



JENSEN HUGHES

Advancing the Science of Safety

**WATER MIST CULTURAL HERITAGE CASE STUDY – MUSEUM
LEONARDO DA VINCI, MILAN**

**Gaetano Coppola
01/06/2022**



**Fire Sprinkler
International
LONDON 2022**

Two-day conference & exhibition

THE MUSEUM

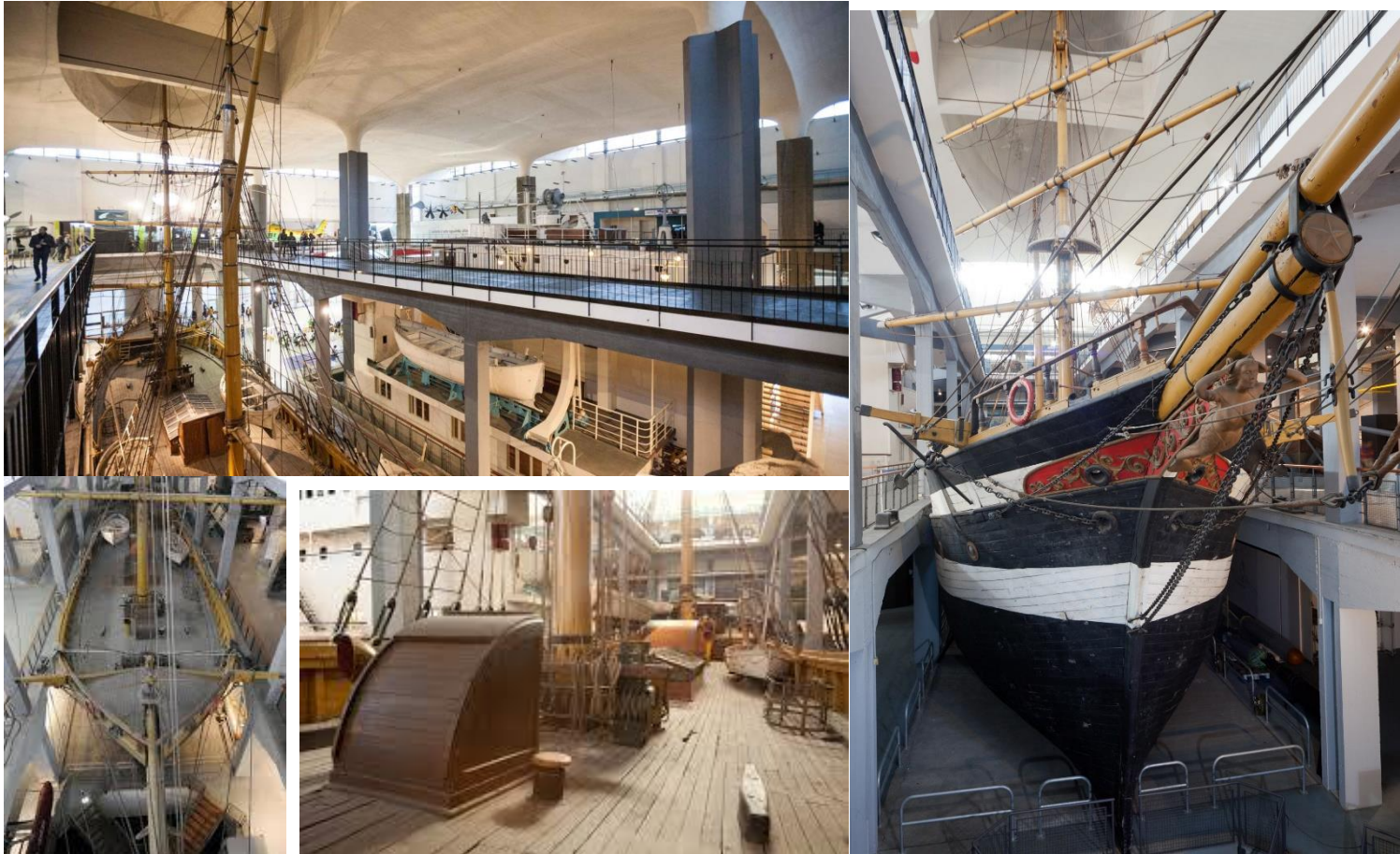
MUSEO NAZIONALE DELLA SCIENZA E DELLA TECNOLOGIA
LEONARDO DA VINCI, MILAN

AERONAVAL PAVILLION - BUILT IN THE FIRST HALF OF THE
1960s (30 m HIGH, \cong 3800 m²) .

FOUR FLOORS INTERCONNECTED BY A CENTRAL VOID
PLENTY OF HISTORICAL ARTEFACTS (HELICOPTERS,
FIGHTER-JETS, SHIPS, CATAMARAN...)



