example for the accident category "collision" is shown in Figure 2. Using this approach the consequences of investigated accident scenarios can be quantified and expressed in "potential loss of cargo per ship year" or "potential loss of lives per ship year". This procedure allows a quantitative comparison of design alternatives or with other ship types.

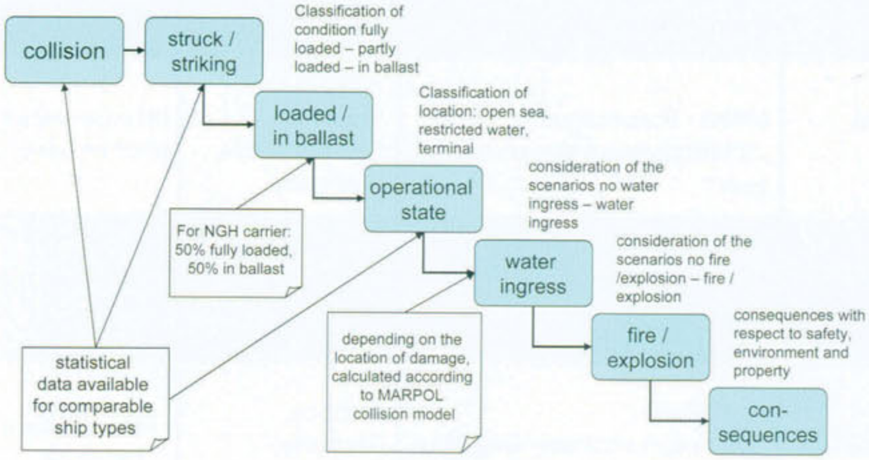


Figure 2: High level event tree sequence for collision.

Calendar

DATE	EVENT	LOCATION	LINK
July 17-21	ICGH7-7th International Conference of Gas Hydrates	Edinburgh, Scotland	http://icgh.org/
August 08-12	Asia Oceania Geologic Society	Taipeh, Taiwan	http://www.asiaoceania.org/aogs2011/public.asp?page=home.htm
August 14-19	Goldschmidt Conference 2011	Prague, Czech Republic	http://goldschmidt2011.org/
August 22-26	IGAS 2011, 25th International Applied Geochemistry Symposium	Rovaniemi, Finland	http://www.iags2011.fi/
August 28-September 01	ACS Fall Meeting	Denver, Colorado, USA	http://www.acs.org/denver2011
September 20-21	BMBF - GEOTECHNOLOGIEN Statusseminar 2011 "Geological Storage of CO_2"	Potsdam, Germany	http://www.geotechnologien.de
October 23-26	AAPG International Conference & Exhibition 2011	Milan, Italy	http://www.aapg.org/milan2011/
December 01	BMWi - Statustagung „Schifffahrt und Meerestechnik 2011"	Rostock - Warnemünde, Germany	http://www.ptj.de/index.php?index=553
December 05-09	AGU Fall Meeting 2011	San Francisco, USA	http://www.agu.org/meetings/
December 06-08	4. Forum Wissenschaftskommunikation, "Wissenschaft im Dialog"	Cologne, Germany	http://www.wissenschaft-im-dialog.de

With best wishes from the B3 partners

A lot has been learned within the subproject B3 of SUGAR over the course of the last three years. New insight into the mechanistic origin of the "self preservation" has been achieved and was and will further be published. The process of methane hydrate pellet production has been scrutinized, potential technologies evaluated, and patents have been filed during the process. A concept for a hydrate carrier has been designed, applicable to the transport of pellets in general, even when exhibiting a slight tendency for sintering. Technologies for the transfer of a solid good in a system insulated and shielded against the atmosphere under offshore conditions have been outlined. The first steps towards a risk assessment of methane and NG hydrates during transport at sea have been taken. Based on assumptions of production rates, with a base case of 20.000 m^3/sec, the process chain and specific investment and operating costs are being evaluated.

Yet, though the individual workscopes have been met and the technology appears feasible, B3 will not be pursued within the 2nd phase of the SUGAR project for two reasons. At the one side, better, site-specific constraints on distance from shore, rates of gas production and gas composition are needed. Moreover, from our current analysis, it is not clear whether the technology will have a window of opportunity relative to the competing transport technologies (LNG, CNG, etc.). Potential secondary benefits of gas hydrate transport, including moderate temperatures and pressures, controlled burning in case of fire due to the endothermic decomposition, or robustness with respect to gas impurities are worth considering.

However, it is also clear that whenever gas production from offshore gas hydrates becomes technologically and economically feasible, availability of a transport option will not be the limiting factor. Consequently, evaluation of the best transport scheme from a gas hydrate resource can be postponed to a later, more defined stage of research towards gas hydrate exploitation.

With this, the partners of B3 say "Farewell" to the SUGAR consortium with best wishes for a successful and exciting 2nd phase of the project.

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CONTROS
L3 communications ELAC Nautik
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