



ASIA TURBOMACHINERY & PUMP SYMPOSIUM
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New Concept of On-Line Wash for Centrifugal Compressor

ExxonMobil
Chemical



**MITSUBISHI HEAVY INDUSTRIES
COMPRESSOR CORPORATION**

TEES
**TURBOMACHINERY
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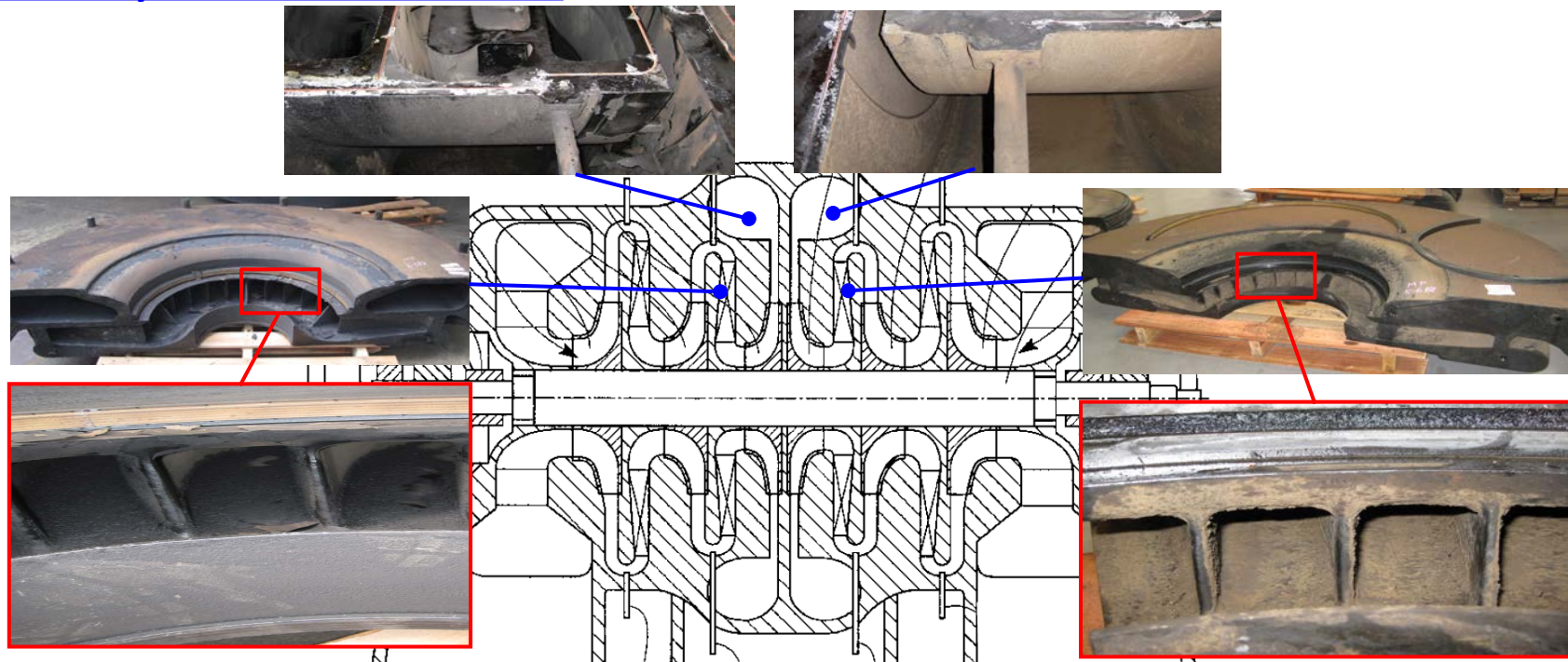
1. Abstract

