# *Fiber Optics Condition Monitoring System for Piping*

## Towards new standard in plant operational safety and equipment reliability

### We assembled a team of most talented and experienced engineers to deliver this cutting-edge system to you, and to create new value for your business.

**Fiber optics condition monitoring can be applied throughout plant facilities, improving the equipment reliability and increasing the effectiveness of plant maintenance.**

The idea of using optical fibers as a tool for the condition monitoring of equipment and structure is very attractive and has been envisioned for many years. The core technologies involved are optical fiber sensing, computational mechanics, special optical fibers manufacturing and installation techniques. However, despite several technological breakthroughs over the recent years, the system as a whole, has never been completed. As it became clear, even if all components were developed and maturing, the expertise on system integration, technology implementation, and management were required.

After almost 10 years of research and development, cooperation in engineering team, and numerous trial-and- error tests and projects at plants facilities, we finally found effective and reliable methods of data acquisition and processing. Now, our consortium of 3 companies can announce a commercial release of the optical fiber condition monitoring system.

The cutting-edge technology of the system should considerably improve the plant operational safety and equipment reliability and plant facilities, and in return, enhance those productivity.

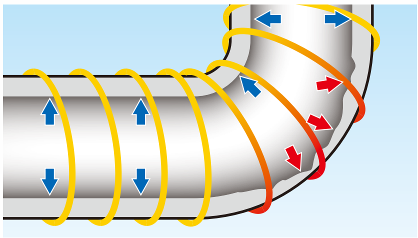
CHIYODA CORPORATION NEUBREX KURIHALANT

# The core technologies

## System principles

### 1.Condition monitoring

Install the optical fiber module in spiral pattern and collect data.



**Optical fiber module for strain/temperature measuring:**

➡In the thinning area strain distribution exhibits a local variation. This can be detected by the optical fiber sensors installed at the outer surface of the pipe. Using obtained strain distribution, the inner thinning can be analyzed.

### 2. Measuring / Analysis

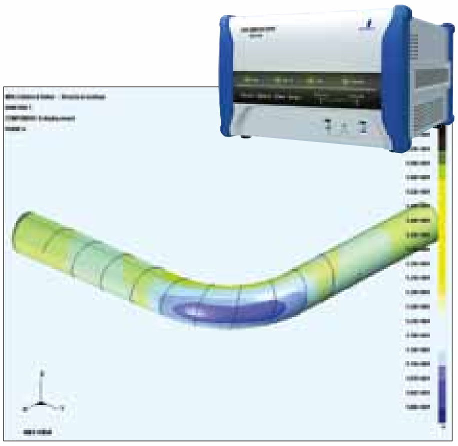
Pulse Pre-Pump Brillouin Optical Time Domain (PPP-BOTDA) measures the surface strain. Using measured data the Inverse Analysis is capable of quantitatively calculating the conditions of piping (deformation / temperature / thinning).

**PPP-BOTDA:**

➡Detectable strain change ± 5 με
Spatial resolution 10 cm

**Computer Aided Engineering (CAE) tools:**

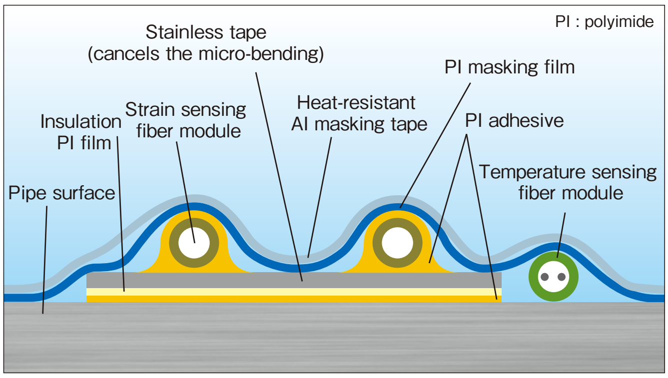
➡Advanced numerical inverse analysis methods.
Identify the conditions of the pipe (and/or the boundary condition) using the measured strain and temperature distributions



## Optical fiber module

### We developed the industry leading optical fiber module.

*Heat-resistant up to 300 °c
*Installable on rough surfaces (against for micro-bending)




## Fiber installation

### Once installed, the fiber enables a long-term monitoring.

*In compliance with the original quality standards for implementation proved by laboratory and verification test, practical installation is carried out.

