2012 WORLDWIDE SURVEY OF SUBSEA PUMPING SYSTEMS

STATUS OF THE TECHNOLOGY

MARCH 2012

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POSTER 96

WORLDWIDE LOCATIONS FOR SUBSEA PUMPING, WATER INJECTION, AND SEPARATION SYSTEMS (As of Feb., 2012)

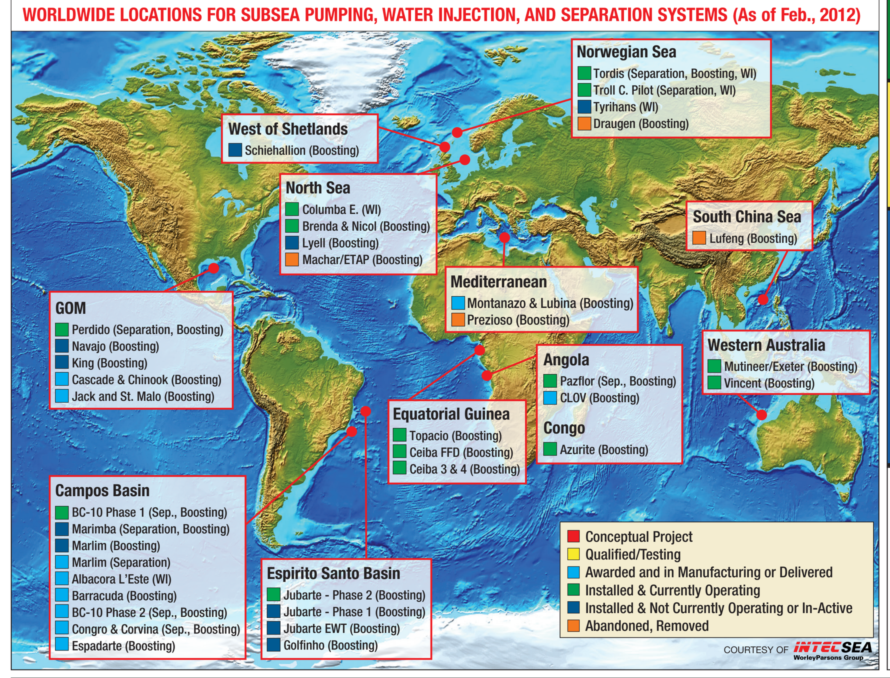


TABLE 1 – 2012 WORLDWIDE SURVEY OF SUBSEA BOOSTING, WATER INJECTION, AND SEPARATION (1)(2)

