JMES The International Journal of
Mechanical Engineering and Sciences
https://journal.its.ac.id/index.php/jmes/index
e-ISSN 2580-7471

Multi-Indicator Shipboard Assessment of a MAN B&W S60MC-C Fuel Valve Before and After Maintenance

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Received: 29 September 2026, Revised: 29 October 2026, Accepted: 4 November 2026

Abstract

This retrospective observational study investigated the condition of a slide-type fuel valve during a maintenance event aboard MV Bulk Nusantara using operating observations, component inspection, pressure-test records, and manufacturer procedures. Opening pressure increased from a recorded 290 bar before maintenance to 350 bar after combined cleaning, inspection, lapping, and spring-setting adjustment, corresponding to 60 bar (20.7%). The initial condition included nozzle-hole deposits, uneven discharge, nozzle-tip dripping, and restricted spindle movement; subsequent checks indicated improved discharge, sealing, and sliding. During the event, the affected cylinder's exhaust-gas temperature declined from approximately 350 °C to 200 °C. A comparison of available OEM data sheets identified two pressure-reference ranges, 320–380 and 350–380 bar, associated with different valve configurations. Accordingly, interpretation of the final 350 bar reading depends on confirming the specification for the installed assembly and the pressure tester's measurement characteristics. The assessment organized pressure, nozzle-flow, sealing, and sliding evidence by measurement type and OEM relevance, with O-ring integrity identified as a separate acceptance check. The resulting evidence-status workflow provides a practical, procedure-oriented method for organizing shipboard observations and identifying verification needs at specification boundaries; its diagnostic performance across multiple cases has not been evaluated.

Keywords: fuel valve, marine diesel engine, retrospective observational study, evidence uncertainty, opening pressure, OEM procedure

1. Introduction

Reliable fuel injection is essential for combustion stability in mechanically controlled marine diesel engines. Opening pressure affects injection behavior, while large two-stroke nozzle geometry and in-nozzle flow influence spray morphology [1, 2]. Controlled research on marine injector opening pressure uses repeatable loading and instrumented measurements to characterize the resulting response [3]. Recent reviews and condition-based-maintenance studies emphasize the distinction between fault indicators and validated diagnostic decisions [4, 5].

During the investigated shipboard event on MV Bulk Nusantara, exhaust-gas temperature in one cylinder decreased to approximately 200 °C from its usual operating value near 350 °C; engine slowdown, black smoke, and reduced rpm were also observed. Subsequent inspection recorded nozzle deposits, an opening-pressure reading of 290 bar, visible nozzle-tip dripping, and restricted spindle movement. The concurrence of these findings motivated a component-level evaluation informed by established research on injector deposits, fouling, and marine-engine condition signatures [6–9].

The principal engineering problem is how to interpret heterogeneous shipboard evidence against the correct manufacturer requirements. For the investigated valve, available technical records contain a 320–380 bar pressure range, whereas a separately reproduced S60MC-C data sheet specifies 350–380 bar. Differences in the referenced valve configurations highlight the importance of configuration-specific specifications, measurement traceability, and the distinction between indicative observations and formal acceptance tests. This study therefore integrates the available operational, inspection, and OEM evidence into a transparent condition-assessment workflow.

The objectives were to (i) characterize the fuel valve before and after the maintenance intervention, (ii) compare the available manufacturer specifications and test procedures, (iii) evaluate the evidential role of opening pressure, nozzle-hole discharge, sealing, and spindle movement, and (iv) establish an explicit verification pathway for measurements near an acceptance boundary or for an incomplete test sequence.

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2. Materials and Methods

2.1. Research Setting, Design, and Materials

A retrospective, descriptive single-case design was used to examine a fuel-valve malfunction aboard MV Bulk Nusantara. The vessel was equipped with a MITSUI–MAN B&W 6S60MC-C main engine rated at 10,320 kW at 89 rpm. The investigated component was a slide-type fuel valve. The research integrated engine-room observations, engineer interviews, maintenance photographs, operating notes, technical specifications, and maintenance documentation for the event. The analysis compared the recorded condition before and after the combined intervention and interpreted the findings with reference to relevant manufacturer procedures.

