Teaser documents for the proposed power plant in UAE

Heads	**Details**
Land Area required in sq mtr. As per law of land build up area is 60% of the total area	[B]
Expected Land Rent to be paid to the government	**[C]**
Desired Land Levelling (As it will be sand)	[B]
Estimated Distance desirable between the land and the sea shore	[B]
Estimated Distance desirable between the land and the power grid	[B]
Power & Water requirement during the construction phase	[B]
Draught of the Sea	[B]
Proposed Movement of Fuel from Sea to Plant	[B]
Nature of Fuel	LNG
Source of Fuel	QATAR or OMAN
Transportation of Fuel	[B] SHIP
Brief Configuration of the Power plant	Appendix A
Brief Configuration of the Cooling Tower	Appendix A
Brief configuration of the Desalination Plant	Appendix C
Envisaged Output of the Power Plant	**[C]**
Total estimated Capital Cost of the power project	**[C]**
Total estimated Operational Cost of the power project	Appendix D
Approximate Cost of Production of Power	Appendix D
Brief Background of the Promoters or Consortium	**[A]**
Brief Background of the Technology Supplier	Appendix A, C
Brief Background of the Equipment Supplier	Appendix A
Source of Fund CAPEX & OPEX for the project	Appendix D
Background reference of the operational power plants in the other parts of the world	Appendix A
PPA Agreement at what rate is expected from the government	Appendix D
Release of the produced power will be for grid completely or also to sale to end users	Optional
Expected Man Power required for EPC & running the power plant	ALNG storage & Regas; Pipeline(s); Power Plant; LT-MED plant --<100
Waste & Effluent Disposal arrangements and treatment	In accordance with local regulations

INFORMATION MEMORANDUM:
PROPOSED UAE RLNG CCGT POWER SYSTEM -- ENERGY GIANT HKSAR LLC

PROPOSER: [A]

Energy Giant LLC HKSAR acts as a system integrator that:

(1) integrates best-of-breed technologies which it funds through Special Purpose Vehicles to beneficiate high value products from local resources [such as in India & Mozambique]; and

(2) develops and funds high-reliability power generation projects for 'green fields' locations at the best possible cost efficiency.

- EG is working with EMEM Mozambique to build a coal-to-diesel and agro-chemical Program in northern MZQ: $4.5 billion
- EG is working with Indian Oil Corp. Ltd. to build a coal-to-diesel and agro-chemical Program at three India ports [Hazira, Ennore, and Kirtania Subarnarekha]: $4.5 billion.
- EG is working with Indian Oil Corp. Ltd. and PetroBangla to build a 2,500 mmscfd LNG storage and regas facility [using CDTS tanks] on the mouth of the Subarnarekha River at the India Bay of Bengal coast that will pipe gas to West Bengal and eastern Bangladesh markets for the first time: $3.9 billion.

EG has organized a specialized aero derivative EPC in Morocco to 'de-conflict' all CCGT projects in 'green fields' markets. All personnel are trained and certified by Siemens in the installation, operation, and maintenance of Siemens/ Rolls-Royce SGT A65 aeroderivative gas turbines and assorted support sub-system described herein.

Many emerging markets have been approached to build over-sized gas turbine power plants where there is no supporting industrial infrastructure for handling, operations or repair. In addition, some emerging markets have no gas grids. EG's solution is to derive a modular and scalable CCGT configuration with its proprietary 'flow acceleration' heat exchanger with a competitive heat rate.

- EG is working with Bright Trade to build out a 2,000 MW CCGT-based power system for the government on the Mediterranean coast of Syria.
- EG is working with the Myanmar government to build out a 3 berth site at Dala port on the Yangon River to receive and regas LNG that will feed three 386MW CCGT systems situated across the river in the MPE refinery premises at Thanlyin to send power to Hlaingeharyar Grid.
- EG is working with the Government of Bangladesh for the distribution of 386 MW CCGT power generation stations along the new gas pipeline to be built in eastern Bangladesh.

A. Land area we will require for all Power Plant sub-systems and in what condition: [B]

<u>CCGT Power Plant</u>:

We propose a 386 MW-rated 3 on 1 SGT A65 Wet Low Emissions (WLE - The injection of water reduces emissions and boosts performance); Inlet Spray Inter-cooling (ISI reduces ambient inlet temperature and decreases the energy required for compression) and 3 on 1 Pressured Fired configuration. Our proposed proprietary 'flow acceleration heat exchanger' will increase output of the 386 MW.

Attached please find Appendix A. "*SGT A65 CCGT Reference Layout with Horizontal-HRSG*". On page one you will note:

Projected Width: 459 ft.

Projected Length: 388 ft.
Total Area: 178,092 ft^2
In square meters: 16,545.29 m^2

Projected Result / MW Configuration: 17,100 m^2

[3] Gas Turbine Package Weight: 238,600 kg

[1] Overall Steam Turbine & Generator Weight: 396,050 kg

We will build an entire floor for the full layout from reinforced concrete capable of sustaining both equipment weights and all the necessary servicing vehicles.

We will implement additional 3 on 1 CCGT systems as power requirements expand.

LNG Storage and Regasification:

In our work with Indian Oil on the 2,500 mmscfd LNG storage and regasification facility at "LNG Kirtania", we expect IOCL to obtain an mmBTU of LNG at about 12.5% of the price of a barrel of Brent Crude, plus about $25 per ton for freight from Qatar / Singapore to India. This LNG will be stored in sixteen CDTS 40,000 m^3 LNG storage modules until regasified. The RLNG will be piped to West Bengal Indian markets, and markets in Bangladesh.

The UAE project will procure LNG from Oman or Qatar – which is virtually next door. However, we will have to receive, store, then regasify the LNG for CCGT use. Our 386 MW 3-on-1 CCGT will require about 42.21 mt of LNG per hour or about 24,652 mt of LNG for 80% availability over 1 month of CCGT Operation.

As in India, we will utilize a Cubic Donut Tanking Modular Storage System (CDTS of Altair Engineering) – two 40,000 m^3 tanks, constructed from 9% Ni Steel. We have standardized on the 40,000 m3 module, and are building the units off-shore for welding and assembly on site. This allows us to obtain safe LNG storage within the CCGT system construction time frame. Attached please find Appendix B. "*31Aug2018_AltairCDTS_Solution_Land Storage*".

Two 40,000 m^3 tanks will require 140.5 X 232 = 32,596 m^3

Optimal risk factored design of LNG Tank Farm layout by China Petroleum University, the required land for the CDTS modules is 67% of the land use required for conventional circular concrete full containment tanks of similar capacity.

Our Indian LNG storage facility, at LNG Kirtania, working with Indian Oil Corp. Ltd., **obtained approval** from the Indian Ministry of Petroleum and Natural Gas- Oil Industry Safety Directorate ["OSID"], for this modular, single containment tank because the OISD-194 section 6.1.3 covering double integrity is fully covered by Altair's CDTS design.

Low-draught [6-8 meters] 22,000 mt LNG carriers will make deliveries about every three weeks for the two CDTS tanks to off-take and store. Best case is to co-locate the CDTS tank facility at a deep-water port. However, if necessary a dolphin can be anchored at sufficient sea depth so a 6-8 m draught 22,000 mt LNG carrier can connect and pipe LNG to the CDTS tanks close by on the beach.

Although a 386 MW 3 to 1 CCGT system burns about 49.34mmscfd -- to achieve operational simplicity expanding power capacity, a single 1100 kW Wartsila 250mmscfd regas train will be deployed. The train weighs about 175 mt. ***Its dimensions: 26 m long X 14.5 m wide X 8 m high. The train is placed on a 4,000 m^3 tract, reinforced to bear 175mt, at sufficient distance (>100 meters) from the CDTS tanks & CCGT power system to satisfy local safety regulations.***

It is more economical & timely to ramp up additional CDTS tanks to feed additional CCGT power systems – five of which can be supplied with RLNG via one 250mmscfd regas train.

Fog technology inlet cooling increases output by up to 20%, improves heat rate up to 5%. Substantial water [28 gal./minute per inlet fogging sub-system] must be demineralized [less than 5 parts per million of Total Dissolved Solids]. The proposed three SGT A65 GT inlet fogging systems utilize 120,960 gallons [458 cubic meters] per day to keep inlet air temperate in 35˚ C high humidity weather prevalent at UAE beaches. The three wet compression combustion systems can evaporate 70 gallons per minute each [0.798 cubic meters/minute, 1,149 m^3 per day].

We use Low-Temperature Multi-Effect Distillation [MED] to desalinate seawater because the primary energy required is free: A 386 MW 3 to 1 CCGT system generates greater than 400˚ C. exhaust heat, far more than the 70˚ C. a MED unit's 'effects' use to generate 100,000 m^3 /day of water with 5 ppm TDS [parts per million of Total Dissolved Solids]. Note: The 'fresh' water consumed by humans is ~1,000 ppm TDS. An LT-MED system makes guaranteed Boiler Feed Water at <5ppm TDS for ~$0.13 /m^3. ***An LT-MED system requires 25 acres [100,000 m^2] at the shore***.

Indicative Budget [C]

LNG Storage and Re-gas plant	$ 78,444,215
If Dolphin Required vice existing Port	$ 25,000,000
386 MW CCGT with flow acceleration	$309,994,347
25,000 m^3/day LT-MED System	$ 27,500,000
Land @ $13 per m^2 [153,696 m^2]	$ 1,998,048

Each additional 386 MW CCGT Capacity Expansion

LNG Storage Expansion	$ 51,400,000
CCGT with Flow Acceleration	$297,750,000
Land [49,696 m^2] @ $13/m^2	$ 646,048

EnergyGiant
Limited

Appendix A.

Resilent Power Plants

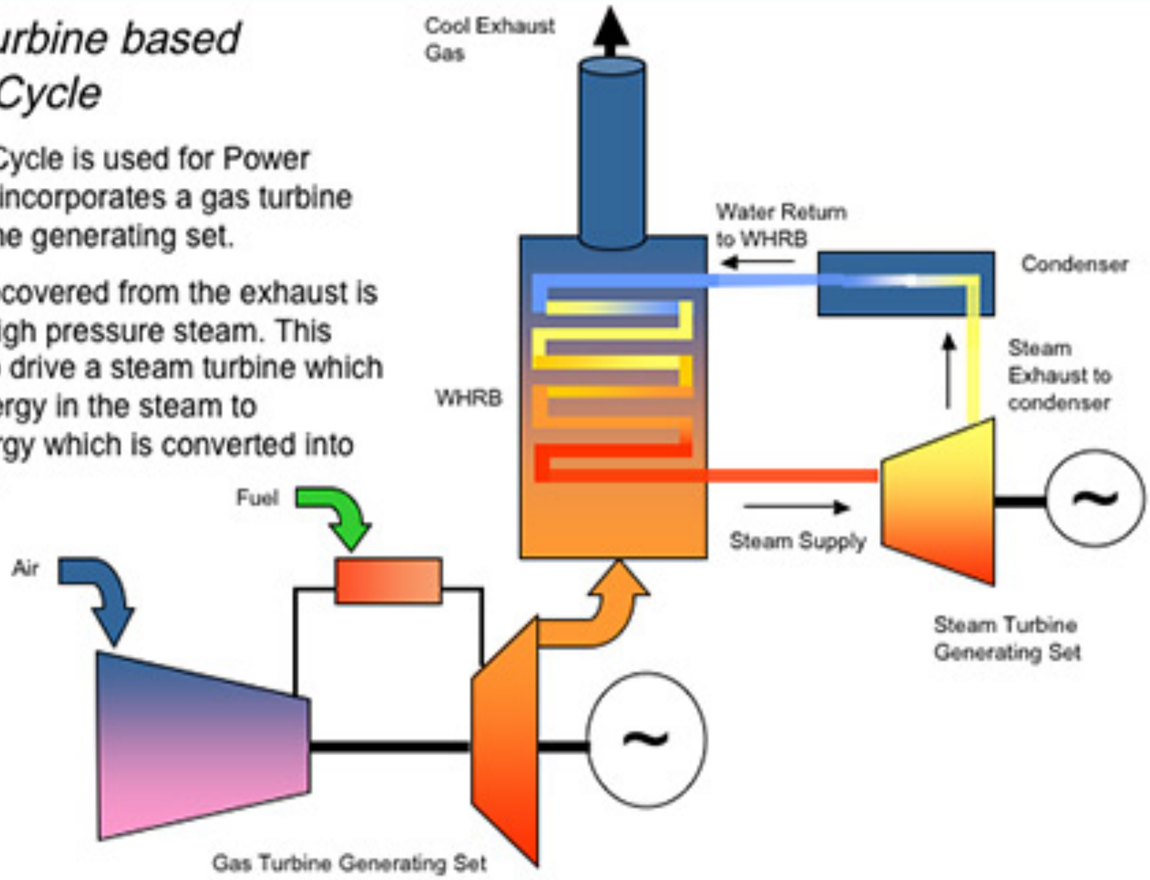
Custom-Tailored Power Solution

- We are developing a versatile engineering capability in Morocco to purchase, integrate, install, and operate modular power plants
- These modular power plants will be standardized on the Siemens 321.9 MW ***SGT A65 WLE ISI 3 on 1 One Pressure Fired*** combined cycle system
- We will purchase standardized 321.9 MW power modules based on the ***SGT A65 WLE ISI*** from Siemens, implement them in Morocco, then pack them up and ship them to our developing country client sites where we will install, operate and maintain them.
- As the power requirements inevitably expand, we will continue to purchase and implement additional Siemens 321.9 MW power modules at our developing country client sites.
- All power plants will be configured similarly to assure singular expertise, availability of spares and parts, and the highest efficiency of operation.
- All 321.9 MW power modules can be trucked into the interior of a developing country client from the port of access. Right-sized component handling equipment will be a standard feature of each configuration. We will bring everything with us that we will need to build, operate, and maintain our power plant modules.
- We will supply all funding, and will contract for a service charge per kWh of electricity generated. The natural gas fuel will remain the responsibility of the power purchasing utility.

The Gas Turbine based Combined Cycle

The Combined Cycle is used for Power Generation and incorporates a gas turbine and steam turbine generating set.

All of the heat recovered from the exhaust is converted into high pressure steam. This steam is used to drive a steam turbine which converts the energy in the steam to mechanical energy which is converted into electrical power.



2. Site Specific Gas Turbine Performance Data (per unit)		
Generator Output	66002	kW
LHV Heat Rate @ Generator Terminals	8661	kJ/kWh
LHV Efficiency @ Generator Terminals	41.57	%
Compressor Inlet Airflow	170.2	kg/s
Exhaust Temperature	422.6	C
Site Performance Data Computed Burning	Gas Fuel	
Site Performance Data Computed with Inlet Loss	7.938	millibar
Site Performance Data Computed with Exhaust Loss	21.97	millibar
Site Performance Data Computed with Water Injection	4.016	kg/s

High power and efficiency: Due to an independent 3 shaft design, this turbine is flexible, offering high power out and fuel efficiency with minimal drop-off at reduced speed conditions

For power generation: One of the most efficient gas turbines on the market, the SGT-A65 provides up to 71 MW in simple cycle service at 43.8% efficiency

Modular design for quick installation and easy on-site maintenance: The SGT-A65 consists of 8 engine modules for easy maintenance. Each module is pre-balanced to make it completely interchangeable.

What's the value of an Aero ?

SIEMENS Ingenuity for life

High Simple Cycle Efficiency	High Power Density	High Cycle Capability
Typically 3~5%pts better than Industrials High pressure ratio EQUALS high fuel efficiency (downside; requires a higher skid edge fuel pressure).	**Typically 30% size and 50% weight reduction** Extensive application of Titanium and high Nickel alloys, which reduces weight.	**No penalty for starting and stopping** Hollow shafts eliminate rotor bow and high Nickel casings eliminate stress.
Fast First & Restart Capability	**Low Black start requirement**	**High Grid Frequency Change**
5' ~ 8' starts and with NO lockout timers after a shutdown Combined benefit of Nickel alloys and design.	**<500kW electrical start-up equates to smaller site back-up generation** Multi-shaft core requires starting only on the smallest, lightest rotor.	**Lightweight rotors allows to respond quickly** Nickel alloys and hollow design allow rapid rate of change.
Experience – mission critical	**"NO" EOH**	**Bearings**
Customers demand operational experience – aero hours prove technology when applied to industrial applications FAA approval and flight hours creates natural experience list.	**Material within an aero GT capable of more extreme operating conditions which leads to longer life and lower OPEX cost** Combined benefit of Nickel alloys and design.	**Anti-friction bearings require less lubrication which reduces OPEX** Ball bearing design is lightweight and low oil flow / consumption.

A SGT-A65 is .....

SIEMENS Ingenuity for life

→ Direct derivative of the aero Trent 800 engine, because .....
  → Proven technology.
  → Low cost solution.

→ 3 shaft gas turbine (HP, IP & LP) – see next slide.
  → Each shaft rotating independently of each other.
  → Excellent future growth.

→ 36:1 Rp gas turbine (50Hz).

→ Environmentally friendly, having both DLE & WLE options.

→ Hot end drive machine.

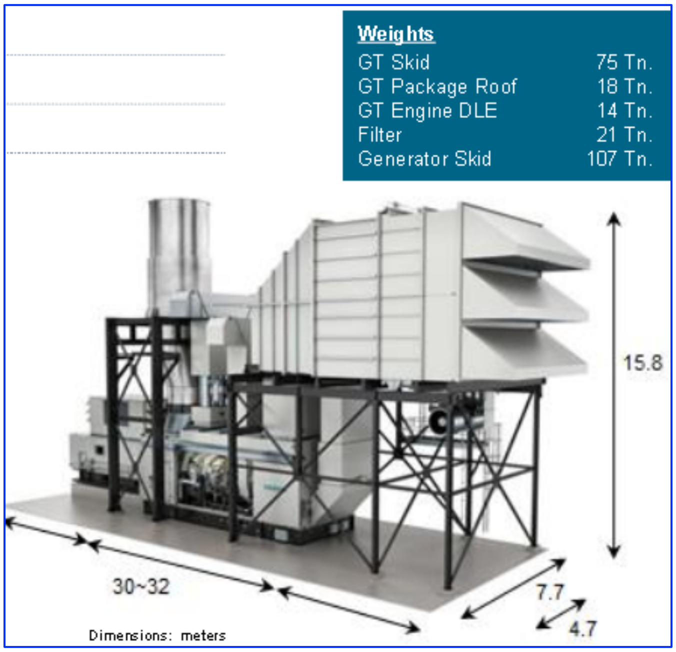
→ **NO** gearbox required for both 50Hz & 60Hz applications.

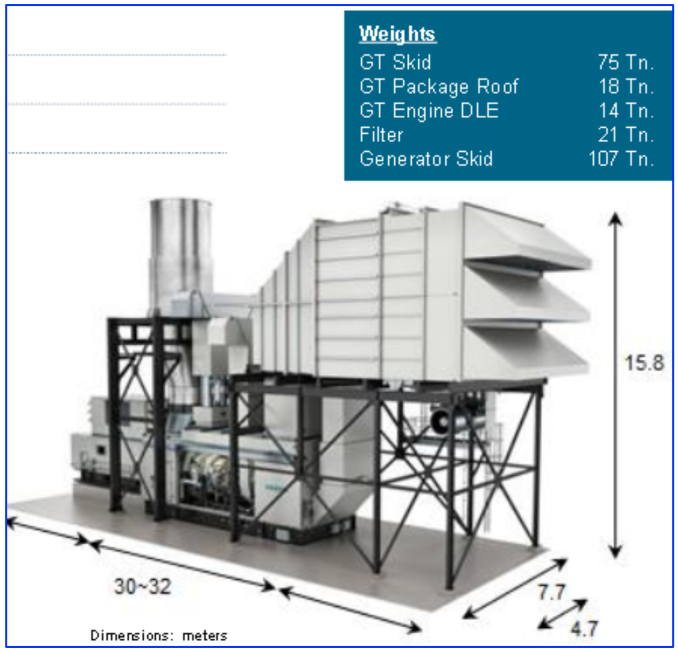
→ Normal start capability; <7mins, from cold metal to full load on either GAS or LIQUID fuel; Ramp rates of 21~40MW/min.

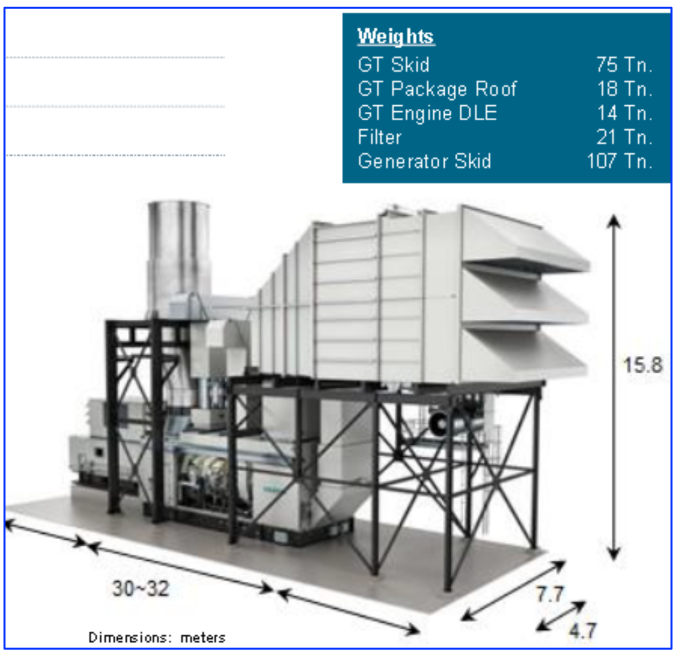
→ High cycling capability, w/limited maintenance cost impact, **NO** EOH, immediate restarting and **NO** lockout period.

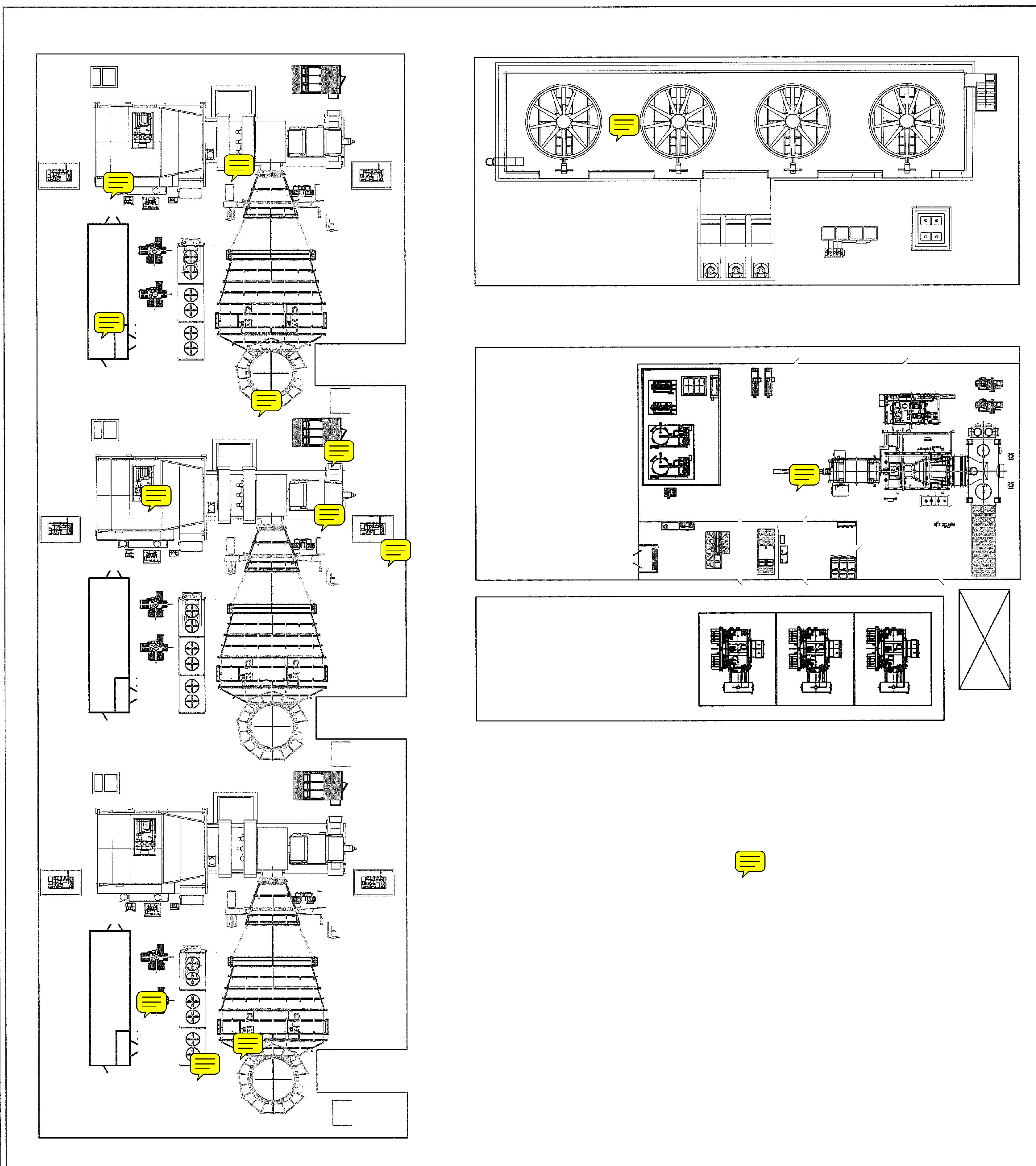
Power Output Analysis of SGT A65 WLE ISI 3 on 1 One Pressure Fired CCGT System

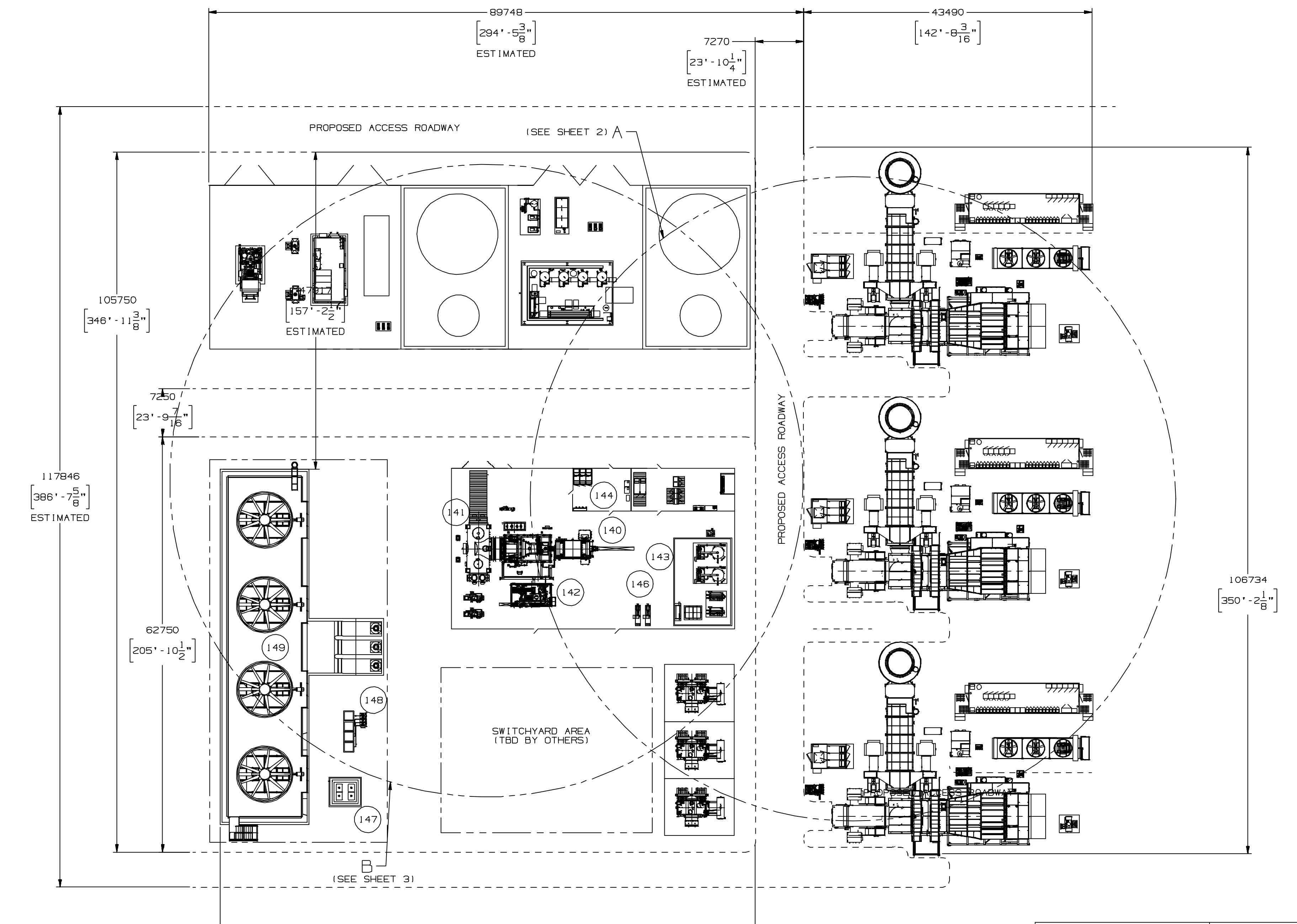
	Generator Output	
SGT A65 WLE ISI No. 1	66,002	kiloWATTs
SGT A65 WLE ISI No. 2	66,002	kiloWATTs
SGT A65 WLE ISI No. 3	66,002	kiloWATTs
Steam Turbine	123,894	kiloWATTs
Total Output	**321,900**	**KiloWATTs**











PROPOSAL NOTE:
1. DO NOT SCALE.
2. DO NOT USE FOR PRODUCTION.
3. DRAWING IS FOR PROPOSAL ONLY.
4. INFORMATION SHOWN IS PRELIMINARY AND IS SUBJECT TO CHANGE.
5. FURTHER DISCUSSIONS WITH CUSTOMER WILL BE REQUIRED TO INSURE THE BEST SOLUTON IS CONSIDERED.

EXPORT-CONTROLLED DOCUMENT
THIS DOCUMENT CONTAINS TECHNICAL DATA WHOSE EXPORT IS RESTRICTED BY THE EXPORT ADMINISTRATION ACT OF 1979, AS AMENDED (TITLE 50, U.S.C., APP 2401, ET SEQ.) AND IS CONTROLLED BY THE EXPORT ADMINISTRATION REGULATIONS 115 CFR PARTS 730-774) UNDER ECCN EAR99. DIVERSION CONTRARY TO US EXPORT LAW IS PROHIBITED.

