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The Future of Class

An IMarEST Supplement in association with ClassNK

ClassNK and Japan's national project to reduce Green House Gas emissions

ClassNK has been very active in implementing many R&D projects both independently and in cooperation with industry on many levels over the years. As part of these efforts, the Society has also participated in many projects such as those related to the 'Support for Technology Development for Curtailing CO_2 from Marine Vessels', a four-year programme, that began in 2009, for assisting the Ministry of Land, Infrastructure, Transport and Tourism in Japan. The Society is now participating in 19 of the 22 projects, already providing some ¥2.2Bn (roughly US$28M) or a quarter of the total budget. An overview of these 19 projects, and the partners involved, follows.

The most important aspect of these efforts is that many of the technologies (such as the micro bubble system described below) are already being tested on ships in service, and all of these technologies are expected to be commercially available over the next few years.

Global warming and related environmental issues have become matters of ever increasing concern in recent years. Topics related to energy conservation and the reduction of CO_2 emissions are everywhere while ever more strident demands for measures against global warming are being made in the international shipping arena. Not only are discussions being held at the IMO and elsewhere around the world related to reducing GHG emissions, but numerous efforts are being made in both the public and private sectors to develop practical solutions to these challenges

■ **Research and development of hull forms suitable for CRP for reducing GHG** *(IHI MU, IHI)*

Contra-rotating propellers (CRP) have significant energy saving effects. This project aims to develop duct and hull forms for enhancing the effects of CRP.

■ **Research and development of a mega container carrier capable of saving energy and reducing GHG** *(IHI MU, IHI, Diesel United)*

The aim of this project is to develop an energy-saving container carrier capable of conserving energy more significantly than in the past through prototype testing and performance checks of twin-skeg hull forms, basic studies on high efficiency main engines, and studies on exhaust heat recovery technology.

■ **Research and development of energy-saving technology for ocean-going ships using an air lubrication method** *(Oshima Shipbuilding, IHI MU, Imabari Shipbuilding, MTI, Sumitomo Heavy Industries Marine & Engineering, Tsuneishi Holdings, Mitsui Engineering and Shipbuilding, Mitsubishi Heavy Industries (MHI), Universal Shipbuilding)*

This project aims to validate the application of an air lubrication method to ocean-going vessels as an effective energy saving technology, and to establish a design methodology for ships using the air lubrication method.

Together with the development of the air lubrication method, a design support system (design tool) for ships is to be developed using this same technology.

■ **Tests to demonstrate the technology to reduce frictional resistance of large shallow draft twin-screw vessels** *(MHI, NYK, MTI)*

In this project, tests are to be conducted to demonstrate the air lubrication system by blowing air onto the ship's bottom using blowers. For the first time, this system has bene permanently installed on a ship, and CO_2 emissions are expected to be reduced by approximately 10%. The tests are being conducted on a module carrier (see pages 6 and 7).

■ **Research and development of anti-fouling paint for hull bottoms, leading to very low fuel consumption** *(Nippon Paint, Nippon Paint Marine Coatings, Mitsui OSK Lines)*

The evolving low-fuel consumption bottom anti-fouling paint LF-SEA, developed by Nippon Paint and Nippon Paint Marine, will be further developed to reduce CO_2 emissions by more than 10% compared to that of conventional anti-fouling paints.

As frictional resistance from sea water accounts for 50-80% of a ship's total resistance when underway, reducing sea water friction will directly contribute to reducing fuel consumption.

■ **Research and development of limited small blade-area non-hub vortex (NHV) propellers** *(Nakashima Propeller)*

Non-hub vortex (NHV) propellers which improve propeller efficiency by reducing and or eliminating hub vortex cavitation have already been developed. As part of this part of this project, a 'small blade area NHV propeller' will be designed to demonstrate the energy-saving effects of both small blade surface area and NHV when fitted to four ships for the purpose of verification. After the manufacture and conversion of actual propellers, comparative tests will be conducted on propellers fitted on actual ships to demonstrate that the new propeller has about 3% energy-saving effect compared to existing high performance propellers.

■ **Research and development of energy-saving appendages using effects of interference between blades** *(Shin Kurushima Dockyard)*

Existing energy-saving appendages have been developed for the purpose of conserving energy by recovering propeller rotational energy. In this project, development is being carried out to enhance propeller efficiency through mutual hydrodynamic interference effects between the propeller blades and appendages.