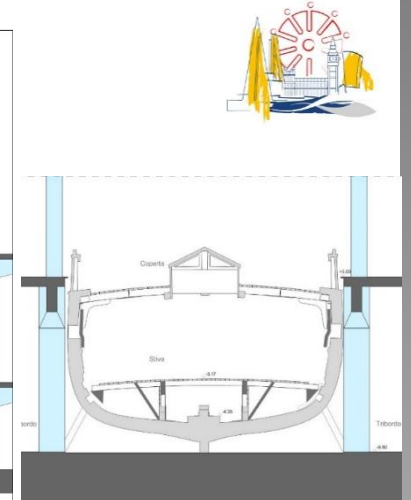
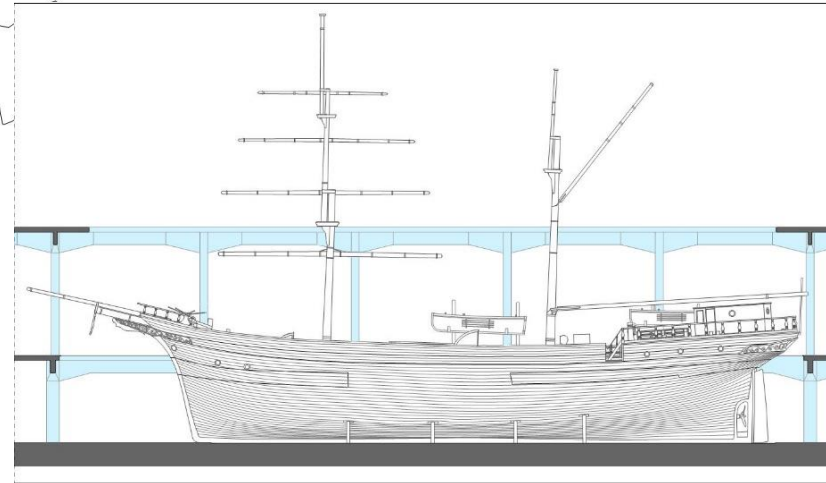
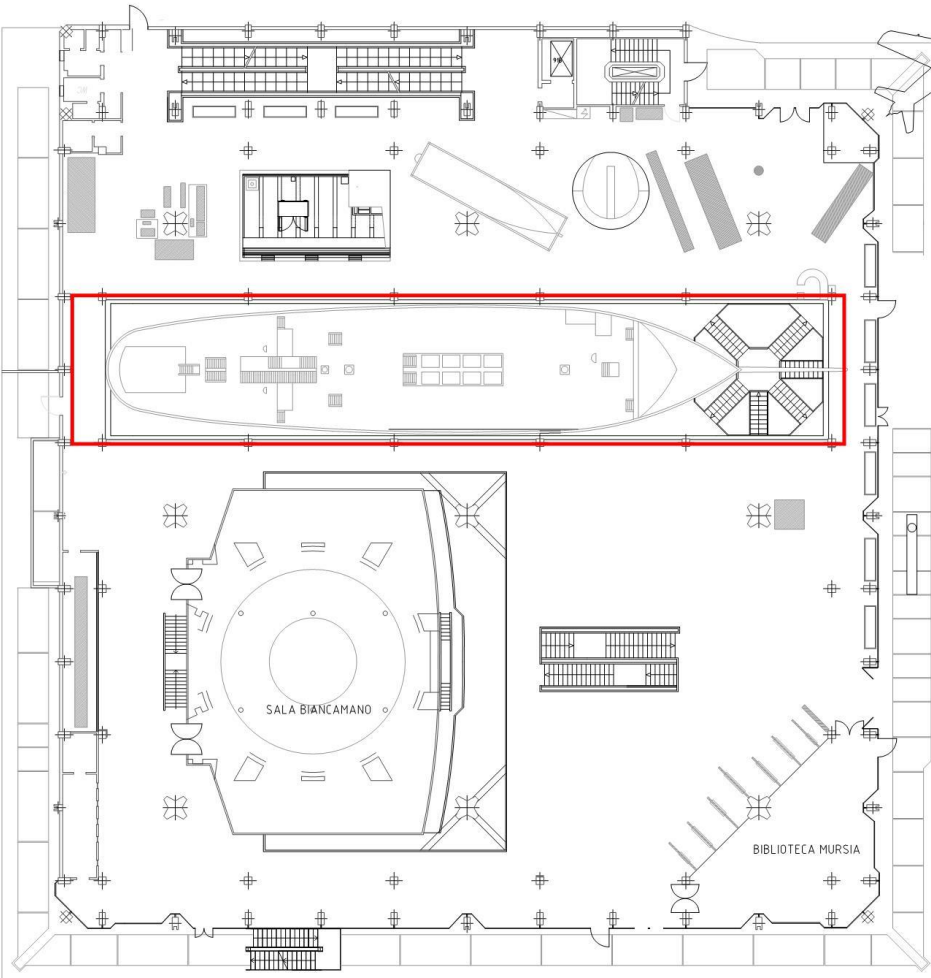
THE BRIG "EBE"



- 40,3 M LONG HULL (50,5 M INCLUSIVE OF THE FIGUREHEAD) 8,4M WIDE.
- BUILT ENTIRELY IN PITCH PINE, OAK, AND SPRUCE.
- WEIGHT-LIGHTENING PROCESS THROUGH THE LAST YEARS (REMOVAL OF THE SAILS, OF ANY INTERNAL EQUIPMENT, LIGHTING AND CABLING, TO MINIMIZE THE STRUCTURAL LOAD OF THE SHIP)



FIRE SAFETY DETAILS OF THE BRIG “EBE”



