THE EXPERIENCES AND APPLICATION OF SPIRAL WELDED PIPES IN PENINSULAR GAS UTILISATION PROJECT

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Dr Samsul Bahar Sadli graduated from University Science of Malaysia in 1985 with bachelor of Applied Science with Hons. His initial career as a Casting engineer in an International Aluminium Casting plant has encouraged him to pursue a higher education. In 1988, he was awarded a grant and scholarship to pursue his further education in Metallurgical Engineering. After spending few years in United Kingdom, Dr. Samsul was then conferred with Doctor of Philosophy in Metallurgical Engineering from University College of Swansea and starts his career as a lecturer in University Science Malaysia. Dr. Samsul is specialize in Advance Material and Casting technology. He has written and present a numbers of technical paper Internationally and local. In 1995, Presently, he is the Quality Assurance Manager in Hicom Petro-Pipes Sdn Bhd in-charge of the Quality department and Research & Development.
Introduction

Natural Gas has become a prominent source of energy in Malaysia as early as 1980. Its share in total Malaysian primary energy supply has expanded from 7% in 1980 to more than 44% in 1999. With abundant reserve, a well-developed gas infrastructure network and a national energy policy supporting the use of gas, Petronas has envisaged continuing with the development of the Gas industry and making gas available for all sectors.

The beginning of the gas era in Peninsular Malaysia kicks off with the implementation of the Peninsular Gas Utilization Project - Stage I or PGU I Project in 1981. The initial construction was approximately 40 km of natural gas, propane and butane pipelines on the east coast of Peninsular Malaysia supplying to a power station and a steel mill. Since then, Petronas Gas Berhad has completed PGU II, PGU III, PGU LOOP 1 and 2 projects including lateral pipeline projects. Currently there are more than 2400 km of gas pipeline installed throughout the Peninsular from the Thai border to Singapore in the south and supplying gas to almost all the major power stations including Penang island and Singapore. The size of the mainline and loopline is NPS 36 with the lateral lines ranging from NPS 6 to NPS 24 and all designed for a maximum operating pressure of 6895 kpa. Fig. (1.0) shows the Peninsular Pipeline systems. The total tonnage of steel used is approximately 500,000 metric tonnes.

The discussion of the specialized manufacturing techniques of the spiral welded pipe adopt by Hicom Petro-Pipes thru and the selection of Petronas Gas to use and install the pipeline for both the onshore and offshore (submarine pipeline) will be elaborated here.

Pipe Selection Process

The minimum technical requirements and recommended practices for pipeline system design, material procurement, fabrication, installation, construction, inspection, testing, commissioning, operation and maintenance are basically governed by ASME B31.8, ASME B31.4, with additional requirements/amendments stipulated in Petronas Standards (PTS) 31.40.00.10 and PGB’s Design Concept Manual. The minimum specification for line pipe requirement is governed by American Petroleum Institute (API) Specification 5L with additional requirements/amendments stipulated in Petronas Technical Standards (PTS) 31.40.00.10 for non-sour service. These additional requirements to API 5L will enhance the line pipe quality and pipeline integrity.

The high level of energy stored in a compressed gas requires that a gas transmission system have an acceptable level of protection against incidents involving gas leak rupture. The system design and requirement to economically transport large volumes of gas or oil over long distances essentially impose the combination of pipe size and operating pressure. Pipeline pressure, material grade, installation location and techniques directly influence the cost and the design. Pipe material or grade affect the wall thickness and determine the choice and limit on the welding installation technique. For a given pressure and pipe diameter, the wall thickness decreases with higher-grade material. However, the cost of steel per metric ton increases and a more stringent construction technique usually accompany higher grade of steel.
The linepipe material selection takes into consideration the safety, reliability and economics to perform the functions intended in the design, which covers the following requirements:

1. Resistance to fracture initiation and propagation
   The toughness level is specified to reduce the risk of fracture initiation and propagation.

2. Material Strength
   A sufficient Minimum Specified Yield Strength is required to safely withstand the design pressure

3. Good weldability in mill and field conditions
   Restriction on carbon and chemical composition are specified to ensure good weldability

4. Fit up requirements
   Placing tighter limits on dimensional tolerances reduces risk of field fit-up problems

5. Manufacturing acceptance criteria
   Inspection procedures are specified so that pipes are free of defects and that sound workmanship and manufacturing standards are being followed.

