Asphalt and Heavy Oil Recovery From Hamza and Wadi Rajil Area Located In The Azraq Region Using Thermal Oil Recovery Methods

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Abstract

Exploratory drilling for upper cretaceous (Cenomanian –Turonian) crude oils in the wadi Rajil- Hamza area of the Azraq depression in the north east of Hashemite Kingdom of Jordan has confirmed the presence of large quantities of residual hydrocarbons (Asphalt and heavy oils)within three zones ,with limestone ,dolomite and sandstone .The estimates area 296520 acres (1200 km^2) could possibly contains 5 billion barrels of original hydrocarbon in place.

It should be noted here that the main purpose of this study has been the evaluation of the hydrocarbon potential of the Ghareb and upper Amman formations .A suitable recovery technique is proposal a pilot project for in –situ combustion underground and horizontal producer wells to increased the productivity , reduce the viscosity of the residual hydrocarbons , and , should prove to be an economically viable means of heavy oil and asphaltic extraction. The study of a pilot project of in-situ combustion to drill one vertical well for injection air in the top reservoir ,the other horizontal well for injection in the middle reservoir and the third horizontal producing well in the line of reservoir .

If the project proves to be profitable producing 124.43 bbl per day at least which means the recovery of capital expenditure in around 999.9days (2 .732 years) and the recovery efficiency proves to be high and by applicable the horizontal producer wells technology to increased the productivity . The project could be expanded in the Azraq region area .

The possible method is proposed for thermal recovery of this reservoir ,a dry Forward combustion and wet combustion underground project is preferred one or alternatively a combination of steam soaking and steam drive .

Key Words : Rajil , Hamza , Ghareb , in-situ combustion , pilot project , horizontal producing wells.

I. INTRODUCTION

The purpose of this study is to provide an assessment of the heavy oil and asphaltic residues which occur in the upper Cretaceous (Maestrichtian) Ghareb and upper Amman (Campanion –Santonian) formations in the Azraq area .

In order to asses the nature and distribution of these bituminous rock which are found in the subsurface at depths ranging from 1108.97 ft Wadi Ghadaf to X7 - 3553.32 ft , in the west Azraq area of The Hashemite Kingdome of Jordan .
The widespread distribution of bitumen and asphaltic bearing rocks of Maestrichtian age of Azraq region has been clearly established through the drilling of 29 oil exploration wells, 16 of which have been located in the Hamza area .Although bitumen ,asphalt and heavy oil are sporadically throughout the stratigraphic column ,the richest occurrences of heavy ,residual hydrocarbons are found in the Ghareb formation of late Cretaceous age .The depth to the top of the Ghareb formation in the area study ranges from 2788.85 ft at Well - X_2 to a currently recorded maximum of 3553.32 ft at Well - X_7 .
If pilot tests is to be undertaken in Wadi Rajil – Hamza area . Figure 1 show the study area ,and if these prove that recovery of asphalt and heavy oil, the technology employed into heavy oil reservoirs is becoming a viable enhanced oil recovery method [1,2,3] .

Figure 1: Location Study area

Heavy oil reservoir are usually shallower, have lower pressure and temperature . Alternatively enhanced oil recovery of heavy oil reservoirs is often carried out using thermal methods ,such as steam or fire flooding ,in which very high temperature more than 200 C^o are encountered [4,5,6] .

In-situ combustion has been utilized for over 80 years, and more than200 hundred fields around the world .It is normally employed as a recovery process in more difficult reservoirs as a secondary or tertiary process [7].

Until 1979 the in-situ combustion is commercially applied mainly in heavy –oil.. However , the widespread acceptance of air flooding as an IOR process in 1994, when the results of commercial high pressure air injection processes in the Williston basin ,north and south Dakota U.S.A, is published[8].

In the last of 1997 eight in -situ combustion projects are in operation in the U.S.A producing about 5200 barrels of oil per day, six of these are implemented in the shallow heavy oil [9] .

In –situ combustion has one the most characteristic that is increasing oil recovery process and by drilling horizontal producing wells which may be applicable over a wide range of crude gravities and viscosities.

