



SUDAN UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF GRADUATE STUDIES

**Laboratory Investigation of Wettability and
Relative Permeability**

**(Case study - A Sudanese sand stone
reservoir)**

**التحقيقات المعملية لقياسات التبلل والنفاذيه النسبيه -
دراسه حاله مكمين رملي سودانى**

**A THESIS SUBMITTED IN PARTIAL FULFILMENTS FOR THE
DEGREE OF M.Sc IN PETROLEUM RESERVOIR ENGINEERING**

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الاستهلال

بسم الله الرحمن الرحيم

قال تعالى :

يا أيها الذين آمنوا
انفقوا من طيبات ما
كسبتم ومما اخرجنا لكم
من الأرض

سورة

(البقرة الآية 267)

Dedication

**For their countless
sleepless nights filled
with prayers and
hopes for our success
in life, the least we
could do is to
dedicate our efforts
to the three most
influential people in
my life Dad Mom**

& Sisters and brothers

....

**The dedication
extended to my
family members,
friends and
colleagues.**

||

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Finally, any omissions, ambiguities or
misrepresentations are unintentional and I
apologize for that.

Nomenclature

Symbols

Cum oil Cumulative oil production, million of stock tank barrel (STB)

f An arbitrary function

g Gravitational acceleration, $\frac{cm}{sec^2}$

h Reservoir Thickness or distance, ft

k Permeability, md

k_o Oil Relative Permeability

k_w Water Relative Permeability

k_{rog} Oil Relative Permeability in the oil-gas system

k_{row} Oil Relative Permeability in the oil-water system

L Length, ft

M Molecular weight

$M = Q_w/Q_o$ Mobility Ratio

P_c Capillary Pressure, psi

P_{cog} Oil-gas capillary Pressure, psi

P_{cow} Oil-water capillary Pressure, psi

P Pressure, psi

P_b Bubble point pressure, psi

| | |
|------------|---|
| p | Reservoir pressure, psi |
| p_s | Static pressure, psi |
| p_{wf} | Flowing well pressure, STB/D |
| q | Oil Production Rate, psi |
| R | Universal gas constant |
| r_e | External radius, ft |
| r_w | Wellbore radius, ft |
| S_g | Gas saturation, fraction |
| S_w | Water saturation, fraction |
| S_o | Oil saturation, fraction |
| S_{wc} | Connate Water saturation, fraction |
| S_{oc} | Critical oil saturation, fraction |
| T | Temperature, $^{\circ}F$ |
| t | Time, sec |
| Δt | Time increment, sec |
| u | Superficial or Darcy velocity, $\frac{cm}{sec}$ |
| V | Volume, cm^3 |
| μ | Viscosity, centipoises (cp) |
| ρ | Fluid Density, $\frac{gm}{cm^3}$ |
| θ | Angle, degree |

Porosity, fraction

Abbreviations

| | |
|---------|---|
| AIME | The American Institute of Mining, Metallurgical and Petroleum Engineers |
| AOFP | Absolute Open Flow Potential |
| API | American Petroleum Institute |
| GOR | Gas-Oil Ratio |
| ECLIPSE | Simulation Software |
| EUR | Estimated Ultimate Recovery |
| FVF | Formation Volume Factor |
| HA | A Sudanese Oil Field in Block 2A which is studied in this thesis |
| IMPES | Implicit Pressure-Explicit Saturation |
| IPR | Inflow performance relationship |
| IPTC | International Petroleum Technology Conference |
| MMSTB | Millions of Stock Tank Barrel |
| NTG | Net To Gross Ration |
| OOIP | Original Oil in Place |
| OTC | Offshore Technology Conference |
| OWC | Oil-Water Contact |
| PDE | Partial Differential Equation |
| PERF | Perforation |
| PI | Productivity Index |

| | |
|-------|--------------------------------|
| PLT | Production Logging Tool |
| PVT | Pressure-Volume-Temperature |
| QC | Quality Check |
| RF | Recovery Factor |
| SCAL | Special Core Analysis |
| SPE | Society of Petroleum Engineers |
| STB | Stock Tank Barrel |
| Thick | Reservoir Thickness |
| WCT | Water Cut |
| WOR | Water-Oil Ratio |
| JBN | Johnson, Baessler and Neuman |
| USMB | U.S. Bureau of Mines |