## Total management solution

**Consulting services, from fiber installation planning to data management, enable you to improve plant monitoring system. In return, they ensure the safety and reliability, and improve profitability of plant assets.**

# Next generation condition monitoring system for plant equipment

Fiber optics condition monitoring system improves the plant operational safety and equipment reliability.

## Highly effective safety control system

### Solutions ~what we can offer~

- Improved plant operational safety and reliability
- Cost competitiveness through manpower saving and increased productivity
- Accurate life estimation by full time monitoring
- Improvement of productivity by efficient maintenance
- Effective plant management via remote monitoring system

### Features

#### Highly accurate remote monitoring system

- Monitoring of entire plant
- Precise distributed monitoring using just a few optical fiber modules
- Remote control using the existing communication lines
- No additional space for sensors required

#### High Safety

- Intrinsically safe(can be directly installed in the flammable atmosphere)
- Non-inductive and is not affected by electromagnetic wave / lightning / electrical surge
- No working risks for inspection

#### Manpower saving

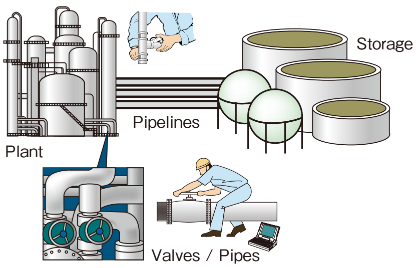
- Installable on existing facilities
- Real time monitoring during plant operation as well as during plant shutdown
- Cost effective maintenance / inspection cost

#### Data management

- Collect data via periodical/regular measurements
- Automatically detects failures and predicts the deformation pattern by analyzing gathered data
- Enables the assessment of the whole plant, such as the life diagnostics

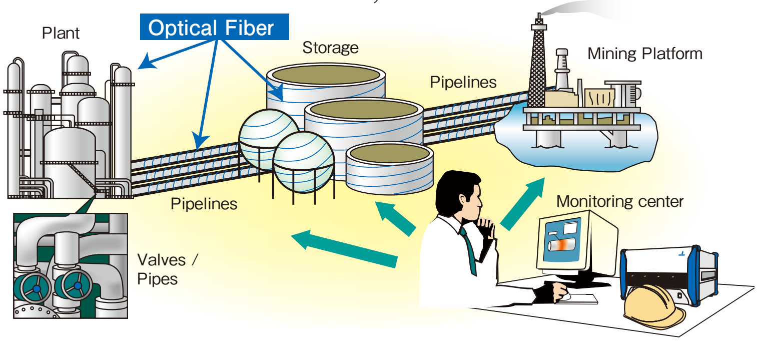
#### before installing the system

- Scheduled and manually measurement
- Requires expertise to inspect




#### After installing the system

- Permanent and remote monitoring
- Data available on demand /automatically

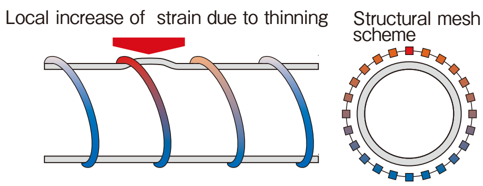



### Suitable applications

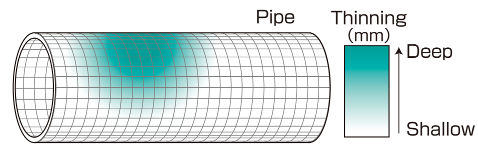
- Oil & Gas
- Chemical plants
- Power plants
- Pipelines
- Structures

### Piping monitoring targets

- Wall thickness
- Thinning (location and shape)
- Deformations (bending and dents)
- Temperature distribution




Layout example appropriate for 3D analysis




3D analysis result in the thinning area

OVERVIEW OF SYSTEM

# Workflow & power plant application example

## 1. Introductory Consulting

**Investigating piping specification, and classifying and selecting services to apply.**

Proposing measuring, specification and schedule of monitoring, based on the purpose and the available period according to the client's direction.

Carrying out site investigation of piping layout, etc., classifying and selecting services to apply.