New concept of on-line wash for centrifugal compressor

- This paper introduces the development of new concept of on-line wash oil injection system which includes the optimization of quantity of washing oil, location of injection nozzles, direction of nozzle entry, hole size as well as control system.
- The process gas compressor is the most critical unit in an ethylene plant and several types of contaminants can often foul the compressor flow path, causing deterioration in performance and significant losses in plant production. In order to prevent the efficiency losses due to fouling during long term operation, wash oil is injected as regular intervals/ continuously in process gas compressors. As common practice, wash oil injection nozzle are usually installed on the suction piping as well as return bend on each stage. Foulant material has been reported during turn around (and with few years of operation) even though wash oil injection has been carried out at required intervals.
- User and OEM investigated the root cause of this phenomenon and constructed the new concept design of on-line wash oil injection system in consideration of wash area, oil quantity, erosion and feasibility of machine construction etc. by means of FEM (Finite Element Method) analysis as well as CFD (Computational fluid dynamics). To verify the effectiveness of this new concept of oil injection system, component test and actual machine verification test was conducted and successfully completed under User's witness.
- After completion of the test, OEM delivered newly developed oil injection system in user site that the fouling materials on the compressors were reported with conventional oil injection system, and commercial operation was started. User and OEM confirmed the effectiveness of newly developed system at site process gas compressor by checking the compressor performance.

2. Background for Improvement of On-Line Wash

Site Survey Result on Turnaround

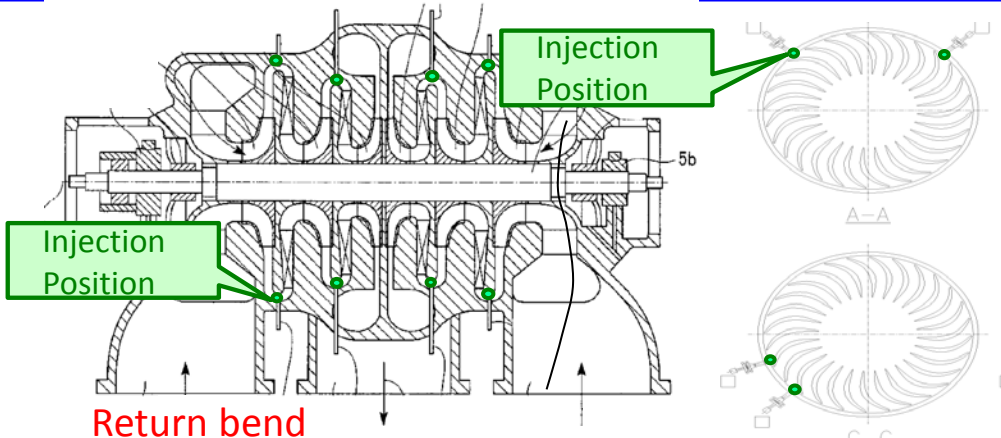


Even though oil injection is carried out from return bend;

- Fouling material on static parts was observed.
- Clogging on wash oil injection nozzle was observed due to fouling.

2. Background for Improvement of On-Line Wash

Investigation of Adhering of Fouling (Conventional Design)

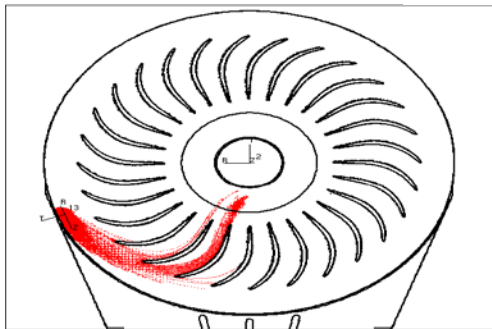
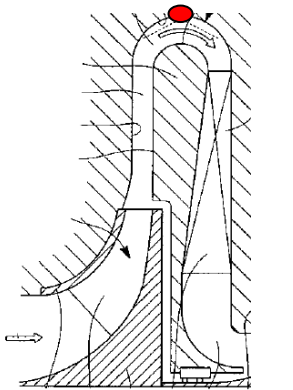


- Injection point is at **return bend** of each impeller stage.
- **2 injection holes** are located per each stages.