Processing Discipline	Count	Field or Project (Ordered by Start Date)	Current Status	Comments	Owner/Field Operator – Company	Region/Basins	Water Depth – Meters	Water Depth – Feet	Tieback Distance – Km	Tieback Distance – Miles	System Total Flow Rate (@Line Conditions) – M³/Hr.	MBOPD MBWPD	Differential Pressure – BAR (4)	Differential Pressure – PSI (4)	Unit Power (3) – MW	In-Service/Operating Information – End or Present	Mths	Operational History & Future Operational Schedule
Full Wellstream Subsea Boosting (Note 1. Seabed & riser only, Note 2. Excludes downhole ESPs)	1	Prezioso (20)	A	MPP at Base of Platform	AGIP	Italy	50	164	0.0	0.0	65	10	40.0	580	0.15	1995		
	2	Draugen Field	A	SMUBS Project, 1MPP	A/S Norske Shell	Offshore Norway	270	886	6.0	3.7	193	29	53.3	773	0.75	15-Nov-96	12.2	
	3	Lufeng 22/1 Field (9) (19)	A	Tieback to FPSO	Statoil	South China Sea	330	1,083	1.0	0.6	675	102	35.0	508	0.40	15-Jul-09	138.0	See OTC Paper 20619, page 7
	4	Machar Field (ETAP Project)	A	Hydraulic Turbine Drive	BP Amoco	UK North Sea	85	277	35.2	21.9	1,100	166	22.0	319	0.65	Never Installed		
	5	Topacio Field	O	1 x Dual MPP System	ExxonMobil	Equatorial Guinea	500	1,641	9.0	5.6	940	142	35.0	508	0.86	1-Mar-12	138.2	
	6	Ceiba C3 and C4	O	Phase 1 SS MPP Project	Hess	Equatorial Guinea	750	2,461	7.5	4.7	600	91	45.0	653	0.84	1-Mar-12	112.3	
	7	Jubarte EWT	I, N	Riser lift to Seillean drillship	Petrobras	Espirito Santo Basin	1,400	4,593	1.4	0.9	145.0	22	140.0	2,000	0.70	1-Dec-05	35.9	
	8	Ceiba Full Field Development	O	Full Field Development (FFD)	Hess	Equatorial Guinea	700	2,297	7.5	4.7	2,500	378	45.0	580	1.20	1-Mar-12	98.3	
	9	Mutineer / Exeter	O	2 x Single MPP Systems	Santos	NW Shelf, Australia	145	476	7.0	4.3	1,200	181	30.0	435	1.10	1-Mar-12	83.4	
	10	Lyell	I, N	SS Tieback to Ninian South	CNR	UK North Sea	146	479	15.0	9.3	1,100	166	18.0	261	1.60	Dec-06	11.0	Non Operational
	11	Navajo (17)	I, N	ESP in Flowline Riser	Anadarko	GOM	1,110	3,642	7.2	4.5	24	4	40.2	583	0.75	1-Aug-07	5.5	Non Operational
	12	Jubarte Field - Phase 1	I, N	Seabed ESP-MOBO, Uses BCSS (14)	Petrobras	Espirito Santo Basin	1,350	4,429	4.0	2.5	120	18	138.0	2,002	0.90	Aug-07	5.0	
	13	Brenda & Nicol Fields	O	MultiManifold with 1 MPP	OILEXCO N.S.	UK North Sea	145	476	8.5	5.3	800	121	19.0	276	1.10	1-Mar-12	58.4	
	14	King (7) (13)	I, N	SS Tieback to Marlin TLP	BP	GOM, MC Blocks	1,700	5,578	29.0	18.0	497	75	50.0	725	1.30	15-Feb-09	15.0	Non Operational
	15	Vincent	O	Dual MPP System	Woodside	NW Shelf, Australia	470	1,542	3.0	1.9	2,700	408	28.0	406	1.80	1-Mar-12	19.0	
	16	Marlim	I, N	SBMS-500 SS Field Test	Petrobras	Campos Basin	1,900	6,234	3.1	1.9	500	75	60.0	870	1.20		0.0	Non-operational due to poor well performance (excessive water)
	17	Golfinho Field	I, N	Seabed ESP-MOBO, Uses BCSS (14)	Petrobras	Espirito Santo Basin	1,350	4,429			146	22	138.0	2,002	1.10		0.0	Non-operational due to poor well performance (excessive water)
	18	Azurite Field	O	Dual MPP System	Murphy Oil	Congo, W. Africa	1,338	4,390	3.0	1.9	920	139	42.0	609	1.00	1-Mar-12	17.5	
	19	Golfinho Field	I, N	Four BCSS Caissons (14)	Petrobras	Espirito Santo Basin	1,350	4,429			146	22	138.0	2,002	1.10		0.0	Not yet operational at press time
	20	Espadarte	M	Horizontal ESP on Skid	Petrobras	Brazil	1,350	4,429			125	19	100.0	1,450	0.90			
	21	Parque Das Conchas (BC 10) Phase 1 (23)	O	Caisson/Artificial Non-Separated	Shell	Campos Basin	2,150	7,054	9.0	5.6	185	28	152	2,205	1.10	1-Mar-12	31.5	
	22	Jubarte Field – Phase 2 (8)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		0.0	
	23	Cascade & Chinook (6)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		0.0	Pump installation expected Q3, 2012
	24	Barracuda	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
	25	Montanazas & Lubina	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
	26	Schiehallion	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Delayed Start Up		Pending FPSO rebuild
	27	CLOV (22)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
	28	Jack & St. Malo	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Water Injection Subsea Pumps	1	Troll C Pilot (15)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1-Mar-12	125.9	
	2	Columba E.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1-Mar-12	57.4	
	3	Tordis	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1-Mar-12	53.0	See OTC paper 20619, page 16
	4	Albacora L'Este Field	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			Awaiting installation, Framo ex-works Sept 09
	5	Tyrihans	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			Installed in May 2010; Restart undefined
Subsea Separation and Boosting	1	Troll C Pilot (15) (21)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1-Mar-12	125.9	
	2	Marimba Field (18)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1-Jul-08	83.8	Non-operational; Restart undefined
	3	Tordis	O	(12), Separation, Boosting, WI	Statoil	Offshore Norway	210	689	11.0	6.8	1,250	189	27.0	392	2.30	1-Mar-12	52.4	See OTC paper 20619, page 16
	4	Parque Das Conchas (BC 10) Phase 1 (23)	O	Sep. Caisson/Artificial Lift Manifold	Shell	Campos Basin	2,150	7,054	25.0	15.6	185	28	152.0	2,205	1.10	1-Mar-12	30.5	
	5	Perdido	O	Caisson Separation and Boosting	Shell	US GOM	2,438	7,999	0.0	0.0	132-264	20-0	158.8	2,303	1.20	1-Mar-12	23.0	
	6	Pazflor (5)	O	3 Gas/Liq. Vert. Separation Sys.	Total	Angola, Blk 17	800	2,625	4.0	2.5	1,800	272	90.0	1,305	2.30	1-Mar-12	6.2	
	7	Marlim	M	In-Line Separation	Petrobras	Campos Basin	878	2,881	3.8	2.4	135	20	245	3,553	1.9			Installation Scheduled for Q1, 2012
	8	Congro (24)	M	VASPS (10) w/Horizontal ESP	Petrobras	Campos Basin	197	646	11.0	7.0	135	20	21	305	0.4			
	9	Parque Das Conchas (BC 10) Phase 2 (23)	M															
	10	Corvina (24)	M	VASPS (10) w/Horizontal ESP	Petrobras	Campos Basin	280	919	8.0	5.0	135	20	21	305	0.4			

Subsea separation and boosting rows 3–10, continued:

Count	Field	Gas Volume Fraction (5) – % of Vol.	System Package – Company	No. of Pumps	Pump Type	Pump Manufacturer	Start (11)
3	Tordis	10-68%	FMC Technologies	1+1 Spare	Helico-Axial	Framo Engineering	Oct-07
4	Parque Das Conchas (BC 10) Phase 1	15%	FMC Technologies	4+2 Future	ESP	Baker Hughes Centrilift	Aug-09
5	Perdido	15%	FMC Technologies	5	ESP	Baker Hughes Centrilift	Mar-10
6	Pazflor	<16%	FMC Technologies	6+2 Spare	Hybrid H-A	Framo Eng./FMC Tech.	Aug-11
7	Marlim	0	FMC Technologies	1	Centrifugal (1P)	Framo Eng./FMC Tech.	Q1, 2012
8	Congro	<10%	FMC Technologies	1	ESP	Baker Hughes Centrilift	Q4, 2012
9	Parque Das Conchas (BC 10) Phase 2		FMC Technologies	4	Centrifugal (1P)	Baker Hughes Centrilift	
10	Corvina	<10%	FMC Technologies	1	ESP	Baker Hughes Centrilift	Q4, 2012

← HISTORICAL — PRESENT — FUTURE →

CURRENT STATUS CATEGORIES
- C Conceptual Project
- Q Qualified/Testing
- M Awarded and in Manufacturing or Delivered
- O Installed & Currently Operating
- I,N Installed & Not Currently Operating or In-Active
- A Abandoned, Removed

TIMELINE CATEGORIES
- Operating
- Installed & Not Operating or In-Active
- Future – Anticipated Operational Period

NOTES:
1. See information accuracy statement below title block and note that the qualification status categorizations shown in this table, and throughout the poster, are based on unverified claims from equipment suppliers and field operators. These qualification status designations are not necessarily derived using technology readiness level (TRL) assessments per API RP 17Q or DNV-RP-A203.
2. The terms 'pumping' and 'boosting' are used interchangeably throughout this poster and in the industry.
3. Pump power listed is the power required to run a single pump.
4. Differential Pressure values are for individual pumps.
5. **GVF** = Gas Volume Fraction at inlet of pump.
6. **Cascade & Chinook** – Utilizes a horizontal ESPs on a skid above mudline. It is an alternative ESP boosting configuration to caisson in the seabed. This technology is designed to cover the low GVF and high DeltaP multiphase flow.
7. **King** utilizes an umbilical which combines HV cables with the service umbilical.
8. **Jubarte Field (Phase 2)** – Installed in 2011; Wells connected to the FPSO P-57. All wells to have gas-lift as a backup.
9. Low wellhead pressure of 100 psig at seabed dictated that artificial lift was required.
10. **VASPS** – Vertical Annular Separation and Pumping System
11. Year indicates first year of operation for the SS processing system.
12. **Tordis Field:** 1+1 Spare Multiphase Boosting Pumps, and 1+1 Spare Water Injection Pumps; Tieback to Gullfaks C platform. Statoil hopes to increase oil recovery from 49% to 55%, an additional 36 MMBO, due to the world's first commercial subsea separation, boosting, injection and solids disposal system.
13. According to BP in Feb., 2010: "Two King pump units are installed in the field but remain shut-in due to operational issues, or capacity constraints at the Marlin TLP related to additional production from the Dorado field and King South well. One King pump is currently being repaired and upgraded."
14. **BCSS** – Centrifugal Subsea Submersible Pumps. Pumps are placed in protective holes in the seabed, 200m from the producing wells. **MOBO** – Modulo de Bombas (Pumping Module).
15. **Troll SUBSIS** – The world's longest operating subsea separation system and first subsea water injection pump system.
16. Manufacturers are: Framo Engineering and Centrilift. There are 2 ESPs per well feeding Framo MPP on seafloor.
17. **Navajo Field** is a SS tieback to Anadarko's Nansen spar.
18. **Marimba VASPS** – 2000 - First installation in Marimba (JIP Petrobras / Eni-Agip/ ExxonMobil, 2001 - Startup and Operation (July to Dec.) until ESP failure, 2002 End of JIP, By-pass production, 2003 - Workover Plan (IWP), 2004 - Workover and Re-start on May 8, 2004. From 2005 until 2008 VASPS operated well until well failure.
19. **Lufeng** – Closed down due to field economics, after 11 years of operation.
20. **Prezioso** – World's first deployment of an electrically driven twin screw MPP operating on a live well. Testing occurred in 1994 and 1995 for a total of 7,850 hours of operation at base of platform on seafloor.
21. **Troll C Pilot** – Separation began on Aug. 25, 2001. See OTC paper 20619, page 10 for further details on operating experience. Note that injection pump data is only shown in the subsea water injection section of the table.
22. **CLOV** – Total reports that the CLOV development will utilize seabed multiphase pumps to boost Cravo, Lirio, Orquidea and Violeta Miocene from First Oil + 2 years.
23. **Parque Das Conchas (BC 10) Phases 1 & 2** – Composed of 3 reservoirs: Ostra, Abalone and Argonauta B-West. Argonauta O-North to be added in Phase 2.
24. **Congro** and **Corvina** are two fields developed as one project.