3RD ANGLE PROJECTION

ENGR. 2:	
ENGR. 1:	C.MILEY
APPR. BY:	N.CARUSO
CHKD. BY:	J.FRANK
DRAWN BY:	J.TAYLOR
DWG. DATE:	28MAR,2018

REV NO	ECO NO / DESCRIPTION REVISION HISTORY	DATE BY
ISSUE	TR EPC, Enprode E & C	

SIEMENS

SIEMENS ENERGY, INC. POWER AND GAS

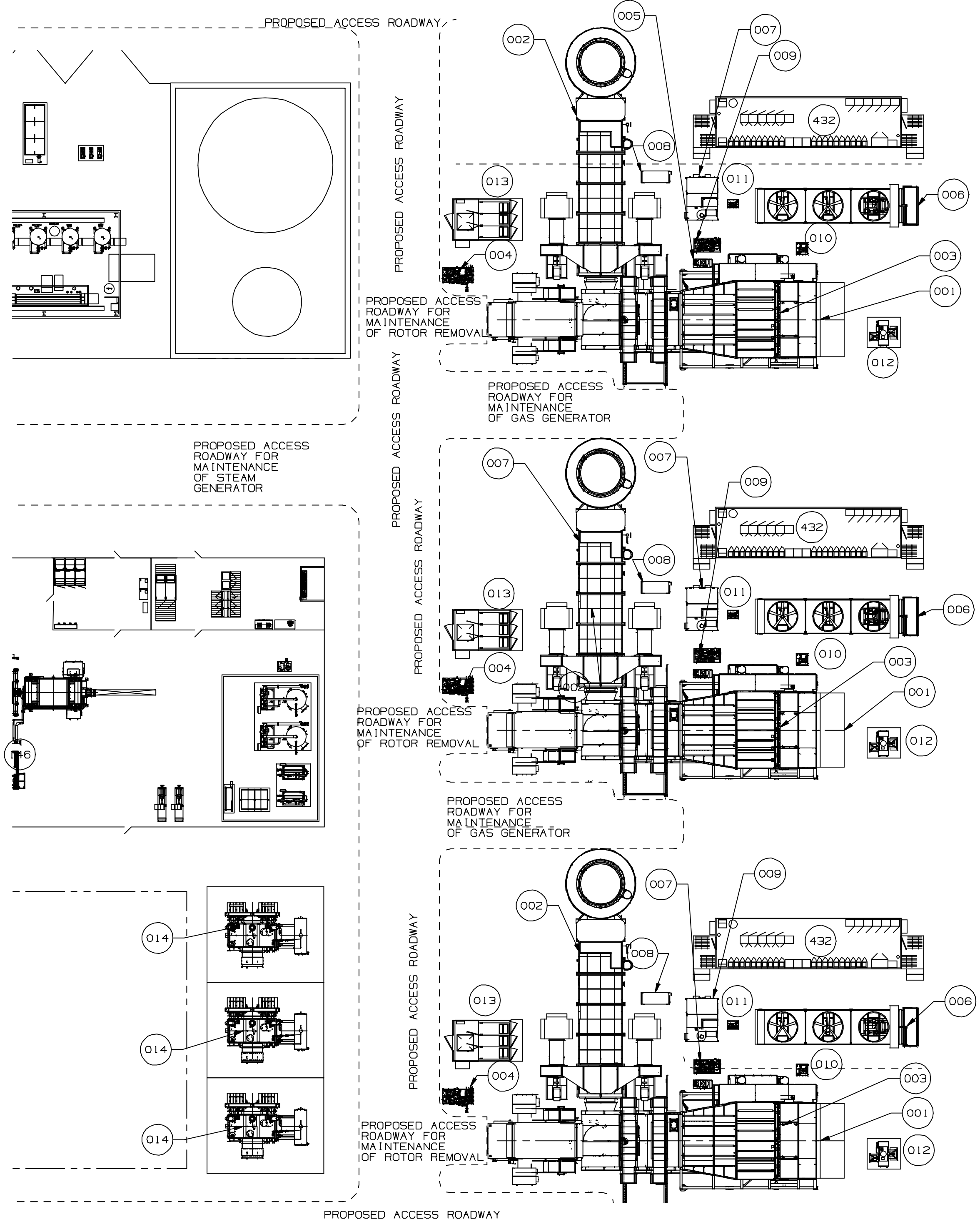
COMBINED CYCLE SITE PROPOSAL

SIZE A1 | SEI-2018-1151 | REV A

SCALE: NONE | SHEET: 1 OF: 3

ALL SHEETS ARE THE SAME REVISION STATUS.

UNIGRAPHICS DRAWING



EQUIPMENT LIST MAJOR COMPONENTS

PINS	DESCRIPTION	QTY	NOTES
001	GAS TURBINE GENERATOR	3	
002	HRSG (HEAT RECOVERY STEAM GENERATOR) VERTICAL	3	
003	ISI AUXILIARY SKID	3	
004	MINERAL LUBE OIL SKID	3	
005	MOBILE WATER WASH	2	SHARED BETWEEN UNITS
006	FIN FAN COOLING SKID	3	
007	WATER INJECTION SKID	3	
008	GT CO2 FIRE PROTECTION SYSTEM	3	
009	LIQUID FUEL FORWARDING PUMP	3	
010	FUEL FILTER SKID	3	
011	DE-MINERALIZED WATER FILTER SKID	3	
012	AUXILIARY TREANSFORMER	3	
013	CIRCUIT BREAKER	3	
014	MAIN TRANSFORMER	3	
015	LV SWITCHGEAR BOP (TO BE SUPPLIED BY OTHERS)	3	
140	STEAM TURBINE GENERATOR (STG)	1	
141	CONDENSER	1	
142	CONDENSATE VACUUM PUMP	2	
143	BOILER FEED WATER PUMPS	2	
144	WATER POLISHING SYSTEM	1	
145	CONTROL SYSTEM MODULE	1	
146	BATTERY (125VDC) SET UP	1	
147	CHEMICAL INJECTION SKID	1	
148	CHEMICAL TOTE FOUNDATION	1	
149	MAIN COOLING TOWER	1	

EQUIPMENT LIST LOCATED INSIDE CONTROL HOUSE (PIN #432) QUANITY REPRESENTS ONE UNIT

PINS	DESCRIPTION	QTY	NOTES
016	UNIT CONTROL PANEL	1 LOT	INSIDE 432
018	TURBINE STARTER PANEL	'	INSIDE 432
018A	ULTRA PROTECTION PANEL	'	INSIDE 432
326	480V SWITCH GEAR	1 LOT	INSIDE 432
327	MOTOR CONTROL CENTER (MCC)	1 LOT	INSIDE 432
337	LIGHTING DISTRIBUTION TRANSFORMER	2	INSIDE 432
338	LIGHTING AND DISTRIBUTION PANEL	2	INSIDE 432
354	VARIABLE FREQUENCY DRIVE (VFD)	1 LOT	INSIDE 432
360	UPS 3-125VDC/120VAC-UCP	1 LOT	INSIDE 432
362	UPS 2-24VDC FIRE AND GAS	1 LOT	INSIDE 432
364	UPS 1-24VDC DC LUBE OIL PUMP STARTER	'	INSIDE 432
454	SCS/PANEL	'	INSIDE 432

DETAIL A
SCALE 1:200 (FROM SHEET 1)
SGT-A65-TR
COMBINED CYCLE PROPOSAL

3RD ANGLE PROJECTION

ENGR. 2:
ENGR. 1: C.MILEY
APPR. BY: N.CARUSO
CHKD. BY: J.FRANK
DRAWN BY: J.TAYLOR
DWG. DATE: 28MAR,2018

REV NO	ECO NO / DESCRIPTION REVISION HISTORY	DATE BY
ISSUE	TR EPC, Enprode E & C	

SIEMENS

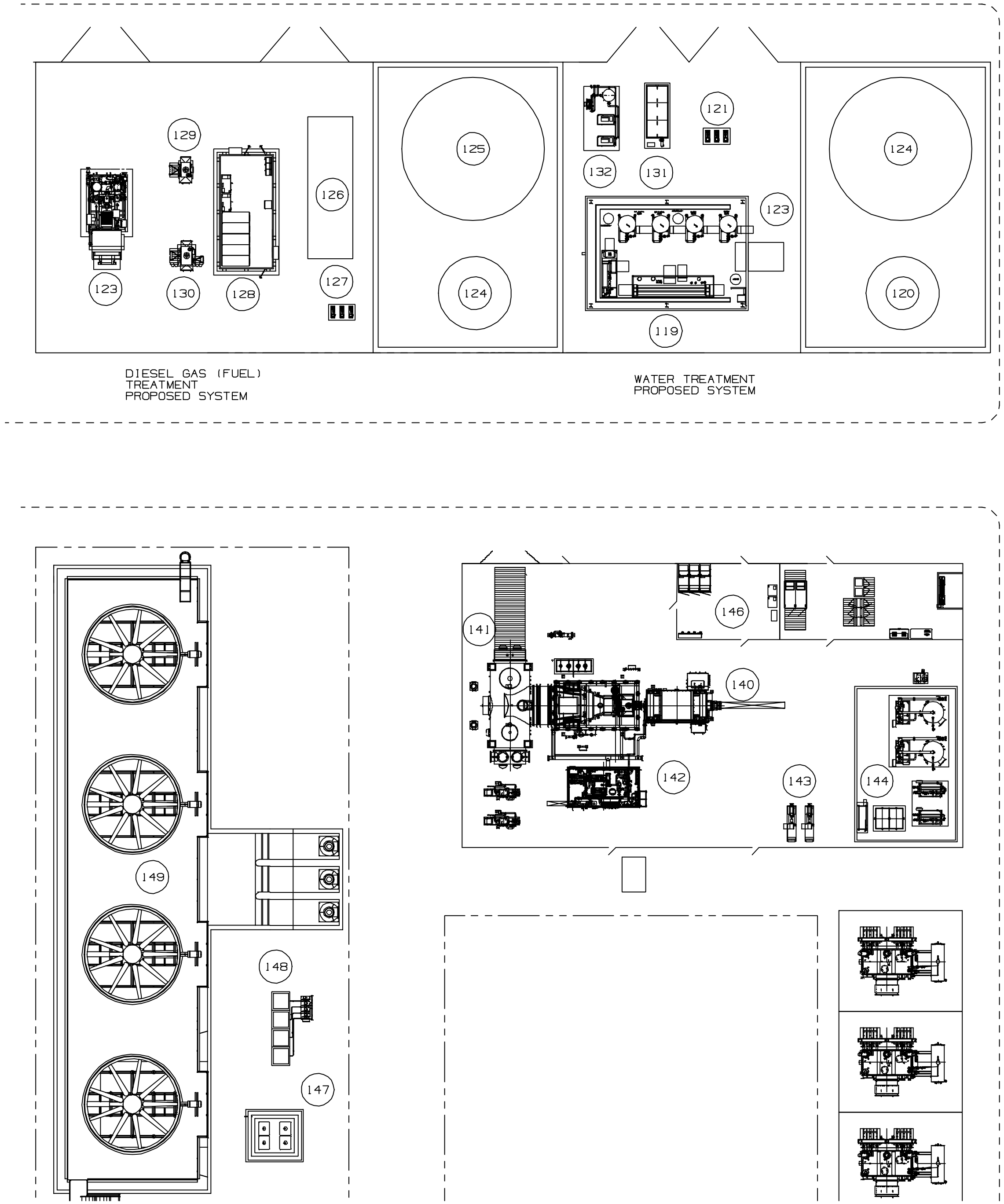
SIEMENS ENERGY, INC. — POWER AND GAS

COMBINED CYCLE SITE PROPOSAL

SIZE A1 — SEI-2018-1151 — REV A
SCALE: NONE — SHEET: 2 OF: 3

ALL SHEETS ARE THE SAME REVISION STATUS.

UNIGRAPHICS DRAWING



DETAIL B
SCALE 1:200 (FROM SHEET 1)
DIESEL GAS (FUEL)
& WATER TREATMENT
PROPOSED SYSTEMS

EQUIPMENT LIST MAJOR COMPONENTS

PINS	DESCRIPTION	QTY	NOTES
119	WATER TREATMENT SYSTEM	1 LOT	
120	DEMIN WATER STORAGE TANK	1	
121	DEMIN FORWARDING PUMPS	1	
123	RAW WATER FORWARDING PUMPS	1	
124	RAW WATER STORAGE TANK	1	
125	RAW DIESEL TANK	1	
126	DIESEL FUEL TREATMENT	1	
127	DIESEL FORWARDING PUMPS	1	
128	MEDIUM VOLTAGE GENERATOR BREAKER	1	
129	AUX TRANSFORMER 13.8kV/4160V	1	
130	AUX TRANSFORMER 4160V/480V	1	
131	OILY WATER SEPARATOR	1	
132	AIR COMPRESSOR	1	
140	STEAM TURBINE GENERATOR (STG)	1	
141	CONDENSER	1	
142	CONDENSATE VACUUM PUMP	2	
143	BOILER FEED WATER PUMPS	2	
144	WATER POLISHING SYSTEM	1	
145	CONTROL SYSTEM MODULE	1	
146	BATTERY (125VDC) SET UP	1	
147	CHEMICAL INJECTION SKID	1	
148	CHEMICAL TOTE FOUNDATION	1	
149	MAIN COOLING TOWER	1	

3RD ANGLE PROJECTION

ENGR. 2:
ENGR. 1: C.MILEY
APPR. BY: N.CARUSO
CHKD. BY: J.FRANK
DRAWN BY: J.TAYLOR
DWG. DATE: 28MAR,2018

REV NO	ECO NO / DESCRIPTION REVISION HISTORY	DATE BY
ISSUE	TR EPC, Enprode E & C	

ALL SHEETS ARE THE SAME REVISION STATUS.

SIEMENS

SIEMENS ENERGY, INC. POWER AND GAS

COMBINED CYCLE SITE PROPOSAL

SIZE A1 SEI-2018-1151 REV A

SCALE: NONE SHEET: 3 OF: 3

UNIGRAPHICS DRAWING

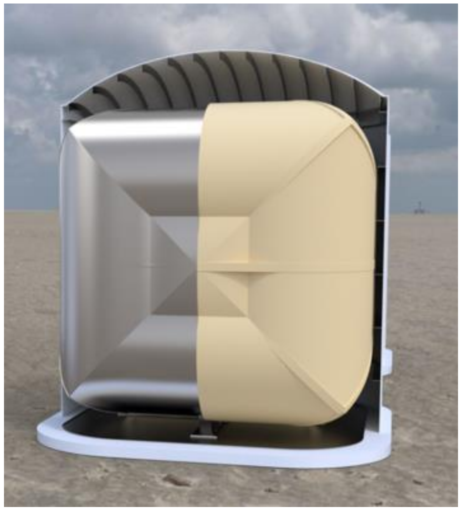
EnergyGiant Limited

Appendix B.

UAE Power System Requirements:

LNG Storage

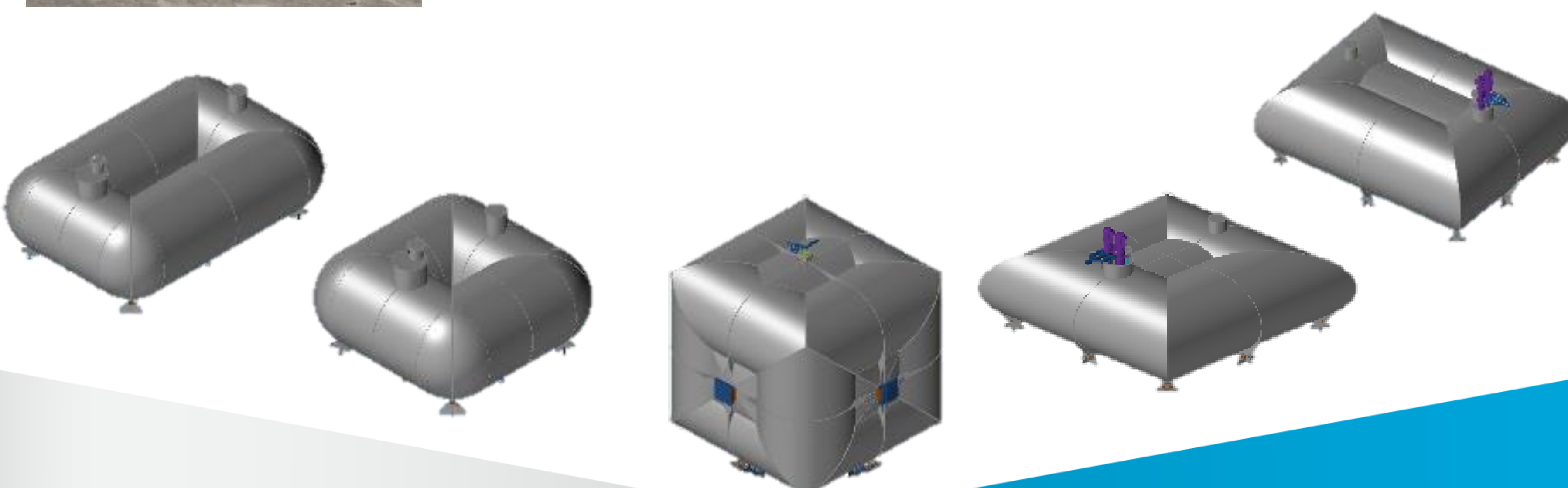
Shiva Egambaram — Senior Process Engineer, Altair Malaysia
Ban-Wee Eng — Principal Naval Architect, Altair Taiwan
Regu Ramoo — VP of Engineering, Altair Engineering, Inc., Troy, Michigan, USA
Prof. Emeritus Thomas Lamb (U. Mich.) — Technical Consultant, IMPD, Seattle, Washington, USA



Altair

Cubic Donut Tank System (CDTS) for Land Storage

July, 2018



Altair

Corporate Overview

Altair

ALTAIR AT A GLANCE

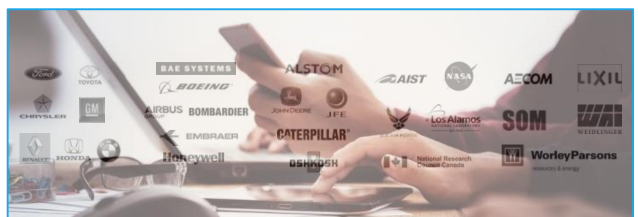
Founded **1985**
Headquartered in Troy, MI US

69offices
in 24 countries

$313M
2016 Revenue

50+
ISV partners under our unique, patented licensing model

2000+
Engineers, scientists and creative thinkers



5000+
Customer installations globally

60,000+
Users

NASDAQ: ALTR

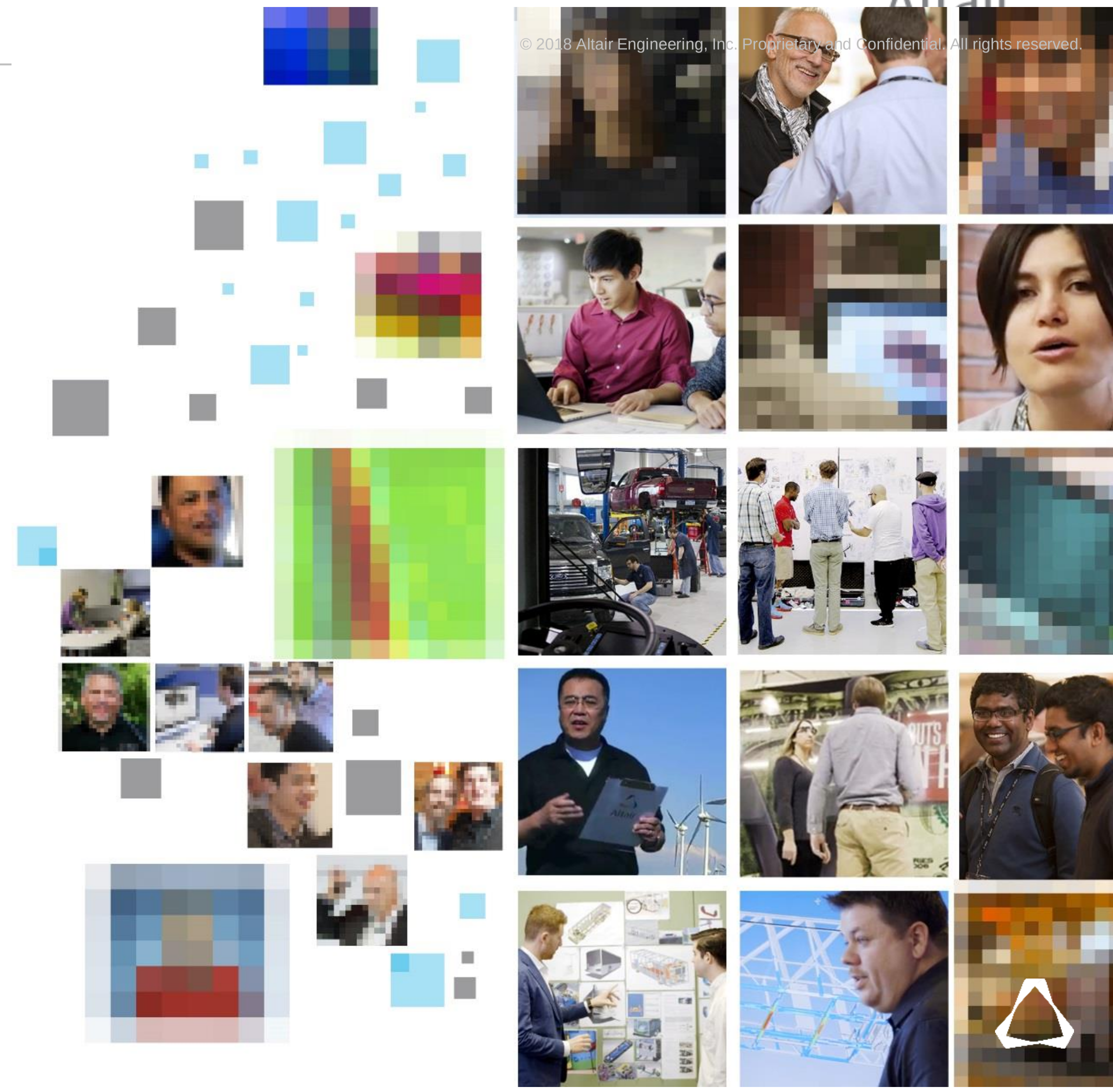
CULTURE & VALUES

Envision the future

Communicate honestly and broadly

Seek technology and business firsts

Embrace diversity and risk taking



OUR VISION

Altair transforms design and decision making

by applying simulation, machine learning and optimization

throughout product lifecycles.

Services – Not Just Another Software Developer

Altair has grown to become a global product development consultancy of 700+ designers, engineers, scientists and creative thinkers. The knowledge of real world product design and manufacturing has never been lost.

Product Engineering

Industrial Design

Technical Staffing

HyperWorks Solutions

Analytics Solutions

We Work with Some of the Best

Altair

Automotive
- Ford
- Toyota
- Chrysler
- GM
- Renault
- Honda
- BMW

Aerospace
- BAE Systems
- Boeing
- Airbus Group
- Bombardier
- Embraer
- Honeywell

Heavy Equipment
- Alstom
- John Deere
- JFE
- Caterpillar
- Oshkosh

Government
- AIST
- NASA
- U.S. Air Force
- Los Alamos National Laboratory Est. 1943
- National Research Council Canada

Life/Earth Sciences
- BASF The Chemical Company
- Bayer
- Dow
- Alcoa
- Merck

Electronics/ Consumer Goods
- acer
- intel
- IBM
- LG
- Bosch

Energy
- ABB
- Chevron
- Valero
- ConocoPhillips
- ExxonMobil

Architecture
- AECOM
- LIXIL
- SOM
- Weidlinger
- WorleyParsons resources & energy

5,000 customers worldwide

Engagements in the Marine Industry

Altair Marine Customers

Altair

HYUNDAI HEAVY INDUSTRIES CO., LTD.

SAMSUNG

DAEWOO

stx Shipbuilding

IHI MARINE UNITED

YAMAHA

WÄRTSILÄ

Sea Ray

LÜRSSEN

NAVAIR NAVAL AIR SYSTEMS COMMAND

Mitsui Engineering & Shipbuilding Co., Ltd.

NORTHROP GRUMMAN DEFINING THE FUTURE

CHORYO ENGINEERING Mitsubishi Heavy Industries Group

ibmv

NAVSEA WARFARE CENTERS

VT Group

ATLAS ELEKTRONIK A joint company of ThyssenKrupp and EADS

CARDEROCK DIVISION NAVSEA WARFARE CENTERS

KOCKUMS

THALES

BAE SYSTEMS

Bath Iron Works A GENERAL DYNAMICS COMPANY

NORTHROP GRUMMAN MISSION SYSTEMS

GENERAL DYNAMICS Electric Boat

WEIDLINGER ASSOCIATES® INC CONSULTING ENGINEERS

babcock

MAN

MARTEC™ Smart Solutions for Engineering, Science & Computing

SWAN HUNTER

MARIC

Kawasaki

Altair Marine Customers

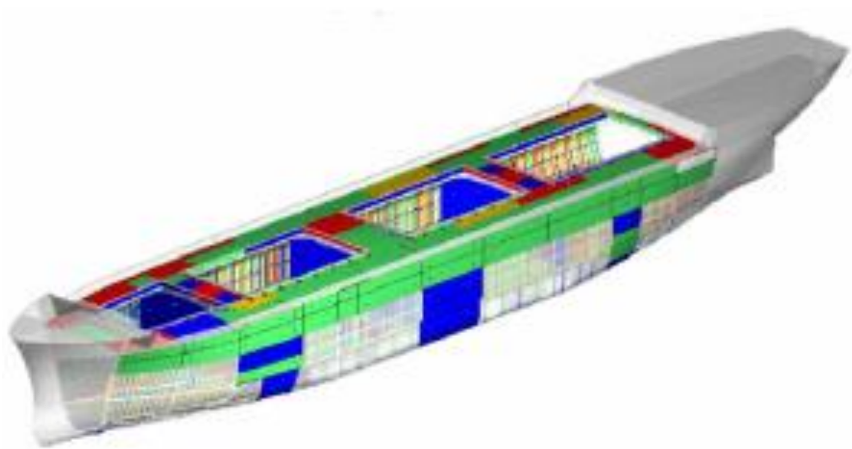
- Altair's HyperWorks software suite is recognized by the marine industry as best-in-class for Computer Aided Engineering (CAE)

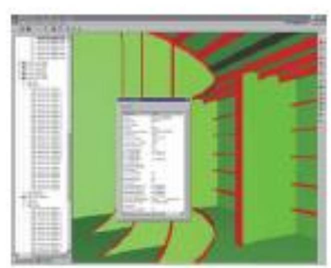
- Leading shipyards and maritime classification societies including Hyundai Heavy Industry, STX, Sumitomo, Tsuneishi, Jiangnan, BAE Systems, General Dynamics Electric Boat, Lloyd's, ClassNK, and ABS have adopted HyperWorks as a next-generation simulation technology for ensuring structural performance and constructability while meeting cost targets.

- Altair's technologies have been applied to vessels ranging from racing yachts and leisure craft, to naval and commercial ships covering hull form drag, dynamic control, underwater explosions, wave response, composite materials usage, electromagnetic compatibility, and manufacturing process assessment,

PrimeShip Hull

- HyperWorks chosen as platform after extensive evaluation.
- Altair Product Design has been awarded to develop the new hull design system

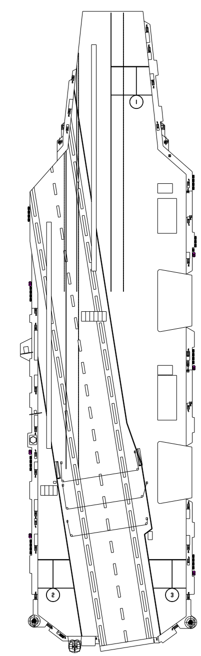




Altair - Structures Design Solution Partner for CVF

- The Royal Navy’s two new aircraft carriers (CVF) are expected to enter service in late 2015 and 2018
- The CVF programme is being managed by Aircraft Carrier Alliance (ACA). The Alliance Partners are:
  - Thales Naval Ltd
  - BVT Surface Fleet Limited (JV VT Shipbuilding & BAE Systems)
  - Babcock Marine
  - The UK MOD
- **The ship structure is being designed to meet the standards of Lloyd’s Register Rules and Regulations for the Classification of Naval Ships and upon completion the vessels will be entered into Lloyd’s Class**
- "**Aircraft Carrier Alliance select Altair as Structures Design Solution Partners**“ (**design compliance with 'Lloyds Register Rules & Regulations for the Classification of Naval Ships**’)
- Altair team work closely with LR on the CVF program

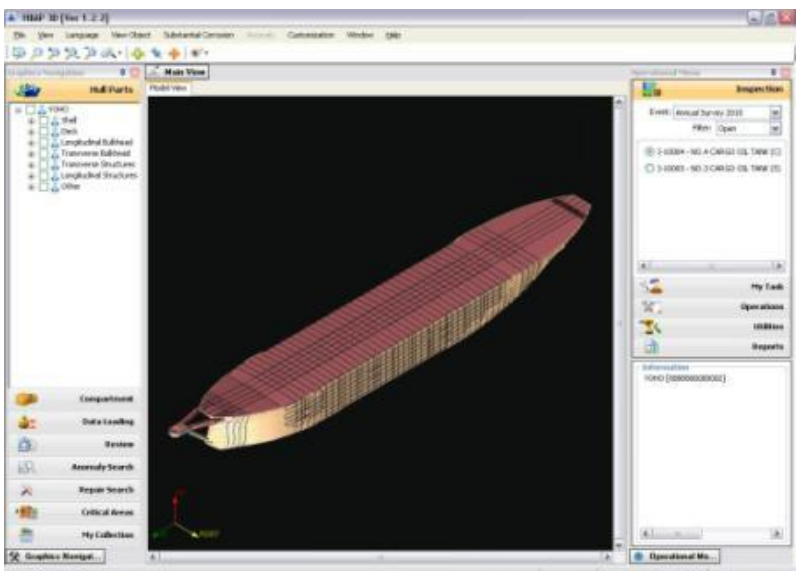
CVF (CV) – UK ~ 65,000 tonnes

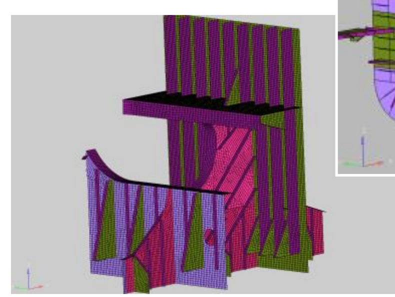


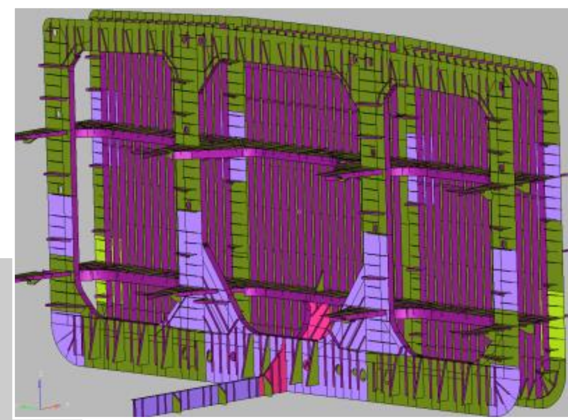
Hull Inspection Maintenance Program 3D (HIMP3D)

Project Objective

Standardize across ABS and its customers a solution for Marine Systems Classification, Inspection and Repair, to include ABS Classification rules build in + an interface to CAE system for the purpose of validating and optimize the repair operations

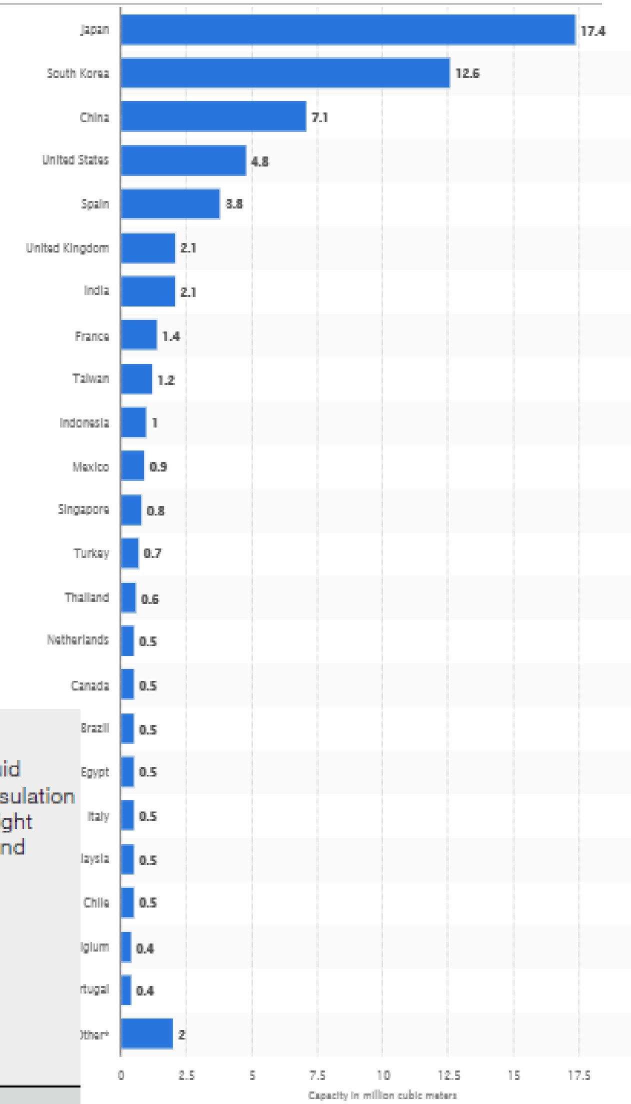






Land Storage LNG Tanks

Storage tank capacity for liquefied natural gas worldwide in 1st quarter 2018, by country (in million cubic meters)



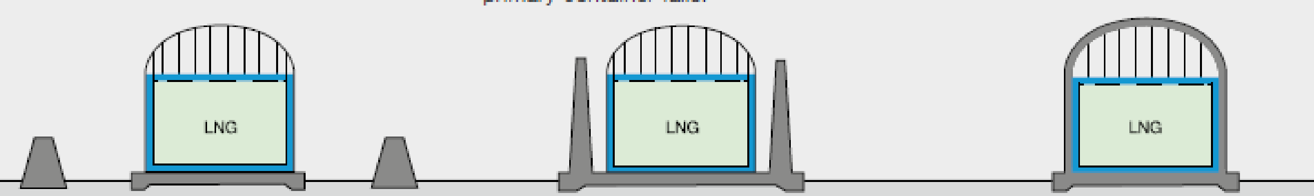
The approximate number of field erected LNG tanks operating worldwide is summarized in the following list[1]:

Single Containment Type	320
Double Containment Type	15
Full Containment Type	110
Membrane Containment Type	30
Membrane In-ground Containment Type	50

Single containment tank
- Primary container contains liquid and vapour
- Outer shell retains insulation
- Bund around the tanks retains liquid (not vapour) if primary container fails.