2-Geological Characterization:

The stratigrphic componence of the two structures includes geologic formations of Paleozoic Ordivician) , Mesozoic (Traiassic ,Jurassic and Cretaceous) . The creataceous varies in thickness between 2952.90 ft to 7218,20 ft .The formations penetrated from are developed in a litofacies predominantly calcareous – dolomatic with sequences of sandstone and interbeddings of schistose clays and anhydrite . characteristics played a major role in of outcome of the many past in –situ combustion process. Tests of the reservoir charactristics of the Ghareb formation ,using petrophysical logs ,the Ghareb formation is correlated across the Hamza area from the Wadi Rajil structures in the west to the Hamza drilling area in the east.

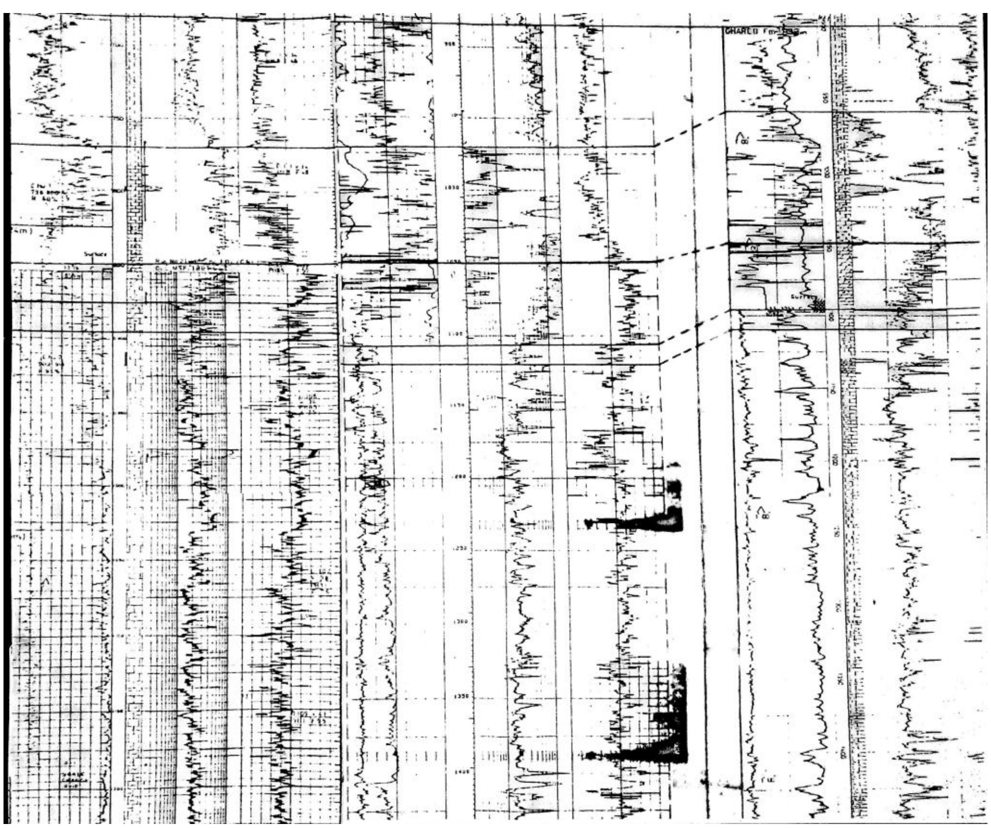

Figure 2: Cross section of wells formation.

The Lithology of the Ghareb formation includes light grey to off-white finely crystalline and slightly sandy limestone with some pyrite marly limestone and dolomite.

Within the Ghareb formation. The principal pay zone interest is in the upper and medium part of the Ghareb formation.

These zones are essentially a light grey ,finely crystalline, medium hard, occasionally cherty dolomite that slightly porous with patchy distributions of asphalt and bitumen .

Although the zone 2 is obtained form the base of Ghareb formation at Well –X_7 and is composed of a dolomite section similar according the core sample which taken. The porosity is described as ' Vuggy to cavernous ' with the fractures and vugs filled with heavy oil ,and black shining asphalt ,with a high content . This zone offers an additional section of prospective interest in the Ghareb formation. The average thickness estimated from logs is approximate 131,24 ft , as shown in figure 3.

Figure 3: core samples from study area.

