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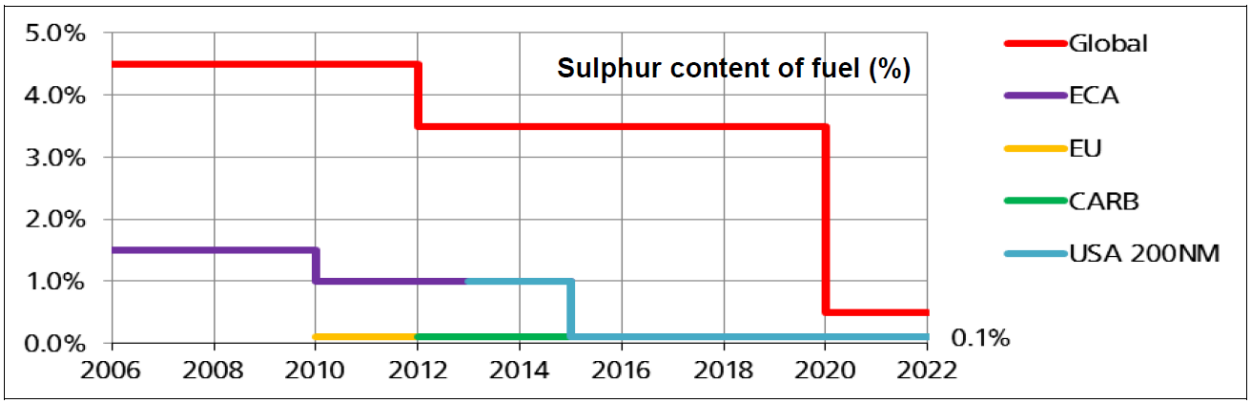
Service Letter

Date : 19th June, 2019
Ref. No.: HGS-HSM-SL-19-001

Subject: Impact on engine by installing scrubber
Type: All HiMSEN Engines
Replaces HGS-HSM-SL-18-007

To whom it may concern.

This Service Letter was written to inform our customers of exhaust gas back pressure for HiMSEN engines with regard to SOx Scrubber installation in order to comply with IMO MARPOL ANNEX VI Reg.14.8 which is to come into force as of 1st January 2020.



Basically, there is no influence when the back pressure is below than 300mmWC for all HiMSEN engine as the engine has been originally designed for maximum allowable back pressure of 300mmWC. In case that the back pressure is increased over the allowable limit due to installation of scrubber, generally increased back pressure causes the deterioration of engine performance.

In this regard, it is required to review the attached TEC2019-K2D0-005-O-R0.

Enclosure: TEC2019-K2D0-005-O-R0 IMPACT ON ENGINE BY INSTALLING SCRUBBER

Faithfully yours,

G. Y. Oh, General Manager
Head of Machinery Service Dep't
Technical Division

TECHNICAL CIRCULAR

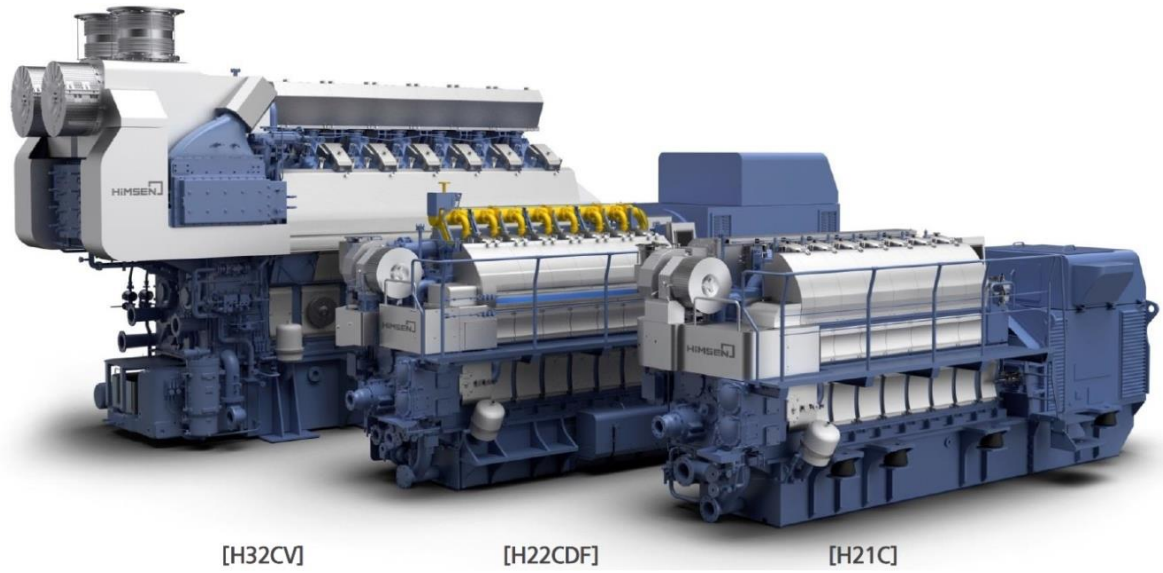
SUBJECT: IMPACT ON ENGINE BY INSTALLING SCRUBBER

TYPE: ALL

DOC No.: TEC2019-K2D0-005-O-R0

DISTRIBUTION

Marine	☑ Ship yard (Y)	☑ Ship owner (O)
Stationary	☐ Power plant (P)	



Date	TEC No.	Write	Checked	Approve	Change	R
190513	TEC2019-K2D0-005-O-RO	KHI	NHM	KHS	First issue.	0
						1
						2
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						4
						5

[BACKGROUND]

As time goes by, exhaust gas emission regulation is getting tighter and tighter. As a countermeasure in the tight exhaust gas emission regulation, after-treatment equipment is getting common such as SCR(Selective Catalytic Reduction) for NOx reduction and SOx Scrubber for SOx reduction.

