Current Status of Deliberation in SANE Committee

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and Lessons Learned from the Niigata-ken Chuetsu-oki Earthquake
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Outline

- Background of establishing SANE Committee, action items and record of activities
- Outline of deliberation status
  - Extraction of the study items from the KK NPS inspection output.
  - Extraction of study items from the integrity assessment flow charts
  - About deliberation status in the working groups
- Discussion about the concept of “Structual Integrity Assessment”

Background of establishing SANE Committee

- No serious damage was externally found on the important safety components of high seismic design class in KK NPS that suffered the earth quake
- It is, however, necessary to confirm the integrity of the important components having experienced the seismic load exceeding the design limit and the leading researchers and specialists in each field got gathered to study the criteria for the integrity assessment.

- ”Structural Integrity Assessment Committee for Nuclear Components damaged by Earthquake (SANE) Committee” was established in September, 2007 by Japan Nuclear Technology Institute.

Study items by SANE

- Study on the integrity assessment method for the components that underwent the seismic load
  - Study on method and procedure for estimating influence (change in strength, strain, etc.,) of the seismic load
  - Study on method and procedure for integrity assessment of the components that underwent the seismic load
  - Study on criteria for integrity assessment
- Integrity assessment and margin evaluation of the plant components
  - Estimate seismic influence with representative components and integrity using analysis.
  - Estimate real strength of actual plants including the design margin.

Components to be evaluated

- Components to be evaluated
  - Important safety components that suffered the seismic load
- Study items
  - Evaluation by inspection and test
    - Standard for VT, Method of additional tests, e.g., NDI
  - Evaluation by analysis
    - Criteria for integrity assessment
    - Study on appropriateness of TEPCO′s analysis results
  - Evaluation of cumulative damage of materials suffered the seismic load
  - Others

Constitution of Committee Members

- Constitution of Committee Members
  - 18 members of erudition leading each academic field
    - ✓Structural strength / Seismic 7
    - ✓Inspection technology 5
    - ✓Fatigue / Material strength 5
    - ✓Anchoring bolt 1
  - Regular participants:
    - ✓Power companies, Plant makers, etc., 40

Record of Committee Activity

- Record of activity
  - The committee held 5 times since establishment in Sep., 2007. More than 60 people concerned participated each time.
  - Walkdown in NPS by Committee members in Oct. and Nov., 2007.
  - Detailed studies by WGs for each engineering field
    - Evaluation Standard WG, Inspection WG, Fatigue / Material experiment WG, Dynamic evaluation WG, Anchor evaluation WG, Aging WG

- Report to be issued
  - Interim report prepared around end of March, 2008

Inspection of KK Nuclear Power Station (1)

Anchor bolts for RPV, Unit 1 (As)

Inside turbine cabin, Unit 1 (B)

Primary loop recirculation. Pump, Unit 1 (As)

Pressure control unit, Unit 1 (As)

No apparent damage observed

Inspection of KK Nuclear Power Station (2)

Fuel tank for emergency diesel generator, Unit 1 (C))

Filtrate tank, Unit 4 (C)

Ground subsidence, Unit 2 (-)

Anchor bolts of main transformer, Unit 2 (C)