The other zone has attractive possibilities in that heavy oil is noted in cored section of Well –X_7, furthermore, a Drill Stem Test conducted at Well –X_3. recovered 4 litter of heavy oil . |The average thickness of this zone is estimated to be about 94.20 ft

From table 2 petrophysical properties of " pay zone " identified in the Ghareb formation in Rajil- Hamza area .Hence an average core derived of porosity of 13-19 % ,estimate of water saturation (SW) for the " pay zone" ,in the Ghareb formation. However ,analysis of a core sample taken from a depth of 3484.22 ft at Well- X4, indicated 24.2 % water saturation calculation of original hydrocarbons in place (O.H.I.P) and recoverable reserves. The Ghareb formation –zone principle residual hydrocarbon bearing zone interest is porous dolomite ,limestone and sandstone with hydrocarbon saturated intervals, are the application of specific thermal methods is possible, specially designed for these formations , the effective thickness of the hydrocarbon saturated layer is calculated from logs is (131.24ft) .The net pay zone approximation of (91.86 ft) is used in calculating potential hydrocarbons in place . The area of the pay zone extended over the region trend to Wadi Ghadaf in the west to Wadi Rajil –Hamza south east and north of Azraq basin .This area covers 1200 km^2, equal 296520 acres.

Table1. Correlation Data for Study Area

Well Name	X1	X2	X3	X4	X5	X6	X7	X8	X9
Well depth (ft)	2870.87-2969.30	2788.85-2870.87	3445.05-3595.97	3484.42-3661.59	3645.19 - 3832.20	3543.48-3691.12	3418.80-3553.32	3481.14-3599.25	3130.05-3257.04
Reservoir average thickness (ft)	98.43	82.02	150.92	177.17	190.29	147.64	134.52	118.11	126.97

Table.2 Reservoir Characteristics [12]

Average depth (ft)	2870 - 3553 ft
Reservoir area	1200 km^2 , equal 296520 acres
Reservoir temperature(C^0)	40 c^0
Reservoir average thickness (ft)	46
Crude pour point (C^0)	75-85 c^o
Oil saturation %	49-76 %
Average porosity %	17.5 %
Horizontal permeability mD Vertical permeability (mD)	1377, 227.92 mD 586 , 181mD
Viscosity (cp)	400 and more
density of oil and asphalt gr/cm^3	0,990- 1 gr/cm3 (8.321- 8.33ppg)
Sulphur	9.92 %

This work presents experimental data which is obtained from tests analysis and well logs .Then we apply the "oxidation cell" method to determine fuel availability, and quantity of air requirements .These parameters are the most important for process and necessary design consideration for in-situ combustion of asphalt and heavy crude oils under variable conditions

Samples with asphalt and heavy crude oil is taken from Wadi Rajil Hamza oil filed.

3- APPARATUS AND MATERIALS:

The Apparatus used to measure the reactivity of different oils in a porous medium is illustrated in figure. 4. A samples packed linear centrally mounted inside a vessel which provide the necessary temperature, pressure and flow controls as shown in Fig. .4. The shape of cell has been designed so that the temperature composition of reactants shouid be as uniform as possible .

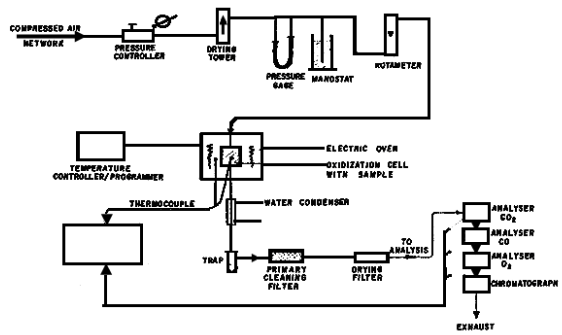

Figure 4: cell oxidation Apparatus

4- OXIDATION PROCEDURE*:*

The Oxidation cell is introduced in a metal vessel The vessel is laid in an electric resistance oven within a thermocouple which is connected to a programmed temperature recorder. The Sample is heated to 500 ^{o}C according to a linear programme as a function of time. The core volume is 32 sm^3, air flux ranging from 24 sm^3 /m^2 /hr to 41 sm^3 /.m ^{2}/hr..

