REDUCE OPEX AND CO2 EMISSIONS IN HEAVY OIL PRODUCTION FIELDS

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RESUME

This paper explains the process optimization achieved in the Rubiales field, located in the Department of Meta, in Colombia South America. In this field heavy oil of 12.5 ºAPI is processed producing up to 200 kBOPD. The oil from these well fluids contains large amount of associated water, with increasing water content level from initial 80% steadily rising up to of 95% after several years of extraction. The viscosity of this heavy oil is extremely high at ambient temperature forming emulsions difficult to separate. Therefore it is necessary to heat these fluids up to 160 to 170 ºF in order to obtain emulsions in a range 25% to 35% BSW in the primary water separator called FWKO. The reduced oil emulsion at this BSW level range is economically suitable to complete the final oil dehydration in the electrostatic high temperature treaters operating at temperatures in the range 220 ºF up to 250 ºF.

Chemical Engineer Luis Klemas invented a new Process concept and a new type of FWKO equipment design in 2008. This invention allows a substantial heating energy economy, by the fact that the new FWKO design performs the fluid heating by means of coils localized inside the FWKO vessel, in the upper section where the emulsion is concentrated. In consequence no energy is wasted heating the large amount of free water incoming from the field wells.

HISTORY OF THE INVENTION

At the beginning of Rubiales field operations in 2005-2007 the oil production increased up to 15,000 BOPD with 80 % BSW. The process scheme was to heat all the well fluids, that is oil and all water, in a set of steam heated exchangers before entering a primary water separation tank configured as a traditional “Gun-barrel”. The piping from the wells to the CPF was not insulated, so that the fluid temperature arriving to the CPF was weather dependant, ranging from 80 to 110 ºF, being colder at night and much colder during rain periods. The production facility capacity was heavily weather dependent, therefore unpredictable.

At this stage the potential of oil production of this field was quite promising and it was decided in 2008 to increase the capacity of oil production up to 50,000 BOPD. The owners of the field, Pacific Rubiales and Ecopetrol contracted the Basic Engineering to a prestigious engineering company located in Houston USA. In this basic engineering the scheme of preheating the well fluid was the same as the existing old production of up to 15,000 BOPD, that is to say, installing a set of heat exchangers to heat the well fluid before entering the “Gun-barrels”.

The owners of Rubiales field asked Strycon SAS to develop the detailed engineering and presented the basic engineering already available for our review. Observing these process basic engineering schemes, Luis Klemas acting as process engineering consultant, proposed a different alternative, to design a FWKO in which the heating would be carried inside the equipment, with suitably designed and localized fluid distributors and heating coils, eliminating the external inlet fluid heat exchangers.

The advantage of this design is that only the oil emulsion is to be heated, thus substantially reducing the heating requirement for the process. In addition the invented FWKO configuration permits the efficient heat integration, recovering most of the heat available in the hot oil and hot water leaving the electrostatic treater section used for the final oil dehydration.

At the same time it was suggested to thermally insulate the piping from oil wells to the CPF demonstrating that the cost of insulation would be beneficial to the economy with a payout time of few months. This suggestion was accepted and implemented in Rubiales oil field. Once the piping was insulated, the fluid arrives at a constant temperature of about 140 ªF (day or night, dry or wet). This increased the facility production capacity, reduced fuel consumption by about 67% and eliminated the operational stress of weather conditions.

The proposal was approved, and a new FWKO design configuration invention was born. The advantages of the new invention are both economic and ecological. Lower process heat requirement – thus lower fuel consumption and lower operating cost (OPEX) as well as lower CO_2 emissions. A good example where economy follows ecology.

From 2008 to 2014 several increments in the production capacity of Rubiales fields CPF1 and then CPF2 and Quifa fields have been implemented using at each the new technology that proved successful since 2008. In 2014 the total installed capacity of Rubiales and Quifa oil fields had reached and exceeded 200,000 BOPD, using several FWKO tanks with the new efficient heating technology invention.

The heating energy savings range from 67% at BSW= 80% to 92% at BSW=95%. Similar reductions in CO_2 emissions are achieved.

