Effektivisering av BOP testing

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History, BOP reliability studies

- Phase I to Phase V Subsea BOP reliability from 1981 to 1991 (“Shallow” Norwegian waters), total experience from 265 wells
- Platform BOPs. Analysis of 48 development wells drilled from three North Sea platforms (1992).
- Deepwater study, phase I DW: Analysis of 144 wells, whereof 100 were deepwater wells. Data mainly from Brazil and Norway(1997)
- Deepwater study, Phase II DW: Analysis of 83 deepwater wells in US GoM OCS, 2000 (*http://www.mms.gov/tarprojects/319.htm*)
- Deepwater Kicks and BOP Performance, 2001 (*http://www.mms.gov/tarprojects/383.htm*)
- Several spin off studies 1985 -2008

Majority of studies carried out under SINTEF contracts

Main objective, latest MMS study

- Establish a quantified overview of the deepwater well kick frequencies and the important parameters contributing to the kick frequency
- Identify and quantify problem areas in well control operations
- Assess the effect of well control operations on the BOP reliability
- Analyze how different BOP test strategies affect the blowout probability

Data collected

BOP failure, BOP equipment, well, and BOP test data collected in Phase II DW study

Well kick data collected in Deepwater Kicks and BOP Performance study

- Main source of information has been daily drilling reports, mainly in electronic format
- MMS well files from the internet
- Data from 26 semisubmersible rigs and drill ships
- 15 different operators
- 83 deepwater wells (>400 m = 1312 ft), spudded in the period July 1, 97 until May 1, 98

BOP subsea test time consumption (from Phase II DW)

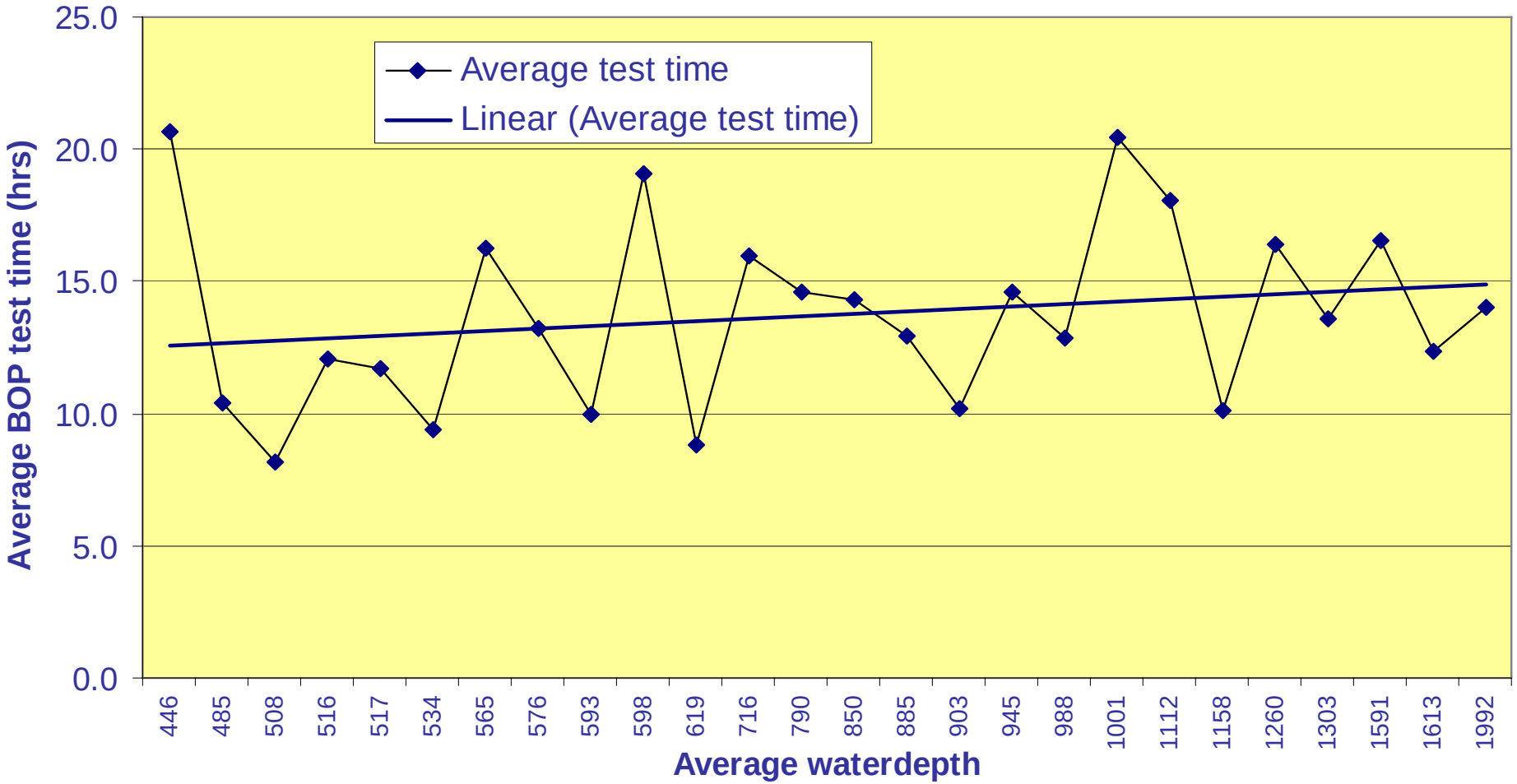
- 333 subsea BOP pressure tests
- 166 subsea BOP function tests
- Total test time consumption: 4749 hours