ABSTRACT

The Wettability has effects on almost all types of core analyses, hereby wettability changes the remaining oil saturation during enhanced oil recovery processes. The objective of this study was to determine the Wettability of core samples from Sudanese sand stone field by U.S.B.M (U.S. Bureau of Mines) Amott wettability method and make quality check by un steady state relative permeability test by using JBN (Johnson, Baessler and Neuman) calculations in modern soft ware from France .

The experiments were performed wettability, The oil flood to initial water saturation then Spontaneous imbibition of water ,Forced water imbibitions ,Spontaneous oil imbibition,Forced oil imbibition These combined technique allows the calculation of both Amott indices and the USBM wettability indexThe combined Amott/USBM method has two main advantages when compared to the standard USBM test The resolution of the USBM (U.S. Bureau of Mines) method is improved by accounting for the saturation changes that occur at zero capillary pressure.The Amott indices are also calculated. The Amott-Harvey technique also offers the possibility to measure the end-point effective permeabilities (k_o at S_{wir} and k_w at S_{ro}), during the same experiment Wettability characteristics could be derived from relative permeability curves: The irreducible water saturation increases as water wetness increase

After establishing S_{wi} by oil flood , then starting imbibitions by inject brine into sample and select three values(time,oil production and delta pressure)after that make calculation of three parameter by JBN to

gain a relative permeability points (K_{ro} & K_{rw} Vrs S_w) from these end point easy to know type of rock wettability.

From two experiment the result had been in same value indicated to water wet reservoir.

تجريد

خاصيه التبلل لها تأثيرات علي معظم تحاليل عينات الباب ونتيجه لذلك تكون تغيرات في الزيت المتبقي في اثناء عمليات الاشخلاق الثالثوي للزيت. هذه الدرايمـ الغرض منها تحديد التبلل معمليا بطريقه (U.S.B.M amott(U.S. Bureau of Mines ومن ثم التحقيق معمليا لنفس العينات بواسطه جهاز النفازيه النسبيه

تحاليل عينات التبلل تكون بالحصول علي التشيع الاولي للماء S_{wi} وذلك بحقن الزيت داخل العينه ومن ثم تغمر العينه في مياه التكوين حتي يتوقفـ تهرز الزيتـ ومن ثم يتم استخراج ماتبقي من الزيت فيـ العينهـ بواسطه قوه الطرد المركزي تدرجيا للتمكن من الحصول علي ضغوط شعيريه وتكرر العمليه مره اخري بغمر العينه في الزيت واستخدام قوي الطرد المركزي لاستخراج ماتبقي منـ طء . استخدام الطريقتين Amott/ methods (U.S.B.M(U.S. Bureau of Mines) في تجريه واحده يعطي نتائج افضل .

تحاليل النفازيه النسبيه بواسطه جهاز النفازيه النسبيه . اولا نقوم بتشيع العينه 100% بمياه التكوين ثم يضخ الزيت حتي نحصل علي التشيع الاولي للمياه (S_{wi}) ثم نقوم بضخ مياه التكوين مره اخري واثناء عمليه الضخ ترصد قراءات للفرق الضغط والزيتـ المنتج مقابل الزمنـ وبعد توقفـ الانتاج (S_{of}) وثبوت فرق الضغط تتدخل القراءات فيـ برنامج CYDREX لحساب النفازيه بطريقه JBN وترسم النفازيه مقابل تشيع الماء ومن خلال نقاط النهايات ونقطه تقاطع المنحنيين يحدد نوع التبلل

ادت النتائج في كلا التجريتين الي ان الصخر water wet

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