ECONOMIC AND ECOLOGIC ADVANTAGES

The process heat requirement in Mbtu/h, fuel consumption in barrels/a, and CO2 emission in TON/a are as follows:

Set of Process conditions:

BOPD	50000	T2 °F	160
Boiler Effic%	84	C% in fuel	86
HHV btu/gal	150000	SG fuel	0,98
HHV btu/bbl	6300000	cost US$/bbl	50
Heat Loss%	10	Capacity Factor Boiler	1,2
oper days/a	365	Boiler Capex $/BHP	1500
		Ton CO2/Barrel	0,49

T1 °F	140	130	120	110	100
T2 °F	160	160	160	160	160
BOPD	50000	50000	50000	50000	50000
Heat Loss%	10	10	10	10	10

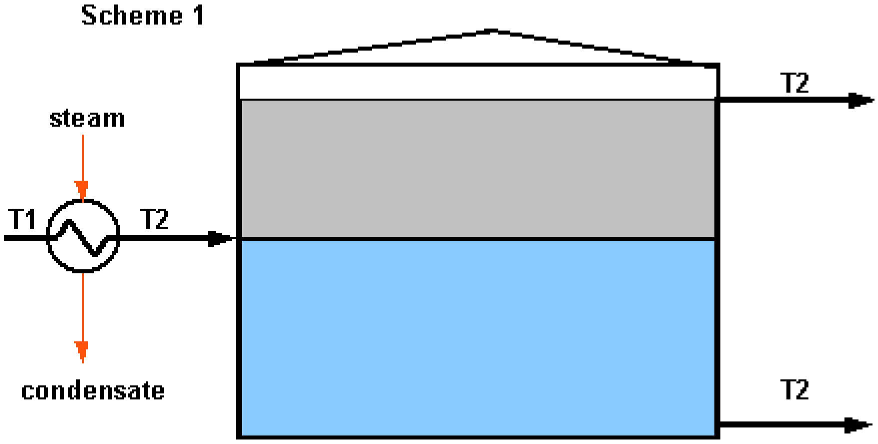
BSW %	Boiler Heat Requirement Mbtu/h				
50	23,91	35,86	47,81	59,77	71,72
80	72,04	108,06	144,08	180,10	216,12
85	98,78	148,17	197,56	246,95	296,34
90	152,26	228,39	304,53	380,66	456,79
95	312,71	469,06	625,42	781,77	938,13

BSW %	Fuel Fired BBL/a				
50	39573	59360	79146	98933	118719
80	119250	178875	238501	298126	357751
85	163515	245273	327031	408789	490546
90	252046	378069	504091	630114	756137
95	517637	776455	1035273	1294092	1552910

BSW %	CO2 Emission T/a				
50	19419	29128	38837	48546	58256
80	58516	87774	117032	146290	175549
85	80237	120356	160474	200593	240711
90	123679	185518	247358	309197	371037
95	254005	381007	508009	635011	762014