Double containment tank
- Primary container contains liquid and vapour
- Outer shell retains insulation
- Secondary container is an open top tank that retains liquid (not vapour) if primary container fails.

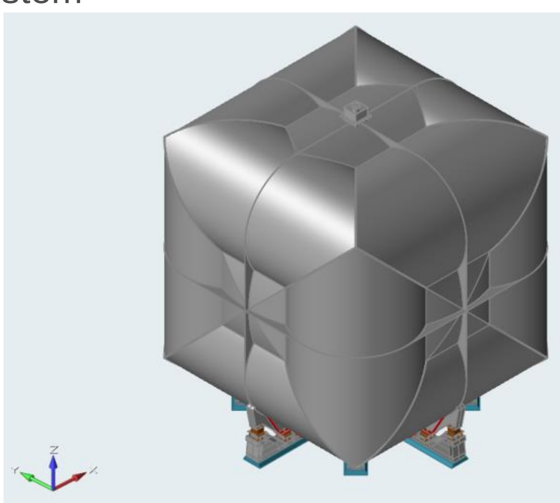
Full containment tank
- Primary container contains liquid
- Secondary container retains insulation and is also liquid and vapour tight
- Smallest foot print since no bund around the tanks is required.

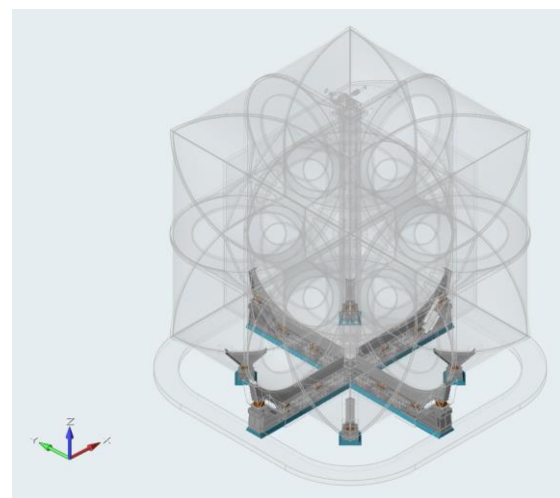


Wartsila

CDTS for Land Storage

- LNG Kitania has sent us an Expression of Interest Letter to Tank EPC and Altair to Supply 16 40K CDTS Tanks
- The Tank EPC will fabricate and erect the CDTS modules. **Altair is the licensor of the CDTS Technology and is responsible for all Design Drawings and Approvals.**
- The Delivery timeline is 24 months after signing agreement to supply the first tranche of ~4 of 40K tanks and the remaining over a 3-year period thereafter
- The tank team is here today at IOCL in New Delhi to introduce and explain the CDTS Technology
- Wartsila is the EPC for the Port, Plat prep., Gas Systems & Engineering for tank and Gasification system





9Ni Single Containment CDTS

LNG Kirtania Ownership, Development & Operation Structure

Consortium Lead & Project Developer

Port Owner & Operator

LNG Terminal Operator, Re-Gasification Infrastructure, Gas Engineering for storage tanks, BoG Handling, Plant Controls, Electronics, Safety, Firefighting Package, metering, Instrumentation, controls & Powerplant

EPC for berths
EPC for Civil Works related to ReGas & Gas Storage

LNG Storage Tank Team

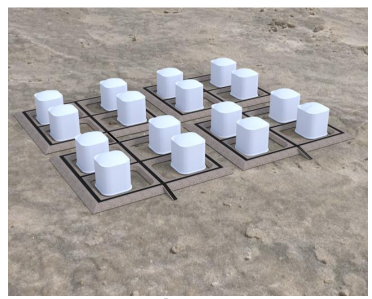
*Licensor of the CDTS Technology

*Overseeing PE

CDTS* Storage Tanks Supplier

CDTS* Environmental Cover Supplier

CDTS* Tank Insulation & Gas System Suppliers up to tie-up point of Wartsila Gasification Unit



LNG KIRTANIA

Owner & Operator* of 640K LNG Terminal

*(LNG Terminal Operations contracted to Wartsila)

Owned by TRANSITION TECHNOLOGIES GLOBAL, Dubai

IndianOil

Off-take of RLNG from 640K LNG KIRTANIA Terminal

TRANSITION TECH
INDIA DEPLOYMENT LLC
Off-take of RLNG from Indian Oil
Owned by
TRANSITION TECHNOLOGIES GLOBAL, Dubai

India Consumers

PETROBANGLA
(Off-Take Agmt. Brought by Energy Giant)

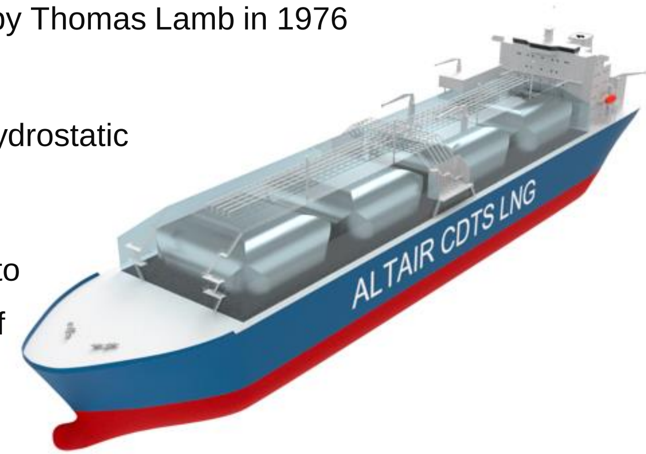
Role and Responsibilities as the CDTS Tank Technology Licensor CDTS

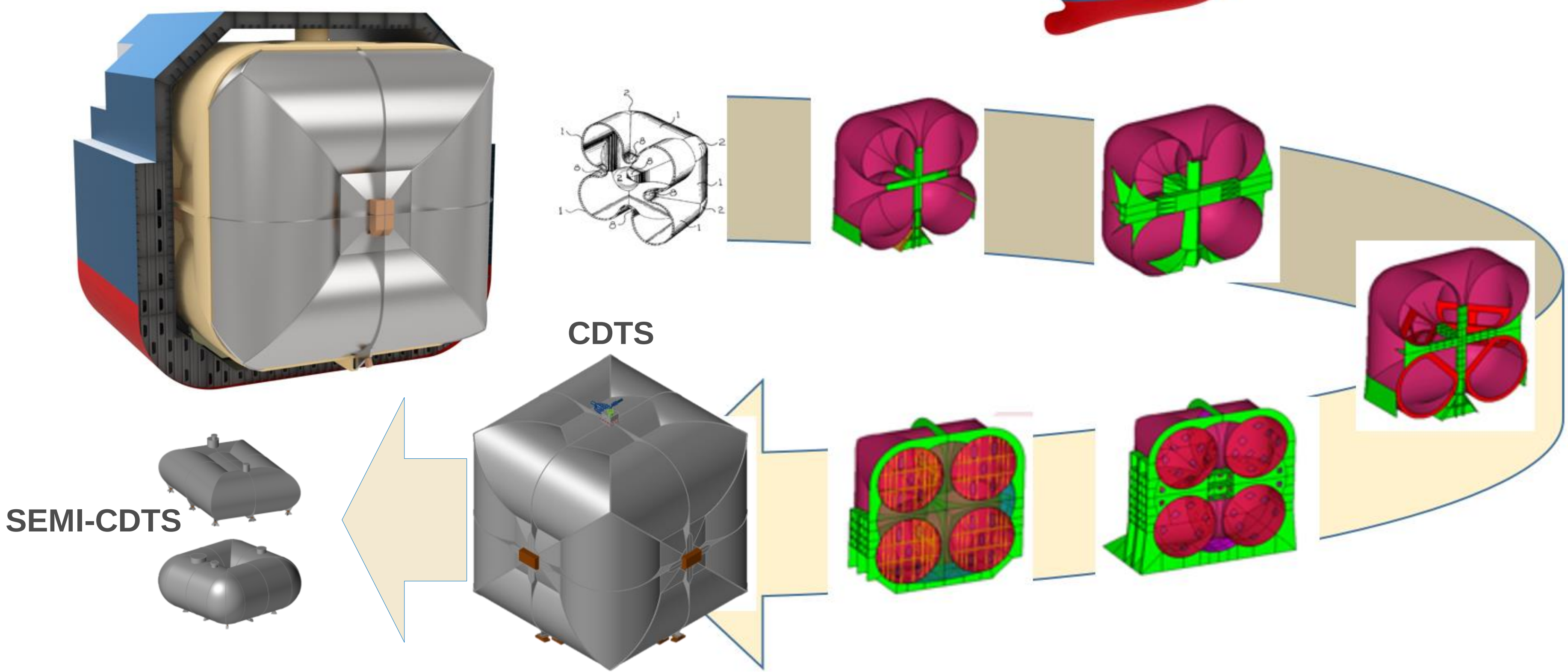
Altair

- Altair **will deliver the 40K net 3-D CDTS Tank Shell Design which meets or exceeds API 620/625 and NFPA59A standards**
- We will appoint a local India based Tankage Engineering PE-Civil to secure API620/625 & NFPA59A or equivalent from local regulators
- Our team will work closely with the tank fabricator(s) who will be responsible for fabricating the CDTS tank modules and the erection of the modules on-site. **Our tank fabricator will provide warranties against tank leakage due to material & weld quality**
- Our **Gas Engineering partner will use our basic Gas Engineering layout to develop the detailed Gas Engineering package, secure relevant approvals, and provide operational and Gas engineering related warranties**.
- Our **Insulation Partner who would use our basic insulation space requirements to develop and install the insulation system and provide LNG Kirtania with the BoG rate warranties.**

CDTS – Origins & Design Evolution

- The Cubic Donut Tank System (CDTS) was first developed and patented by Thomas Lamb in 1976 (Prof. Emeritus, University of Michigan)
- The objective being that it is as efficient as the spherical tank system for hydrostatic containment and has the volumetric efficiency of membrane tanks
- Altair's Award-winning design synthesis technology Optistruct® was used to improve on the unique geometry of the CDTS to provide the best trade-off between spatial & structural efficiencies





Understanding Shape Influence on Structural Efficiencies for Hydrostatic Containment

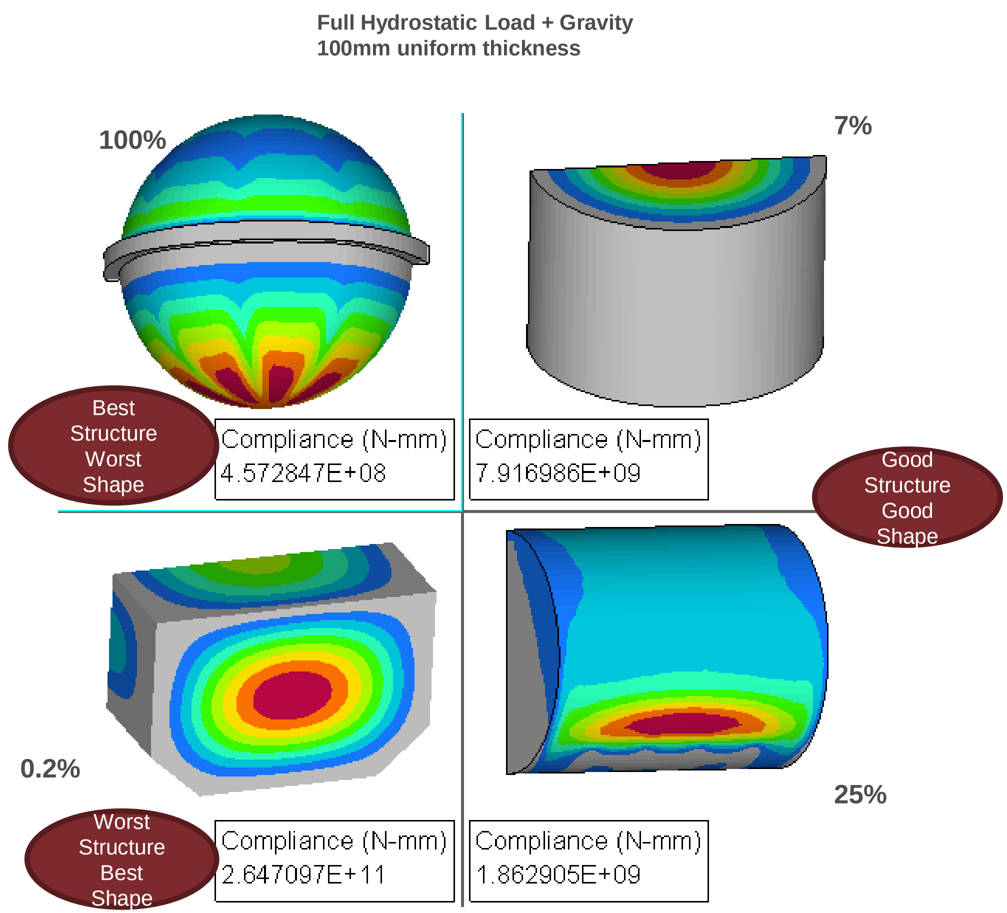
For self-standing Independent tanks, structural compliance provides a measure of structural efficiency

- Spherical Shapes have the highest structural efficiency
- Cylindrical Shapes have good structural efficiency
- Prismatic shapes have the worst structural efficiency

For maximum stiffness (K), the compliance (C) can be minimized. For a structure with an applied displacement (U), the compliance (C) can be considered a direct measure of the stiffness (K)

$$C = \frac{1}{2}U^T F = \frac{1}{2}U^T K U = \frac{1}{2}\frac{u^2}{K},$$

$$with \quad \frac{1}{2}u^2 = constant$$



CDTS DEVELOPED USING Altair's AWARD WINNING TECHNOLOGY

Altair Optistruct®:

Award-winning design synthesis technology

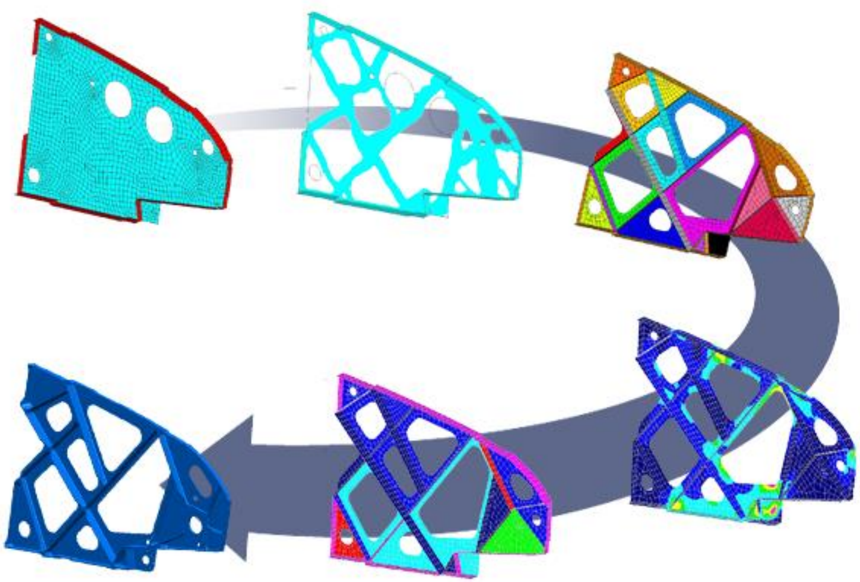
American Business Awards 2012

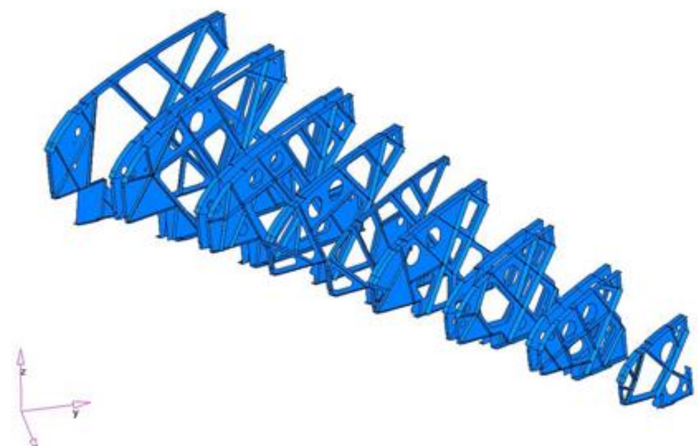
Company/Organization Awards Category Stevie® Award Winners

Companies of the Year –

Automotive & Transport Equipment:	Ford Motor Co.
Computer Hardware:	Apple Inc.
Computer Software:	**Altair**
Aerospace and Defense:	BE Aerospace
Telecommunications:	Qualcomm

Industry Success - *Leading Edge Rib Design for the AIRBUS A380*





Results:

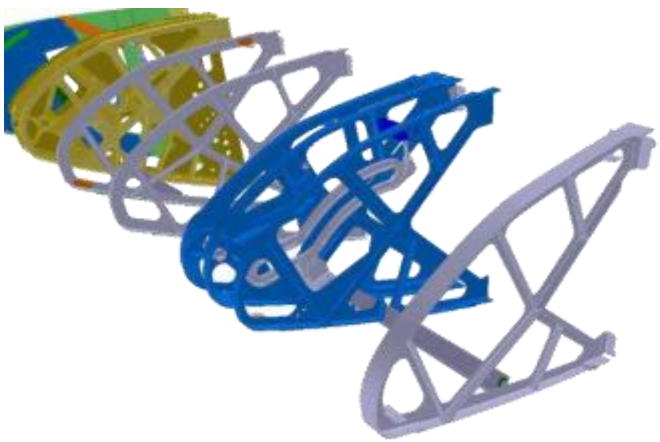
Mass Savings of 44% (500kg)

Deadline met: Ribs developed in 13 weeks

Aerospace Success Story

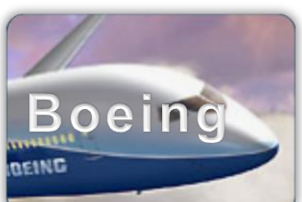
Topology, Size & Shape Optimization on the 787 Wing Structure

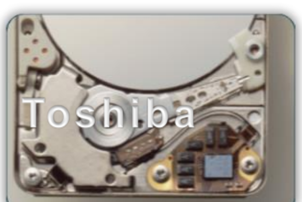
Met the target weight reduction: -12%
Quicker and more robust process development

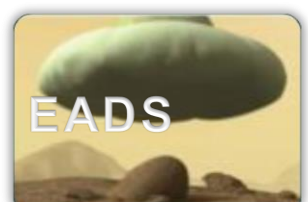


"Boeing and partner Spirit AeroSystems are extensively using the OptiStruct optimization tool to design Fixed Leading Edge Wing Ribs. 50 unique rib designs have been created using the process and many are now being produced. The expected weight savings has been achieved."

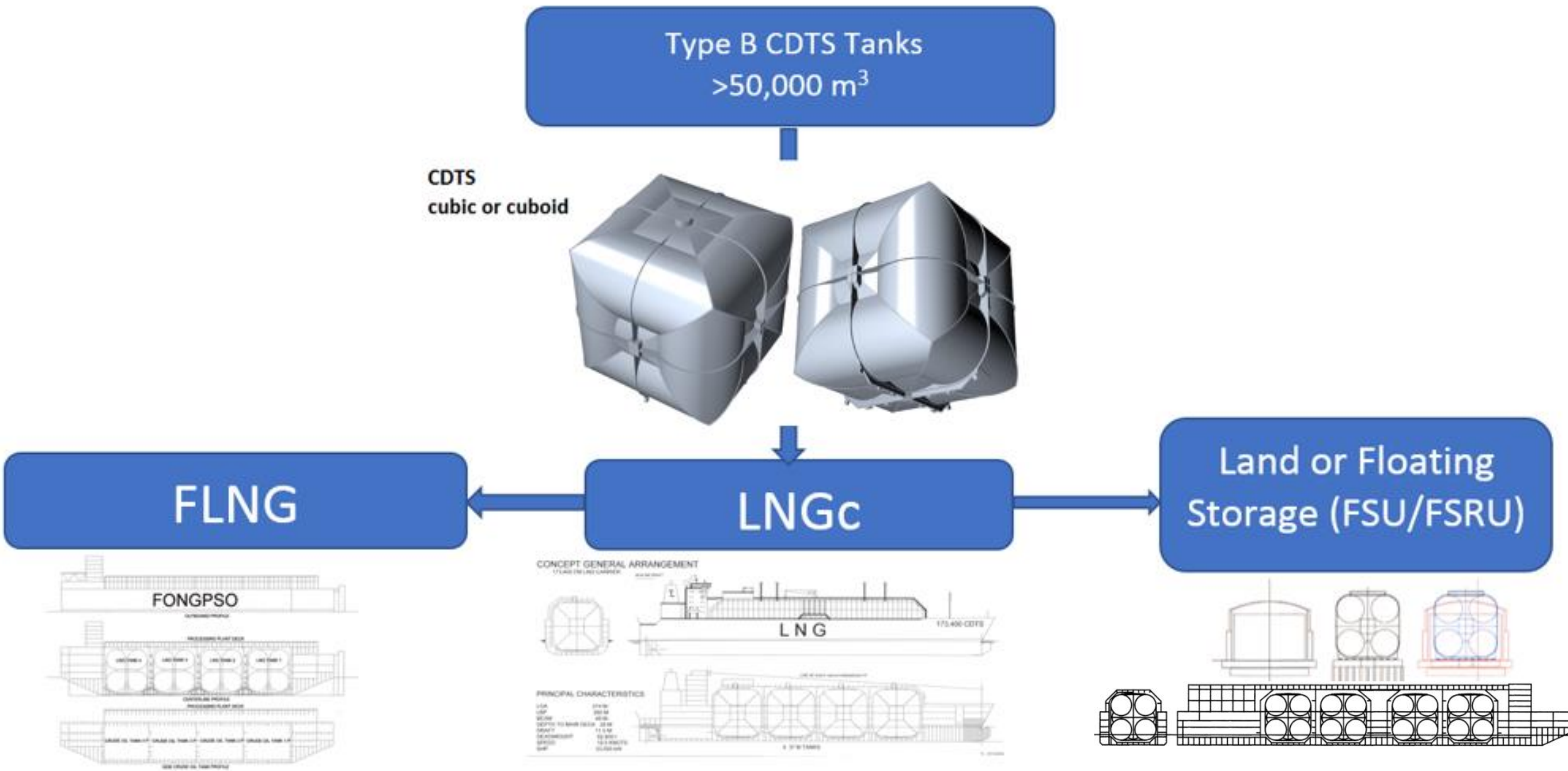
Stephen Amorosi, The Boeing Corporation, Seattle, WA



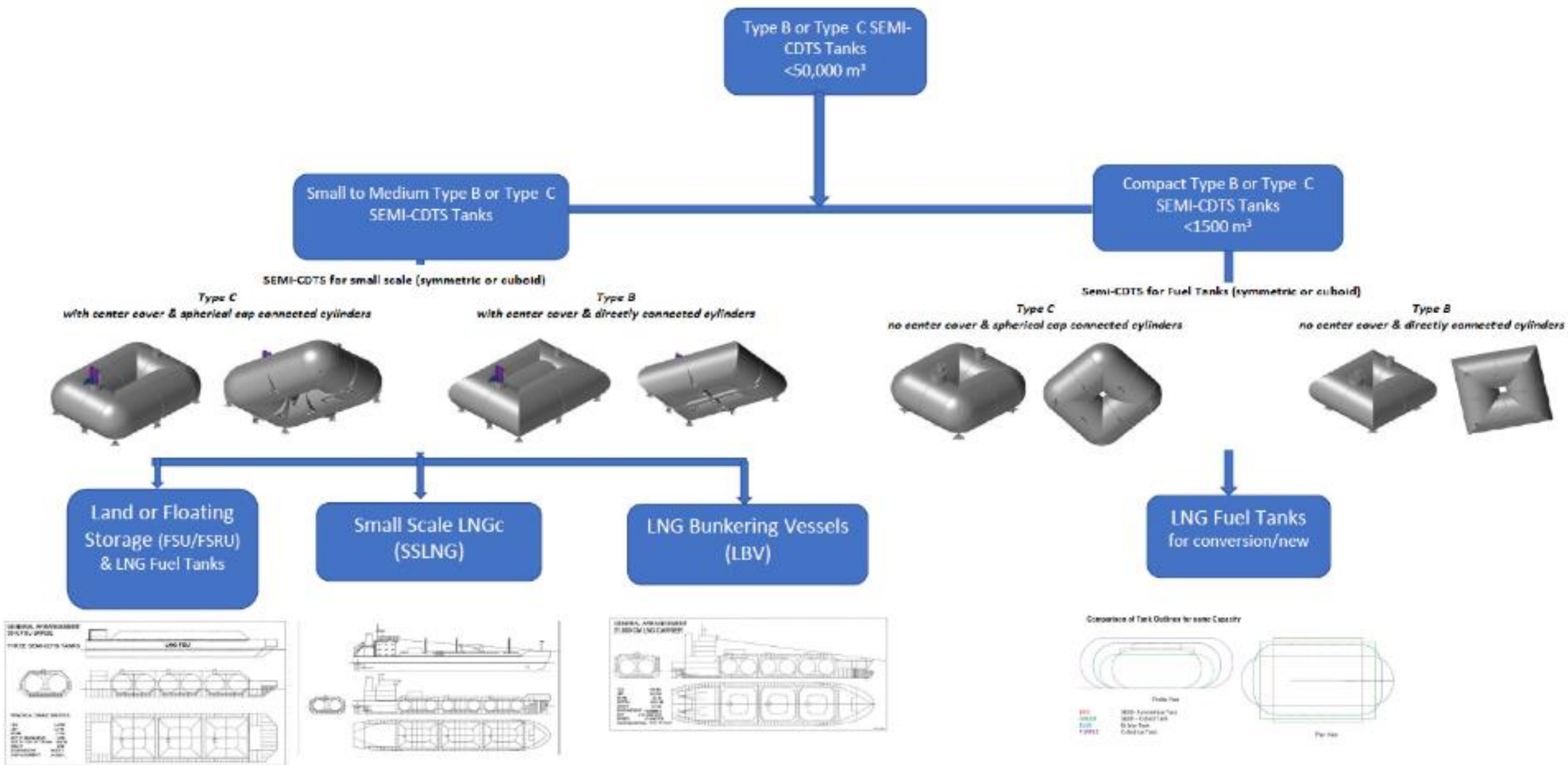




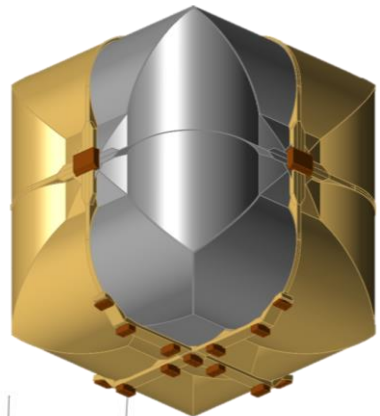
CDTS – Applications



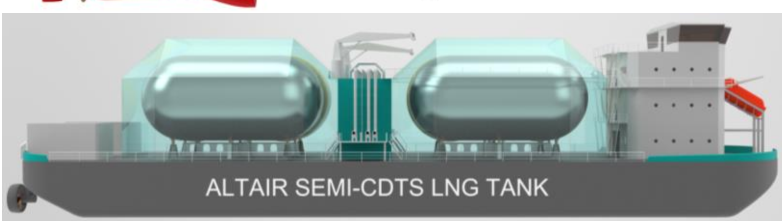
SEMI-CDTS – Applications



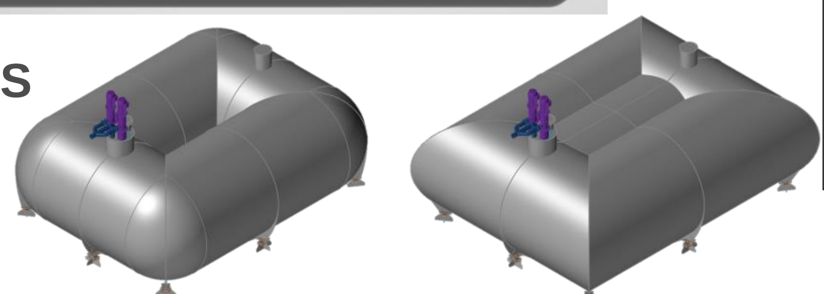
Approval-In-Principle (AIP) from ABS



CDTS



Semi-CDTS



ABS FOUNDED 1862

Ref.: TASK#: T1333681
Project#: 3464039
Date: 30 April 2015

Certificate of Approval in Principle

As requested by:

Altair Product Design

ABS has reviewed documentation as specified in ABS letter dated 30 April 2015 for:

Cubic Donut Tank System (CDTS) for LNGC - Concept Design

and found the system to be satisfactory with respect to the intent of the following:

1- ABS Rules for Building and Classing Steel Vessels, Jan. 2014
2- ABS Guidance Notes on Review and Approval of Novel Concepts, Jun. 2003
3- ABS Guide for Building and Classing Liquefied Gas Carriers with Independent Tanks, Jan. 2010
4- International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code), 1993 Ed. and new IGC code effective July 2016 notwithstanding any additional detailed analyses that may be required when the new IGC code comes into force

subject to compliance with the comments in the above letter and the Rules. All drawings, calculations, test reports, and certificates for components are to be found acceptable to ABS.