These 4749 hours represent 5 % of the total no. of BOP-days, on average 1.19 hours/BOP-day.

Average BOP pressure test time:

- Phase II DW: 13.9 hours/test
- Phase I DW (deepwater wells): 9.6 hours/test

Rig specific average BOP times sorted on average depth



BOP failures from Phase II DW

BOP subsystem	*BOP on the rig*			*Running BOP*		BOP on the wellhead				Total
	Observed on test prior to running BOP	Other obser-vation	Un-known	Test during running of BOP	Other obser-vation	Install-ation test	Test after running casing or liner	Test scheduled by time	Other obser-vation	
	Safety non-critical period						Safety critical period			
Flexible joint									1	1
Annular preventer	1					1	4	3	3	12
Ram preventer	3				1	1	5	1		11
Connector	2	2				2			4	10
Choke and kill valve	9					1	1	2		13
BOP attached line	1			1						2
Riser attached line	1			2					1	4
Jumper hose line				1			1			2
Control system	16		3	5		13	6	7	12	60
Dummy Item	2									2
Total	**35**	**2**	**3**	**9**	**1**	**16**	**17**	**13**	**21**	**117**
	34.2%			**8.5%**		**13.7%**	**43.6%**			**100%**

Failures occured in safety critical period

BOP sub-system	Failure mode distribution	No. of failures
Flexible joint	External leakage	1
Annular preventer	Failed to fully open	6
	Internal leakage	4
Ram preventer	Internal leakage	3
	Failed to open	2
	Failed to close	1
Connector	Failed to unlock	4
Choke and kill valve	Internal leakage	2
	Failed to open	1
Jumper hose line	Bursted line	1
Riser attached line	Plugged line	1
Control system	Loss of all functions both pods	1
	Spurious operation of BOP function(s)	2
	Loss of all functions one pod	4
	Loss of several functions both pods	1
	Loss of several functions one pod	3
	Loss of one function both pods	1
	Loss of one function one pod	7
	Unknown	2
	Other	4
Total	All	51

Mean time between kicks

Phase	No. of kicks	No. of wells	BOP-days in operation	MTBK (wells between kicks)	MTBK (BOP-days between each kick)
Development drilling	9	25	1000	2.8	111.1
Exploration drilling	39	58	3009	1.5	77.2
Total	48	83	4009	1.7	83.5