**Specified Minimum Yield Strength**

The selection of steel grade is based on the cost effectiveness for each size of pipe used. Generally, the grade that allows minimum acceptable wall thickness to be maintained at the most effective cost shall be selected. Final selection will take into consideration the manufacturing processes, premiums for higher grade steel material and allowable diameter to thickness ratios. In general, it is desirable to use higher strength or higher grade material as possible. The yield strength is the point at which plastic deformation begins to occur as the applied stress is increased.

Although the use of the higher strength material results in a cost saving, some engineering requirement should be fulfilled. For example, thin component may be more susceptible to construction and handling damage. The compressive loads applied during transportation or field fabrication (during bending) can cause denting or buckling.

ANSI/ASME guideline on the D/t ratio or the slenderness ratio, was used to minimize the possibility of handling damage during transportation or buckling during field installation, where minimum values of pipe wall thickness will be specified for each pipe size which may exceed those required solely for pressure containing purpose. Selecting higher grade linepipe material also improves the integrity of pipeline against cyclical load and fatigue failure. The fact is particularly evident from designing road, railways and river crossing as well as near compressor station.

**Fracture Control**

Fracture control is one of the main design aspects considered in the selection of the pipeline materials. In the unlikely event that a leak occurs, fracture initiating from the leak should be controlled. It is required that the leaks caused by mechanical damage, corrosion, defects in the material or any other reason should not propagate. Initiation of fracture of the components involved shall be avoided.
The basic method used to achieve this “fracture initiation control” is by specifying that the material have sufficient notch toughness or resistance to fracture. The toughness is determined through Charpy impact testing and the amount of energy absorbed by the material during fracture is the basis of acceptance. Resistance to fracture initiation and propagation will be achieved by specifying the minimum levels of fracture toughness for the maximum design pressure and lowest design temperature.

Weldability

The chemical composition limits has been carefully specified in addition to those in applicable industry standards to facilitate welding by fusion electric arc process. The welding materials (quality, flux, hydrogen content) and procedure (heat input, welding speed etc) has been strictly specified and controlled. Single proof test in accordance to WIC (Welding Institute of Canada) has been incorporate to qualify the weldability. Weldability of plate material is regularly conducted according to requirements.

Pipe Selection Process for Submarine Application

The selection of spiral welded pipe for Submarine application was based on various published standards and technical paper, data and information and technical discussion. The decision to use spiral welded pipe was seriously evaluated in view of the following factors;

- Spiral welds are approximately 80% extra weld length compared to longitudinal weld.
- Hence, the total leak frequency of a spiral welded welds are expected to increase (by additional 80%) to 3.6%

In depth understanding by PGB relevant authorities and evaluation by experienced international parties show that spiral welded pipe is fit for purpose for the intended use. It was finally concluded that the spiral welded pipe of X-60 grade was fully justified subject to wall thickness limitation and precaution during construction. Various salient features incorporated in both of the production stages are explained below which significantly enhance the quality, productivity and high integrity of such spirally welded pipes.

Pipe Manufacturing Process

The pipes were manufactured in Hicom Petro-Pipes Sdn Bhd using the latest technology based on two-step manufacturing of spiral welded process originated from Germany. In this two-step process, the forming of the spiral pipe and the submerged arc welding process are separated.

The diameter of the pipe to be produced is directly related to the width of the coil used and the angle of the feeding coil or the forming angle. Figure (2.0) illustrates the computation of the pipe diameter. In the first stage, the skelp is edge trimmed to size by milling cutters and V-cut by chamfering to produce the weldable edge. This process enables a constant strip width during forming at high speed. The centering of the coil during forming is achieved through a centering device. This close looping system device is supported by a pair of camera located on top of each edge of the strip. The strip is then flattened by a series of flattening rollers. The strip then goes through an edge pre-bending process to eliminate the “bamboo” appearance or the peaking effect. During this process, the strip are pre-bent in the opposite direction prior pipe forming process. This is achieved by installing two rollers at the side of the strip, one at the top and one below the strip edge. This pre-bending roller can be adjusted so that any radius may be achieved. The pre-bending rollers can be adjusted so precisely that no additional edge offset will occur. As the pipe been formed it passes a series of forming cage roller, which acts as a mould to form, and guide the curve
strip into a pipe as feeding continues. As the pipe is formed, it is automatically and continuously tack welded by CO\textsubscript{2} shielded welding process. The diameter of the pipe can be easily controlled and monitor. As the pipe is tack welded a travelling plasma cutter then cuts the pipe into the desired length.