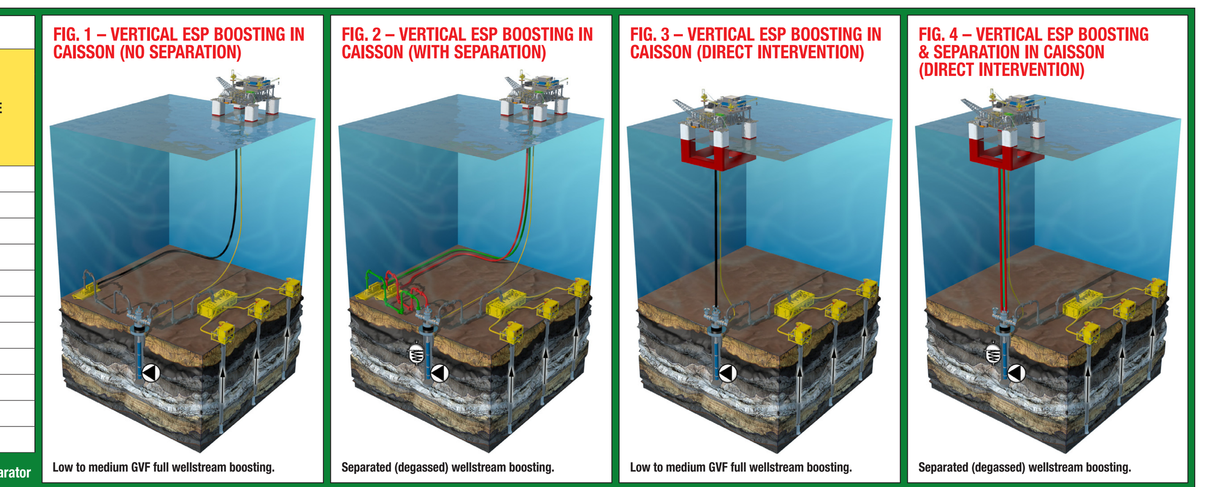
COURTESY OF INTECSEA WorleyParsons Group

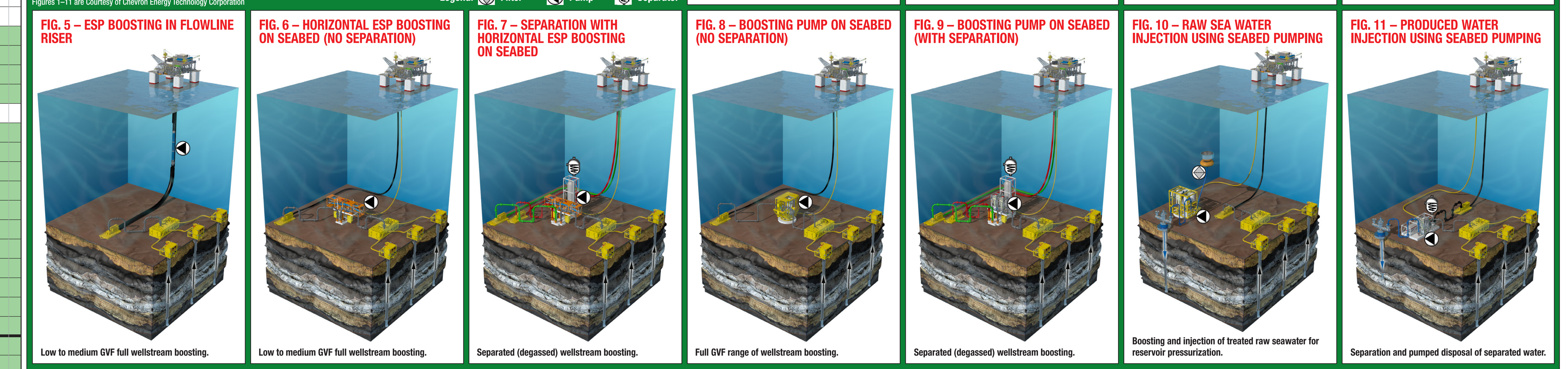
TABLE 2 – SUBSEA BOOSTING METHODS/CONFIGURATIONS

Fig. No.	Service	Pump Type & Configuration	Location: Seabed Caisson	Location: @ Mud Line	Location: In Riser	Separation: Separated	Separation: Non-Separated	Intervention: Direct Vertical (Rig) Access	Intervention: Intervention Vessel	Project Reference
1	Wellstream Oil Boosting	Vertical ESP	●				●		●	BC-10/Jubarte
2	Wellstream Oil Boosting	Vertical ESP	●			●			●	BC-10
3	Wellstream Oil Boosting	Vertical ESP	●				●	●		NA
4	Wellstream Oil Boosting	Vertical ESP	●			●		●		Perdido
5	Wellstream Oil Boosting	Vertical ESP			●		●	●		Navajo
6	Wellstream Oil Boosting	Horizontal ESP (Slant)		●			●		●	Espadarte/Cascade-Chinook
7	Wellstream Oil Boosting	Horizontal ESP (Slant)		●		●			●	Congro-Corvina
8	Wellstream Oil Boosting	Various (see Table 6)		●			●		●	Ceiba/Lufeng/Lyell/King
9	Wellstream Oil Boosting	Various (see Table 6)		●		●			●	Pazflor
10	Raw Water Injection Pumping	Centrifugal Pump		●		Filtration			●	Columba-E/Tyrihans/Albacora
11	Local Re-injection of Produced Water	Centrifugal Pump		●		●			●	Troll/Tordis