Interviews were conducted with the Chief Engineer, Second Engineer, and Third Engineer. Photographs documented disassembled components and the shipboard pressure-testing arrangement. The principal quantitative record contained opening-pressure values of 290 bar before and 350 bar after maintenance. Component-inspection notes and operating observations were organized alongside the pressure results, while measurement traceability and the availability of matched operating variables were considered in the research-method assessment.

2.2. Manufacturer-document Applicability Assessment

Fuel Valve Data sheet D10911, Edition 0047, included with the technical records specifies 320–380 bar, a valve mass of 7.2 kg, and an inlet-seat dimension of 18 mm [10]. A reproduced MAN B&W S60MC-C Data Sheet 109-11, Edition 04, specifies 350–380 bar, 13 kg, and 25 mm [11]. The differences indicate distinct valve specifications and require matching the applicable data sheet to the installed assembly using its component identification and controlled onboard manual. Both pressure intervals were consequently retained as reference scenarios for interpreting the recorded measurements.

The maintenance-interval document accompanying the field records concerned the ME-GI engine family. For the MC/MC-C family, MAN Service Letter SL2017-650/SRJ supersedes SL2017-643/SRJ and provides the more relevant guidance [12]. For the applicable fuel-valve design, this guidance includes an indicative 8,000 h overhaul interval, dependent on fuel quality, and distinguishes expected service lives for individual components, including 16,000 h for the nozzle and 32,000 h for the spring. The interval framework was used to contextualize maintenance planning rather than to infer the actual hours accumulated by the investigated valve.

Service Letters SL2016-628/KEL and SL2021-719/JNN apply to MAN four-stroke engines [13, 14], whereas the investigated MC-C engine is a two-stroke unit. Accordingly, technical criteria were evaluated with priority given to the two-stroke fuel-valve procedure 909-11.1 and the component-specific OEM documentation [15]. This distinction is particularly relevant to nozzle-flow checks, cleaning practice, and exhaust-temperature criteria.

2.3. Assessment Evidence and Test Completeness

Opening pressure was the principal numerical injector measure, with values of 290 and 350 bar recorded before and after maintenance. The available records describe visual checks of nozzle discharge, nozzle-tip leakage, and spindle movement. A sealing condition of 300 bar for 10 s is stated in the operating notes. The assessment distinguished these observations from the complete OEM procedure, including the separate O-ring integrity check. Instrument model, scale resolution, accuracy class, calibration history, and repeated-lift readings were not available

Table 1. Manufacturer-document comparison and implications for the investigated fuel valve.

Document / source	Reported data	Applicability assessment
Data D10911, Ed. 0047 [10]	320–380 bar; valve 7.2 kg; inlet seat 18 mm	Alternative valve configuration; component identification determines applicability.
S60MC-C Data Sheet 109-11, Ed. 04 [11]	350–380 bar; valve 13 kg; inlet seat 25 mm	S60MC-C reference scenario; confirm the installed valve and data-sheet edition.
Pressure-test observations and images	290 and 350 bar; equipment shown	Recorded opening-pressure comparison; tester metrology addressed in Section 4.3.
Procedure 909-11.1 [15]	Jet/flushing; pressure; sealing/sliding; O-ring test	Manufacturer sequence used to organize test interpretation and verification.
SL2017-650/SRJ [12]	MC/MC-C valve overhaul interval; component expected lives	MC/MC-C-specific maintenance-interval guidance, subject to valve design.

Table 2. Evidence hierarchy and verification pathway for the investigated fuel valve.

Assessment domain	Observed information	Evidence category	Verification role
Opening pressure	290 → 350 bar	O: numerical; Q: reference and instrument	Confirm the component-specific pressure range and measurement accuracy.
Nozzle jet control	Irregular before; open passages reported after	O: descriptive; Q: test setting	Supports assessment of passage continuity and nozzle deposits.
Fuel-valve sealing/sliding	Dripping/restriction before; dry/smooth after	O: qualitative; Q: procedure	Confirm the OEM sealing and sliding test sequence.
O-ring pressure integrity	Test result not documented	M: separate OEM integrity check	Complete the O-ring integrity test for final assembly acceptance.
Post-repair EGT at matched load	Initial operating symptom; matched follow-up series absent	O: initial; M: matched follow-up	Collect load-matched data to quantify engine-level response.

in a form sufficient for quantitative uncertainty analysis; these factors were retained as considerations in interpreting the 350 bar boundary value.