In the second stage, the preformed and tack welded pipe is rolled into a separate Double Submerged Arc Welding station. The movement of the pipe is programmable logic controlled and supported by an orthogonal rollers system, which enable the pipe to move laterally, and rotated precisely. The pipes are finally welded inside and outside by a programmable logic controlled welding system, which control both the pipe movement, and the welding system. The tack-welded pipe is first welded internally by a three head multiple wire submerged arc-welding process. As the pipe move spirally the pipe is then welded externally with two heads wire. During the welding process the initial tack welding will be completely re-molten to become an integral part of the complete weld. The welding process is supported by a laser tracking system which enables the seam to be precisely located and the information fed to the welding head for precise welding along the spiral seam. The welding system is equipped with data logging system where all the welding parameters are stored and archived. Welding records and parameters can be readily obtained in hardcopy.

**Quality Assurance**

Hicom Petro-Pipes Sdn Bhd is the first pipe mill in Malaysia accredited by the prestigious American Petroleum Institute (API) and is licensed to apply the API Monogram on its products. In addition the Quality Management system conform to the requirements of ISO 9001 Quality System Standard. The establishment of the in-process inspection and in-house laboratory testing facilities reflects Hicom Petro-Pipes commitment to the highest level of quality.

**In-Process Inspection & Testing**

The in-process inspection and testing facilities accommodate both the client’s and also established standard specification requirements. The welded pipe from the submerged arc-welding station is visually inspected internally and externally before it is subjected to hydrostatic testing. The testing pressure and the holding time for individual are recorded in a hard copy. After the hydrostatic testing, the welding seam and the base material are then subjected to an automatic non-destructive ultrasonic testing for longitudinal and transverse defect. Four probes in K type arrangement are dedicated to inspect the weld seam with the support of the weld seam tracking systems. This allows the precise positioning of the probes during inspection. The inspection of the base material is dedicated by sixteen probes oscillating forward and backward as the pipes moves forward and rotates at the same time. The movement of both the pipes and probes enables the entire pipe body to be inspected. The ultrasonic inspection system is incorporated with spray paint, which spray at a particular position whenever the system triggers any potential defects. The potential defect is further inspected manually with manual ultrasonic equipment before acceptance. The acceptance criteria are based on API specification and customers’ requirements. Hicom Petro-Pipes in-process inspection is equiped with X-ray and real time fluorscopy inspection of weld seam. The computerized recording system records data and captures images of X-ray and Fluroscopy inspection.

The production flow system is supported by Production Process Computer System which is capable of tracking the movement of the pipes during production. This system provides the control of the pipe movement from one station to another and every single pipe has to pass through all the designated stations.

The in-house Non-Destructive Testing technical experts are qualified and certified to a minimum ASNT level II (American Society for Non Destructive Testing).
**In-House Laboratory**

Parallel with the In-Process Inspection and Testing carried out in the mill, mechanical and chemical testing is performed on every heat or batch produced. This testing involved both the base material and the weld seams. The In-House Laboratory is equipped with Spectrometer for chemical analysis, tensile testing, Charpy V-notch impact tester, drop weight tear test, guided bend test and hardness tester. Macrostructures and microstructures analysis are carried out with the support of well-trained and qualified technical personnel.

**Linepipe coating requirement**

Coating of pipe externally is an established method in preventing external corrosion of underground pipelines. The material selection for external coating need to be carefully studied in terms of handling during construction and the long term integrity of the pipelines. The coating systems commonly applied to the bare pipe are Fusion Bond Epoxy (FBE) or Polyethylene (PE). In the execution of the projects by PGB, the application of external coating was reviewed for potential areas of improvement to enhance the reliability and integrity of the pipeline.

During the initial stage of PGU 1 project, in early 1980’s, coal tar coating was used and this was subsequently replaced with Fusion Bonded Epoxy (FBE) for the PGU II and early stage of PGU III Projects. As a result of thorough study, taking into account the long term reliability and integrity of the pipeline coating and the requirement of pipeline operations, three layer polyethylene coatings were used for the later stage of PGU III and LOOP I and 2. This is attribute to the following major factors:

1. During the construction stage, coating defects normally occurred due to mishandling of the pipes. Three layer PE coating have a higher resistance to the mechanical damage than FBE, therefore reducing the most frequent contribution factor of coating damage.

