Hydrates Risk Assessment On Deepwater Fields Following Long Unplanned Shutdown

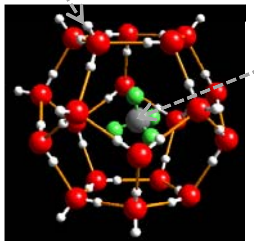
Christophe CANDELIER
Co-Author Thierry SAINT-PIERRE
TOTAL E&P

TOTAL
Committed to Better Energy

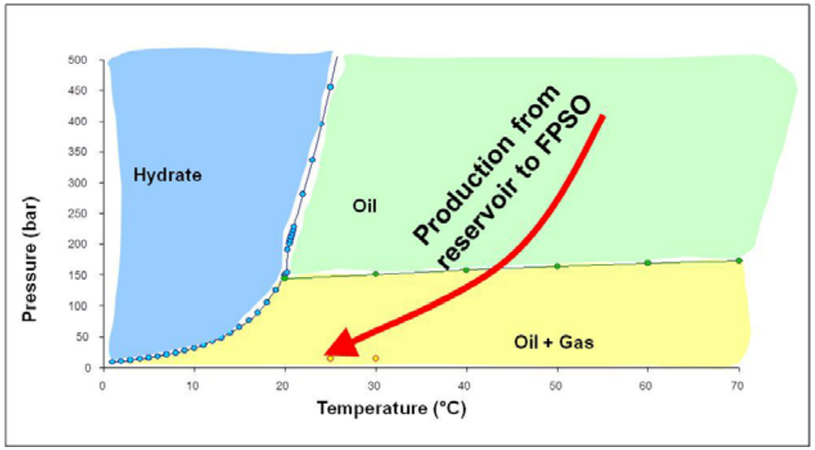
MCEDD
DEEPWATER DEVELOPMENT

What are hydrates ?

Water molecule “cage”



Gas molecule



- Gas inclusions into structures of water molecules
  - Solid crystals looking like compact snow or porous ice
  - Formed at low temperature and high pressure
- Critical components
  - Light hydrocarbon: C1, C2, C3, C4
  - Acid gases: CO_2, H_2S

  & only these !
- To form hydrate in production lines, 4 conditions are required
  - Low temperatures and high pressure
  - Presence of free water (free, dissolved or emulsified)
  - Presence of light hydrocarbons (free, dissolved)
  - Mixing – Energy

  If one of the 3 missing ➔ No hydrates
- Line plugging due to hydrates = undesirable outcome in Deepwater
  - Function of hydrocarbon nature
  - Production line bathymetry & operating conditions
  - Phases present
  - Etc.

MCEDD DEEPWATER DEVELOPMENT

TOTAL Committed to Better Energy

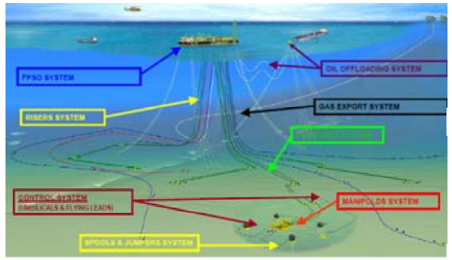
The facts !

- Several deepwater fields have experienced unplanned shut-down with durations exceeding the hypothesis selected for project design
  - Due to several constraints, subsea preservation sequence was not launched as per field procedures
  - Long shut-downs duration : more than 20 hours for all sites

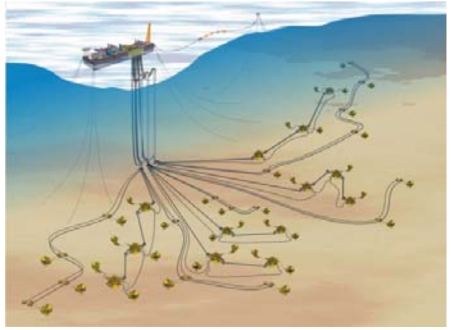
- FIELD A – April 2014 – ESD0
  - Preservation of the X tree and jumpers after 30 hours
  - Anhydrous line restarted to warm-up line before circulating Dead Oil

