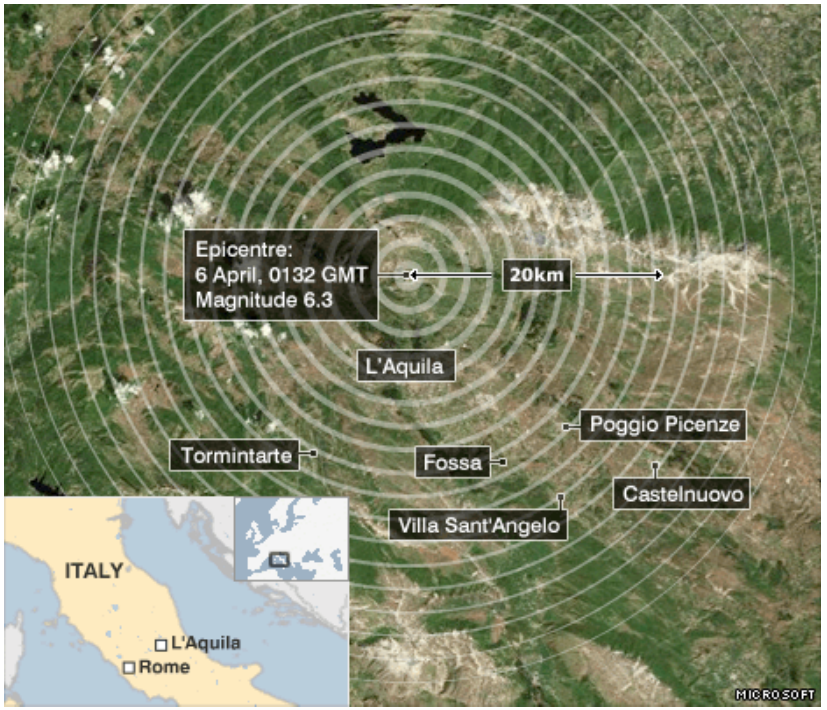
Water Mist Systems Designed For Earthquake Conditions



Eng. Marco Pesaola EUSEBI IMPIANTI

Earthquake Protection

It appears that according to recent events Fire Fighting design should more and more take earthquake protection in account.

Richter Magnitude Scale 0-10

-Sumatra 9.2 (2004)
-Chile 8.8 (2010)
-Haiti 8 (2010)
-Pacific coast of Tohoku (Fukushima, Japan) 9 (2011)

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Earthquake Protection

Many new industrial installations, power plants, nuclear power plants, refineries, high risk facilities are installed or planned or under construction in countries with potential earthquake high risk.

Civil Design is a well consolidated matter while Plant design and in particular Fixed Fire Fighting Systems have quite limited development into current Standards .

This could lead to FF systems failures with relevant huge damages

•Water Mist = Eco-Friendly

One of the most eco-friendly fire extinguishing solutions is increasingly being chosen for protecting high risk industrial Facilities.

It’s well known water mist solutions require small volumes of water in comparison to constant water and foam mix systems and more..

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Differences When Comparing HPWM to Sprinkler/Deluge System

High Pressure WM systems have:

- Very High Cooling capability
- High extinguishing capability
- Typically smaller water droplets then other water based FFS
- ***Lower water demand***
- **Smaller piping sizes**

- **But…what about working after an earthquake????**

Earthquake Protection: Possible Standards For the design of New Water Mist systems

- NFPA 750: Protection of systems components against damage where subject to earthquakes: “where subject to earthquakes water mist systems shall be protected to prevent pipe breakage in accordance to seismic requirements of NFPA 13, “Standard for Installation of Sprinkler Systems”.
- CEN TS 14972: ref. to EN 12845

- Factory Mutual: FM DS 4-2 -Water Mist Systems-” 2.1.1.6.6 Protect piping and containers subject to earthquakes in accordance with Data Sheet 2-8, *Earthquake Protection for Water-Based Fire Protection Systems.*

Water Mist Earthquake Protection: FM and NFPA requirements

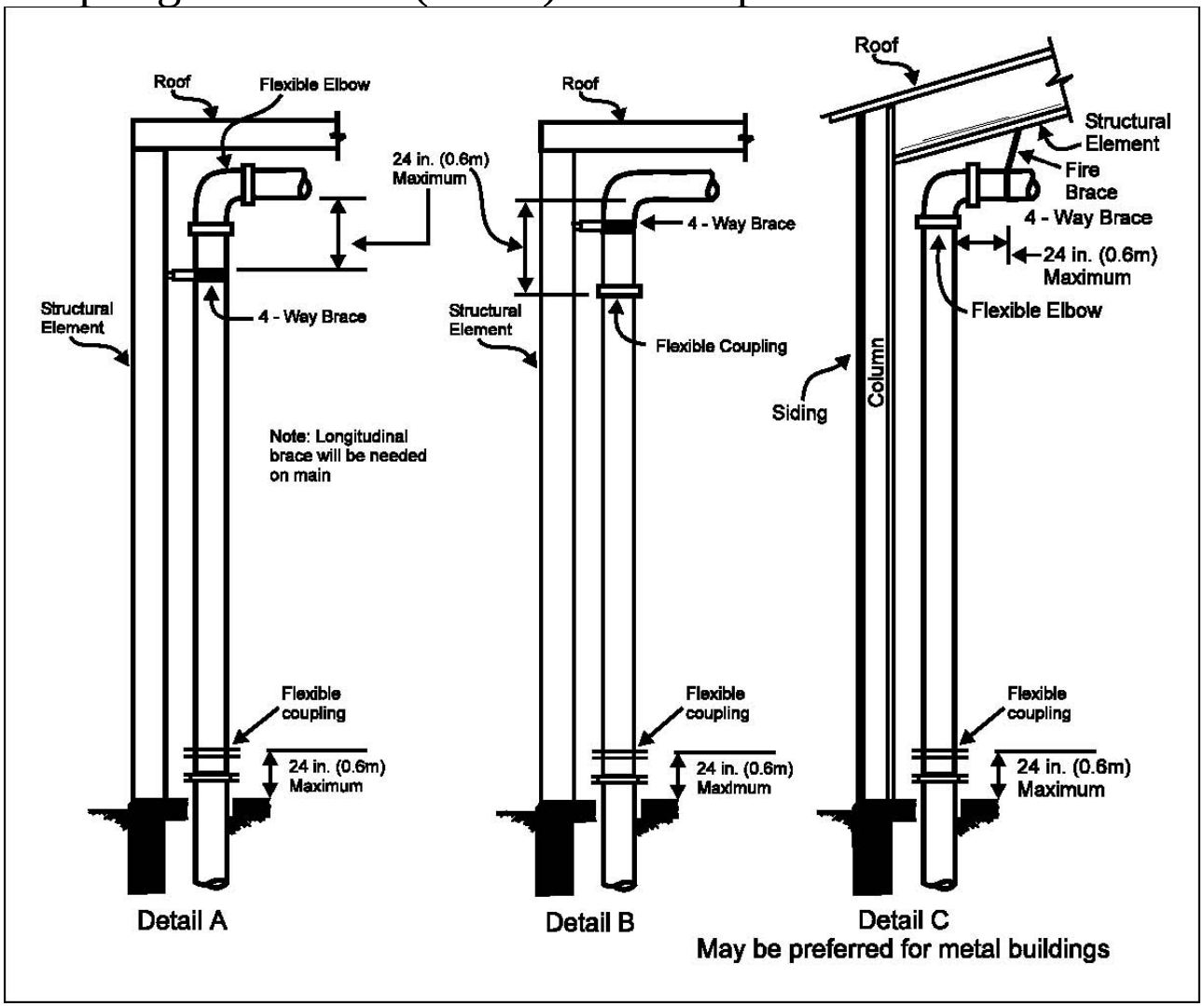
- *“Earthquake-related strains are imparted to a fire protection system through the building or the ground to which it is attached, or through inertial movement within the system itself.*
- *Uncontrolled differential movement can cause damage when fire protection systems are not provided in a systematic manner with the necessary features that incorporate sway bracing, flexibility, clearance, and anchorage where needed.*
- *Because an uncontrolled fire after an earthquake can result in a devastating loss, the primary concern related to deficiencies in earthquake protection is that the fire protection systems will be impaired as a result of strong ground shaking. “*

Key Issues are flexible couplings (grooved mainly) or sway bracing devices intended to limit piping movements

Water Mist Earthquake Protection: FM and NFPA requirements

flexible couplings or sway bracing

-*RISERS :* Provide a flexible coupling within 2 ft (0.6 m) of the top and bottom of each individual riser



Water Mist Earthquake Protection: FM and NFPA requirements

flexible couplings or sway bracing

-RISERS PASSING THROUGH FOORS : Locate the flexible coupling within 1 ft (0.3 m)of the floor either above or below the floor