SOx emission is normally created by sulfur contained in fuel oil during the combustion process. In IMO MEPC 70 (70th session of the Marine Environment Protection Committee), it was agreed that a global 0.5% cap and a SECAs* 0.1% cap were set from year 2020. All the ship sailing within ECAs** will be subject to IMO regulation regardless of their date of construction.

* SECAs : SOx Emission Control Areas

** ECAs : Emission Control Areas

There are two kinds of way for reducing SOx emission at this moment. One is to use LSFO(Low Sulfur Fuel Oil) as a fuel oil and another is to apply after-treatment system namely SOx Scrubber(hereafter Scrubber).

This technical circular provides the guidance in relation to increased back pressure caused by installation of the scrubber on their vessels in HiMSEN engine.

[EFFECT ON ENGINE BY INCREASED BACK PRESSURE UPTO 500mmWC]

The scrubber installed in exhaust duct after engine causes a pressure loss and thus back pressure after engine (hereafter back pressure) is increased accordingly. Normally 100~200[mmWC] of pressure loss is expected according to the supplier of scrubber. Thus back pressure is expected to be increased upto 400~500[mmWC] in case of installation of scrubber system at 100% load in HiMSEN engine. The following [Fig.1] shows an expected typical back pressure trend depending on the increment of back pressure at 100% load in HiMSEN engine.

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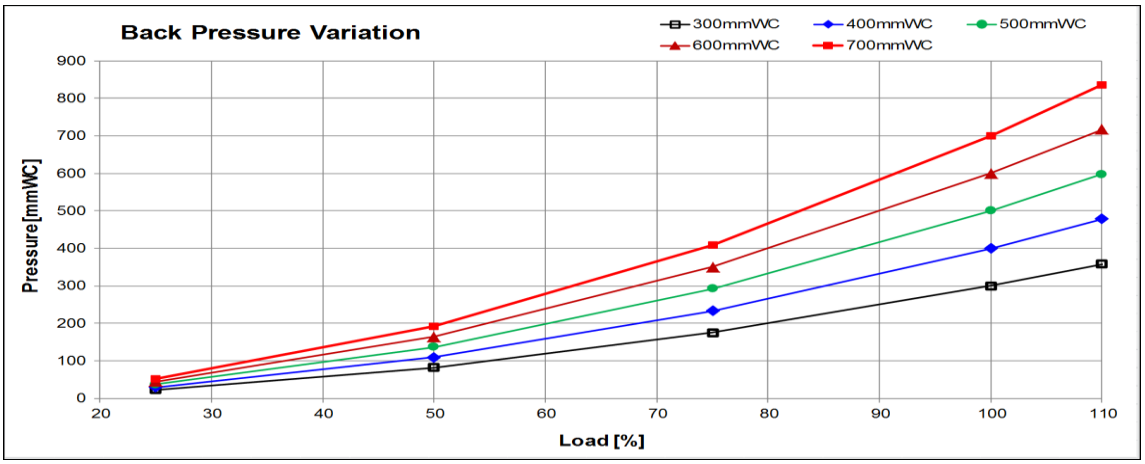


[Fig. 1] Example of typical back pressure trend caused by after-treatment equipment

HiMSEN engine has been originally designed for maximum allowable back pressure of 300[mmWC]. In case that the back pressure is increased due to installation of scrubber, generally increased back pressure causes the deterioration of engine performance as followings:

1) SFOC, exhaust gas amount, Turbine outlet temperature

The table [Table 1] below shows the performance deviation in case of increasing the back pressure.

Load [%]	SFOC [g/kWh]	Exh. gas amount [%]	Turbine outlet temp.[℃]
100	+ 1.0	- 1.0	+ 10
75	+ 1.0	- 0.6	+ 10
50	+ 0.5	- 0.2	+ 5

[Table 1] Performance effect of increased back pressure (300→500mmWC @100%)