- FIELD B – November 2014 – Several consecutives ESD during 5 days
  - Three loops circulated with dead oil > 2 days after shut-down
  - One loop restarted without preservation 4 days after shut-down

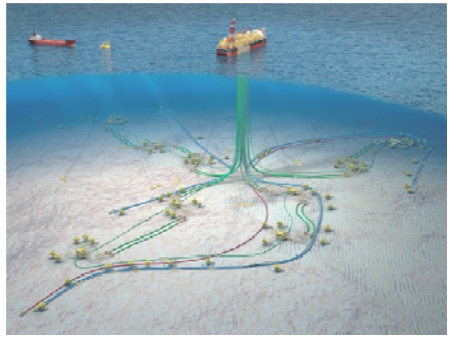
- FIELD C – February 2013 – ESD0
  - Preservation of Xtree and jumper > 20 hours after shut-down
  - Dead oil circulated after 27 hours
  - Line restarted without preservation after 27 hours
  - PI server down (monitoring system)



FIELD A



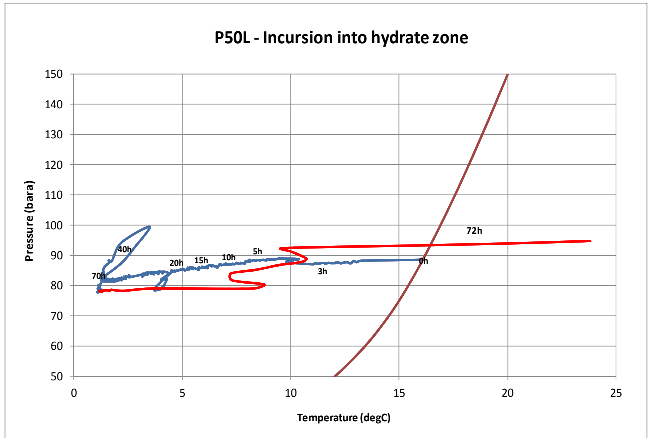
FIELD B



FIELD C

Site observations during ESD events

- Preliminary analysis by field operations team indicated that the manifolds, jumpers entered into the hydrate risk zone
  - Based on subsea P&T sensors installed and available
  - Only <u>**local**</u> information with regard to hydrates risks status – Sensors at manifold and Wellheads



FIELD B – P&T @ manifold agaisnt hydrates curves
Left branch

	Steady State Fluid data (before SD)				During Shutdown - *do the facilities enter into the HYD risk zone?* *(Preliminary. Analysis by TEPNG)*			Restart
	Q_{liq} (blpd)	BSW (%)	GOR (Sm3/Sm3)	PW Salinity (g/l)	Wellheads	Jumpers	Manifolds	
P10L	15,000	0%	340	*NA*	YES	YES	NO	- Depressurization of R branch - L branch well(s) started to warm up branch - SD & Depressurization of L branch - DO Circ (L - R)
P10R	35,818	45%	331	*NA*	YES	YES	NO	
P20L	26,220	18%	329	*NA*	YES	YES	NO	- Depressurization of L and R branches - DO Circ (L - R)
P20R	39,063	36%	565	*NA*	YES	YES	NO	
P30L	28,630	27%	484	*NA*	YES	YES	*YES-MP31L	- Depressurization of L branch - R branch well(s) started to warm up branch - SD & Depressurization of R branch - DO Circ (R - L)
P30R	13,900	0%	426	*NA*	YES	YES	*YES-MP31R	
P40L	30,303	1%	917	*NA*	YES	YES	NO	- Both branches warmed up (wells restart) - Depressurization of both branches - DO Circ (L - R)
P40R	23,838	1%	998	*NA*	YES	YES	NO	

FIELD A – P&T conditions in the different production loops

No evidence of hydrates plugs
Successful restart of the production lines

We were lucky !! Hydrate formed but did not plug the line

We were not exposed to hydrate risk in the production line !!!