2. Three layers coating require less current density for cathodic protection system than FBE coating.

Table (2.0) Some of the major difference FBE and Three layer PE coating

<table>
<thead>
<tr>
<th>Property</th>
<th>FBE</th>
<th>Three layer PE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Coating system</td>
<td>a) Blasted to a near white finish&lt;br&gt;b) FBE coating application</td>
<td>a) Blasted to near white finish&lt;br&gt;b) Chromate surface treatment&lt;br&gt;c) Fusion Bond Epoxy Powdered Primer&lt;br&gt;d) Polymeric adhesive&lt;br&gt;e) Polyethylene outer sheath</td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>Approx. 0.3 to 0.5</td>
<td>Approx. 1.5 – 4.0</td>
</tr>
<tr>
<td>Application and QC</td>
<td>Electrostatic Spray&lt;br&gt;Close control</td>
<td>Spray &amp; Extrusion&lt;br&gt;Relative simple</td>
</tr>
<tr>
<td>Pipe surface quality and Contamination</td>
<td>Highly sensitive</td>
<td>Sensitivity not demonstrated</td>
</tr>
<tr>
<td>Coating application temperature</td>
<td>232 - 243</td>
<td>215 – 239</td>
</tr>
<tr>
<td>Properties</td>
<td>API 5L X 60</td>
<td>API 5L X 70</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>NPS</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Design Pressure (psig)</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Wall thickness required (mm)</td>
<td>15.24</td>
<td>13.06</td>
</tr>
<tr>
<td>Weight (kg/m)</td>
<td>337.8</td>
<td>290.2</td>
</tr>
<tr>
<td>Cost (RM/m)</td>
<td>898</td>
<td>772</td>
</tr>
<tr>
<td>Weight saving (kg/m)</td>
<td>-</td>
<td>47.6</td>
</tr>
<tr>
<td>Cost saving (RM/m)</td>
<td>-</td>
<td>127</td>
</tr>
</tbody>
</table>

As a result, it is translated into a cost saving of RM 127,000 for every 1 km of pipe installed or RM 12.7 million for every 100 km of pipe installed.

**Local manufacturer**

Due to transportation limitation and other factors, imported longitudinal weld seam pipes are normally procured in 12 metre lengths. However, since the spiral welded pipe are procured and manufactured locally, the length constraint is more relaxed. On average the spiral welded pipes were delivered in 15 metres lengths. This has resulted in fewer pipe joints per kilometre for the spiral welded as compared to long seam pipe i.e. 66 joints versus 83 joints per kilometre. For a pipeline construction of 100 km length, a saving of approximately RM 6 million can be made in as a result of the reduction in welding cost.
Indirect saving

By choosing a higher grade material, the thickness is obviously reduced and hence a lower cost in transportation, handling and welding related cost. The cost saving in transportation cost is attributed to the less tonnage of steel pipe transported by shipping and road haulage. In welding process, thinner wall pipe requires thinner bevel preparation, less welding filler materials, shorter time to complete one joint-weld and X-ray cost and similarly the handling cost during construction is reduced as a result of reduced tonnage per pipe.

External coating

It has been proven that three-layer PE coatings show a significant improvement in the performance of external coated pipeline. Although the cost of a three layer PE coating is approximately 30% higher than FBE coating, the overall cost saving during pipeline construction in terms of handling, backfill damage and cathodic disbondment resistance will substantially compensate for the three layer PE coating cost in the long term.

Pipeline construction

The spirally welded pipe produced by HICOM has been successfully installed and commissioned in both onshore and offshore. The land construction includes the traditional trenching, laying and back-fillings, roads, rivers, railways and highway crossings. The offshore installation used lay barge plus pulling approach and the Horizontal Directional Drilling. The offshore installations will be discussed in the succeeding section. The route selection was carried out by PGB and the criteria used in selecting the routes includes the followings;

- Shortest possible route
- Avoid hazardous area
- Avoid existing anchoring zone with the planning to include a portion of the selected route as part of non-anchoring zone.
- Avoid other pipeline or cable crossings as much as possible
- Avoid bottom constructed or depression as much as possible that may create the massive pipe span.
Table (4.0) shows the typical pipeline construction type, method and basic design criteria adopted in the PGU pipeline.