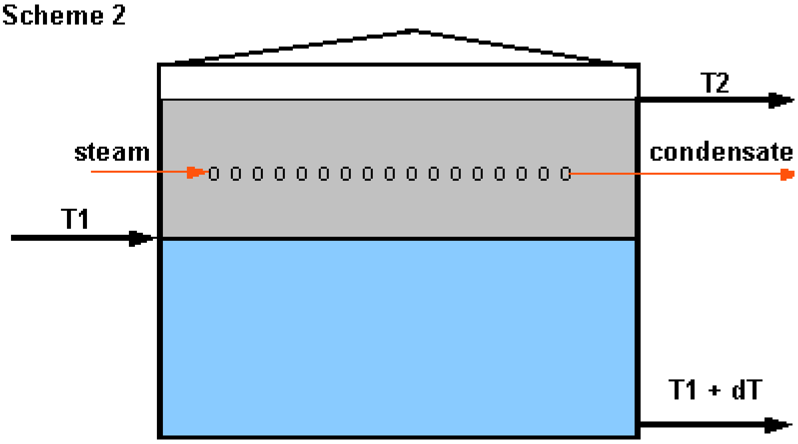
T1 °F	140	130	120	110	100
BSW %	Opex cost of combustion Fuel USM$/a				
50	1,98	2,97	3,96	4,95	5,94
80	5,96	8,94	11,93	14,91	17,89
85	8,18	12,26	16,35	20,44	24,53
90	12,60	18,90	25,20	31,51	37,81
95	25,88	38,82	51,76	64,70	77,65
BSW %	Boiler capacity required in BHP				
50	857	1285	1714	2142	2571
80	2582	3874	5165	6456	7747
85	3541	5312	7082	8853	10623
90	5458	8187	10917	13646	16375
95	11210	16815	22420	28025	33630
BSW %	CAPEX for Boilers, M$				
50	1,29	1,93	2,57	3,21	3,86
80	3,87	5,81	7,75	9,68	11,62
85	5,31	7,97	10,62	13,28	15,93
90	8,19	12,28	16,37	20,47	24,56
95	16,81	25,22	33,63	42,04	50,44
BSW %	Total CAPEX+10 OPEX - M$				
50	21,07	31,61	42,14	52,68	63,22
80	63,50	95,25	127,00	158,75	190,50
85	87,07	130,60	174,14	217,67	261,21
90	134,21	201,32	268,42	335,53	402,63
95	275,63	413,45	551,27	689,08	826,90