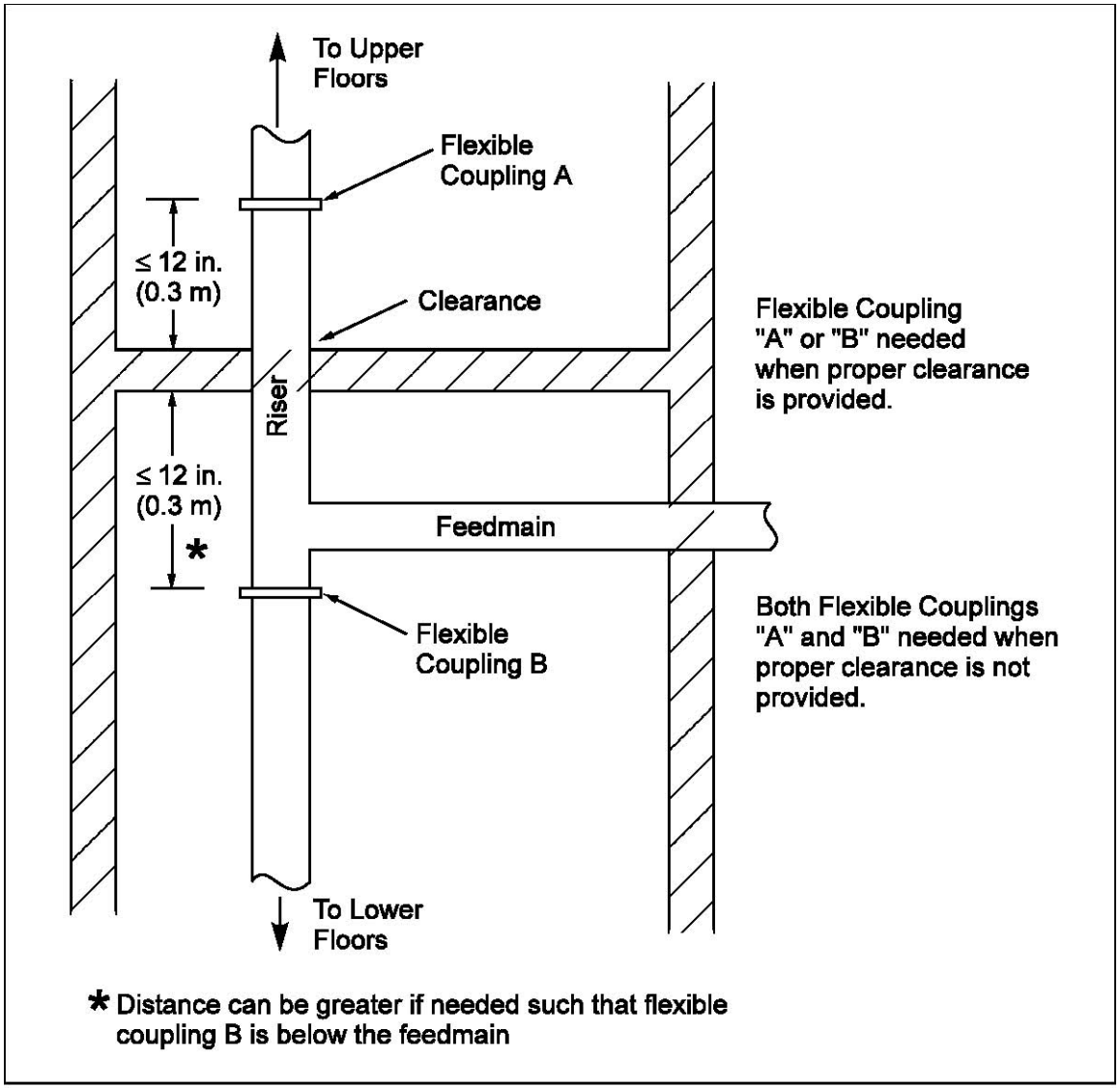
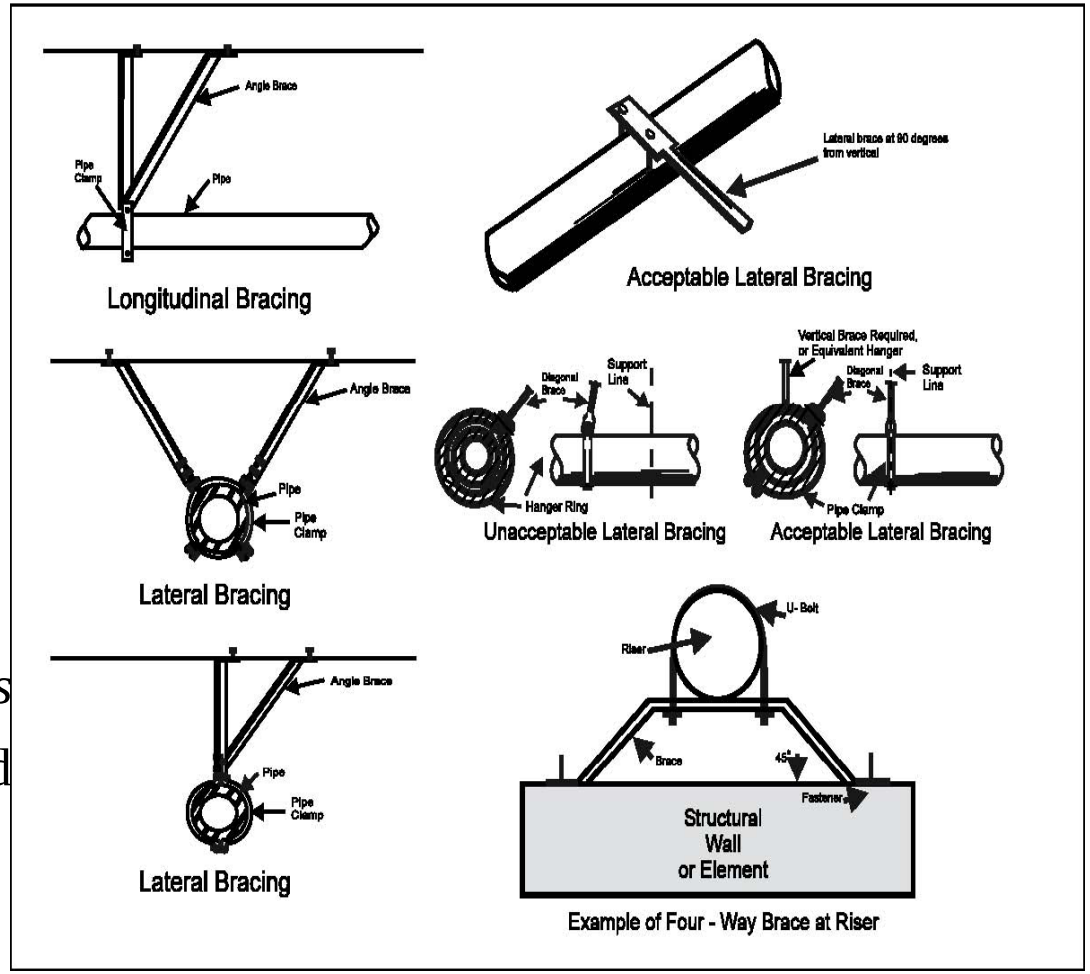


Fig. 18. Arrangement of flexible couplings for risers passing through floors of multistory buildings

Water Mist Earthquake Protection: FM and NFPA requirements

SWAY BRACINGS:

To not allow movements in
the longitudinal direction o
or in the lateral direction
(2 ways) or both (4 ways).
Where:
four-way sway brace
within 2 ft (0.6 m) of the
top of the riser and each 12.2
m *along feed mains and cross mains*
(12.2 m) for lateral sway bracing and
80 ft (24.4 m) for longitudinal sway
bracing



Water Mist Earthquake Protection: FM and NFPA requirements

This is a good base for standard water base FFS but:

- it’s sometimes not applicable to particular building structures
- It’s not suitable for many and high pressure systems
- *There are many simplifications that may lead to a not correct design*
- *It’ s mainly focused on piping and hangers and not on equipment, so…*

- *High risk applications need a comprehensive seismic evaluation and QUALIFICATION according to local Seismic Construction Code*

SEISMIC QUALIFICATION OF A HIGH PRESSURE WATER MIST SYSTEM

For seismic qualification of **components and equipment** shall be applied mainly real scale tests:

Pump skids
Control Cabinets
Area Section Valves
Water storage tanks
Filter unit

For seismic evaluation of **piping** shall be used calculation of seismic resistance during detailed design stage.

SEISMIC QUALIFICATION OF A HIGH PRESSURE WATER MIST SYSTEM

· **Seismic class 1a** - seismic resistance is required to maintain full availability till maximum design basis earthquake level SL-2.

· **Seismic class 1b** – seismic resistance is required to maintain a mechanical integrity in accordance with relevant standards and codes. Partial functional unavailability is possible till maximum design basis earthquake level.

· **Seismic class 2a** – systems and components of equipment, buildings and structures could cause a loss of availability, strength, tightness or position stability of elements ranked as seismic class 1 directly or indirectly due to seismic interactions.

· **Seismic class 2b** - other components of NPP that are not required to meet seismic resistance criteria.

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SEISMIC QUALIFICATION OF A HIGH PRESSURE WATER MIST SYSTEM

QUALIFICATION METHODS

Qualification test shall simulate the effects of environmental factors on equipment under qualification when they are subject to:
Normal operative condition when the environmental parameters values inside the equipment installation rooms corresponds to the relevant design values.
Ageing factors like radiation, temperature, mechanical vibrations, functional cycling (simulation of long term operations (40 years).
Accident and post accident conditions due to the effects of an earthquake

QUALIFICATION METHODS

In order to qualify the Equipment under the previously mentioned conditions, the following qualification sequence shall be adopted:

I. Initial visual inspection of Equipment / component and verification of documentation compliance

II. Initial functional test in normal environment conditions

a) nominal values

b) established limit values of normal operation

III. Ageing (SERVICE LIFE 40 YEARS)

a) Thermal (like self-heating of the components during life time)

b) mechanical vibrations

IV. Accident and post accident tests

a) seismic resistance test

V. Final functional test in normal operation conditions, in the end of test sequence

VI. Final visual inspection of Equipment / component

SEISMIC QUALIFICATION OF A HIGH PRESSURE WATER MIST SYSTEM

SEISMIC QUALIFICATION SPECIFICATION

Seismic load

The evaluation of seismic risks for nuclear power plants imply that the qualified equipment has to resist against seismic effects equivalent to five (5x) design earthquakes (SL-1) followed by one (1x) earthquake of the intensity of maximum calculation earthquake (SL-2).

Reference Floor Response Spectra

The seismic qualification of each piece of equipment must be performed on the basis of the calculated floor response spectra at equipment position installation.