The results of an oxidation run of an medium gravity oil in rock sample are shown in figure .5. The gas analysis data showed how the produced gas compositions changes due to run progresses

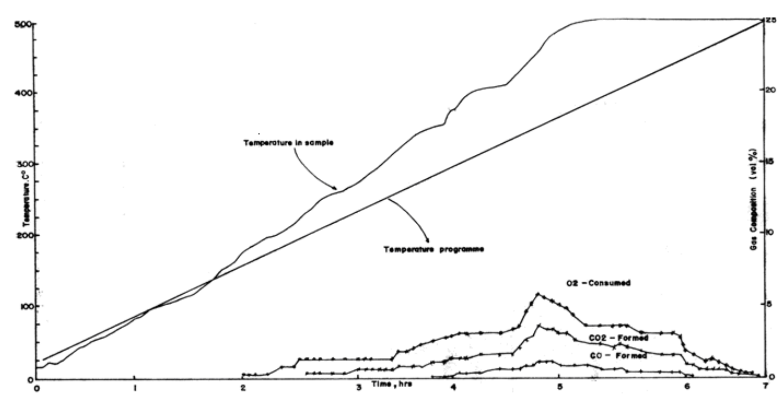

Figure 5: effluent gas analysis during oxidation of crude oil in porous media

5- In-situ combustion pilot project in the Wadi Rajil –Hamza Azraq basin area:

A pilot project involves drilling three wells , one vertical well for injection air in the top reservoir ,the other horizontal well for injection in the middle reservoir and the third horizontal producing well in the line of reservoir ,the concept depends on the vertical and horizontal permeability of reservoir to make good distribution of gas in the reservoir . The air is injected through horizontal well ,then air is moved to the combustion front ,and generate the heat to reduce the oil viscosity and provide to flow by gravity to the horizontal production well ,it means the sweeps of oil from reservoir to horizontal producing well.

The technology of horizontal wells for production of crude oil from conventional ,asphalt ,heavy oil and tar sand has been implemented successfully in many fields for in –situ combustion .

Horizontal wells provide a large area of contact with the reservoir than do vertical wells ,and the lateral transportation of fluid may be the area of contact more times larger than that of a vertical well completed through the depth of the reservoir.

The aim of the use of horizontal wells are improved the sweep efficiency ,enhanced producible reserves and decrease the number of wells recommended for field development . figure 6. It could test the response of the field to this method

It could test the response of the field to this method . If it shows good efficiency and economic feasibility, the scheme could expand to the whole project area and divided to three blocks ,(1- Wadi Rajil block , 2- Hamza block ,3-Wadi Ghadaf block S).

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Well spacing should be (210 ft) .This is a moderate number giving a well drainage ,the pattern area is 2.471 acres . The volume of the pattern pay is 2910600 ft^3 The dipping of reservoir varies between ($2\text{-}10^0$). This means that gravitational forces will be significant in the recovery process.

The most important parameters affected on the performance of an in-situ combustion process are fuel deposit, air requirement, air flux, air injection rate, air-oil ratio, injection pressure, and oil recovery rate.

Several authors have presented procedures to engineer an in-situ combustion project (Nelson and McNeil, 1961 ; Gates and Ramey, 1980; Brigham et al., 1980; Fassihi et al.,1981.

The pilot project suggested should be placed vertical well injection on top of the structure and the horizontal injector well in the middle, one horizontal producing well through the reservoir in to study the normal placing to benefit from the gravitational forces .

Well spacing should be 210 ft. This is a moderate number giving a well drainage ,the pattern area is 2.471 acres (10000.137 m^2) .

The volume of the pattern pay is 291o6oo ft^3. The dipping of reservoir varies between ($2\text{-}10^0$). This means that gravitational forces will be significant in the recovery process.

The volume of air required to bum a unit volume of the reservoir based on analysis oxidation cell gas produced [13].

6- RESULTS AND DISCUSSION:

The rate of heating temperature is ranged between 68.92-78.5 ^{0}C /hr on core samples that the heat conduction cause the difference of rate of heating temperature between core and device (80 ^{0}C / hr). This give evidence that the potential flow of heavy oil under this condition is possible.

Table4 :Results of oxidation under Programmed heating Temperature

Well Number	Well depth ft	Flow Rate Sm^3/m^2. hr	Heating Rate C^o At initial consumed O2	Heating Rate C^o/hr	Air consumed Sm^3 /m^3 Rock	Carbon burned/100 grRrock	- CO_2/ CO Ratio
X_1	2870.87	46.8	125	69	404	4.71	7.85
X_2	3545.12	23.41	190.5	78.5	408	4.73	6.65
X3	3445. 05	23,41	140.5	68.92	366.6	4.59	5.54
X4	3484.22	23.41	150.4	72.5	375.5	4.45	7.5 4
X5	3773.15	23.41	155.8	77.4	405	4.41	8.44
X6	3658.15	23.41	175.4	76.6	408	4.31	9.40
X7	3538.23	23.41	188.5	79	410	4.42	8.65
X8	3093.98	46,8	145.6	69.75	368.5	4.62	7.45

Two successive reaction appear ,one at a relatively peak at low temperature between **125** -190 ^{0}C ,and the other peak above the 200 ^{0}C . The second oxidation reactions is characterized by the fact that practically all the Oxygen which has been used up is combined in carbon oxides, it means that correspond the partial oxidation of the oil.