Figures 1–11 are Courtesy of Chevron Energy Technology Corporation

Legend: Filter, Pump, Separator





UMBILICAL CROSS SECTIONS

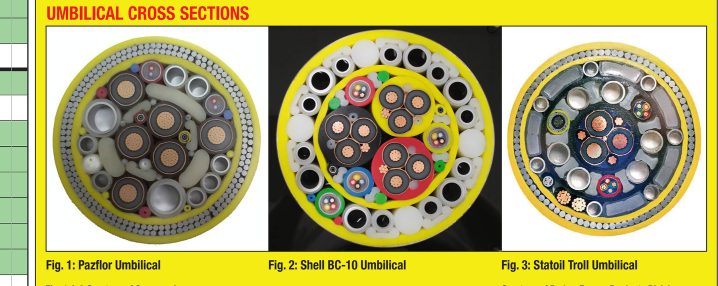
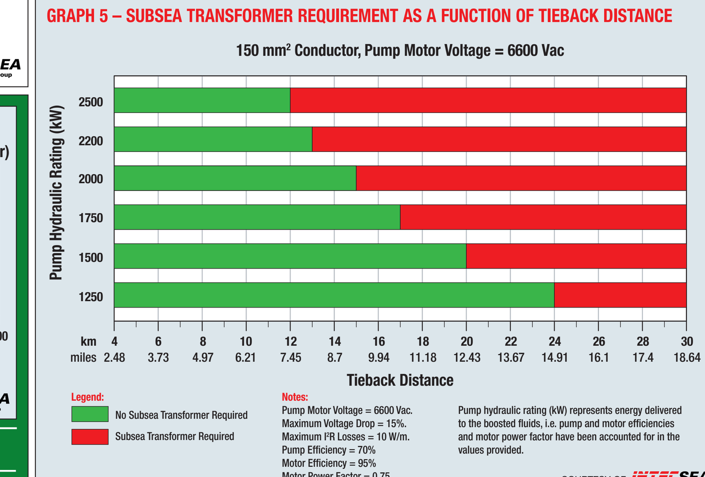