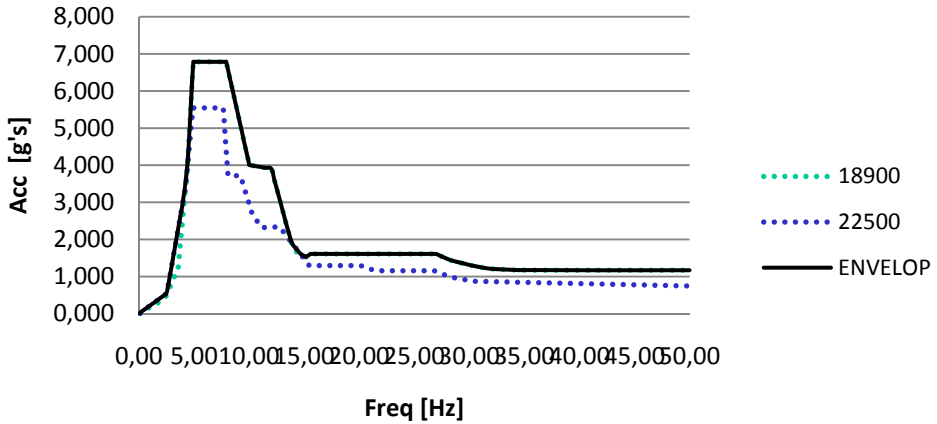
For each axis direction (X, Y, Z) the smoothed FRS calculated for damping values of 1, 2, 3, 4, 5, 7, 10% shall be available.

The damping values to be applied by the Supplier for Equipment qualification depend on the mechanical characteristics of each enclosure and shall be consistent to specifications.

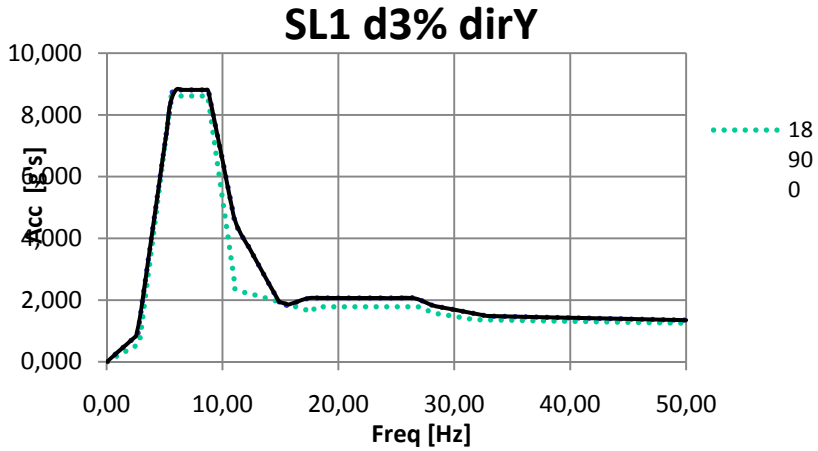
SEISMIC QUALIFICATION SPECIFICATION

Reference Floor Response Spectra

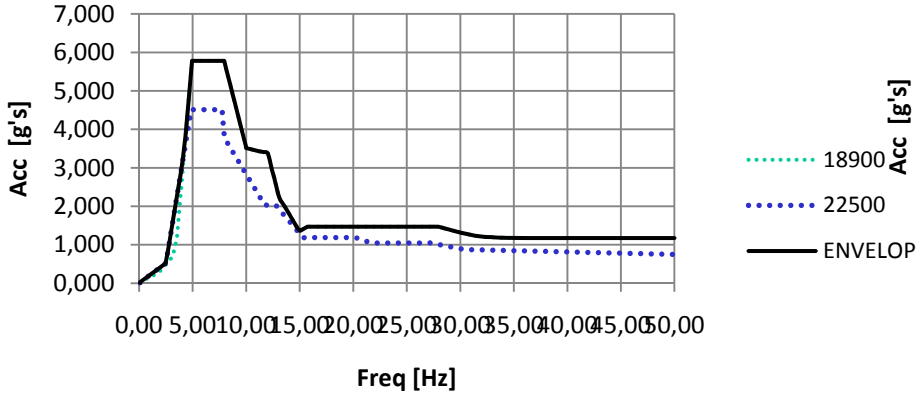
SL1 d3% dirX



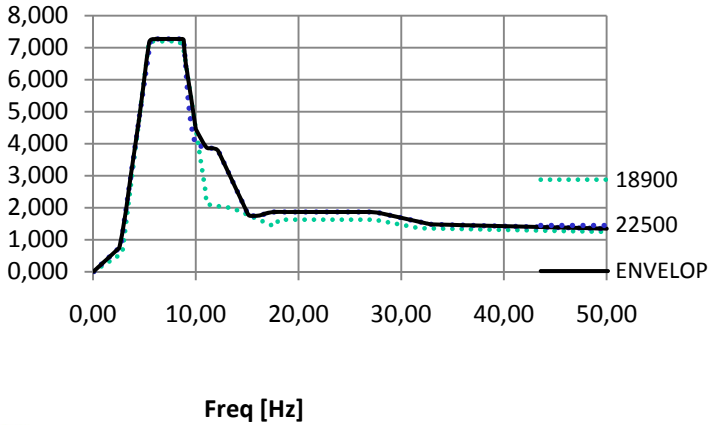
SL1 d3% dirY



SL2 d4% dirX



SL2 d4% dirY



SEISMIC QUALIFICATION OF A HIGH PRESSURE WATER MIST SYSTEM

SEISMIC QUALIFICATION SPECIFICATION

Damping

Equipment compound as assembly of several individual parts, usually, does not have only one value of a damping. The self attenuation has got each part of the equipment as well as the mounted or welded structure also each used material or small part. The damping value can vary with the place selection for equipment and it is influenced by several factors. Typical for the attenuation is its dependence on dynamic characteristics of the system (mode characteristics of the structure) and therefore it is practical to choose damping values according to area of interest of the frequency range considering attenuation depending on frequency. The damping values to be applied shall be in compliance with the following

	Design Earthquake level (SL-1)	**Max. Calculation Earthquake level (SL-2)**
Piping systems	3%	4%
Pressure Vessels, Heat Exchangers, and Pump and Valve Bodies (pressure boundary)	2%	3%
Electrical panels, Motor control centers		

SEISMIC QUALIFICAT

SEISMIC

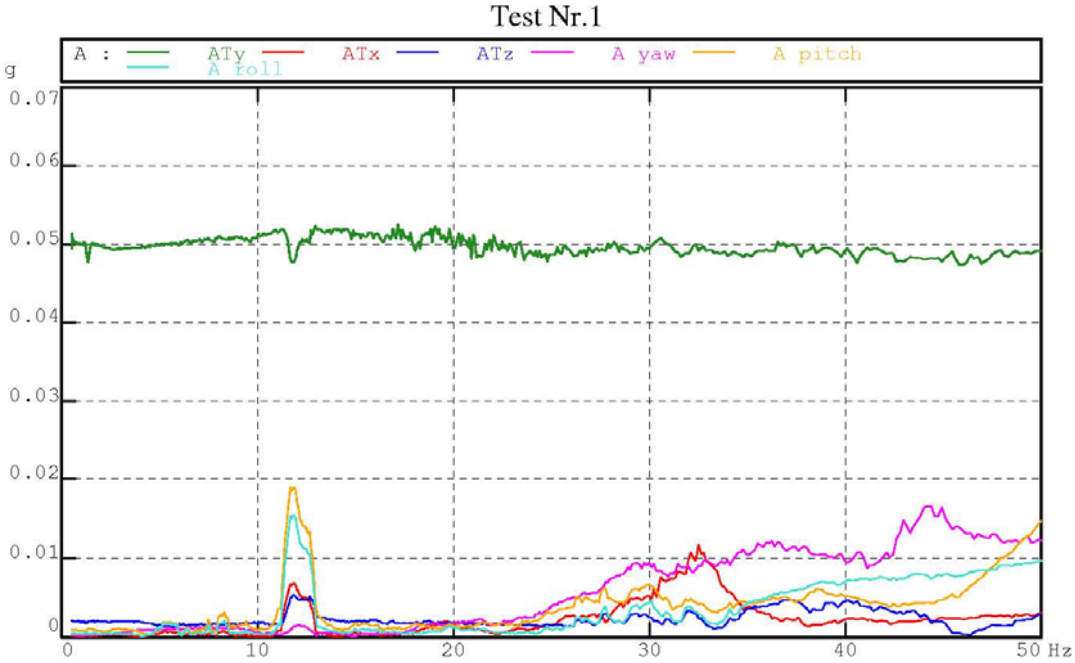
Exploratory test

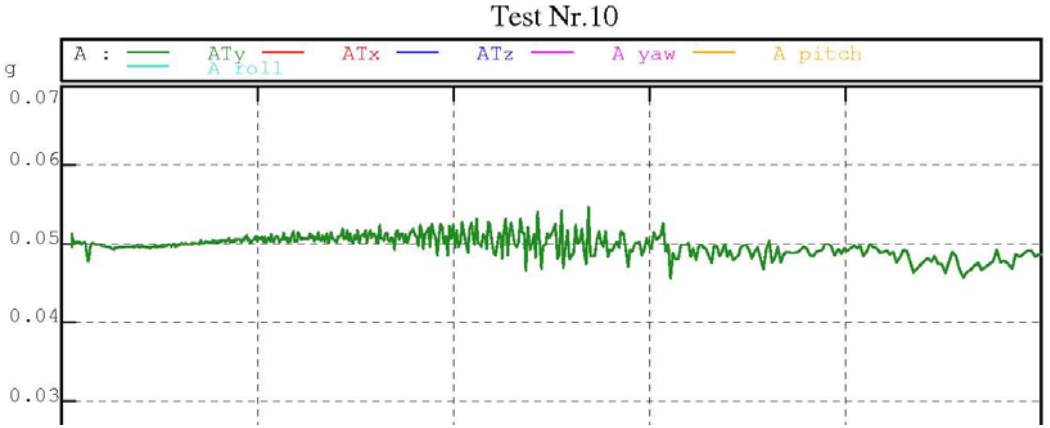
The exploratory test is a low
over the frequency range of
(3) orthogonal directions. In
sweep and one downward sv
maximum sweep rate is two
by this test shall be investiga

