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An Independent Look at the Round Hull Concept

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A Wild Idea?

Back in 2000/2001 while working in Houston for a leading FPSO contractor (Bluewater), I traded emails with Gary Quenan, a founder of SSP Offshore.

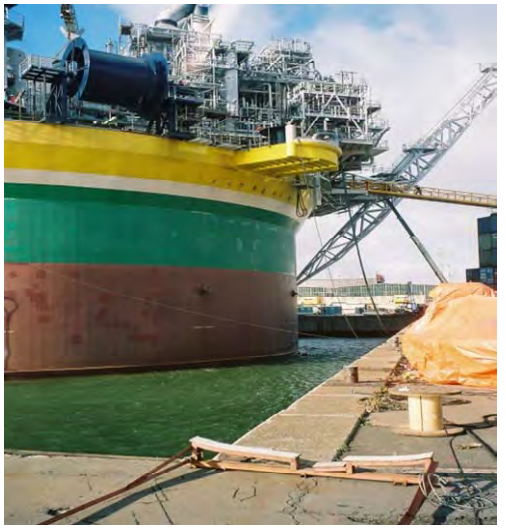
It sounded like he had a wild idea - making FPSO hulls ROUND!

One sees a lot of unusual things in the business development world and so I thought nothing of it.

Then at the Offshore Technology Conference (OTC) in Houston in 2003, a Norwegian company promoted the same idea of a round hull for FPSOs. Again, one sees many concepts at OTC, some later become reality and others disappear.

Then it got more serious.

In late 2006, I visited the first round FPSO being outfitted in the Netherlands for Sevan Marine, to check out its feasibility for projects for Devon Energy, my then employer.



The First Round Hull FPSO

In 2007, Sevan's FPSO started oil and gas production in the *Piranema* field, Brazil, under a lease contract with Petrobras.

So the round hull idea really had been accepted, and by a leading offshore production company!

The round hull FPSO had got operators' attention worldwide!

A gestation period of a little more than six years. Not bad . . .

Meantime Back in Houston
One Operator's Reaction on Round FPSO Hulls

Devon Energy (NYSE: DVN) in 2006 had multiple development prospects, internationally and in US GoM that could use an FPSO. For US GoM we had a particular interest, being 50:50 with Petrobras (NYSE: PBR) in *Cascade,* where the first FPSO in US GoM would ultimately be deployed.

1. Like other large independents, we did look at new ideas but were not in the business of trying out new technologies - looked instead for more proven designs to mitigate business risks;

2. The 2005 hurricanes taught us that an FPSO laden with crude oil had to be disconnectable (unrealistic in round FPSOs);

3. Export of oil would have to be with DP2 shuttle tankers from a round FPSO. Might be doable, depending on region.

Conclusion – Round was out for projects we were then faced with.

2006-2007 Discussions Led to FPSO and Shuttle Tankers Operation in US GoM Like This:

Offloading from a disconnectable FPSO in US GoM

Petrobras operates the *Cascade/Chinook* development, with FPSO *BW Pioneer* on charter from BW Offshore, with two non DP, enhanced maneuverability, Jones Act shuttle tankers chartered from OSG.

Round Hulls for Offshore Service
Competition Continued in Marketing & Development

Despite these early 2000 conversations, SSP Offshore in Houston was thus not the first to commercialize the round hull FPSO. It was not for want of trying;

in 2008, SSP Offshore invited me to a two-day meeting about the design and operation of its round FPSOs. There were representatives from a number of other oil companies with offshore field developments that possibly might employ a floating production system like this. Lots of questions and discussion ensued;

It certainly seemed that the round hull design was workable for much of the world;

Marketing and design development continued and operators continued to watch for who else would go first.

Financing the Path to Commercialization

The funding of a route to commercialization was different for the two round hull FPSO competitors:

Sevan in Stavanger succeeded in attracting early venture capital and then in doing an IPO in 2004 on the Oslo Stock Exchange (OSX) that helped its trek towards early commerciality;

SSP Offshore in Houston continued its development with private funding until an IPO on the Toronto Ventures Exchange (TSX) five years later in 2009.

Along the way, the two competitors settled patent differences between them.