<table>
<thead>
<tr>
<th>Construction type</th>
<th>Method</th>
<th>Design criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>Trenching, laying and backfilling</td>
<td>Depth, width and slope</td>
</tr>
<tr>
<td>Road crossing</td>
<td>Open cut, Pipe jacking, micro tunneling</td>
<td>Similar to highway crossing</td>
</tr>
<tr>
<td>Railway crossing</td>
<td>Pipe jacking and micro tunneling</td>
<td>Similar to highway crossing</td>
</tr>
</tbody>
</table>
| Highway crossing  | Horizontal Drilling, Directional Drilling | Stress due to soil load, vehicle load and internal pressure.  
|                   |                                     | Cross at right angle                                  |
|                   |                                     | Type and weight of soil                               |
| River crossing    | Horizontal Drilling, Directional Drilling | Weight of water and soil beneath river at deepest point.  
|                   |                                     | 100 years flood level.                                |
|                   |                                     | HDD requirements                                      |

The longest and the deepest river crossing is at Perak River spanning 1500 meters in length and 15 meter in depth.

**Submarine Pipeline Experience**

Gelugor Mainline Project completed in 2000 involves the laying of 7 km of NPS 24 sub sea pipeline from Prai on the mainland to Gelugor power station on Penang Island. It crosses the Straits of Penang almost parallel with the Penang Bridge, the longest bridge in South East Asia. The pipeline design pressure is 70 bar (6895 kPa). The route run over undulating terrain with varied seabed lithology with depth up to 16m and crosses an active shipping lane, zone of live electrical cable and a system of submarine pipeline. The Location Plan is shown in Figure (3.0).

The Gelugor Mainline design has adopted an extensive design approach to ensure the pipeline was constructed to the best of engineering practice. Some of the pipeline design criteria adopted for the project are as follows:

- Wall thickness, buckling and collapse analysis. Highest Astronomical Tide (HAT), inclusive of surface wave height is used in the design for both installation and operational condition.
- Spanning analysis. Since the pipeline is post trench and Horizontal Directional Drilling (HDD), this analysis is perform for the installation and hydrotest cases where free spans may result from laying the pipeline onto uneven seabed.
- In-situ stress analysis. Both fully restrained and unrestrained pipeline section conditions were investigated here.
- On-bottom stability analysis. An installation condition (pipeline empty) subjected to 1-year return period wave and current was included here.
• Pipeline expansion analysis. Both operating and hydrotest cases plus expansion offset was investigated which include the following basis: no axial restraint at the end of the pipeline, maximum operating temperature, minimum installation temperature, design pressure, low (realistic) estimation of axial friction and minimum content densities where applicable

• Pipeline installation analysis. This includes pipelay initiation, abandonment and recovery analysis.

• Cathodic protection design. Design to cater for minimum design life of 25 years and pipe to soil potential between -0.8 and -1.1 v (silver/silver chloride reference cell)

• Pipe supports design inclusive of maximum pipe load together with environmental (wind) loading.

• Rock armoring or rock cover. The design involves in selecting the right rock size plus the filtering layer around the pipe prior to it.

• Impact analysis. This is to determine the approximate required rock cover thickness due to impact load associated with the transfer of energy from the impacting trawl board to the pipe and its coating. The impact direction and the amount of energy transferred to the pipe depend on the pipe diameter, span height, shape of the front of the trawl board/anchor and the direction of travel relative to the pipeline.

A pipeline installation methodology based on a lay barge pulling operation activity concurrently with HDD activity and post trenching activity was implemented. For the shore approach, once a section of the pipeline in completed it will be towed out to the respective HDD hole and pull into it. The pipeline will be partially filled with water via an insertion of a HDPE pipe inside the steel pipe to ensure the pipe is not buoyant. The fabrication area will be on the lay barge and the pipe string will be pulled accordingly until a section spread is completed prior to towing out. A total of three (3) above water tie-ins' were performed for the 7 km stretch.

By implementing the above construction methodology, the contractor has managed to achieve the same result in comparison to having the fabrication work onshore. The pipe fabrication activity on the lay barge is an independent activity prior to having any effect to the shipping movement across the shipping lane in the port area as previously identified.