Consumed rig time, kicks, BOP failures, and BOP testing

Time "loss" contributor	BOP days in service	Total time consump-tion (hrs)	Average hours lost per day	% of avail-able drilling time
Kick circulation	4009	2299	0.57	2.4 %
Prepare for side-track or abandon well (kick related) *)	4009	2095	0.52	2.2 %
BOP failures restoration	4009	3638	0.91	3.8 %
BOP testing	4009	4761	1.19	4.9 %
Total	4009	12793	3.19	13.3 %

*) Not including the side-tracking

BOP test strategies and BOP configurations vs. the blowout probability

Analysis needs

- **BOP reliability model (Fault tree)**
- **BOP component failure probability**
- **Experienced kick frequencies**
- **Tubulars running through the BOP when kick occurs**
- **Ram types and sizes**
- **BOP test strategy**

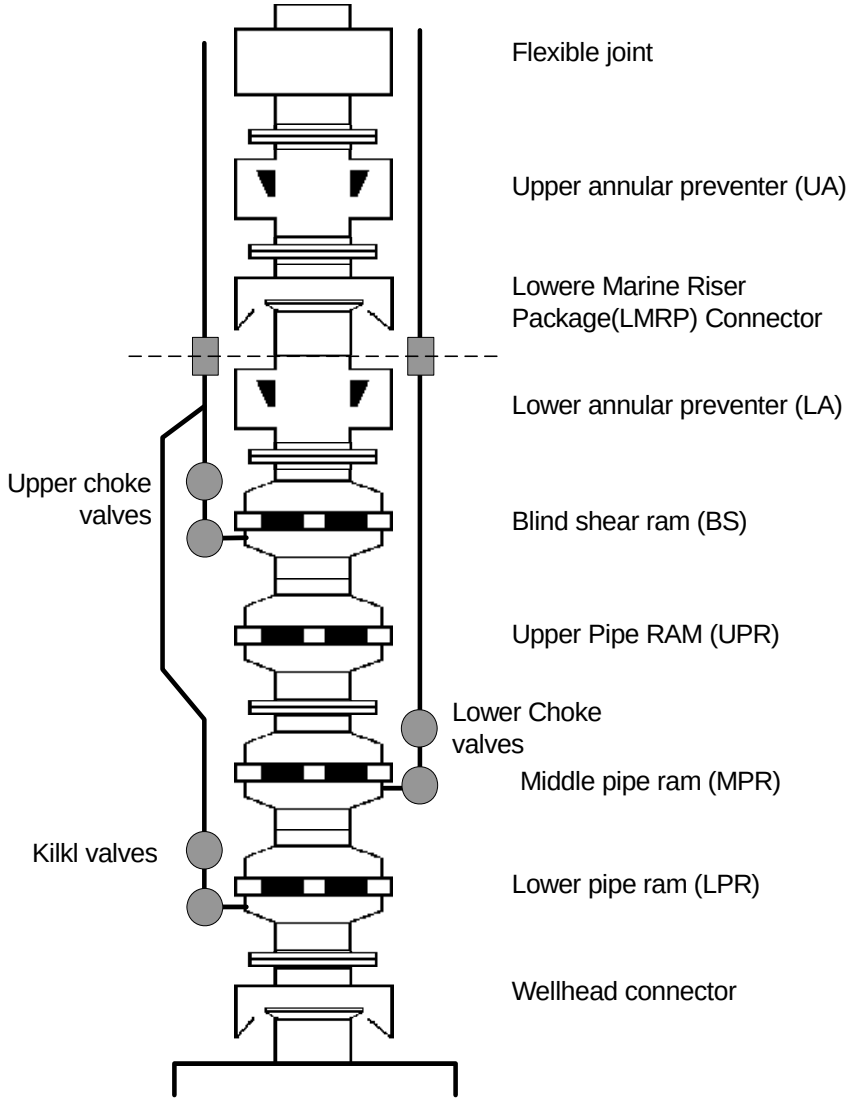
Blowout types considered

The model only consider blowouts that could have been prevented by the BOP.