The 2012 First Annual Texas Roundup and Shootout on Round Hull FPSOs

I devised this session to explore how an offshore-savvy audience viewed the pros and cons of three round-hulled FPSO designs submitted by different designers;

Each designer made a presentation to an audience at the Emerging FPSO Forum in Galveston in September 2012;

The audience voted on which they would prefer for their field development, were they to make a choice: a traditional ship-shaped FPSO, or one of the three round hull designs;

Results were surprising: the audience of 100+ equally favored Sevan's new round hull design and the traditional ship-shaped hull;

Less surprisingly, the two round-hulled designs that had *not* been built received significantly fewer votes.

The First Annual FPSO Texas Round Up and Shoot Out on Round Hull FPSOs

The First of Two Questions to the Audience

What do you think is the most important factor in choosing a round FPSO for your next field development:

29%	A.	The oilpatch has always liked boats with a pointy end
11%	B.	Round is simple and cheap to build
35%	C.	No need for an expensive turret and swivel
25%	D.	Round FPSO technology has now matured to where it will win in a shoot out

The First Annual FPSO Texas Round Up and Shoot Out on Round Hull FPSOs

The Second of the Two Questions to the Audience

For my FPSO development, I choose:

43%	A.	Sevan
7%	B.	Nagan Srinivasan
9%	C.	S S P
41%	D.	Ship Shaped FPSO

[Answers are after the Shootout – all Gunslingers did survive!]

Technology Readiness Level (TRL)

A Gauge on Design Maturity - Cross Check on the Vote

	TRL Designation		Definition
Conception	**TRL 0**	**Unproven Idea** (paper concept, no analysis or testing)	At TRL 0, a technical need has been identified and a concept has been conceived. The description of the technical need is general in nature without specific performance or functional requirements. The concept has been refined to the point that the physical principles have been documented and simple sketches, if applicable, have been produced. No analysis or testing has been performed.
Proof-of-Concept	**TRL 1**	**Proven Concept** (functionality demonstrated by analysis or testing)	At TRL 1, the concept has been refined to the point where the basic physical properties (dimensions, material types, rates, etc.) have been developed and documented and preliminary drawings, if applicable, have been produced. The primary technical requirements are documented. Analysis and/or testing have been performed demonstrating that the concept functions as conceived. The testing may be conducted on individual subcomponents and subsystems without integration into a broader system. The concept may not meet all of the technical requirements at this level, but demonstrates the basic functionality with promise to meet all of the requirements with additional development.
	TRL 2	**Validated System Concept** (breadboard tested in "realistic" environment)	At TRL 2, the concept is developed into an ad-hoc system of discrete components (breadboard/mock-up) to establish that the components work together prior to prototype construction. The system validates that it can function in a "realistic" environment, with the key environmental parameters simulated. Appropriate material testing and reliability testing may be performed on key parts or components.
Prototype	**TRL 3**	**Prototype Tested** (prototype developed and tested)	At TRL 3, the technical specifications are developed further and a prototype has been developed. The technical specifications include details of the performance, functional, environmental, and interface requirements. The prototype is tested in a robust design development test program over a limited range of operating conditions to demonstrate its functionality. Reliability growth tests and accelerated life tests may also be performed. The relevant lab test environment may not be field realistic. This is an isolated test program for this technology, without its integration into a broader system.
	TRL 4	**Environment Tested** (prototype tested in field realistic environment)	At TRL 4, the technology meets all of the requirements of TRL 3 and below, except that the testing is conducted in a relevant environment (simulated or actual) over its full operating range.
	TRL 5	**System Integration Tested** (prototype integrated with intended system and functionally tested)	At TRL 5, the technology meets all of the requirements of TRL 4 and below and is integrated into its intended operating system and tested. The testing includes full interface and functional testing. The system integration test environment may not be field realistic. (This TRL may not be applicable for all technology.)
Field Qualified	**TRL 6**	**Technology Deployed** (prototype deployed in field test or actual operation)	At TRL 6, the technology has been developed into a field-ready prototype or production unit and has been integrated into its intended operating system and installed in the field. The technology has successfully operated for <10% of its expected life.
	TRL 7	**Proven Technology** (production unit success-fully operational for >10% of expected life)	At TRL 7, the technology is now in production and has been fully integrated into its intended operating system and installed in the field. The technology has successfully operated with acceptable performance and reliability for >10% of its specified life.