Buckling, Deformation, Failure, etc., observed among low seismic class

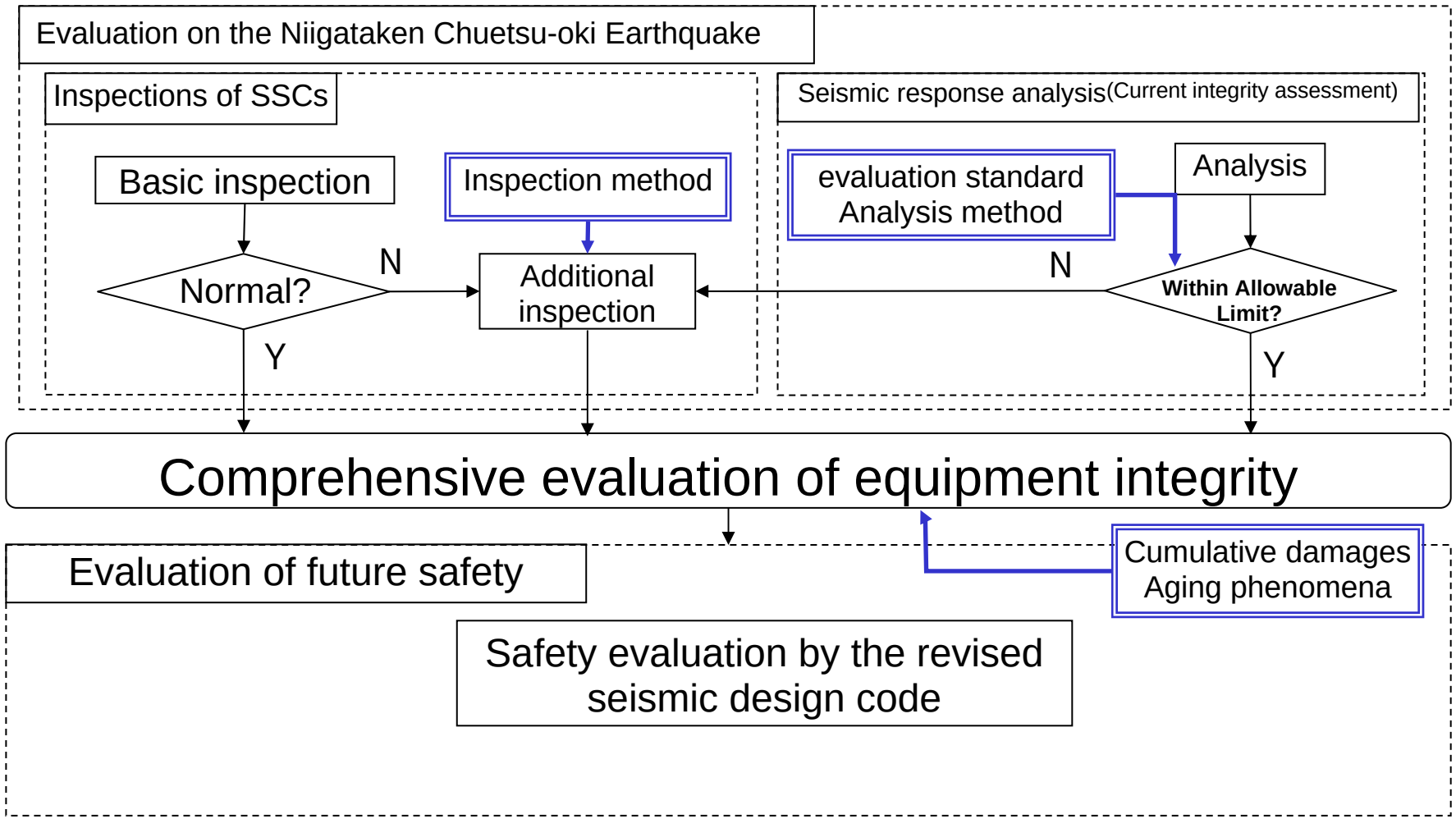
Comments during inspection

- This inspection revealed that at least the components and pipe of As and A class have no structural damages.
- Damages took place only in the area where relatively large displacement occurred between the buildings and the ground or on the components of the lower seismic classes.
- For the tanks and bolts, degree of the damage differs depending on their seismic classes. Seismic strength of them should be compared and discussed.
- It is recommended to investigate the possibility of detecting small displacement in the components for confirmation.

Integrity assessment

Object：Static components of A or As seismic class and class 1
-Pipe, Vessel, Support, Anchors　etc,.

:Theme for integrity assessment



Working Groups under SANE Committee

- 6 WGs under the committee made detailed studies on the below important fields.
  - Estimation Standard WG
  - Inspection WG
  - Fatigue / Material Test WG
  - Dynamic Estimation WG
  - Anchor Bolt & Nut WG
  - Aging WG

Estimation Standard WG (1)

Integrity assessment for the present
(immediately after Niigataken Chuetsu-oki Earthquake)

Definition of Integrity

All of the followings shall be achieved.

- Certain achievement of the safety functions of “Shut down”, “Cool down” and “Isolation” on the Earthquake
- No excessive plastic deformation and enough margin to lower limit of collapse load
- No progressive deformation
- No fatigue failure

>> Allowable Stress Condition “III_AS” of JEAG4601 or “Equivalent III_AS” is satisfied.

Estimation Standard WG (2)

Integrity assessment for the present
(immediately after Niigataken Chuetsu-oki Earthquake)

Status estimated to be integrity

1) No abnormality found by Basic Inspection and the calculated arising stresses satisfy the allowable stress condition III_AS of JEAG4601

2) No abnormality found by Additional Inspection and the calculated arising stresses satisfy Equivalent III_AS standard defined based on the latest knowledge from the domestic / foreign codes

If estimated to be integrity >> Evaluate the future safety
If estimated not to be integrity >> Repair, Strengthen, Exchange

Estimation Standard WG (3)

Safety assessment for the future

Definition of Safety

All of the followings shall be achieved.

- Certain achievement of the safety functions of “Shut down”, “Cool down” and “Isolation” on the Standard Design Earthquake, “Ss”
- No plastic deformation leading to elastic failure
- No progressive deformation
- No fatigue failure

>> Allowable Stress Condition “IV_AS” of JEAG4601 or “Equivalent IV_AS” is satisfied

Estimation Standard WG (4)

Safety assessment for the future

Status estimated to be safety

Status estimated to be integrity and

1) Arising stress due to “Ss” predicted by analysis satisfy the allowable stress condition IV_AS of JEAG4601
2) Arising stress due to “Ss” predicted by analysis satisfy Equivalent IV_AS standard defined based on the latest knowledge from the domestic / foreign codes

If estimated not to be safety >> Repair, Strengthen, Exchange

Estimation Standard WG (5)

- Study Items for analysis and estimation
  - Conservativeness of JEAG4601(“Guideline for Seismic Design of Nuclear Power Station”)
    - ✓Pipe’s damping ratio is small
    - ✓Piping system experiment performed by NUPEC shows enough safety margin
    - ✓Revision of the code for Seismic Design of Nuclear Power Station with the latest knowledge is proceeding in Japan
  - ASME revised the standard of the allowable stress for pipe based on dynamic test results (1994)

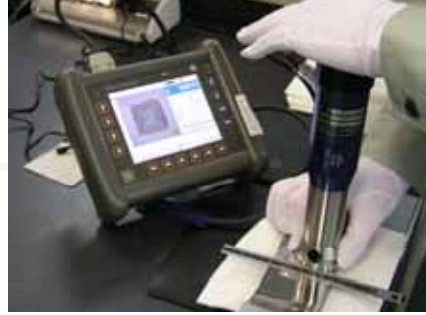
Estimation Standard WG (6)