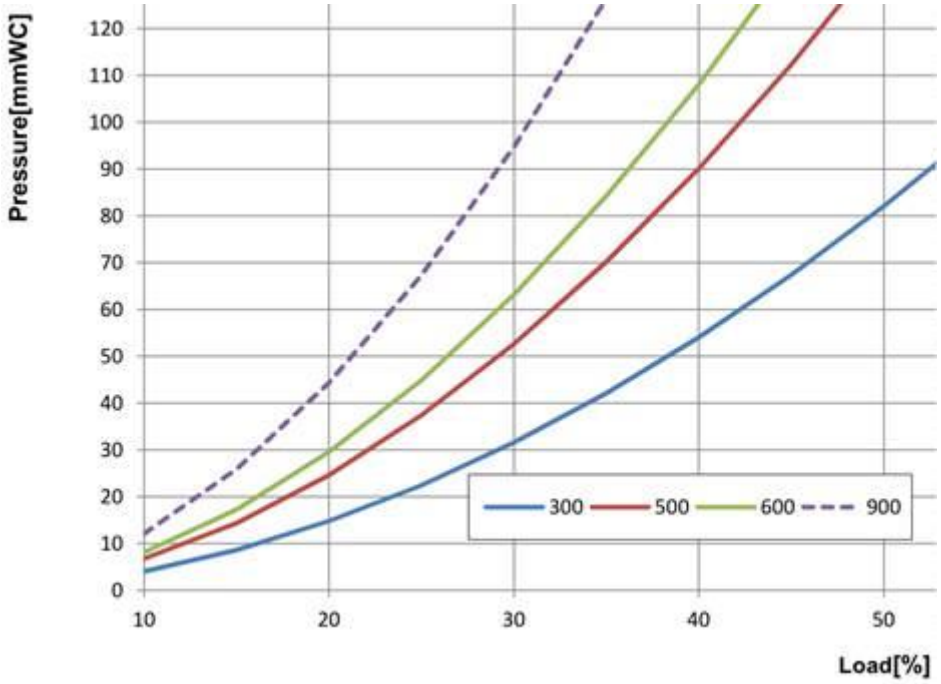
2) Engine low load operation

Higher back pressure means that the resistance of exhaust gas flow is increased. It makes that the turbine and compressor speed are decreased. Therefore, the charge air flow is reduced due to the higher back pressure. Furthermore, during low load operation, the exhaust gas flow is lowered and the charge air flow is insufficient. Higher back pressure with low load operation generates the lack of the charge air and incomplete combustion. It finally affects emission and engine durability.

3) Startability (Tier II engine)

In case that the HiMSEN engines applied Tier II and delivered before 2019 (hereafter Tier II

engine), the charge air suction duration is narrow due to the enhanced miller timing to reduce NOx emission. According to the test, even though the back pressure is low at starting and deviation is under 5[mmWC] between the initial back pressure 300[mmWC] and 500[mmWC] at 100[%] load, it effects the starting behavior. In hence, Tier II engine has a possibility of suffering the starting issues such as longer starting time and the increased starting air consumption.



[Fig. 2] Example of back pressure at starting for Tier II HiMSEN engine

4) Acceleration ability (Tier II engine)

The transient characteristics of generating sets have to follow the requirement of ISO 8528-5. For Tier II engine, engine response to a sudden load increase, especially at low load operation, can be instable because of the limited charge air amount.

[PROPER COUNTERMEASURE AGAINST AN ADVERSE EFFECT OF ENGINE PERFORMANCE]

1) Engine low load operation

When the back pressure is increased, basically low load operation has to be avoided. The attachment #1 explains about the low load operation. (Project Guide, HFO: under 20%, MDO/MGO: under 15%). If the engine inevitably faces to run at low load, the flushing operation described in the Project Guide has to be more frequent and longer time.

2) Startability (Tier II engine)

In order not to suffer from starting matter, the by-pass system is recommended to install to the vessel before reaching scrubber. Through the by-pass system, the engine can be safely started without higher back pressure influence. After starting the engine, the by-pass system will be opened engine's exhaust gas toward the scrubber.

3) Acceleration ability (Tier II engine)

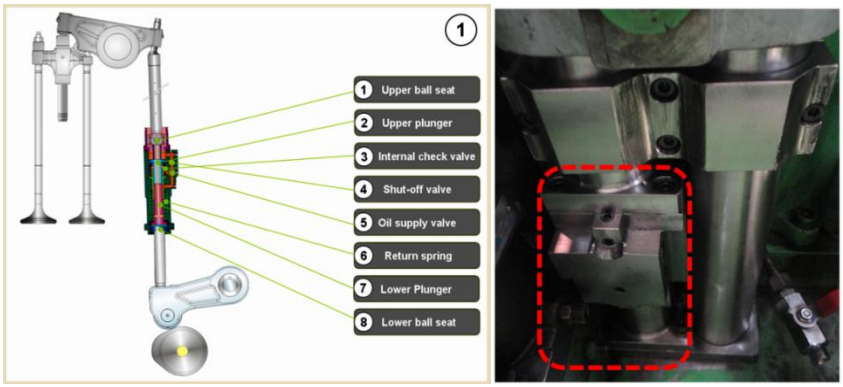
Continuous Jet Assist at low load or DVT (Dual Valve Timing) system can be selected the engine to improve the acceleration performance.

3-1) Continuous Jet Assist at low load

Jet Assist is a system to provide additional air to the cylinder chamber. The Jet Assist system is already equipped to the HiMSEN diesel engines. In order to improve the acceleration and/or the low load operation when the back pressure is increased, Jet Assist has to be continuously operated during low load (HFO: under 20%, MDO/MGO: under 15%). The capacity of compressed air of Jet Assist is to be checked whether the existing volume of compressed air system can cover and to be consulted to engine builder project by project. Also, the existing engine's ACS (Automatic Control System) to be revised to implement the function of continuous Jet Assist working (please refer to the attachment #2 for Jet Assist system).