The evidence was grouped by function: opening pressure was treated as a numerical measurement; nozzle-hole jet control as an indicator of discharge continuity and blockage; sealing and sliding observations as evidence of valve-seat closure and mechanical mobility; and O-ring integrity as a distinct OEM verification requirement. This separation avoids conflating visual bench checks with in-cylinder atomization performance and allows the recorded improvement to be described independently of a final serviceability decision.

2.4. Evidence Grading and Conservative Disposition

An evidence-status framework was established with three categories: observed or documented (O), conditionally interpreted (Q), and not documented (M). A measurement was compared with an acceptance threshold only after identifying the applicable component specification. Results with sufficient test detail were classified by the relevant criterion; measurements near a specification boundary were flagged for instrument-aware confirmation, and completion of required OEM tests was assessed separately. The framework provides a practical assessment and documentation method for linking each observed indicator to the corresponding OEM verification step. It is not a replacement for manufacturer acceptance testing or a separately validated diagnostic algorithm.

The decision sequence assigned priority to mandatory OEM requirements. A confirmed failed test indicates non-conformity; a favorable result near a specification boundary is retained as conditional until the applicable limit and instrument characteristics are established; and completion of the O-ring integrity check is included before full-assembly acceptance is concluded. These states preserve useful information on maintenance response while distinguishing it from final verification for service.

2.5. Maintenance Procedures and Analysis Boundaries

The maintenance work comprised disassembly, removal of deposits, nozzle-hole cleaning using an implement described in the records as a special wire, inspection of moving components and seating surfaces, lapping, adjustment of spring preload by shim/disc, reassembly, and bench retesting. The sequence was treated as one combined intervention. Manufacturer guidance on approved tools, contact surfaces, and test sequence was used as the basis for assessing procedural alignment [15].

The recorded pressure difference was calculated as $\Delta p = 350 - 290 = 60$ bar, representing an increase of $(60/290) \times 100 = 20.7\%$ relative to the initial reading. All other changes were compared descriptively by inspection domain. This approach preserved the distinction between the numerical pressure comparison and the qualitative indicators of fuel-valve condition.

3. Results

3.1. Operational Event and Observed Injector State

During the investigated event, the affected cylinder's exhaust-gas temperature fell from approximately 350 °C to 200 °C, a reduction of 150 °C (42.9% of the typical reported value), accompanied by slowdown, black smoke, and reduced rpm. Inspection after valve removal identified deposits obstructing nozzle passages, irregular jet discharge, nozzle-tip dripping, and restricted movement. The recorded opening pressure was 290 bar. Together, these findings supported a targeted fuel-valve assessment within the broader operating context of the engine [9].

The 290 bar reading is 60 bar below the lower limit of the 350–380 bar reference and 30 bar below the lower limit of the 320–380 bar reference, equivalent to shortfalls of 17.1% and 9.4%, respectively. These alternative com-

Table 3. Fuel-valve observations before and after the combined maintenance intervention.

Observation	Before maintenance	After maintenance	Assessment relevance
Opening-pressure reading	290 bar	350 bar	60 bar (20.7%) increase; assess against the applicable OEM range.
Nozzle-hole discharge	Non-uniform/partly blocked	Reported fine and holes open	Visual indication of improved nozzle-hole discharge.
Sealing observation	Visible fuel droplets	Reported dry nozzle tip	Dry-tip observation during the reported sealing check.
Spindle/sliding motion	Restricted	Reported smooth	Improved mechanical mobility.
O-ring integrity test	No record	No record	Separate OEM verification step to be completed.
Cylinder exhaust temperature	$\sim$350°C typical $\rightarrow$ $\sim$200°C during event	No matched numeric series	Operating symptom documented; matched-load follow-up recommended.