**Horizontal Directional Drilling (HDD) Method**

There were initially three HDD areas to be performed, each at the shore approach and one across the shipping lane. However the construction methodology was changed during the construction stage where only the shore approach part was materialized. HDD is accomplish by drilling a directionally controlled hole to accommodate the pipe, along a predetermined curved path under the obstacle and drawing a pre-joined, coated and tested pipe-string back through the hole. The technique is now well understood and widely practiced by specialist contractors worldwide. Crossings for pipelines up to 42 inch diameter have been successfully completed. The longest recorded 18 inch diameter HDD pipeline crossing is more than 1700 meters in length. The Gelugor HDD 1100 m was successfully completed.

In sand, loam or softer clays the drilled hole may be achieved by jetting. The jetting tool at the leading end of a drill string has a beveled face with mud jets strategically placed to favor material removal on one side in preference to the other. Soil is removed from the hole by mudflow. In order to produce a straight portion of hole the complete drill string is uniformly rotated. To initiate a curve the drill string is held in the preferred directional allowing the jet tool, in conjunction with tool thrust, to establish and sustain the required curve. The required hole for entry and exit points
for the shore approach and intervening ground surface are surveyed before any drilling is commenced. This data governs the design of the drill in both plan and elevation which is carefully planned to ensure that the minimum radius of curvature is acceptable for both the pipe to be inserted and the drilling process. Here 500D is the required minimum radius.

To ensure that the drill path adheres to the design as closely as possible and to provide position and directional data during drilling, the driller uses a down-hole survey tool which is located in the drill string behind the bit and motor. At regular intervals during drilling a reading is taken from the survey tool to provide the position of the instrument relative to the drill entry point. This position is compared by specialized computer software to the pre-entered design path thus allowing corrective action to be taken by the drilling superintendent when appropriate. The HDD method has indeed benefited the construction contractor in many ways as follows:

- Avoidance of environmental disturbance during construction. i.e. rearing of caged fishing activity and houses on stilt.
- Enable some crossings not previously possible.
- Increase the number of alternative pipeline routes available. i.e. shore approach at both power plants.
- Improve security for the completed crossing (against natural and third party hazards).
- Provide overall cost reduction.

**Lay Barge Plus Pulling Method**

The pipelay vessel for the project was built partly from sketch. It requires an overlapping vessel concept between offshore application and shore approach. The barge is a non self-propelled ‘make-up’ flat top barge design for working in the area. The pipe lay vessel chosen requires less tension load thus widening the choice of vessel for installation. Lower pipeline tension has the benefit of lower pipeline residual tension which leads to a shorter pipeline unsupported spans and reduction in the risk to the installed pipeline. An elevated pipe lay ramp was fixed on the starboard side and runs along the entire length of the barge. A fixed 24 m stinger section is attached to the stern to support the pipe overboard region. The barge has 3 welding stations arranged for maximum 15 m long pipes with no pipe tensioning capacity. Pipes are loaded from the port side of the barge using a 136 ton crawler crane. Using a boom length of 140 feet, the crane loads the pipes and moves it to the ready rack. It is transferred onto the bead stall for beveling and to the stalking (line up) station. The pipelay vessel also included A-davit for tie-in purpose, cabins which function as offices, NDT viewing facilities, compression chamber, cooking area and the relevant welding stations inclusive of radiographic examination area and mastic application area.

**Conclusion**

The Peninsular Gas Utilization Project has been successfully undertaken by PETRONAS. With this success, it has proven that the Spiral Welded pipe produced locally by Hicom Petro-Pipes is capable of replacing imported longitudinal welded pipe. The maiden straits crossing pipeline or the submarine application is another example on the suitability of Spiral Pipe for off shore application. The usage of spiral welded pipe as a submarine pipeline is without question applicable and proven feasible.
Techniques used in shallow water pipe laying includes shallow water barge (for laying and pulling activities), Horizontal Directional Drilling and the post trenching activity. The know-how associated with laying pipeline in shallow water has further enhanced the knowledge in the field of the local contractor. The successful completion of this extremely difficult project was due to the excellent performance of all parties.

The economic justification has been thoroughly addressed focusing not only on the bottom line and values creation without sacrificing safety. Cost is one of the variables that have been control. The typical saving based on 100 km of pipeline constructed amount to approximately RM 19.0 million for the direct material cost.

Acknowledgements
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References


PGB Design Concept Manual
Petronas Technical Standards

Fig. (2.0), Illustrates the computation of pipe diameter
Fig (1.0) Peninsular Pipeline System
Figure 3. Location plan for Submarine Pipeline System.