Based on CFD analysis, Washing oil does not expand for whole surface by conventional injection method even though the oil flow capacity is increased.



Improvement of washing oil is required for the Fouling protection.



CFD Result

CD-adapco
pro-STAR 4.0
13-MAY-09
VIEW
0.000
0.000
-1.000
ANGLE
0.000
DISTANCE
1.417
CENTER
0.000
-0.000
-1.431
DROPLET PLOT
COUPLES

3. New Concept of On-Line Wash

Implementation step for New Concept of On-Line Wash

Step 1

Investigation of Conventional model

1. Check the washing oil condition for conventional model.
2. Fouling condition survey at site
3. Deposit analysis

Step 2

Development of New concept of On-Line Wash

1. Optimization of nozzle arrangement by CFD.
 - Injection Location
 - Injection droplet size
 - Injection angle
 - Injection flow rate
2. Apply the idea of Momentum Ratio

Step 3

Water Injection Simulation Experiments for Flow Path (Component Test)

1. Fabricate flow path of return vane, Inject water per optimum nozzle arrangement to evaluate CFD analysis result.
2. Test for adjusting injection direction and nozzle arrangement to investigate the effective injection direction and arrangements.

Step 4

**- Full Scale Test
- Risk Assessment for applying existing compressor**

1. Test at full scale model compressor to evaluate New concept of On-Line Wash.
2. Conduct the risk assessment for applying the actual compressor

Step 5

Oil Wash Effectiveness Evaluation on Actual Machine

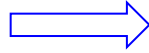
New concept of On-Line Wash has been applied for process compressor in user site, and effectiveness is evaluated.

3. New Concept of On-Line Wash

CFD Analysis Result (Improved Method)

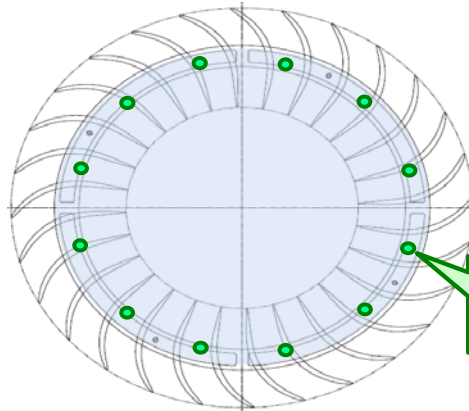
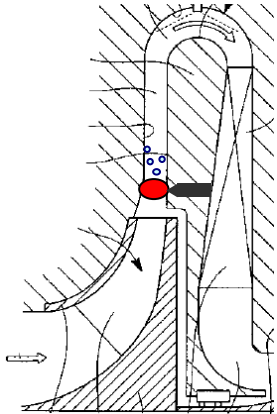
Optimization of following;

- Injection location
- Injection droplet size
- Injection angler
- Injection flow rate



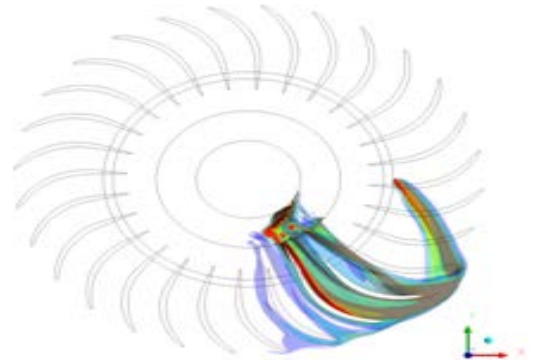
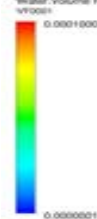
- Confirmed injection from impeller tip (Hub Side) is most appropriate
- Confirmed Momentum Ratio method is applicable to decide injection flow rate and injection hole size.

