



Modularisation Capability

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1 Introduction

thyssenkrupp Industrial Solutions (tkIS) is pleased to present our 'Modularisation Capabilities' to prospective clients.

Modularisation can be a very effective element in realising project opportunities and managing risks, including Safety, Productivity, Resource Availability, Schedule, Quality.

tkIS has the modularisation capability and is committed to working with clients to deliver excellence in Project execution through our proven Project Management, Engineering & Design, Procurement, Construction Management and Commissioning processes.

Our key strengths to ensure successful delivery are:

- Excellence in Health, Safety & Environmental Performance
- Extensive modularisation expertise and experience
- Full Service Delivery capability – from Concept to Reality
- A culture of Continuous Performance Improvement and Innovation
- A global organisation with financial strength and resources

tkIS has been active in Thailand for almost 30 years and maintains significant experience and expertise in the Downstream Oil and Gas, Petrochemical, Chemical, Clean Coal/Gasification and Alternate Fuels industry sectors. Modularisation continues to be a key philosophy implemented on those Projects where schedule acceleration, work front opening and minimisation of site exposure hours is desired.

Our commitment to Safety, Health, Environment and the Community, in which we operate is paramount and is a core value for all tkIS personnel. This commitment is embodied within our mission and values statements and policies and is demonstrated in our excellent HSE Performance.

tkIS provide the full range of modularisation services 'in house' including: Project Management, Concept Planning, Preliminary Engineering, Detailed Design, Procurement, Construction Management and Commissioning. From Concept to Reality - We have the capability to complete and manage the entire modularisation scope in accordance with client requirements.

tkIS and its clients share many common visions with our collective appreciation and commitment towards health, safety, environment and community that is balanced against the requirements for cost effective, technically sound and timely solutions. The 'modularisation' concept embodies all these facets and we look forward to further discussing our capabilities with you as tkIS have the organisational structure, resource depth and 'can do' attitude to deliver a successful outcome now and in the future.



2 Modularisation Technical Capability

2.1 Background

“The method of Plant Design which enables fabrication and assembly of a large proportion of the plant to take place in a location remote from the project site.”

Modules and Pre-Assembled Units (PAUs) typically consist of equipment items arranged in modular steel structures that can be assembled off-site, transported to site and lifted into place. The equipment is connected with piping to the fullest practical extent, instrumentation is installed and cabled to junction boxes, lighting and cabling is installed, steelwork is fireproofed up to the connection points, tracing and insulation on equipment and piping, and painting is completed as far as practical.

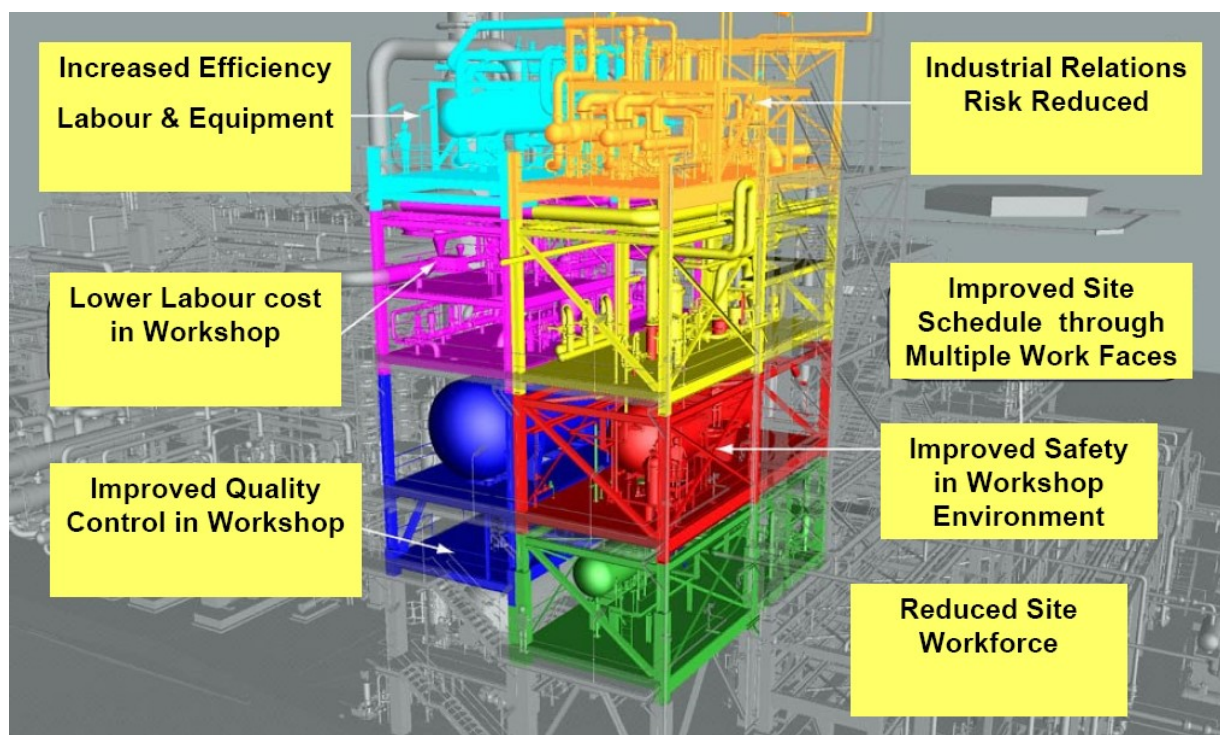
There are typically four categories or concepts of modularisation applied:

- PAU/PAM (Pre-Assembled Units/Modules)
- PAR (Pre-Assembled Rack)s
- VAU (Vendor Assembled Unit)
- VPU (Vendor Packaged Unit)

This capability document focuses on pre-assembled modules and pre-assembled racks as they best demonstrate the value offered by tkIS with its proven planning, design, logistics, hook-up and commissioning processes.

Opportunities for modularisation are assessed at the outset of every project. tkIS personnel work with our Clients to evaluate their needs, the project's size, the installation site, and other factors to identify the most appropriate construction option.

Most large projects allow for some modularisation and a combination of modular and stick-build construction is identified as the most effective in the majority of cases.



2.2 Drivers for Modularisation

The main advantages of modular execution are:

- Improved safety due to the workshop environment and reduced requirements to work at height
- Reduction in Industrial Relations risk
- Reduction in the site work force
- Improvement in schedule due to opening up multiple work-fronts and minimised impact of weather
- Increased efficiency of labour and equipment
- Lower labour costs in workshops
- Improved quality control
- Potential for testing and some pre-commissioning prior to delivery to site

The project drivers for modularisation range will include:

- Inaccessibility of the site such as offshore oil/gas platforms
- Remote site location
- Safety
- Schedule improvement, particularly if a short time is available for project implementation
- Limited availability of construction workforce
- Industrial relations issues
- High cost of construction workforce at site
- Impact on local community and infrastructure
- Improved Risk Management

2.3 Modularisation Planning

Effective planning of the modularisation philosophy must be integrated within the overall Project implementation/execution planning process. Key elements include

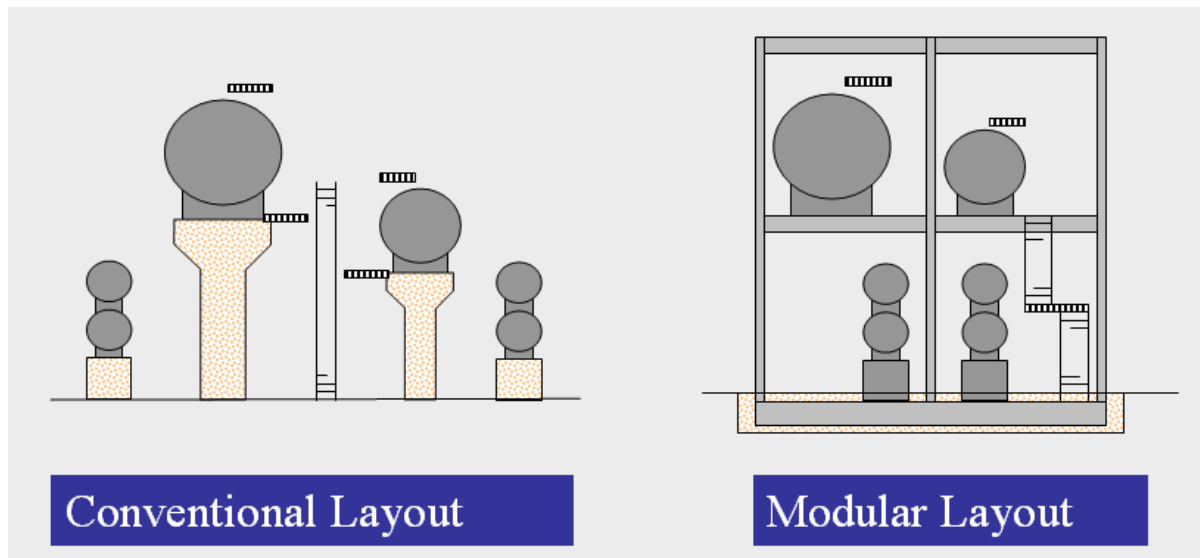
- Selection of logical grouping of equipment that satisfy Process requirements
- The transportation envelope on the delivery routes to the site and access to the construction location
- Lifting capabilities at the site including availability of cranes and soil bearing capacity
- Restrictions to site assembly/placement
- Fabrication location/capacity
- Address risks to modularisation – weather, damage
- Materials Management plan including supply to fabrication shops, early orders for Long Lead items.
- Engage pre-assembly fabricators with capability of working to tight tolerances.