### Contents of investigation

**Investigation through hearing of the client and analysis of existing data**
- The number of parts / operating history / records of inspections
- Piping materials / operating condition ( temperature / pressure )

**Classification and selection of applicable services**

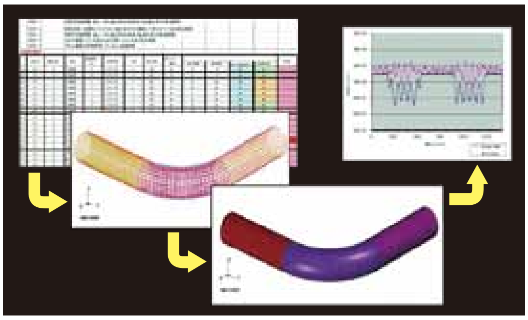
**Decision on measuring program depending on the purpose**
- Estimation of wall-thickness　Estimation of remaining life span

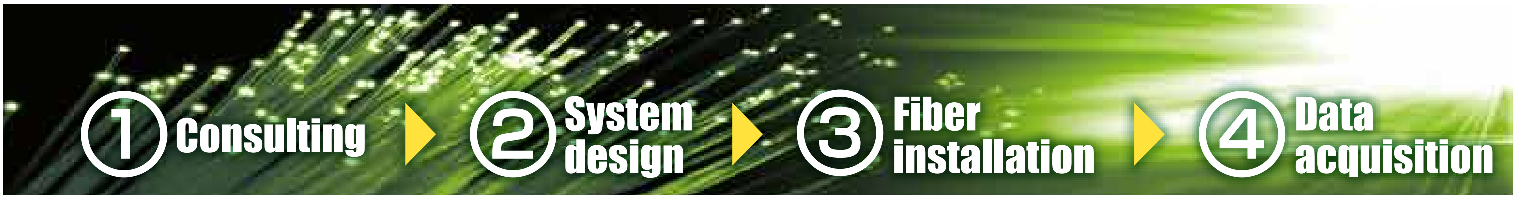
## 2. System design

**System design and component selection are based on the field study.**

### Input basic data of piping layout

Piping diameter / Design pipe wall thickness / fluid pressure / Temperature / Young's modulus / Elbow curvature / preliminary Investigations analysis, etc.





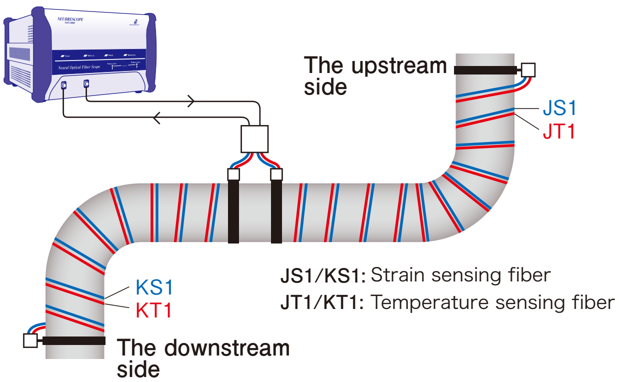

## 4. Strain distribution data acquisition

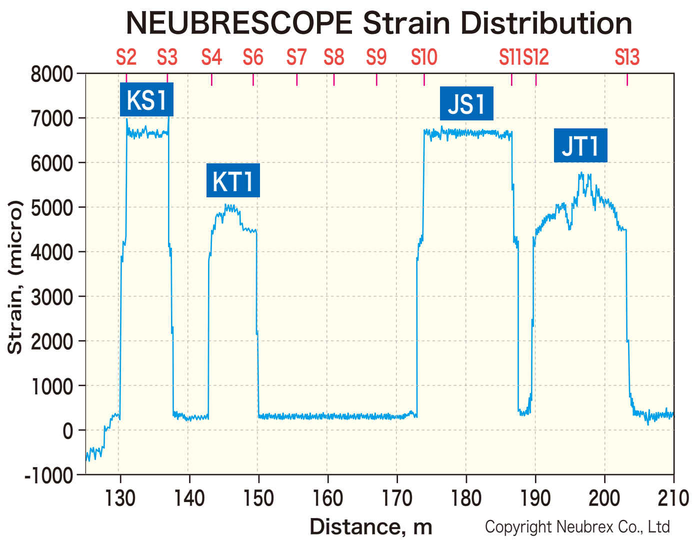
**Collect required data.**

Input the optical fiber location into the analysis system and link it with measurements results.