Near Impeller tip



Injection Position

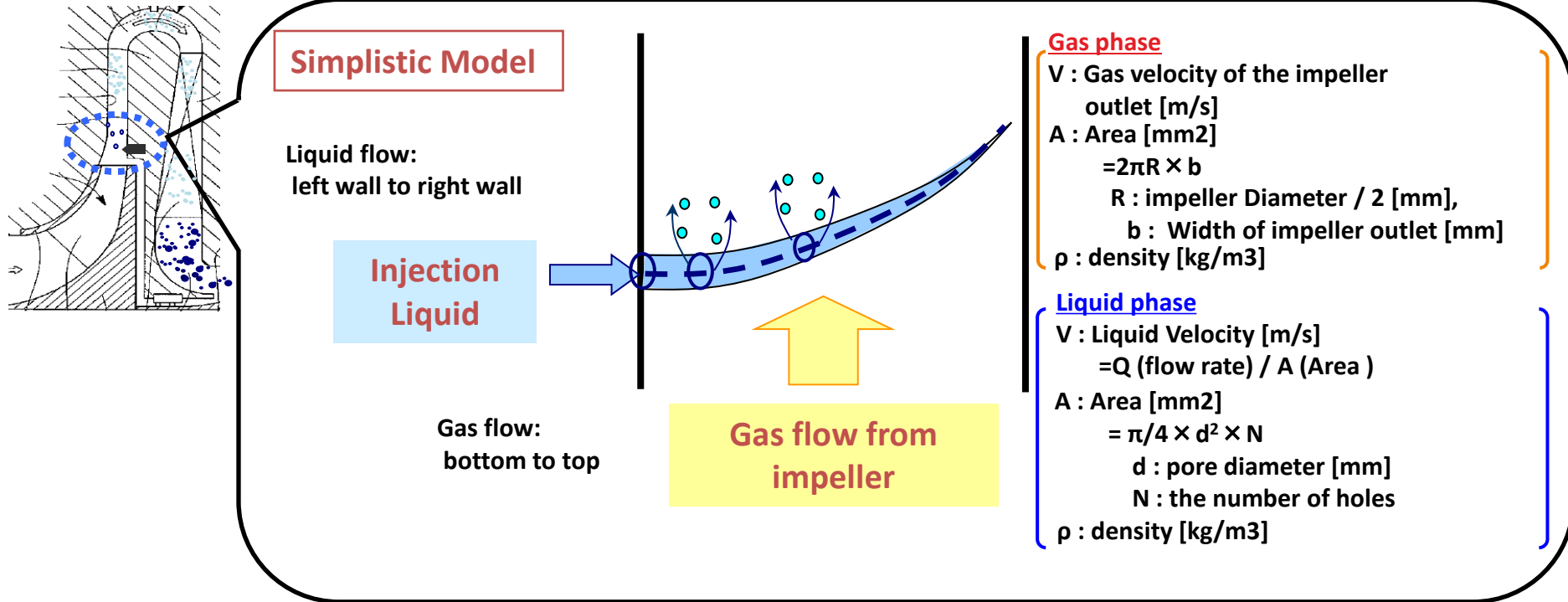
CFD Analysis



Washing oil was expanded 3 flow passages of return vane per 1 injection hole (30 ~ 40 deg) with improved method.