Blowouts not included in the model:

- **Shallow gas blowouts (before the BOP is landed)**
- **Blowouts outside the BOP**
- **Blowouts through the drillpipe**
- **Underground blowouts**
- **Blowouts caused by spurious disconnect of the riser connector and lack of riser margin (also disabling the BOP control)**

Some assumptions



- BOP stack design as sketch
- No acoustic back-up system
- Kick frequency:
  - 12.0 kicks/1000 BOP-days
- Deepwater BOP failure data from US GoM OCS
- BOP pressure tested every two weeks (pressure test one pod, function tested one pod)
- The BOP is function tested every two weeks (both pods)
- An observed BOP failure is repaired before the operation continues

Tubulars running through the BOP

Type of tubular	Size (inches)	No. of kicks
Empty hole	-	1
Wireline	-	1
Test tubing	4.5	1
Drillpipe	5	25
Drillpipe	5.5	9
Drillpipe	Unknown	11
Total		**48**

Kick experience

Available preventers initial kick suituation (Reliability model input data)	No. of kicks	Distri-bution
Only the blind-shear ram could be used	2	4.2 %
The LPR and the MPR could not be used	1	2.1 %
The LPR could not be used	4	8.3 %
All preventers could be used	41	85.4 %
Total	**48**	**100.0 %**