TRL = 0
Untried

TRL = 7
Well Tried

TRLs a Measure of Commerciality
TRLs and Common Sense in Sync?

TRLs come in 7 and 9-level scales, tailored to different industries (space, military, nuclear, US DOE, etc). I used the DeepStar scale, which was set up to deal with new deepwater technologies and systems such as this.

I assigned a Technology Readiness Level (TRL) to each of the designs, to check for a correlation between that vote and how far each design had advanced.

Common sense would indicate the design actually built would be more credible, and it was no surprise to see that the TRL rating pretty well tracked the level of design maturity the audience had indicated.

Thus the ship-shaped hull had a TRL of 7: been in use for centuries, on countless thousands of ships. Sevan's round hull design had been tried and operated for at least five years and used on at least five round hulls in service in 2012, and qualified to have a TRL of 7, while the untried designs had significantly less: 2-3 (SSP) and 1-2 (Srinivasan).

Correlation of TRLs and the Vote

Table 1: Round Up and Shoot Out on FPSOs in 2012

Hull Shape	Designer	TRL (a) (b)	Comments	Audience Response System (ARS) vote. %
ShipShape FPSO	Many	7	About 165 now operating, FPSOs been in use for many years	**41**
Round FPSO	Sevan	7	3 hulls in use as FPSOs, 2 hulls in use as MODUs	**43**
Round FPSO	SSP	2-3	None built or contracted, multiple model tests, many studies	**9**
Round FPSO	Nagan Srinivasan	1-2	None built or contracted, limited model tests and studies	**7**
				100
Notes				
(a)	The TRL scale used here is that adopted by Deepstar, consisting of seven (7) levels defined carefully for petroleum industry use. The TRL values given here are by Peter Lovie.			
(b)	The TRLs estimated here for round FPSOs show some correlation with a vote by a conference audience on their willingness to accept these different designs in Session IX at the Second Emerging FPSO Forum, Galveston, 26-27 September 2012			

After the Shootout
The Other Two Round Hull Designers

So what happened to the other two round hull designs since "The 2012 First Annual Texas Round Up and Shoot Out"?

SSP continues in business today:-

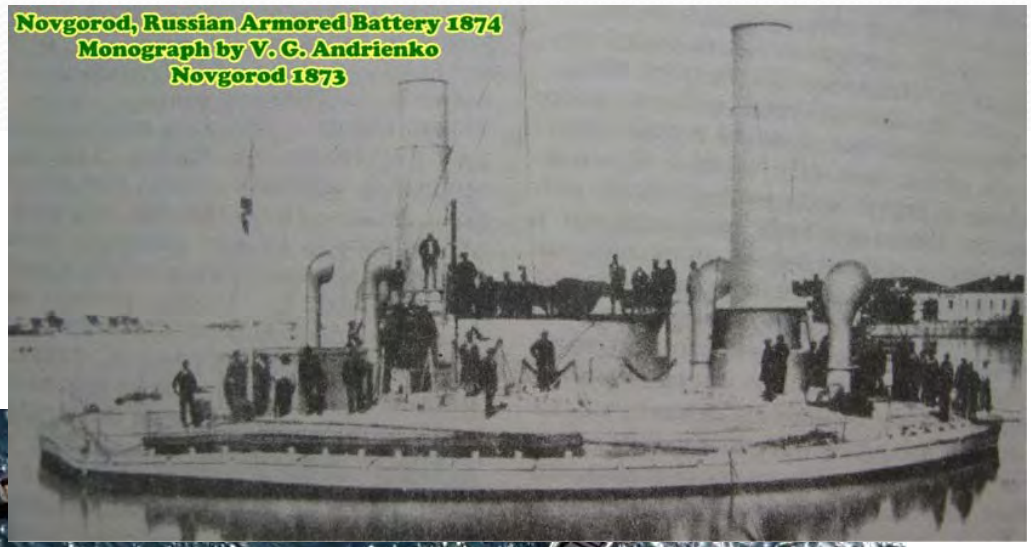
- Promoting its round hull designs, despite fifteen years with no round hulls built to their design;
- Round hulls marketed for other than FPSOs: such as FPDSOs, offshore supply hub bases and MODUs;
- In late 2014, SSP became a subsidiary of Sembcorp Marine of Singapore, through which SSP designs are now offered on a complete design and construction basis, following the trend of offshore shipyards towards contracting on an EPC basis.

