Jurong Rock Caverns

Development of Underground Rock Caverns for Storage of Liquid Hydrocarbons on Jurong Island

Er. Teo Tiong Yong
Stakeholders

**Developer**
JTC Corporation

**Project Management Team**
Sintef-Tritech-Multiconsult Consortium

**BED / Superintending Officer**
Geostock (Access Shafts)
Geostock-Jurong Consultants Consortium (Tunnels & Caverns)

**Main Contractors**
Sato Kogyo (Access Shafts)
Hyundai Engineering & Construction (Tunnels & Caverns)

**Consultants**
Kiso-Jiban Consultants
Parsons Brinckerhoff Singapore
K L Au Consultants
Beca Singapore
JRC is located below the seabed at Banyan Basin, Jurong Island
Development of Jurong Rock Caverns
Underground Rock Caverns for Oil Storage

Aboveground land used for production; underground land used for storage

- Creating a competitive advantage
- Saving surface land
- Improved security
- Improved health & safety

Storage in aboveground tanks

60 Ha of surface land freed up

Storage in underground rock caverns
Jurong Rock Caverns Journey

2001: Feasibility & Business Studies, Soil Investigation and Funding Approval

2006: Construction of Access Shafts & Engineering Design of Main Caverns

2007: Started construction of access shafts

2009: Started construction of main caverns

2Q 2014: Completion of 1st two caverns to serve JAC

1Q 2017: Completion of Jurong Rock Caverns

Site Investigation

Access Shaft Construction

Tunnel Excavation

Completed Cavern
Overall Development of JRC

Access Shaft 3

Access Shaft 1

Multi-purpose Product Jetty

3.2 ha

Phase 1 & 2 = 30 Ha

Phase 1

<table>
<thead>
<tr>
<th>Caverns Notation</th>
<th>Product</th>
<th>Cavern Storage Volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cavern 1</td>
<td>Crude Oil, Condensate</td>
<td>1 x 150,000</td>
</tr>
<tr>
<td>Caverns 2 to 5</td>
<td></td>
<td>4 x 330,000</td>
</tr>
<tr>
<td><strong>Total Storage Volume (m³)</strong></td>
<td></td>
<td><strong>1,470,000</strong></td>
</tr>
</tbody>
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*Condensate is a hydrocarbon liquid for production of aromatics which in turn is used to make fabric and plastic.*
Layout Plan of Phase 1
Cross Section of Shafts, Tunnels & Caverns

Access Shaft 1

Maintenance Chamber

Banyan Basin

Operation Tunnels

Access Tunnels

Access Shaft 3

132m belowground

Oil, Seepage

Water Pump

Sump

Oil Storage Cavern

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Typical Cross Section of a Cavern Gallery

1. 9 storeys high (27 m)
2. Length = 340 m
3. Excavation using drill and blast method with grouting (if required)
4. Volume per storage cavern = 165,000 m³
   (two typical storage tanks of 80,000 m³ capacity)
Technical Innovation: How Does the Underground Oil Storage Work?

- Our Caverns are unlined
- Caverns roofs are below groundwater table
- Water pressure keeps oil within the caverns
- Water that seeps in is collected and pumped up automatically
How deep is Jurong Rock Caverns?

- 10m
- 20m
- 30m
- 40m
- 50m
- 60m
- 70m
- 80m
- 90m
- 100m
- 110m
- 120m
- 130m
- 140m
- 150m

- Underground Expressways, Underpasses & Shopping Malls
- MRT System
- Singapore Power Cable Tunnel
- Deep Tunnel Sewerage System
Construction of Access Shafts, Tunnels and Caverns

Access Shaft 1

Access Shaft 3

Cavern 1

Cavern 2

Cavern 3

Cavern 4

Cavern 5

Level 0 Access Tunnels

Level 1 Operations Tunnels

Water Curtain Gallery

Access Shafts Contractor: Sato Kogyo

Caverns Contractor: Hyundai Engineering and Construction
Construction of Access Shafts

**Diaphragm Wall with Ring Beams**

**Concrete Lining**

**Shotcrete and Rock Bolts**

**Reclaimed Sand**

**Fine to Coarse Sand**

**Clayey Silt (Residual Jurong Formation)**

**Siltstone and Sandstone (Jurong Formation)**

**Siltstone and Sandstone (Jurong Formation)**

**Typical Cross Section**

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Construction of Tunnels and Caverns using Drill and Blast Method

**Access tunnels** are temporary tunnels used to create the caverns. They may be flooded after the caverns are built.

Each of the five **caverns** is 27m high, as high as a nine-storey building and about 300m long and 20m wide.

**Operational tunnels** used to lay pipes that lead in and out of the caverns.

**Water curtain galleries** are tunnels that pump water into the underground rocks. This is to enhance hydrostatic pressure and keep oil within the caverns.
Construction Challenges: Limitations in the Sequencing of Underground Works

Use of T-Lift for mucking out and vehicle movement
Construction Challenges: Limitations in the Sequencing of Underground Works
Technical Challenges: Geological & Hydrogeological Risks
Technical Challenges:
Geological & Hydrogeological Risks

• Venturing so deep underground in sedimentary rock is breaking new ground
• Unpredictable geological conditions
• Adopting systematic deep investigation boreholes and probe holes.
• Pre-grouting to reduce groundwater seepage
• Continual probing and site investigation before excavation
• Pre-grouting to reduce groundwater seepage
• Adapt excavation methods to site conditions
Technical Innovation: Use of Explosives

- Explosives Storage Houses (ESH) were constructed to have 24hours/7days access to explosives for excavation works to improve construction productivity.
Movement of Products

Pipelines connecting JAC and JRC
Pipelines to Very Large Crude Carrier Jetty
Overview of Aboveground Facilities

- Vapour Recovery Unit
- Export Booster Pump & Metering Area
- Wastewater Treatment Plant
- Valve Manifold Area
- Pipe Rack & Pipes
- Administration Building
- Pipe Rack & Pipes
- Jetty

Jurong Rock Caverns – Er. Teo Tiong Yong

Singapore – 11 November 2016
Status of JRC Project

Caverns 1 and 2
• Construction of caverns completed in Aug 2013
• Construction of supporting facilities completed in Mar 2014
• Testing and commissioning from Apr 2014
• Started operations for Jurong Aromatics Corporation on 1 Jul 2014

Caverns 3, 4 and 5
• Construction of caverns completed in Jun 2014
• Construction of supporting facilities completed in early 2016
• Testing & Commissioning currently on-going
ASEAN Outstanding Engineering Achievement Awards 2015

IES Prestigious Engineering Awards 2015

TOP 50 Engineering Feats @ IES-SG50 (2016)

SPMI – Project of the Year Award 2015 - 2016
(Engineering & Construction)

SG Mark Platinum 2015

Singapore Structural Awards 2014
Commendation Award for Industrial Structures

Thank You