Input for reliability model

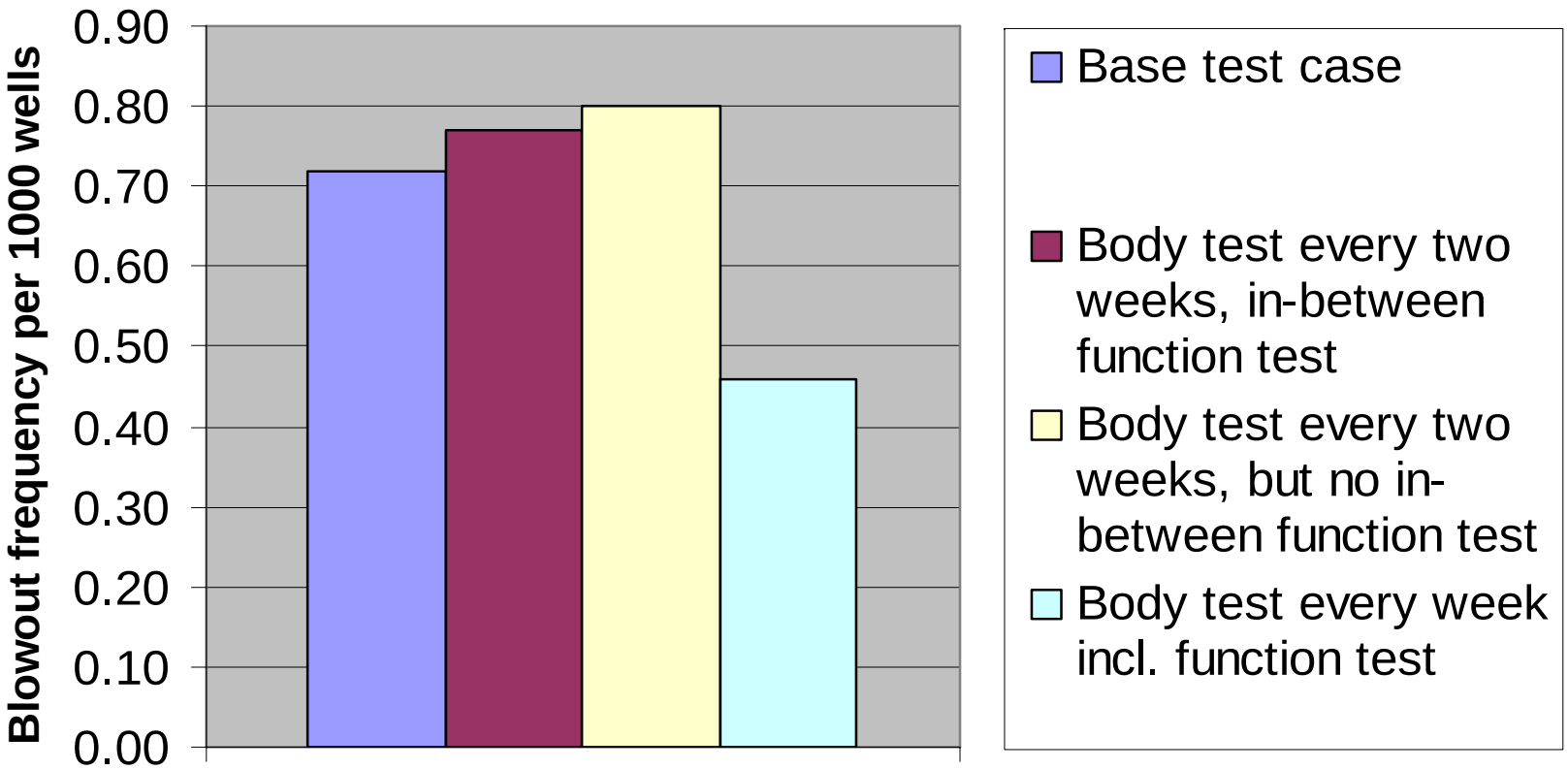
Test strategies analyzed

- **Base test case (similar to present regulations)**
- **Body test* every two weeks, in-between function test**
- **Body test* every two weeks, but *no* in-between function test**
- **Body test* every week incl. Function test**

