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DIAMOND POWER SPECIALTY CORPORATION
DIAMOND MODEL DP-3000 DURA-PORT CAGE

Evaluation Report
NBTL Project No. B-518
Subtask 4181
SF013-06-16
12 March 1963
by
J. ISINGER

NAVAL BOILER AND TURBINE LABORATORY
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DIAMOND POWER SPECIALTY CORPORATION
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APPROVAL INFORMATION

Approved by:

W. W. BRALEY
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**LIST OF ILLUSTRATIONS**

- (Dura-Port) BI-Color Navy Type Water Gage Assembly Dwg. No. 103656-1056  | 1
- Illuminator and Wide Angle Hood Assembly Dwg. No. 103657-1154           | 2
- Photograph-Main Body of Gage                                          | 3
- Photograph-Gage with Viewing Hood and Illuminator Attached            | 4
Tests were conducted on a pressure gauge.

ABSTRACT

A Diamond Power Specialty Corporation "Dura-Port"
Gauge, designed to operate at pressures up to 3000 psig, was evaluated to determine its suitability for shipboard service.

The gauge was first shock and vibration tested at the Naval Research Laboratory. The gauge insert withstood shock and vibration tests without leakage or glass failure; the illuminator and hood assembly required modification to provide adequate shock and vibration resistance.

The gauge was installed on the Laboratory's DDG-15 boiler for determination of clarity and angle of visibility. Readability of the gauge, requiring reliance on the color-refraction principle, was considered satisfactory while incorporating a better than 100° viewing angle. Optimum discernment of water level was obtained at distances ten to fifteen feet from the gauge.

A 256-hour full pressure test, with blowdown every forty-eight hours and a rapid pressure drop and rise every twenty-four hours, was conducted on the Laboratory's water-gage test facility without steam leakage or mica or glass failure of the main insert. The shut-off valves showed no leakage at hand tightness during and after cooling. The leakage through the closed ball check was excessive with an average of approximately 1000 cc every 3 minutes and 10 seconds.
The Problem

Evaluate a Diamond Model DP-3000, Dura-Port Water Gauge for naval service on 1200 psi boilers. Agenda for testing was to be in accordance with revised specifications MIL-G-46356B of 25 September 1961, paragraphs 4.2 through 4.2.7. and 4.5 through 4.5.6, shock and vibration tests were to be in accordance with MIL-S-901 of 19 December 1955, and MIL-S-167 of 20 December 1954, respectively.

Findings

After modifications to the gage, illuminator, and hood the entire assembly successfully withstood shock and vibration tests with the exception of light bulbs which failed during shock tests.

Evaluation of the gage on both an operating boiler and the water gage evaluation facility indicated discernment of water level was good. The gage was reliable and required little or no maintenance during several hundred hours of operation. Performance of water gage assembly valves was satisfactory with the exception that excessive leakage occurred through the closed ball check.
This project was authorized by BUSHIPS ltr 9510/1-3 Ser 651D-1450 of 18 October 1961. Costs were chargeable to Allotment 290/RDT & EN 62.2421, Budget Project 50. This is a final report of an RDT & E project.
DESCRIPTION OF MATERIALS

The ported boiler water gage submitted for evaluation was manufactured by Diamond-Power Specialty Corporation. This gage, designated as a Diamond Model DP-3000 Dura-Port Gauge, included an illuminator and wide angle hood, and was designed and built to operate at pressures up to 3000 psig. This gage was to be an improved design over the Diamond Multi-Port Gauge previously evaluated at the Laboratory under NBTL Project B-379 and found to be unsatisfactory because of glass and mica failures.

Previous dual color gages operating on the refraction principle required direct "head-on" viewing to ascertain correct water level. This was a distinct disadvantage. The subject gage was designed to provide a viewing angle of approximately 100°. Details and description of the Dura-Port gage can be obtained by referring to the drawings and photographs included as Plates 1 to 4 of this report. Information as to maintenance and operation of the gage can be obtained from the Diamond Instruction Manual, Bulletin No. 2572, of November 1961.