- Investigation on the latest technologies and study on applicability of them
  - Technical background of the code of seismic design for nuclear power station (JEAC4601-2008) which is being revised
    - ✓ Pipe's damping ratio, allowable standard
  - JSME Code design and construction for Nuclear Power Facilities
    - ✓ 【Code Case】"Alternative rule of strength estimation of Class 1 vessel using elastic-plastic FE analysis" (currently calling for public opinions)
  - ASME Code (Sec. III Allowable stress standard for pipe)
    - ✓ Application of allowable stress standard
  - EPRI
    - ✓ EPRI NP-6695

      "Guidelines for Nuclear Plant Response to an Earthquake"
  - IAEA
    - ✓ Safety Reports Series No.28

      " Seismic Evaluation of Existing Nuclear Power Plants "

Inspection WG (1)



- Study Items
  - Position of inspection / test in integrity assessment
    - ✓Distinguish the important components with the analysis results from the other components without them
  - Inspection / Test for the actual plants
    - ✓Select inspection points in accordance with the analysis output and degree of representative
    - ✓License and skill required for inspection and estimation
  - Inspection / Test method
    - ✓VT
    - ✓NDI (PT, UT, etc.,)
    - ✓Plastic strain measurement (Trial)

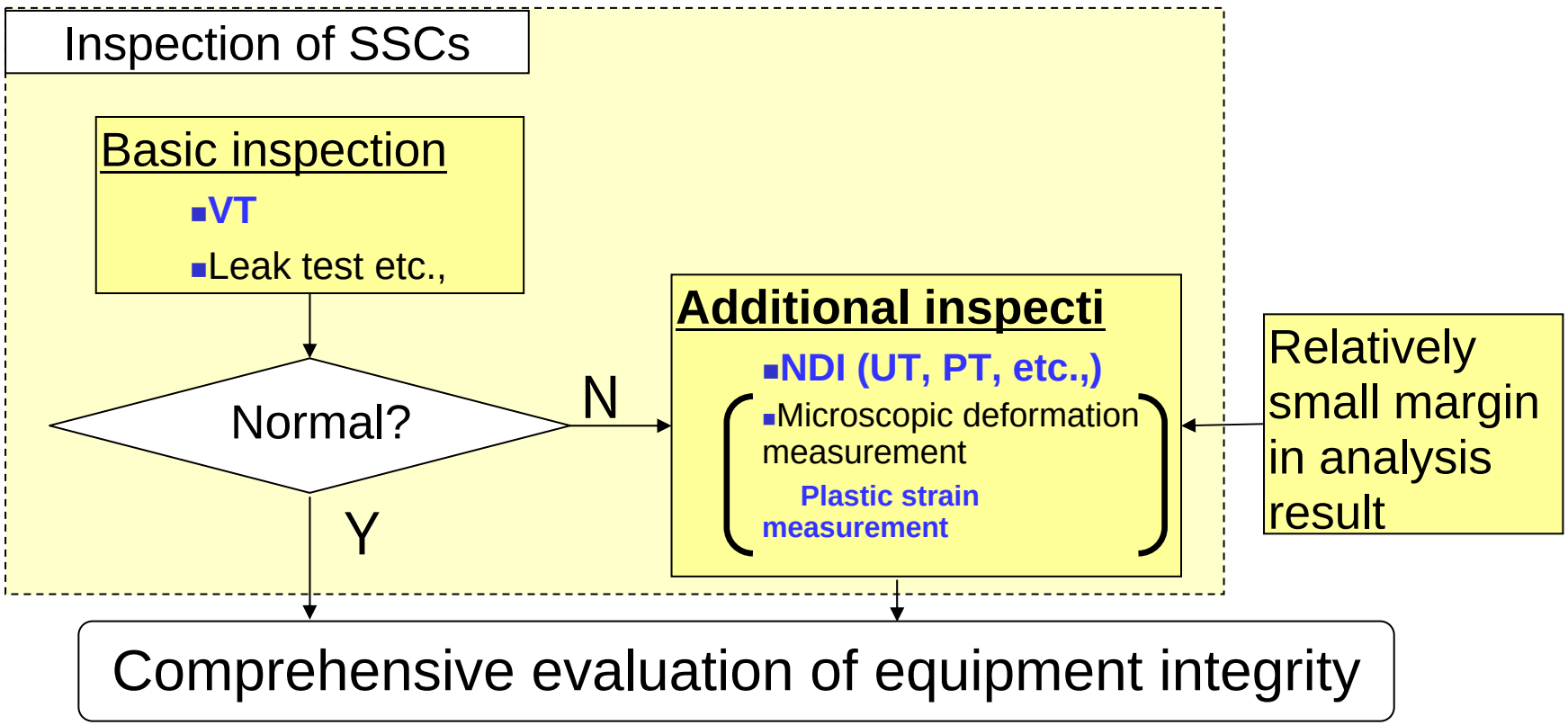
Inspection WG (2)

- License and skill required for inspection and estimation
  - VT
    - Verification of eyesight
      - Application of NDIS 3413 “Method of vision acuity and color vision test for non-destructive testing personnel”
    - Term of experience, companies’ internal certification, education, record of training, etc., requisition for appropriate skill
  - NDI
    - Requirement for license / skill
      - NDIS 0601 NDI engineer, class 2 or higher
      - JIS Z 2305 License and certification of NDI engineer, class 2 or higher
      - Skill equivalent to the above