The target is an energy savings of about 3%.

■ **Development of load fluctuation stabiliser for periodic disturbance from weather and sea conditions** *(NYK, MTI, Terasaki Electric, Kawasaki Heavy Industries)*

The fuel consumption of a ship varies with the way the main engine is affected by weather and sea conditions. This project aims to reduce fuel consumption of the main engine by equalising load fluctuations, and developing a new control system for variable pitch propellers and shaft motor generators.

■ **Research and development of CO_2 reduction technology for large low-speed marine diesel engines** *(Mitsui Engineering and Shipbuilding)*

CO_2 emissions can be reduced by using an exhaust heat recovery system, as well as a high and low temperature exhaust separation system for large low-speed diesel engines (electronically-controlled). Specifically, a four-cylinder test engine (500mm bore) will be manufactured and various tests carried out in this project. The new engine is likely to have a similar specification as engines expected to be manufactured 15 years hence.

■ **Research and development of exhaust heat recovery system in marine diesel engines** *(Yanmar)*

Exhaust heat recovery systems in large diesel engines are already in use on land and on ships. Such systems have not been practical in small engines.

Research and development of a highly efficient and economical steam expander and exhaust heat recovery system will be carried out in this project for use with small diesel engines used as auxiliaries for power generation and as main engines in coastal vessels. The aim is to reduce the amount of CO_2 generated in the engine by approximately 6%.

■ **Research and development of next generation dual-fuel engines for ship propulsion** *(Niigata Power Systems)*

European manufacturers have already developed marine dual-fuel (DF) diesel engines. Such engines have been used for power generation in large LNG ships, but have not yet been used in general cargo ships. The engine to be developed as part of this project is mainly for coastal vessels. The aim is to manufacture medium speed engines with outputs of up to 10 000hp, and which reduce CO_2 emissions by approximately 15% compared to conventional engines.

■ **Development of hybrid turbocharger technology applicable to marine vessels** *(NYK, MTI, Universal Shipbuilding, MHI)*

This project involves equipping a capesize bulk carrier (to be completed in 2011) with a hybrid turbocharger power generating system and demonstrating its effectiveness. This power generating system consists of a small high-speed generator and a power frequency converter within the turbocharger, which is installed on a low speed diesel main engine. The system can supply all the power needed on the ship during a normal voyage. (See pages 8 and 9).

■ **Research and development of voyage support system with the aim of reducing CO_2 emissions by optimised operation** *(Universal Shipbuilding)*

The voyage support system 'Sea-Navi' has functions to search for the optimum route for a voyage with the shortest distance and least fuel consumption, based on sea and weather data, and on the features of the hull and main engine. An energy-saving effect of some 5 to 8% through CO_2 reduction may be anticipated. Development of this software is almost complete, and demonstration tests will then be carried out by installing the system on a number of vessels.

■ **Development of an international navigation control system** *(NYK, MTI)*

Efficient navigation is a prerequisite for reducing CO_2 emissions. In this project, development has started on a worldwide time-reservation system for berth windows and canal passage. Introduction of an international port control system will enable vessels to further reduce their time in port and to navigate at lower speeds.

■ **Research and development related to operational performance of vessels as they increase in size** *(NYK, MTI, Japan Marine Science)*

In this project, the ability of pure car carriers of lengths above 200m to avoid collisions will be validated using simulation technology. Based on this research, the project will propose requisite technologies for large vessels so as to achieve the same level of operational performance as that of conventional vessels.

■ **Research and development of a 'navigation support system'** *(Oshima Shipbuilding, Kyushu University, Fluid Techno, Oshima Engineering)*

This project aims to assist the navigator to select the optimum route based on weather and sea data. At the same time, a navigation support system is to be developed to support optimum navigation in rough seas and in restricted areas.

■ **Development of a system for monitoring ship performance** *(NYK, MTI, NYK Trading, Kawaju Techno)*

A navigation monitoring system featuring comprehensive integration between vessels and land operations is to be developed in this project. This system will be used to accurately monitor the current condition of the ship from land, and suggest an appropriate speed for the vessel. The project also aims to measure waves and ship motions more accurately, and to estimate their effects on the propulsion performance of the ship.