MCEDD DEEPWATER DEVELOPMENT

TOTAL Committed to Better Energy

Why initiative to run a REX ? Objectives of the REX

- Following successful restarts of the production lines, two different visions in Company
  - Optimistic vision:
    - **Hydrates are a myth !!!!**
    - Preservation is useless. No need to preserve the production line in case of future shutdowns
  - Cautious vision:
    - **We were not exposed to hydrates risk in the production lines, but only at manifolds, jumpers and Xtrees - Cold spots of each production network**
    - May be are we over designing our equipment and **design covers 20 years operations**
    - Site took the right operational decision

Difficult to conclude who is right without advanced analysis of the events ...

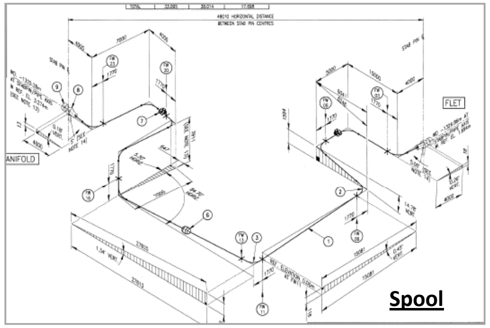
- REX initiative launched by Head Quarter end of 2014 - Multidisciplinary study (Hydrates, flow modelling, operations, Etc.)

- Main objectives of the REX
  - Get a clear and confident overview of the P & T conditions observed in the overall production network during the different ESDs.
  - **Evaluate the exposure to hydrates in the whole production network and avoid too fast and easy shortcuts based on site observations during restart**
  - **Propose improvements to the operating procedures considering present operating conditions (High Water Cut, Etc.),**
  - **Identify potential improvements to the design philosophy – Lean design !!!!**

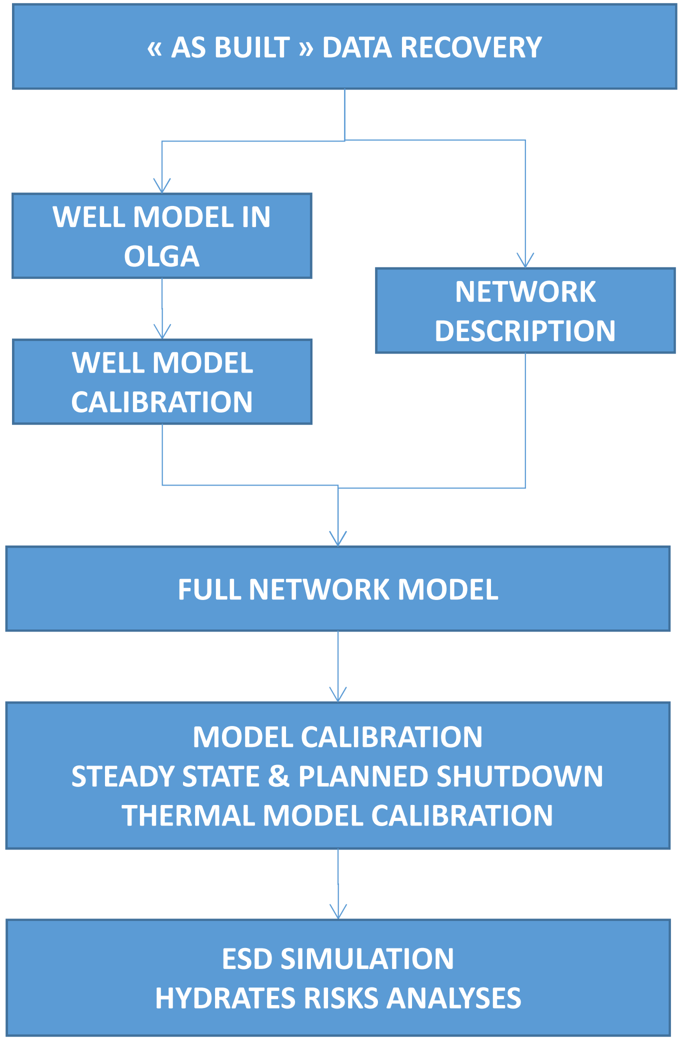
Methodology

- Selection of the subsea system of highest interest / highest anticipated exposure to hydrates for each field
    - *<u>Example: FIELD B –Main - P50 :</u>* Restarted without preservation 4 days after shut-down,
    - *<u>Other example: FIELD A:</u>* Long static cool-down (30 hrs) and preservation with adjusted procedures.