- MANUAL CALL POINTS FOR FIRE ALARM AROUND THE EXTERNAL WALLS
- FIRE EXTINGUISHERS IN THE VICINITY OF THE BRIG
- POINT SMOKE DETECTION WITHIN THE HULL AND AT CEILING OF THE BUILDING
- NO SPRINKLERS
- INTERNAL FIRE EMERGENCY TEAM (NOT 24h/7)

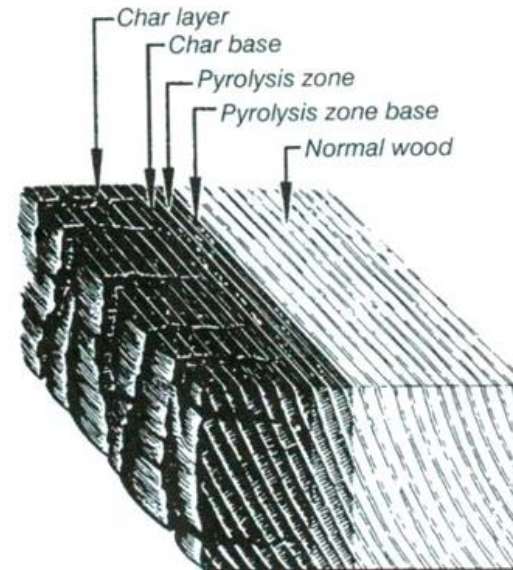


ANALYSIS OF THE MATERIALS

- AT TEMPERATURES ABOVE 100°C - 150°C, THE STRENGTH OF THE WOODEN ELEMENTS BEGINS TO DECREASE.
- BETWEEN 100 °C AND 200 °C, WOOD DEHYDRATES AND GENERATES WATER VAPOR AND OTHER NON-COMBUSTIBLE GASES INCLUDING CO₂, FORMIC ACID, ACETIC ACID AND H₂O.
- BETWEEN 200 °C AND 300°C, SOME WOOD COMPONENTS BEGIN TO UNDERGO A SIGNIFICANT PYROLYSIS PROCESS, WITH AN IMPORTANT PRODUCTION OF CO RELEASED WITHIN THE SURROUNDING SPACE

Table 18-3. Charring rate data for selected wood species

Species	Density ^c (kg m ⁻³)	Wood exposed to ASTM E 119 exposure ^a				Wood exposed to a constant heat flux ^b					
		Char con- traction factor ^a	Linear charring rate ^d (min mm ⁻¹)	Non- linear charring rate ^e (min mm ^{-1.25})	Thermal penetra- tion depth ^f (mm)	Linear charring rate ^d (min mm ⁻¹)		Thermal penetration depth d^g (mm)		Average mass loss rate (g m ⁻² s ⁻¹)	
						18- kW m ⁻² heat flux	55- kW m ⁻² heat flux	18- kW m ⁻² heat flux	55- kW m ⁻² heat flux	18- kW m ⁻² heat flux	55- kW m ⁻² heat flux
Softwoods											
Southern Pine	509	0.60	1.24	0.56	33	2.27	1.17	38	26.5	3.8	8.6
Western redcedar	310	0.83	1.22	0.56	33	—	—	—	—	—	—
Redwood	343	0.86	1.28	0.58	35	1.68	0.98	36.5	24.9	2.9	6.0
Engelmann spruce	425	0.82	1.56	0.70	34	—	—	—	—	—	—
Hardwoods											
Basswood	399	0.52	1.06	0.48	32	1.32	0.76	38.2	22.1	4.5	9.3
Maple, hard	691	0.59	1.46	0.66	31	—	—	—	—	—	—
Oak, red	664	0.70	1.59	0.72	32	2.56	1.38	27.7	27.0	4.1	9.6
Yellow- poplar	504	0.67	1.36	0.61	32	—	—	—	—	—	—



INITIATING EVENTS



Trends in systems & causes, Inland waterways only	2018	2017	2016	2015	2014	2013	2012
[Note - All fire & CO events only]							
Totals	54	69	65	63	69	91	80
Deliberate Fire setting	5	11	5	11	12	11	11
Conflagration	3	4	5	11	3	3	5
Totals of accidental and original incidents	46	54	55	41	54	75	64
Bulky goods	1	1	0	0	0	0	0
Electrical [system / appliances]	6	7	11	7	8	15	15
Engine / engine room / exhaust	7	2	7	2	5	6	4
Flammable vapours (not yet identified)	2	7	5	4	3	3	2
Other domestic, galley, smoking, candles, etc	0	2	4	1	0	0	3
Gas escape / installed gas appliance	2	3	3	2	0	4	3
Not known [inconclusive / tbc to BSS]	18	21	10	15	27	28	21
Oil fired stoves and heaters [installed]	3	3	-	1	0	1	2
Other [inc machinery, welding, DIY, etc]	0	0	-	-	2	1	2
Petrol related - leaks, refuelling, etc	1	2	2	2	2	2	2
Portable engines / outboards / generators	0	1	-	-	2	2	0
Portable items [pg, oil, BBQ, electric, etc]	1	0	1	-	0	2	0
Solid fuel stoves	6	6	12	7	5	13	10

Deliberate Fire setting	5	11	5	11	12	11	11
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Electrical [system / appliances]	6	7	11	7	8	15	15
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Other domestic, galley, smoking, candles, etc	0	2	4	1	0	0	3
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INITIATING EVENTS