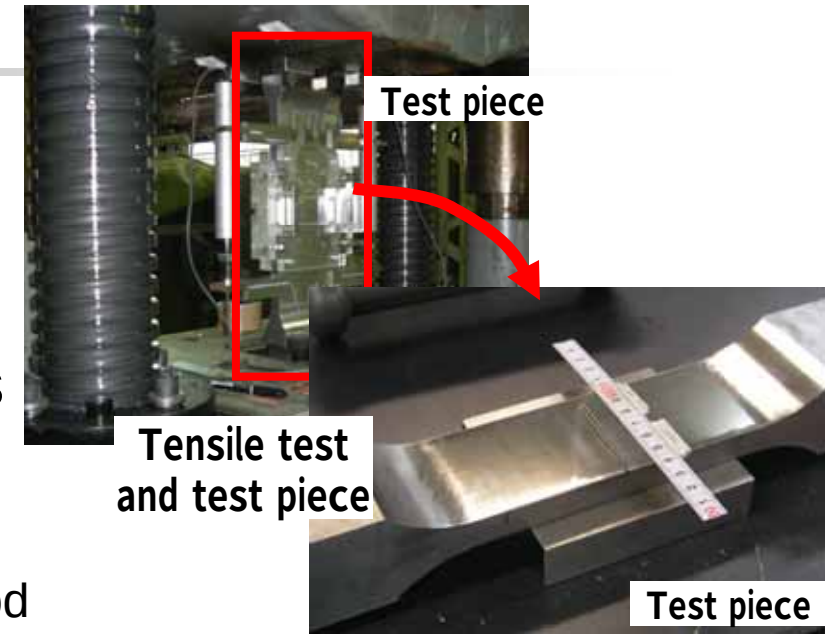
Inspection WG (3)

Inspection of SSCs consists of Basic inspection and Additional inspection

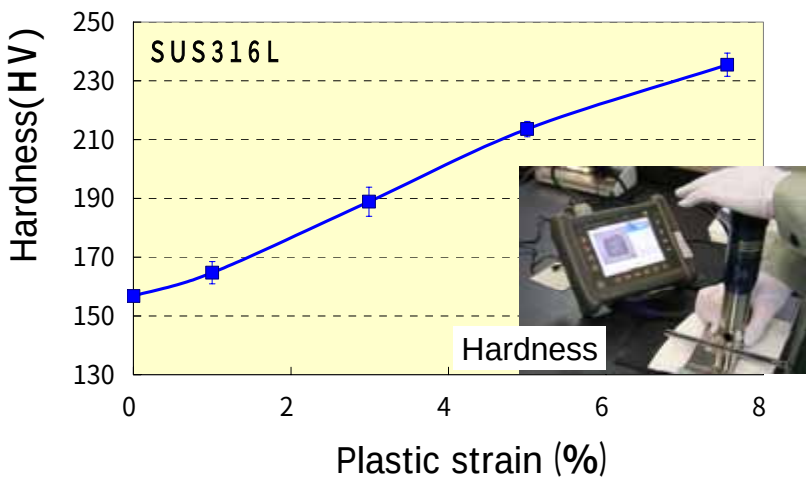
- Basin inspection: Inspection commonly conducted for each SSCs, e.g., VT
- Additional inspection: Inspection conducted corresponding to Basic inspection result, including NDI (UT, PT, etc.,). Possibility of measurement of microscopic deformation (plastic strain) is studied.



Inspection WG (4)



- Plastic strain detection
  - Candidates of detection methods
    - ✓Hardness Method
    - ✓Magnetic strain Method
    - ✓Hypothetical Sonic Velocity Ratio Method
    - ✓Barkhausen Noise Method
    - ✓Metallurgical Observation (Replica)
    - ✓Eddy Current Test, etc.,