- Develop advanced, rigorous and representative models of the subsea networks
    - Production well included in the model to cover restart
    - Cold spots included in the model
        - Spools, and FLETs
        - Manifolds (***<u>holding the sensors on site</u>***)
        - Etc.
    - “As built” geometry to capture liquid accumulation in low points
    - Advanced thermal model for complex geometries (Bundle, Riser)

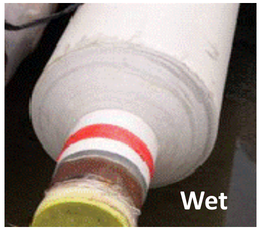


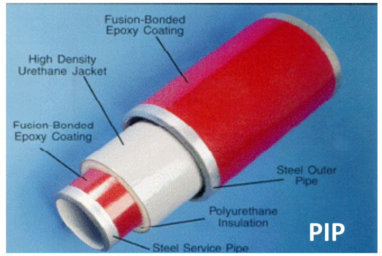
- Specific “step by step” validation / tuning approach against production data
    - Well calibration (Productivity Index, WHFP, WHFT, WHSIP)
    - Steady state, planned shutdown with Dead oil circulation
    - *<u>Main objective:</u>* get confidence in model results and reduce uncertainties



Substantial effort in developing the models
Main challenge: Get accurate data

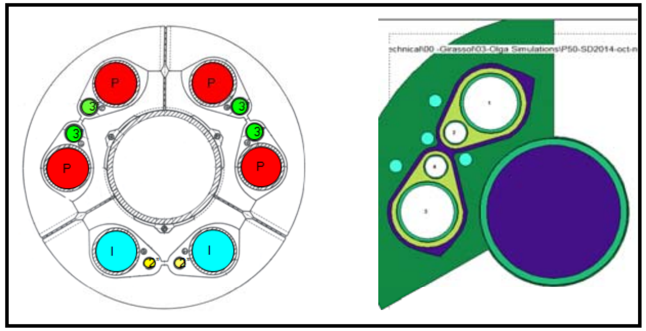
Thermal modeling – A key in the REX !





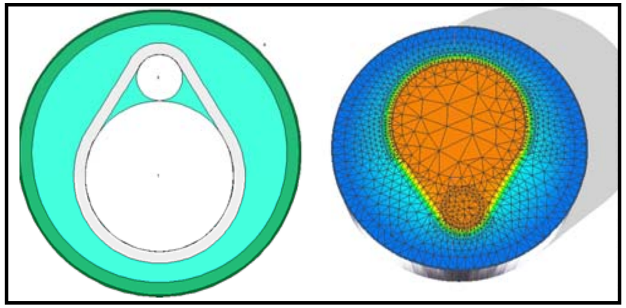
- No major challenge for FIELD A and FIELD C production network
  - Well-known equipment easy to simulate
  - Wet insulation for FIELD A & PIP system for FIELD C
  - Ageing of material taking into account

- FIELD B network – Complex production bundles with non negligible thermal coupling between the different lines and high thermal inertia
  - FIELD B – Main : 2 bundles
    - Bundle of production lines in the flowline
    - Bundle of Gas Lift and production lines in the Riser
  - FIELD B - Bis: Bundle of Gas Lift and production lines in the BHOR

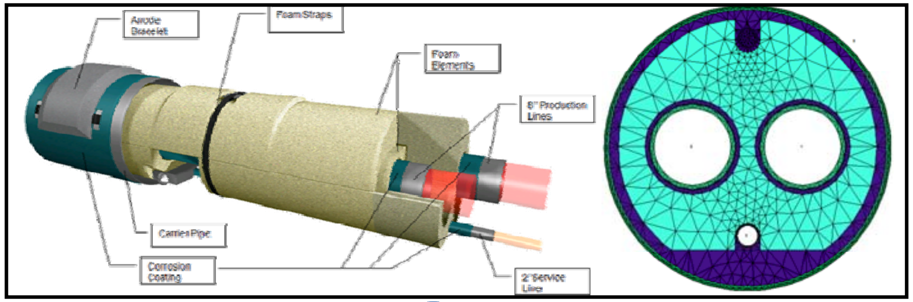


FIELD B – Main - Production riser

- FEMTherm module used in Olga to get a representative thermal coupling between the production lines in production and during shutdown