Fig. 1: Pazflor

AC Power Systems and Subsea Transformers

GRAPH 5 – SUBSEA TRANSFORMER REQUIREMENT AS A FUNCTION OF TIEBACK DISTANCE



TYPICAL PRODUCTION AND PUMPING SYSTEMS TOPSIDES SUPPORT EQUIPMENT ON HOST

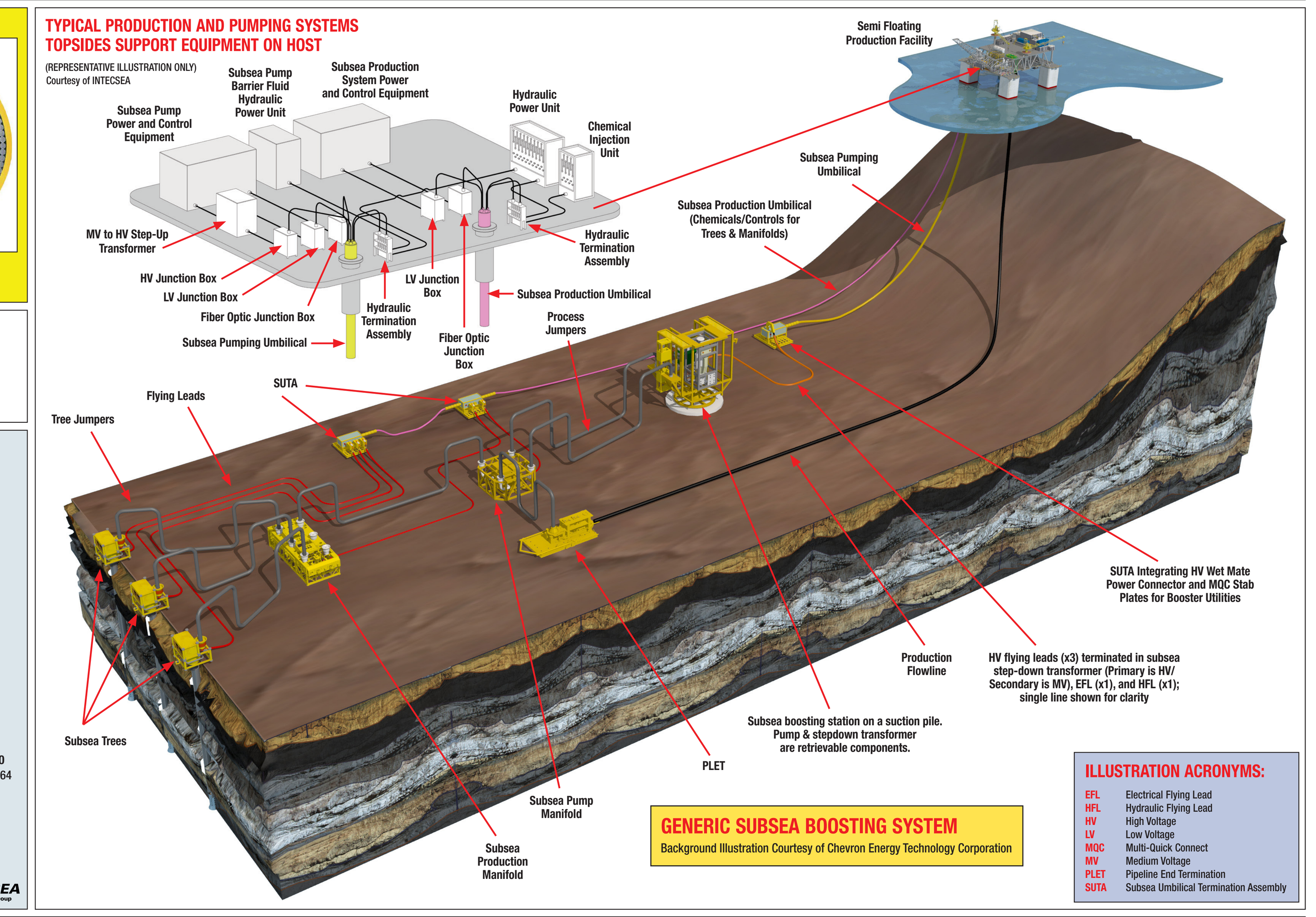
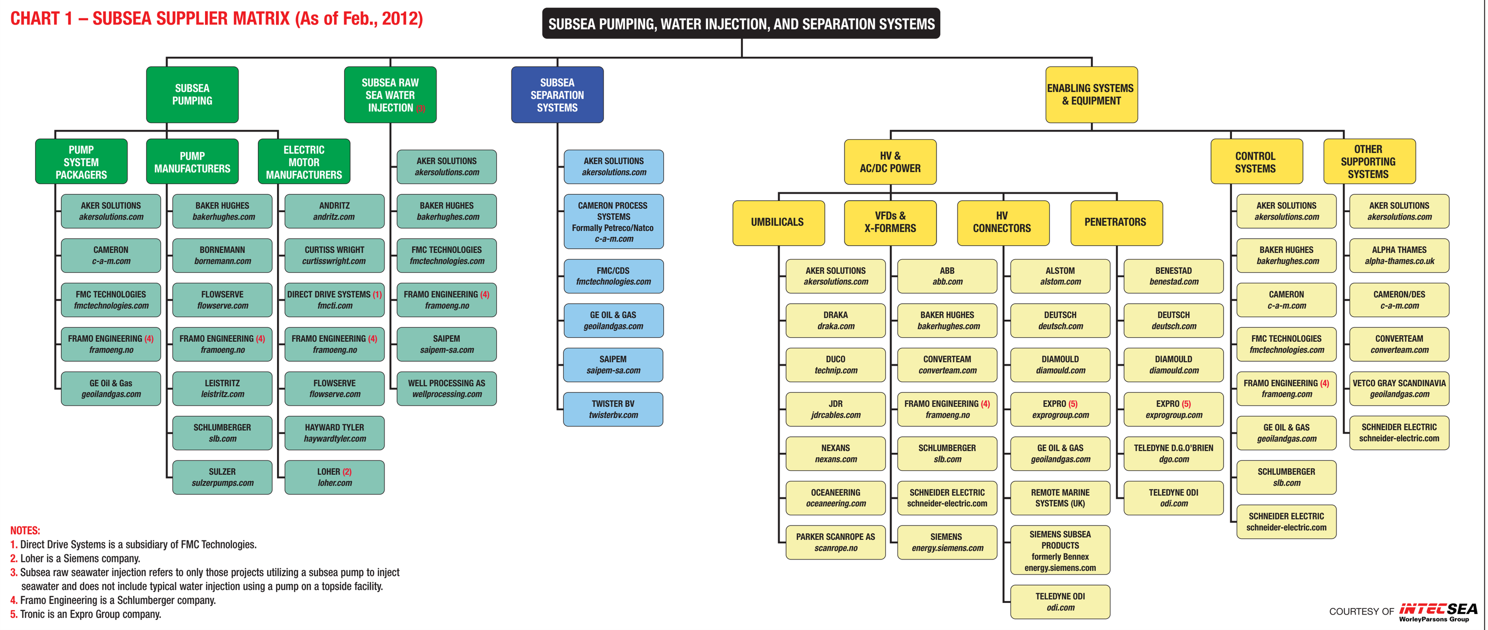


CHART 1 – SUBSEA SUPPLIER MATRIX (As of Feb., 2012)



GRAPHS 1A, 1B, 1C – SUBSEA BOOSTING POTENTIAL

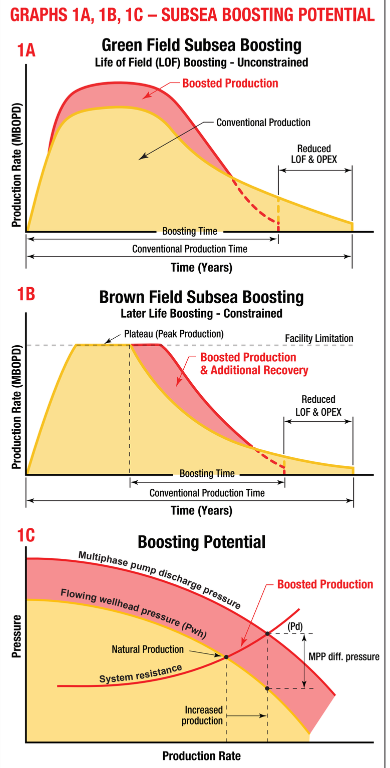


TABLE 3 – OTHER INFORMATION RESOURCES

TABLE 4 – DRIVERS/REASONS FOR:

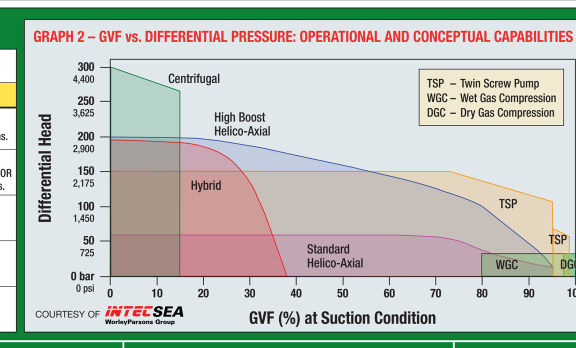
TABLE 5 – INDUSTRY ACRONYMS & ABBREVIATIONS

SUBSEA BOOSTING PUMP TYPES

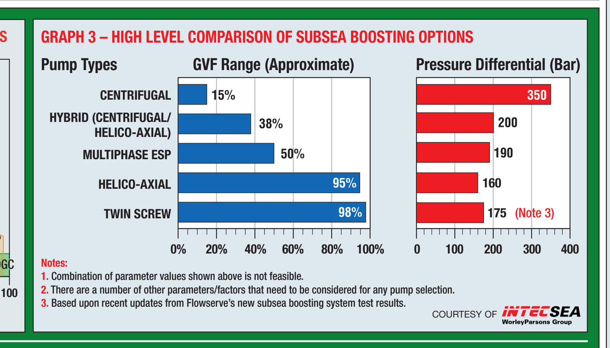
TABLE 6 – PUMP TYPES & APPLICATIONS

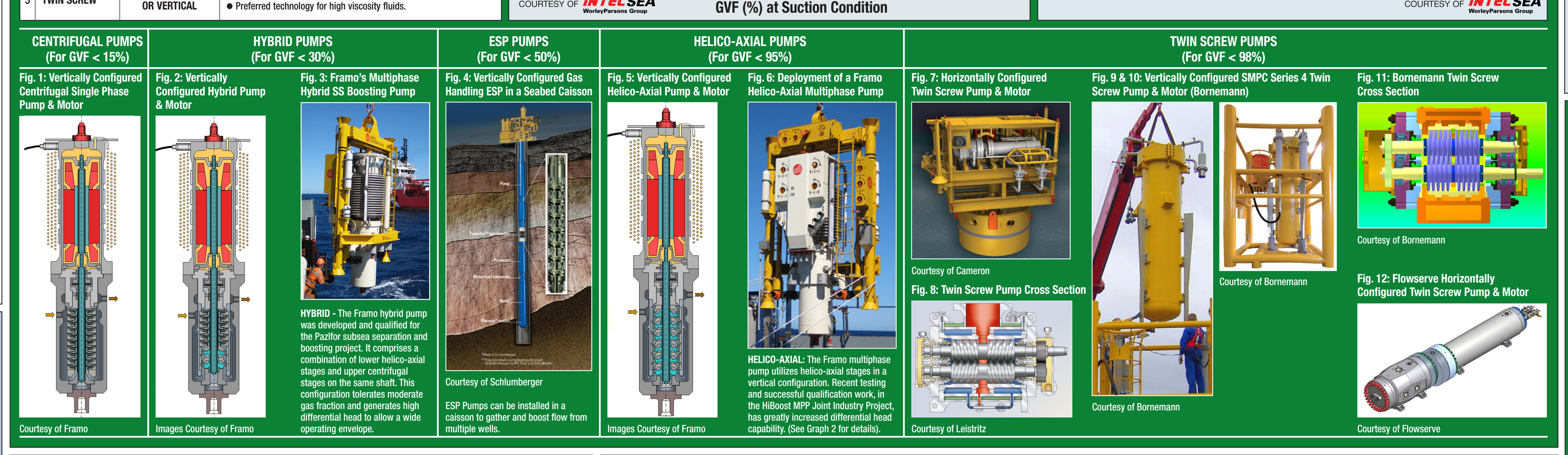
	Type	Normal Config.	Application
1	CENTRIFUGAL	HORIZONTAL OR VERTICAL	● Highest differential pressure capability among pump types. ● Handles low Gas Volume Fraction (GVF) < 15% at suction conditions.
2	HYBRID (CENTRIFUGAL & HELICO-AXIAL)	VERTICAL	● Combination of helico-axial and centrifugal impeller stages ● Primary application is for use downstream of separator or in low GOR [illegible]
3	ESP	HORIZONTAL OR VERTICAL	[illegible]
4	HELICO-AXIAL	VERTICAL	[illegible]
5	TWIN SCREW	HORIZONTAL OR VERTICAL	[illegible]