ABS Americas

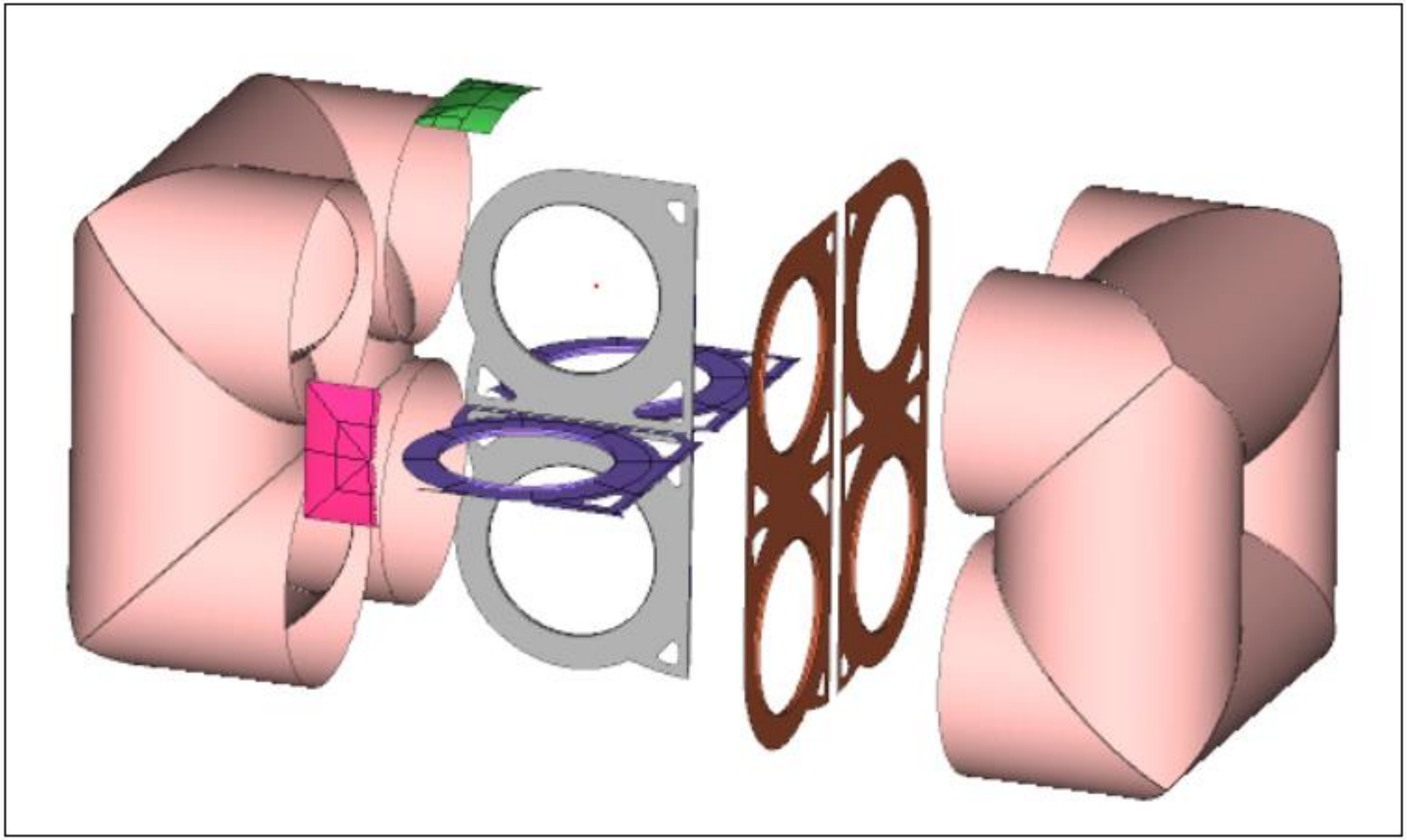
Suresh Pisini,
Manager of Houston SED

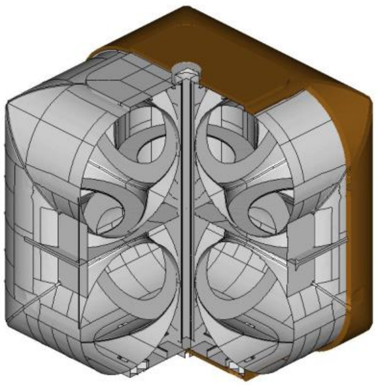
ABS CORPORATE, Technology

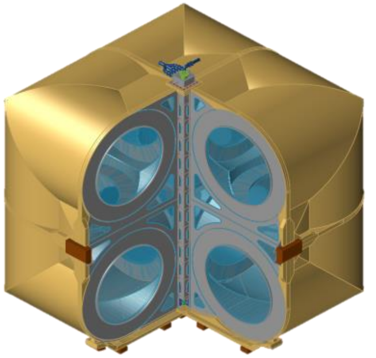
Yung S. Shin,
Head of Cargo Containment Systems Group

Note: This certificate evidences compliance with one or more of the rules, Guides, standards or other criteria of American Bureau of Shipping or a statutory, industrial or manufacturer's standards and is issued solely for the use of the Bureau, its committees, its clients or other authorized entities. Any significant changes to the aforementioned product without ABS approval will result in this certificate becoming void. This certificate is governed by the terms and conditions in the ABS Rules.

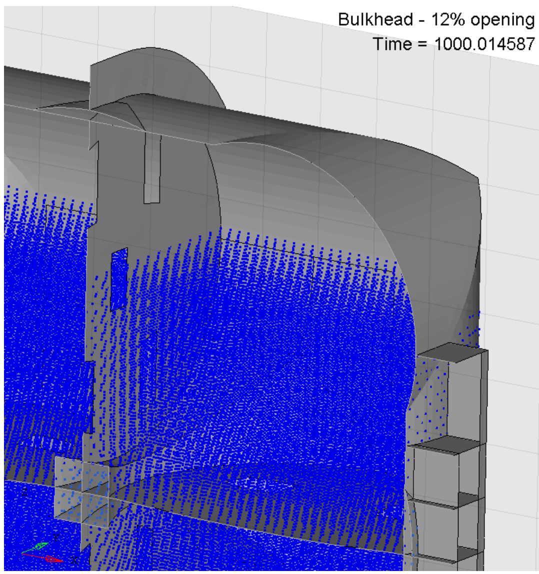
CDTS Exploded View

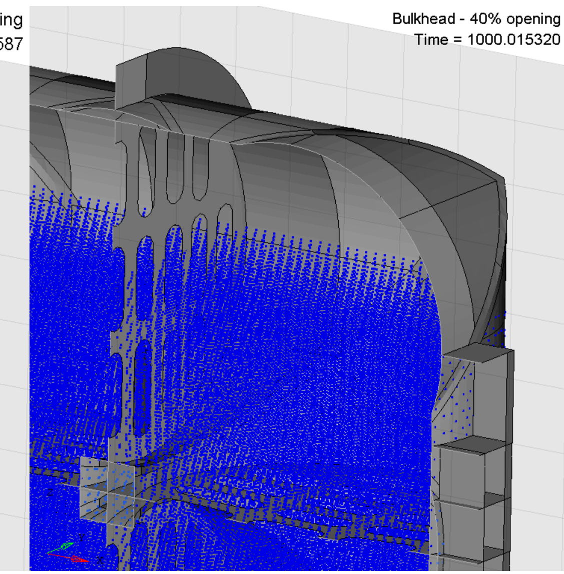


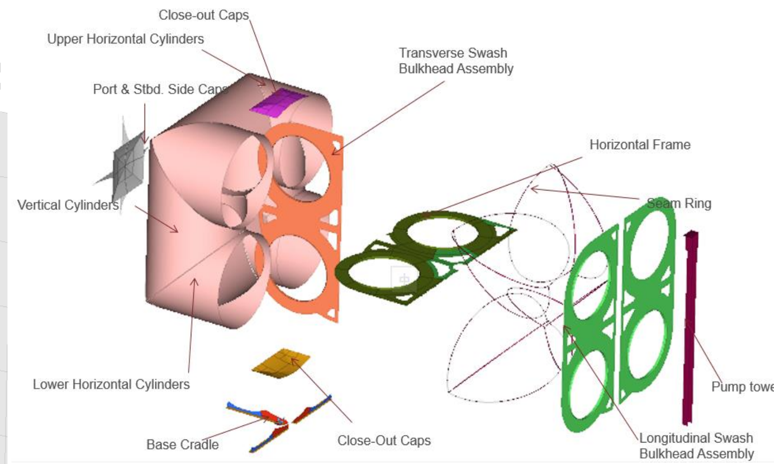


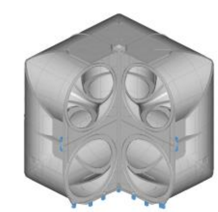


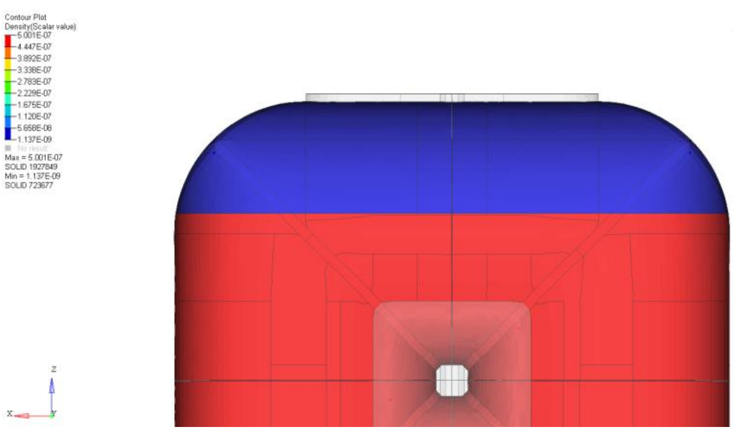
CDTS SLOSHING MITIGATION FEATURE

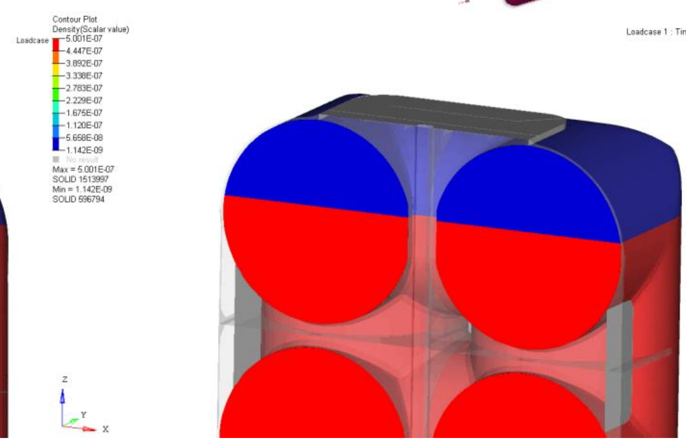


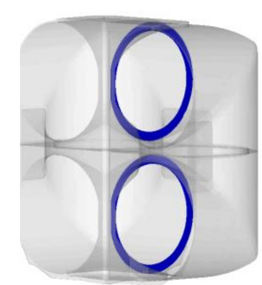




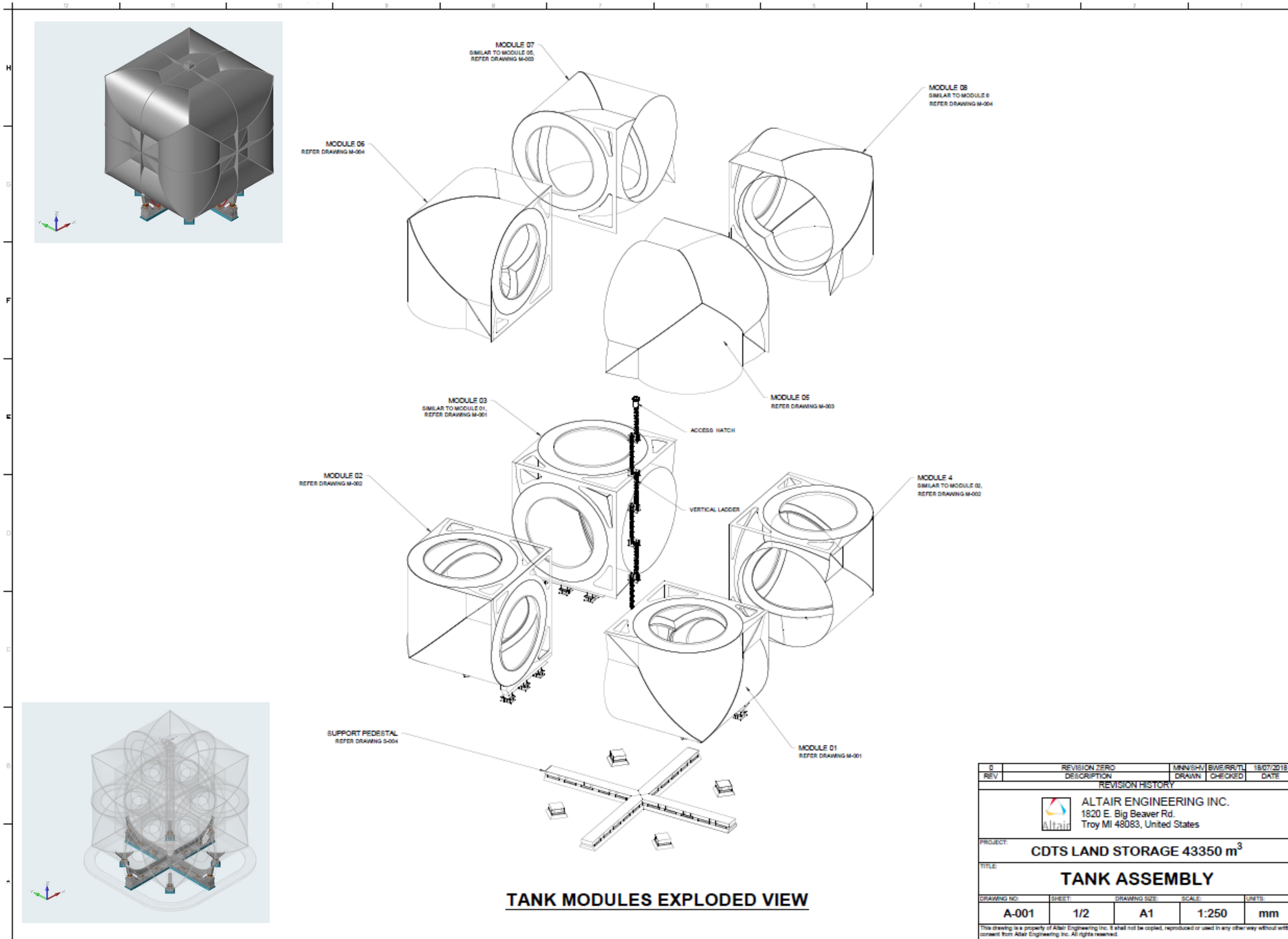








9Ni Single Containment CDTS



Conventional Cylindrical Containment Tanks

Figure 7 Comparison of roof platforms with and without side wall discharge (courtesy Cheniere and Coers [11])

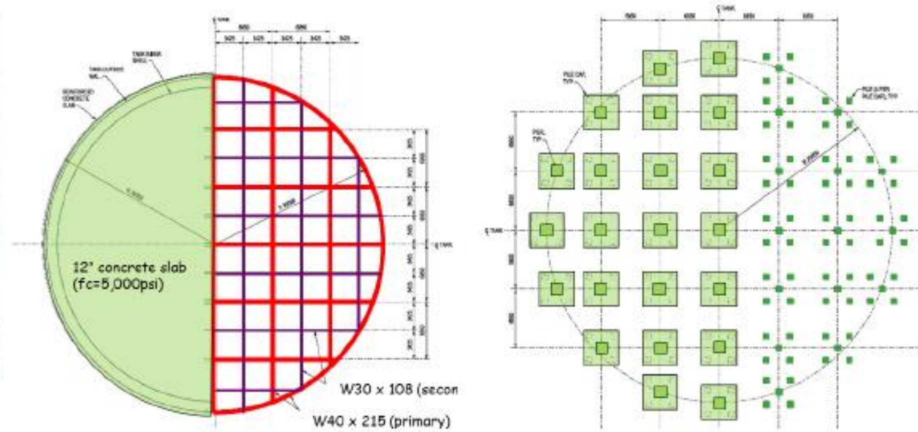


Figure 4 40k m³ 9%Ni Steel Single Containment Modular LNG Tank General Arrangement

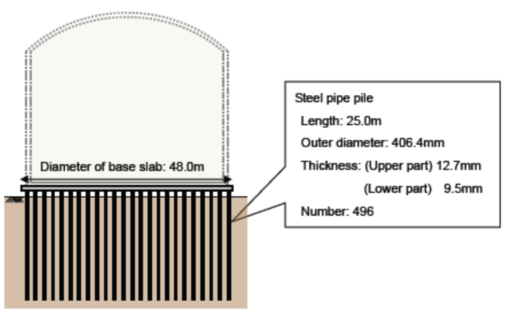


Figure 3.3. Specification of tank foundation

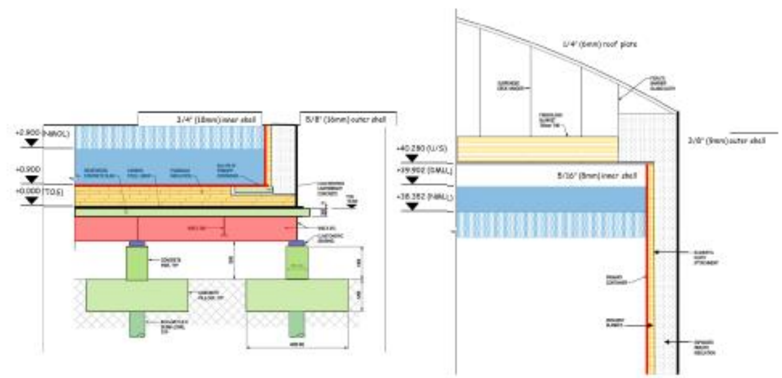


Figure 5 40k m³ 9%Ni Steel Single Containment Modular LNG Tank Details

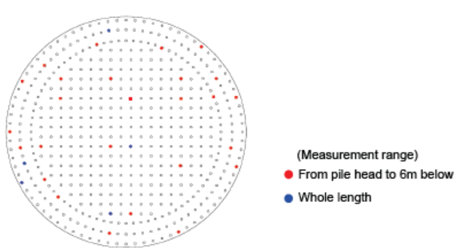
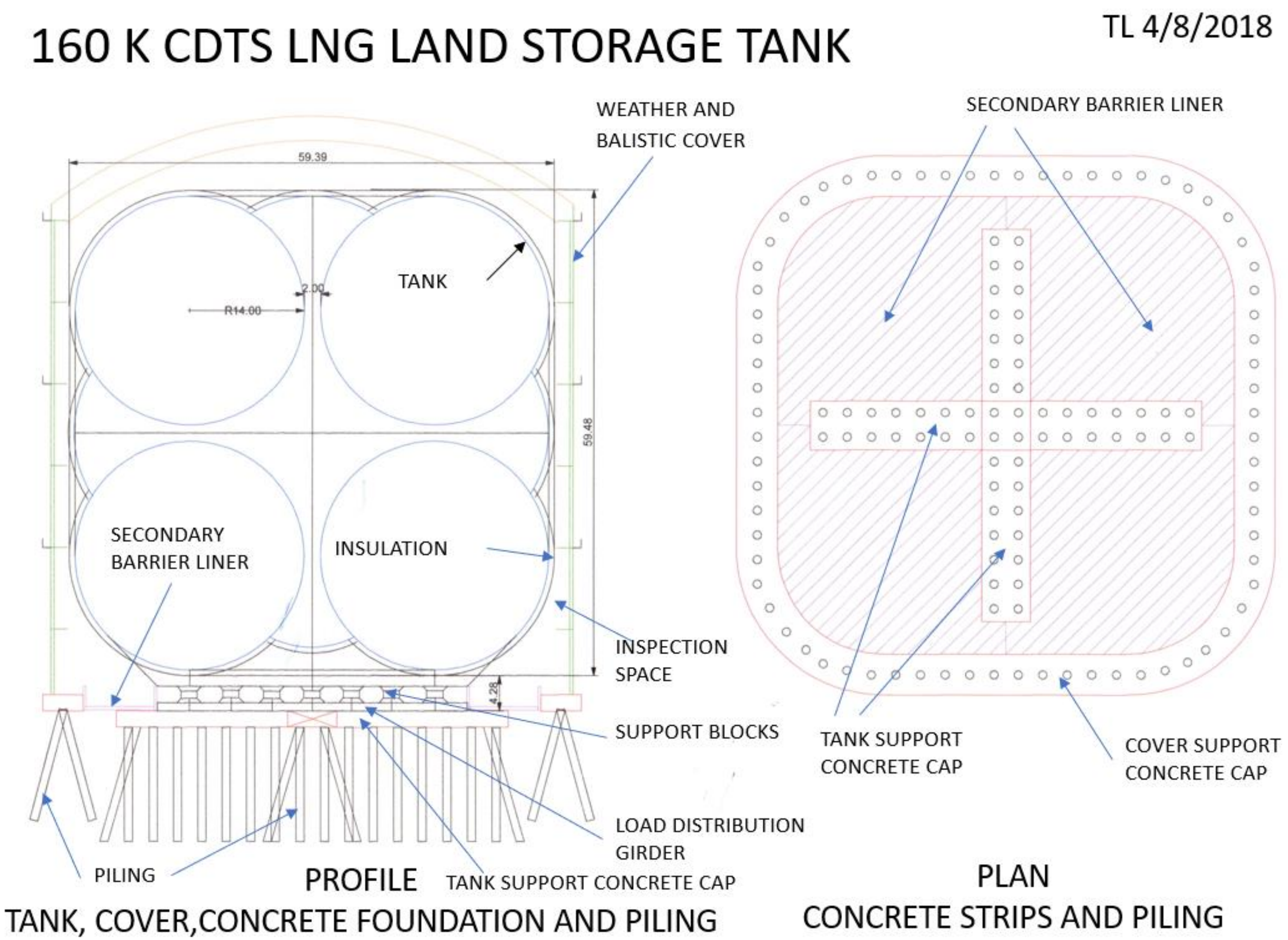
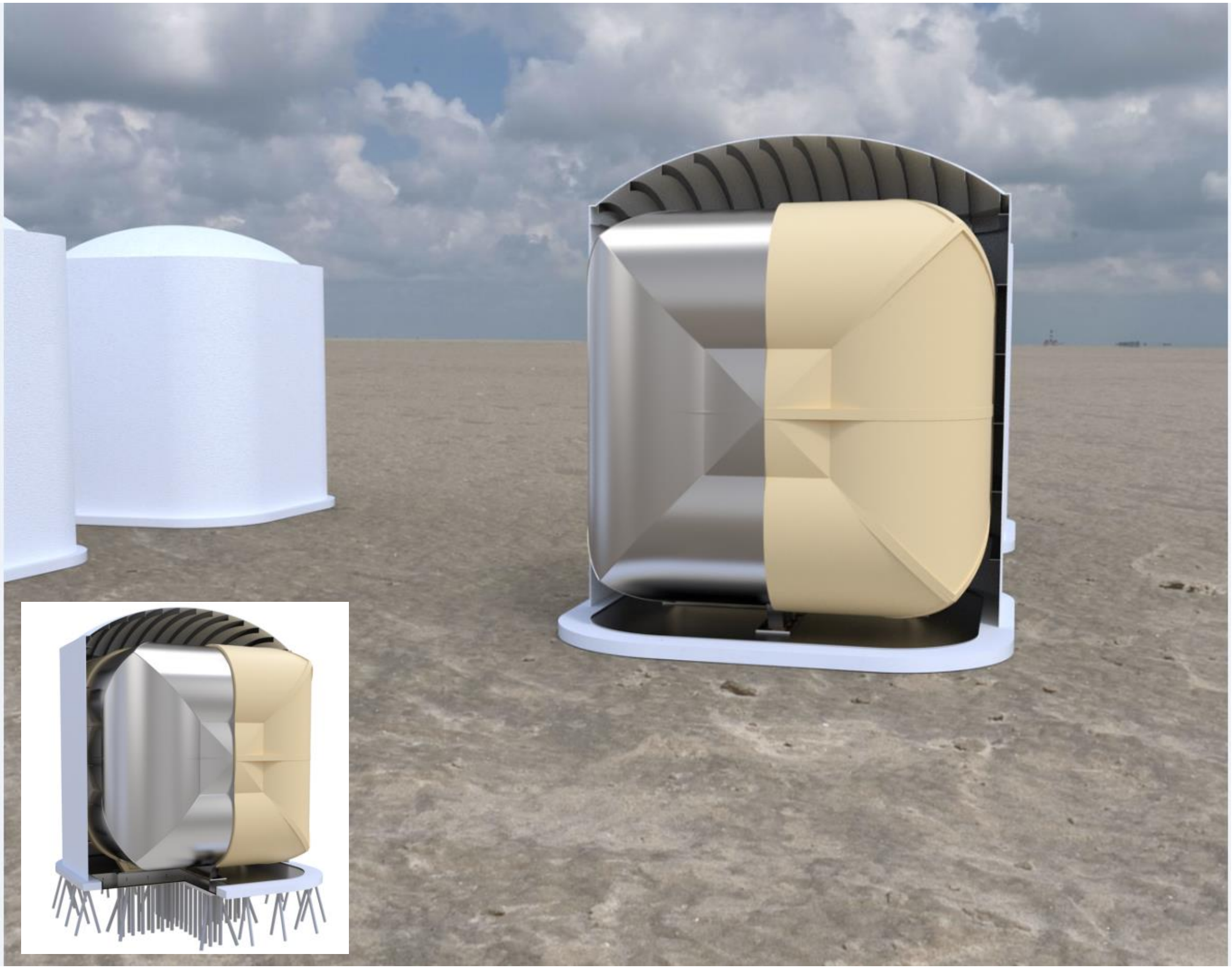


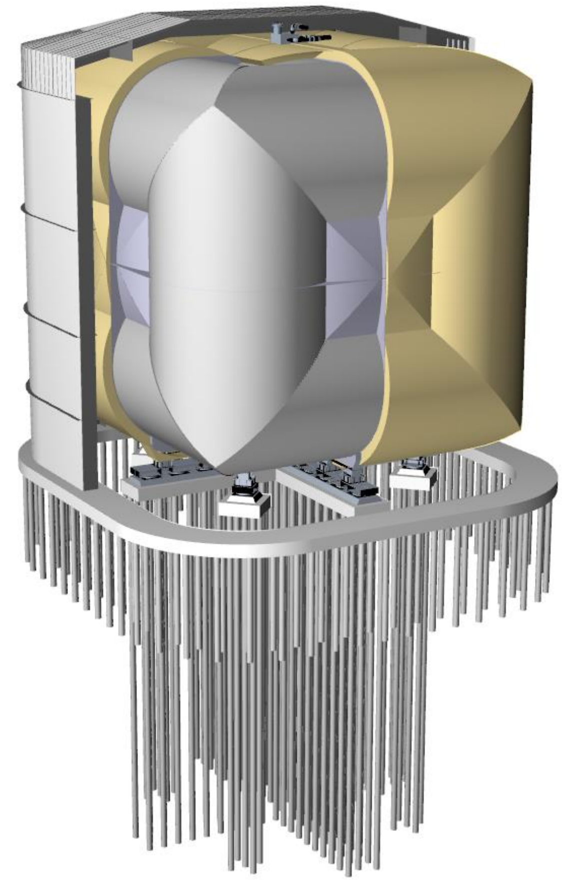
Figure 3.4. Framing plan of piles and the measured piles in corrosion survey

CDTS for Land LNG Containment



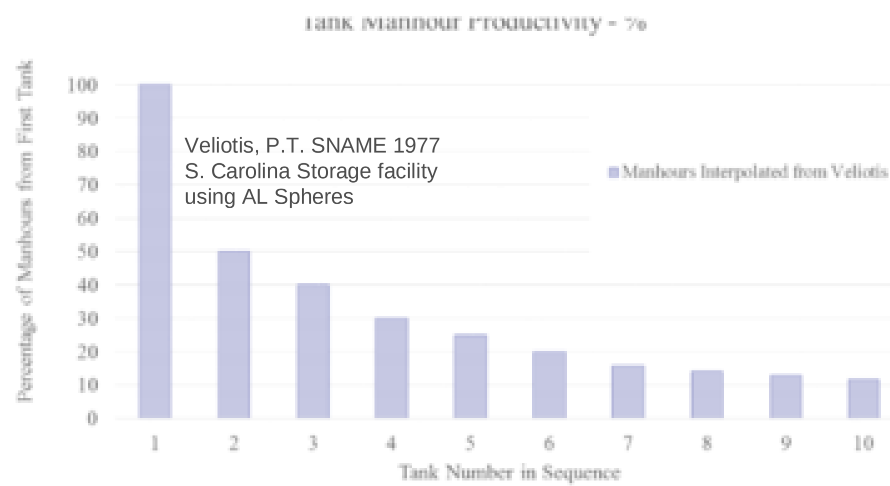
CDTS for Land LNG Containment



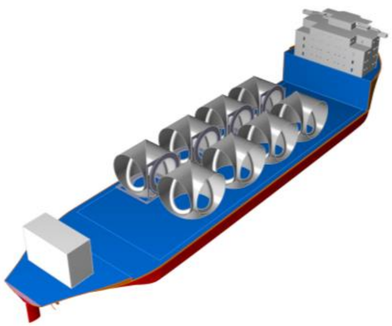


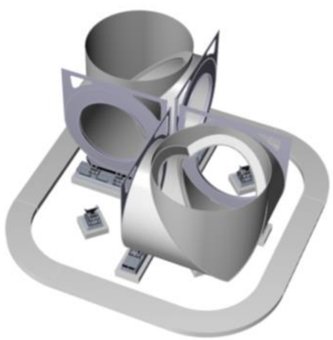
Benefits of Modularized Construction of CDTS Tanks

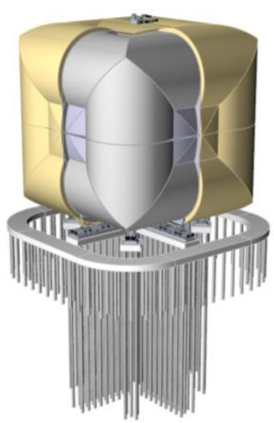
- Currently, most tank systems must be completely constructed on site, especially when they are large, as typically for land storage purposes
- Our self-standing tanks can be built at another site (by a third party company, perhaps specializing in constructing tanks), this is NOT possible for conventional tanks
- The proposed manufacturing method uses an assembly consisting of eight corners of the tank welded together leading to higher quality and productivity
- This enables CDTS tanks (40K CM Capacity) weighing a total of 2400t to be delivered as eight corners each weighing ~300 t or if lifting capacity at site is available, they can be delivered as a full tank
- The use of identical modular corners, built off-site as well as multiple smaller volume tanks to build the required storage volumes brings economies of scale to the tank farm with a much shorter time to build out and commissioning than a tank farm with few very large conventional tanks that must be built *in-situ*



9Ni CDTS Land Storage Tank







- True Plug & Play
- Standardization of **Modules and Design**
- Dedicated Yard Leading to **significantly Higher Productivity & Quality since modular**
- Off-site Tank Pre-fab in Parallel to Foundation Construction
- On-site **commissioning of Tank only once** for all stake-holders together with other EPC partners
- **Can Ship in Modules as they are completed, more cost effective and logistically efficient**
- Reduced Man-Hours on-site compared to full containment concrete and **only have to transport 8 ~300t modules as they are completed at yard**
- **Total Weight of tank is expected to be under 3000t with higher safety margins than conventional land storage cylindrical containment tanks**

Dyke Height and Perimeter Distance

$X = Y + H_{LNG\ @\ 0.7\ barg}$

P = Pressure (Pa) in the vapor space above liquid

ρ = Density of fluid (LNG) (kg/m^3)

g = Acceleration due to gravity (m/s^2)

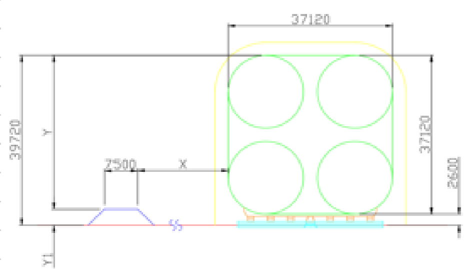
$H_{LNG\ @\ 0.7\ barg}$ = Head pressure (m) of LNG at 0.7 bar(g)

$P = \rho g H_{LNG\ @\ 0.7\ barg}$

70000 = 450 x 9.81 x h

$H_{LNG\ @\ 0.7\ barg}$ = (m)

15.8568

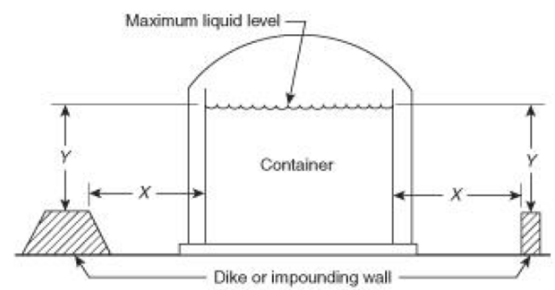


X = Y + 15860

X = (39720 - Y1) + 15860

Y1	Y	X	Dike L	Dike W	Volume Contained, m3	Road Width
1000	38720	54580	146280	146280	21397.84	2000
2000	37720	53580	144280	144280	41633.44	4000
2250	37470	53330	143780	143780	46513.55	4500
2500	37220	53080	143280	143280	51322.9	5000
3000	36720	52580	142280	142280	60730.8	6000
3750	35970	51830	140780	140780	74321.28	7500
4000	35720	51580	140280	140280	78713.91	8000
5000	34720	50580	138280	138280	95606.79	10000
6000	33720	49580	136280	136280	111433.4	12000

5.2.2.9 The dike or impounding wall height and the distance from containers operating at 15 psi (100 kPa) or less shall be determined in accordance with Figure 5.2.2.9.



Notes:

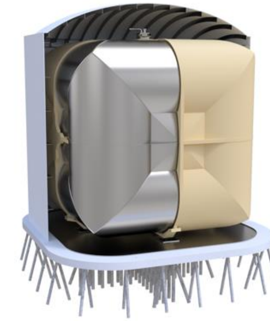
- *X* is the distance from the inner wall of the container to the closest face of the dike or impounding wall.
- *Y* is the distance from the maximum liquid level in the container to the top of the dike or impounding wall.
- *X* shall equal or exceed the sum of *Y* plus the equivalent head in LNG of the pressure in the vapor space above the liquid.