PROCEDURE AND RESULTS

Introduction

The Bureau of Ships authorized the Laboratory to evaluate the manufacturer's latest design Dura-Port gage according to requirements of the
revised specifications MIL-G-16356B. Specified tests included operation on both the high pressure water gage test facility and a Laboratory 1200 psi boiler, and a complete shock and vibration evaluation.

**Shock and Vibration Evaluation**

Because the weight of the water gage plus its mounting exceeded the limit for the Laboratory's vibration testing machine, the Naval Research Laboratory was authorized by the Laboratory to perform both the vibration and shock tests.

While there was no leakage or glass failure during vibration tests, modifications were required to enable the complete gage assembly to meet requirements. The single expansion loop at the top of the gage was replaced with a double, symmetrical loop arrangement, shortening the radius of the loop, producing a more vibration resistant construction in this area; the sides of the wide angle viewing hood were strengthened; other modifications were made to the gage, illuminator and hood. After incorporation of all modifications, the complete assembly successfully passed the vibration requirements of MIL-STD-167 (Ships) for all frequencies between 0 and 33 cps and in each of the three principal directions of vibration.

The gage proper and the wide angle viewing hood and its lens successfully withstood the shock tests, but the function of
the illuminator was impaired because its light bulbs failed and
the glass lenses cracked and/or broke.

A complete description of the procedure and results of the
shock and vibration tests are presented in Appendix I, the Naval
Research Laboratory's report on the tests.

Installation on Operating Boiler

After shock and vibration tests, the gage was installed on
the Laboratory's DDG-15 boiler for determination of clarity and
angle of visibility and simplicity of installation.

Although the sharpest designation of water level was had at
distances between ten and fifteen feet of the gage, readability, de-
pendent upon the two-color or light refraction principle, was
satisfactory with close ups from four to six feet. Difficulty was
experienced while mounting the insert to the already assembled
bottom valve; the small metal sealing gasket was dislodged from
its position on the surface of the raised face of the valve flange.
The result of this was considerable steam leakage and a damaged
raised face.

Installation on Water Gage Evaluation Facility

The gage was installed on the Laboratory's high pressure
water gage testing facility and subjected to a series of rapid
pressure drops and rises, blowdowns, and pressures and temperatures and water conditions representative of those encountered in current naval power plants. Operation was conducted for 256 hours at full pressure of 1250 psig with blowdown every 48 hours and a rapid pressure drop and rise every 24 hours. A 1000 hour evaluation of the gage was not completed because of reports of successful operation aboard USS SARATOGA (CVA 60).

The gage illuminator assembly functioned satisfactorily throughout the total operating time. No leaks occurred at the port assemblies, no mica or glass failures occurred, and no maintenance was required. Three light bulb failures occurred. Visibility or discernment of water level was good, with a better than 100° viewing angle on the DDG-15 boiler; the distant views were the best. Some difficulty was encountered in replacing burned out light bulbs due to heat from the main insert and the bulb assembly. Gage valve operation was satisfactory, with no leakage through either the steam, water or drain valves during and after cooling and throughout the securing tests. The ball check rose readily, requiring approximately 58.6 lbs. per hour of escaping saturated steam. The seating ability of the ball check, however, was not satisfactory.
allowing an average leakage of approximately 1000 cc every three
minutes and ten seconds, well above the allowable leakage stated in
specification MIL-G-16356B, paragraph 3.12.7.2.

During the initial steam and water shut-off valve hot cycling
operation, the handwheel torques required for tight valve closure
averaged 20 lb. ft. Further valve cycling produced slight packing leaks
that were stopped by tightening the gland follower just enough to prevent
leakage. Following the gland tightening, valve cycling operation was
resumed and it was disclosed that increased handwheel torques were
now required for tight valve closure. Torques up to 40 lb. ft. and
35 lb. ft. were necessary for tight closure and subsequent re-opening,
respectively. These torques are above the 15 lb. ft. allowable stated
in specification MIL-G-16356B, paragraphs 3.10.2 and 3.10.3.
CONCLUSIONS

Performance of the gage proper and illuminator during observation and operating test indicated adequate reliability for service use.