3SGF01BZ001 Control Panel

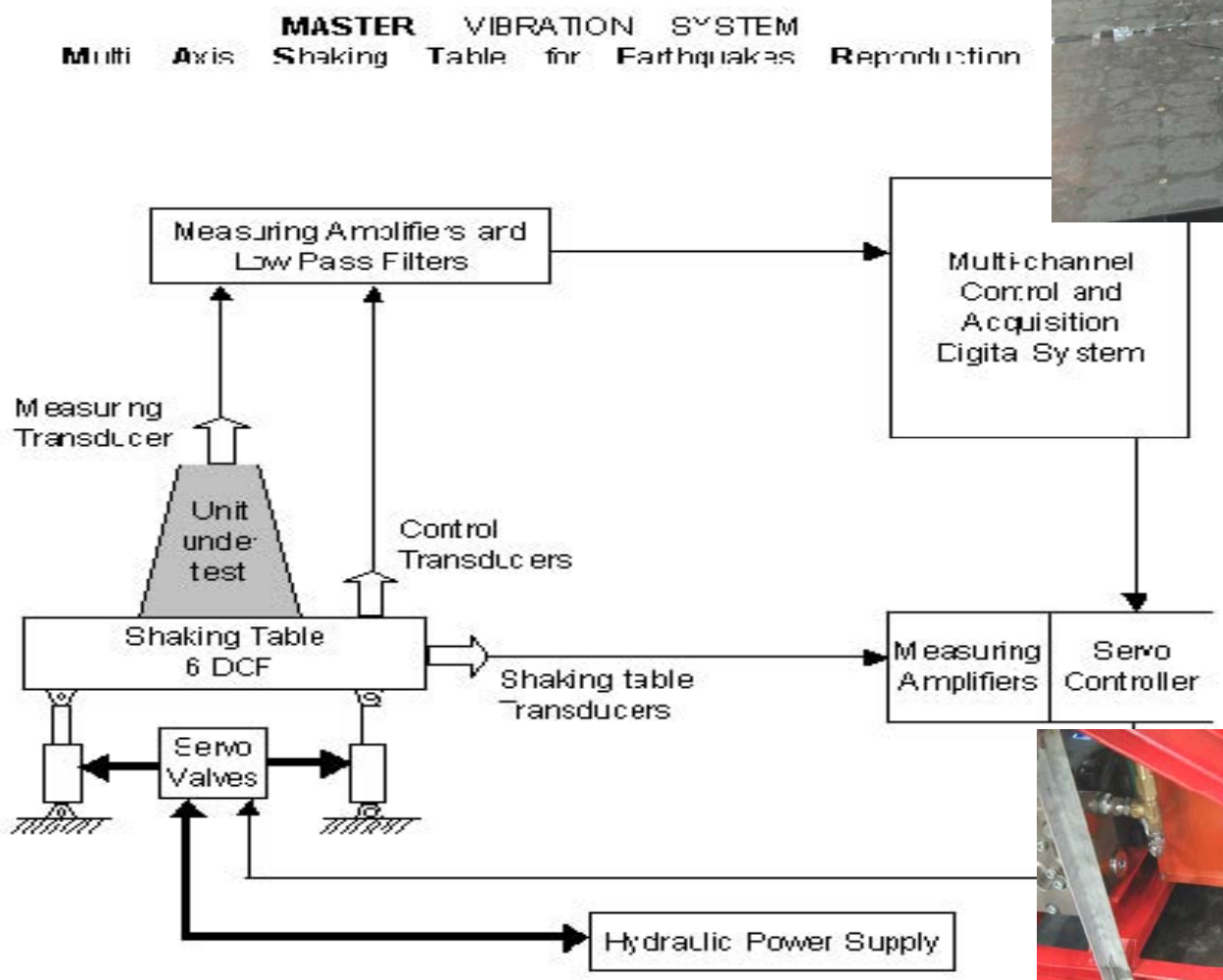
Test Nr.1 and 10 # Frequency search # Axis: Y # Level: 0,05g

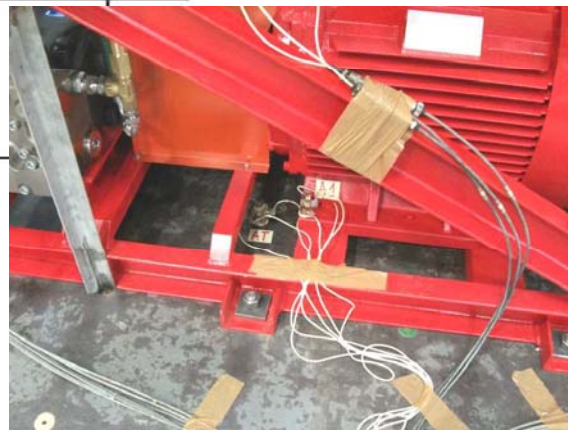
Response curve of Control channel ATy with transversal and rotational motions