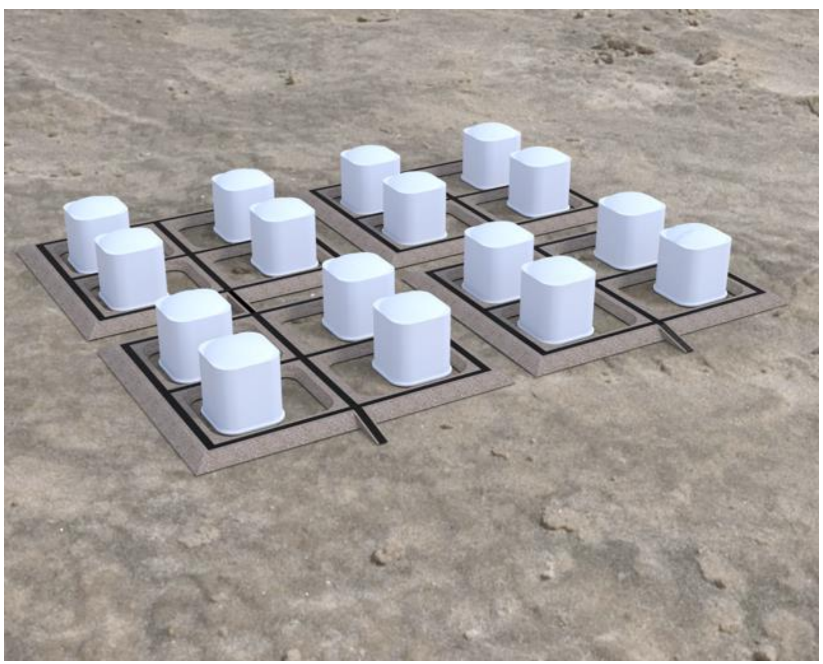
Exception: When the height of the dike or impounding wall is equal to or greater than the maximum liquid level, X may have any value.

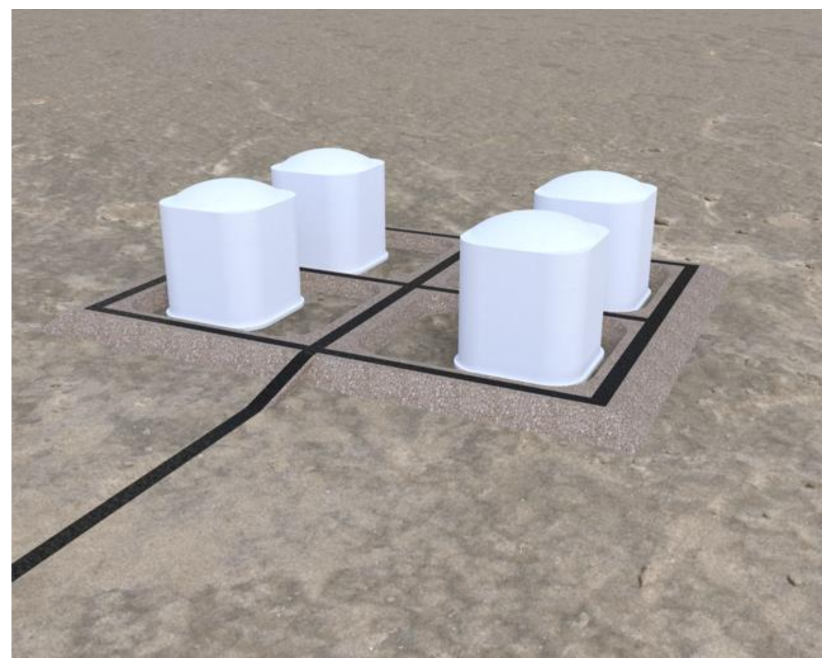
FIGURE 5.2.2.9 Dike or Impoundment Wall Proximity to Containers.

Regulatory Approvals

- Conformance (exceeds) to API 620/625 and NFPA59A
- OISD-STD-194 & CCOE-Nagpur can be met if Local Regulatory Authorities require conformance
- ABS Requirements (or equiv. for approval of modules at fabrication site)
- Our CDTS system was originally designed per IGC Code & ASME Section VIII







Specifications of CDTS Tanks

- Tank Type – Above Ground, Stand-alone Structural Single Containment
- Inner Tank – 9% Nickel Steel
- Roof – Integral with CDTS Tank
- Base – Integral with CDTS Tank
- Support – Extended Transverse & Longitudinal Frames on Lignostone Blocks
- Designed Seismic Loads: [Horizontal] - SSE 0.2g, OBE 0.1g; Vertical - 2/3 * (Horizontal)
- Design Pressure Internal – 1 bar (0.1 Mpa)
- Design Vacuum – -0.005 bar (0.0005 Mpa)
- Design Temperature - -170 C
- Specific Gravity of LNG - 0.48
- Design BoR – 0.05%/day

Specifications of CDTS Tanks

Altair

- Tank Volume – 43,350 m3
- LNG Volume – 40,000 m3
- Tank Dimension – 37 m x 37 m x 37 m
- Max. Operating Level – 36.5 m*
- Min. Operating Level – 0.5 m*
- Insulation Type – 5 layer of PUF Blocks
- Insulation Thickness – 1100 mm
- Tank Height above Concrete – 2 m
- Overall Height 40 m

*needs to be confirmed with Gas Engineering Partner

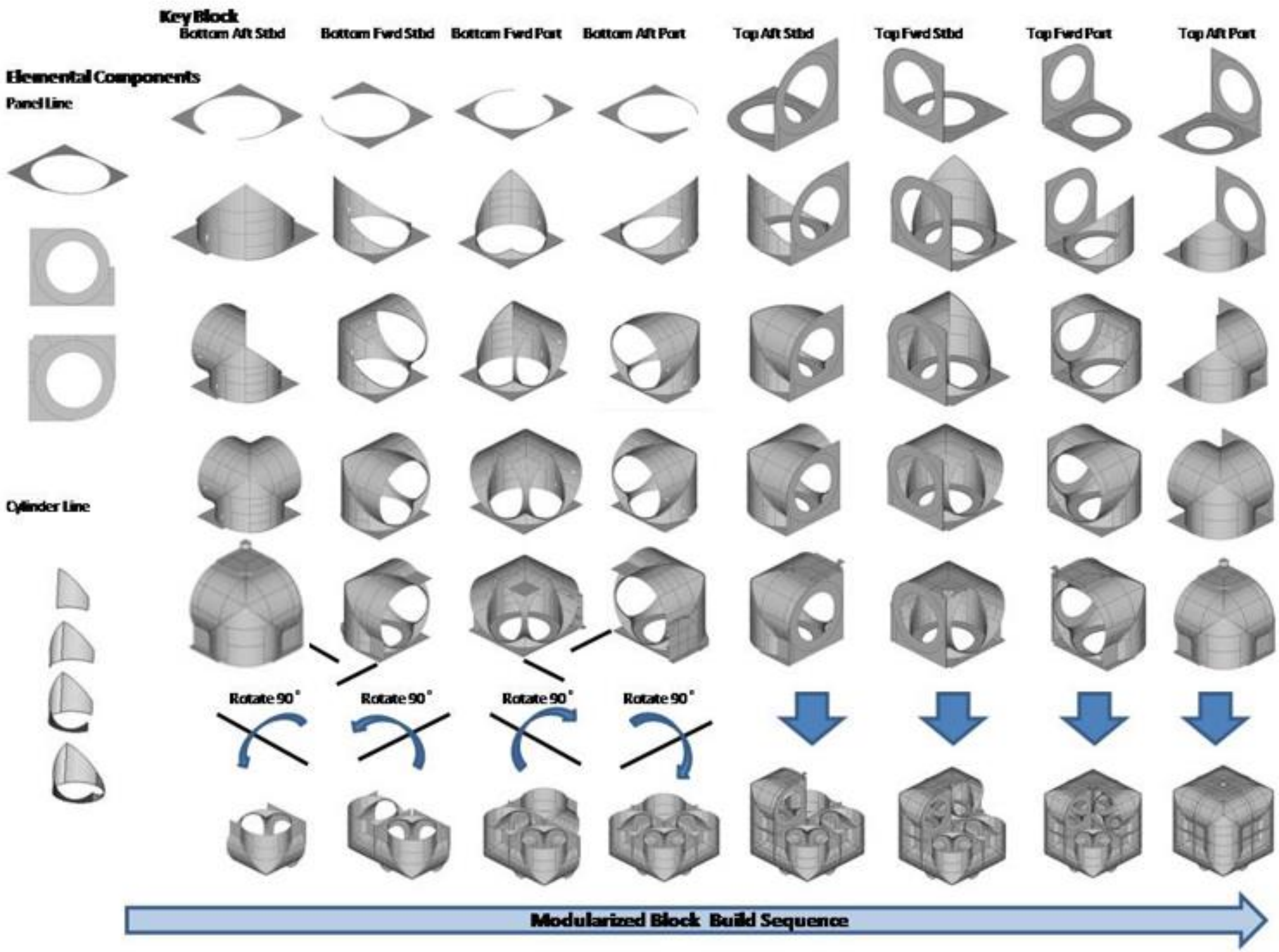
Specifications of CDTS Tanks

- Outer Tank – A36 Steel Enclosure
- Enclosure Dimensions – 40 m x 40 m x 43 m
- Enclosure Thickness – 0.75 mm
- Hydrostatic Test Load – 1.25 x full head of LNG
- 1 m of LNG = 0.48 m of H_2O
- Hydrostatic Test Load = 1.25 x 0.48 =0.6 * Height of liquid head in H_20
- Concrete Support Design Load – 3 times tank weight
- Lignostone Support Load – 3 times Block Load
- Differential Settlement Perimeter – 1:500
- Differential Settlement Center to Edge – 1:300
- Planar Tilt Angle – 0.002 radians

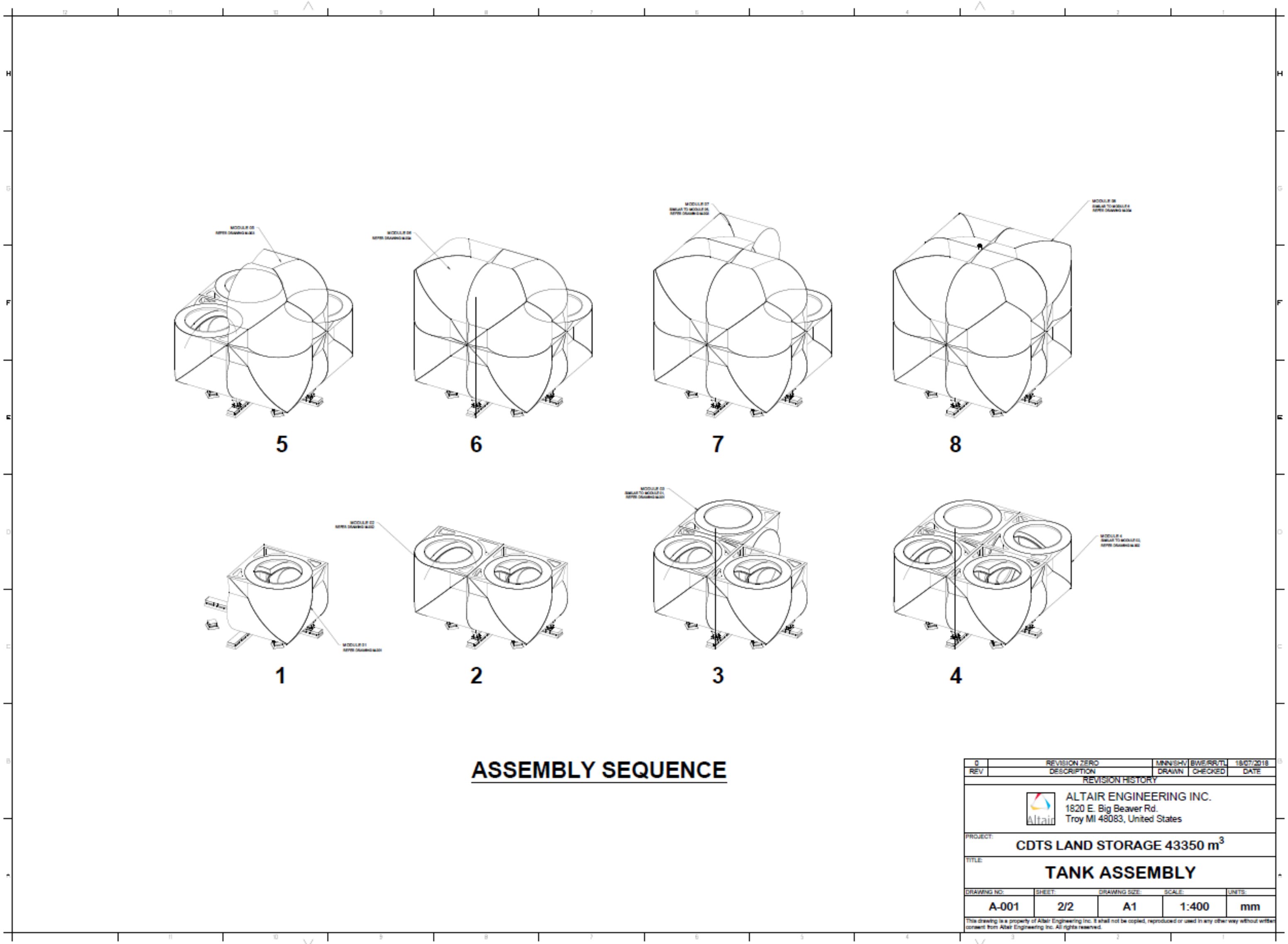
Preliminary Specifications for Concrete Base Slab

- G30 ~ G35 Concrete Slab on piles
- Pile Spacing and Depth (~25m) will depend on geo-mechanics and seismicity of site
- Slab height estimated at 500mm ~ 800mm
- Project Site Environmental Conditions may effect Design somewhat but not expected to be significant

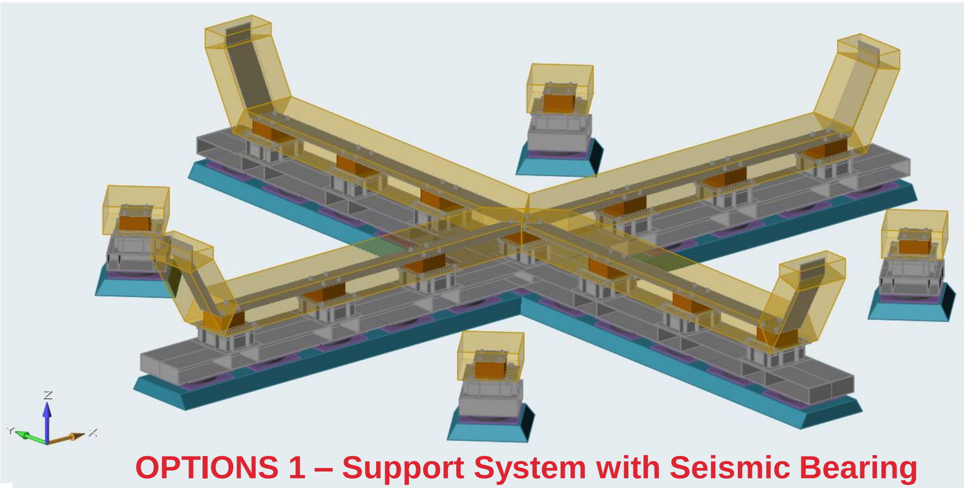
CDTS Manufacturing Methodology



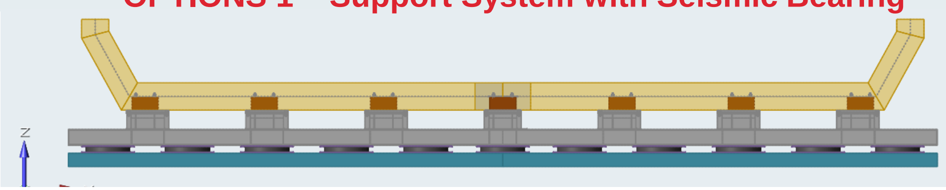
9Ni Single Containment CDTS

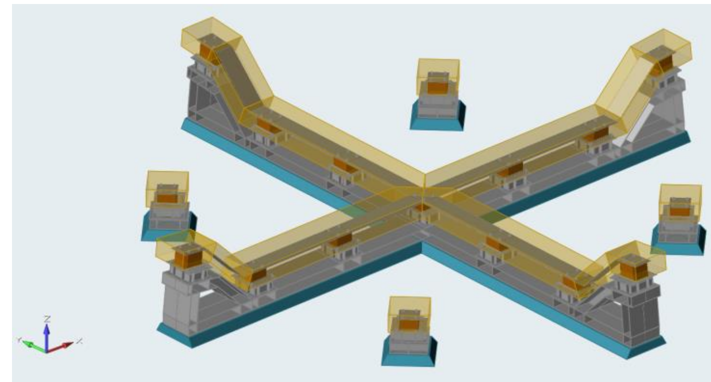


9Ni single Containment CDTS



OPTIONS 1 – Support System with Seismic Bearing





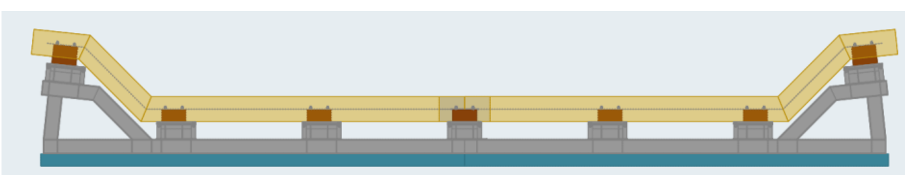
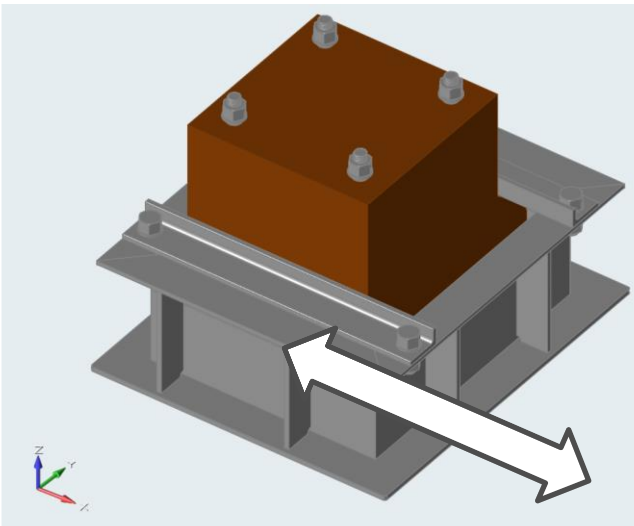


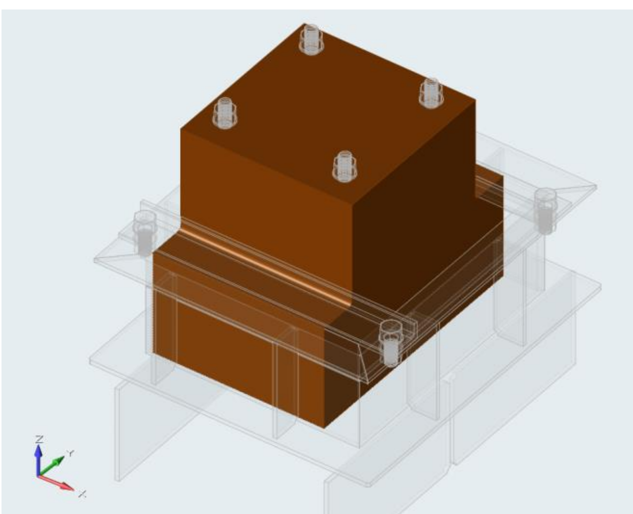
Figure 11 Peru LNG Tank 130,000m3 with 256 Triple PendulumTM bearing (courtesy of EPS)

Figure 12 Incheon LNG Terminal founded in elastomeric bearings

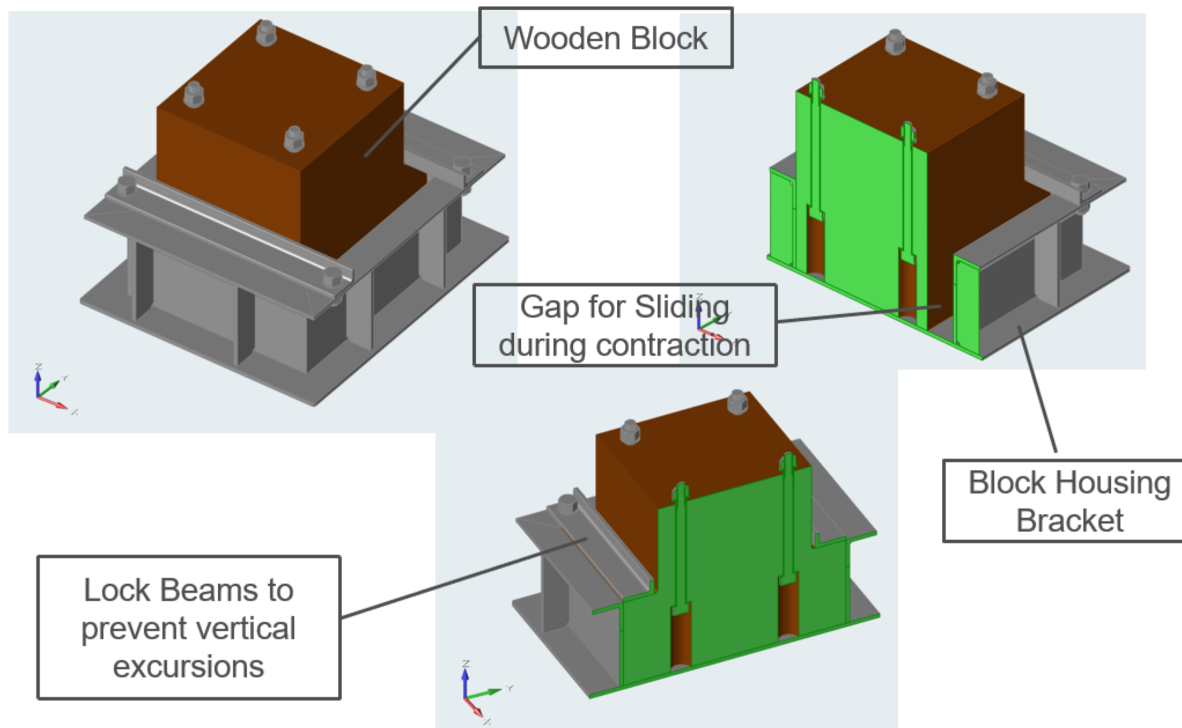
OPTIONS 2 – Support System with Slanting O/B Support

Sliding Support Mechanism



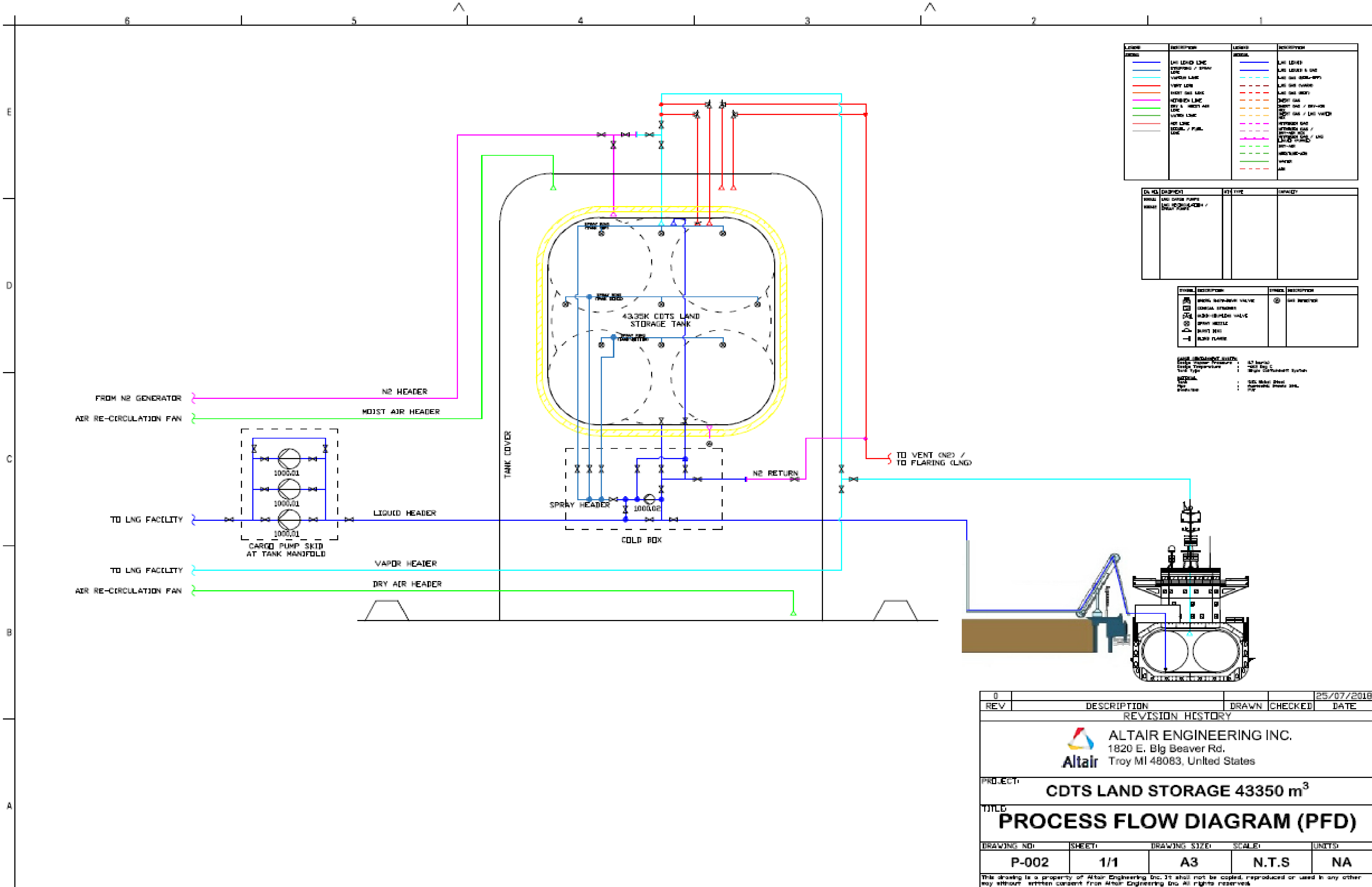


- Lignostone Blocks are attached to the CDTS Bottom Support via 4 bolts
- The blocks sit in support housing per our marine variant that allow excursions in one direction to accommodate contraction



Gas System

- Similar System used in well proven & robust Vertical Bullet Tanks



Insulation System

5.2 Calculation of Heat & BOR

In ANSYS, the heat is calculated through the formula below

$$q_{total} = q_{qtr} \cdot 4$$

where q : Total heat loss

q_{qtr} : heat calculated by the quarter size model

BOR is calculated as below

$$BOR = \frac{q_{total} \cdot 3600 \cdot 24}{h_{fg} \cdot V \cdot \rho_m} \cdot 100\%$$

where q_{total} : Total heat loss

V : Total cargo volume of a tank (43350 m³)

h_{fg} : Latent heat of pure methane (511kJ/kg)

ρ_m : Density of pure methane (425kg/m²)

Results are summarized as below.

Thickness of TiG PU panel [mm]	BOR target [/day]	Total heat loss [W]	Calculated BOR [/day]	Safety margin*
1000	0.05%	51064	0.0469%	6.27%
700	0.08%	77560	0.0712%	11.03%
580	0.10%	96820	0.0889%	11.15%
380	0.15%	146148	0.1341%	10.58%

**) Safety Margin = (BOR Target - Calculated BOR) / BOR Target*

Table 3 Heat results summary

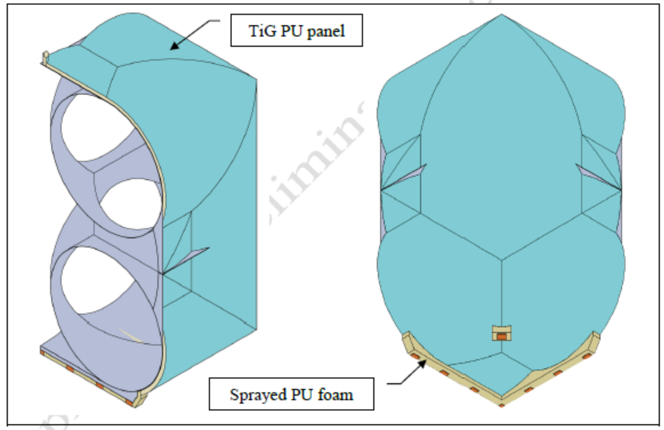


Figure 1 Cargo tank and insulation system

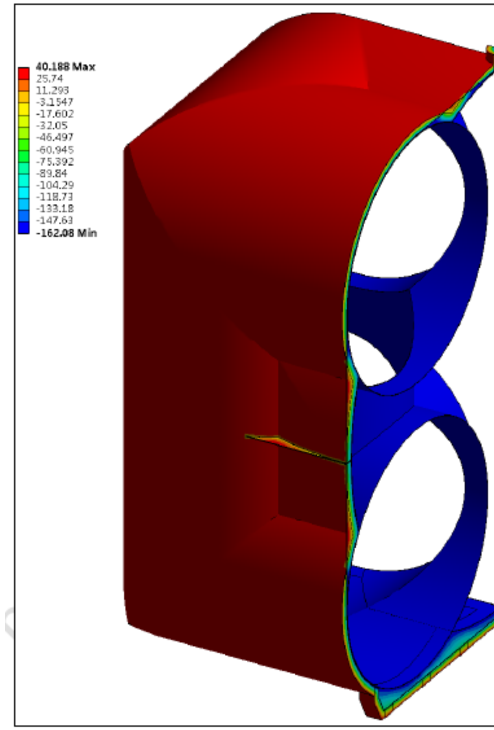


Figure 2 Temperature distribution in a typical case

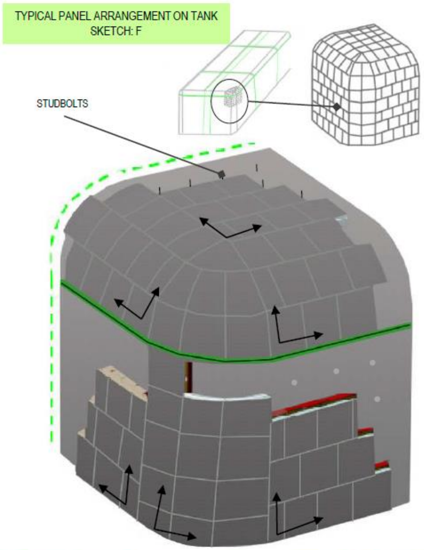
4. Boundary Condition

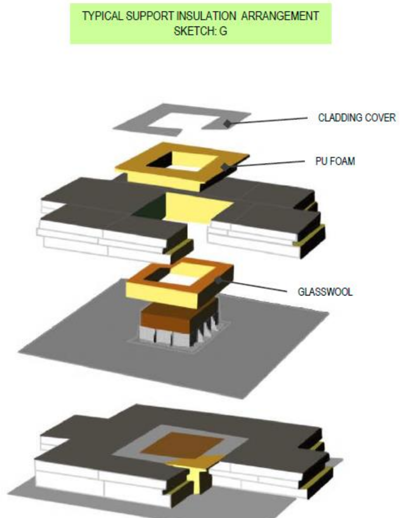
Area	Type	Temperature [°C]	Heat transfer coefficient [W/m2K]
Hold space	Convention	40	5.8
Bottom of support	Conduction	40	-
Inside Tank	Convention	-161.5	500

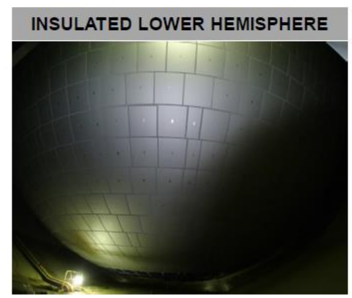
Table 2 Boundary condition

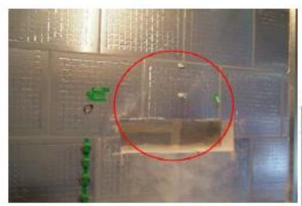
Radiation heat transfer is not considered.