Gary Quenan, with whom I had discussed the round hull in 2000-2001, went on to become president of another engineering company.

Nagan Srinivasan, the third round hull designer, appears to have abandoned active promotion of round hulls, joining Chevron in 2013 as a lead engineer.

Other Round Hulls in Modern Times:
Admiral Popov's Round Warships of 1873

	History
Laid down:	17 December 1871
Launched:	21 May 1873
Commissioned:	1874
Decommissioned:	4-Jul-03
Struck:	1900
Fate:	Scrapped 1912
General characteristics	
Displacement:	2,491 tons
	2,671 tons at full load
Length:	30.8 m
Beam:	30.8 m
Draught:	3.75 m
Propulsion:	8 coal-fired boilers, 6 screws, 2,000 ihp
Speed:	7 knots
Complement:	128
Armament:	2 × 11 inch guns
	2 × 4-pounder guns
	16 × 37 mm guns
Armour:	Belt: 230 mm
	Deck: 60 mm



Other Round Hulls in Modern Times:
The *Kulluk* MODU of 1983-2014

This round arctic mobile offshore drilling unit entered service in 1983, was mothballed for many years and then modified to work for Shell (2012 picture here), before Shell's 2014 decision to scrap it.

This round hull MODU has been replaced by a semisubmersible (*Polar Pioneer*) and a drillship (*Noble Discoverer*). In late September 2015 Shell abandoned this program.

Other Round Hulls in Modern Times:
A Design for a Round FPSO back in 1984

Houston-based engineering company Marine Technology Corporation created a design with a flared deck, as featured on the modern round FPSO hulls;

Arrangement drawings showed use of with a hybrid riser system, akin to that used with the ship-shaped FPSO at *Cascade/Chinook* in the GoM, which started production in 2012;

The **C**ircular **O**ffshore **M**oored **P**roduction **A**nd **S**torage **S**ystem [COMPASS] concept of a round hull was driven by seeking:

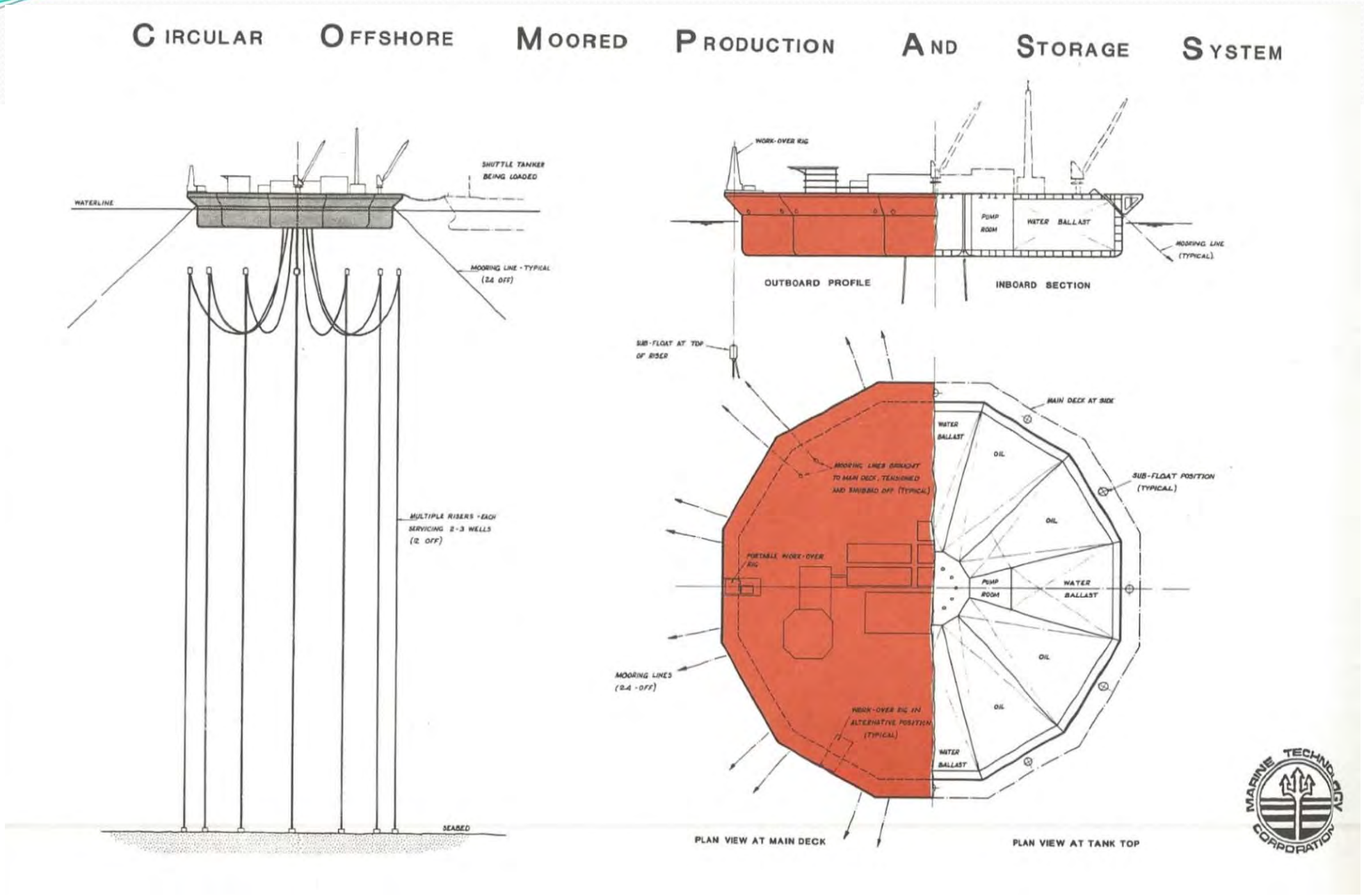
Ease of manufacture - the assembly of pie-shaped sub-modules, and by:

Deck layout,

i.e. the same arguments used by SSP and Sevan in the 2000s;

COMPASS would seem to represent prior art on round-hulled FPSOs that is worth a look . . .

Other Round Hulls in Modern Times:
A Design for a Round Hull FPSO back in 1984



Other Round Hulls in Modern Times:
Comments from the Originator of COMPASS

The originator of the COMPASS design of round hull FPSO was Peter Noble: later became chief naval architect at ConocoPhillips, just finished a term as national president of SNAME.

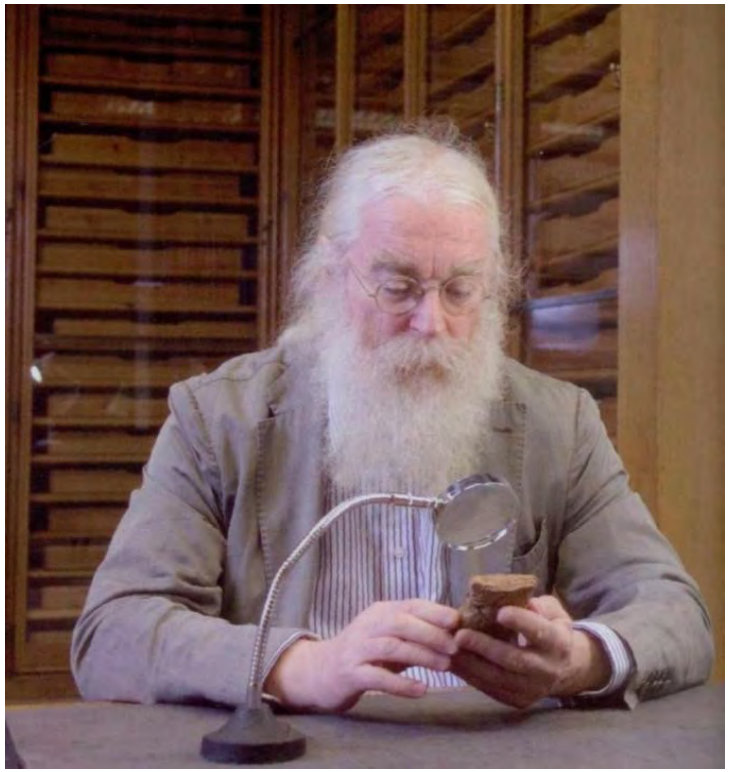
He comments:

> *"Hydrodynamic studies showed some issues with combined pitch and roll but the large mass of the unit [~ 300,000 tonnes displacement and about 150m in diameter] took care of these within operational limits.*
>
> *"Concluded a circular FPSO would be a good solution as long as it was big enough and the environment wasn't too severe.*
>
> *"Most of these vessels reported significant problems with motions in a seaway".*

And now Round Hulls in *Antiquity*

Dr. Irving Finkel's Discoveries

Most people know the story of Noah's Ark and the Flood as recounted in the Book of Genesis. Since the 1870s it has been known that a similar, but much older story existed centuries before in ancient Babylon, but much was shrouded in mystery.