The illuminator, required for proper water level indication, is adequate from a shock and vibration standpoint; determination of clarity and angle of visibility was satisfactory although there is still room for improvement for close up views of four to five feet from the gage.

The main gage insert possessed advantages, namely in its lightweight and ease in changing parts; however, care must be used in the assembly of the main insert to the bottom water valve, to avoid dislodging the small sealing gasket.

The ball check valve was closed by 58.6 lbs per hour of escaping saturated steam, which is below the required flow rate. The seating ability of the ball check was unsatisfactory, allowing an average leakage of approximately 1000 cc every three minutes and ten seconds.

Although the shut-off valve operation was satisfactory with no leakage throughout the securing tests, as stated on page 4, it was determined that the handwheel torques required for tight closure and re-opening ranged between 20 and 40 lb. ft.
REVISED LIST OF MATERIAL QUANTITIES FOR ONE RH ASS'Y & ONE LH ASS'Y

<table>
<thead>
<tr>
<th>No.</th>
<th>NAME</th>
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<tr>
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<td>Quantity 4</td>
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<tr>
<td>5</td>
<td>Item 5</td>
<td>Manufacturer E</td>
<td>Quantity 5</td>
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</table>

LEGEND FOR ASSEMBLIES

- A: Assembly A
- B: Assembly B
- C: Assembly C
- D: Assembly D
- E: Assembly E

NOTES:

1. All materials are to be delivered on or before the due date.
2. Any changes in material quantities will require a new revision.
3. A detailed bill of materials is available for reference.

PROJECT: B-516

ELEVATION: View A
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**NOTES:**

1. ILLUMINATOR ASS'Y 103280-048
2. HOOD ASS'Y 103190-017

**ELEVATION**

**SECTION X-X**
Shock and Vibration Folder No. 920

Subj: Dura-Port Boiler Water-Level Gage, vibration and shock testing of; NRL Problem F03-15; report on

Ref: (a) NBTL ltr Code 2722-9510(B-490) (B-518) (B-526) of 2 Feb 1962
(b) Mil Spec MIL-STD-167 of 20 Dec 1954 for vibration
(c) Mil Spec MIL-S-901B(Navy) of 9 Apr 1954 for shock

Fig: (1) Gage assembly, prior to modifications, mounted on the table of a reaction type vibration machine. (The boiler drum nozzles are shown in an intermediate stage of development.)
(2) Gage assembly on vibration machine following modifications and development of boiler drum nozzles.
(3) Sketch of suitable boiler drum nozzles to which gage assembly was secured.
(4) Close-up showing modified upper suspension system for gage.
(5) Gage assembly mounted on vibration machine table for testing in horizontal direction perpendicular to the front.
(6) Gage assembly secured to a 30-degree inclined bulkhead fixture and mounted on the table of a medium-weight high-impact shock machine.

Introduction

1. As requested in reference (a) vibration and shock tests in accordance with references (b) and (c) respectively were conducted on a DP-1000 Dura-Port Boiler Water-Level Gage manufactured by Diamond Power Specialty Corporation of Lancaster, Ohio. This report concludes the vibration and shock work on this phase of the problem.

Encl (1) to NRL ltr 6253-49:RCN:dd
SER: 9818
2. The tests were conducted at the U. S. Naval Research Laboratory Washington 25, D. C. during the period 26 February through 16 April 1962 and were witnessed by representatives of the manufacturer, Naval Boiler and Tubbine Laboratory, and BUSHIPS.

Description of Unit

3. The gage assembly without the illuminator and wide-angle viewer weighed 175 lb. Its maximum dimensions were: Height 50-1/2 in.; Width 29 in.; Depth 12 in. The aluminum illuminator and steel wide-angle viewer totaled 33 lb. The illuminator was equipped with seven (7) 28-volt, 40 watt reflector type lamps manufactured by Grimes Mfg. Co. of Urbana, Ohio (Grimes part No. 18022). The gage was hydrostatically pressurized to 1500 psig during the variable frequency, and 2-hr endurance vibration tests, and the shock tests.