Figure 1. Fuel-valve components inspected after disassembly during shipboard maintenance.

parisons are presented to preserve the distinction between the recorded observation and the component-specific pressure criterion determined by the applicable data sheet.

3.2. Maintenance Activities and Post-maintenance Record

Maintenance involved deposit cleaning, lapping, spring-preload adjustment using a shim/disc arrangement, and bench retesting. Following the intervention, the recorded opening-pressure reading was 350 bar, an increase of 60 bar relative to the initial value. This reading lies at the lower boundary of the 350–380 bar S60MC-C reference scenario [11] and within the alternative 320–380 bar range [10]. The disassembled fuel-valve components and pressure-testing arrangement are shown in Figures 1 and 2, respectively; interpretation of the numerical result follows the pressure-test record and the specification comparison in Section 2.2.

After maintenance, the observations indicated more uniform nozzle discharge, a dry nozzle tip during the reported sealing check, and smoother spindle movement. Engine-room records also described a return to normal operation and more uniform cylinder exhaust temperatures.



Figure 2. Shipboard pressure-testing apparatus used for fuel-valve adjustment and retesting.

The operational response was interpreted qualitatively because the available record did not include a synchronized post-maintenance temperature series at comparable engine load and rpm.

3.3. Supporting Operating Observations

Operational records and engineer interviews provided context for the component findings. Fuel-filter contamination, accumulated service hours, and maintenance scheduling were identified as relevant considerations for nozzle condition and injection-system performance. These observations informed the interpretation of possible deterioration mechanisms and the importance of routine fuel-system inspection.

The observed deposits and restrictions were compatible with a combination of fuel-system contamination and component deterioration. The maintenance event consequently provides a practical example of how operating symptoms, component inspection, and bench testing can be combined to guide follow-up checks and interpret changes after maintenance.

4. Discussion

4.1. Differentiating Condition Observations from Formal Fuel-valve Acceptance

The four inspection domains provide complementary information, but their roles differ within the OEM verification sequence. Opening pressure provides a numerical indication of spring-setting behavior; nozzle jet control helps identify obstructed discharge passages; sealing and sliding checks examine closure and mobility; and the O-ring test addresses a separate integrity requirement. For this case, the numerical and visual findings indicated improved valve condition after maintenance. The pressure-specification comparison and completion of the OEM test sequence determine the remaining steps for final acceptance [5].

The principal practical contribution is a structured link between shipboard observations and the verification steps needed for maintenance decisions. It relates each observation to its measurement type, its position in the OEM procedure, and the verification required for a decision. Unlike probabilistic FMEA approaches that derive explicit weights or risk rankings [16], the proposed classification uses traceable evidence categories and preserves the manufacturer's acceptance criteria. It is intended for maintenance records combining quantitative readings and qualitative inspections; its reproducibility across multiple valve cases remains to be assessed.

4.2. Nozzle Cleaning, Seat Work and Possible Mechanism

Carbonaceous deposits can restrict nozzle passages and alter discharge behavior [6, 7]. Deposits or resistance in moving parts can also affect the observed opening-pressure response during bench testing [15]. In the investigated event, cleaning, seating-surface work, and spring-setting adjustment were performed as a combined maintenance package, followed by improved pressure and functional observations. The evidence supports a before-and-after association for the overall intervention, while the contributions of individual actions and the precise roles of spring condition and wear remain topics for targeted component measurements.

The maintenance notes describe cleaning nozzle holes with a wire-type implement and lapping a seating surface. The relevant MC-C overhaul procedures specify the appropriate cleaning tools and the permissible treatment of precision-contact surfaces [15]. Evaluation of these operations therefore requires the exact fuel-valve design and its approved procedure. This distinction is important because service letters for four-stroke engines address configurations outside the present two-stroke application [14].