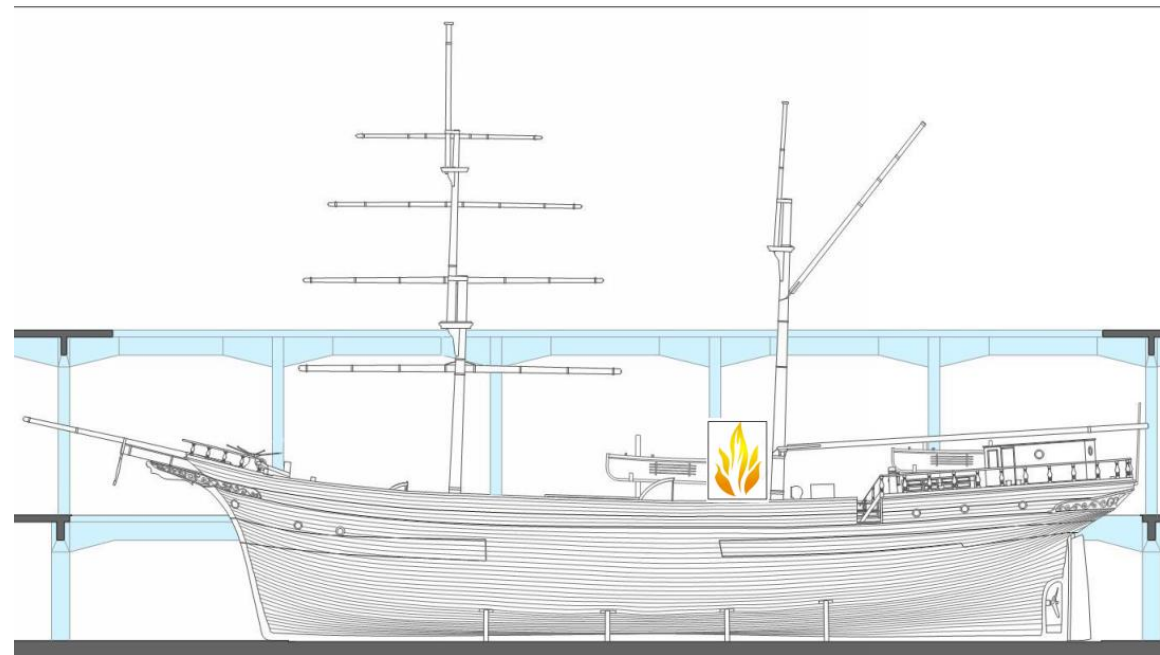
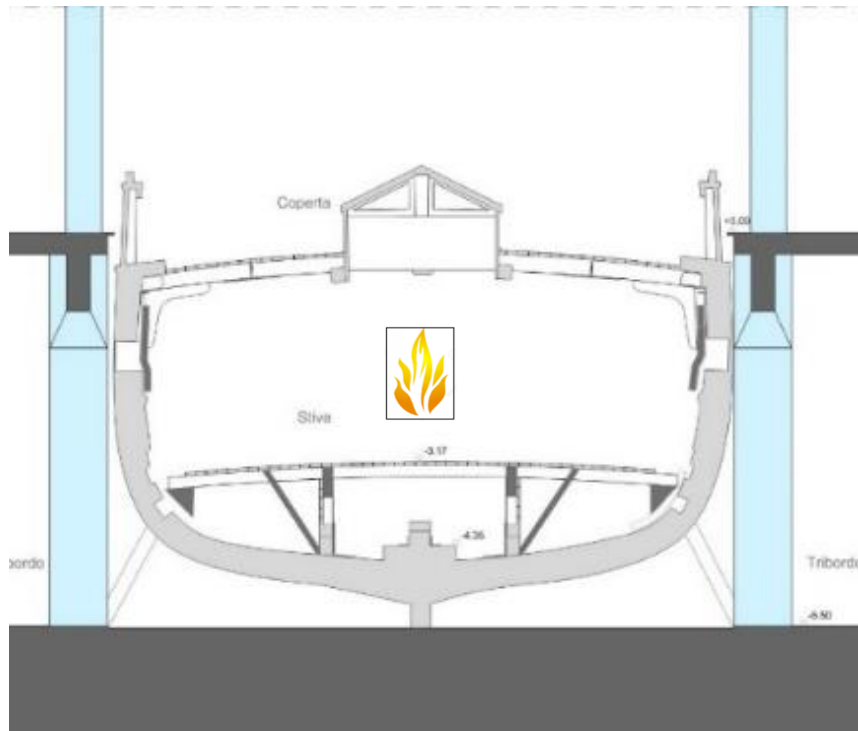
INITIATING EVENT #1	principle of fire triggered by mobile, electrical equipment or lighting devices
INITIATING EVENT #2	principle of fire triggered by cigarette or similar source of ignition
INITIATING EVENT #3	principle of fire derived from arson