3-2) DVT system (Option)

DVT system can be optionally equipped for the Tier II engine. Not only acceleration ability, but also startability can be improved without scrubber by-pass system in case of applying DVT system. Minor modification of part and addition of item will be necessary for installing the DVT system. The guidance of the modification and addition of part will be informed separately project by project. In addition, NOx technical file amendment is required due to the DVT system which can change the valve timing. For the detail information about DVT, please refer to the attachment #3. Example of configuration and Installation of DVT system is shown in the [Fig.3].



[Fig. 3] DVT's Installation

[EFFECT ON ENGINE BY INCREASED BACK PRESSURE MORE THAN 500mmWC UPTO 600mmWC]

Apart from the action mentioned in above [EFFECT ON ENGINE BY INCREASED BACK PRESSURE UPTO 500mmWC], the engine performance changes and the additional actions, for examples, power de-rating and/or T/C re-matching should be taken into consideration in case of the back pressure more than 500[mmWC].

1) SFOC, exhaust gas amount, Turbine outlet temperature

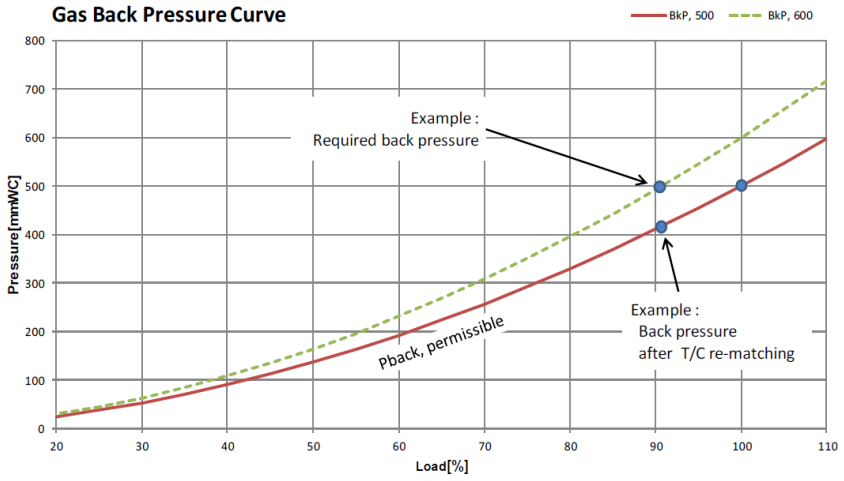
Additional deterioration of engine performance is unavoidable due to more increased back pressure, exceed 500[mmWC] upto 600[mmWC] as below table.

Load [%]	SFOC [g/kWh]	Exh. gas amount [%]	Turbine outlet temp.[℃]
100	+ 0.5	- 0.5	+ 5
75	+ 0.5	- 0.3	+ 5
50	+ 0.3	- 0.1	+ 3

[Table 2] Additionally worst performance by more back pressure(500→600mmWC @100%)

2) Power de-rating and/or T/C re-matching

Power de-rating and/or T/C re-matching are/is required for better engine operation. The figure below shows an example in case that back pressure is around 600[mmWC] at 100% load. This should be consulted to engine builder and carried out considering the engine operation condition project by project. NOx technical file amendment is required due to change the internal T/C component by T/C re-matching.



[Fig. 4] Example of power de-rating and/or T/C re-matching.

[CONCLUSION]

Recently, scrubber has been installed as a solution against the stringent emission regulation. However this kind of after-treatment system inevitably leads to increased back pressure after engine and it generally has an impact on the engine performance:

1) SFOC, exhaust gas amount, Turbine outlet temperature,
2) Engine low load operation,
3) Startability (Tier II engine),
4) Acceleration ability (Tier II engine)

While scrubber is running, engine operation at low load has to be minimized in order not to have a negative influence on the performance, emission and durability, etc. For Tier II engine, engine starting is recommended under the condition that the scrubber is closed by the by-pass system. Also in order to improve acceleration ability and/or low load operation, continuous Jet Assist modification or DVT has to be applied to the engine.

In case of extreme back pressure over 500mmWC at 100% load, the additional deterioration of engine performance has to be considered with power de-rating and T/C re-matching.

[ATTACHMENT]