Unless there is a clear advantage to the contrary then each module will contain all features required in that area. This would include:

- All defined equipment
- Piping and valves (including supports)
- In-line and Field Instrumentation cabled to junction boxes on the module
- Electrical items (up to the module local JB frame)
- Cable ladder and conduits
- Lighting and power outlets installed and cabled to junction boxes on the module
- Thermal tracing
- Painting and insulation
- All ladders, platforms and handrails and access requirements
- All the testing associated with the above.

It is important to note that the commitment to a modularisation philosophy should be instigated at the Project design definition phase and carried through the FEL/FEED phase. Freezing “Layout & Design” as early as possible as well as engaging and working with Construction Logistics/Craneage Specialists to develop the safest and most cost effective installation sequences are all critical in ensuring the modularisation philosophy delivers the optimum value.

The diagram below typifies the difference between conventional and modular lay-out.



2.4 Module Types

Typically modules are complete plant assemblies weighing 100 tonnes and above. PAUs are similar to modules but smaller, typically weighing up to 100 tonnes. In addition to modules containing equipment, the inter-connecting pipe-racks in the plant can also be modularised. The various types of module and PAU for consideration are:

Large Complex Modules

The size and scope of these modules are only limited by the physical constraints of the transportation route to the site location and the available capacity of heavy-lift and transportation equipment.

Modules for offshore projects usually fall into this category. Onshore modules can typically range up to 5,000 tonnes, although the maximum practicable size and weight will vary from project to project. The use of large modules for onshore plants usually requires the site to be on or near the coast with direct ship access.

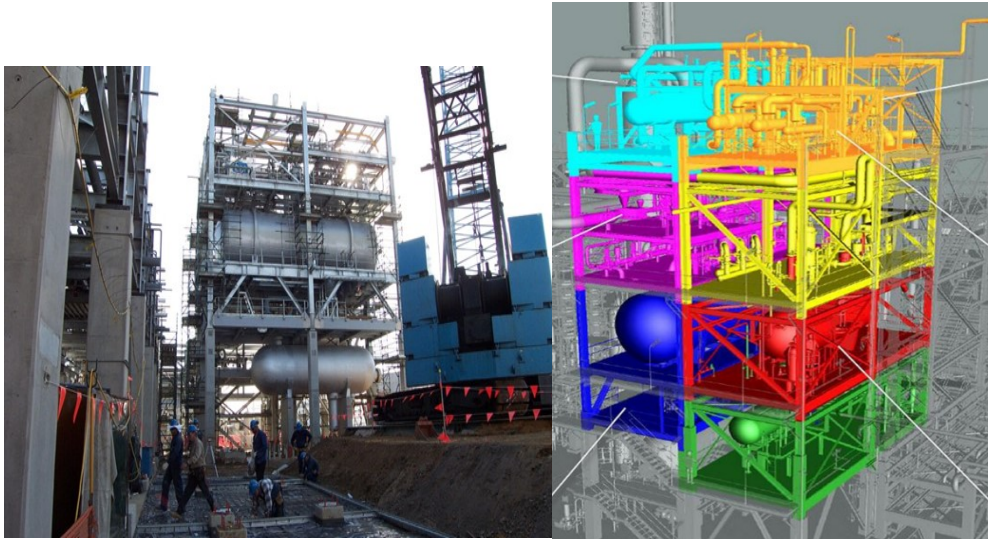
Modules with Transportation Limitation

Where the site does not have deep-water access, then significant land or canal transportation of the modules will be required. In these cases, the module size will be limited by the restrictions of the transportation method.

A preliminary transportation study, undertaken during the feasibility stage, is essential for these projects.

Equipment Modules

The figure below shows the 3D model and the final installation of a section of plant made up of stacked interconnected modules. The colours in the 3D model view indicate the individual modules; with the dimensions of these modules set by the transportation envelope. The modules would be trial-assembled in the module yard and interconnecting piping installed and match-marked. After testing, the various modules will be separated for shipping.



Pipe-rack Modules

Modularisation of pipe-racks is one of the key areas where efficiency gains can be achieved. A typical layout of a pipe-rack module is shown below.



Modules for Brownfield Projects

In cases where major sections of plant are required to be installed in an existing unit during a short shutdown window, then consideration should be given to modularising these sections of plant and building the modules on the site within lifting or hauling distance of the final location. Module assembly would then take place with the existing unit in operation, with only the lifts, final connections and hook-ups to the modules to be completed during the shutdown period. The size of these modules would be limited by the heavy lift capacity or the hauling design. The photograph shows a large modularised plant section that has been assembled on site for installation during a shutdown.

Modularised Buildings

The extent of modularisation should include the project buildings. Consideration should be given to control-rooms, amenities buildings, sub-stations, switch-rooms and instrument rooms being fully pre-



assembled and fitted-out off-site. The size of these modules could range from shipping containers through to complex buildings consisting of several modular sections.

Consideration should also be given to pre-assembly of sections of steel buildings, either off-site or on-site at ground level to be lifted into place in sections.