Insulation System



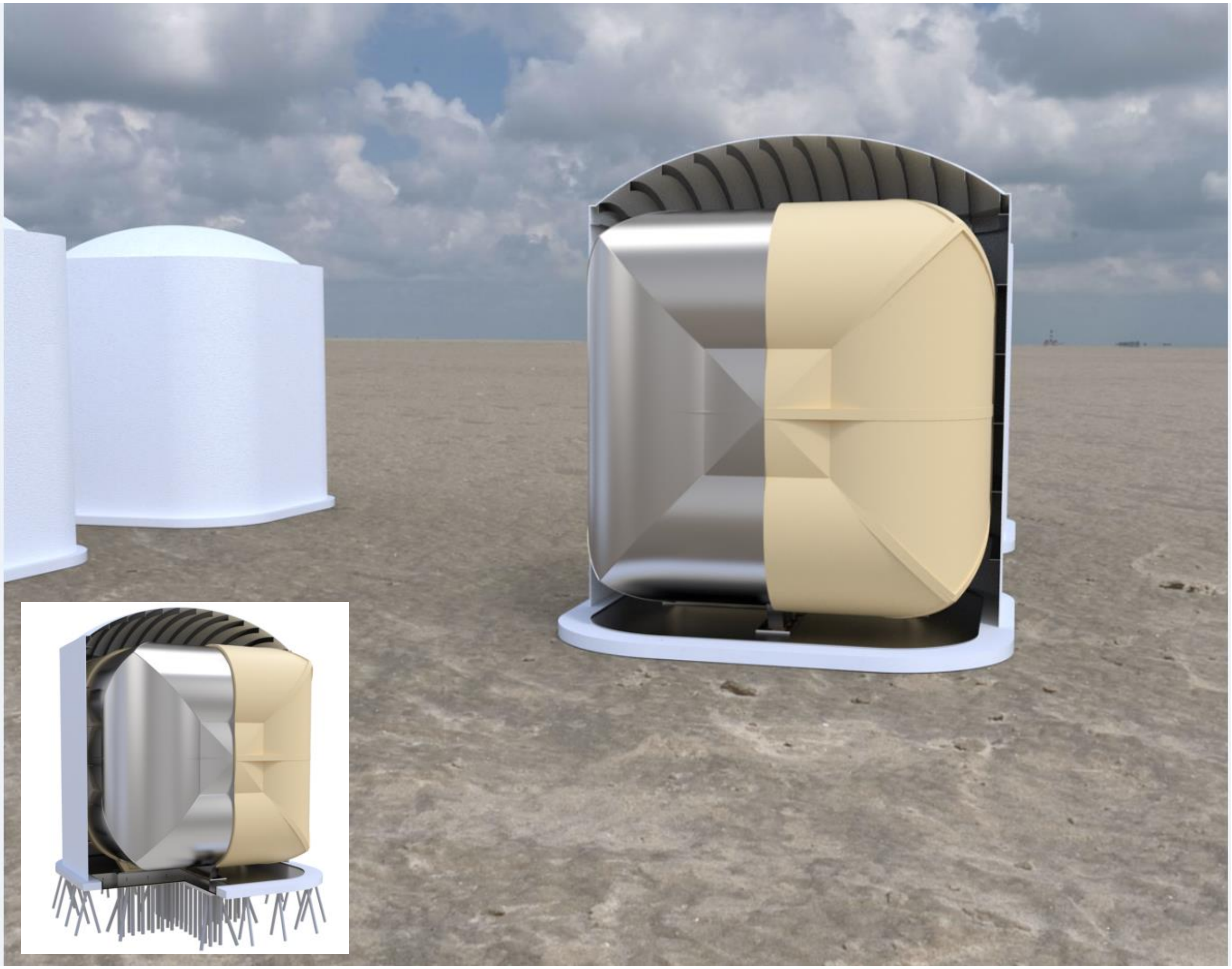


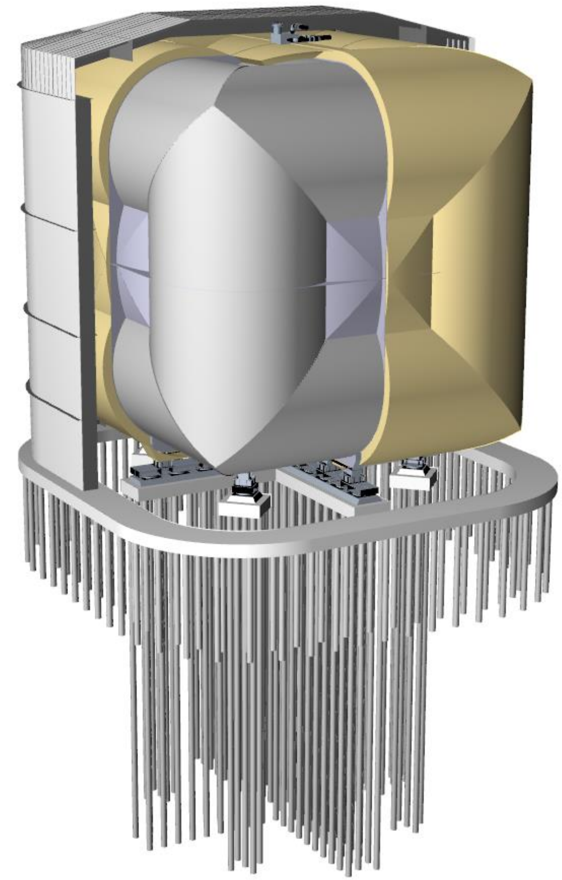




The entire TiG insulation system has been rigorously tested under cryogenic conditions under strict class (LR) control and verification. The system was dismantled and inspected while in fully frigid condition in order to discover any weakness or problems. The class could witness that the integrity of the system was fully satisfactory. This testing was completed in 2007 after a long testing pprogram.

CDTS for Land LNG Containment





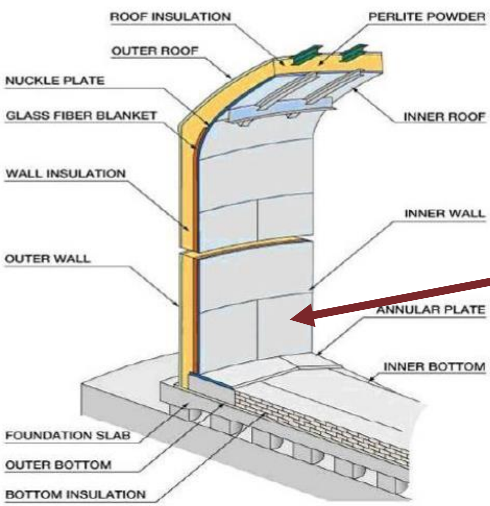
CDTS Tanks vs Cylindrical Tanks

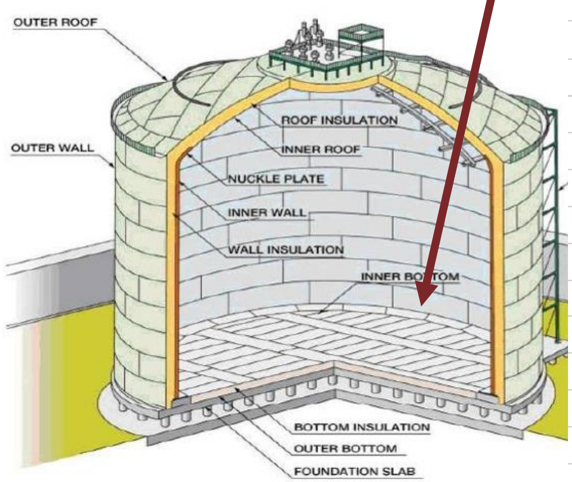
$$\sigma_\theta = [Pr. \times Dia.] / (2\,t)$$

$$\sigma_a = 0.5 \times \sigma_\theta$$

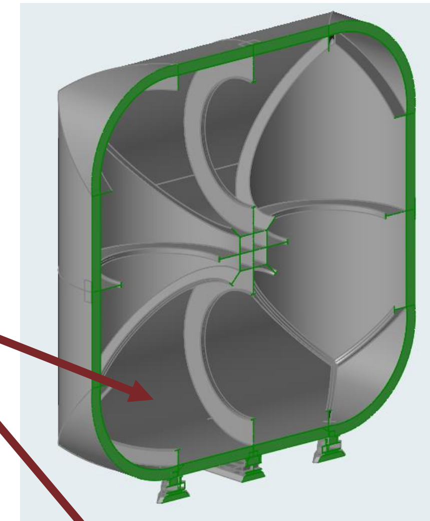
350 MPa

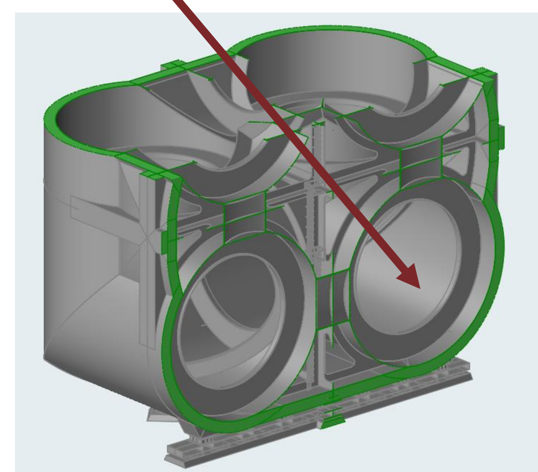
200 MPa





40K Tank Comparison			
	Cylindrial 9Ni Single Containment	ALTAIR 9 Ni CDTS	
Inner Shell (t)	640	2400	Tank Shell (t)
Shell Thickness			
Top (mm)	10	15	
Bottom (mm)	25	30	
Base Support (t)		60	Base Cradle (t)
Concrete (t)	990		
Steel Grillage (t)	212		
Insulation	Perlite	PUF (aged)	
Density (kg/m^3)	130	43	
Thickness (m)	1.275	1.0	
κ (W/mK)	0.047	0.0142	
Insulation (t)			
Vertical Wall	467		
Roof	50		
Base	502		
Total Insulation Weight (t)	1019	298	





SABINE PASS – 2 Storage Tanks Shut-Down due to Leakage

NATURAL GAS

Feds order partial shutdown at Cheniere LNG export site

Jenny Mandel and Mike Soraghan, E&E News reporters

Energywire: Monday, February 12, 2018

Tanks store liquefied natural gas at Cheniere Energy Inc.'s Sabine Pass LNG terminal. Roy Luck/Flickr

Federal regulators have ordered Cheniere Energy Inc. to shut down part of its liquefied natural gas export terminal in Louisiana after multiple leaks from storage tanks were discovered in late January.

The Pipeline and Hazardous Materials Safety Administration (PHMSA) announced Friday that it had ordered Cheniere to shut down two tanks at its Sabine Pass facility, which in 2016 was the first of several U.S. LNG export projects under development to start shipping gas.

PHMSA allowed the company to continue importing and exporting gas and use three other LNG storage tanks at the site.

PHMSA is investigating a Jan. 22 incident in which workers discovered that LNG had been leaking into a containment ditch around a storage tank. Further inspection revealed that natural gas vapors were leaking from 14 points around the base of a second LNG storage tank.

Sabine Pass has five LNG storage tanks; all were designed by Mitsubishi Heavy Industries Ltd. Three of the tanks were built by Matrix Service Inc. between 2005 and 2008 and were placed into service in 2008, while the other two were built by Zachry Industrial Inc. and put into service in 2009, according to PHMSA.

Plymouth LNG– 1 Storage Tank Shut-Down due to Leakage from Shrapnel Puncture

Aerial view taken shortly after the failure. Looking South toward Columbia River.

Aerial view taken shortly after the failure. Fires still burning. Perlite insulation leakage from the penetrated outer LNG-1 storage tank. Control room lower left.

What happened at Plymouth LNG?

LNG is simply natural gas that has been refrigerated to -260 degrees Fahrenheit. At this temperature, natural gas becomes liquid and condenses to 1/600th of the space it occupied as a gas. Cryogenic refrigeration allows plant operators to store large quantities of natural gas in tanks that could not otherwise hold such a large volume. If liquid natural gas is not kept extremely cold, it turns back to a gas. When a utility needs to use the LNG it has stored, workers simply pipe LNG out of the refrigerated storage tank and return its temperature to normal.

Plymouth is the largest LNG storage facility in the Pacific Northwest, boasting two 14.6 million gallon storage tanks. Shortly after 8:00 a.m. on March 31, 2014, gas processing equipment at Plymouth LNG exploded into a towering, mushroom-shaped cloud. Nearby residents saw flames shoot into the air, and people living three to six miles from the plant could feel the explosion. The blast sent 250 pounds of debris and shrapnel flying as far as 300 yards, damaging buildings and equipment and puncturing one of the large LNG storage tanks.

Shrapnel injured four of the fourteen employees on duty, and a fifth worker was hospitalized for burns. Debris from the blast also damaged the main rail line on the north side of the Columbia River, which delayed more than 40 trains before BNSF Railway completed repairs on Tuesday afternoon. (Sightline has previously calculated that on a typical day, several notoriously combustible oil trains traverse the route that passes by the Plymouth LNG facility.)

In the hours that followed, 14.3 million cubic feet of gas spewed from a large gash in the storage tank and other damaged equipment on site. Video and photos show vaporized LNG escaping from a puncture low on the tank. Williams says the damaged tank was only one-third full.

Spill of LNG won't count as LNG spill

In addition to not being considered a threat to public safety, the Plymouth LNG spill is not even considered an LNG spill. The data retrieved from PHMSA's website states that even though 14,270 barrels (599,340 gallons) of LNG spilled, no LNG was lost. When Sightline contacted PHMSA about the apparent error in the report, an agency official responded that in fact no LNG was spilled at all. The official clarified that *evaporated* natural gas was spilled, not *liquid* natural gas.

Tank Technology Selection Study

For the Hong Kong LNG Terminal

- Because much on an in-ground is covered with soil, tank inspection and monitoring is difficult and possible problems may go unnoticed. When problems do occur, it is much harder to repair them. For example, the in-ground tanks in Yung-An (Taiwan) have been leaking for years, but due to the difficulty in pinpointing the leak location and accessibility, have elected not to try to repair the leak.

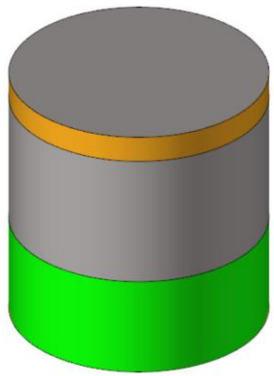
9Ni Single Containment CDTS vs Cylindrical

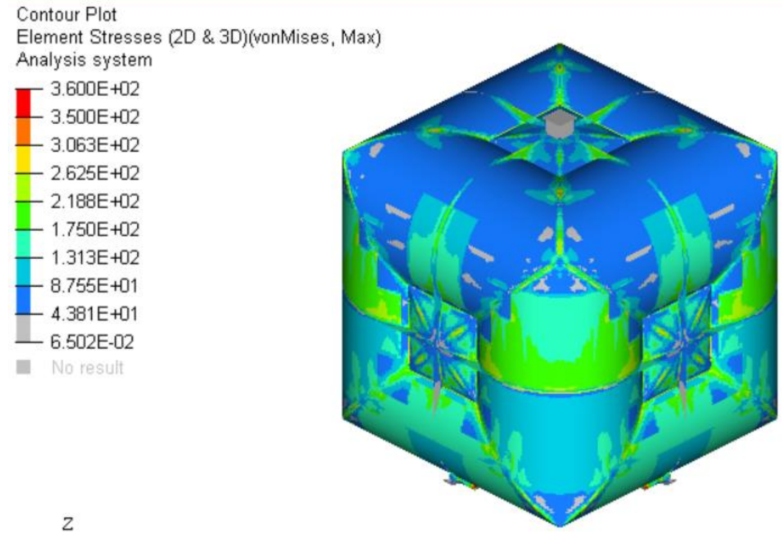
Loading

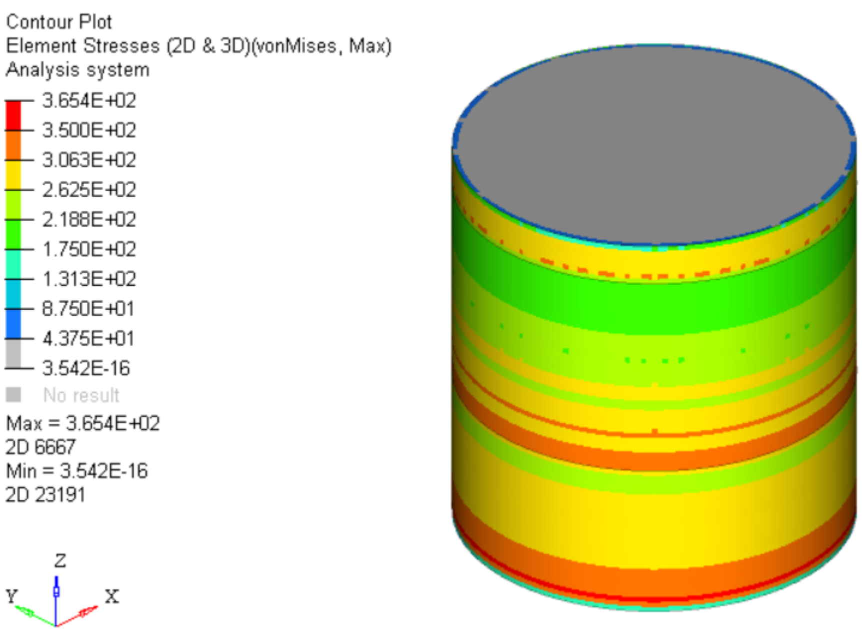
1. Hydrostatic load (25% margin)

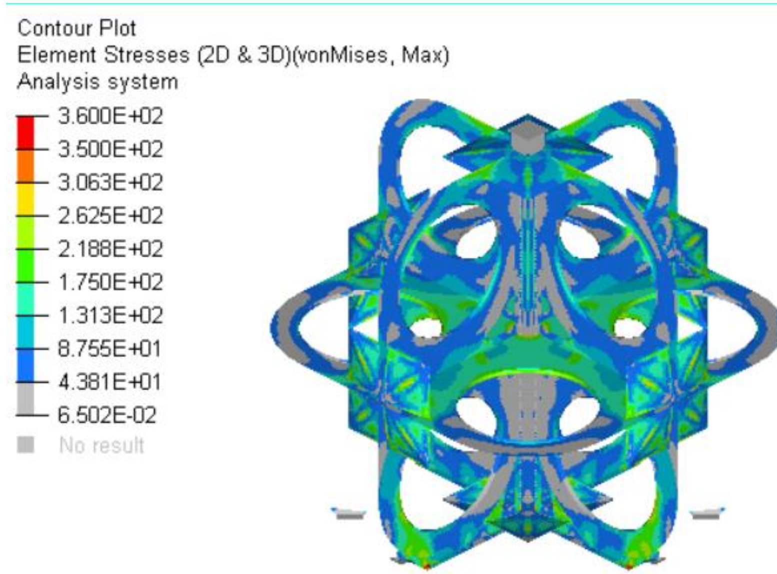
2. gravity load

3. pneumatic load (25% margin)









Altair

Altair HyperWorks®

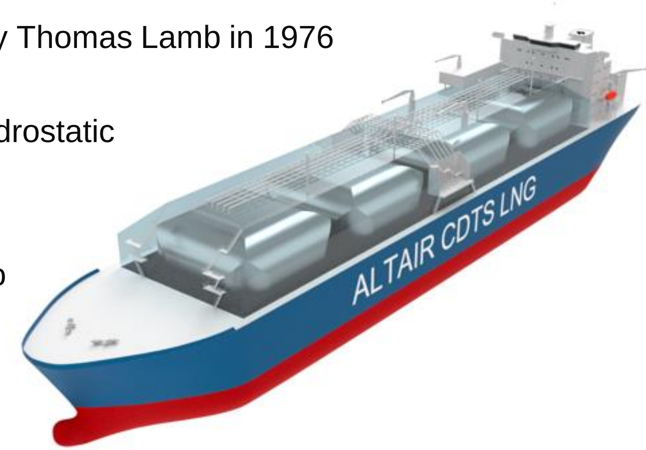
CDTS 40K m^3 :

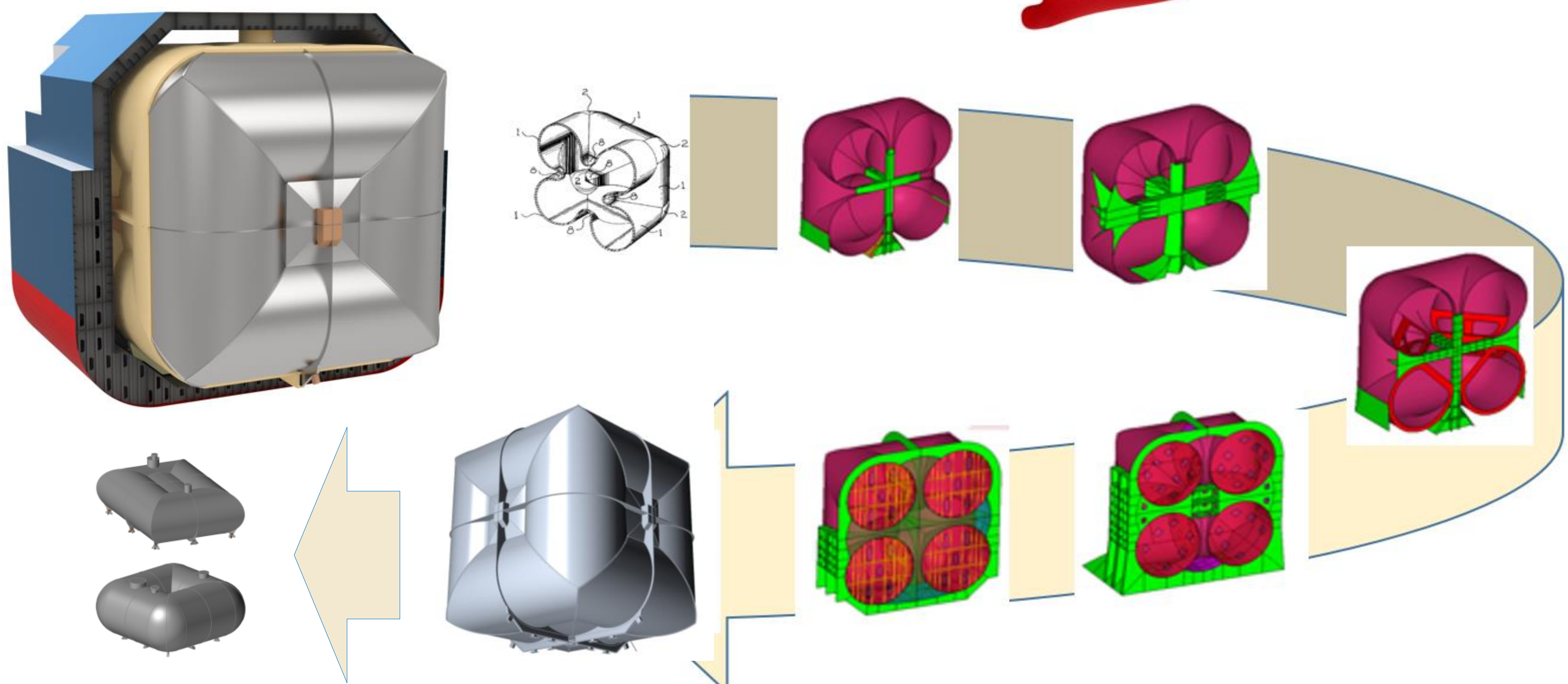
Land Storage Tank Stress Analysis

Eng Ban-Wee, Principal Naval Architect, Altair Engineering, Inc

CDTS – Origins & Design Evolution

- The Cubic Donut Tank System (CDTS) was first developed and patented by Thomas Lamb in 1976
- The objective being that it is as efficient as the spherical tank system for hydrostatic containment and has the volumetric efficiency of membrane tanks
- Altair's Award-winning design synthesis technology Optistruct® was used to improve on the unique geometry of the CDTS to provide the best trade-off between spatial & structural efficiencies





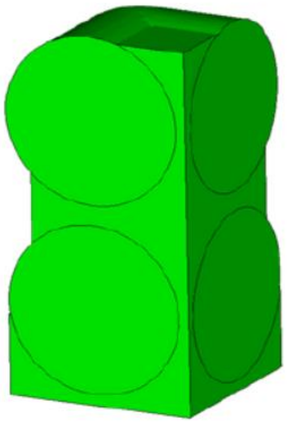
Concept Level Optimization Types

Topology Given a design envelope, topology optimization finds the optimum material placement within that space according to the constraints and objective

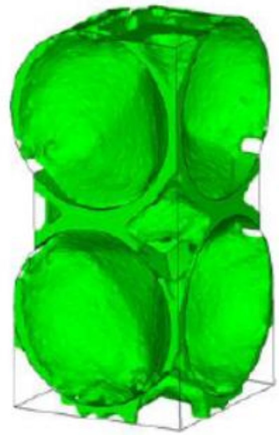
Topography Given a shell structure, topography optimization creates a bead pattern from the elements that meets the constraints and objective

Free Size Given a shell structure, free size optimization finds the optimum thickness on an element-by-element basis that meets the constraints and objective

Optimization process for CDTS

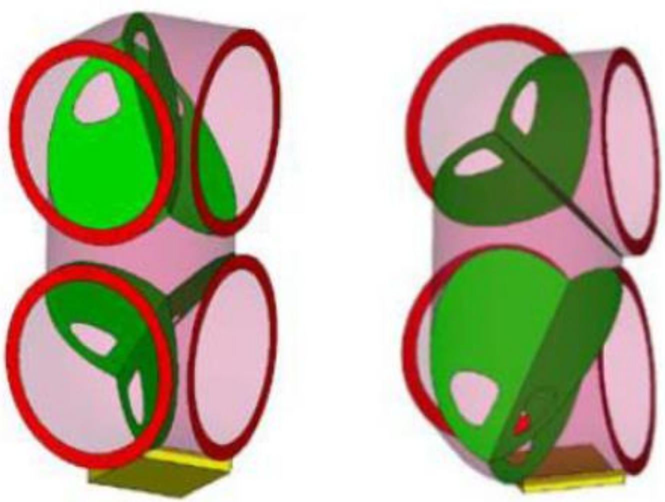


Design space

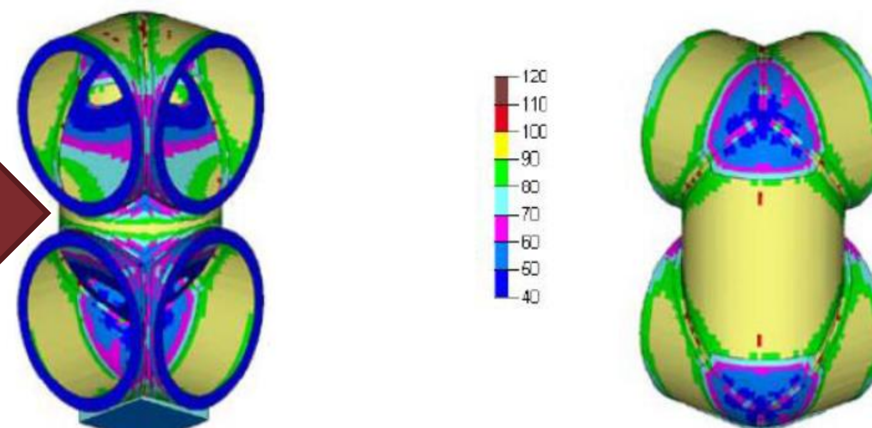


Load path from Optimization

Load path from Optimization



Adding more requirements



Freesize thickness

Loading Type & Combination

- Dead load(D_L)
- Hydrostatic (use 100% instead of 60% H_2O) and pneumatic tests (H_t)
- Loads from connected piping (L_p)
- Loads from platforms and stairways (Ls)
- Minimum roof live load (L_r)
- Pressure (P_g): gauge pressure
- Pressure (P_v): maximum partial vacuum
- Seismic (E)
- Snow (S)
- Stored liquid (P_l)
- Wind (W)

a) $D_L + P_g + P_l$

b) $D_L + W_L + 0.7P_g$

c) $D_L + W_L + 0.4P_v$

d) $D_L + P_v + 0.4(L_r \text{ or } S)$

e) $D_L + 0.4P_v + (L_r \text{ or } S)$

f) $D_L + 0.7P_g + P_l + E + 0.1S$

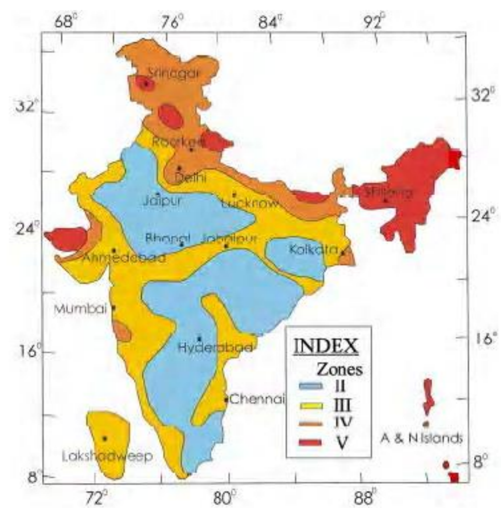
g) $D_L + H_t$

h) $D_L + L_s$

i) $D_L + L_p + P_g + P_l$

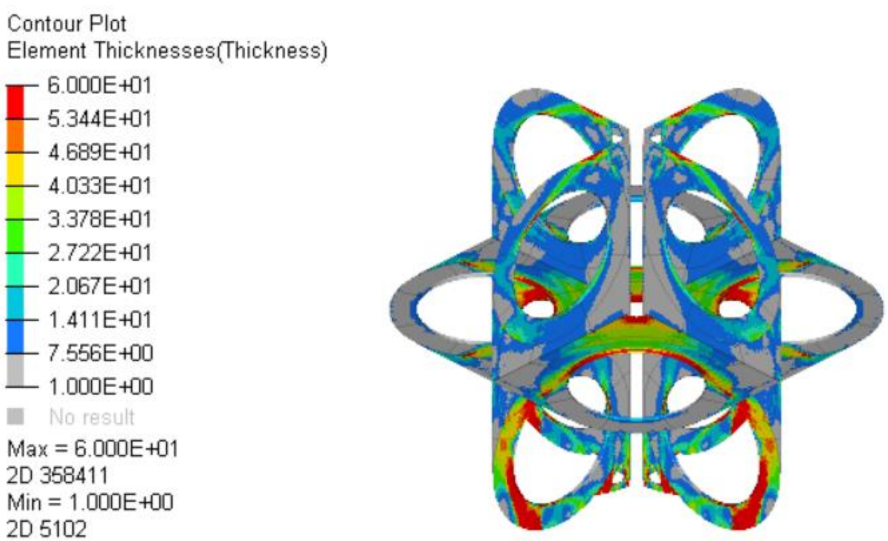
Table 3. Comparison of Peak Ground Accelerations (PGA's) from different studies for major cities in India

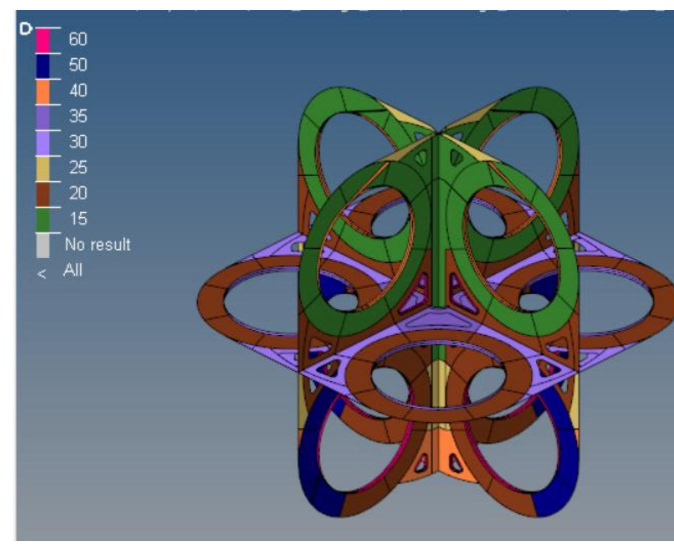
Location	IS 1893 Zone	Zone factor based on IS 1893 -2002 for MCE	(PGA's) having a 10% probability of being exceeded in the next 50 years based on this Arup Study	NDMA (2011) PGA's having a 10% probability of being exceeded in the next 50 years	Comment
Delhi	IV	0.24 g	0.065 g	0.08 g	The Zone factor provided by IS – 1893 (2002) is for MCE. The DBE is taken as half of that value
Patna	IV	0.24 g	0.062 g	0.04 g	
Sikkim	IV	0.24 g	0.325 g	0.18 g	
Kolkatta	III	0.16 g	0.135 g	0.09 g	
Mumbai	III	0.16 g	0.047 g	0.09 g	
Bangalore	II	0.10 g	0.033 g	0.02 g	