SEISMIC QUALIFICATION OF A HIGH PRESSURE WATER MIST SYSTEM



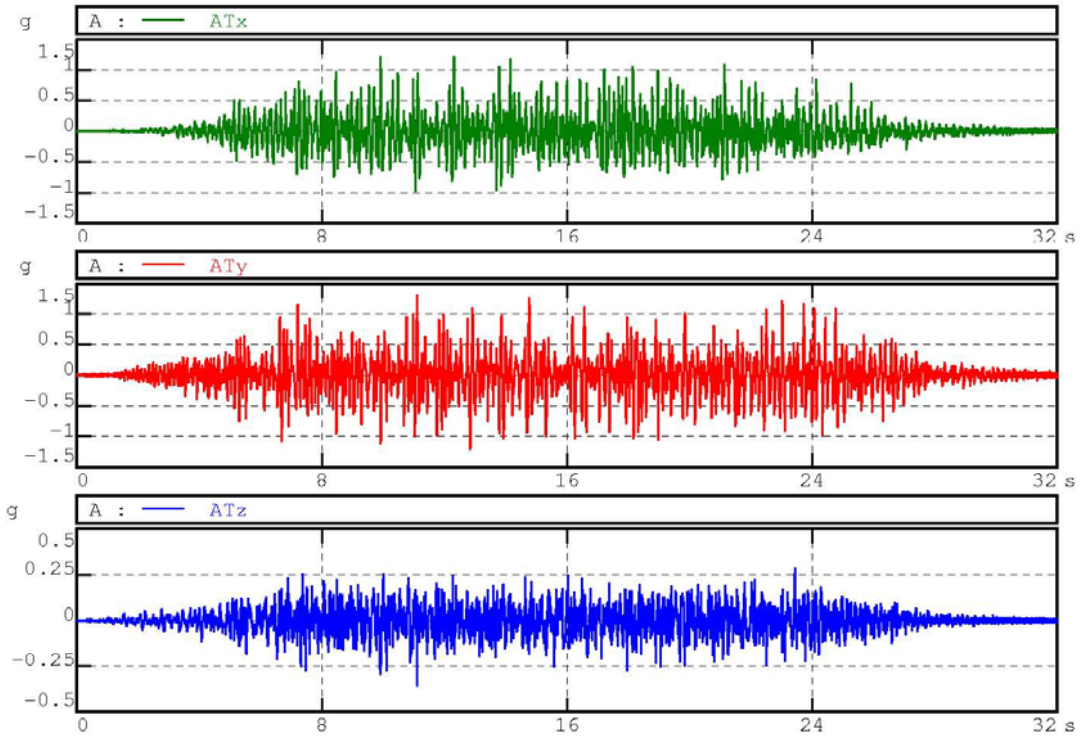


EMist® HIGH PRESSURE

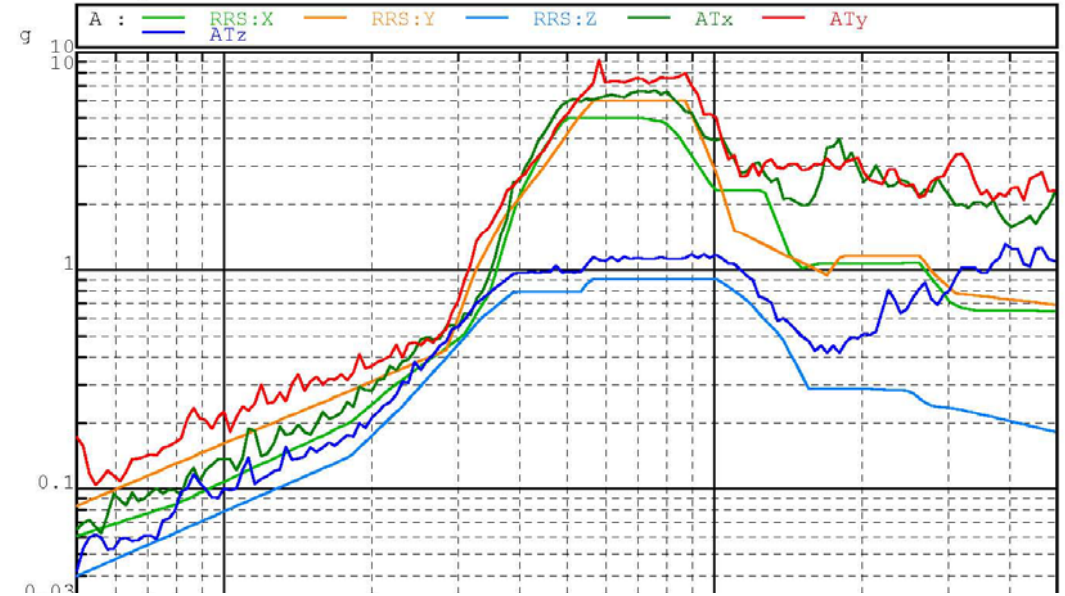
3SGF01BZ001 Control Panel: TEST LIST

Test Nr.	Unit condition	Axis	Test type	Severity	Excitation level	Diagram Fig.N.	Checks after test	Date
1	Control Panel energized at 220 Vac	Y	Resonance frequency search	Sine sweep test Typ: Continuous - Direction: UP Freq.Range: 0,5 - 50 Hz rate: 1 oct/min - N.lines: 1024 F sampl.=4000 Hz - Rect. Window BW prop. 0,5-2 Hz = 50% BW prop. 2-16 Hz = 25% BW fixed. 16-37 Hz = 4 Hz Low pass filters = 80 Hz	0,05 g	4,5	-	25 Mar 2011
2	Like test n.1	X	Resonance frequency search	Like test n.1	0,05 g	6,7	-	25 Mar 2011
3	Like test n.1	Z	Resonance frequency search	Like test n.1	0,05 g	8,9	-	25 Mar 2011
4 5 6 7 8	Control Panel energized at 220 Vac. See Doc.|1| Par.5.6.1a for 5 different working conditions	X Y Z	Tri-axial Seismic test	Triaxial Seismic test Smoothed FRS for level +18.90 m ZPA (x) = 0,65 g ZPA (y) = 0,69 g ZPA (z) = 0,18 g Damping 2% Seismic duration=32s Strong part > 20 s Correlation < 0,15 Freq. Range = 0.5 - 50 Hz F samp = 500 Hz Low pass filters = 80 Hz	SL-1 SL-1 SL-1 SL-1 SL-1	10-12 13-15 16-18 19-21 22-24		25 Mar 2011
9	Control Panel energized at 220 Vac. See Doc.|1| Par.5.6.1b for working condition	X Y Z	Tri-axial Seismic test	Triaxial Seismic test Smoothed FRS for level +18.90 m ZPA (x) = 1,29 g ZPA (y) = 1,38 g ZPA (z) = 0,36 g Damping 3% Seismic duration=32s Strong part > 20 s Correlation < 0,10 Freq. Range = 0.5 - 50 Hz	SL-2	25-27		25 Mar 2011

Time histories of Control channels



Overplot between RRS and TRS



WATER MIST SYSTEM

SULTS

CLASSIFIED EQUIPMENT RESULTS

Laboratory statement after seismic test: After seismic tests no visible damages were detected on Pump skid and 3SGF01BZ003 Electrical Switchboard. No instability on Auxiliary contactors and pressure contacts.

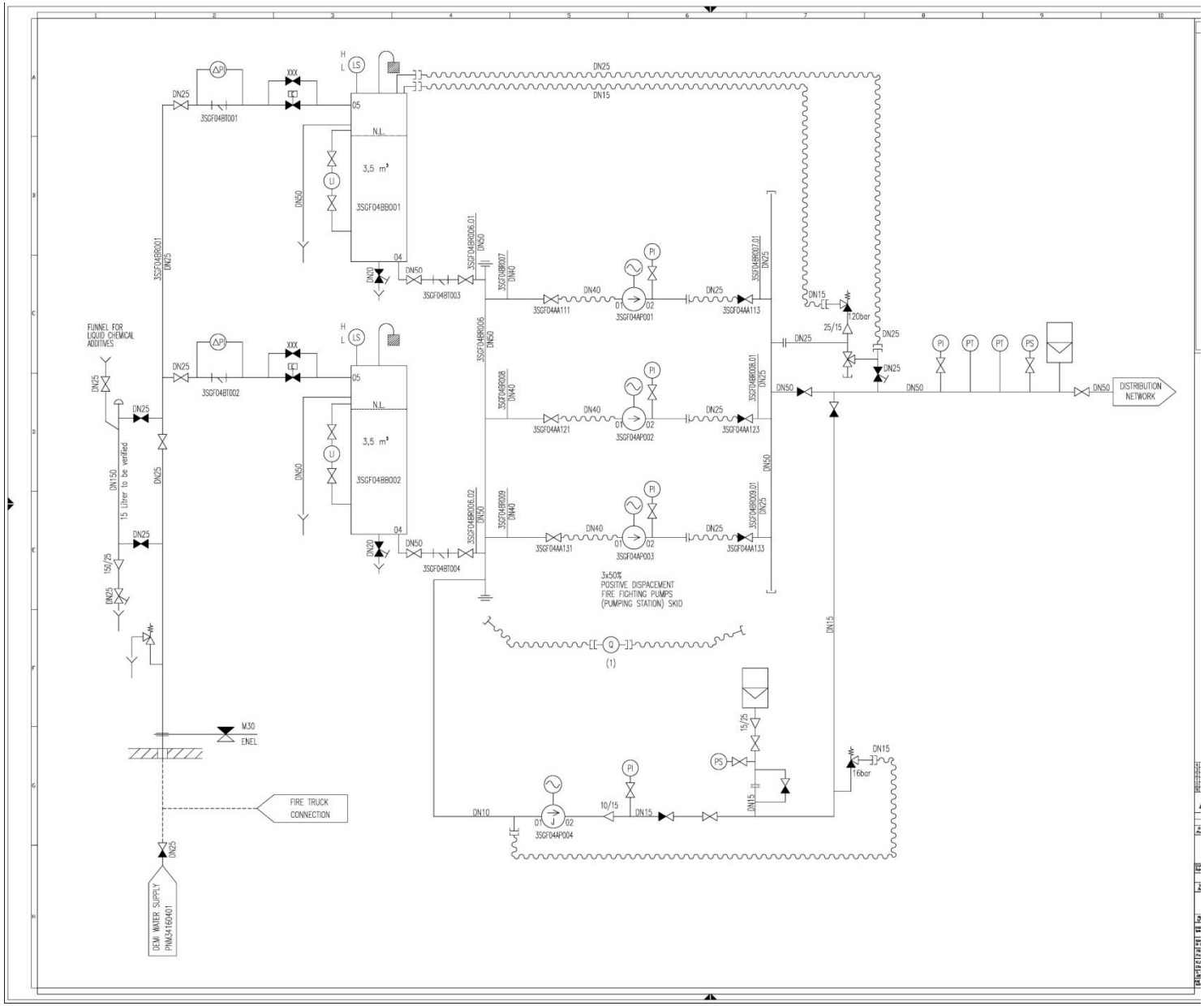
“During and after each seismic test auxiliary contactors, pressure contacts and manifold pressure signals were regular”.

“Seismic test have been done with different working condition:

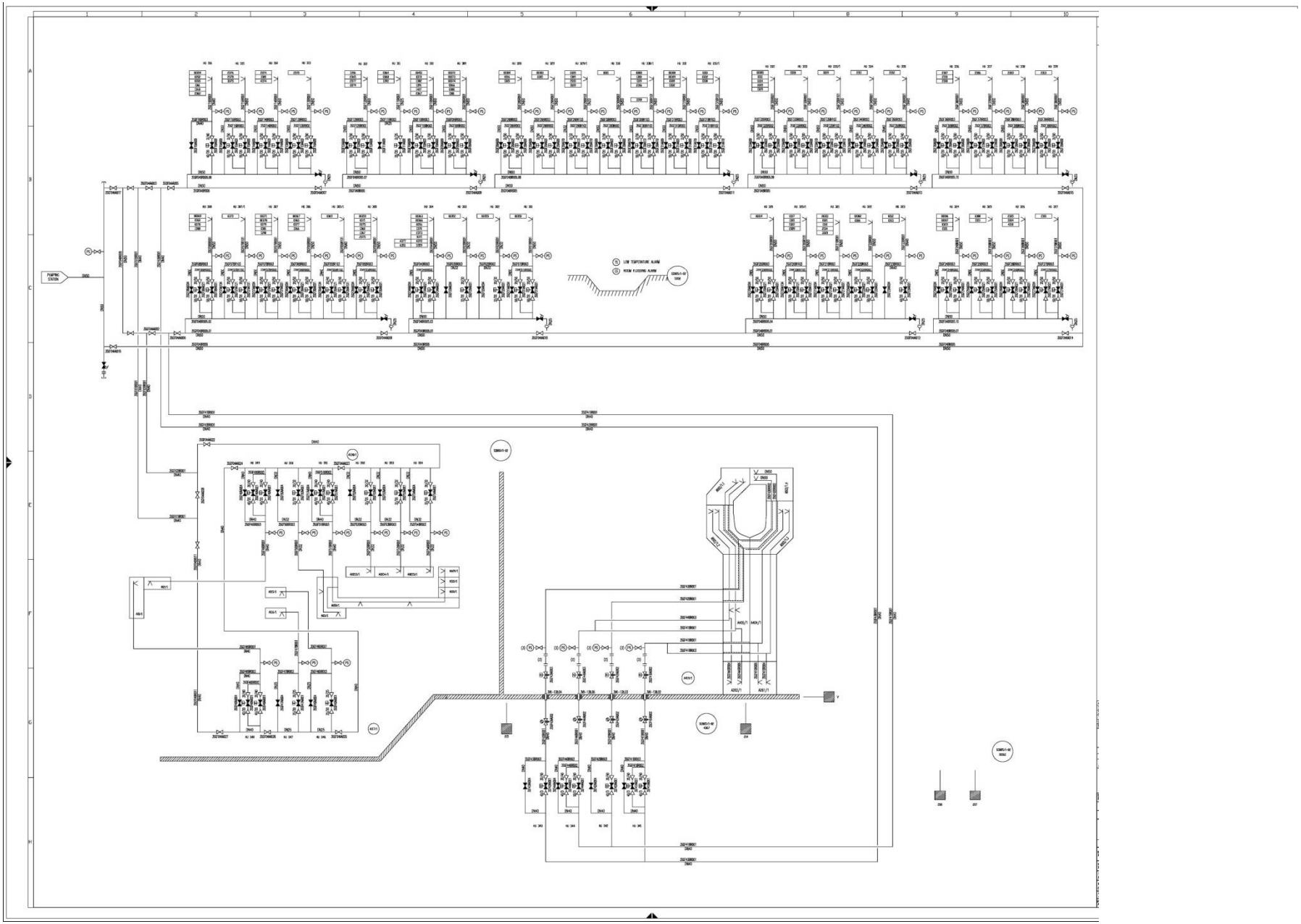
Sample video

EMist® HIGH PRESSURE

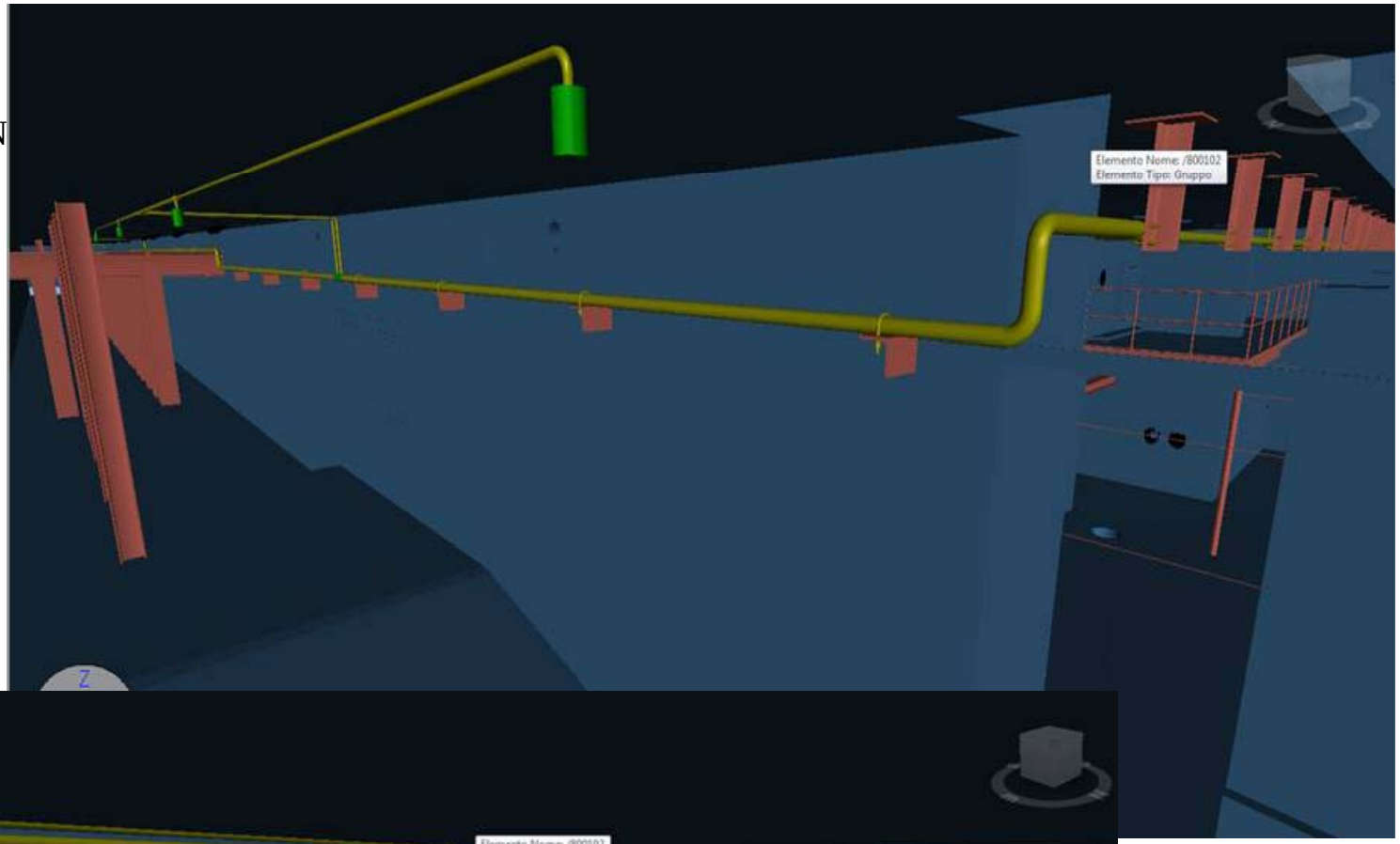
PIPING QUALIFICATION

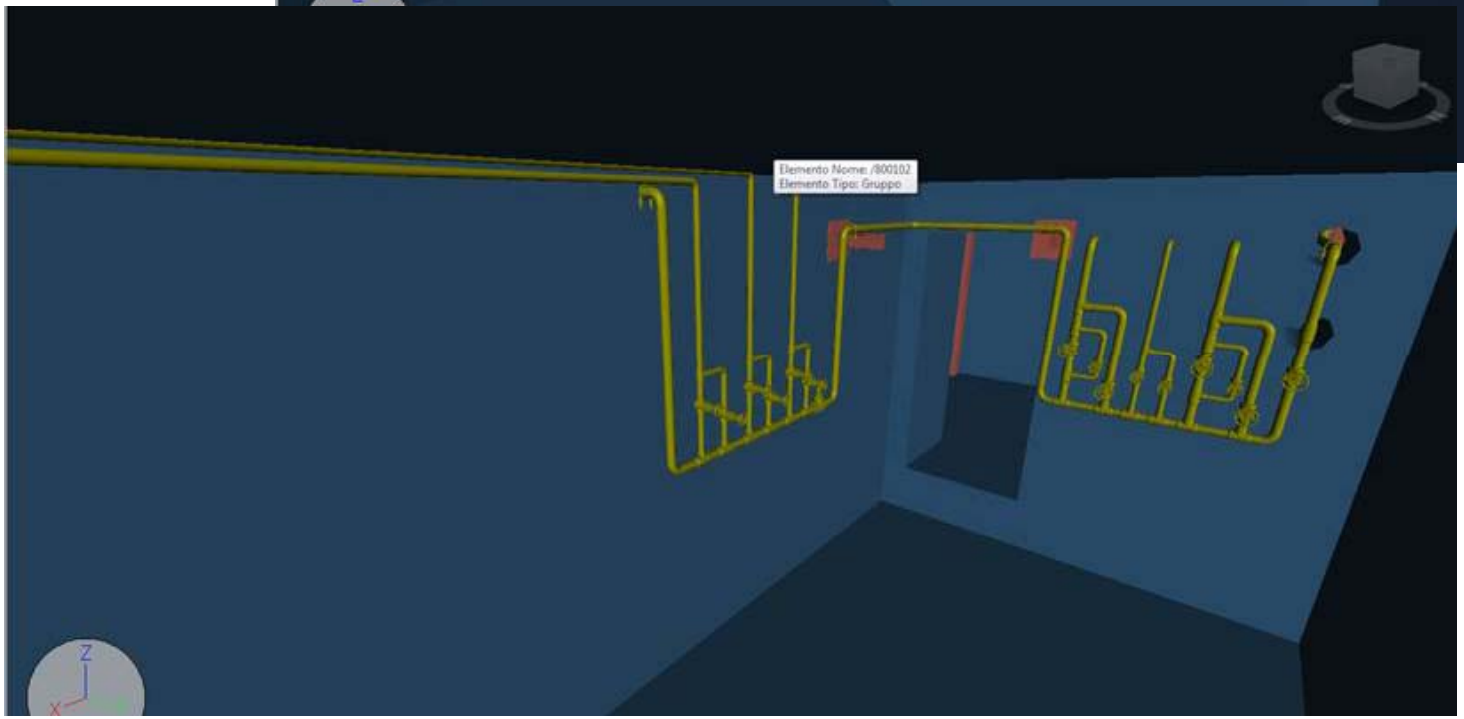


PIPING QUALIFICATION

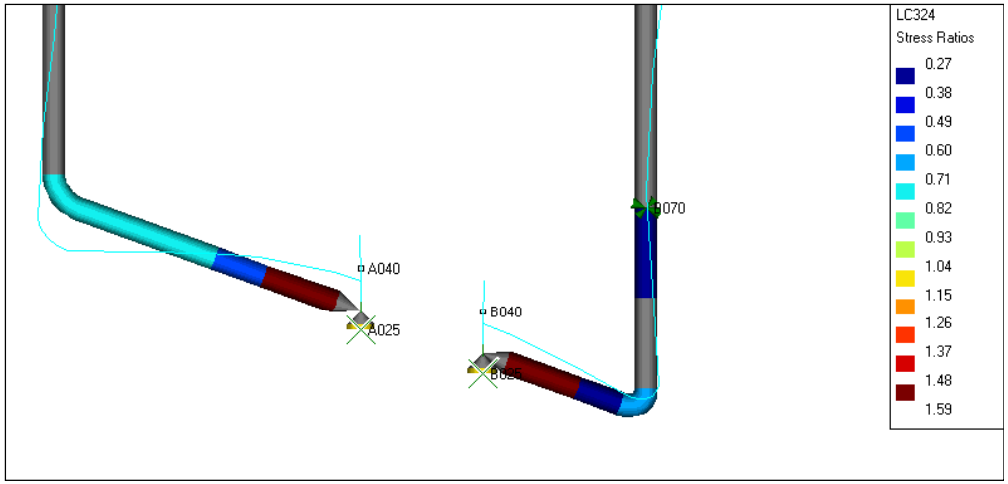


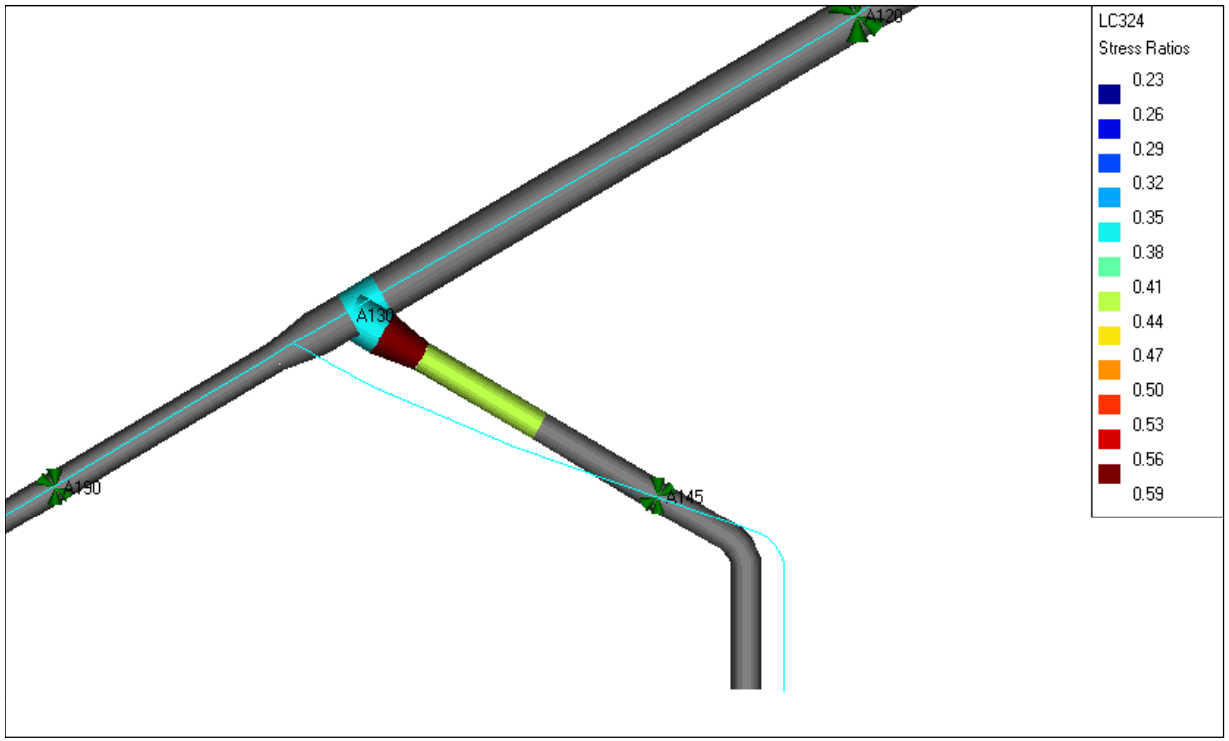
PIPING QUALIFICATION
SAME METODOLOGY
BUT WITH
SIMULATIONS
ACCORIDNG
TO ASME CODE AND
RELEVANT
STRESS LIMITS

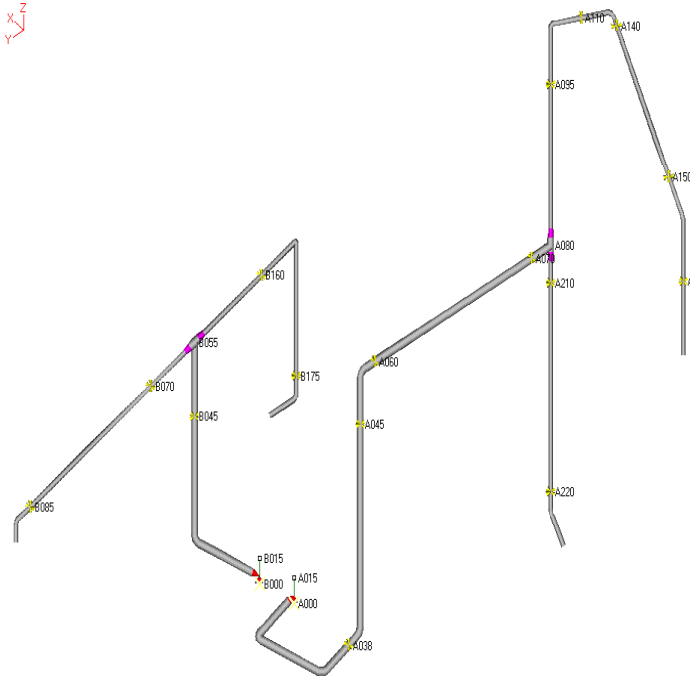




PIPING, SUPPORTS, HANCORS, QUALIFICATION
SAME METODOLOGY BUT
WITH SIMULATIONS ACCORDING
TO ASME CODE AND RELEVANT
STRESS LIMITS







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CLASSIFIED EQUIPMENT
RESULTS

Stress Results and Ratios

Piping stresses for all loading combinations as defined in Section table 5.1, ASME Code Sections NC-3600. The maximum value for each primary stress and secondary stress loading combination are tabulated. The complete list of all piping stresses at all locations and for all conditions is included in the output files of the report.

Plant Condition	Loading Combination	Case Number	Node	ASME Code Equation	Stress Ratio	Stress Ratio with solution
SKID_04						
LEVEL A ()	P + Deadweight	10	A120	8	**0.404**	
Hydrotest	Hydrotest	15	A115	9U-T	**0.465**	
LEVEL B (Upset)	P_{MAX} + DW + Total DE	341	A120	9U	**0.406**	