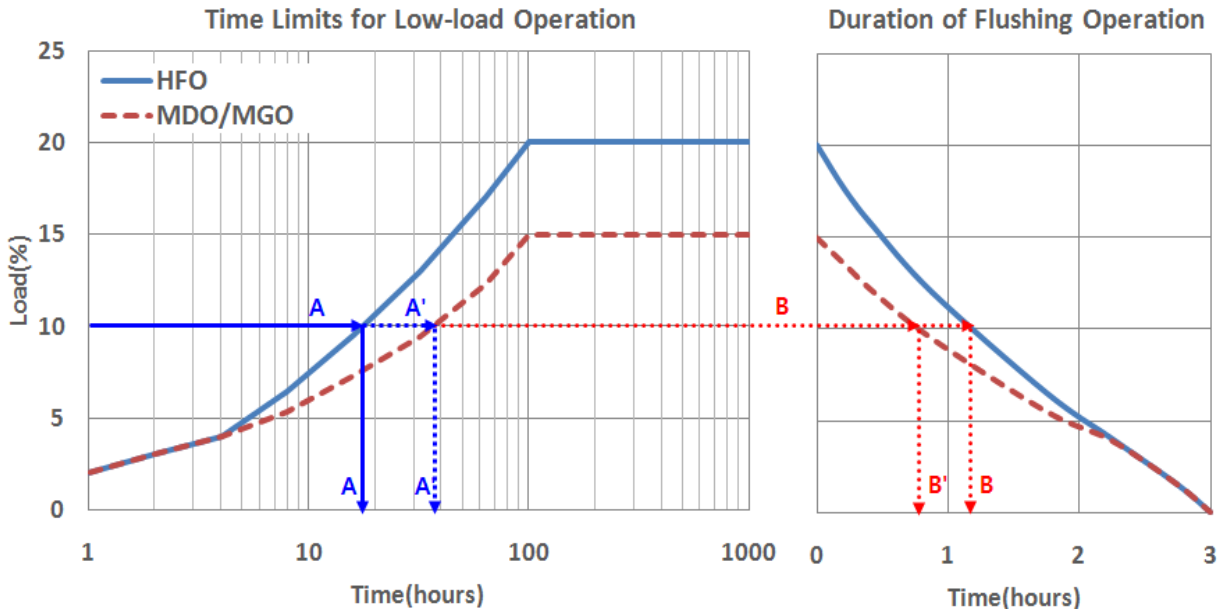
Attachment #1: Low load operation (Project Guide)
Attachment #2: The material for Jet Assist System explanation
Attachment #3: The material for DVT System explanation

[The end]

Yours sincerely,

H.S.KIM / Senior Engineer
Head of HiMSEN Engine Engineering Dep't

<Low Load Operation Criteria>



A no-load operation is recommended for a minute, not exceed 5 minutes.

'Time Limits for Low Load Operation'(Left) shows admissible operation time at certain load, and 'Duration of Flushing Operation' shows the time duration that operates at not less than 70% of full load in order to have deposits burnt away.

<Example>

1. Time Limits for Low Load Operation(Line A, A')
   At 10% of full load, HFO operation is permissible for about 17 hours(Line A), whereas MDO/MGO operation for 37 hours(Line A').

2. Duration of Flushing Operation(Line B, B')
   Engine should be operated for roughly 1.15hours(HFO) and 0.75 hours(MDO/MGO) at not less than 70% of full load.

HYUNDAI HiMSEN

TECHNICAL CIRCULAR

SUBJECT: IMPROVEMENT OF JET AIR ACTIVATION

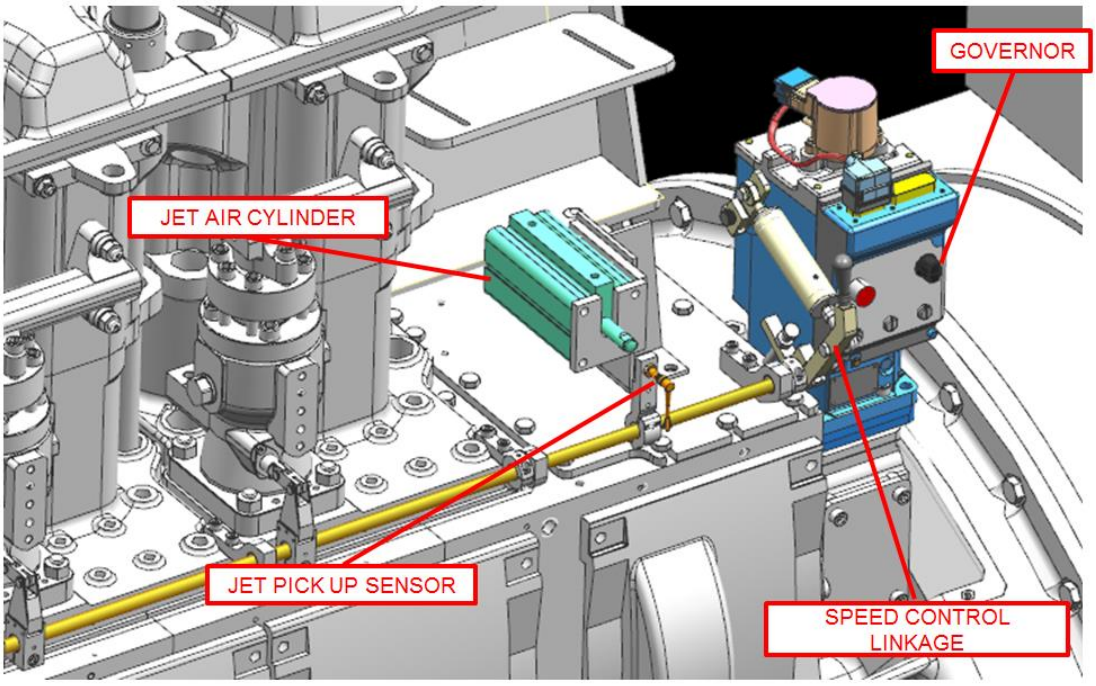
TYPE: H17/28, H21/32, H25/33, H32/40

Ref. No.: TEC2017/K9I0 - 001
Date: 17th March. 2017

[BACKGROUND]

Jet air system is used to improve engine acceleration for sudden load. Jet air is triggered when jet pick-up sensor touch with jet air cylinder's stroke and then compressed air is directed to air chamber. More combustion air leads to rapid response of engine acceleration against new coming load. However, a fault of jet pick-up sensor or improper installation can't initiate jet air. Therefore to improve the activation method of jet air from unexpected fault condition, the programmable logic is implemented instead of jet pick-up sensor. It contributes to better reliability of jet air system. The jet programmable logic will be adapted on H17/28, H21/32, H25/33 and H32/40.