4.3. Instrument Uncertainty and the 350 bar Boundary

The final 350 bar reading merits particular attention because it coincides with the lower boundary of the 350–380 bar reference scenario. Near a specification limit, the interpretation of conformity depends on the applicable valve specification, gauge resolution and accuracy, calibration status, and repeatability of opening events. The available material establishes the recorded pressure change, while the instrument details necessary to calculate an uncertainty interval remain to be verified. Thus, the 60 bar improvement is a directly reported within-case difference, whereas formal OEM acceptance of the 350 bar result remains conditional on the approved fuel-valve specification, the measuring instrument, and completion of the required tests.

For complete verification of this boundary result, the recommended procedure is to identify the installed valve and corresponding OEM pressure range; document the tester model, accuracy class, calibration status, and repeated opening readings; and perform the specified sealing/sliding and O-ring integrity checks. These steps provide a reproducible acceptance record and improve comparison across subsequent maintenance cycles.

4.4. Operating Context and Scope of Inference

The 150 °C exhaust-temperature reduction and associated operating symptoms provided a clear trigger for investigating the affected cylinder. Interpretation of cylinder exhaust temperature is strengthened by considering load, rpm, inter-cylinder differences, and sensor behavior, as emphasized in marine condition-monitoring studies [5, 9]. The 40 °C inter-cylinder deviation and near-alarm guidance in SL2016-628/KEL concerns particular four-stroke engine applications [13]. For the two-stroke MC-C engine, the applicable operating criteria are those specified for its installed configuration.

The study provides a detailed examination of one documented maintenance event. Its strongest inference concerns the observed change in fuel-valve condition following the combined intervention. Further work with

linked maintenance records for several identified valves, calibrated pressure measurements, and matched operating conditions would allow the proposed reporting framework to be evaluated for reproducibility and broader application. Instrumented marine diagnostic investigations [2, 3, 8] provide useful methodological benchmarks for such an extension.

Complementary experimental articles in JMES have characterized injector spray response under fuel magnetization [17] and diesel-engine operating and emission responses to changes in compression ratio [18]. Although the equipment and experimental conditions differ from the present marine-engine maintenance case, these studies provide useful context for separating component-level inspection evidence from engine-level performance assessment.

4.5. Minimum Audit Trail for Subsequent Shipboard Work

A practical audit trail for subsequent fuel-valve assessments should identify the engine and valve part number, the revision-controlled OEM data sheet, tester model and calibration status, repeated opening-pressure readings, nozzle-flow observations, the manufacturer-specified sealing/sliding and O-ring test results, maintenance actions, and synchronized operating conditions (load, rpm, and cylinder-wise exhaust temperature). Linking these records to the responsible engineer and service date would strengthen trend analysis and support consistent decisions across maintenance events.

5. Conclusions

This retrospective engineering study documented an increase in the opening-pressure reading of a slide-type main-engine fuel valve from 290 to 350 bar after a combined maintenance intervention, corresponding to 60 bar (20.7%). The post-maintenance checks also indicated more uniform nozzle discharge, improved sealing behavior, and smoother spindle movement. The initial malfunction coincided with an exhaust-gas-temperature decline from approximately 350 °C to 200 °C in the affected cylinder. Taken together, the findings show a consistent improvement in the recorded fuel-valve condition following the maintenance package.

Comparison of the available OEM data sheets demonstrated that pressure interpretation is configuration-dependent: the documented ranges were 320–380 and 350–380 bar, making the 350 bar reading a specification-boundary result under the latter reference. The study therefore distinguishes the observed pressure response from final component acceptance, which requires the applicable OEM specification, instrument traceability, and completion of the prescribed integrity checks. The proposed evidence-status framework provides a practical assessment structure for integrating numerical readings, inspection findings, and manufacturer requirements during shipboard fuel-valve maintenance without claiming new diagnostic validation. Extension to linked multi-case datasets and calibrated repeated tests would enable further evaluation of its reproducibility and decision-support value.

Acknowledgments

The authors thank the engine-room personnel of MV Bulk Nusantara and Banten Merchant Marine Polytechnic for their cooperation and assistance with shipboard observations and maintenance documentation.

References

[1] A. A. K. Mahanggi, B. Sudarmanta, and H. Soebagyo, “Experimental study on effect of injection pressure to spray characteristics, performance and emissions of diesel engine DI 20 C using biodiesel fuel,” *JMES*, vol. 2, no. 1, pp. 18–25, 2018.