3. New Concept of On-Line Wash

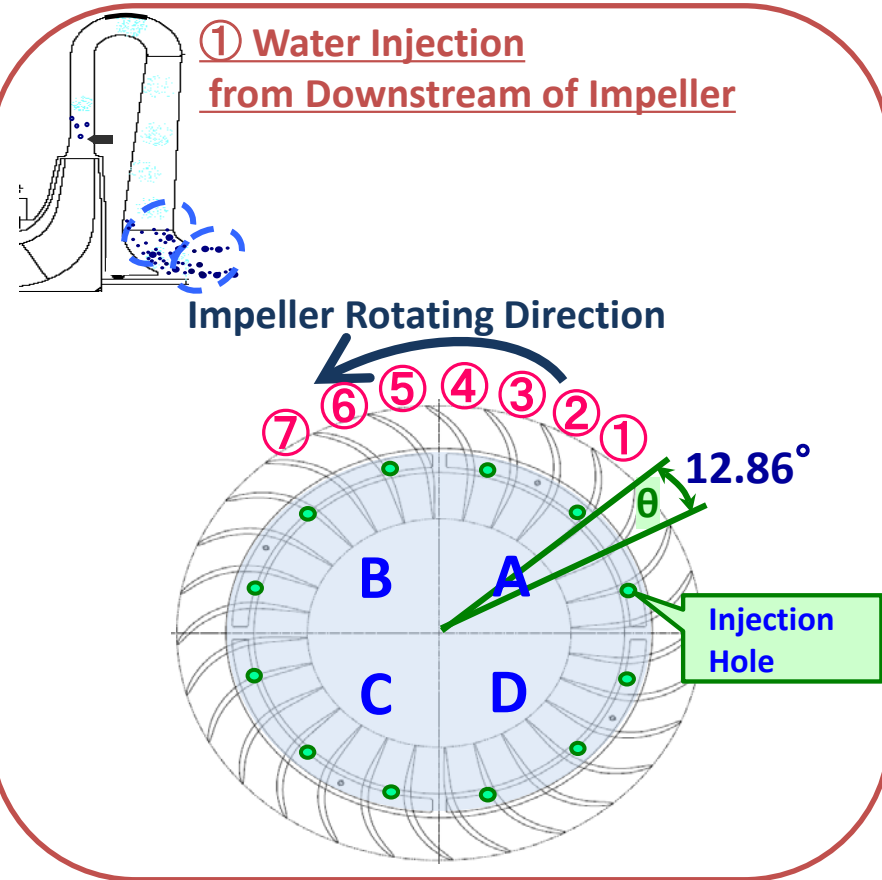
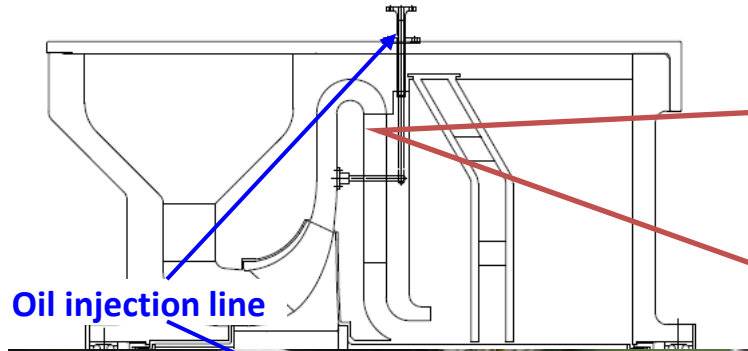
Idea of Momentum Ratio (Gas phase / Liquid phase)



Injection flow rate is decided by Momentum Ratio

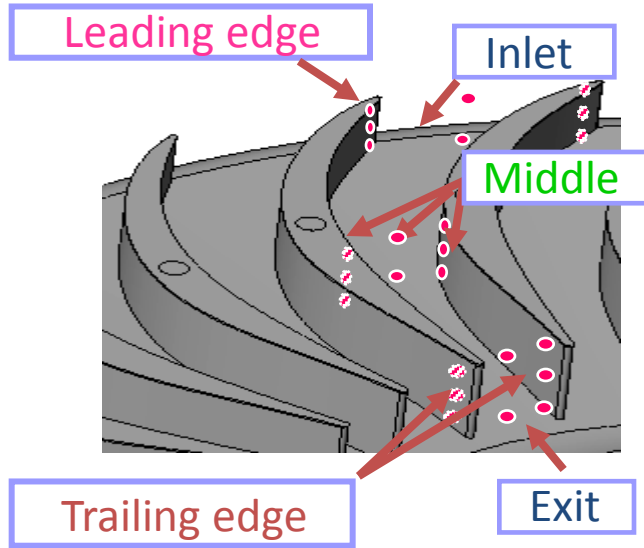
4. Verification Test for New Concept of Oil Injection