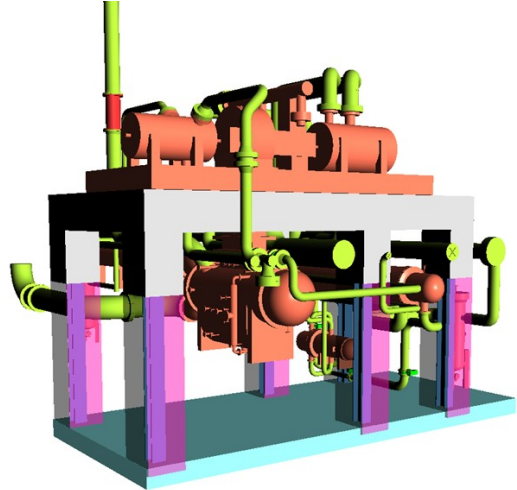
Modularised Vendor Packaged Equipment

Equipment specifications should define that equipment should be modularised as far as possible by the vendor. This should include aspects such as: rotating equipment and drivers mounted on baseplates, lube-oil systems delivered complete on skids, air compressors and dryers on skids with valving installed.

Complex packages such as PSA Units and TEG Units should also be specified as modular construction with minimum site-work required.

Major equipment such as reformers and convection banks should be designed in modular sections for ease of installation.

The design of major rotating equipment, such as steam-turbine driven compressors, could consider the use of a modular approach, where the vendor delivery would include part of the concrete table top with equipment, piping and I/E pre-installed.



Other Pre-assemblies

In addition to the modularised sections of plant described above, consideration is given during the design to minor pre-assemblies that could minimise work at the site. Examples of these are:

- Pre-cast concrete foundations and plinths
- Use of pre-cast concrete for table-tops
- Use of pre-cast columns socketed and grouted into pre-cast pockets in foundation slabs. This approach could be applicable to columns under reformer boxes and pipe-rack columns that require passive fire protection
- Sub-assemblies – stairways, ladders and trusses
- Pipe assemblies at control valves, pressure relief valves and pump sets
- Steam trap and drain hook-ups

The use of pre-cast sections and other pre-assemblies can be particularly applicable for Brownfields projects where construction access to the operating plant will be limited. A typical example of a pre-cast concrete table top is shown below.



2.5 Execution

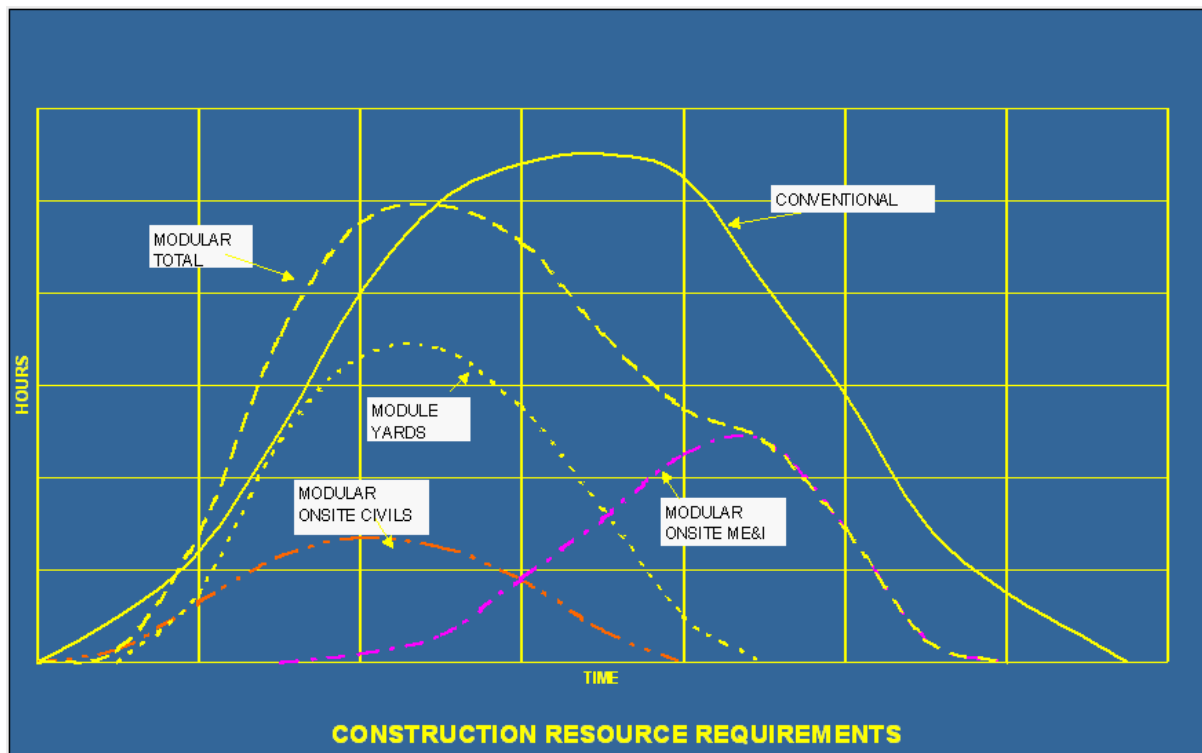
The application of the modularisation philosophy for a Project must form part of the overall Project planning, execution and risk management processes. Typically, we see the key benefits to include improvements in quality and productivity, cost savings from workshop costs Vs site costs, schedule improvements and mitigations of site risk, especially via HSE performance and Industrial Relations performance.