GRAPH 2 – GVF vs. DIFFERENTIAL PRESSURE: OPERATIONAL AND CONCEPTUAL CAPABILITIES

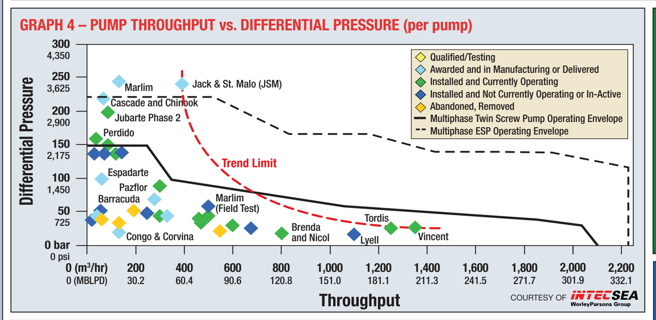


GRAPH 3 – HIGH LEVEL COMPARISON OF SUBSEA BOOSTING OPTIONS

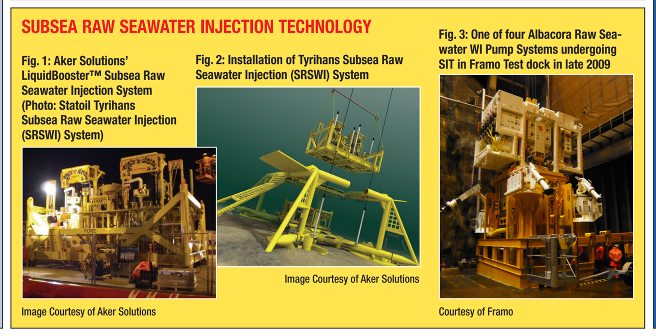




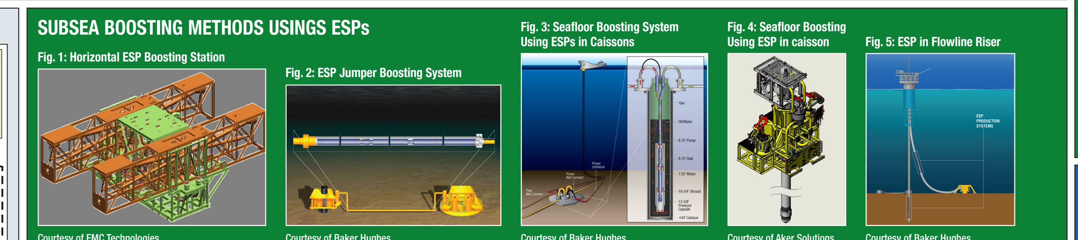
GRAPH 4 – PUMP THROUGHPUT vs. DIFFERENTIAL PRESSURE (per pump)



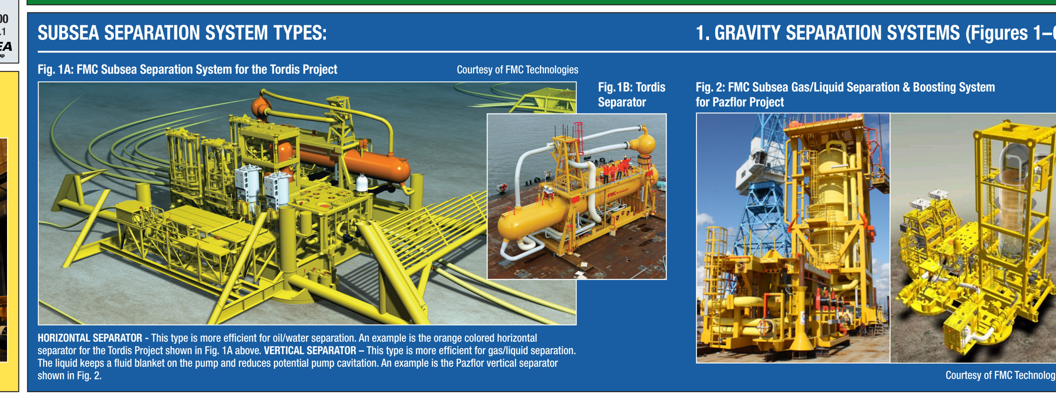
SUBSEA RAW SEAWATER INJECTION TECHNOLOGY



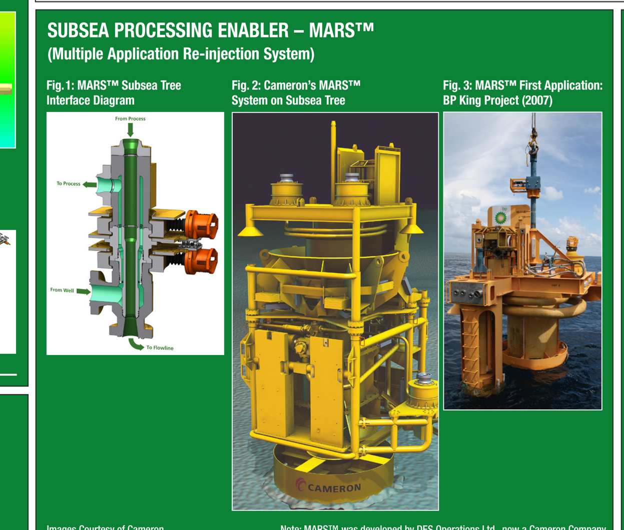
SUBSEA BOOSTING METHODS USINGS ESPs



SUBSEA SEPARATION SYSTEM TYPES:



SUBSEA PROCESSING ENABLER – MARS™



SUBSEA MULTIPHASE BOOSTING SYSTEMS BY COMPANY (Delivered & Conceptual)