[DESIGN IMPROVEMENT]



(1) Current jet air activation

Governors moves toward the position of speed control linkage which makes more fuel injection when sudden load is applied. If the movement of speed control linkage is excessive where charge air pressure increases, the piston of jet air cylinder will touch the proximity sensor and the compressed air will be supplied to the engine’s air chamber.

(2) New jet air activation

In new concept, jet air logic on control system plays a role in trigger of jet air as substitute of the Jet air cylinder and jet pick-up sensor.

The implemented logic is below.

- Triggered on speed switch function (under 97 % of rated speed)
- Triggered on speed drop rate function (△5 rpm/sec.)
- Above 80 rpm after start command

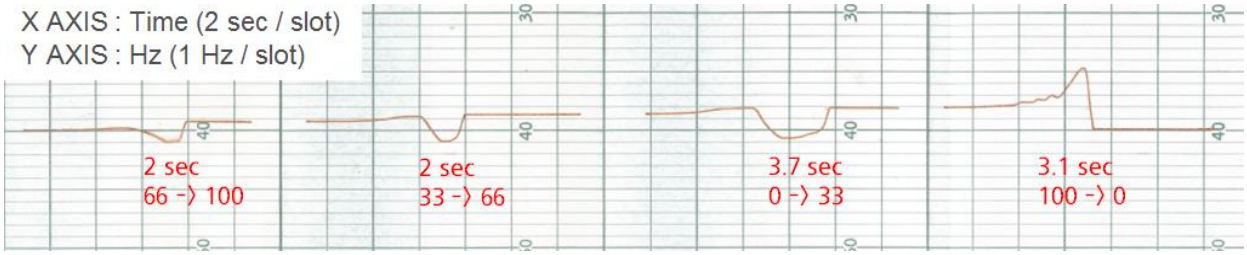
[VERIFICATION TEST RESULT OF NEW JET AIR ACTIVATION]

To verify the program logic, the test was performed according to 3-step interval depending on the load.

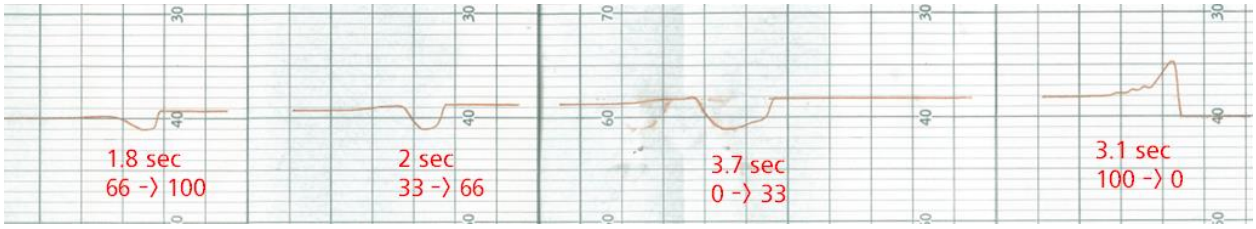
It was carried out based on general marine classification rules.

- Max instant load step : 0 % – 33 % – 66 % – 100 %
- Max speed variation ≤ 10 %
- Steady-state speed band ≤ 1.0 %
- Recovery time ≤ 5 sec
- Time between next load step ≥ 180 sec

(1) Current jet air activation



(2) New jet air activation



Sudden load (%)		100 -> 0	0 -> 33	33 -> 66	66 -> 100
Max speed variation (%)	The program	8.3	4.8	3	3
	Jet pick up	8.3	5	3	3
Recovery time (sec)	The program	3.1	3.7	2	1.8
	Jet pick up	3.1	3.7	2	2
Time between next load step (min)	The program	3	3	3	3
	Jet pick up	3	3	3	3

[CONCLUSION]

The results with new jet air system shows that it was satisfied with marine classification such as recovery time and speed max variation, etc. and better performance can be achieved at one part of recovery time in comparison of current system's one.

In addition, as a jet pick-up sensor and jet air cylinder are not applied in new jet air system for free of installation and maintenance. We can expect that the above mentioned improvement can reduce our customer's effort to maintenance work and remove the possibility of improper installation.

[The end]

Yours sincerely,

S. H. Ryu / Head Researcher
Head of Intelligent Control Research Dep't

HiMSEN Dual Valve Timing System

HiMSEN engine was launched successfully with best power density, high fuel efficiency and low NOx emission by optimized combustion with Miller timing (Early Intake Valve Closing) at the first in medium speed engine market. Although HiMSEN engines in production meet IMO Tier II, more aggressive Miller timing is required to comply with IMO Tier III regulation to be come into forced around in 2016 or 2021.