FIELD B – Bis Production riser

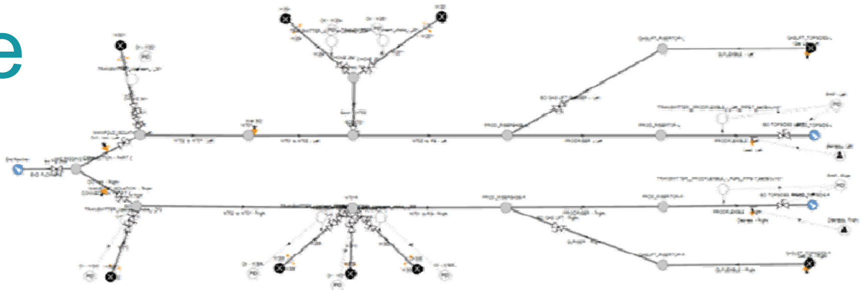


FIELD B - Main production bundle

MCEDD DEEPWATER DEVELOPMENT

TOTAL Committed to Better Energy

Overview of model calibration phase



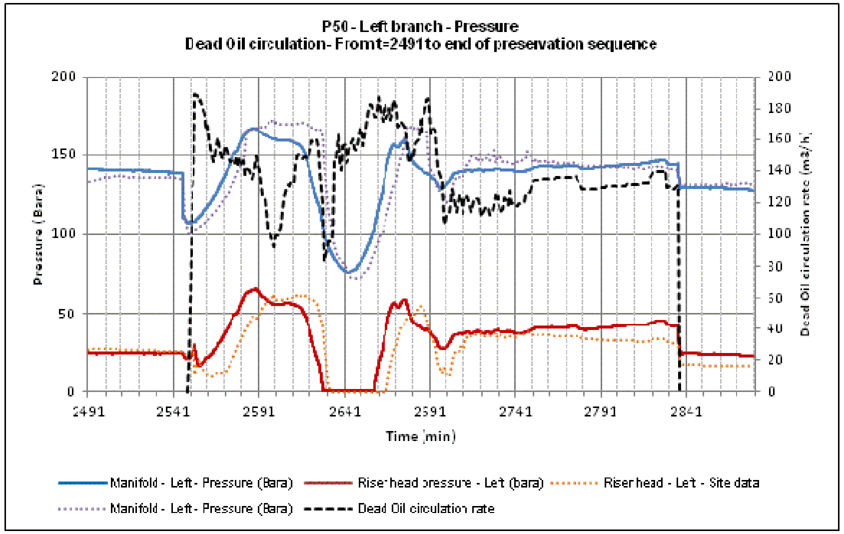
- Different "usual" operations on site simulated using Olga® software
  - Production line depressurizations
  - Dead oil circulations
  - Static Cool Down
  - Production restarts

Get confidence in Olga model prediction
Justified as historian server (PI – Monitoring system) offline during some ESD events