■ **Research and development of application technology for secondary batteries on ocean-going vessels using large-capacity nickel hydrogen batteries** *(Kawasaki Heavy Industries, NYK, MTI)*

This project aims to develop a hybrid power supply system by combining an existing diesel generator and a new type of large capacity nickel hydrogen battery (Kawasaki Heavy Industries' Gigacell®). Verification test devices will be installed on car carriers and tests will be carried out in the area of navigation.

■ **Research and development of CO_2 emissions reduction technology by hybridization of power systems in car carriers** *(Mitsui OSK Lines, MHI, Sanyo Electric)*

This project aims to develop a hybrid power supply system by combining a solar power generating system and lithium ion batteries. The aim is to use natural energy more effectively by accumulating electricity, generated by solar power during voyages, in lithium ion batteries, and use these batteries while the ship is at anchor. The diesel engine can be stopped resulting in zero emissions while at anchor.

A 'hybrid car carrier' equipped with this system will be constructed (for completion in 2012), and the effects of CO_2 emissions reduction will be validated and assessed through actual operation, with the aim of establishing effective reduction technologies in the future.

Hybrid technology for turbos

The 180,000dwt bulk carrier *Shin Koho*, built by the Universal Shipbuilding Corp for NYK, is the first vessel to be fitted with a hybrid turbocharger

At the end of May 2011, Japanese shipping company NYK took delivery of a new 180,000dwt bulk carrier, the *Shin Koho*, at the Tsu Shipyard of the Universal Shipbuilding Corporation. This is the first bulk carrier in the world to be fitted with a hybrid turbocharger

Table 1. Main specifications of the MET83MAG hybrid turbocharger

Type	MET83MAG
Total length (mm)	4,013 (exc. connection box)
Total width (mm)	2,250
Total height (mm)	1,188
Total weight (kg)	15,700
Max speed (rev/min)	11,300
Max gas temp. (˚C)	580
Generator type	Permanent magnet-type 3-phase synchronous
Number of poles	4
Max output (kWmi)	754
Bearings	Externally forced lubrication sleeve bearings
Cooling	Freshwater, air

The development of a hybrid turbocharger that makes use of some of an engine's waste energy, is another step towards maximising the efficiency of the ship's machinery and thereby cutting overall fuel consumption and emissions including CO_2. In addition to its use of the waste energy, the hybrid turbocharger still maintains its original function of boosting the output power of the engine by enabling it to aspirate at a level higher than that for the original engine displacement.

In operation, the hybrid turbocharger utilises the extra rotational power generated by its turbine for electric power generation such that in the case of the *Shin Koho* all of its onboard electric power requirements for normal operation can be met solely from this source instead of through running diesel generators.

Turbocharger technology

Generally, exhaust gas from the main diesel engine is directed entirely to the turbocharger turbine; the efficiency of the turbocharger is measured by the ratio of the adiabatic heat drop of the turbine to the adiabatic compressive work of the compressor. Due to the increased efficiency of marine diesel engine turbochargers in recent years, sufficient air can be supplied to the engine even when a portion of the exhaust gas is diverted from the engine for purposes such as electrical power generation.

The unit installed on the *Shin Koho's* main engine was developed jointly by four companies – NYK, the Monohakobi Technology Institute (MTI), the Universal Shipbuilding Corporation, and Mitsubishi Heavy Industries Ltd – as part of a subsidised project overseen by the Ministry of Land, Infrastructure, Transport and Tourism under the 'Support for Technology Development for Curtailing CO_2 from Marine Vessels' project, and supported by ClassNK as part of its programme to support innovative research in maritime industry.

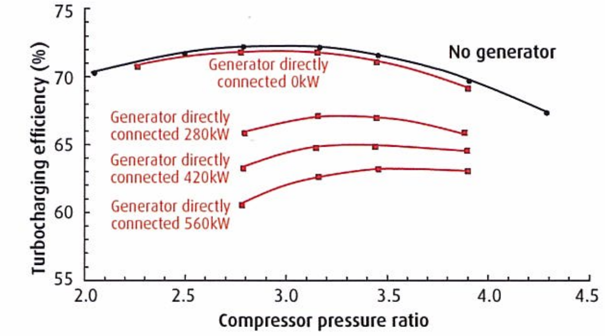
The hybrid arrangement

The unit installed on *Shin Koho* is based on the Mitsubishi MET83MA turbocharger and is designated the MET83MAG, details of which are given in Table 1.The power generating system consists of a small high-speed generator and an external power frequency converter.