[2] R. Balz, B. von Rotz, and D. Sedarsky, “In-nozzle flow and spray characteristics of large two-stroke marine diesel fuel injectors,” *Applied Thermal Engineering*, vol. 180, p. 115809, 2020.

[3] M. Kluczyk, A. Grądziela, A. Polak, M. Pająk, and M. Gajda, “Analysis of changes in the opening pressure of marine engine injectors based on vibration parameters recorded at a constant torque load,” *Sensors*, vol. 23, p. 8404, 2023.

[4] Y. Lv, X. Yang, Y. Li, J. Liu, and S. Li, “Fault detection and diagnosis of marine diesel engines: A systematic review,” *Ocean Engineering*, vol. 294, p. 116798, 2024.

[5] Ç. Karatuğ, Y. Arslanoğlu, and C. Guedes Soares, “Design of a decision support system to achieve condition-based maintenance in ship machinery systems,” *Ocean Engineering*, vol. 281, p. 114611, 2023.

[6] C. M. McGilvery *et al.*, “Characterisation of carbonaceous deposits on diesel injector nozzles,” *Fuel*, vol. 274, p. 117629, 2020.

[7] R. D. Burke, M. Madamedon, and R. Williams, “Newly identified effects of injector nozzle fouling in diesel engines,” *Fuel*, vol. 278, p. 118336, 2020.

[8] S. Drewing and K. Witkowski, “Spectral analysis of torsional vibrations measured by optical sensors, as a method for diagnosing injector nozzle coking in marine diesel engines,” *Sensors*, vol. 21, p. 775, 2021.

[9] P. Puzdrowska, “Diagnostic information analysis of quickly changing temperature of exhaust gas from marine diesel engine part I: Single factor analysis,” *Polish Maritime Research*, vol. 28, no. 4, pp. 97–106, 2021.

[10] MAN B&W Diesel A/S, “Fuel valve—data D10911, edition 0047.” Manufacturer-style data sheet retained in shipboard technical documentation (applicability to installed assembly unverified).

[11] MAN B&W Diesel A/S, “Fuel valve—data sheet 109-11, edition 04, S60MC-C.” Reproduced public manual; vessel-unit applicability unverified.

[12] MAN Diesel & Turbo, “Guiding overhaul intervals—updated tables,” Service Letter SL2017-650/SRJ, MAN Diesel & Turbo, Aug. 2017. MC/MC-C table, p. 13.

[13] MAN Diesel & Turbo, “Fuel injection valve condition,” Service Letter SL2016-628/KEL, MAN Diesel & Turbo, Oct. 2016. Four-stroke engine scope.

[14] MAN Energy Solutions, “Cleaning of fuel injection nozzles,” Service Letter SL2021-719/JNN, MAN Energy Solutions, Dec. 2021. Four-stroke engine scope.

[15] MAN B&W Diesel A/S, “Fuel valve checking, procedure 909-11.1, and related overhaul instructions, S60MC-C / S60–70MC-C.” Publicly reproduced maintenance-manual editions; exact vessel edition to be confirmed.

[16] Q. Shi, Y. Hu, and G. Yan, “A novel FMEA approach based on probabilistic linguistic best-worst method and TOPSIS with application to marine diesel fuel injection system,” *Journal of Intelligent & Fuzzy Systems*, vol. 45, pp. 3835–3854, 2023.

[17] A. D. Utami, B. Sudarmanta, B. U. K. Widodo, A. B. K. Putra, and I. B. Suryo, “Experimental study of the effect of magnetization on bioethanol injectors on spray characteristics for applications in the SINJAI-150 engine,” *JMES The International Journal of Mechanical Engineering and Sciences*, vol. 3, no. 2, pp. 17–26, 2019.

[18] A. Setiyawan and A. Fadhlullah, “The effect of compression ratio on a diesel engine fueled with a mixture of medium sulfur high speed diesel and ethanol,” *JMES The International Journal of Mechanical Engineering and Sciences*, vol. 3, no. 2, pp. 35–43, 2019.