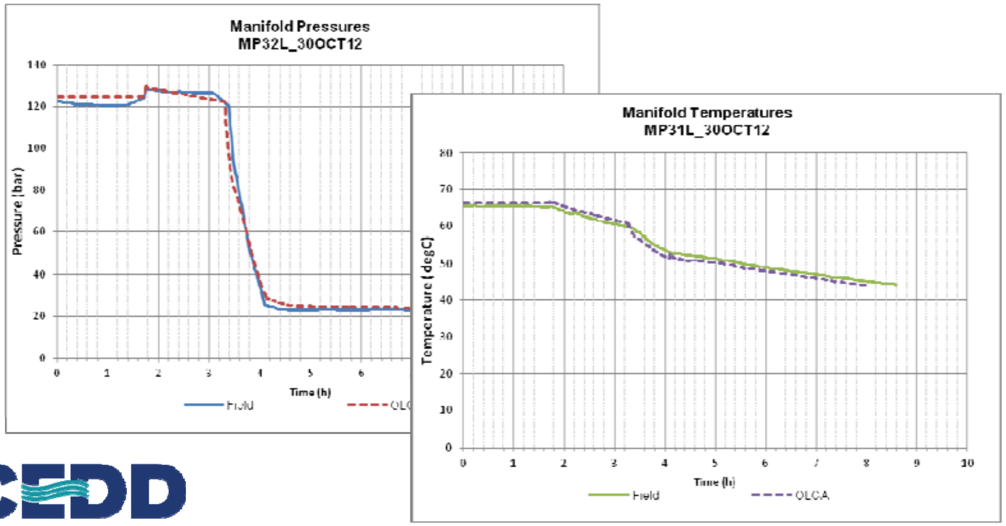
Pressure (bara)	RIGHT BRANCH		
	Field	OLGA	Deviation
M – 302-1	69.54	70.95	2.03%
M – 302-2	70.63	71.62	1.4%

Temperature (°C)	RIGHT BRANCH		
	Field	OLGA	Deviation
M – 302-1	51.06	49.5	-3.06%
M – 302-2	No sensor	N/A	N/A
U/S T. Choke	43.28	42.64	-1.48%