Scheme 1



FWKO - EXTERNAL Heating - Traditional Scheme

Scheme 2



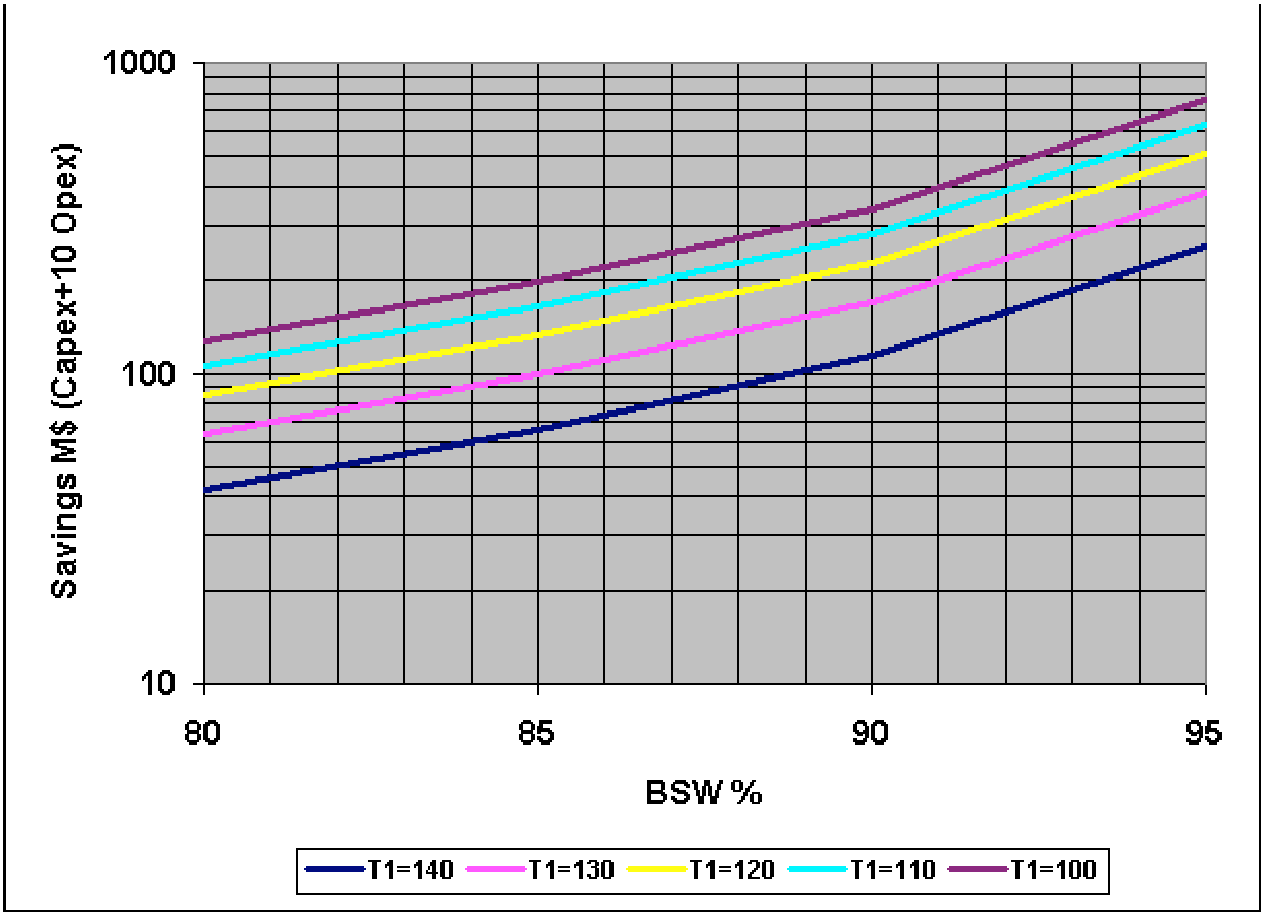
FWKO - INTERNAL Heating - New Invention

T1 °F	140	130	120	110	100
BSW %	Difference (CAPEX+10 OPEX)$_1$ - (CAPEX+10 OPEX)$_2$ - M$				
80	42,43	63,64	84,85	106,07	127,28
85	66,00	99,00	131,99	164,99	197,99
90	113,14	169,71	226,28	282,85	339,41
95	254,56	381,84	509,12	636,40	763,68
BSW %	Difference Emission (CO2)$_1$ - (CO2)$_2$ - T/a				
80	39098	58647	78195	97744	117293
85	60819	91228	121637	152046	182456
90	104260	156391	208521	260651	312781
95	234586	351879	469172	586465	703758

SUMMARY OF ECONOMIC AND ECOLOGIC ADVANTAGES OF THE INVENTION

In summary for the case of BSW = 95% the economic advantage of the new invention vs the traditional scheme expressed by Δ(Capex + 10 Opex) may range from 254.6 millions dollars for T1 = 140 ºF to 763.7 million dollars for T1 = 100 ºF for a production of 50000 BOPD.

For the same set of conditions the new invention allows a reduction of CO_2 emission ranging from 234586 TON/a for T1 = 140 ºF to 703758 TON/a for T1 = 100 ºF.



Oil Reserves and potential Production of Heavy Oil during the transition period to a sustainable world Energy scenario

According to the bp-statistical-review-of-world-energy-2015, the total world oil reserves are estimated at 1700 billion barrels. World oil production in 2014 was 88.7 million BOPD. World Oil consumption in 2014 was equivalent to 92 miillion BOPD.

232-5 billion barrels of reserves are in North America, of which 172.9 billion barrels are in Canada, mostly in extra heavy oils in tar sands and bitumen formations.

330.2 billion barrels of reserves are in South America, of which 298.3 billion barrels are in Venezuela, mainly in the Orinoco belt region mainly extra heavy oils and bitumen.

According to ENI 2014 data the heavy oil world production was of 10 million BOPD in 2013 representing 13 % of the 76.7 million BOPD total world production reported in 2013. The heavy oil fraction has increased from 11.7% in 2000 to 13.1% in 2013.

The 1700 billion barrel world estimated reserves, consumed at nearly 90 million BOPD will exhaust in time of 51.8 years, assuming that the oil production remains steady.

However the conventional oil reserves not including the canadian and venezuelan extrahevy oil reserves amounting to 471 billion barrels amount to 1700-471 = 1229 billion barrels. This reserve of conventional oils may last only 37 years at a rate of 90 million BOPD consumption.

Therefore to extend the oil supply beyond a 37 year limited horizon, it is imperative to increase sharply the heavy oil production from the actual 10 million BOPD to 20, 30, 40 and 50 million BOPD in the next 20 to 50 years.