When intake valve close timing is more advanced, the volumetric efficiency is decreased. As a result, undesirable heavy smoke will be emitted especially in low load operation. Therefore variable valve timing system is required to provide optimal combustion condition for low load operation.

The simple and reliable Dual Valve Timing system has been developed and is ready for a supplement on new products as well as retrofit for engines in service. HiMSEN DVT system can take a role as an optimizer for low load operation with reasonable cost.

Features

- **Simple system**

  DVT is developed with simple hydraulic principle. The aimed timing retard is achieved by oil passages in the housing and movements of plungers. So it is not necessary to adopt complex control system based on crank angle sensor.

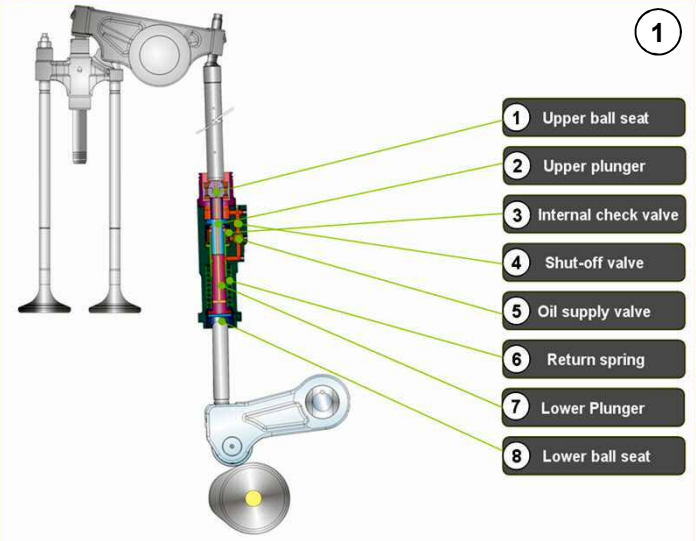
- **Reliable system**

  DVT is basically driven by mechanical parts. So even if unexpected oil supply failure happened, valve actuation is performed normally except timing retard function.

- **Retrofit**

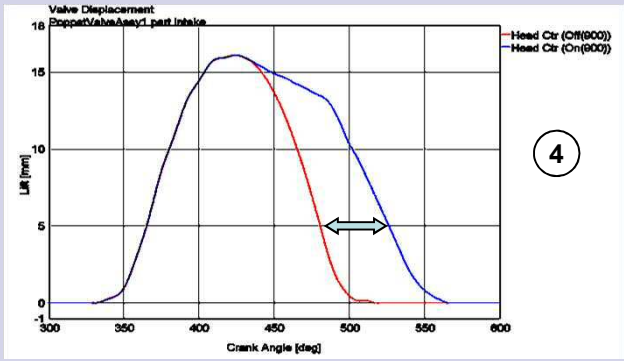
  DVT can be retrofitted by replacing pushrod cover without engine modification.
  (H21/32, H25/33 require water jacket modification)

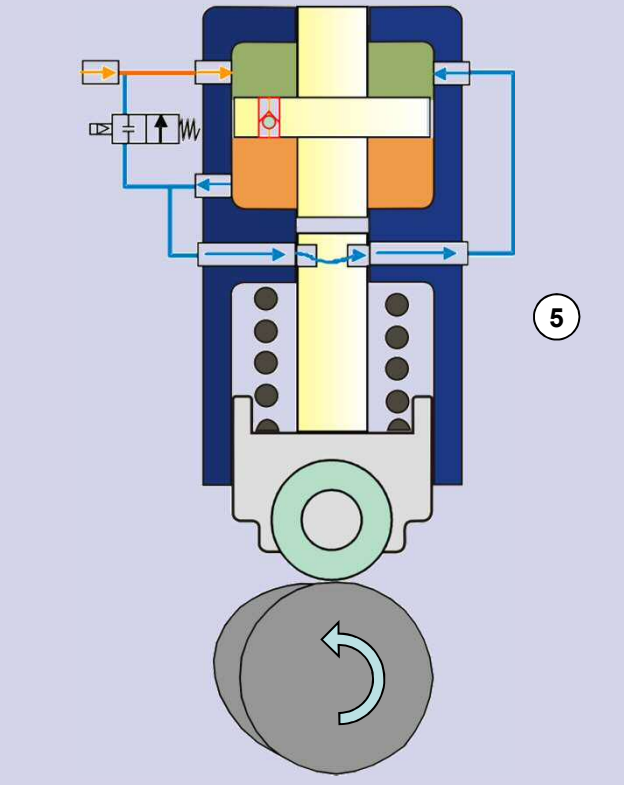
HiMSEN Dual Valve Timing System



① **DVT Components**
② **Installation on engine block**
③ **Durability test on test rig**