Modular construction offers many advantages over the conventional "stick build" methodology of construction. With the majority of the fabrication and assembly works performed at facilities remote from the Construction site, this allows us to ensure all work is performed according to our high standards, under controlled working conditions.

Also, by reducing field exposure hours, we also minimise the project's impact on the customer site, a significant advantage when the installation site is an operating plant. Modular construction also minimises lay-down space, an important benefit when the field site is small or congested, and reduces delays due to adverse weather. In-air work is minimised, and foundation requirements are often simplified.

Requirements for highly skilled labour onsite are minimised, an advantage in areas where skilled labour is either costly or unavailable. Procurement is often simplified, especially when the installation site is located in an area where raw materials and equipment are expensive or difficult to obtain.

In addition, modular construction can shorten schedules by allowing for concurrent processes, such as fabrication, permitting and logistical arrangements.



The table above identifies indicative savings in total resource requirements and manhours that are gained by applying modularisation philosophy.

3 Benefits of Modularisation

3.1 Improvement in Safety Performance

- Experience has shown that compared to conventional construction, projects employing modular techniques achieve significantly better safety results measured in terms of total recordable and lost-time cases
- More work done in a shop environment
- Additional work fronts available at grade
Less work performed at high elevation
- Reduced time of working overhead
- Reduced scaffold requirement
- Reduced number of cranes and non-engineered lift activities Heavy lifts are under more control with exclusion zones
- Reduced site peak labour numbers
- Compare site contractor historical performance with that of module yards
- Work area is free and clear of typical site constraints



3.2 Reduced Capital Cost

- Transfer craft work-hours from field construction site to a modular assembly site producing lower unit labour costs and significantly greater labour productivity
- Improved efficiencies result at the field site due to smaller labour force and lower work density
- Controlled environment for most assembly work allowing craft labour to work regular hours without stoppage for inclement weather
- Reduction of overheads, particularly camp costs, per diems and support facilities
- Modules can be procured lump sum thereby increasing price certainty for a larger portion of the project scope
- Lunch, toilets, materials, laydown areas, works shops all in close proximity allow for greater workforce efficiency



3.3 Schedule

- Higher productivity in a shop/yard environment
- Modules are completely assembled, tested, painted, insulated, heat traced, pre-wired
- Requires less time at the plant site as well as a significantly lower peak manpower level
- Schedule reduction translates to project cost savings
- Shop environment has established systems for procurement and material tracking
- Shop has access to stock material and local suppliers for improved material delivery
- Less affected by weather (with indoor facilities)
- Additional services are close by eg Chemical Cleaning, specialised NDT Services etc.



3.4 Quality

- Shop environment lends itself to better quality control with established labour, methods, and quality control procedures
- Smaller environment with better oversight
- More qualified and consistent labour pool than remote project site where qualified labour may not be readily available
- Specialists are more readily available than at a remote site
- Quality control – perform extensive check-out and testing at the module fabrication shop which reduces mechanical completion items in the field
- Cost and duration of inspections and corrective actions is low



3.5 Environment/Socioeconomic

- Reduced footprint provide environmental value to company, community, country
- Reduced high peak craft levels, created local environmental impact
- Reduced transient population impact to local communities and environment
- Standardised so that the design can be used as basis for future facilities



4 Modularisation Reference Projects

Provided in this section are examples of modularisation projects executed by thyssenkrupp Industrial Solutions.



Project: Polyol Plant

Client: MOL

Location: Tiszaújváros, Hungary

Period: 2017 - 2020

Modularisation Scope/Description:

tkIS proprietary process technology, 5 train batch plant.

45 Process Modules planned and designed by tkIS according to Hungarian standards and PED (EU) certified. Modules fabricated and assembled in Thailand with all piping and equipment installed, tested and insulated.

Module dimensions: 27m (L) x 5.5m (W) x 4.5m (H) – Weight max 140t



Modules design, fabrication, assembly and shipping.

Project: Alkoxylation Plant

Client: Oxiteno

Location: Pasadena, TX, USA

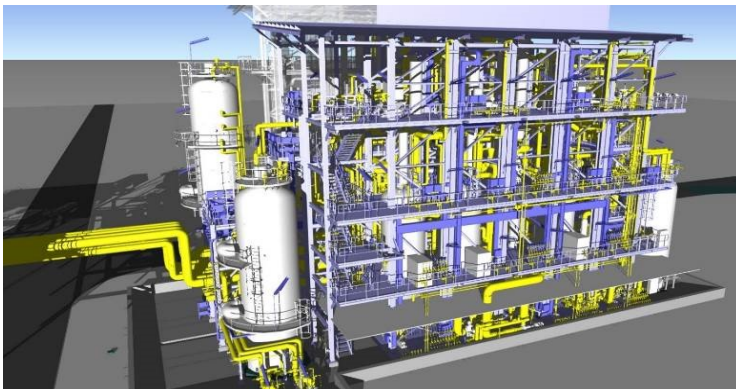
Period: 2015 - 2018

Modularisation Scope/Description:

tkIS proprietary process technology, 2 train batch plant.

