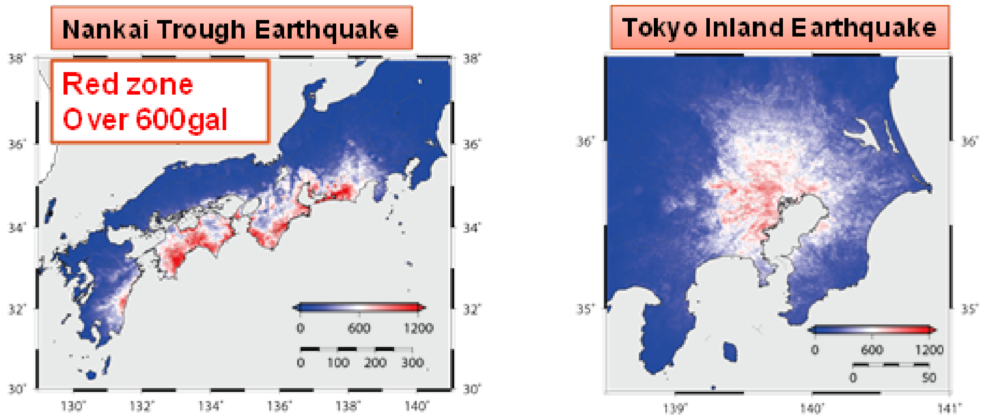
4.4 Damage evaluation of high pressure gas equipment due to earthquakes (Japan)

OECD GP Activity	UN SF Activity	UN SD Goals / Targets
4. Natech prevention: consideration of natural hazards in design and layout	1. Understanding disaster risk	Non-specific targets relevant for Natech Risk Management (3.8, 6.3, 9.4, 11.5, 11.B, 12.4)

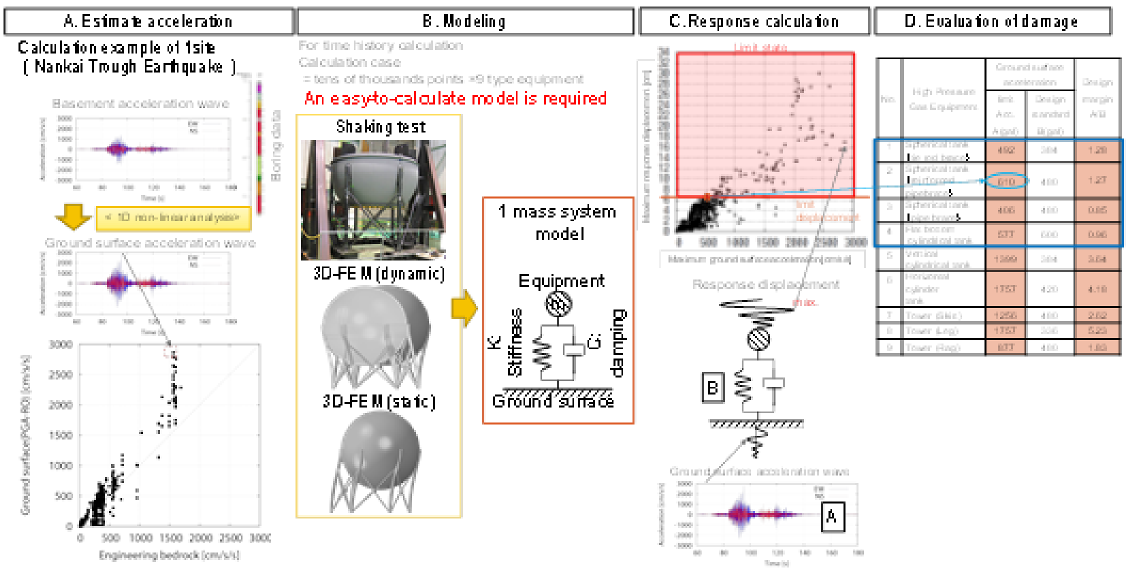
Classification according to OECD Guiding Principles, UN Sendai Framework Priorities/Activities, and UN SDGs and Targets

Figure 1 Estimation of ground surface acceleration of assumed earthquakes



Source: ©The High Pressure Gas Safety Institute of Japan

Figure 2 Damage evaluation of high pressure gas equipment



Source: ©The High Pressure Gas Safety Institute of Japan

Short Facts:	Natural Hazard(s) Considered:
Governance approach: Seismic design standards **Source:** The High Pressure Gas Safety Institute of Japan **Entry into force:** 2018 **Targeted Stakeholders:** Manager, Operators, Designers **Scope of applicability:** Enterprises, sites, installations	• Earthquakes **Climate change:** Not related

Description

Seismic design standards for high-pressure gas equipment in Japan have been revised each time there has been damage from earthquakes. After the Great East Japan Earthquake, which caused major damage, Japan recognised the importance of protective measures. They examined whether equipment based on the current seismic design standards can withstand the huge earthquakes that are expected in the near future.

Estimation of ground surface acceleration of assumed earthquakes

The assumption of the Nankai Trough Earthquake and Tokyo inland earthquake is made public by the Cabinet Office of the Japanese Government. The published data is the acceleration waveform on the engineering basement surface. In the design standards, the acceleration is defined on the ground surface and the maximum ground surface acceleration is 600 gal. To compare these, it is necessary to obtain the acceleration of the ground surface from the acceleration of the engineering basement surface.

There are several methods to estimate the ground surface acceleration from the basement surface acceleration. Since the number of data is large, a conversion formula is used. Please note that the validity of the results has been confirmed by one-dimensional response analysis in several thousand points.

The figures above show the estimation results of ground surface accelerations of the Nankai Trough Earthquake and Tokyo inland earthquake. The area over 600 gal is shown in red. The acceleration would be over 600 gal in areas close to the epicentre and over 1000 gal in some places.

The evaluation of the design margin was carried out following 4 steps:
A. Obtain the acceleration waveform of the ground surface
B. Construct an analysis model
C. Perform response analysis
D. Evaluate damage

In the estimation of the ground surface acceleration, the one-dimensional non-linear response analysis of the ground was performed to obtain the acceleration waveform of the ground surface. The estimation of the ground surface acceleration was calculated by using the acceleration waveform of the basement and the data of the national electronic ground map published by the government.

For response calculation, one mass system model was chosen because time history response analysis took much time. Whether an appropriate solution could be provided with one mass system model was confirmed by shaking tests and three-dimensional Finite Element Analysis (FEA). Parameters used in the one mass system model were also provided by experiments and FEA.

The response analysis procedure**:** The ground surface acceleration waveform calculated in the first step is the input for the model constructed in the second step and the response displacement was provided by the one-dimensional nonlinear response calculation. When the response displacement is larger than the limit displacement, it will be rejected. We repeated this calculation at each point. This chart shows the maximum value of the input acceleration versus the maximum value of the response displacement at each point. Because the response depends not only on the magnitude of ground surface acceleration but also on periodic characteristics and phase characteristics, variations in calculated values of response displacement occur. Among the points within the red frame, the smallest ground surface acceleration is the limit acceleration. This is the threshold of occurrence of damage.

The table shows the limit acceleration of the equipment.

Considering the design margin as the ratio between the critical acceleration and the designed acceleration, the design margin of the equipment of No. 1 to No. 4 among the blue line is small.

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Comments by the UN/OECD Natech-Steering Group:

1 Gal = 0.01 m/s^2. This example is for high pressure gas equipment, but may be useful for other types of equipment as well.

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