In order to recover those extra heavy oils it will be necessary to dilute with light oils to convert the extraheavy oils in heavy oils with a range of ºAPI between 12 to 20.

That means that the 471 billion barrels of extra heavy oils will need between 50 to 100 billion barrels of light oils to obtain between 520 to 570 billion of new heavy oils.

Therefore the potential reserve of new heavy oils averaging 550 billion barrels will have to be processed in a time range of 30 to 40 years, that is with a production capacity of 40 to 50 million BOPD.

POTENTIAL ECONOMIC VALUE OF THE INVENTION

We have seen that for a small production of 50000 BOPD the economic advantage of our invention may range from 254 to 764 million US$.

For a 10 million BOPD production the multiplying factor becomes 200 times, for 20 million BOPD the multiplying factor becomes 400 times.

So for a conservative estimation of 20 million BOPD heavy oil production the economic advantage of the invention may reach 100 to 300 billion US$ expressed as Capex advantages + 10 years of Opex advantages. These potential economic savings can make the difference that may allow heavy oils and the extra heavy oils production to become economically feasible if required and desired.

	2000	2005	2010	2012	2013	Share of total 2000	Share of total 2013
World	**68,026**	**73,900**	**74,100**	**76,686**	**76,724**		
Light	21,648	21,094	21,975	23,785	23,658	31.8%	30.8%
Medium	37,473	42,014	41,023	41,932	42,155	55.1%	54.9%
Heavy	7,958	9,794	10,234	10,129	10,077	11.7%	13.1%
Unassigned production	947	998	868	840	834	1.4%	1.1%

Crude Production by Sulphur Content (*)

(thousand barrels/day)

	2000	2005	2010	2012	2013	Share of total 2000	Share of total 2013
World	**68,026**	**73,900**	**74,100**	**76,686**	**76,724**		
Sweet	24,892	25,599	26,725	27,120	27,045	36.6%	35.2%
Medium Sour	6,530	7,611	8,906	9,073	9,230	9.6%	12.0%
Sour	35,657	39,693	37,601	39,653	39,616	52.4%	51.6%
Unassigned production	947	998	868	840	834	1.4%	1.1%

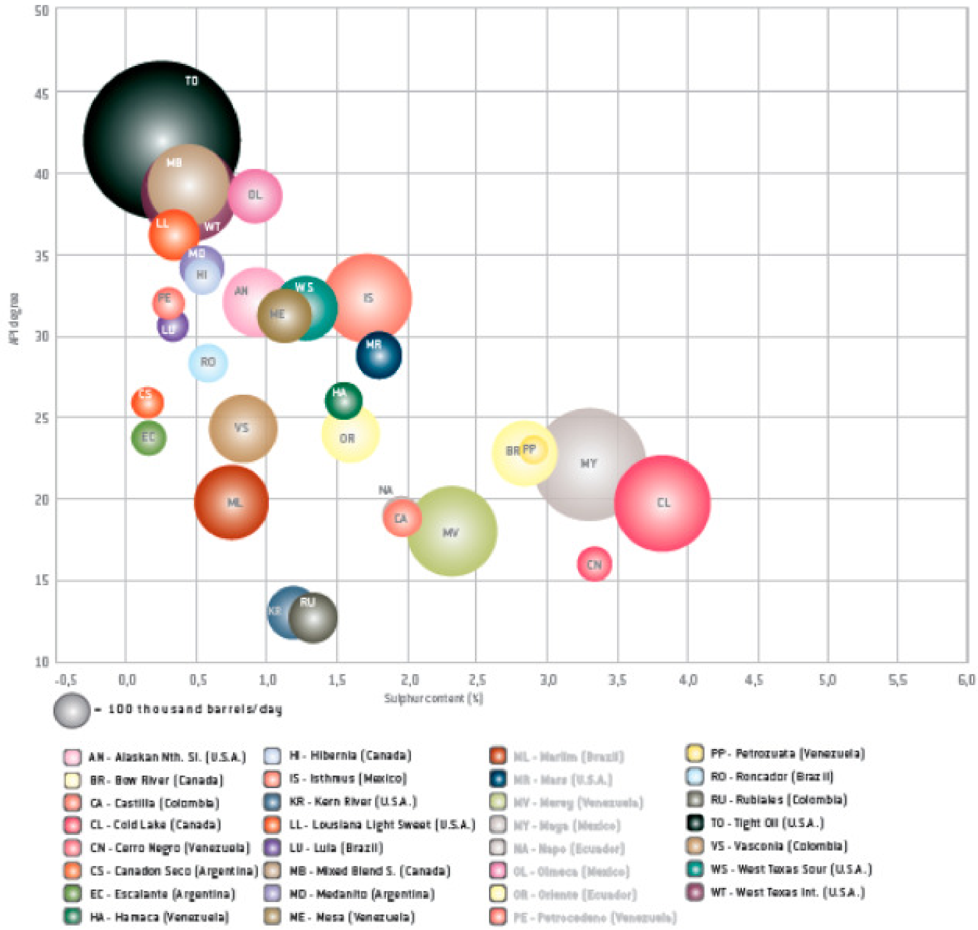
Crude Production by Quality (*)