The oxidation cell is shown in table(5),the average air required is 393.18 Sm^3/m^3 rock burn, the heat value of fuel around 340 KJ/Kg , the air consumed is 311.53 Sm^3/m^3 rock of reservoir burned.

Table. 4. shows that the amount of air necessary to burn fuel product during process is ranged between 366.6 - 410 m^3/m^3 rock.

The rate of fuel produced fuel availability through laboratory tests illustrated in table 4,shown the rate of (2.84 pound/cu ft).˙ It could be the amount of fuel produced is medium to higher.

The amount of fuel produced an increase of oil viscosity and saturation of the rocks.

The air requirement for the laboratory experiment by a cell oxidation is 388.53 scf/ft^3

Based on foregoing findings and access to what published (17)of papers and research and filed test on the use of thermal methods for the production of heavy oil . Table 5 has been shown that it is possible to stimulate the reservoir by the thermal recovery methods (Wadi Rajil - Hamza) from the Azraq Basin.

Table 5. **Field Data for pilot project**

Air requirement	16.92 scf/acre-ft	**Total time for project**	999.9days =2.73 year
Total air for Pilot pattern	14.15 mm scf	**Maximum air injection pressure**	687psi
Air flux	52.45 scf/ft2 day	**Compressor horse power requirement**	3743.28 bhp
Maximum air rate	3.467mm scf/day	**Oil displaced per acre –ft burned**	1044 B/ acre -ft
Time required	56.8 days	**Oil displaced per acre –ft unburned reservoir**	419.2 B/acre -ft
Volume of air injected for this period	98.46 mm scf	**Total oil recovery**	606.64 B/acre-ft
Volume of air injected during the period	1536 mm scf	**Overall recovery efficiency**	57.92 %
Duration of the rate	886.3 days	**Oil air ratio**	35.89 B /mmscf

Table. 5 show the air required in mmscf injected for the pilot project computed as 21.18 mscf/acre-ft. efficiency of pattern 98.46 mm scf.

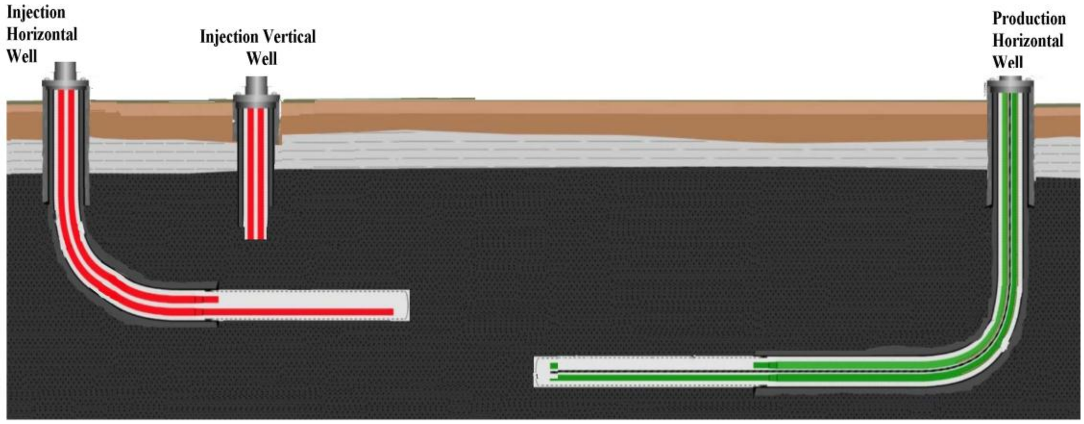

Figure 6: Pilot project of in-situ combustion

the minimum air flux required to sustain combustion 52.45 Scf/ft^2 day of burning front area.

Several authors have presented procedures to engineer an in-situ combustion project (Nelson and McNeil, 1961[15] . Gates and Ramey, 1980 [16] Brigham et al., 1980 [17]; Fassihi et al., 1981 [18].