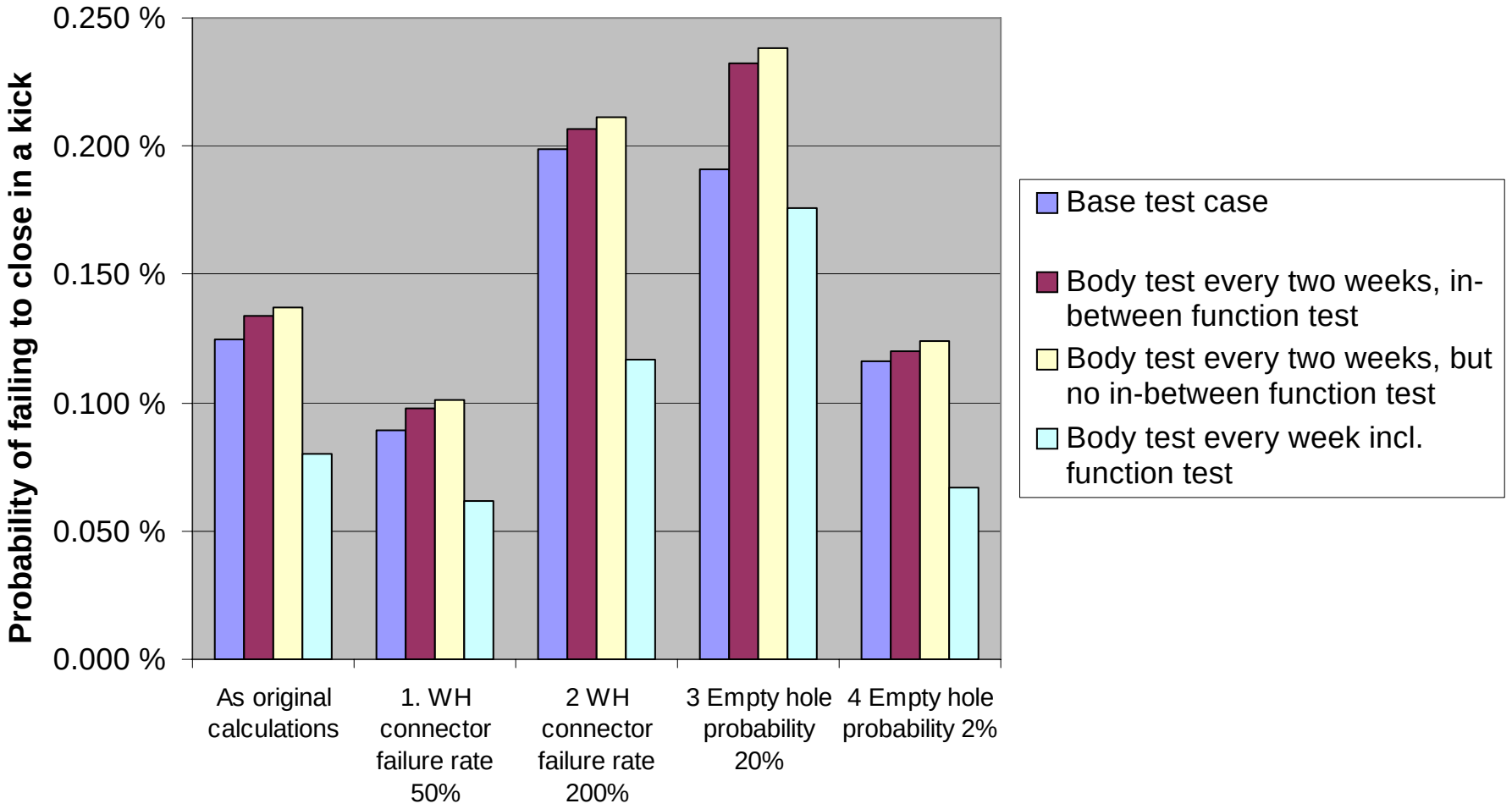
For the body test strategies it was assumed that the:

- *complete BOP installation test*
- *well duration is 50 days*
- *blind-shear ram is tested every 20 days in association with casing running*