Vibration Testing Procedure

4. The unit was tested on a reaction-type vibration machine and was subjected to the outlined test procedure separately in each of the 3 mutually perpendicular directions. The test procedure in accordance with reference (b) was as follows:

   a. Exploratory Vibration Test. With a table excursion of 0.020 in., an exploratory vibration check was conducted between 5 and 33 cps in discrete frequency intervals of 1 cps at 15 sec per interval.

   b. Variable Frequency Test. Vibration was conducted between 5 and 33 cps in discrete frequency intervals of 1 cps at 5 min per interval. The frequency and corresponding table vibratory excursions were as follows: 5-15 cps, 0.060 in.; 16-25 cps, 0.040 in.; and 26-33 cps, 0.020 in.

   c. Endurance Test. A 2-hr test in each direction was required at 33 cps or at any resonant frequency below 33 cps, at the appropriate table vibratory excursion outlined in paragraph 4b.
Exploratory Vibration - Horizontal Direction Parallel with the Front Boiler-Drum Nozzle Development

5. The gage assembly was secured at its mounting flanges to the flanges of a pair of boiler drum nozzles supplied by NBTL. The 1-5/8-in OD x 13/16-in ID steel nozzles were welded to a steel plate which simulated a boiler drum and was secured to a mounting bulkhead on the table of a reaction type vibration machine (Figure 1). With no reinforcing gussets welded to the nozzles the mounted assembly resonated at 14 cps with a TR of 33.5:1 (Transmissibility Ratio is the ratio of the unit's excursion to the vibration table excursion) measured at the gage body. In several stages of development maximum rigidity and the best vibration characteristics of the nozzles were achieved with 4 gussets welded to the nozzles and flanges and steel mounting plate as shown in Figure 2 and delineated in Figure 3. With this arrangement resonance of the gage assembly was observed at 27 cps with a TR of approximately 10:1 measured on the gage.

Development of Gage-Assembly Suspension

6. During the exploratory vibration test the following developmental corrections and modifications were incorporated in the gage assembly to improve its structural and vibration characteristics:

   a) Relative motion between the gage upper and lower valve mounting flanges and the nozzle mounting flanges was eliminated by inserting a ring-type steel spacer between the 2 flanges (Figure 4).

   b) The single-pipe expansion-loop suspension at the upper end of the gage was replaced with a more rigid double-pipe expansion, loop suspension (Figure 4).

   c) Side-to-side relative motion between the upper valve assembly and the upper end of the gage assembly was reduced by a key and keyway block assembly (Figure 4). Clearance between mating parts must be provided at the upper suspension area to allow for thermal expansion.

   d) The suitcase-type latches did not adequately secure the illuminator and wide-angle viewer which were suspended each on four 1/4-in diam. steel pins projecting from the gage. The latches
were removed. The 1/4-in diam. steel pins were each replaced with a 5/16-18NC hex-socket-head cap screw which secured the illuminator and viewer to the gage (Compare Figures 1 and 2).

e) Cracks developed in the viewer around its suspension slots and at the sharp 90-degree bend where it fitted around the gage. The portion of the viewer which was fitted and secured to the gage was reinforced by tack and spot welding a 7/64-in thick formed steel plate to the full length of each side (Figures 2 and 5).

The foregoing corrections and modifications raised resonance above 33 cps and lowered the TR to approximately 6:1 measured at the upper end of the gage body when vibrated in the horizontal direction parallel with the front.

Variable Frequency and Two-Hr Endurance Tests - Horizontal Direction Parallel with the Front

8. The variable frequency test from 5 through 33 cps, and the 2-hr endurance test at 33 cps in accordance with paragraphs 4b and 4c respectively were completed satisfactorily.

Vibration Testing - Vertical Direction

9. No resonances were observed below 33 cps in this direction and the maximum TR of 4.3:1 was measured at the upper end of the gage body at this frequency.

10. The variable frequency test from 5 through 33 cps, and the 2-hr endurance test at 33 cps were conducted without damage or hydraulic leaks.