14 Process Modules planned and designed by tkIS according to USA standards and PE certified. Modules fabricated and assembled in Thailand with all piping and equipment installed, tested and insulated.

Module dimensions: 24m (L) x 5m (W) x 4m (H) – Weight max 120t



Modules design, fabrication, assembly.

Project: Alkoxylation Plant

Client: Oxiteno

Location: Coatzacoalcos, Mexico

Period: 2012

Modularisation Scope/Description:

Single train batch plant.

Process Modules planned and designed by tkIS.



Project: Oxiteno – Fatty Amine Plant

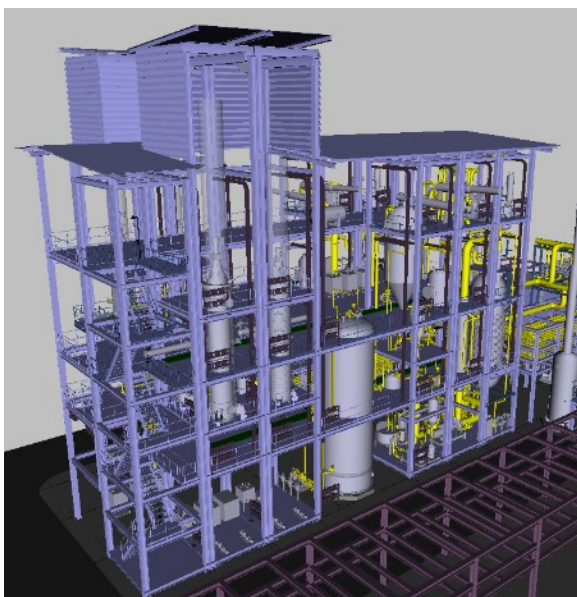
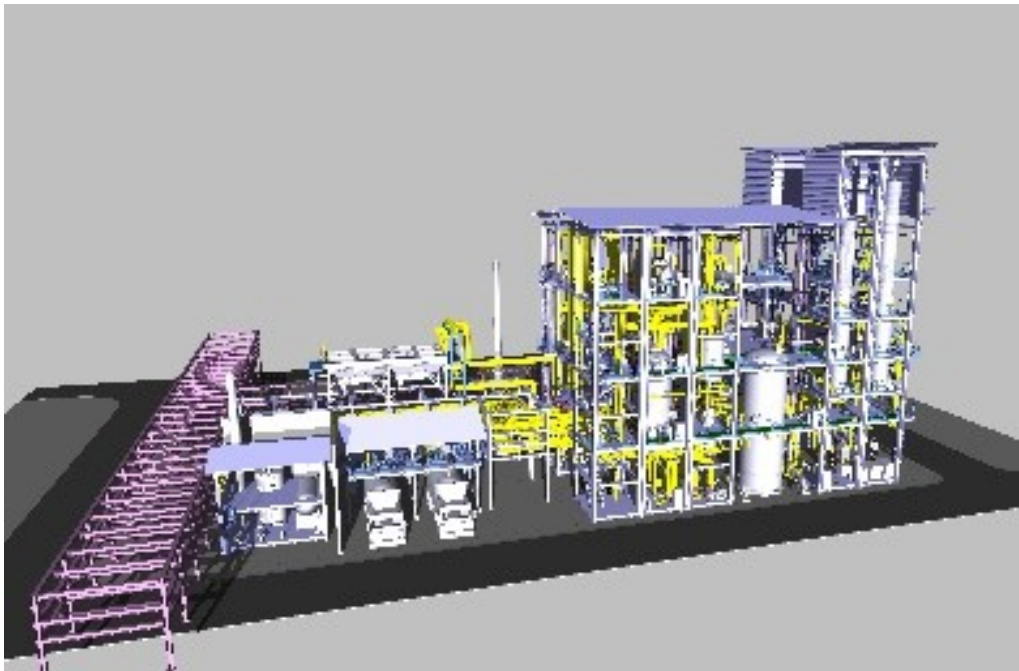
Client: Oxiteno Nordeste SA

Location: Camacari, Brazil

Period: Mar, 2014 - Jun, 2014

Modularisation Scope/Description:

tkIS executed the Basic and Detail Engineering for a Fatty Amine Process plant including OSBL scope. As part of the Basic Engineering tkIS developed together with the Licensor (Inventa) a Modular Layout concept.