FIELD C – Steady state



FIELD B – Main – Dead Oil circulation



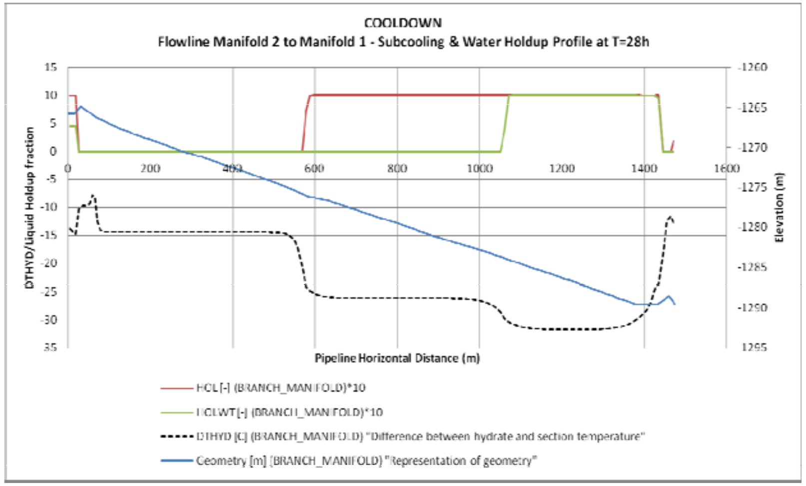
FIELD A – Shutdown & depressurization

MCEDD DEEPWATER DEVELOPMENT

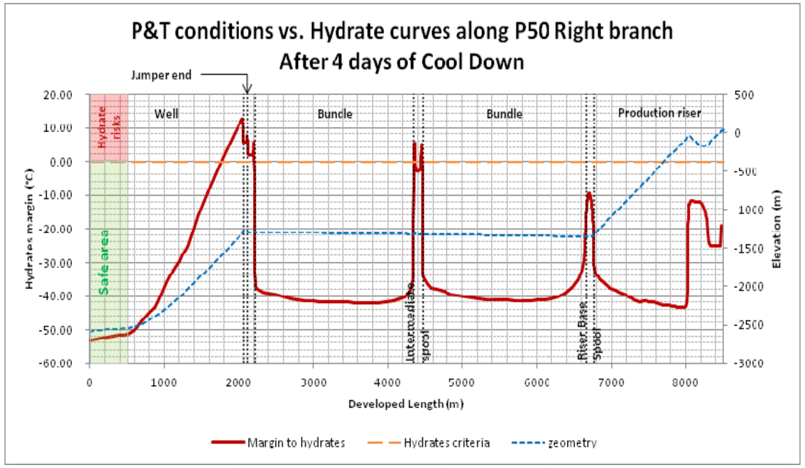
TOTAL Committed to Better Energy

ESD events assessment

- Good performances of the thermal insulation on all the production sites
- Fluid segregation at shut-down was beneficial
- Careful procedures implemented on sites ➔ Contribute to the positive results
  - *FIELD A :* Depressurization in 5 hours instead of 2 hours,
  - *FIELD B – Main :*
    - Depressurization (20 – 30 bar savings with Riser Base Gas Lift injection)
    - Restart supported with RBGL to operate the production network at low pressure
  - *FIELD C :* Restart supported Riser Base Gas Lift to operate the production network at low pressure
- No significant ingress in the hydrates region
  - Efficient passive thermal insulation on the production lines
  - High Water Cut operating conditions ➔ High thermal inertia offering long Cool Down
  - Xmas tree and Jumper exposed to hydrates risks further mitigated by injection of MeOH at restart
  - Some of the manifolds and spools exposed to hydrates risks
    - Relatively short sections compared to production network
    - Restart allows flushing these equipment relatively quickly



FIELD C - Before restart – 27 hours Cool Down



FIELD B – Main - Before restart – 4 days Cool Down

MCEDD DEEPWATER DEVELOPMENT

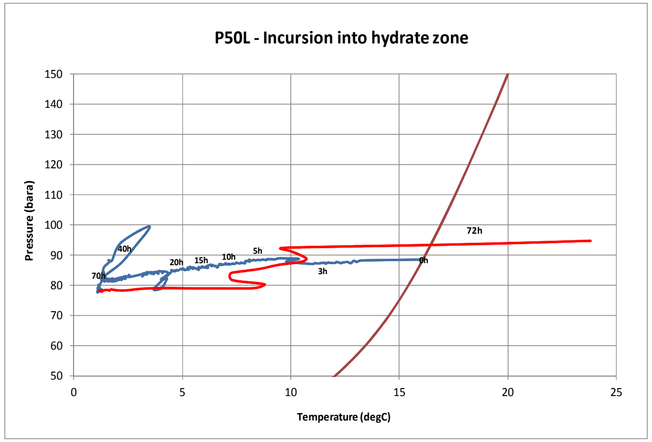
TOTAL Committed to Better Energy

Conclusions of the REX

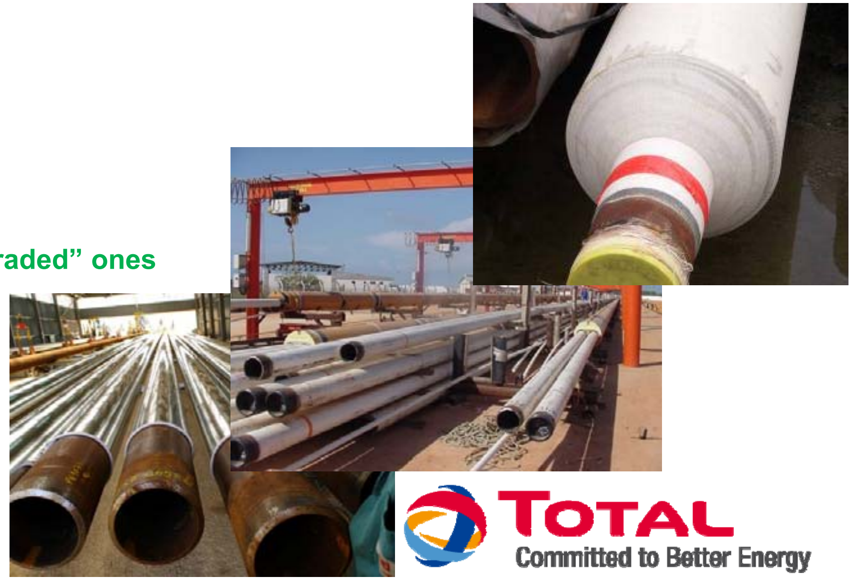
- Long duration shut-downs on our deepwater fields give a unique opportunity to evaluate the hydrates risks in actual operating conditions – Olga® software was a good support to conclude on the risks of hydrates.