As the generator is integrated within the turbocharger main unit, the space that the hybrid occupies is essentially the same as that for a conventional turbocharger, and no major modifications are required on the engine side. Use of the generator as a motor is technically possible, but the prototype on the *Shin Koho* does not include this function.

Wherever possible the components in the MET83MAG are the same as those in the conventional MET83MA, with modifications on the compressor side that enable the generator to be housed within the silencer. The resulting hybrid version is 313mm longer and 4,600kg heavier than the standard unit. At a speed of approximately 9,500rev/min, the maximum design output is 754kW for a permanent magnet-type synchronous generator rotating at the same speed as the turbocharger.

The generator is positioned within the turbocharger silencer, but since the silencer itself lacks sufficient rigidity to support the generator, a two-part (upper and lower) cast steel shell is attached to the compressor scroll to compensate. Consequently, the compressor scroll has also been redesigned to provide greater rigidity.

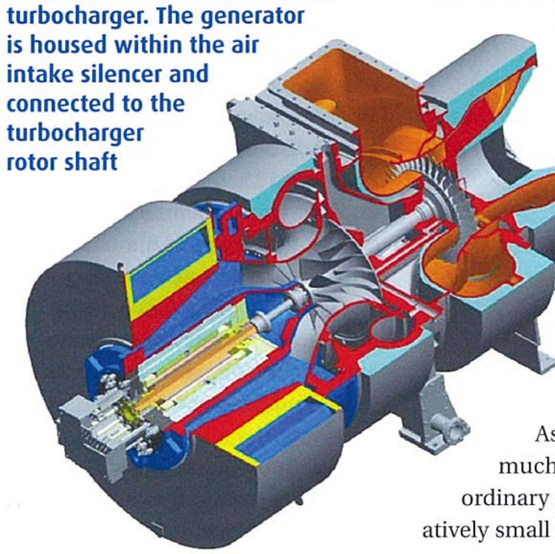


Turbocharging efficiency of the hybrid turbocharger during testing

The generator rotor features magnets that are fixed in an arc encircling the periphery of the steel shaft. To prevent detachment due to centrifugal force during high-speed revolutions, they are further fixed by carbon fibre windings, and a cooling water jacket made of aluminium surrounds the outside of these rotor windings. External cooling air is supplied to points at both ends and at the centre of the windings. The radial sleeve bearings are the same as those of the MET53MA turbocharger, an advantage when replacement parts are required. Labyrinth seal fins are employed to prevent oil from leaking on the output shaft side or entering the windings, and sealing air is circulated in the gap between the fins and the shaft to prevent external oil leakage.

The bearings and the seal labyrinth are supported at both end bells, with the centre housing sandwiched in between. The aluminium alloy housing is in two (upper and lower) pieces, but since the rotor slides in axially, this structure does not have to be disassembled during maintenance.

The generator output shaft is mechanically connected to the turbocharger rotor shaft by means of a diaphragm-type flexible coupling.



Cross-section of the MET83MAG turbocharger. The generator is housed within the air intake silencer and connected to the turbocharger rotor shaft

Generator cooling

As the generator speed is much higher than that of an ordinary generator, its size is relatively small compared to its output. However, cooling is an issue due to the level of heat accompanying the output. In addition, since the generator is placed inside the silencer, the external dimensions must be as small as possible. Accordingly, supply and discharge channels are provided within the generator housing for cooling water, cooling air, and lubricating oil. Since air scavenged from the engine is used for cooling air, the higher the load and the more heat generated the greater the pressure of the cooling air will be.

Assuming an effective flow of cooling air and cooling water, a safe temperature was predicted to be maintained even during continuous operation at maximum output. Temperature sensors are embedded in the windings of the actual generator, and these are used to trigger an alarm in the event of an abnormal increase in the winding temperature.