Project: APCI Tees Valley EFW Project - Phase 1**Client:** Alter NRG Corp. / Great Britain**Location:** United Kingdom**Period:** 2012 - 2013**Modularisation Scope/Description:**

tkIS support Alter NRG already in BD and the conceptual design of the plant. Modules are fabricated in Thailand, Design following European requirement e.g. PED/CE certification.



Project: APCI Tees Valley EFW Project - Phase 2

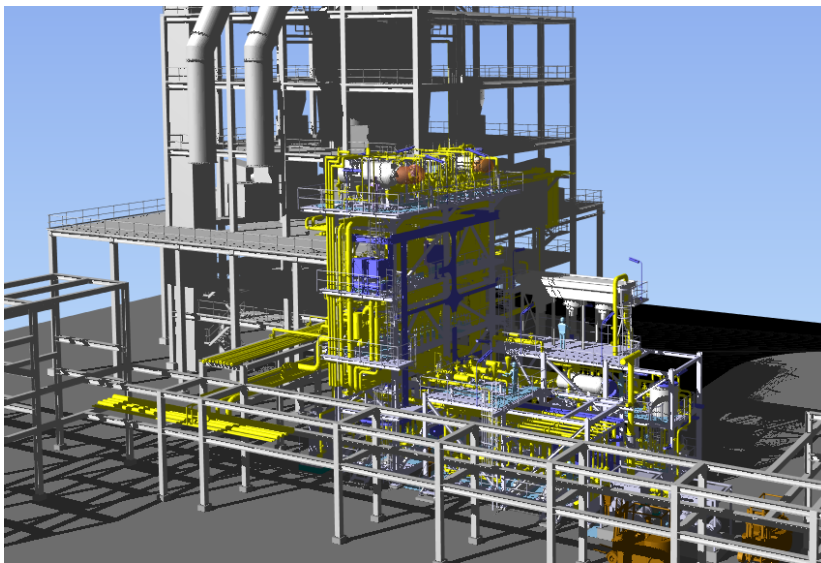
Client: Alter NRG Corp. / Great Britain

Location: United Kingdom

Period: Nov, 2013 - Nov, 2014

Modularisation Scope/Description:

Alter NRG awarded tkIS Thailand to design and fabricate the 2nd phase of the Project with an identical capacity as Phase 1.



Project: Aker TS-VRU 8 Modules Project

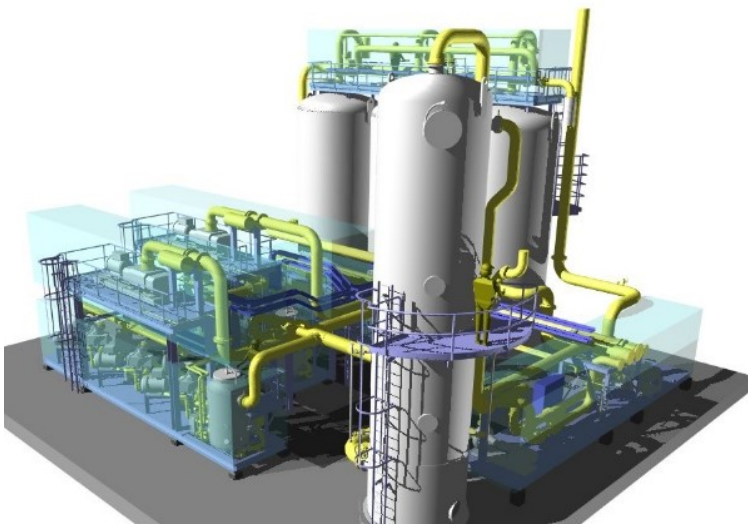
Client: Aker Cool Sorption A/S / Worldwide

Location: Denmark

Period: 2012

Modularisation Scope/Description:

tkIS evaluated different concepts (containerised, module and stick built design) for the complete product range including cost comparison for potential plant location in Europe, Asia and South America.



Project: Devil Creek Onshore Gas Plant Development**Client:** Clough Australia**Location:** Western Australia, Australia**Period:** 2009**Modularisation Scope/Description:**

Detailed design and procurement Assistance of the Apache/Santos owned Devil Creek Gas Development Project, North - Western Australia. The project is a green field onshore gas process plant. The plant was design to be fabricated and modularised in Thailand then transported to Australia.