LEVEL D(Faulted)	P + DW + Total MDE	342	A120		**0.438**	
Level A	Deadweigh	9		F8	-	
Level C	Abs Th Max Level C	324	A050	10a	**0.515**	
SKID_05						
LEVEL A ()	P + Deadweight	10	B060	8	**0.375**	
Hydrotest	Hydrotest	15	B060	9U-T	**0.271**	
LEVEL B (Upset)	P_{MAX} + DW + Total DE	341	B155	9U	**0.318**	
LEVEL D(Faulted)	P + DW + Total MDE	342	B065		**0.208**	
Level A	Deadweigh	9		F8	-	
Level C	Abs Th Max Level C	324	A025	10a	**1.219**	**0.586**

CLASSIFIED EQUIPMENT
WATER STORAGE TANKS

The design checks to be considered are:

•Test operating load case: combination of the hydrostatic pressure (with the tank full of water) addicted to a maximum operating pressure (equal to 0.5 bar) multiplied by a factor of 1.43;

•Normal operating load cases, in which the loads combination concern the dead weight, live weight and the SL-1 floor response spectra with damping of 2%, derived from the SL-2 floor response spectra with a load multiplier of 0.5

•Exceptional load cases, in which the loads combination concern the dead weight , live weight and the SL-2 floor response spectra with damping of 3%

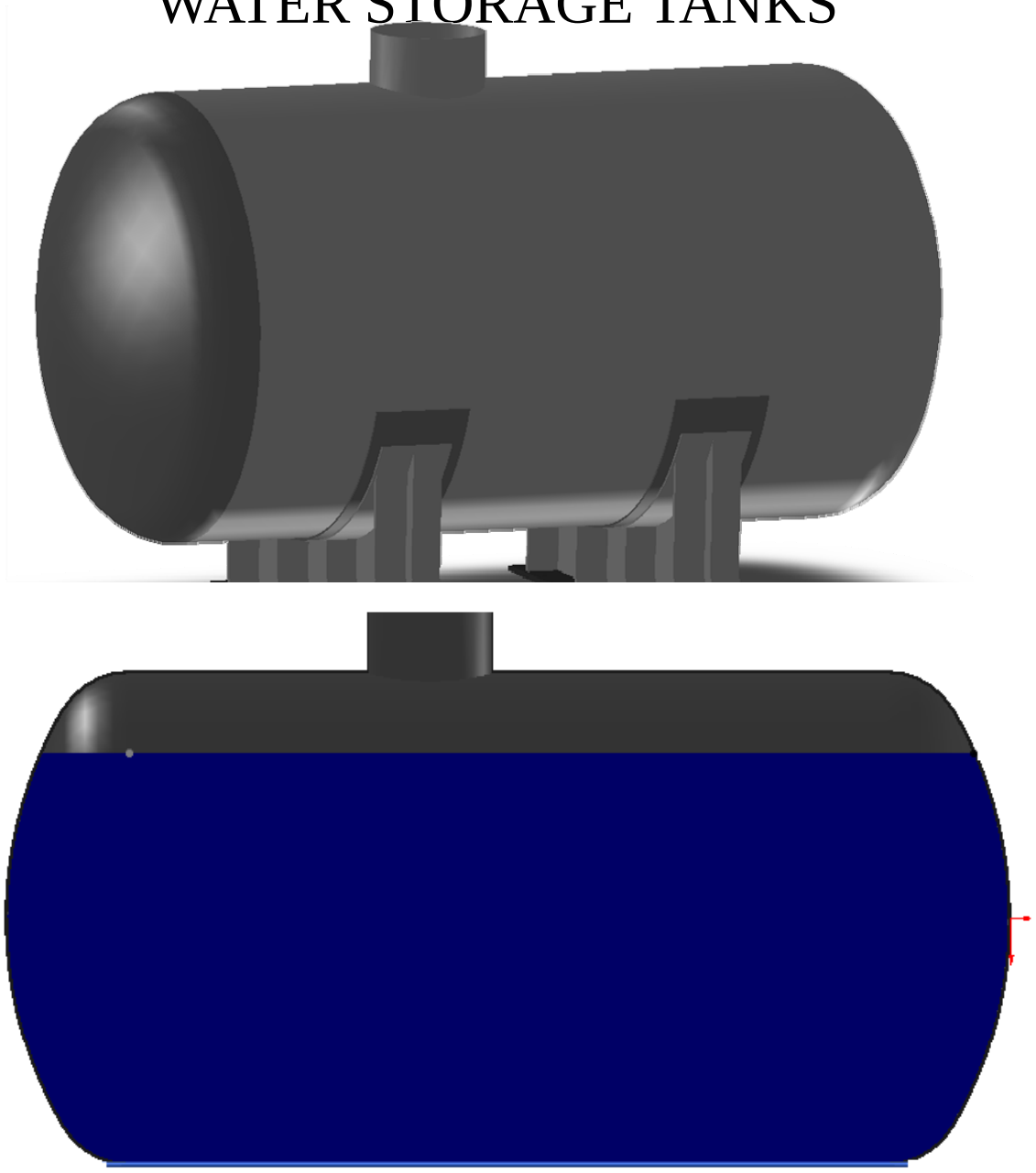
The structural analyses to verify:

the **shell** component by the “design by analysis method” following the European Standard UNI EN 13445-3