Optimization process for land storage tank

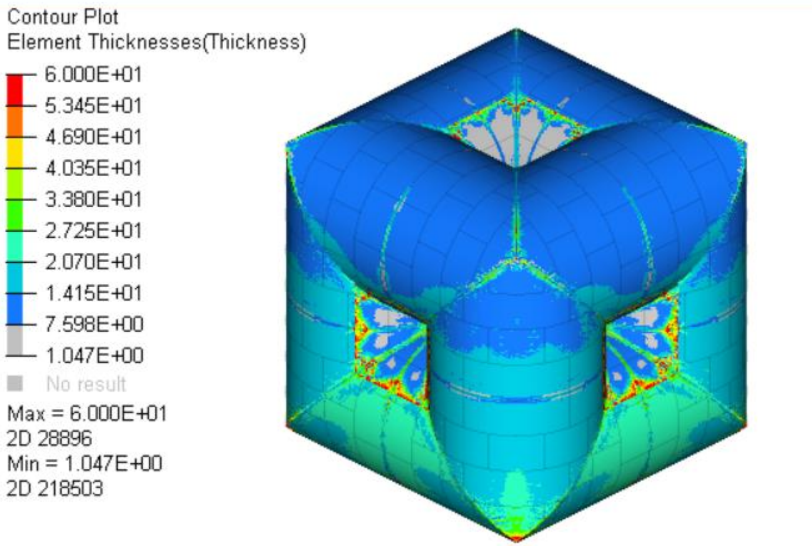
- Constraint the mass and stress of the structure
- Objective is maximum the stiffness(rigidity)of the structure

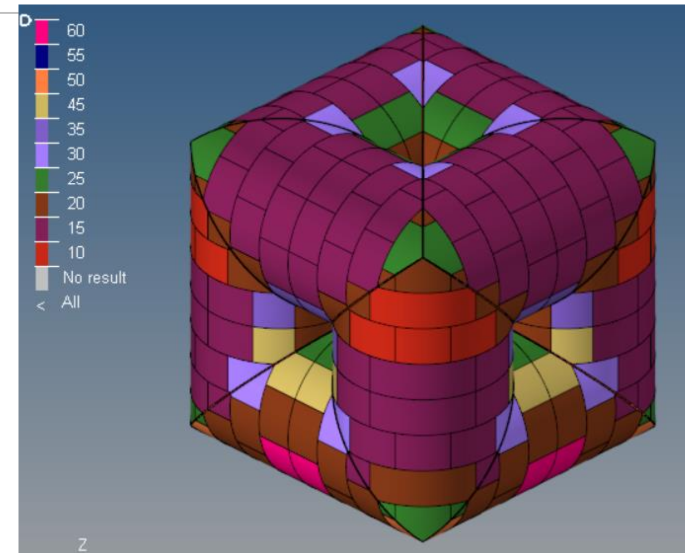


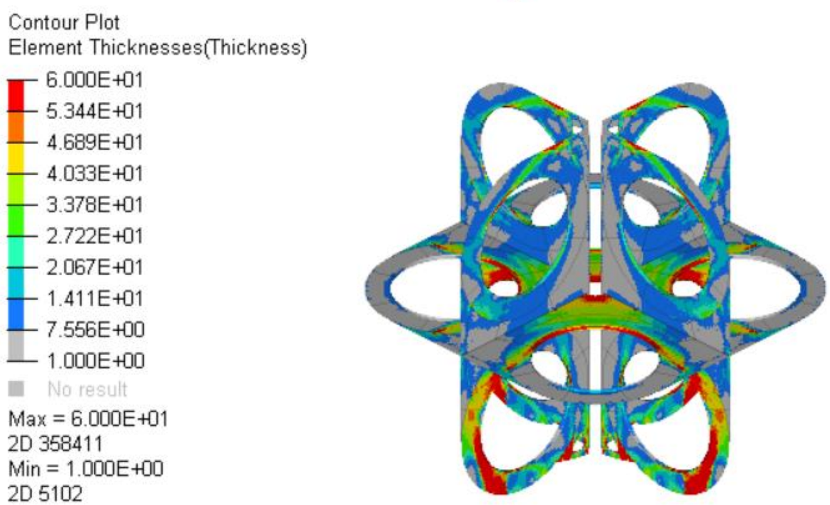


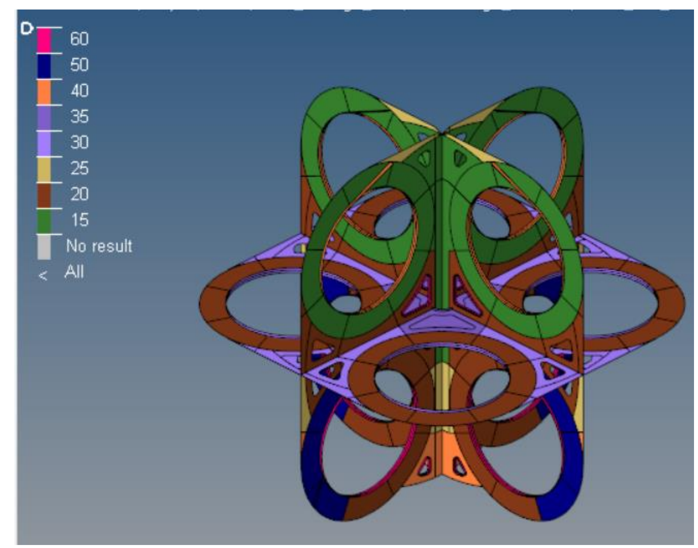
Optimization Process

Altair







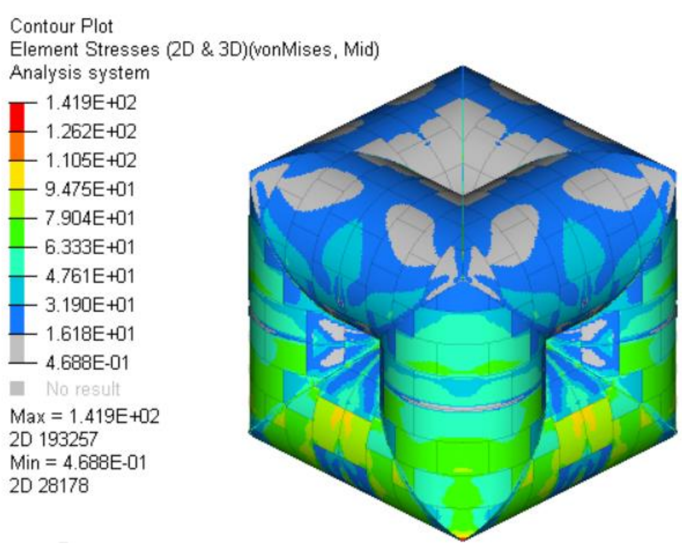


Stress criteria :

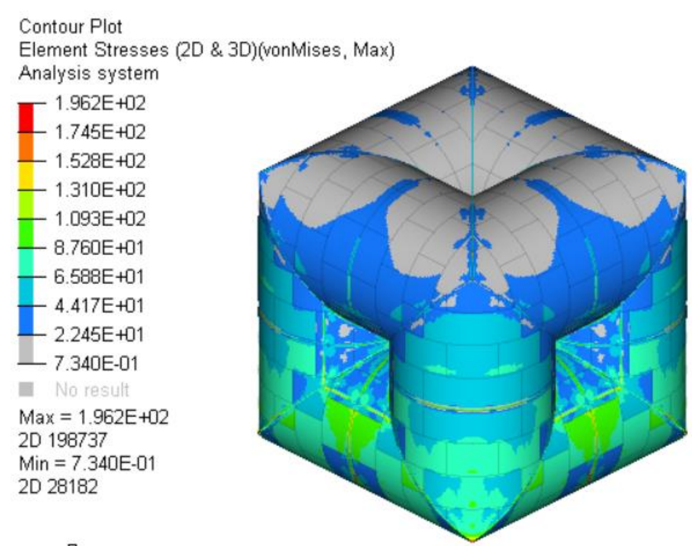
- **Using ASME pressure vessel code for the design standard**

IGC Stress Allowables	Nominal	Local
Allowable membrane Stress (MPa)	212	318
normal pressure loading or plate structures under in-plane loading)		
Allowable Total Stress (MPa)	318	318
(i.e., structural segments that are subjected to membrane and bending loads)		

API Rules	75% of min yield@586 = 440 Mpa



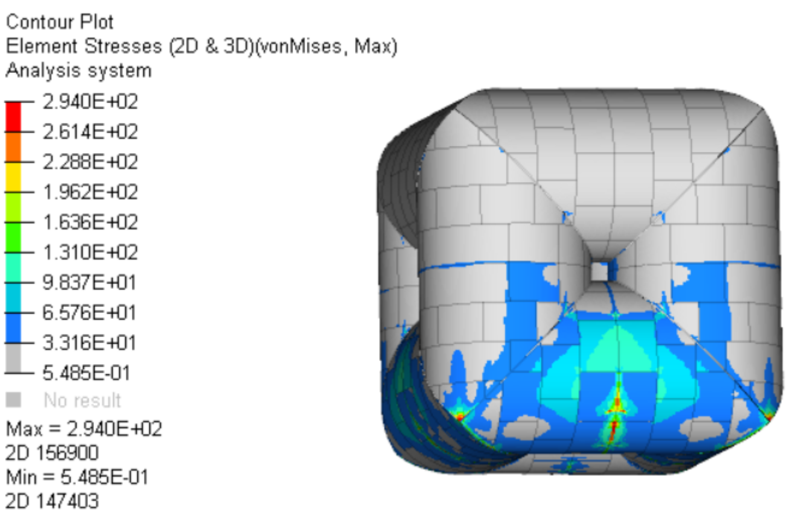
Membrane stress



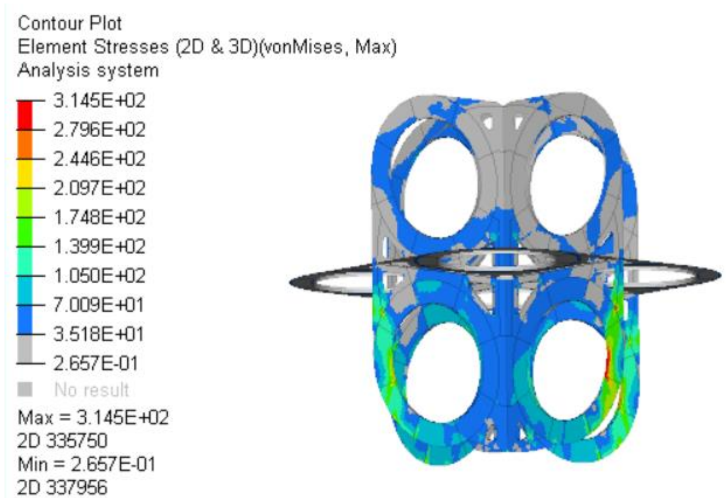
Von mises stress

Load combination f:

- **Seismic load + storage liquid force**



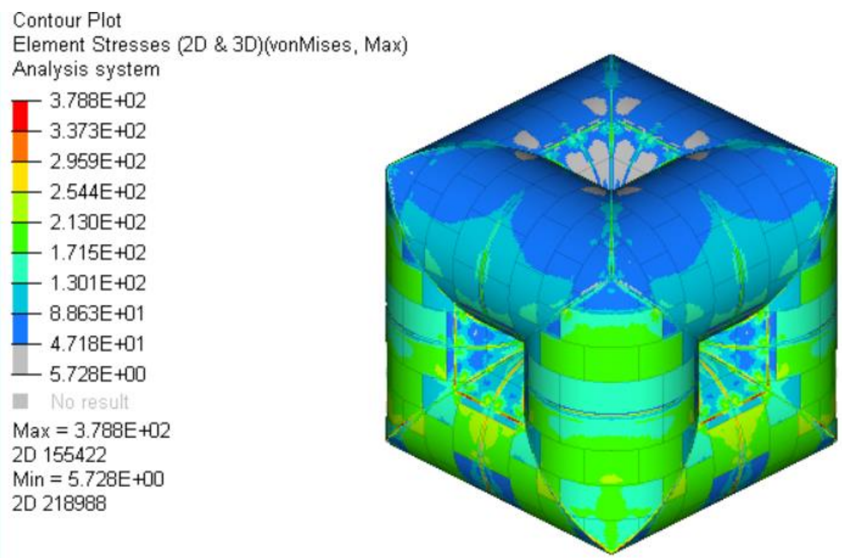
Von mises stress



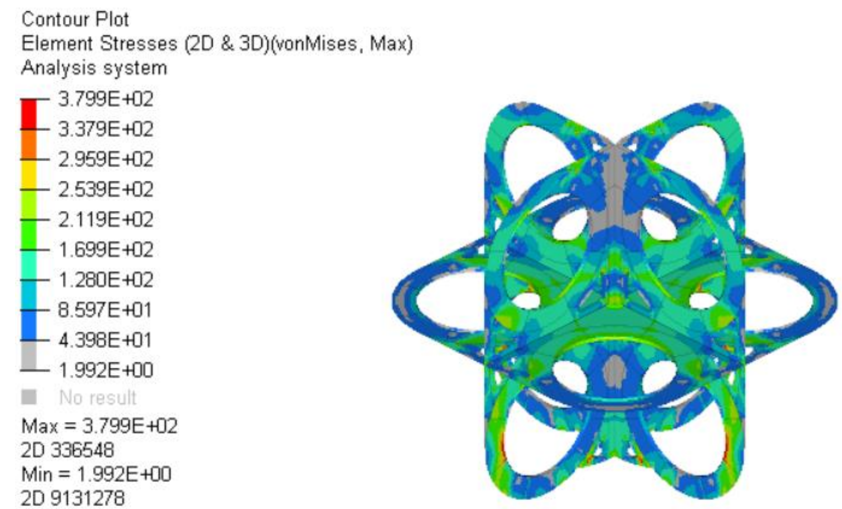
Von mises stress

Load combination g:

- **hydrostatic test + dead load**



Von mises stress



Von mises stress

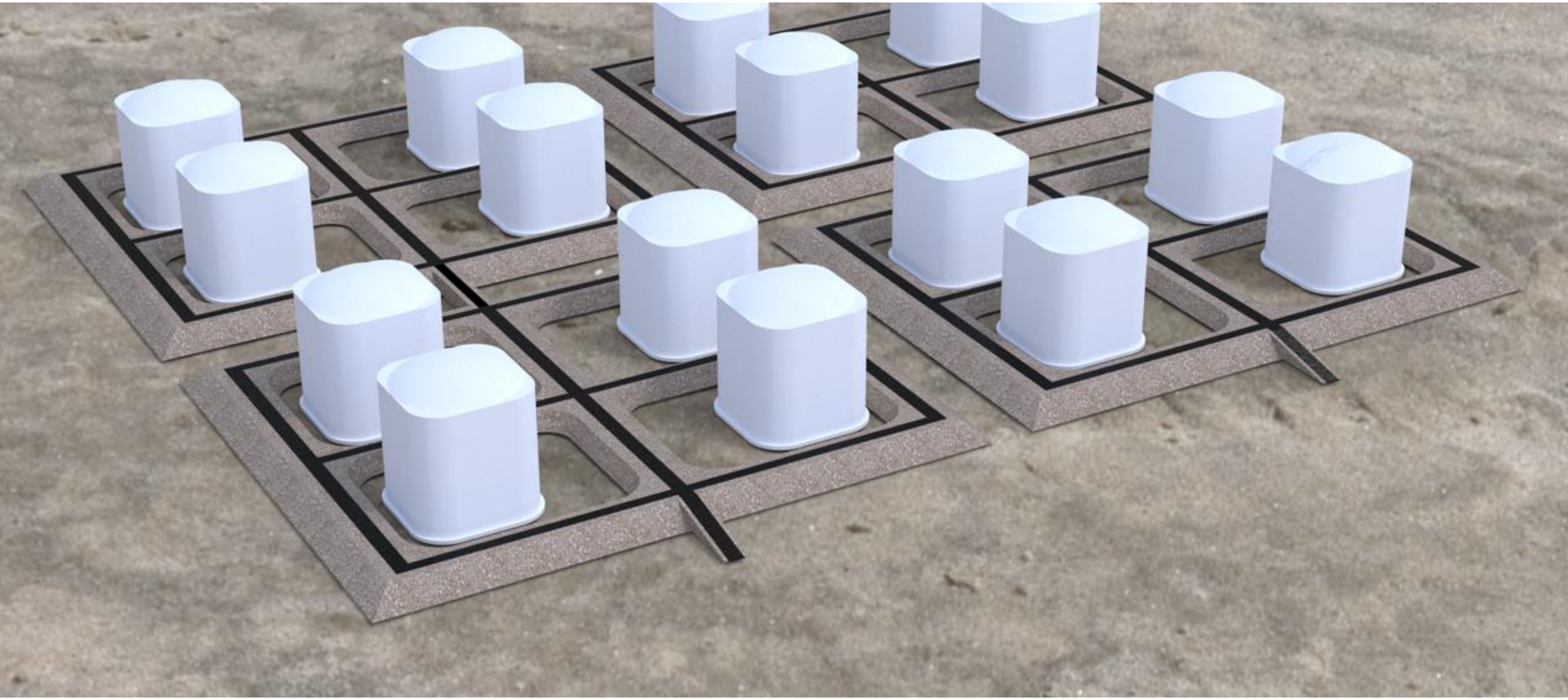
Von Mises Stress summary

Load	Tank shell stress (MPa)	Bulkhead stress (MPa)
a) $D_L + P_g + P_l$	175	221
b) $D_L + W_L + 0.7P_g$	40	66
c) $D_L + W_L + 0.4P_v$	80	91
d) $D_L + P_v + 0.4(L_r \text{ or } S)$	183	144
e) $D_L + 0.4P_v + (L_r \text{ or } S)$	76	75
f) $D_L + 0.7P_g + P_l + E + 0.1S$	294	315
g) $D_L + H_t$	379*	380*
h) $D_L + L_s$	39	64
i) $D_L + L_p + P_g + P_l$	175	221

*using >75% of yielding stress

IGC Stress Allowables	Nominal	Local
Allowable membrane Stress (MPa)	212	318
normal pressure loading or plate structures under in-plane loading)		
Allowable Total Stress (MPa)	318	318
(i.e., structural segments that are subjected to membrane and bending loads)		

API Rules	75% of min yield@586 = 440 Mpa



CDTS FABRICATION, ERECTION & OUTFITTING AND PROCESS SYSTEMS

SHIVARAJH • Sr Project Engineer • July 2018

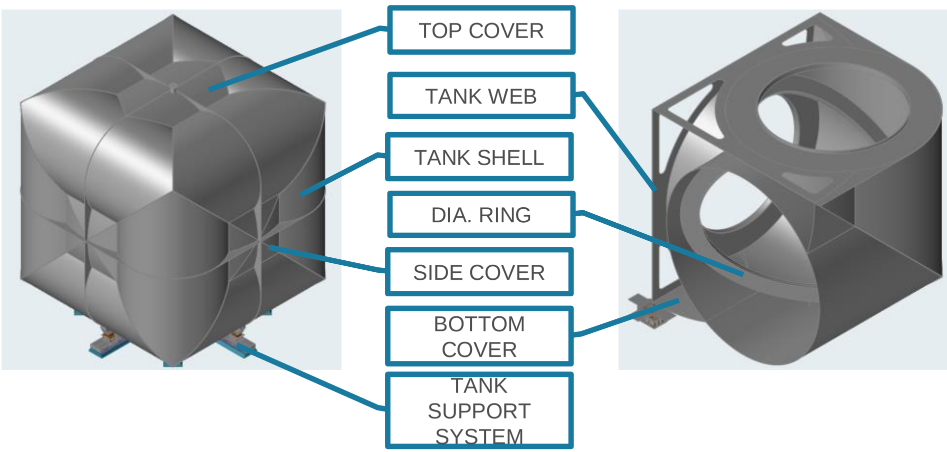
CONTENTS

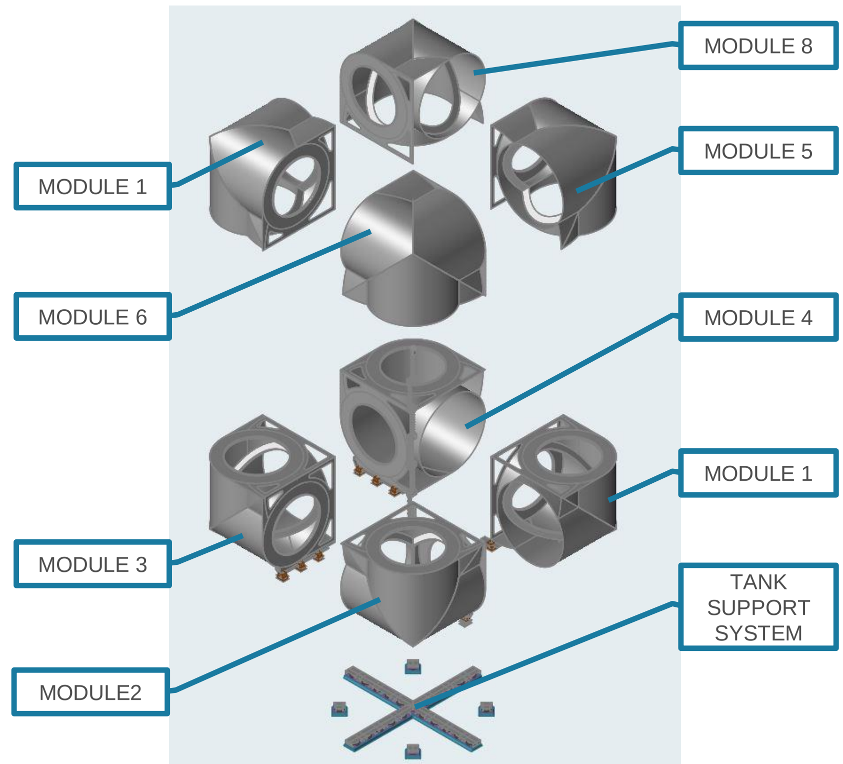
Altair

CDTS MODULAR ASSEMBLY

TANK PARTS & MODULES

- CDTS compromise of eight (8) modules
  Identical / Mirror to each other
- Enables modules fabricated at yard
  and erected on site





MODULE FABRICATION

- TOP MODULES

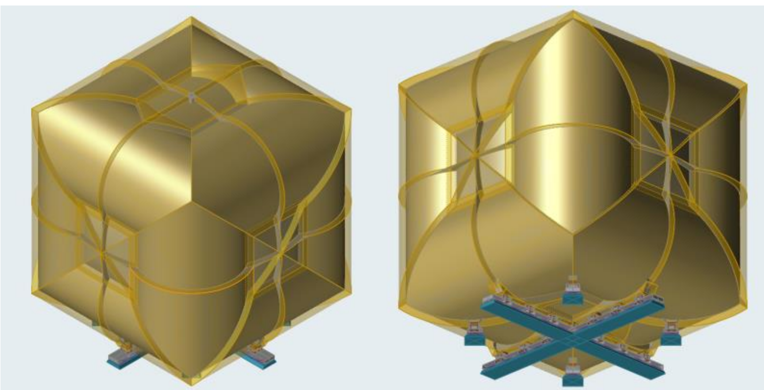
- BOTTOM MODULES

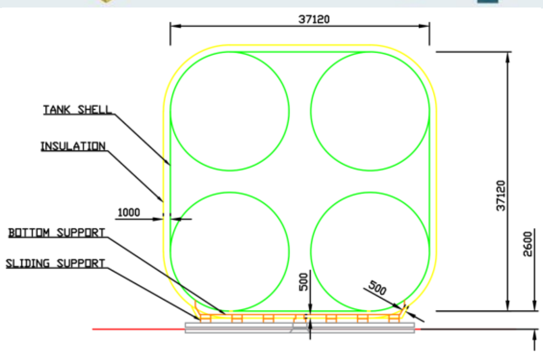
TANK ERECTION

INSULATION SYSTEM

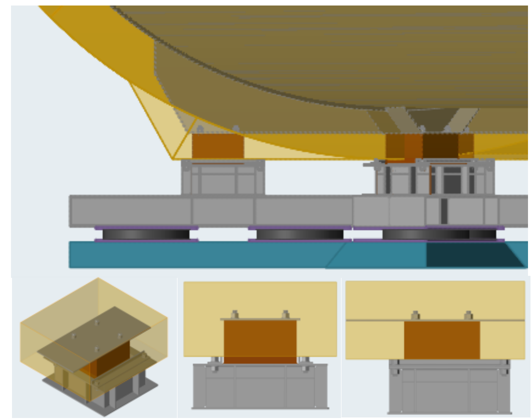
CDTS INSULATION

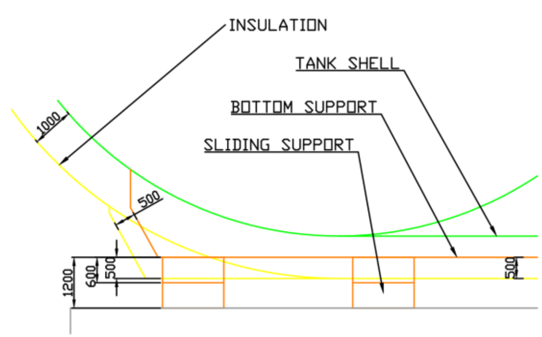
- **TANK INSULATION**





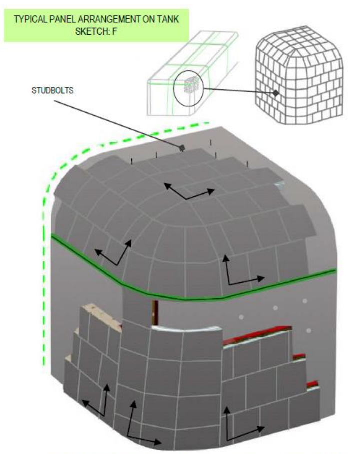
- **SUPPORT**

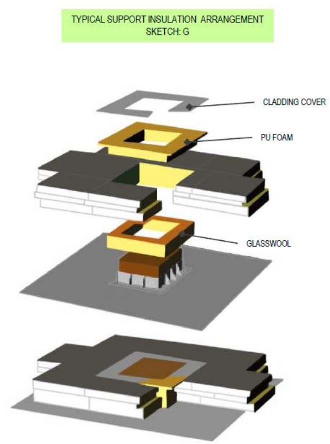


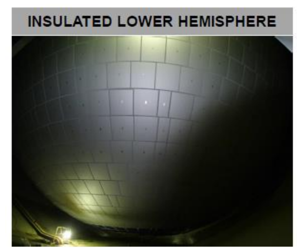


- INSULATION DETAILS
  - BoR target : 0.05%/day
  - Insulation System : PUF system
  - Insulation density : 43 kg/m3
  - Tank volume : 43,000 m^3
  - The tank surface : 7819 m^2

TI CALLENBERG FOR INSULATION

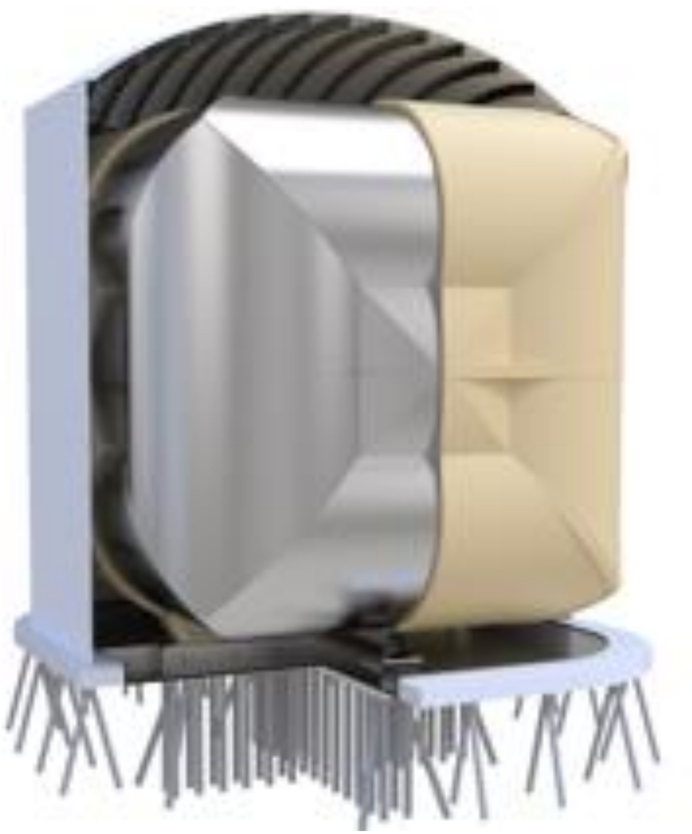






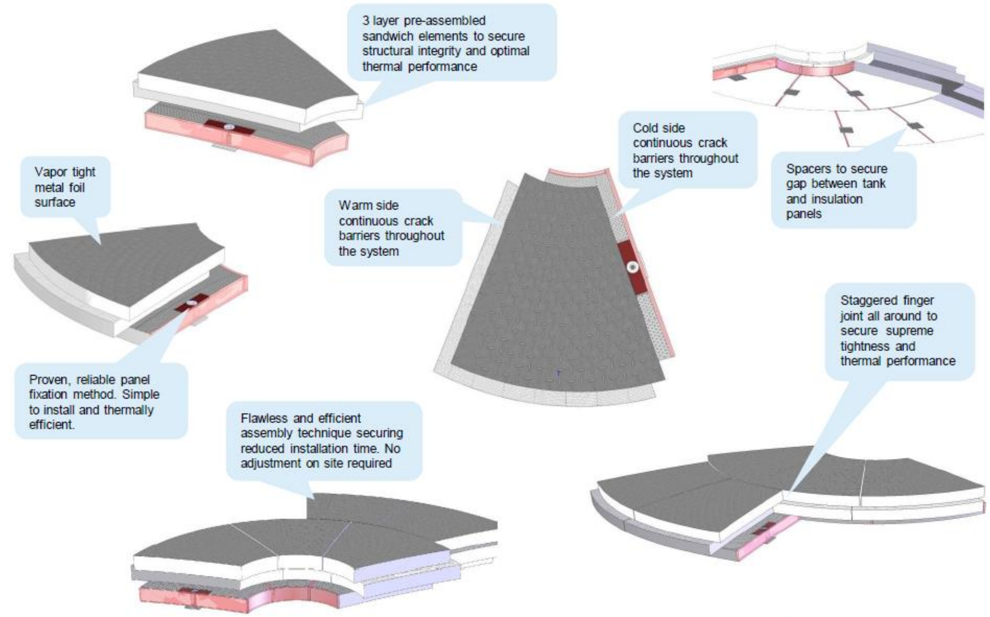
The entire **TiG** insulation system has been rigorously tested under cryogenic conditions under strict class (**LR**) control and verification. The system was dismantled and inspected while in fully frigid condition in order to discover any weakness or problems. The class could witness that the integrity of the system was fully satisfactory. This testing was completed in 2007 after a long testing pprogram.

INSULATION SYSTEM



TiG INSULATION SYSTEM BASIC DESIGN

A COMPLETE, PREFABRICATED AND TAILOR MADE CRYOGENIC INSULATION SOLUTION WITH PROVEN TRACK RECORD. THE SYSTEM IS EASY AND EFFICIENT TO INSTALL BASED ON A TRANSPARENT INSTALLATION TECHNIQUE WHICH SECURES HIGH QUALITY.