Relationship between plastic strain and hardness

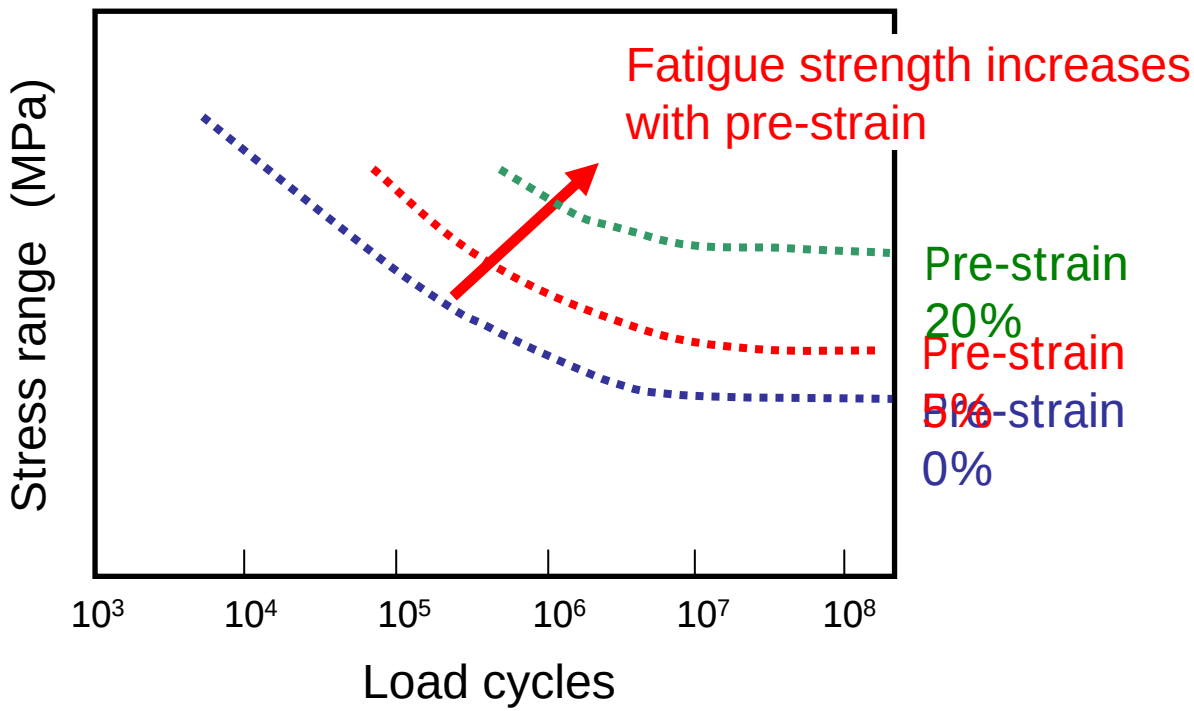
Trial application to actual plants

Inspection WG (5)

- Current output
  - Position of inspection / test
    - For the important components, inspection / test is one of the methods to evaluate integrity as well as analysis
    - For the other components, inspection / test is the main methods to evaluate integrity
  - License / certificate for inspection and evaluation
    - Provisions should be expressed for each method (VT, NDI)
  - Small plastic strain detection
    - Screening based on experimental results and applicability to actual components

Fatigue/Material Test WG (1)

- Expansion of fundamental data
  - Materials experienced excessive load get hardened to enhance high cycle fatigue strength. Data for low cycle fatigue are also expanded to verify the material strength.