Since the voltage and frequency of the three-phase ac power from the generator are dependent on the turbocharger speed, output power cannot be applied directly to meet shipboard needs. Firstly, it undergoes dc rectification, and then is converted to the appropriate voltage and frequency for shipboard consumption. To accomplish this, the system uses an IGBT for active rectification, as well as an inverter. Since these two elements also function in reverse power from the ship can be supplied to the generator, so that it acts as a motor to accelerate the turbocharger rotor. In the case of a two-stroke, low-speed diesel, sufficient air for combustion cannot be supplied by the turbocharger alone during low-load operation, and hence an auxiliary electrical blower is provided. In addition, since air is compressed efficiently by the turbocharger, the power required is less than what would be consumed by a blower.

Details of the *Shin Koho*, which is being operated transporting iron ore from Australia and other countries are given in Table 2.

Table 2. Particulars of the *Shin Koho*

Length overall	292m
Breadth	45m
Designed load draught	18.15m
Gross tonnage	93,031t
Deadweight tonnage	180,000t

A hybrid energy system

Nippon Yusen Kaisha (NYK) and Nippon Oil & Energy Corporation developed the *Auriga Leader* partly as an experimental vessel to gather statistical research on how solar power can assist in powering a ship at sea

The 60,213gt solar-powered-assisted car carrier *Auriga Leader* was developed jointly by NYK and Nippon Oil & Energy Corporation, as part of a two-year experiment into how solar power can be used to assist with powering a vessel. Early results of the trials were very encouraging. In the roughly two years since setting out on its maiden voyage in 2008, the *Auriga Leader's* solar-panel system 86MWh or roughly 3% more than would have been generated on land in Tokyo over the same period. Further research to determine the exact reason suggests that the stronger sunlight caused by the high sun altitude and more daylight are thought to have played a part. Moreover, the wind the vessel encountered cooled the system, thus improving generating efficiency. As initially anticipated, solar power was able to provide 0.05% of the ship's propulsion power and 1% of the electricity used on the vessel, such as required for pumps and lights. This change reduces fuel consumption per year by an estimated 13t (14kl) and the CO_2 resultantly produced by approximately 40t. Nippon Yusen Kaisha (NYK) and Nippon Oil & Energy Corp developed the *Auriga Leader* partly as an experimental vessel to gather statistical research on how solar power can assist in powering a ship at sea.

Towards a Hybrid Energy System

Another purpose of this project was to verify the endurance of solar panels in the harsh conditions of actual navigation. Through the vessels first four voyages, the vessel encountered rough conditions such as three straight hours of rain and lightning, 20 straight hours of strong wind (about 20m/s), and 48 straight hours of waves 3 to 4m high, but the system continued to operate well. NYK and Nippon Oil & Energy Corporation plan to continue this experiment so that the use of clean solar power can be practically applied to powering seagoing vessels and thus help to reduce the carbon footprint of this efficient form of transport. The latest series of tests, which mate the existing solar panel system with a Gigacell Nickel-Metal Hydride (Ni-MH) Battery System developed by Kawasaki Heavy Industries (KHI) will last until March, 2013.

The need for power

The power required for general onboard use (eg air conditioning system, lighting, auxiliary machinery, etc) while the *Auriga Leader* is in operation is about 500kW, and the solar electric power system can produce up to 40kW, about 8% of the power required. However, 40kW would amount to about 0.3% of the ship's total power requirement including main engine output. In the future, installation of a much larger system that will be able to produce around 250kW, that is about 1 to 2% of the total demand, is planned. Due to changing weather, however the amount of power that the solar panels provide is not consistent, and thus increasing the portion of power provided by solar power presents a number of challenges in terms of ensuring a stable power supply for safe operations.

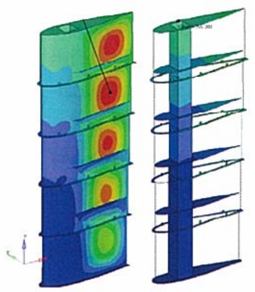
Batteries present one solution to this problem and in order to test their potential, NYK installed a new battery system utilising Gigacell technology developed by Kawasaki Heavy Industries (KHI) when the *Auriga Leader* was drydocked in June 2011. The installation and testing of this system is being carried out in partnership with MTI, KHI, and ClassNK, and is receiving further support as part of Japan's national GHG reduction programme.

While the estimated cost of installing batteries is a few million dollars in this project, its benefit is to stabilise then output of electric power generated by solar system, making the use of large scale hybrid systems on vessels a very real possibility. In the future, if a larger combined system capable of producing 250kW is installed, about 60t of fuel oil and 180t of CO_2 emission per year can be saved. If these tests on the *Auriga Leader* prove successful, these systems might be employed on any types of vessels where solar panels could be installed.