FIRE SCENARIOS



- **FIRE SCENARIO #1** –
FIRE LOCATED BELOW DECK (INSIDE) OF THE BRIG

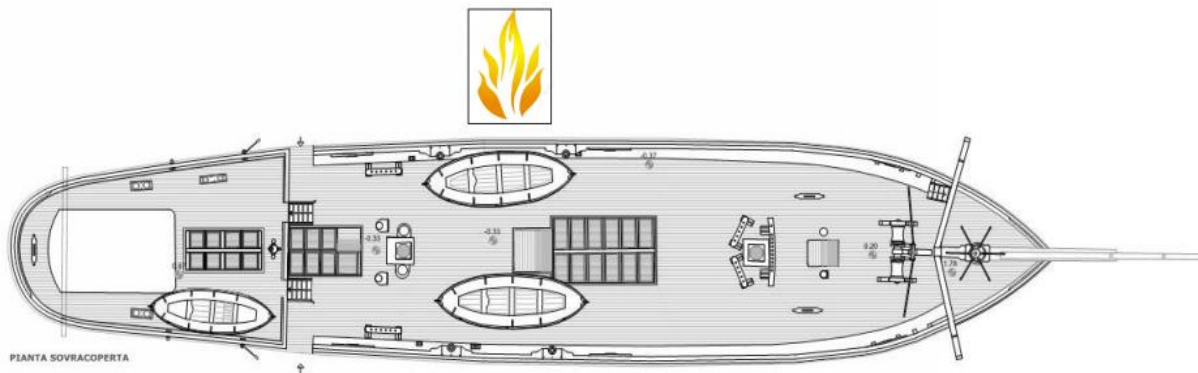


- **FIRE SCENARIO 2** –
FIRE LOCATED ON THE UPPER DECK OF THE BRIG

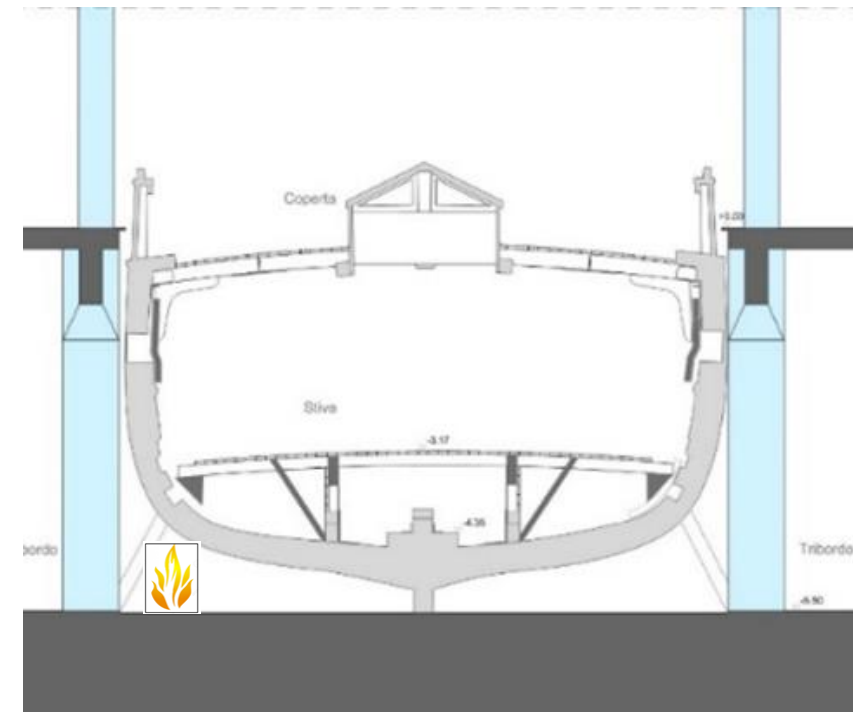


FIRE SCENARIOS

- **FIRE SCENARIO #3** –
FIRE POSITIONED AT AN ALTITUDE (floor height) OF +0.00 NEAR THE HULL OF THE BRIG



- **FIRE SCENARIO #4** –
FIRE ORIGINATED AT AN ALTITUDE OF -5.50 METERS
NEAR THE HULL OF THE BRIG



HISTORICAL DATA



PRINCE WILLEM (FULL SCALE SHIP REPLICA) – 68 m LONG AND 54m HIGH – INSTALLED AT «DEN HELDER MUSEUM», HOLLAND



CUTTY SARK - 64,6 m LONG AND 10,94 m WIDE - INSTALLED AT THE MARITIME GREENWICH WORLD HERITAGE, LONDON.



RISK EVALUATION



- SIGNIFICANT MATERIAL DAMAGE, CULTURAL AND HISTORICAL LOSS OF HIGH VALUE
- A FIRE NOT PROMPTLY CONTROLLED WOULD RESULT IN A SHUTDOWN OF MUSEUM ACTIVITIES

			Impact			
			1 Acceptable	2 Tolerable	3 Unacceptable	4 Intolerable
			Little or No Effect	Effects are Felt but Not Critical	Serious Impact to Course of Action and Outcome	Could Result in Disasters
Likelihood	Improbable	Risk Unlikely to Occur				
	Possible	Risk Will Likely Occur				
	Probable	Risk Will Occur				

- DEEMED UNACCEPTABLE FOR THE MUSEUM'S ACTIVITIES (\cong 600k PAYING VISITORS PER YEAR)