Vibration Testing - Horizontal Direction Perpendicular to the Front

11. The gage assembly was mounted on the vibration machine table as shown in Figure 5 for testing in this direction. No resonances were observed below 33 cps and the maximum TR of approximately 2:1 was measured at the upper end of the gage.
12. The variable frequency test, 5-33 cps, and the 2-hr endurance test at 33 cps were conducted satisfactorily.

Shock Testing Procedure

13. The gage and nozzle assembly mounting plate was secured to a 30-degree inclined-bulkhead fixture which was mounted on the table of a mediumweight high-impact shock machine (Figure 6). The gage was pressurized to 1500 psig. during the shock testing procedure.

14. With a total of 2925 lb. on the shock machine table the assembly was subjected to a total of 6 Class A shock blows in accordance with reference (c). The shock blows consisted of 2 hammer drops from a height of 1.25 ft with a 3-in table travel, 2 drops from a height of 2.25-ft with a 3-in table travel, and 2 drops from a height of 2.25 ft with a 1-1/2-in table travel. The lamp positions in the illuminator were designated numerically with No. 1 at the top.

15. The results of the shock blows were:

a. Blow 1. 1.25 ft hammer drop, 3-in table travel.

   1. The filaments of bulbs Nos. 1, 3, 6, and 7 fractured. New bulbs were inserted. No other damage resulted.

b. Blow 2. 1.25-ft hammer drop, 3-in table travel.

   1. The filaments of bulbs Nos. 2, 6, and 7 fractured. The bulbs were replaced.

c. Blow 3. 2.25 ft hammer drop, 3-in table travel.

   1. The filaments of bulbs Nos. 1, 3, and 6 fractured. No replacements were made.

   2. A 0.070 in. vertical clearance was measured between the keyblock and keyway block.

d. Blow 4. 2.25-ft hammer drop, 3-in table travel.
1. The filaments of bulbs Nos. 4 and 7 failed. The bulbs were not replaced.

2. A clearance of 0.115 in. was measured between the keyblock and the keywayblock.

e. Blow 5. 2.25 ft hammer drop, 1-1/2-in table travel.

1. The filament of bulb No. 5 failed. The bulb was not replaced.

2. A 7/32-in clearance was measured between the keyblock and keywayblock.


1. No additional obvious damages resulted from this blow.

16. Following completion of shock testing examination of the interior of the viewer showed the lower strip lens to be fractured at the retaining spring, and the upper strip lens was chipped at its lower support bracket. The progressive increase of clearance between the keyblock and keywayblock resulted from slight deformation of the double-pipe expansion assembly. The use of a dovetail-shaped key and keyway would prevent separation of mating parts. No hydrostatic pressure drop resulted in the gage from the 6 shock blows. Following shock testing the gage was pressurized hydrostatically to 2250 psig for 30 min and no leaks were observed.

Conclusions

17. On the basis of the tests conducted the subject gage is considered satisfactory for vibration and shock conditions as defined by references (b) and (c) respectively subject to compliance with the following recommendations.

Recommendations

18. It is recommended that:

a. The gage assembly shall be secured to boiler drum nozzles which are at least as rigid as the modified nozzles developed at NRL and shown in Figures 2 and 3.
b. The modifications and corrections noted in paragraphs 6a through 6e or their equivalent be incorporated in the production model gage assembly.

c. If available, the use of Navy "rough-service" type lamps in the illuminator should be considered.

Report prepared by

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/s/ Harold M. Forkois
Harold M. Forkois
Mechanical Engineer
BOILER GAUGE NOZZLE REINFORCEMENT

60-1-63
6253-49A
Figure 3
| The gage was shock and vibration tested at NRL. The gage insert withstood shock and vibration tests without leakage or glass failure; the illuminator and hood assembly required modification to provide adequate shock and vibration resistance. Readability of the gage, requiring reliance on the color-refraction principle, was considered satisfactory while incorporating a better than 100° viewing angle. Optimum discernment of water level was obtained at (See other card) |
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