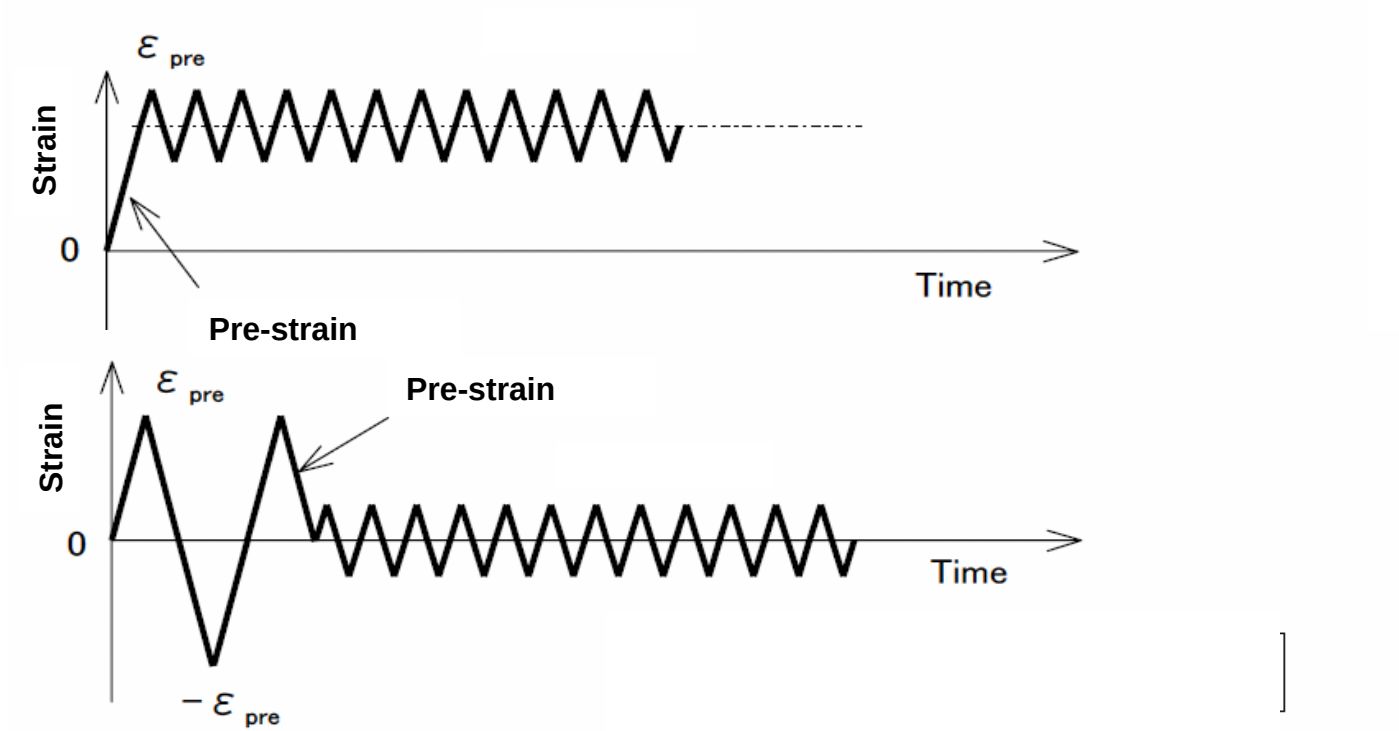


Fatigue strength of pre-strained material

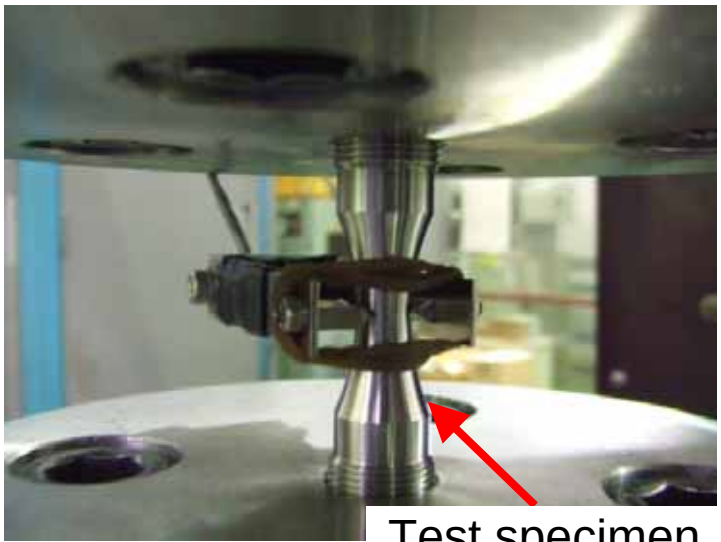
Fatigue/Material Test WG (2)

Contents of action item

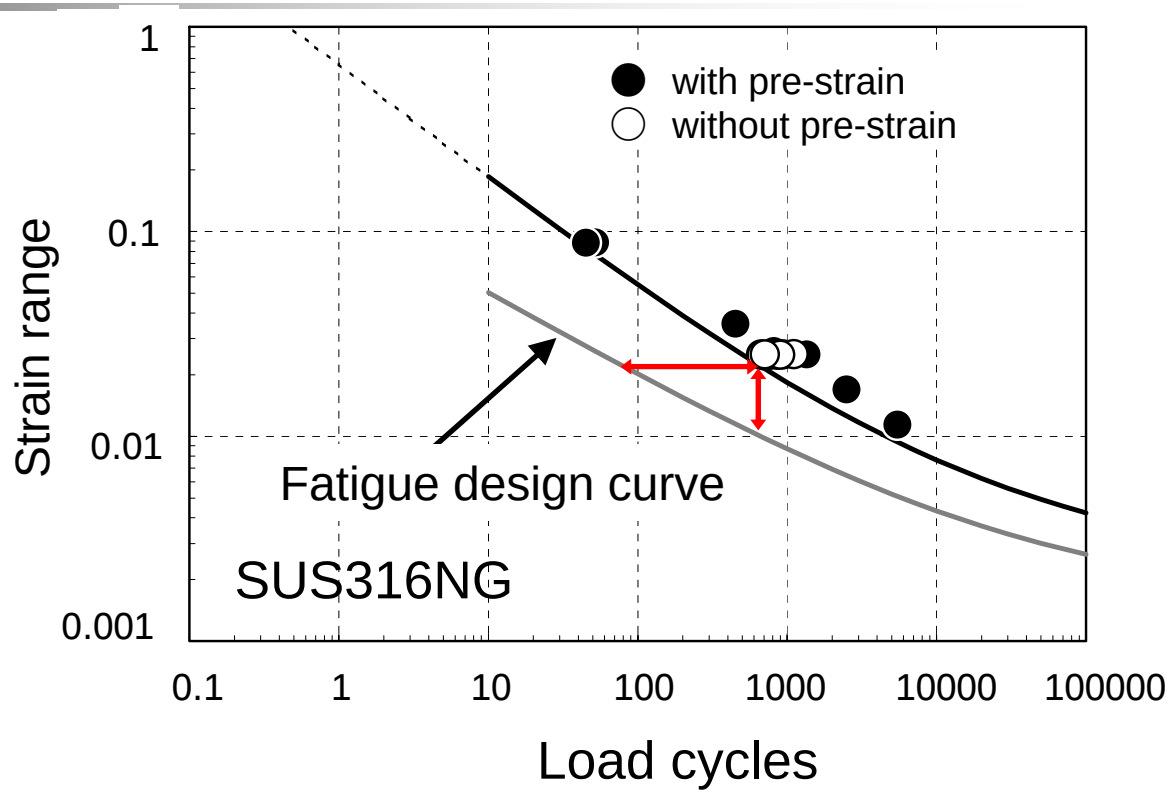
- Evaluation of low cycle fatigue strength of material pre-strained by the simulated seismic load
- Integrity assessment of components based on material strength



Fatigue/Material Test WG (3)



Fatigue test



Fatigue test result with pre-strained material ($\Delta \varepsilon_{pre}$=8%)

- Even for low cycle fatigue experiments, no significant pre-strain effect has been observed as shown in the figure above
- So far, all of the experiment results proved to have sufficient margins compared to the fatigue design curve.