### PPP-BOTDA detection levels

| | |
|---|---|
| Detectable strain change: | ± 5 με |
| Detectable temperature change: | ± 0.25 °C |
| Measurement speed: | 5 s / 100 m |



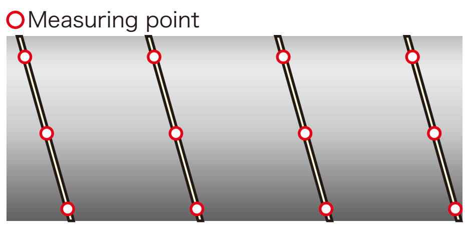

## 5. Data analysis

**The data analysis algorithm depends on the diameter of monitored pipe.**

### Pipe diameter 4 inches or more

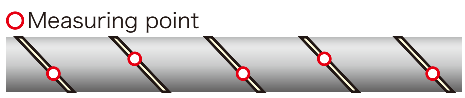
PPP-BOTDA* system offers 10 cm spatial resolution and thus provides enough measurement points for 3D inverse analysis. Inverse analysis enables the quantitative assessment (location, thinning size, remaining thickness etc.) of pipeline state.

Note: *PPP-BOTDA = Pulse Pre-Pump Brillouin Optical Time Domain Analysis




### Pipe diameter less than 4 inches

On the small-diameter pipe, the number of measurement points is lower than required for full 3D inverse analysis and qualitative or semi-quantitative methods are employed.




① **Qualitative analysis**
- Specify possible thinning location
- Determine UT inspection priority level

② **Semi-quantitative analysis**
- Set strain threshold value, thinning level, and corresponding warning level

## 3. Optical fiber sensor installation

### A specially trained technicians install the system in the existing facilities

**Installation procedure**

1. Remove insulation
2. Mark a line along the route of sensor laying , and remove rust preventive from the pipe
3. Lay strain and temperature compensation fiber
4. Repaint rust preventive
5. Reinstall insulation and restore
6. Start monitoring

*1 For the arrangement of one monitoring section, it takes for a maximum of 2 days. ( setting up scaffolding excluded . Several workings in parallel are practicable. )





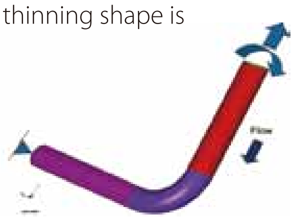



## 5-A. Quantitative analysis

Quantitative analysis is performed by means of inverse methods. Pipe thickness is estimated, location, and thinning shape is estimated using distributed strain data.

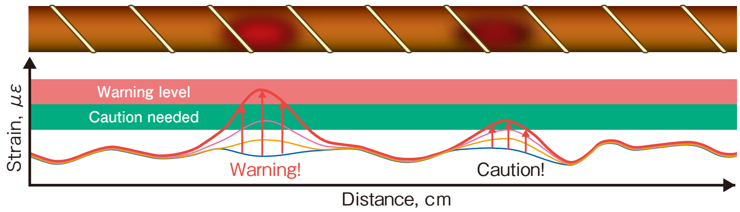
- Pre-processing: Prepare the 3D mesh model / Apply boundary condition*
- Analysis: Estimate the thinning shape and location

*Boundary condition: load superposition principle



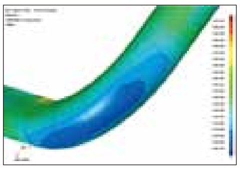

## 5-B. Qualitative analysis

Qualitative analysis and alarm setting can be performed using threshold-based analysis of the measured data.




## 6. Reports

All analysis results can be displayed in 3D, exported to third-party formats, backup, and stored in NEUBREGATE (option) database system.



## 7. Long-term management

**Measurements data, residual life analysis, and thinning rates are stored in NEUBREGATE (option) database system.**

The system leverages company's maintenance and knowledge sharing support by

- Incidents management
- Defects reporting (using defined/imported failure codes)
- Investigation & Solution reporting
- Knowledge management

**NEUBREGATE System**

- Creates and manages predefined responses to problems and lessons learned
- Schedules preventive, predictive, routine maintenance
- Assists in management decision-making process

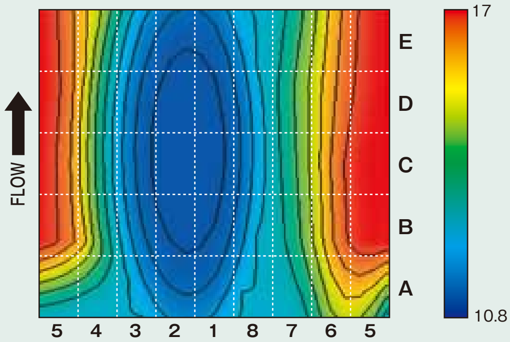
## Inverse analysis vs. existing methods (UT testing)