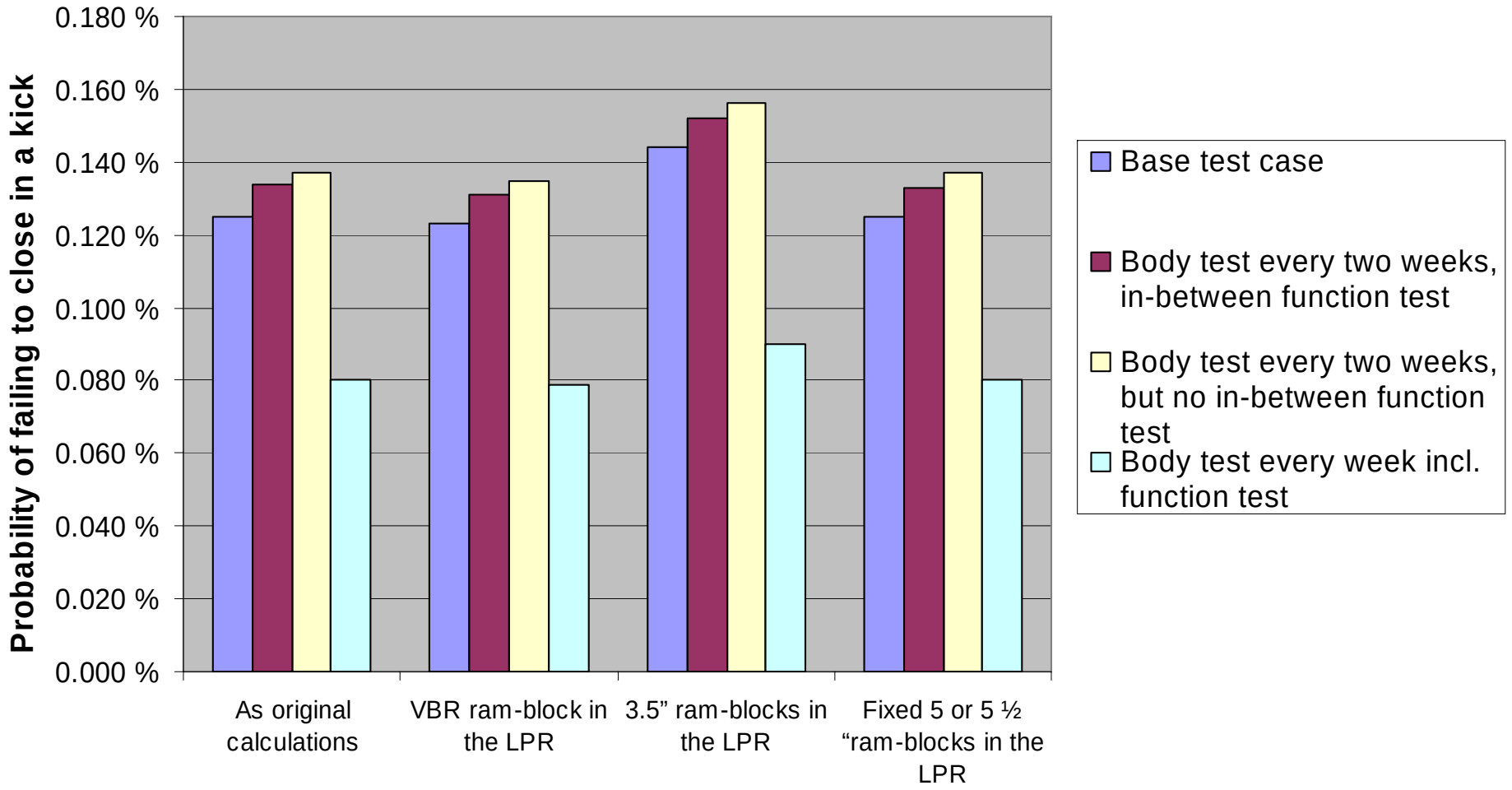
Test strategy vs blowout frequency



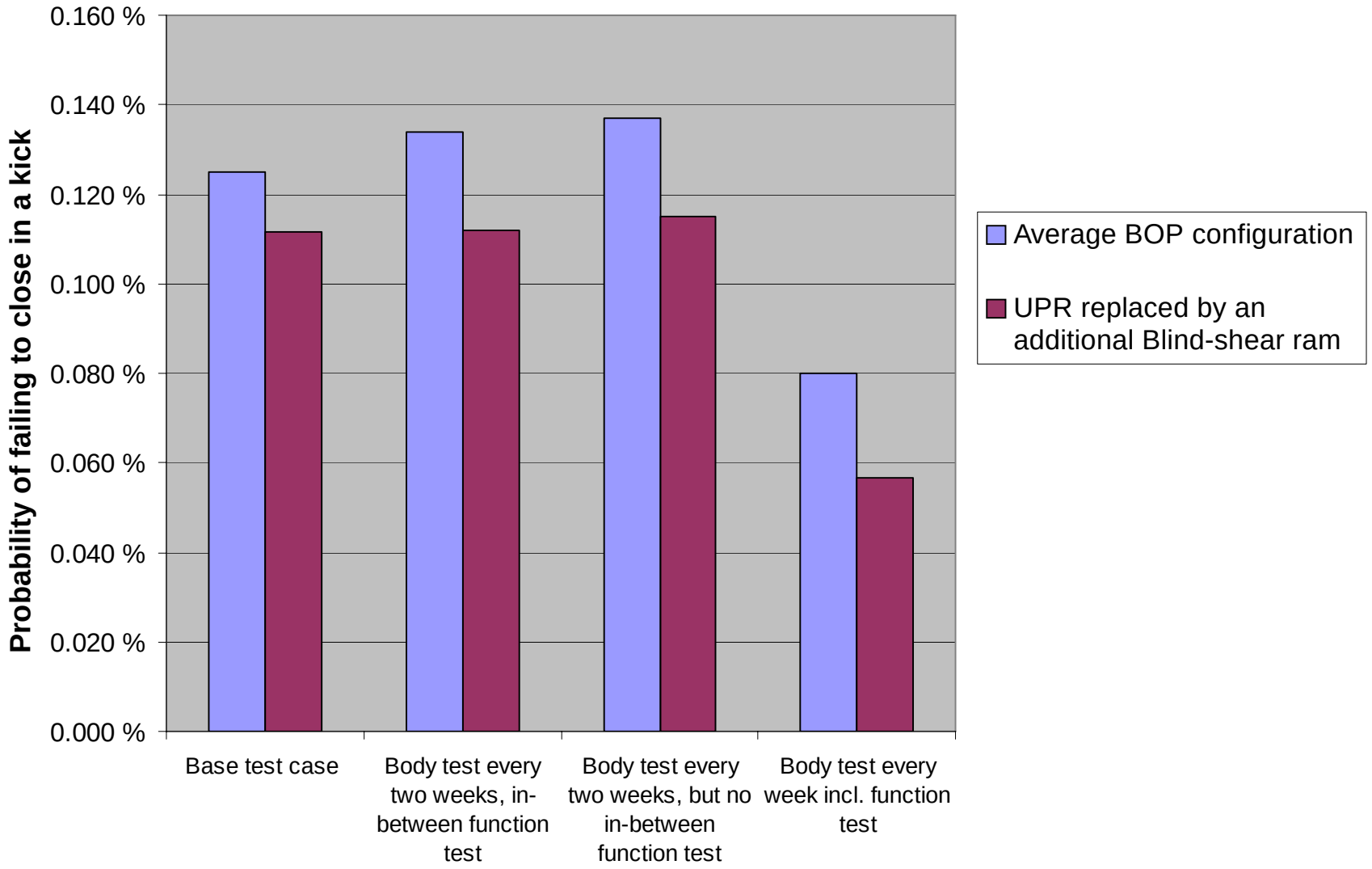
Sensitivity evaluation



Type of ram block in LPR



UPR replaced by an extra BSR



Recommended BOP configuration and testing

BOP stack design

- One (or two annulars)
- Two blind shear rams
- Two pipe rams (at least one VBR, both rams should be able to seal around normal drillpipe)

BOP testing

- Detailed installation test
- Periodic test, body test against MPR, function test both pods (every 2 weeks)
- Periodic function test both pods (every 2 weeks)
- Periodic detailed pressure test (every 50 days)
- Test after running casing or liner, body test against MPR, function test both pods, pressure test the BS rams independently against the casing or liner

Pros and cons in terms of economic aspects

Additional costs

Replacing the UPR with a blind-shear rams in a BOP stack will cause investments

- new type of blind-shear ram blocks
- boosters and control system modifications (if required)

Potential saving

Reduced BOP test time.

- Proposed test strategy for the 83 Phase II DW wells would reduce BOP test time with app. 2200 hrs, i.e, 2.3 % or one week for each rig each year.

Type of test	BOP tests recorded in Phase II DW			Estimated time consumption with proposed test strategy	
	No. of tests	Total test time (hrs)	Average test time (hrs)	Average test time (hrs)	Total test time (hrs)
Installation test	78	1110	14.23	14.23	1110
Pressure tests scheduled by time	102	1462	14.33	7.00*	714
Test after running casing or liner	153	2059.25	13.46	4.00*	612
Function test scheduled by time	166	118.5	0.71	0.71	118.5
Total	**499**	**4749.75**			**2554.5**

* Only body and function test