Part of Wilhelmsen Maritime Services, a Wilh. Wilhelmsen group company

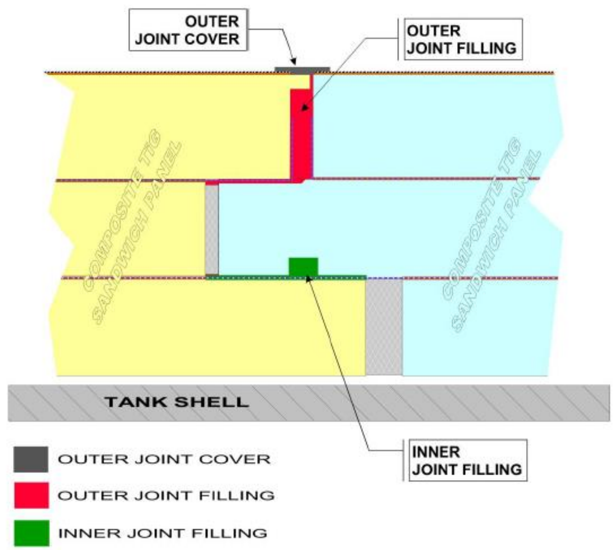
23

Wilhelmsen Technical Solutions 28FEB2014

INSULATION SYSTEM (CONT')

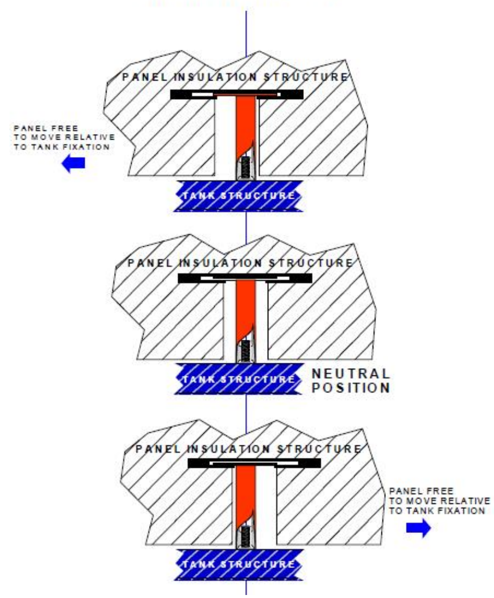
TiG SYSTEM PROVEN PANEL JOINT FILLING TECHNOLOGY FOR IMPROVED INSULATION SYSTEM TIGHTNESS AND ENHANCED THERMAL EFFICIENCY

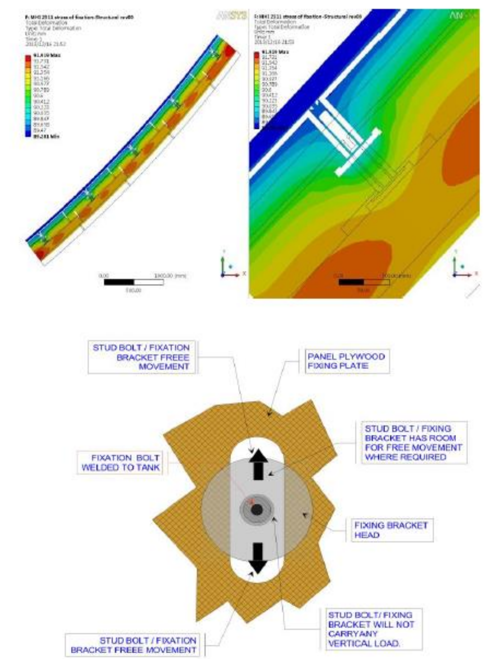
TiG PANEL STAGGERED TONGUE AND GROOVE JOINT DESIGN SECURES SUPERIOR TIGHTNESS AND THERMAL EFFICIENCY



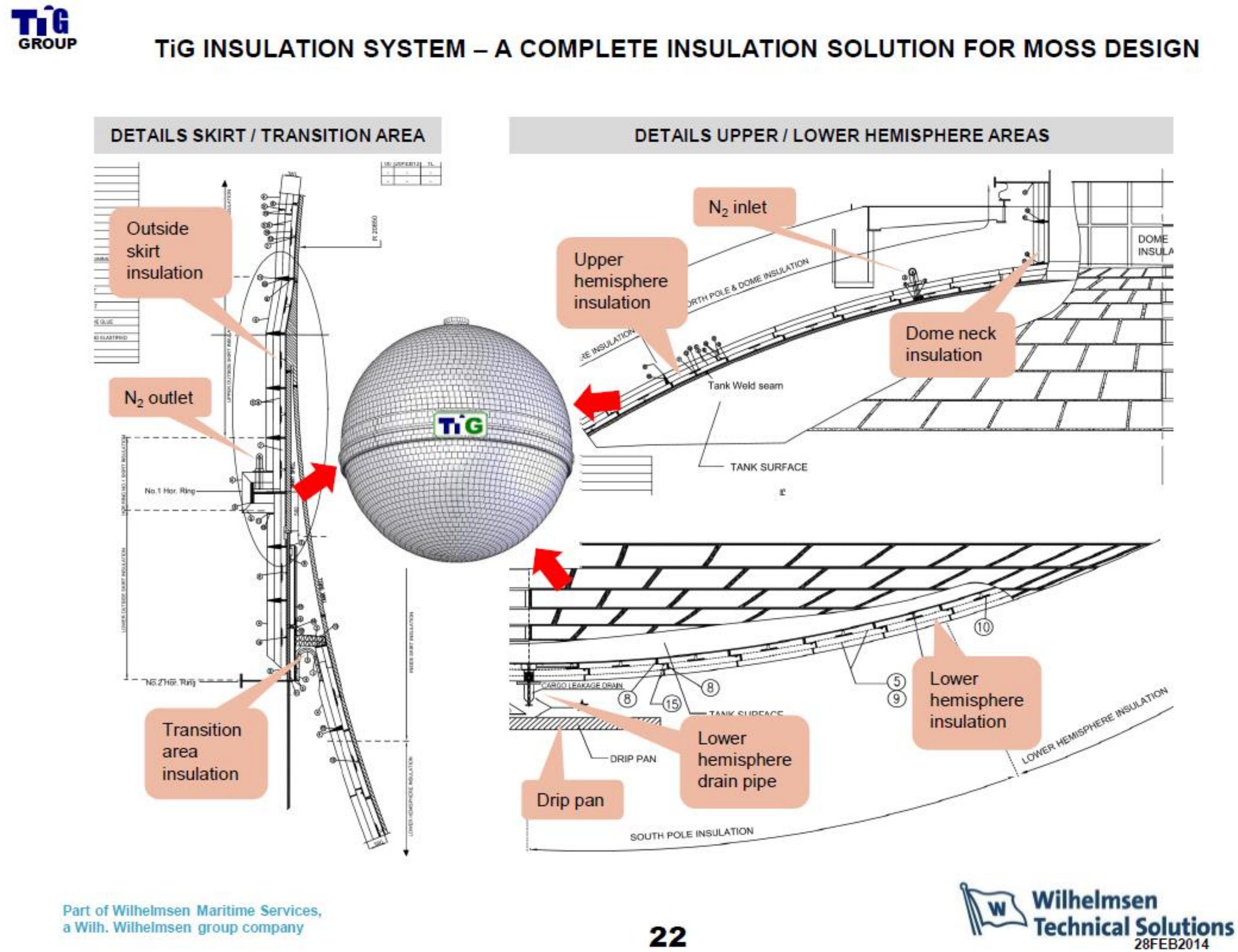
TiG SYSTEM PROVEN FIXATION METHOD TO AVOID FATIGUE PROBLEMS

NO BENDING OR FATIGUE STRESS ON FIXATION BOLT





INSULATION SYSTEM (CONT')

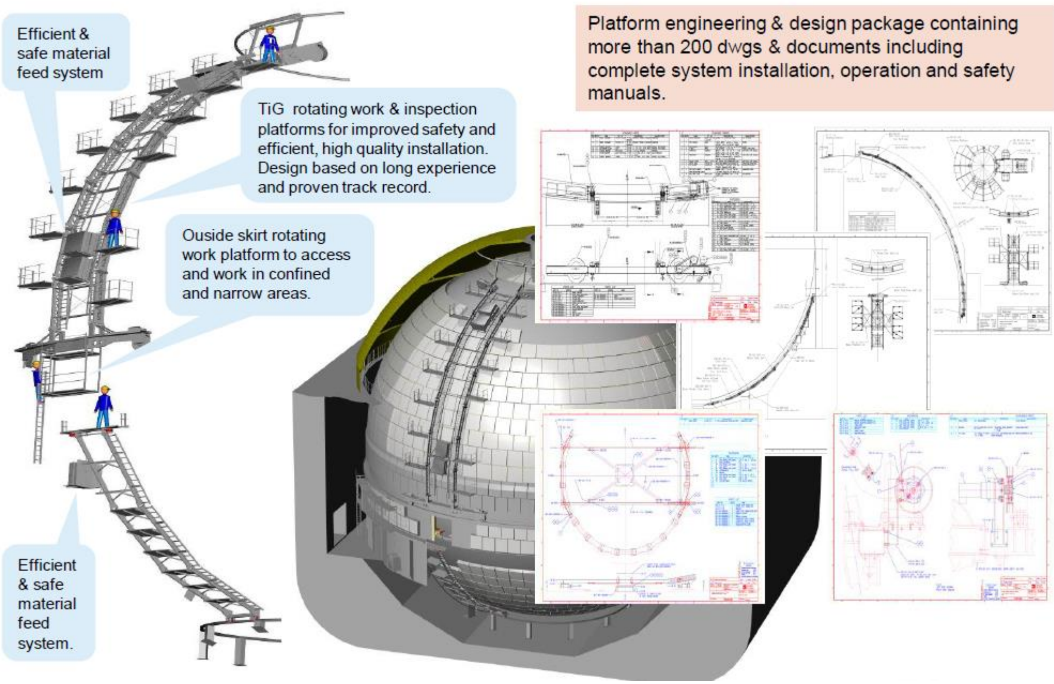


INSULATION INSTALLATION

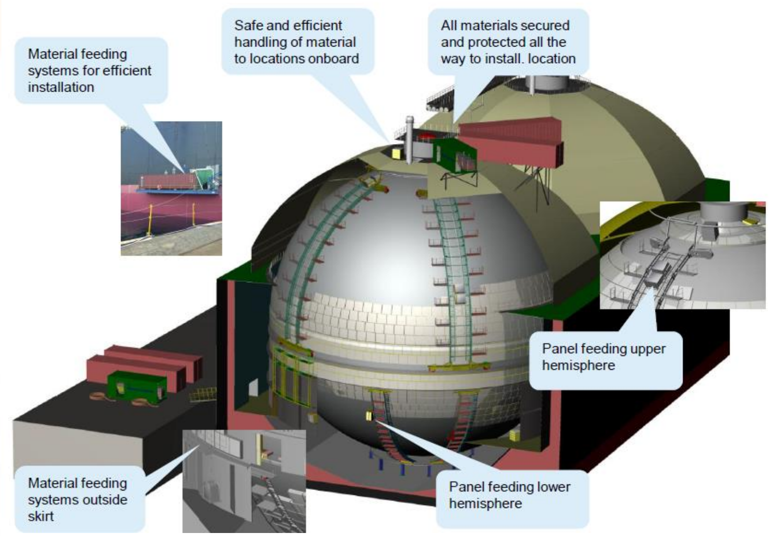
TiG GROUP

ROTATING WORK & INSPECTION PLATFORMS INCLUDING MATERIAL FEEDING SYSTEM, TAILOR MADE TO DELIVER HIGH QUALITY WORK SAFELY AND EFFICIENTLY IN CONFINED SPACES.

Platform engineering & design package containing more than 200 dwgs & documents including complete system installation, operation and safety manuals.



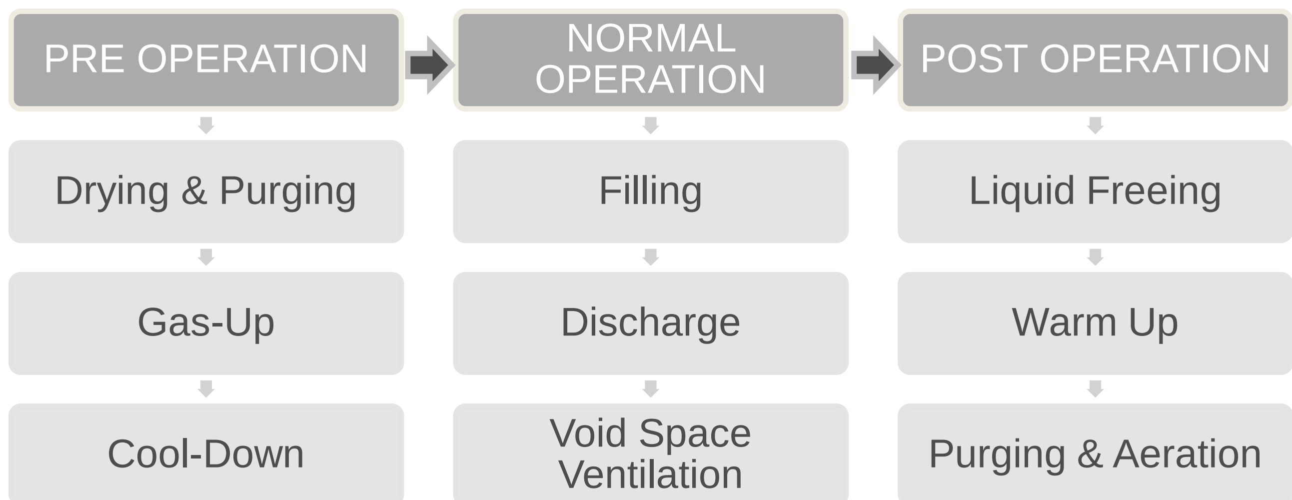
COMPLETE MATERIAL FEEDING / HANDLING SOLUTIONS FROM SHORE STORAGE TO VESSEL AS WELL AS ONBOARD LOGISTICS



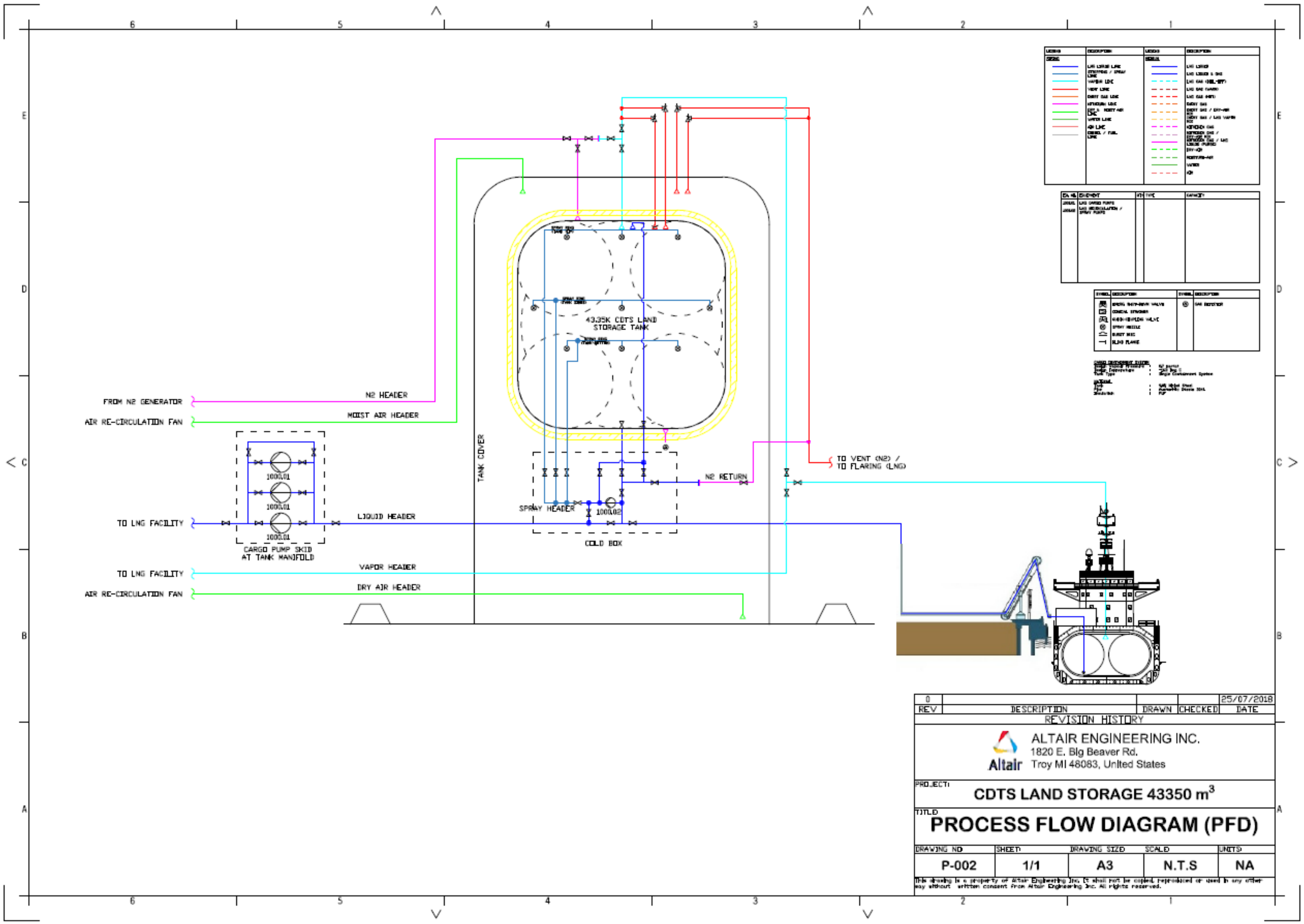
Altair

PROCESS FOR LAND STORAGE

SEQUENCE OF OPERATION

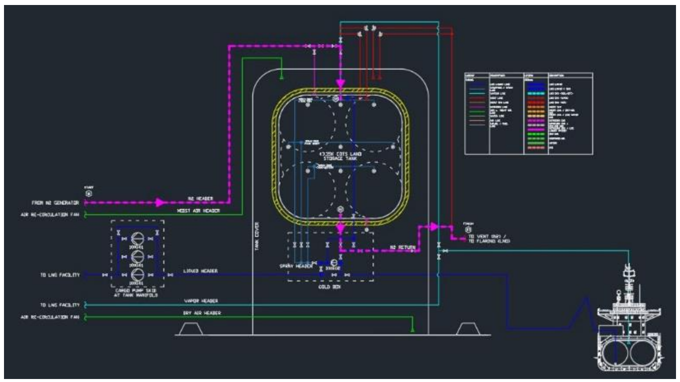


PROCESS FLOW DIAGRAM

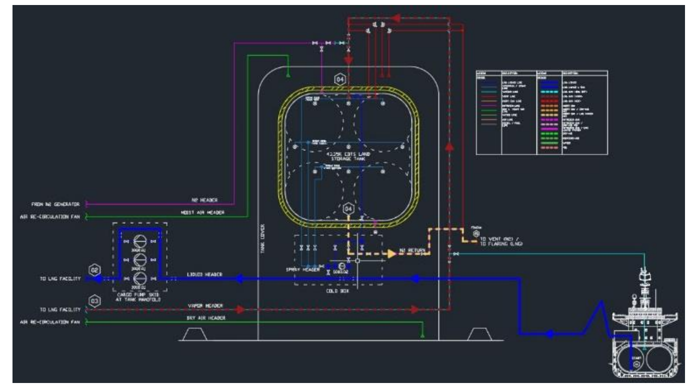


PROCESS FLOW DIAGRAM (CONT')

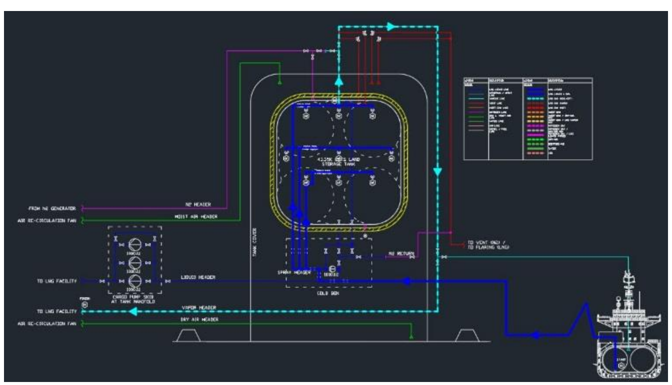
- **01 - N2 Purging**



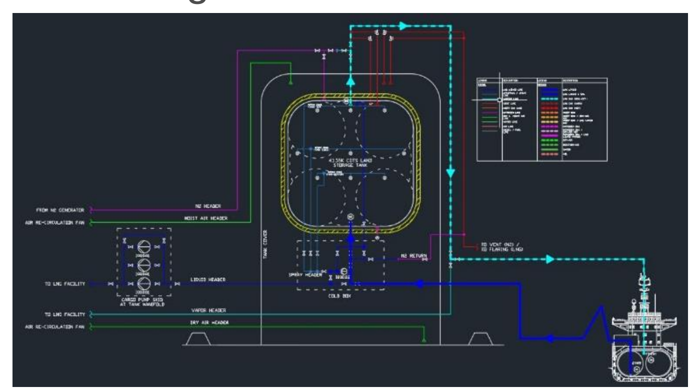
- 02 - Gas Up



- 03 - Cool Down

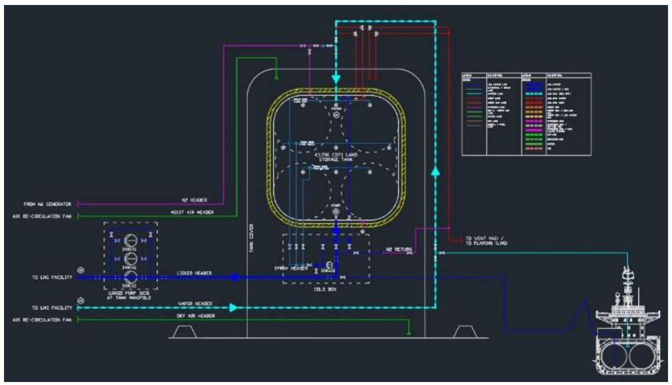


- 04 - Filling

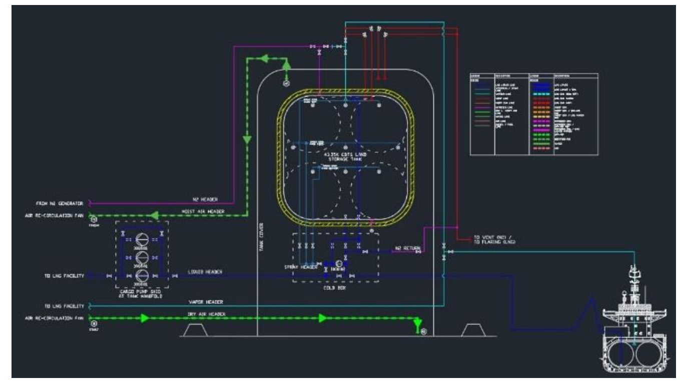


PROCESS FLOW DIAGRAM (CONT')

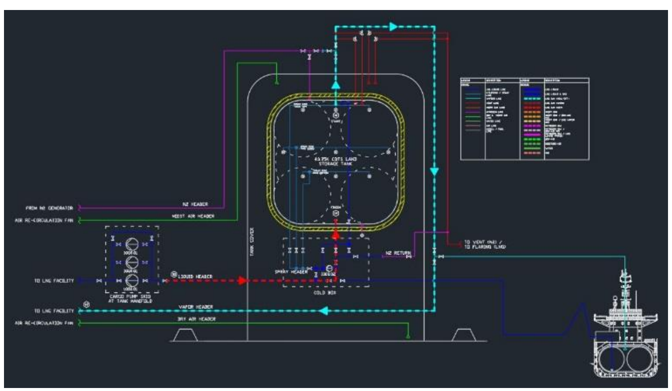
- **05 - Discharge**



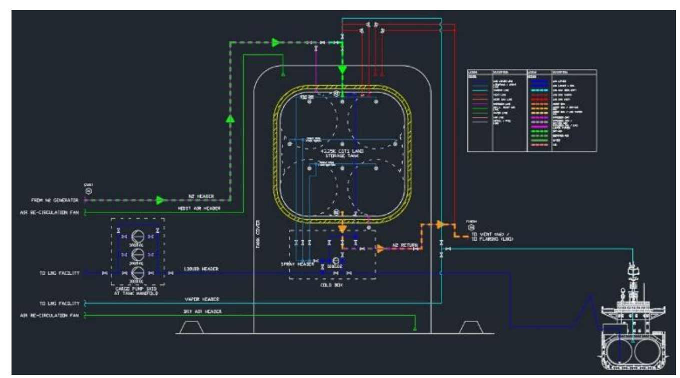
- 06 – Void Space Ventilation



- 07 – Warm Up



- 08 – Purging / Aeration



EnergyGiant Limited

Appendix C.

Multi-Effect Distillation Desalination

Refineries, power plants and other industries need high purity water. The thermal desalination process uses energy to evaporate water and subsequently condense it again. Waste heat powering thermal desalination is a most efficient and viable solution.

Low Temperature [70˚ C.] -- Multi-Effect Distillation is a low-pressure steam process. The LT-MED approach achieves exceptional thermal efficiency and reliability – a multi-effect process in which a spray of seawater is repeatedly evaporated and then condensed, with each effect at a lower temperature and pressure. This process multiplies the quantity of pure water that can be produced using a given quantity of energy, resulting in a significant cost reduction.

PROPERLY DESIGNED LT-MED's KEY BENEFITS

- Safe and reliable continuous operation
- Lower operation and maintenance costs
- Eco-friendly solutions to minimize impact on the environment
- Fast installation time
- Low temperature process minimizes desalination costs
- Large pitch design delivers reliable, non-clogging wetting operations
- An on-line ion trap prevents heavy metal ions from entering the plant
- Use large wetting areas in heat transfer tubes to prevent scaling and fouling
- Use rubber grommets to seal heat transfer tubes with electrical insulation to protect against galvanic corrosion
- Use non-erosive titanium condenser components to extend lifecycle

Process of Multiple Effect Distillation plant:

The steam enters the plant and is used to evaporate heated seawater. The secondary vapour produced is used to generate tertiary steam at a lower pressure.

The primary steam condensate is returned to the boiler of the power station since it is of extremely high quality that is needed for turbine steam production.

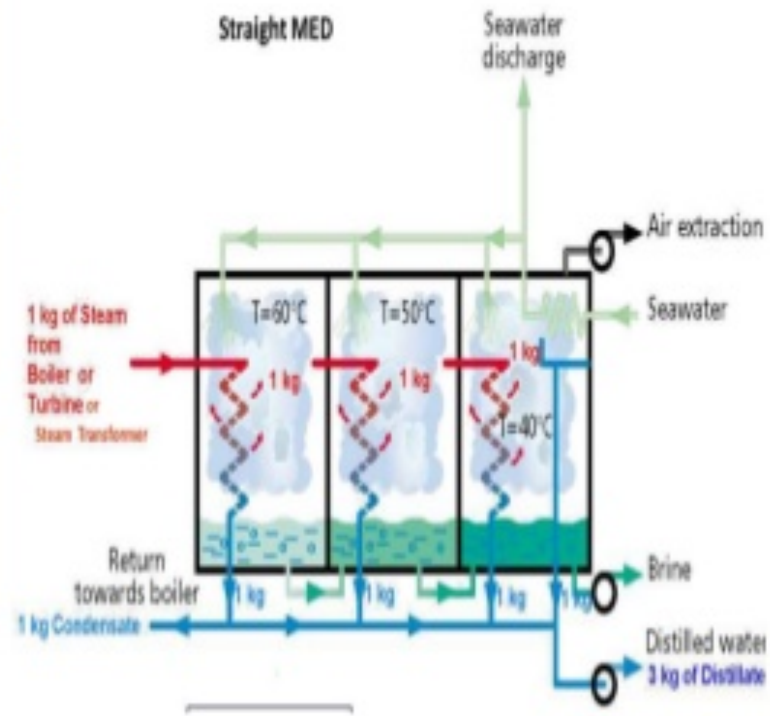
The MED technique is based on double-film heat transfer. Latent steam heat is transferred at each stage by steam condensation through the heat transfer surfaces to the evaporated falling film of seawater.

The process is repeated up to 16 times in existing plants between the upper possible temperature and the lower possible cooling water.

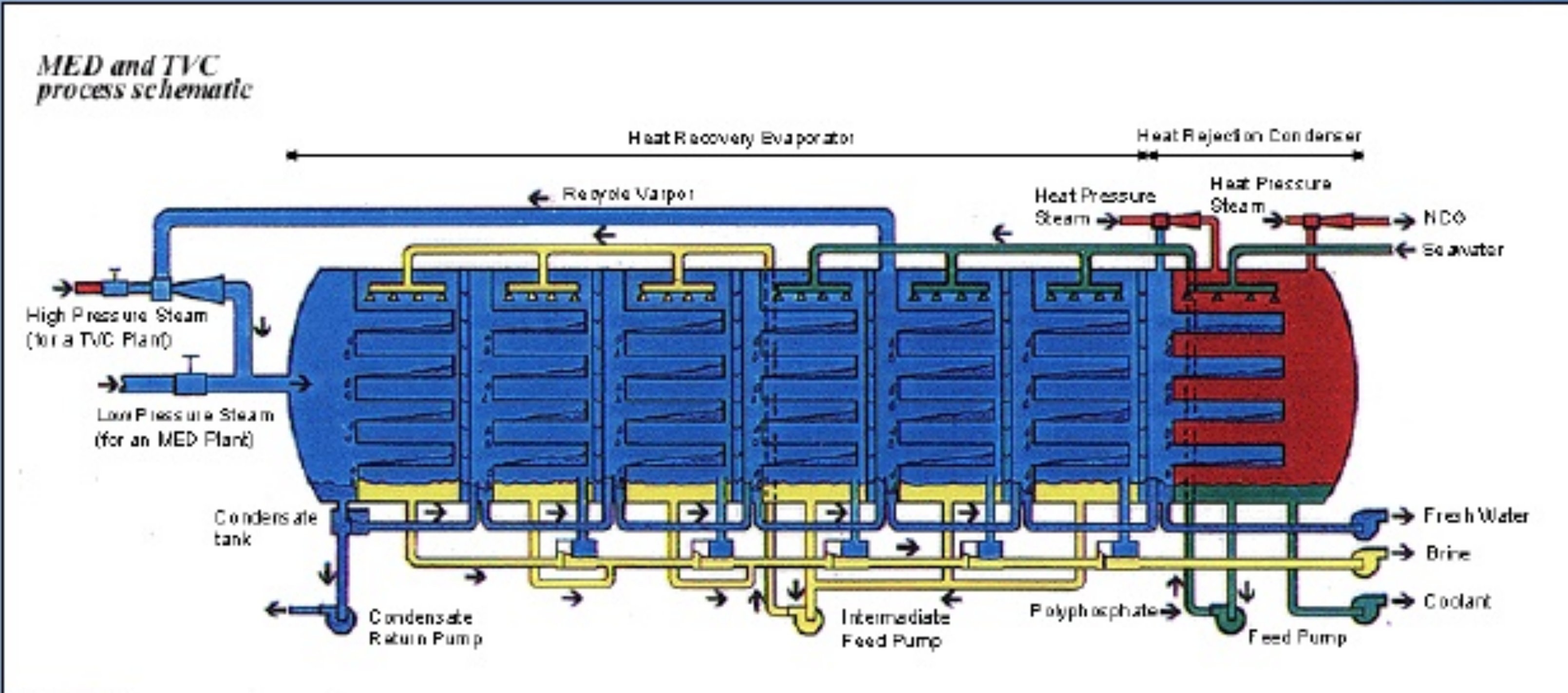
A compressor is used to maintain the gradual pressure gradient inside the vessel by removing the accumulated non condensable gases together with the remaining water vapour.

The pressure gradient along the MED effects is dictated by the saturation pressure of the feed stream and the saturation pressure of the condensing steam exiting the last stage.

It is condensed by cooling with seawater. Typical pressure gradients of 5-50 kPa across the system (less than 5 kPa/stage) are typical.



Multi Effect Distillation - Horizontal Tubes - IDE Design



EnergyGiant Limited

Appendix D.

Cost Plus Basis

at 321 MW CCGT plant plus RLNG & LT-MED facilities		
CAPEX		$US
321 MW CCGT wth flow acceleration & RLNG; LT-MED		477,608,908
Total power (MWh) delivered at 80% efficiency		
(386 MWh at 80% eff)	2,705,088	
Gas consumption (NG MSCF.y)	14,406,346	
Effective NG cost $ per MSCF	8.17	117,667,426
OPEX		
Cost of NG consumed $ per kWh	0.0435	117,667,426
Effective cost of LT-MED desalination system $ per kWh	0.0819	747,338
O&M ($2.25 per MWh)	2.25	6,086,448
Mgt & Engineering ($2.50 per MWh)	2.50	6,762,720
Other OH (insurance, administration,...) per MW	0.50	1,352,544
Distribution fees ($1.00 per MWh)	1.00	2,705,088
Total OPEX per kWh	0.0500	135,321,564
Amortization (5%,10 yrs) loan & cost per kWh	0.0140	37,972,093
Effective cost of power production per kWh	0.0641	173,293,657
Developers Margin per kWh	0.0200	$ 54,101,760
All in service cost per kWh	$ 0.0841	$ 227,395,417
Proposed tariff	$ 0.1000	$ 270,508,800
Margin	$ 0.0159	$ 43,113,383
	19%	19%
An array of three 60MW aeroderivatives fed into one steam turbine		
that generates 321.9MW plus 20% more with Flow Acceleration Heat Exchanger		
equaling 386MW for the price of 321MW of fuel		