(thousand barrels/day)

	2000	2005	2010	2012	2013	Share of total 2000	Share of total 2013
Americas (A)	**17,176**	**17,395**	**17,551**	**19,022**	**20,098**		
Ultra Light							
Light & Sweet	3,361	2,605	3,010	4,751	5,635	19.6%	28.0%
Light & Medium Sour	553	190	363	363	340	3.2%	1.7%
Light & Sour							
Medium & Sweet	887	1,416	1,469	1,518	1,652	5.2%	8.2%
Medium & Medium Sour	1,613	1,664	1,728	1,421	1,421	9.4%	7.1%
Medium & Sour	4,038	3,758	3,584	3,289	3,263	23.5%	16.2%
Heavy & Sweet	305	252	348	336	299	1.8%	1.5%
Heavy & Medium Sour	1,147	1,399	1,785	1,780	1,722	6.7%	8.6%
Heavy & Sour	4,935	5,750	4,953	5,274	5,486	28.7%	27.3%
Unassigned production (B)	337	361	311	290	279	2.0%	1.4%
% Unassigned production (B/A)	2.0	2.1	1.8	1.5	1.4		

Ref. bp-statistical-review-of-world-energy-2015

Quality and Production Volume of Main Crudes 2013 (**)
(thousand barrels/day)



(*) Data source: Eni's elaborations on IEA data.
(**) Data source: Eni's elaborations.

Ref.: World Oil & Gas Review - ENI 2014

Conclusion

At the present time of international concern with the environmental global warming nefarious effects on the well being of our planetary human society, the efforts to reduce CO2 emissions defined in the Kyoto protocol, and the various UN sponsored international programs and agreements. It is expected that the next International Conference on Climate Change to be held en Paris in December 2015, will reach international consensus to achieve a substantial reduction of CO2 emission in all countries, specially in USA and China, to limit the increase of planet temperature below 2ºC.

Therefore the oil industry, starting with oil production fields, must also be committed to a substantial reduction of it CO2 emissions. We hope that the case study presented in this paper will inspire many oil companies and many engineers working in this field of technology to become as efficient as possible during the time left for the usable oil reserves of oil, before new renewable sun based energy technologies (photovoltaic, wind, hydroelectric, etc) take the relay to achieve a really sustainable development for the next generations.

In the region of Latin America, mainly in Venezuela, Mexico and Colombia, most of the proven oil reserves are in the heavy oil range (10 to 21 ºAPI). The technology outlined in this paper is particularly suitable and efficient for any project of heavy oil production. For the case of extraheavy oils with ºAPI < 10, it is necessary to dilute the oils with nafta or light crude to increase the API at least to a level of 12 ºAPI to make feasible the water separation from the oil. When pipeline transport is considered for dispatching the dehydrated oil, a higher dilution is required up to 18 to 24 ºAPI, depending on the viscosity of the oil and the economic optimum for the pipeline design.