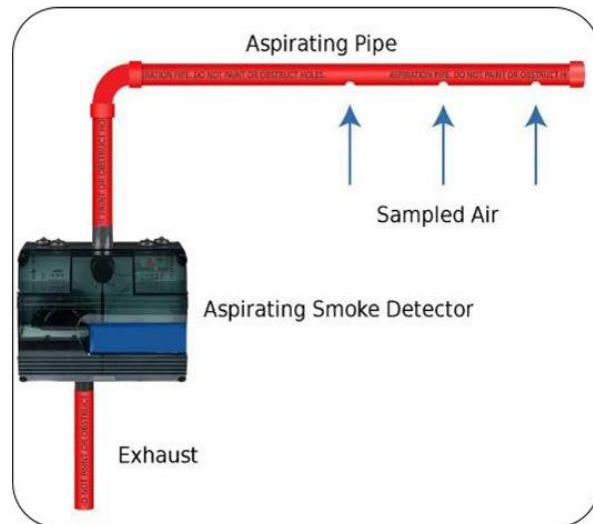


PROPOSED SOLUTIONS BASED ON RISK EVALUATION

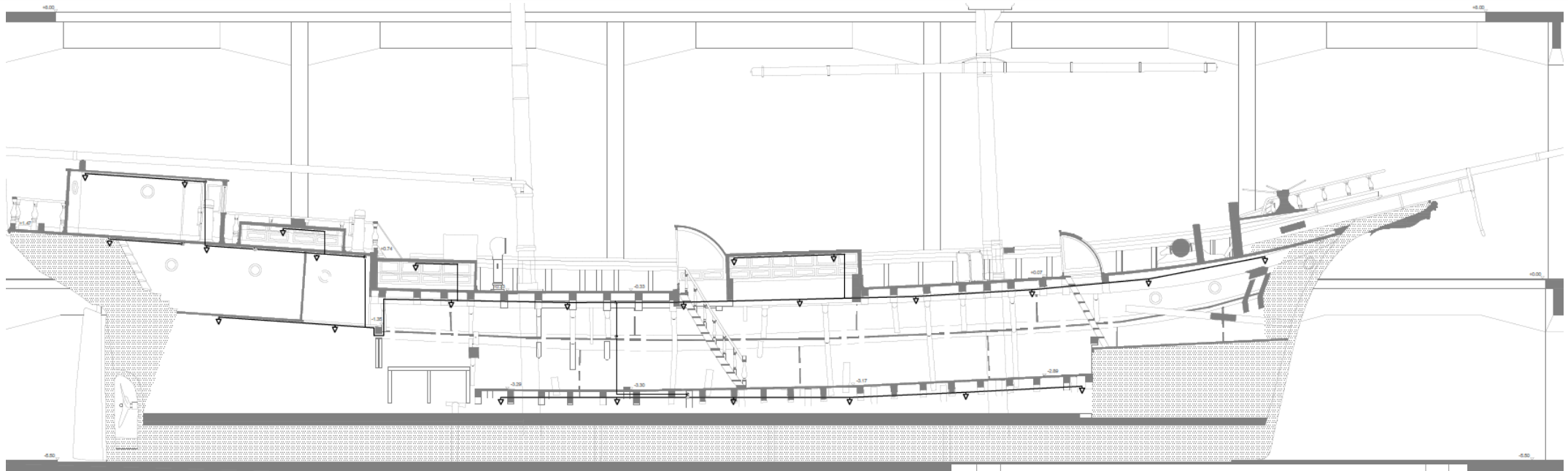


SUGGESTED IMPROVEMENTS:

- IMPLEMENT THE FIRE DETECTION SYSTEM WITH A MORE RESPONSIVE SOLUTION (e.g ASD SYSTEM)
- INTRODUCE A FIRE CONTROL SYSTEM.

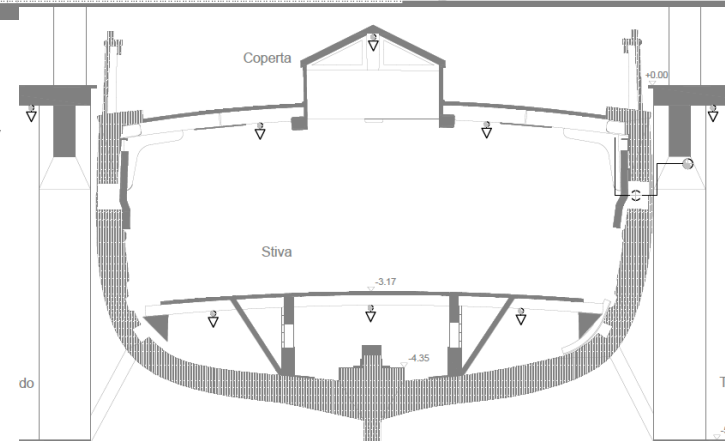


HIGH PRESSURE WATER MIST SYSTEM



WATER MIST:

- Reduced impact of water supply (tank/pump) with less water demand/consumption.
- Less invasive hardware installation.
- Use of High-Pressure System
- Availability of protocol for design specification according to classification NFPA 750: LH (*Light Hazard - HC-1*)



HIGH PRESSURE WATER MIST SYSTEM

WATER MIST DESIGN CLASSIFICATION:

Classification according to NFPA 750: LH (*Light Hazard - HC-1*)



WATER MIST DESIGN SPECIFICATIONS:

Jensen Hughes specify the WM system for tender purpose selecting a specific hardware, in order to be able to define the main WM system features like nozzles spacing, pressure and water demand.