Aging WG

- Selection of aging phenomena for integrity assessment
  - Detailed inspection and estimation on SCC etc.,

Dynamic Estimation WG

- Confirm appropriateness of dynamic analysis simulating the seismic load
- Compare the seismic damages on the components between the different seismic classes

Damage analysis of tanks

Petrol Tank
Seismic class: As “equivalent”
Status：No damage

Deionized Water Tank
Seismic class: C
Status：Buckling

Filtration Tank
Seismic class: C
Status：Buckling

Analyze the difference of seismic classes and damage due to the earth quake to make appropriate reinforcement

Anchor Bolt & Nut WG

- Study on integrity assessment method for anchor bolts & nut such as the bolts for RPV and the transformer
- Integrity assessment of anchor bolt
  - Evaluation standard
    - ✓Integrity assessment for failure
    - ✓Occurrence of Loosening
  - Inspection method
    - ✓Proposal of another inspection corresponding to loading modes in addition to the regular inspection, VT

Sound anchor bolts for RPV (As)

Damaged anchor bolts for transformer (C)

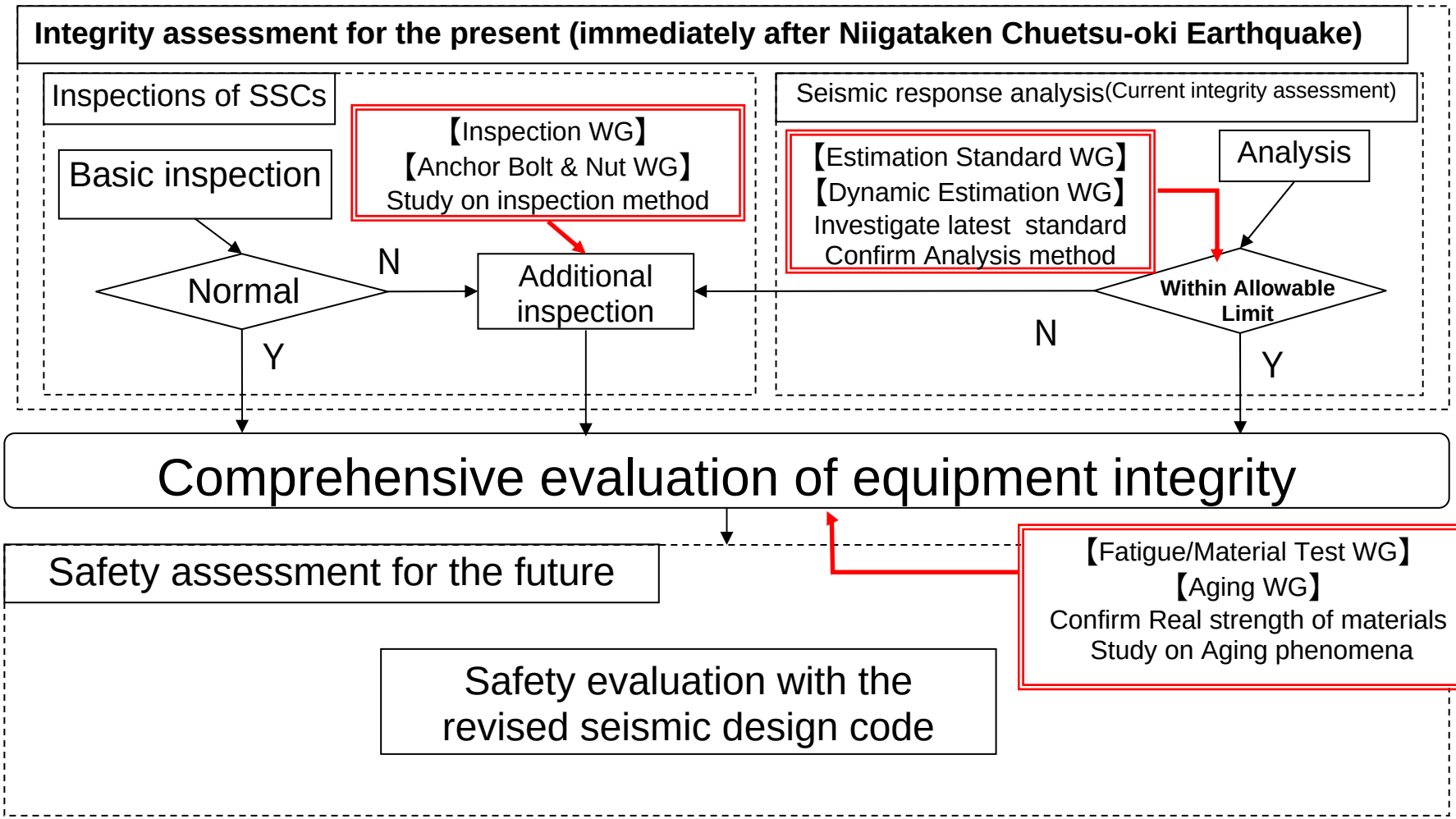
For tension dominant mode: Evaluation based on NDI

For sheer dominant mode: Addition of inspection for loosened bolts by checking torques