Full Scale Verification Test

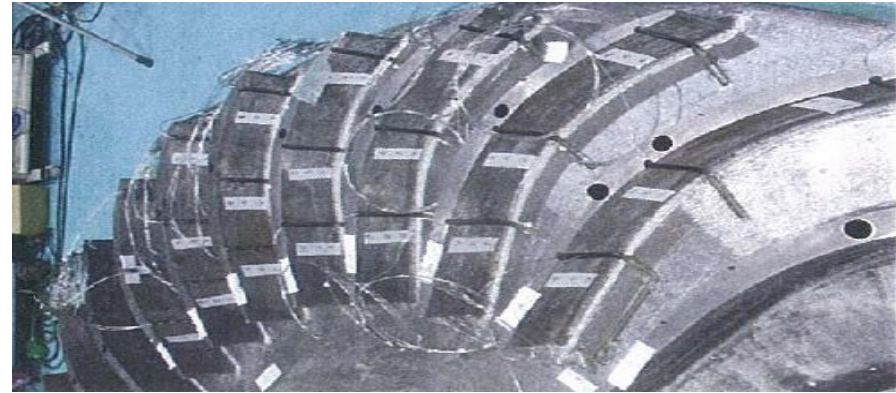


4. Verification Test for New Concept of Oil Injection

Application of Temperature Sensors to confirm wash oil spray condition



Return vane



8 probes for Leading edge / Middle / Trailing edge
(Applied for 7 return vane)



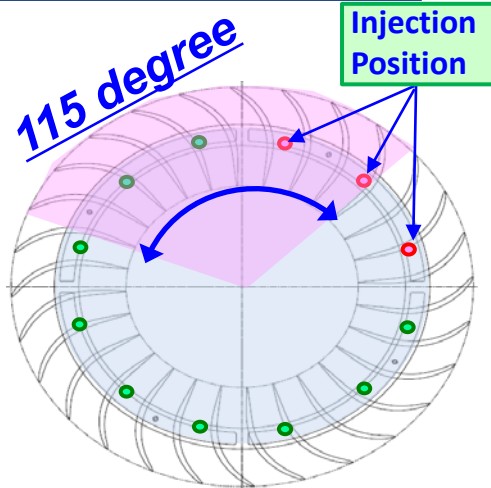
Total 168 points



4. Verification Test for New Concept of Oil Injection

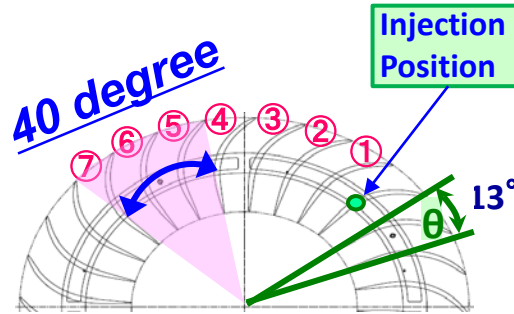
Comparison with Component Test & CFD Calculation

< Full Scale Test Result >



Water was expanded 9 flow passages (about 115 degree) of return vane per 3 injection holes.

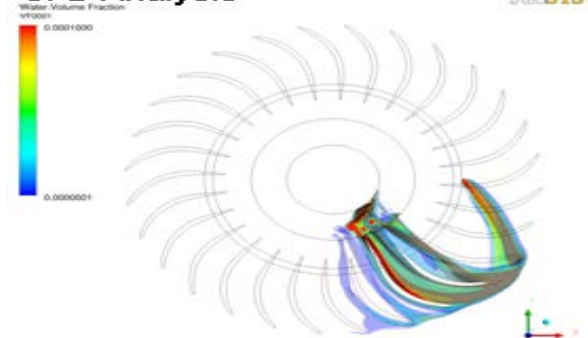
< Component Test Result >



Water was expanded 3 flow passages of return vane per 1 injection hole.