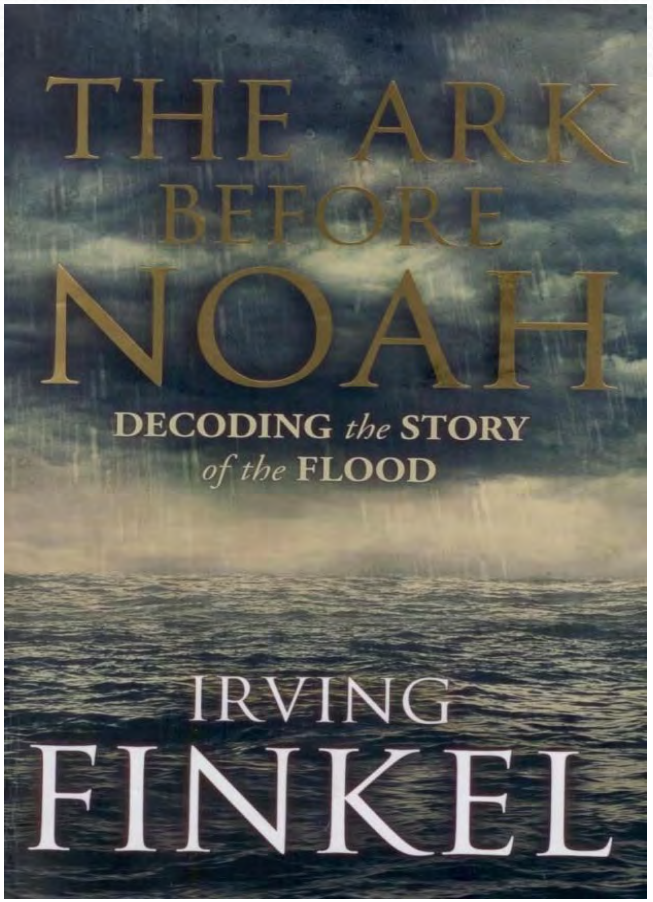
Dr. Irving Finkel of the British Museum, deciphering one of the cuneiform clay tablets.

In 2008, Dr. Irving Finkel, a curator in the British Museum and an authority on ancient Mesopotamia, found himself involved in a detective story of decipherment and discovery when a member of the public arrived at the museum with a particular cuneiform tablet which he had inherited from his father.

Unlike paper, which is easily burned or destroyed over the years, clay tablets last forever (just about). Dr. Finkel explains how they were used for recording all kinds of commercial transactions and daily events.

Round Hulls in Antiquity:

The Ark Before Noah: Decoding the Story of the Flood



Detective Finkel's truly cold case . . .

In January 2014, Dr. Finkel revealed how decoding the symbols on an almost 4,000 year-old piece of clay enabled a radical interpretation of the Noah's Ark story, indicating it may not be a myth after all.

Where this gets particularly interesting for the offshore community is Dr. Finkel's discovery how large the Ark was, and that it was ***ROUND***.

The gradual decoding of this ancient message reveals where the Babylonians believed the Ark came to rest and has led to a new explanation of how the old cuneiform story ultimately found its way into the text of the Bible.

Round Hulls in Antiquity:
Revelations from the Clay Tablets

Tablets are from an era before written language – instead, symbols were engraved in the clay.

Literally thousands of them exist today – British Museum is said to have 130,000.

An onerous task to interpret one or two, let alone sift through a huge number of them, making Dr. Finkel's discoveries all the more remarkable.

Not only did the tablets reveal a new version of the Babylonian Flood Story, but the ancient writer (from about 1850 BC) had described the size and a completely unexpected shape of the Ark, giving fairly detailed "shipbuilding" specifications.

To modern-day offshore engineers, Dr. Finkel's book is a revelation on what was accomplished with limited materials and expertise, something like 4,500 years ago.