The design and sizing of the proposed solution was based on the system produced by the ULTRAFOG Company and, specifically, in accordance with the following Approvals / Certifications:

- “FM (Factory Mutual) Approval Number 3043823 - Occupancies, Hazard category 1 (HC-1)” for application within civil buildings such as hotels, museums, hospitals, offices with area height up to 5m and based on the Fire Test Report No.140508-142 by DFL (Danish Fire Laboratories), carried out on January 5, 2015, by the company “ULTRAFOG”.
- “DNV (Det Norske Veritas) Certificate N° F-204128 or TAF00000XH - “Equivalent Sprinkler System with type designation(s) Ultra Fog Accommodation Sprinkler Approved for use as an automatic water sprinkler system for Accommodation area, Public spaces, and Store rooms “ issued on August 12, 2012.



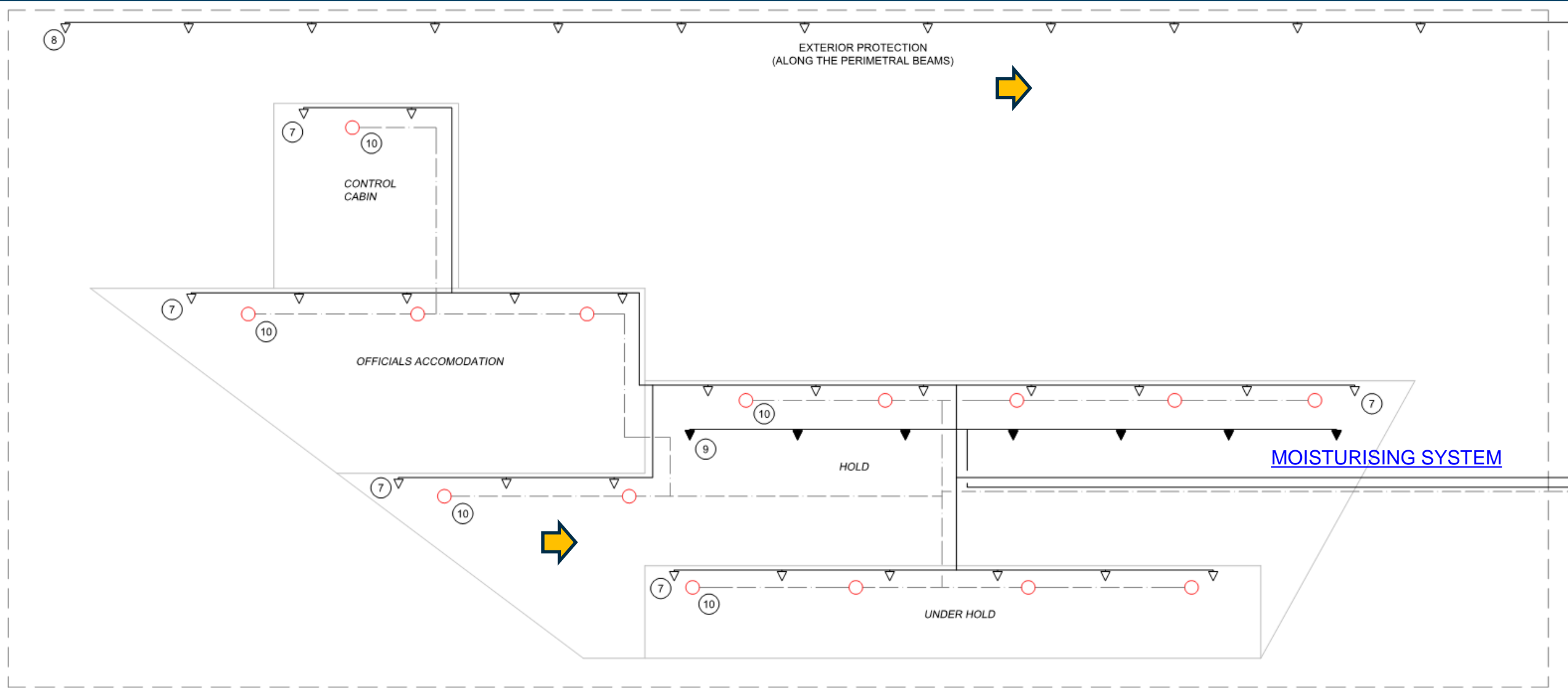
HIGH PRESSURE WATER MIST SYSTEM

WATER MIST DESIGN SPECIFICATIONS:

- Pendent Ultrafast Nozzles, rated at 57°C as activation temperature
- Operating Pressure: **65-100 bar**
- System designed to have **6 nozzles** operating simultaneously. (72m² op.area)
- High-Pressure Electric Pump with dedicated power supplies and water tank on unit (**70 kW Pump for 300 lpm at 140 bar 400V/3ph/50Hz**)
- Water Inlet flow: **300 l/min at 2-6 bar** from Main City water supplies (6" pipe)
- Water Duration: **60 min** (30 required by NFPA 750)
- Max 12mm pipes within the brig (stainless steel AISI 316L – high pressure at 25 bar in standby conditions)
- Water Droplet \cong **200 μ m**