- Complete modelling of system was necessary as :
  - Accurate model where not available in affiliates
  - Complex geometries of some systems required specific models
  - P,T information from Xtree or Manifold are not sufficient to evaluate the risks

- Hydrates risks considered as “nil / low” for all the cases
  - **Robust design of the passive thermal insulation of the production network**
    - Thermal insulation designed at project phase in turndown conditions
    - Early life conditions considered ➔ Water Cut = 0%
  - Careful restart procedures implemented on the different sites
  - **Operating conditions at the moment of the ESD0 significantly different than the “degraded” ones considered in the original design**
    - **High liquid content and high water content ➔ High thermal inertia**
    - **Operations at nominal flow ➔ High temperatures in the production line**



FIELD B – P&T @ manifold agaisnt hydrates curves Left branch



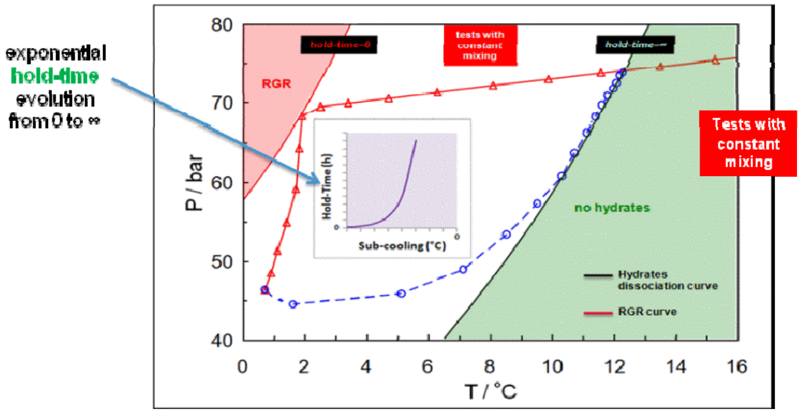
MCEDD DEEPWATER DEVELOPMENT

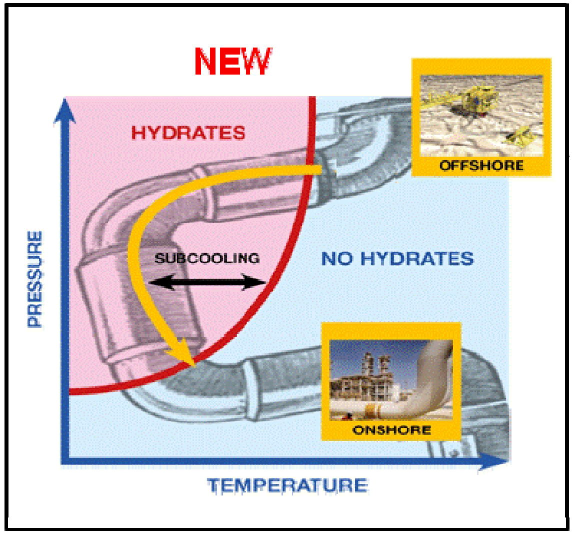
TOTAL Committed to Better Energy

What’s next ?

- What’s next:
  - *Operation :* Improve the procedures to limit shortfalls while managing risks and considering high water content
    - Extended NTT based on P&T conditions in the production lines
    - Derive improvements to current operating procedures with an objective of delaying preservation when safely manageable
  - *Design:* Review the scenario considered for thermal insulation specifications
    - Turndown packed conditions is no more relevant based on operational feedback
    - Need for a lean design even if operating flexibility could be slightly affected

- And pushing the design limits forward ... **@ Next conference ... ☺**
  - New design perspective implemented on recent projects
  - Take full benefits of capabilities of some crudes in delaying hydrates formation, namely induction time
  - In other words: operate inside hydrate thermodynamic zone but outside hydrates forming conditions





MCEDD DEEPWATER DEVELOPMENT

TOTAL Committed to Better Energy

Questions?

- Contact information:

Christophe CANDELIER
Flow Assurance - Multiphase flow Specialist
Development - Support to operations

Tél : +00 33 (0)1 41 35 55 84
Fax : +00 33 (0)1 47 44 37 71
Email : christophe.candelier@total.com