Project: Songkhla Oil Field Development

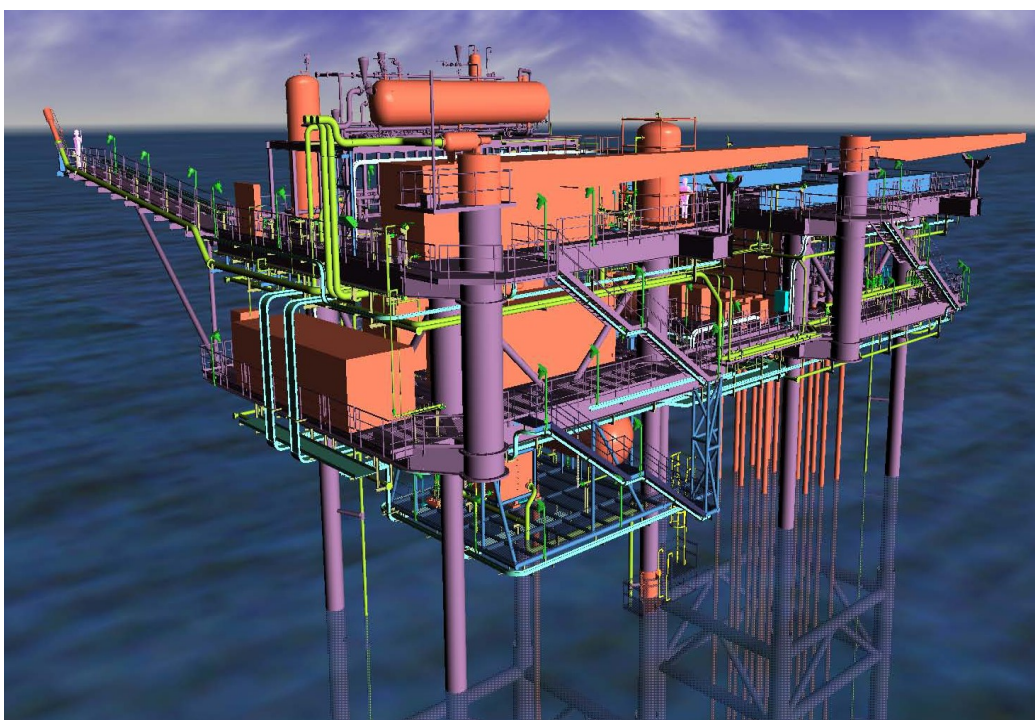
Client: NuCoastal (Thailand) Limited

Location: Songkhla, Thailand

Period: 2007-2008

Modularisation Scope/Description:

Detailed engineering and design of the Songkhla process and well head platform. tkIS also assisted in the procurement process for Long Lead Items.



Project: Alumina Plant

Client: Alcan Australia

Location: Australia

Period: 2006

Modularisation Scope/Description:

Detailed design of a number of pre-assembled modules (PAM's) which we shipped by sea from Thailand to Australia for the G3 Expansion of Alcan's Gove alumina refinery. tkIS undertook the detailed design of process and pipe rack PAM's weighing up to 500 tons.



Project: Diesel Hydrotreater No#2 (DHTU2) Project

Client: Caltex

Location: Brisbane, Australia

Period: 2008 - 2009

Modularisation Scope/Description:

10 Pipe Rack Modules planned and designed by tkIS. Modules fabricated and assembled in Brisbane with all piping and equipment installed, tested and insulated.

Module dimensions: 24m (L) x 6.5m (W) x 4.5m (H) – Weight max 55t

Modules to Lytton Refinery by road, unloaded and lifted into position on pre-cast columns.



Modules being lifted into position at Caltex Lytton Refinery.

Project: RCCU Particulates Reduction Project

Client: Shell

Location: Geelong, Australia

Period: 2006 - 2007

Modularisation Scope/Description:

Module planned and designed by tkIS. Module contained 4th stage separator fabricated in workshop and then assembled in on temporary footings adjacent to final position. Module lifted into existing structure using 500t crane.

Module dimensions: 11.7m (L) x 10.5m (W) x 17.5m (H) – Weight max 171t



Module being assembled on temporary footings (above) and then lifted into existing structure at Refinery site (below).



Project: Third Stage Expansion Project

Client: Nabalco (ALCAN)

Location: Gove, Australia

Period: 2005 - 2006

Modularisation Scope/Description:

120 Pre-assembled Modules planned and designed by tkIS. Modules fabricated and assembled in Thailand workshop with all piping and equipment installed, tested and insulated.

Transport modules by sea to Gove, unloaded and transported to site, lifted into position on existing structures.



Module being sea transported and road transported to Alumina Refinery site.

Project: Clean Fuels Project

Client: ExxonMobil

Location: Altona, Australia

Period: 2004 - 2005

Modularisation Scope/Description:

Process Modules for DHTU and BRU planned and designed by tkIS. Modules fabricated and assembled in workshop with all piping and equipment installed, tested and insulated.

Module dimensions: 5.5m (L) x 4.8m (W) x 4.5m (H) – Weight max 38t

Transport modules by road to Altona Refinery site, unloaded and lifted into position on existing structures.



Module being transported and lifted into position at Altona Refinery.



Project: HDS2 Project (Diesel Hydrotreater)

Client: Shell

Location: Geelong, Australia

Period: 2002 – 2003

Modularisation Scope/Description:

Pipe Rack and Process Modules planned and designed by tkIS. Modules fabricated in Brisbane and assembled in Brisbane with all piping and equipment installed, tested and insulated.

Module dimensions: 27m (L) x 6m (W) x 5.8m (H) – Weight max 55t

Barge used to transport modules down to Port of Geelong (adjacent to Refinery), unloaded and lifted into position on pre-cast columns.



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