Round Hulls in Antiquity

"Instructions on Building the Ark"

Dr. Finkel keeps this brown clay tablet in a special red box labelled "Instructions on Building the Ark". The Ark Tablet is written in Akkadian, a Sumerian dialect.

[Looking at the pictures, how that tablet can be deciphered from the shape it is in, sure would take some talent!]

Round Hulls in Antiquity:
In Noah's Day, Shipbuilding Capability was *LIMITED*

For millennia, people built and used rowboat-sized round hulls called quaffas.

But the Ark was BIG with multiple compartments and decks, different from the quaffas.

In Noah's day there was no steel to build a big vessel like an Ark. Dr. Finkel's investigation showed that the Ark was constructed with ropes of reeds of the kind commonly found in the delta areas and along the banks of the Euphrates and Tigris rivers located in modern day Iraq.

There were no forests of big trees to provide heavy beams, decking and ribs, like shipbuilding elsewhere for centuries to follow.

The hull was caulked with bitumen. There were no processing plants back then to order bitumen by the tonne whenever it was needed.

We now know of Iraq's huge oil reserves, and so it is logical to believe that Noah's bitumen came from seeps from petroleum reservoirs.

Round Hulls in Antiquity:

Estimating the Size of the Ark before $A = \pi r^2$

When these tablets were 'written', people did not have the mathematics to rigorously describe a circle – 'pi' was not yet invented – and so areas of circles - and other shapes - were not exact but estimated as a 'ground plan'.

Page 314 posits a ground plan of 15,000 square cubits as the most reliable number.

A cubit was an ancient measure of length, being the distance from the elbow to the tip of an outstretched middle finger, Today it is accepted to be 0.4572m.

Going from the area of the circle, estimated at 15,000 square cubits, now using Microsoft Excel, we arrive at an Ark diameter of **63.2m**

Coincidentally almost the same as the diameter of the first round FPSO at the *Piranema* in 2007, which featured a diameter of **64.3m**.

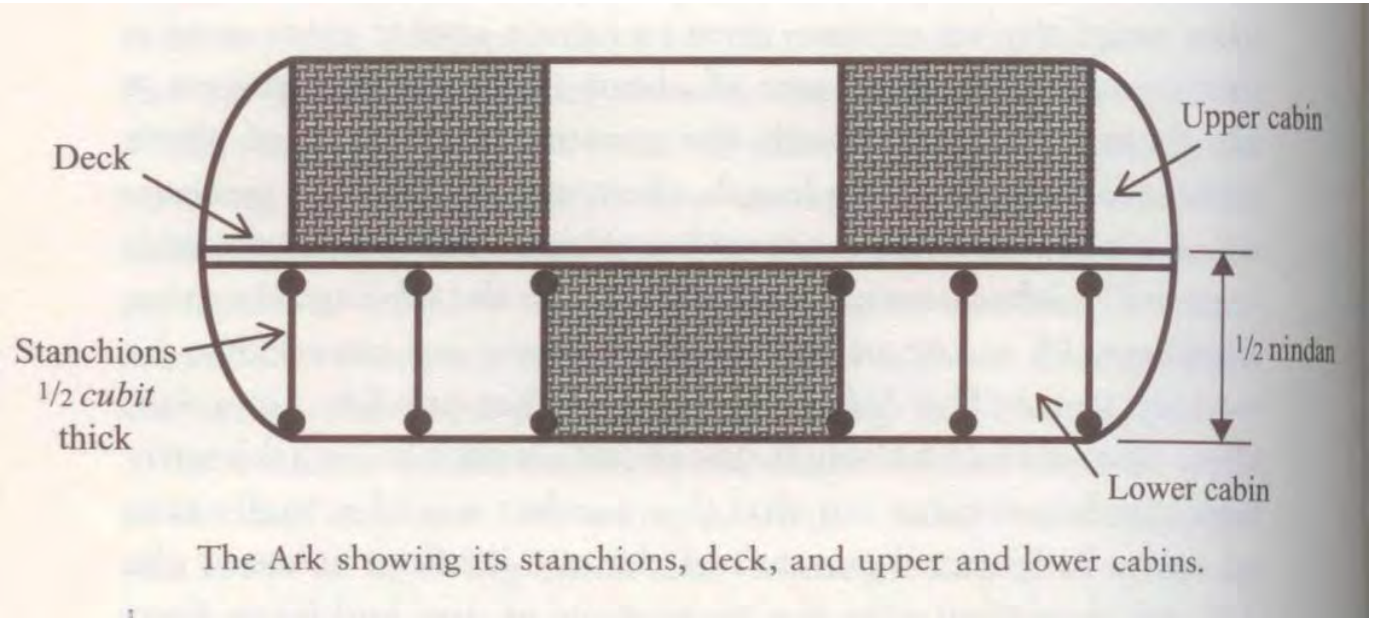
Round Hulls in Antiquity:
The Ark, where the Animals Went in, Two by Two