< Calculation Result >

CFD Analysis



Water was expanded 3 flow passages of return vane per 1 injection hole.

➔ **Test results and CFD calculation result are well agreed.**

5. Application of New On-Line Wash for Existing Comp.

Configuration for Existing Compressor

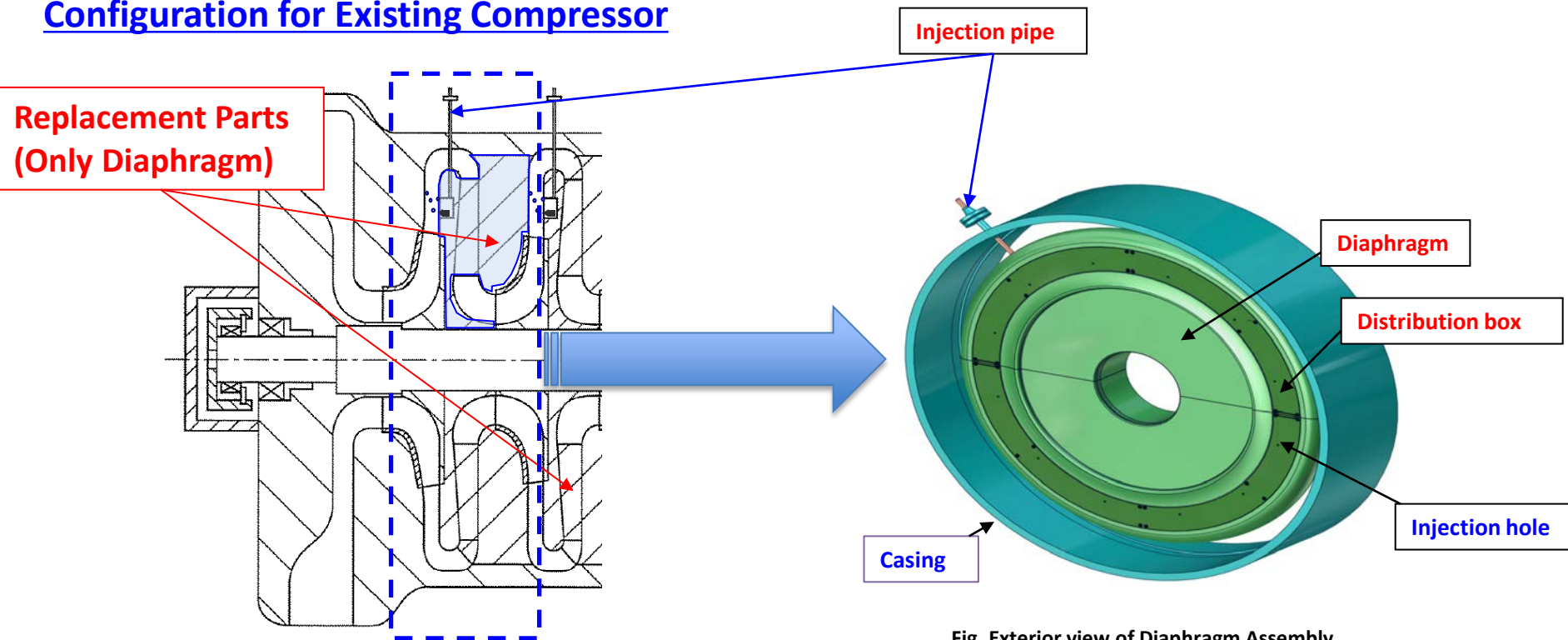


Fig. Exterior view of Diaphragm Assembly

5. Application of New On-Line Wash for Existing Comp.

Verification Test of Wash Oil Injection System



< Hydraulic test >



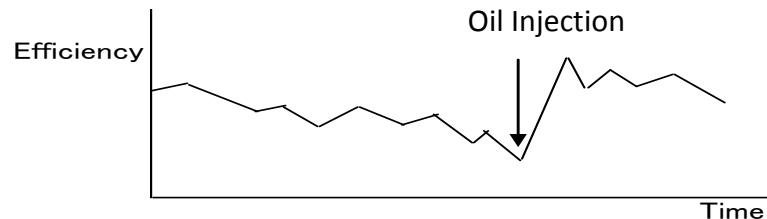
< Flow was sprayed equally >

5. Application of New On-Line Wash for Existing Comp.

Evaluation Point in User Site

➤ Confirmation of Performance Trend;

Investigate the effectiveness of washing oil system by performance trend data.