In the design method proposed by Nelson and McNeil [15].The rate of air injection depends on the desired rate of advance of the burning front, table. 5 show the maximum air rate is 3.467million scf /day .

The air-oil ratio is the most important economic parameter in fire flooding.

it is measure the quantity of air that must be injected to recover a barrel of oil. Table. 5 show the air-oil ratio is calculated with range 28050 Scf air /bbl of Oil.

The time in days (t_1) from table 5 show the required for the increasing rate period of the operation is 56.8 days .

The volume (V1) of air injected during this periods 98.46 .mmscf . In the last final stage of the burning operation decreasing air injection rate will be used and the air rate is decreased linearly from the maximum rate .

The volume of air V_3 injected over time, t_3 during the final stage of burning is identical to the volume injected during the increasing air injection rate period.

The total volume $\mathbf{V_T}$ of air injected to burn the pilot project in the field, then the volume of air V_2 injected at the constant (maximum) rate period will be 594.62 mmscf for second stage of the operation.

The time in days required for this part of the operation is t_2 the period for this stage 886.3 days. The total time required in days for the entire burning operation is 999.9 days =2.73 years , the volume of air injected in pilot project during these period is $7.079*10^{10}$ mmscf.

In the design of an in-situ combustion of air injection pressure is needed to determine the compression facilities.. Table. 5 shown the maximum air injection pressure is 687 psi.

The compressor horsepower requirements for a pilot project sequence is 3743.28 bh this is the horsepower per stage.

The total quantity of oil displaced by the combustion front is dependent on the volumetric sweep of the front. Field data indicate that in addition to the oil displaced by the concept horizontal producer well. Also, considerable volume of oil is produced as a result of heated regions adjacent to the burned zone .

The oil displaced per acre-feet of the reservoir burned , heavy oil reservoirs, some regions are not contacted directed by the fire front may have been produced by a combination of gravity drainage and hot gas drive.

The oil displaced per acre –ft burned is 1044 B/ acre –ft , percent of the produced oil can be assumed to have come from the unburned region of the reservoir.

The oil displaced from the unburned reservoir is in range 419.2 B/acre-ft.

The total oil recovery from the burned and unburned region are assumed to be 606.64 B/acre-ft , also horizontal wells productivity increased two times than vertical wells it means the quantity is 1213.28 B/acre –ft .

The overall recovery efficiency is 57.9 % .The oil recovered per million scf of air injected Oil/ air ratio is equal 35.65 B /mmscf . Table. 5 show the maximum oil production rate is 124.43 B/day.

Conclusion

- By the geological exploration wells there were evidenced ,in the area of Wadi Rajil-Hamaza –Wadi Ghadaf structure ,accumulations of asphalt and heavy oil in the Ghareb (Maestrichtian)and upper Amman (Campanian –Santonian) formations.

- These accumulations of hydrocarbon are placed between 2231 ft and 5413.65 ft in Ghareb formation and between 4298.11 ft to 6693.24 ft in upper Amman formation .

- The hydrocarbon accumulations have an uneven distribution ,from small spots to cracks and caverns filled with asphalt and heavy oil and are in direct relation with the porosity and fracturing degree of the collector rocks . The reservoir rock is made up of limestone and dolomite.

- Due to the number of mechanical cores extracted from dispersed wells , coring the whole section with occurrences of hydro carbon and the number of analysis.- The asphalt has a sulpher content in range 9 .92 % and fusion point 75-85 c^o .

- For the heavy oil there exists , analysis bulletin at well- X_1 from Ghareb formation zone3, which indicated the specific gravity of 0,990 gr\cm3 , and a viscosity of approximate 400 cp at $40c^{o}$,.

- From the two formations with occurrences of hydro carbons there are selected as zones with more important hydro carbon accumulation the zones 1 and 2 at Ghareb formation and zone 3 in upper Amman formation .

- The possible original hydro carbons in place is estimated approximately 5 billion barrels , but they extend the study on the wadi Ghadaf block , The area after extended study covers about , 1200 km^2 , equal 296520 acres , limestone , dolomite and sandstones with hydrocarbon saturated intervals ,where the application of specific thermal recovery methods is possible ,especially designed for these formations, according the experimental test by a cell oxidation which provide to a pilot project for a limited area can be designed ,in order to apply some thermal method ,such as in-situ combustion processes underground .

- Based on the results obtained by this pilot project a feasibility study can be drawn up ,to clarify the problem of economic efficiency of producing these hydrocarbons

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