Dr. Finkel estimates it took 520 kilometers of ropes woven from reeds to help hold the hull components together: quite an industrial operation!

The scale of the Ark must have taken some real talent and inspiration to build.

The book goes into substantial detail of how the Ark had been built, indicating a cross section like this:-

(shown in page 350)



The Ark showing its stanchions, deck, and upper and lower cabins.

Famous Round Hull Designers . . .

Table 2: Round Hulls: History or Coincidence?

Era	Designer	Owner	Application	Diameter, meters
2001-2014	Sevan Marine	Sevan et al	Offshore production (FPSOs), drilling (MODUs), accommodation	**64.3** (First FPSO)
circa 2400 BC	Jehovah / Noah	Noah	Survival of Noah & family plus pairs of animals during the Flood	**63.2**

Question: Do you now think that Sevan might have had divine guidance for building their first round FPSO?

A Side Story:
Why Remains of the Ark Never Been Recovered

The fact that construction of the Ark was with reeds, instead of heavy wood beams as employed later in ships for three millennia, is significant for what might be left of it today.

Despite the fabled resting place of Noah's Ark on Mount Ararat, no heavy wooden ribs, nor the keel of a large wooden hull, have been found there.

Construction using reeds would have rotted away in perhaps a century or two and so nothing would be found today.

Round Hulls in Antiquity and Modern Times:

In ancient Mesopotamia, or Iraq in 1914, hull design changed little in four millennia!

A boatload of ragheads

Quffa- Baghdad 1914

In the era of Lawrence of Arabia, the British Army served in the Middle East: the “Tommies”, referred to the locals as ”ragheads”- you can see why from their headgear in this picture of a river taxi near Baghdad a century ago!

River transport in round hulls like this has been used for a *LONG* time.

“Quaffas” in ancient Mesopotamia, “coracles” in Europe.

The round hull configuration in the tablets was the norm!

Now Back to Round Hulls in Today's World

By 2015, the round hull had accomplished considerable acceptance in the offshore world – not just for FPSO service, but also in dynamically positioned hulls in MODU service, and most recently for offshore accommodation facilities.

The presentation by Sevan Marine at this conference last year cited round-hulled projects either in operation or under construction as:

Six FPSOs;
Four MODUs;
Three accommodation units.

A contracted total of 13 round-hulled vessels committed to offshore service – six more than at the time of the 2012 "Shoot Out".

A remarkable accomplishment, regardless of who thought of the round hull first!

Closing Thoughts to Round Out this Story

1. In the conservative marine world, the rapid acceptance of the round hull for service in the offshore oil and gas business is truly an achievement: thirteen round hulls in service or under construction in less than a decade - a tribute to the persistence and management of Sevan.

2. Noah's achievement in building a round hull more than 60 meters in diameter, with the resources available to him, was a design and project management marvel by today's standards for offshore projects: design, procurement of "ship building" materials, planning and executing the construction.

3. You think on-time delivery is important for an FPSO? Noah could not miss the deadline of the impending flood. All with no PEs, no PMPs, no modern technology: makes one wonder how he did it without extraordinary outside guidance!

4. Now with the precedents of Noah's Ark plus modern day round hulls in offshore service, our civilization may be encouraged to use this hull form even more widely, with patent authorities scratching their heads about prior art on a truly biblical scale.

Acknowledgements

The author is indebted to Dr. Irving Finkel for what he has done to inspire this story. Credit is also due to Sevan Marine for the information quoted here from their conference presentations, to Peter Noble of SNAME for his thoughts on round hulls and The Guardian newspaper of UK for certain information and pictures used here.

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[You can find it on www.lovie.org]

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. . . Thank you . . .

Questions?

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