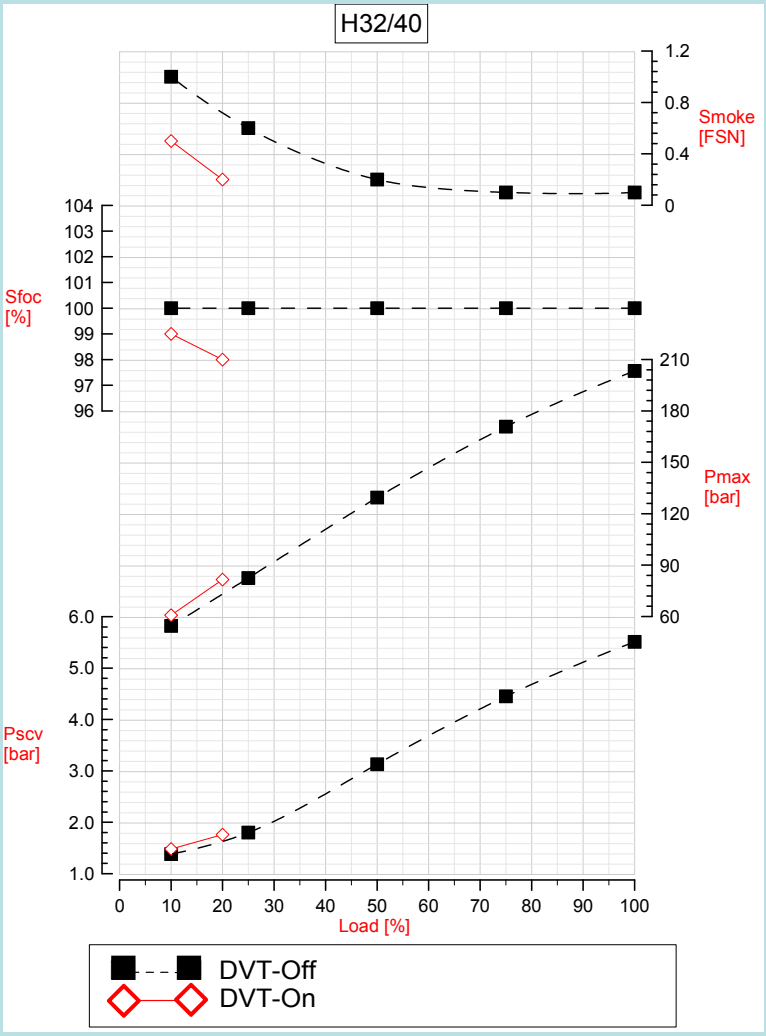
The operating principle of DVT is based on hydraulic non-return valve mechanism.
The DVT actuator is positioned between the upper and lower pushrod. The actuator consist of non-return valve parts and flow direction control valve. The lubrication oil is used as hydraulic medium.
The flow of oil in chamber is controlled by the non-return valve and direction control valve while the pushrods is driven by cam and follower.
If the direction control valve opens the return passage to upper side, the oil can flow from lower chamber to upper side without retardation. In this case, early intake close timing (Miller timing) is occurred as designed cam profile.
When the oil passage to upper side is blocked by the control valve, the downward movement of the upper pushrod is delayed until the passage is opened by the groove of lower plunger. As a result, intake valve is closed later than original timing.



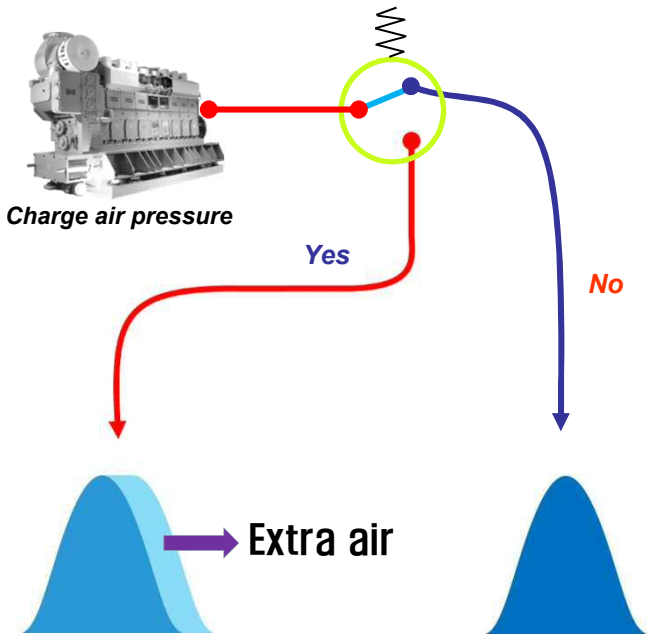


④ **Valve timing variation with DVT**
⑤ **Operation diagram of DVT**

HiMSEN Dual Valve Timing System



⑥ DVT test results (Engine type: 16H32/40V)



Optimized part load performance by DVT

The NOx limitation is one of the critical factor and should be kept for merchandise. So the proper solution for decreasing it with minimized loss of an engine performance is biggest concern in the concept design of engine development.

Miller timing is an effective technology for reduction of NOx emission as well as SFOC (Specific Fuel Oil Consumption). However, Miller timing also cause heavy smoke especially at low load operation due to less intake duration.

DVT system can increase the volumetric efficiency as well as effective compression ratio and thus can solve the drawback of Miller timing at low load.

In addition, it can improve starting performance and reduce the amount of air consumed during engine start.

The engine performance at low load can be improved with DVT system and was verified by measurement of HiMSEN engine as shown in left side.