Adopting wind power to cut CO_2 emissions

The use of the wind to propel a ship is as old as shipping itself but ceased to be the chosen means for commercial shipping in the 1920s and 1930s with the dominance of mechanical systems such as steam machinery and diesel engines. There was a revival of interest in the 1970s, at the time of the energy crisis, but this soon passed as fuel costs reverted to their former level. Now there is a renewed interest due to wind power being seen as a means of cutting CO_2 emissions.

One project that aims to use wind power to cut CO_2 emissions by as much as 50% is the Wind Challenger Project, launched in Japan in September 2009. The project is being carried out under the direction of the University of Tokyo with the support of NYK Line, Mitsui OSK Lines, Kawasaki Kisen Kaisha ("K" Line), Oshima Shipbuilding, TADANO, and ClassNK.



Sail mast (SPAR) with telescopic mechanism. Each of the five panels can be retracted over the panel below to control the amount of surface area exposed to the wind at any given time for maximum effect
(Uzawa, Kimura, et al., Conference Proceeding of JASNAOE, Vol. 10, May 2010).

The cornerstone of the project is a 180,000dwt Capesize bulk carrier, the design of which is scheduled to be completed during 2012. The ship would be equipped with a total of nine masts and rigid sails positioned between the ship's hatch covers. When at sea the ship would be driven by the sails but these would be retracted when in port to enable cargo handling. In addition to the sail power, the ship would be equipped with diesel machinery for use in port or in poor wind conditions when at sea.

Sail design

The sails are one of the key elements in the design and would be constructed from CFRP (Carbon Fibre Reinforced Plastic). Each sail will be composed of five connected sections arranged vertically and positioned around a supporting mast.

The wind driven bulk carrier in port
(Tokyo University web site)

The sections are telescopic so that the sail area can be adjusted to suit the wind conditions. To ensure the sails have the optimum aerodynamic shape, they will be designed using 3D CFD (Computational Fluid Dynamics) and tested in wind tunnels.

In operation, the 'setting' of the sails will be vital to achieve optimum performance and accordingly a control system will be developed in order to set each sail at the appropriate angle for the wind strength and direction, as well as the ship's speed and proposed course. Development of this system will require wind flow analysis for multiple sail configurations using 3D CFD.

Working with the weather

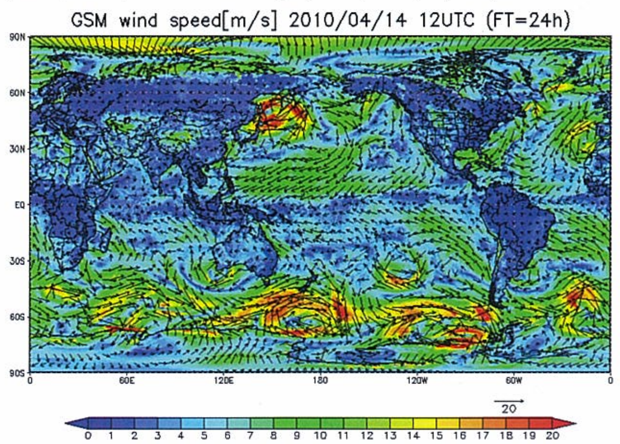
While the sail system may be optimised for the projected weather conditions, it is essential that these conditions are met in reality and hence another key part of the Wind Challenger Project is the development of an integrated navigation system. This will be designed to combine normal navigational functions with a form of weather routing.

Whereas conventional weather routing is intended to steer ships away from areas of strong winds etc, for a wind powered ship this system would navigate it along the optimum route for the wind conditions, so as to maximise the sails' propulsion effect. The system under development is based on the latest studies of ocean winds and other weather conditions and should enable the ship's master to achieve the best sailing performance while minimising CO_2 emissions.

It is hoped that this project will demonstrate the effectiveness of sail power and be the first of a new generation of wind powered ships sailing the oceans with the aid of state-of-the-art computer technology.

The wind driven bulk carrier at sea
(Tokyo University web site)

An example of ocean wind forecast
(Waseda, Nishida, Conference Proceeding of JASNAOE, Vol. 10, May 2010)



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