The **welded** connections following the European Standard UNI EN 13445-3

The **bolted** connection following the European Standard UNI EN 1993-1-8

CLASSIFIED EQUIPMENT
WATER STORAGE TANKS



CLASSIFIED EQUIPMENT
WATER STORAGE TANKS

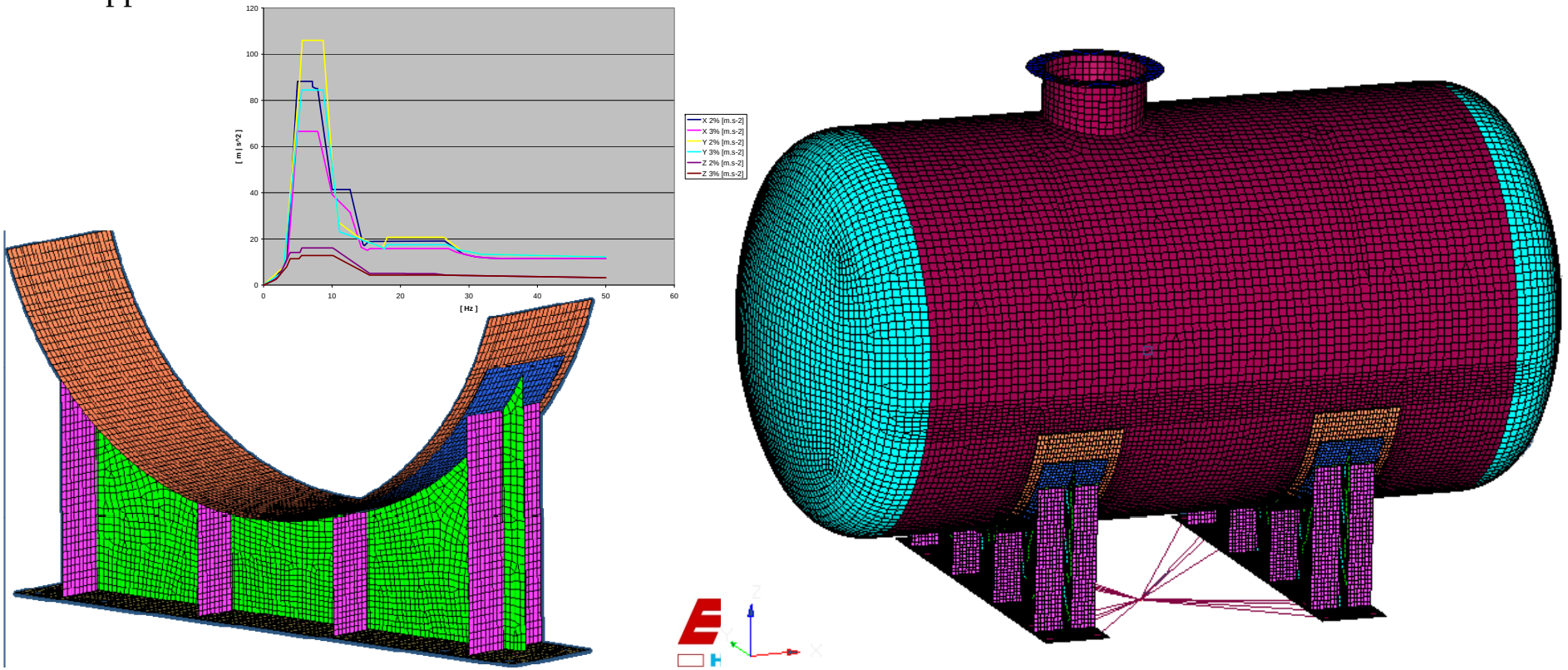
FEM Model

The FEM model generation (i.e. nodes and elements creation, model partitioning, materials assignment) has been done by means of the Altair/Hypermesh preprocessing program.

Eventually, the model is exported to the ANSYS 12.0 environment where the final setup (loads, constraints, etc.) takes place.

Four nodes shell elements have been used for modeling the system. Rigid elements have been used for the application of the design loads and constraints.

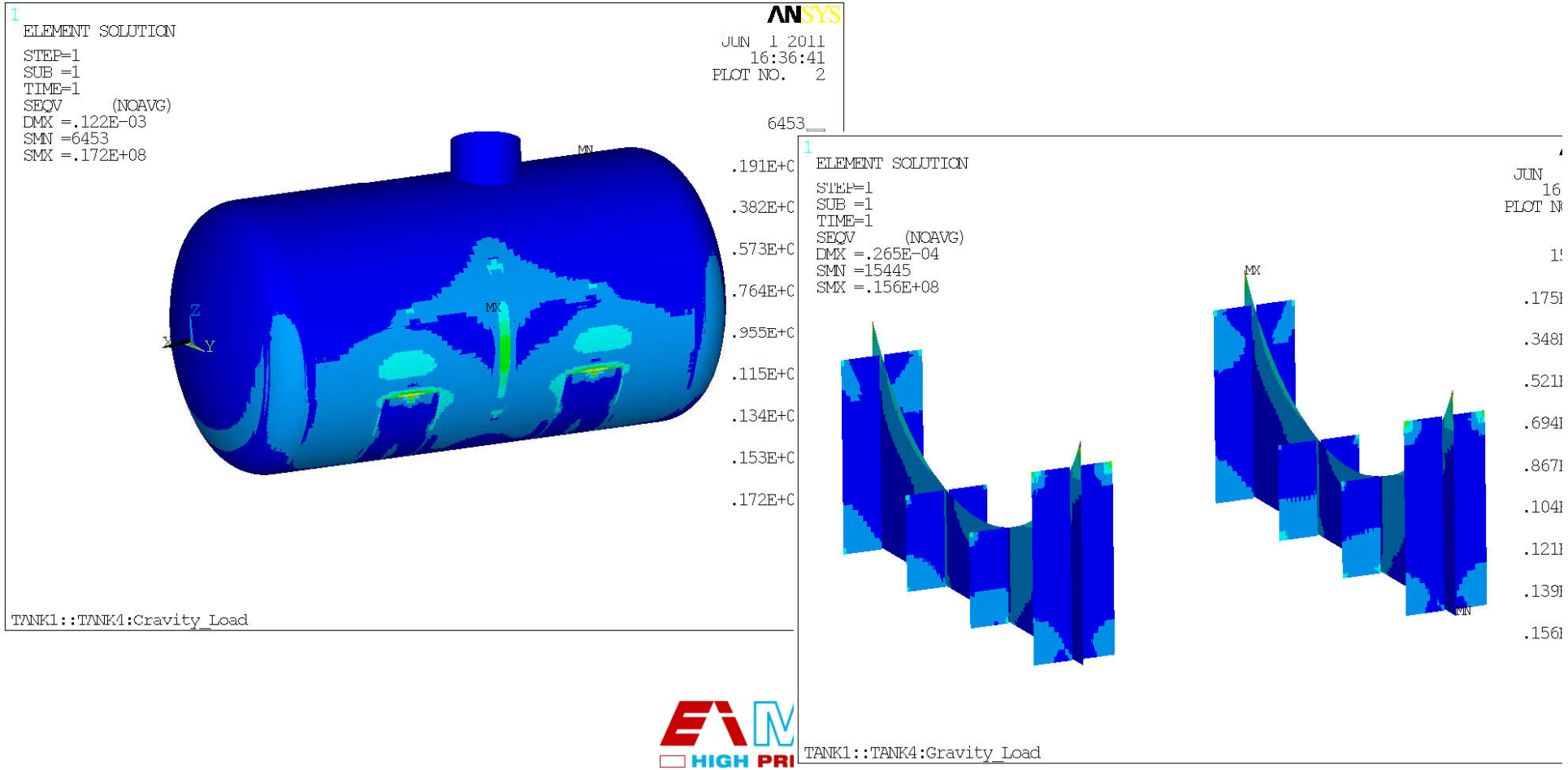
Dummy mass elements and spring elements have been used (as “masters” of rigid body “spiders”) in constrain load application nodes.



CLASSIFIED EQUIPMENT
WATER STORAGE TANKS

FEM Model

DESIGN CHECKS ON SHELLS, WELDINGS, SADDLES AND BOLTS ARE ACCEPTABLE



Conclusions and Remarks:

The Various Water Mist Capabilities:

- Faster Fire Control immediately after system activation
- Reduction in water consumption leading to:

-Minimises the damage caused by the extinguishing agent

-Reduction in piping diameters up to 10 times

System validation by Full Scale Fire Tests

Was a significant performances with respect to Standard Water Fire Fighting Systems so it’s now one of the most eco-friendly fire extinguishing solutions is increasingly being chosen for high risk facilities like traditional and nuclear power plants, refineries, high rise buildings

Conclusions and Remarks

- The HPWMS Technology and Components can be validated to be fully consistent with seismic requirements and laws
- Reduces weights and sizes due to seismic consistency to the minimum
- Is able to grant superior Reliability during seismic and accidental events because 100% validated for the Fire Extinguishing and Seimic resistance .

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Thank you for your attention!

QUESTIONS??

Eusebi Impianti srl