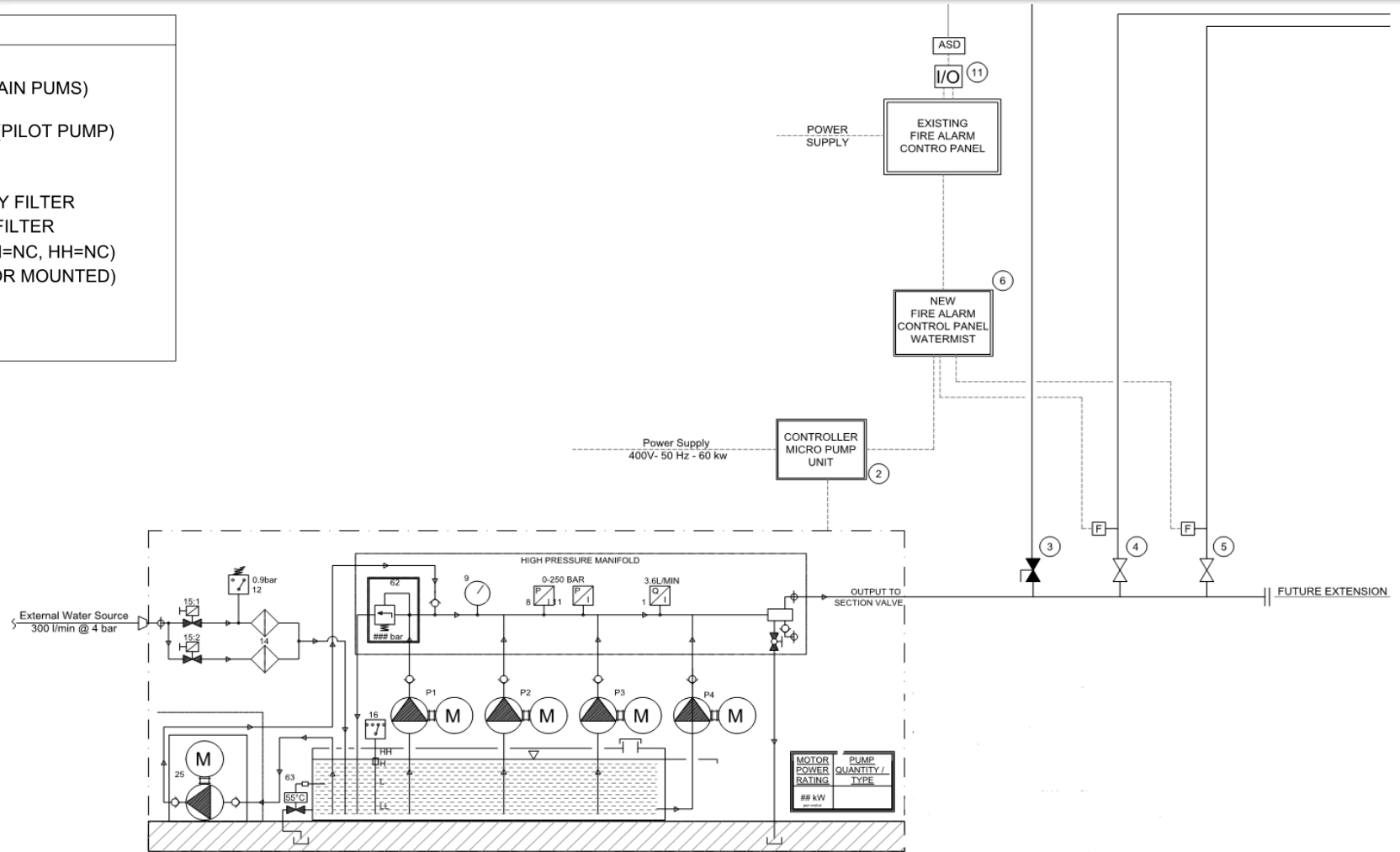
WATER MIST SYSTEMS



HIGH PRESSURE WATER MIST SYSTEM

DESCRIPTION

- 1 FLOW SWITCH
- 8 PRESSURE MONITOR (4-20mA (MAIN PUMS))
- 9 PRESSURE GAUGE
- 11 PRESSURE MONITOR (4-20 mA) (PILOT PUMP)
- 12 PRESSURE SWITCH (NC)
- 14 MAIN FILTERS
- 15:1 SOLENOID VALVE TO PRIMARY FILTER
- 15:2 SOLENOID VALVE TO SPARE FILTER
- 16 LEVEL SWITCH (LL= NO, L=NO, H=NC, HH=NC)
- 25 ELECTRICAL PILOT PUMP (FLOOR MOUNTED)
- 62 PRESSURE REGULATOR
- 63 TEMPERATURE VALVE



ACKNOWLEDGEMENT

- Museo Nazionale Scienza e Tecnologia «Leonardo Da Vinci» (<https://www.museoscienza.org/en>)
- Prof. Florenzo Galli, Director of the MNST- «Leonardo Da Vinci»
- Jensen Hughes Milan- Project Team:
 - Luciano Nigro
 - Simona Zanotti
 - Giovanni Cosma



QUESTIONS?

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