UT tested result in a meshed model

| | 5 | 4 | 3 | 2 | 1 | 8 | 7 | 6 | 5 |
|---|---|---|---|---|---|---|---|---|---|
| E | 17 | 15.3 | 13.4 | 11.7 | 11.2 | 11.6 | 13.8 | 15.9 | 17 |
| D | 17 | 15.3 | 12.8 | 11.3 | 10.8 | 11.7 | 14.2 | 16.1 | 17 |
| C | 16.9 | 15.1 | 12.7 | 11.3 | 10.9 | 11.6 | 14.1 | 16.4 | 16.9 |
| B | 16.8 | 15.3 | 12.7 | 11.2 | 10.9 | 11.5 | 13.9 | 16.3 | 16.8 |
| A | 12.5 | 12.3 | 12.5 | 11.7 | 11.3 | 11.8 | 13 | 14.7 | 12.5 |

**Detected minimum wall thickness: UT testing: 10.8 mm**

Optical fiber monitoring result




**Detected minimum wall thickness: Optical fiber sensing: 10.3 mm**

Comparison of UT scan (left) and optical fiber sensing (right)

### <Monitored site>

Electric power plant
Steam drain-piping
Material STPG370
Components: 8inches Sch80 90° elbow
Designed wall-thickness: 12.7 mm
Pressure (operating): 4.52 Mpa
Temperature(operating): 228 °c

## Detection levels

**The system can detect strain change of 5 με. Table below lists the detectable thinning levels.**

Note: Results below are obtained by simulations. The results on actual pipeline may vary.

| Pipe size | | Detectable thinning<br>Thinning percentage/thinning amount | | | |
|---|---|---|---|---|---|
| Inner pressure | | 1MPa | 3MPa | 7MPa | 15MPa |
| 100A<br>4B | Sch40<br>wall-thickness 6.00 mm | 40.4 % | 18.4 % | 8.8 % | 4.3 % |
| | | 2.42 mm | 1.11 mm | 0.53 mm | 0.26 mm |
| | Sch80<br>wall-thickness 8.60 mm | 49.3 % | 24.5 % | 12.2 % | 6.1 % |
| | | 4.24 mm | 2.10 mm | 1.05 mm | 0.52 mm |
| 200A<br>8B | Sch40<br>wall-thickness 8.20 mm | 32.9 % | 14.0 % | 6.5 % | 3.2 % |
| | | 2.70 mm | 1.15 mm | 0.54 mm | 0.26 mm |
| | Sch80<br>wall-thickness 2.7 mm | 43.1 % | 20.2 % | 9.8 % | 4.8 % |
| | | 5.48 mm | 2.56 mm | 1.24 mm | 0.61 mm |
| 300A<br>12B | Sch40<br>wall-thickness 10.3 mm | 30.1 % | 12.4 % | 5.6 % | 2.72 % |
| | | 3.10 mm | 1.28 mm | 0.58 mm | 0.28 mm |
| | Sch80<br>wall-thickness 17.4 mm | 41.3 % | 19.0 % | 9.2 % | 4.6 % |
| | | 7.20 mm | 3.31 mm | 1.60 mm | 0.8 mm |
| 400A<br>16A | Sch40<br>wall-thickness 12.7 mm | 28.7 % | 12.2 % | 5.51 % | 2.68 % |
| | | 3.65 mm | 1.55 mm | 0.7 mm | 0.34 mm |
| | Sch80<br>wall-thickness 21.4 mm | 40.5 % | 18.7 % | 8.9 % | 4.4 % |
| | | 8.66 mm | 4.0 mm | 1.9 mm | 0.95 mm |

0-5%
5-10%
10-15%
15-20%
20-25%
25-30%
30-35%
35-40%
40-50%
50%
Out of range

A : mm B : inches

Condition 1: Carbon steel pipe (for pressure piping / JIS G3454-1998)
Condition 2: Installation pitch equals to pipe outer diameter (spiral layout)
Condition 3: Overall thinning
Condition 4: Pipe temperature is 25℃ (ambient temperature)
Condition 5: Restrictions along the pipe closed caps ends
Condition 6: Straight pipes

## The consortium of 3 specialized companies offers you the next-generation solutions for plant maintenance


Contact us


**NEUBREX Co., Ltd.**

Sakaemachi-dori 1-1-24, Chuo-ku, Kobe, Hyogo 650-0023, JAPAN

TEL +81-78-335-3510 FAX +81-78-335-3515

www.neubrex.com/