Integrity assessment

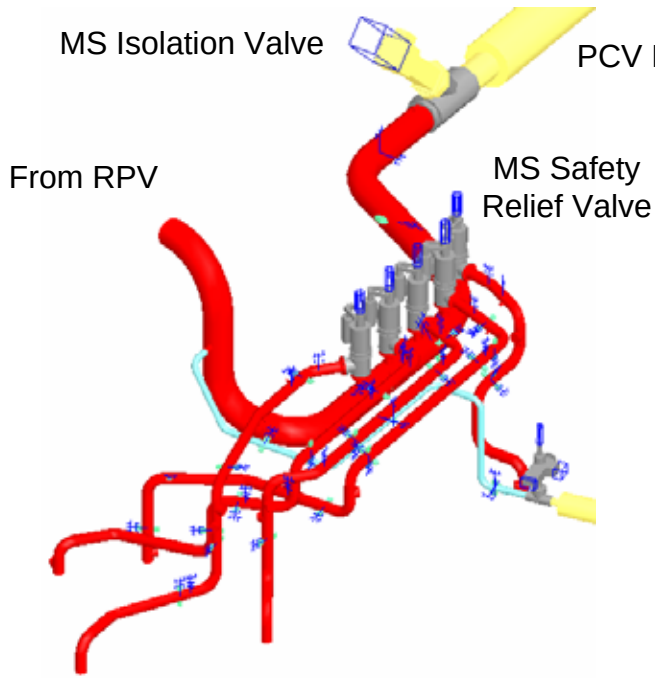
Object：Static components of A or As seismic class and class 1
-Pipe, Vessel, Support, Anchors　etc,.

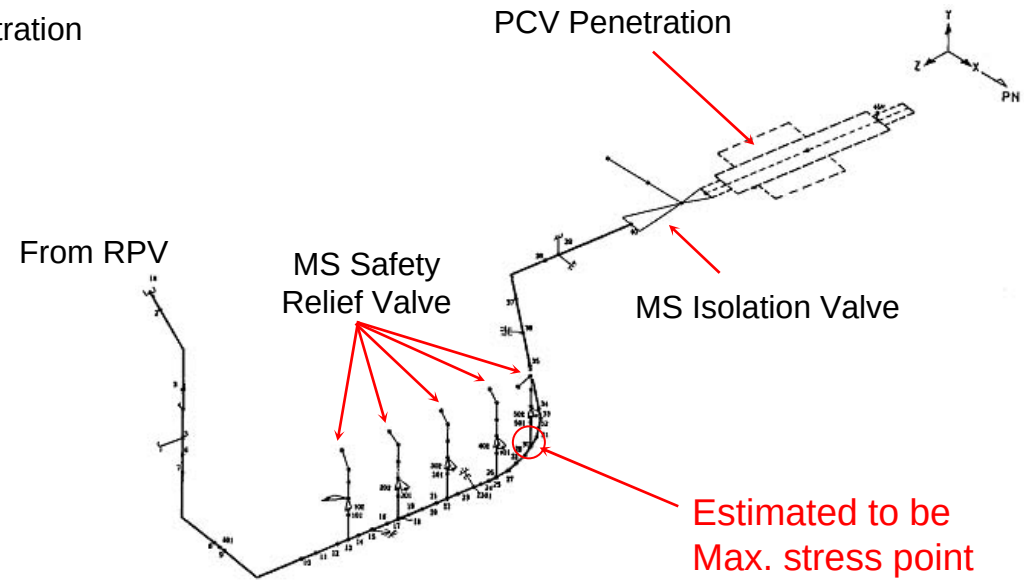
:Main theme for SANE Committee



Study on Analysis Result

- Studied appropriateness of analysis conditions & results of seismic response analysis with Unit 7 of KK NPS.
- Although stress due to seismic load proved to satisfy allowable limit, further analyses like time-domain analysis of phenomena were recommended to figure out the margin.





Concept of “Integrity assessment”

- Entire Concept
  - Integrity assessment for SSCc (System, Structure and Components) are comprehensively judged in accordance with result from inspection and analysis.
  - On integrity assessment, appropriately grasp conservativeness included in the seismic design code and consider adoption of the latest information.
  - Material evaluation of sampling from the actual plant could be an option if necessary.

Concept of “Integrity assessment”

- Inspections of SSCs
  - Inspections of SSCs consist of the basic inspection (VT, functional test, etc.,) and the additional inspection including NDI that would be performed depending on the results from the basin inspection and analysis.
  - If appropriateness of the additional inspection result, integrity of the components, etc., needs to be proved, sampling from the actually used components or mock-up experiments, etc., could be performed.
  - If evaluation of plastic strain in the components is necessary, adopting the latest various technologies as well as the hardness measurement should be considered.

Concept of “Integrity assessment”

- Numerical analysis and estimation standard
  - “Integrity” requires the certain achievement of “No excessive plastic deformation”,”No progressive deformation” and “ No fatigue failure” , in addition to the safety functions of “Shut down”, “Cool down” and “Isolation” on the Earthquake.
  - “Integrity” requires the certain achievement of “No plastic deformation leading to elastic failure”,”No progressive deformation” and “ No fatigue failure” , in addition to the safety functions of “Shut down”, “Cool down” and “Isolation” on the Standard design earthquake, Ss.
  - On integrity assessment, appropriately grasp conservativeness included in the seismic design code,and consider adoption of the latest information and the elastic-plastic FE analysis

Conclusions

- The activities of SANE committee are as follows;
  - Discussion about the study items to be required for the structural integrity assessment for the nuclear components suffered from the earthquake
  - Survey and study of the latest information and experimental result about the structural integrity assessment
  - Discussion about the concept and standard for the structural integrity assessment referring the recent seismic design code
- The committee will continue the discussion about the latest technical information and the additional test for structural integrity assessment, if necessary
- Considering the result of inspection and analysis for the component in Kashiwazaki-Kariwa NPS, the committee will advance the structural integrity assessment method and standard with a secure safety margin as a major premise