➤ Confirmation of Actual Fouling Area;

Investigate the place where fouling occurs or does not occur, and compare the data of past & [forthcoming](#) turnaround.

➤ Confirmation of Condition of Injection Hole;

Confirm no clogging occurred on injection hole at [forthcoming](#) turnaround.

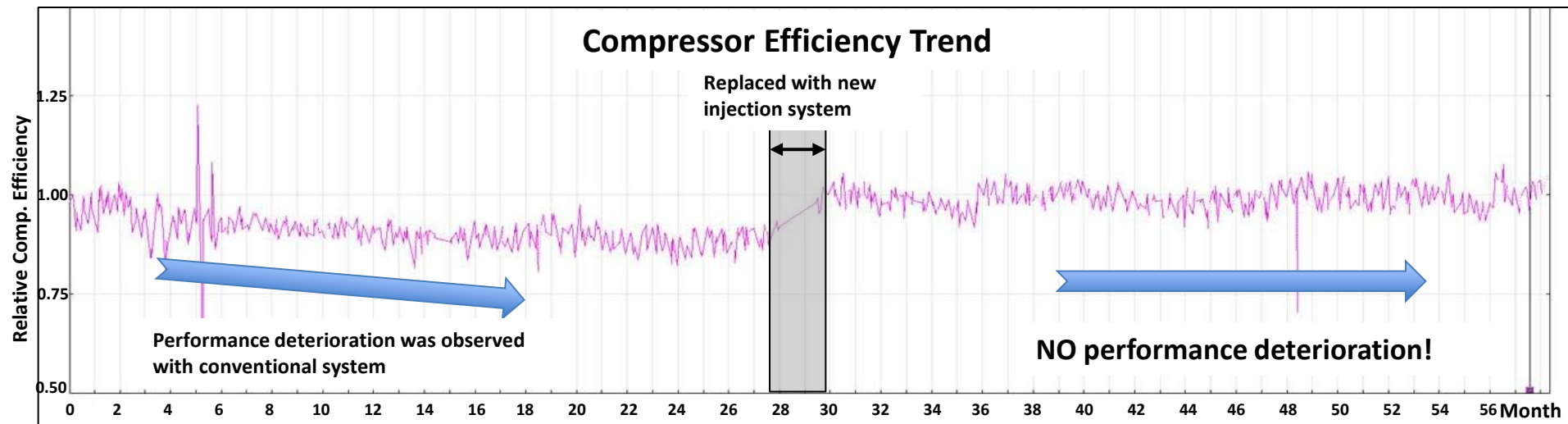


5. Application of New On-Line Wash for Existing Comp.

Evaluation Point in User Site

➤ Confirmation of Performance Trend;

Investigate the effectiveness of washing oil system by performance trend data.



NO performance deterioration was observed after replacement with new injection system for more than 30 months.

Effectiveness of new injection system was confirmed.



6. Conclusion

- 1. The fouling materials on the compressors were reported with conventional oil injection system.**
- 2. New Concept of On-Line Wash was developed**
 - Optimization of following;
 - Injection location
 - Injection droplet size
 - Injection angler
 - Injection flow ratio
 - Application of Momentum Ratio
- 3. Wash oil injection from near impeller tip is effective.**
- 4. Application of Momentum Ratio is effective for deciding injection flow rate and hole size.**
- 5. Effectiveness of newly developed system was confirmed by compressor efficiency trend and compressor internal condition will be checked at forthcoming turnaround.**

Thank you for your attention

