Using SPE Technique for studying bit performance for selected wells in North of Iraq

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Abstract

The present study deals with drilling specific energy technique used to study the performance of bits drilled an oil well in southern Iraq and exactly in oil well (west Qurna no.15 in Basrah).

SE_d had been calculated for different depths and bit types.

Using the relationship between specific energy vs. depth, best bit performance can be indicated where, lowest value of calculated SE_d refers to the optimum bit used to drill the determined section and consequently reduces highly drilling costs.

الخلاصة

الدراسة المقدّمة تتناول تقنية الطاقة المحددة المحفورة و المستخدمة لدراسة ادائية الحافرات لبئر نفطي في جنوب العراق و(بالتحديد البئر النفطي غرب القرنة رقم 15) ، حيث تم احتساب SE_d لأعماق مختلفة و لحافرات متنوعة .

و باستخدام العلاقة بين الطاقة المحددة و العمق تم تأشير افضل ادائية للحافرات.

و ان أدنى قيم للـ SE_d المحسوبة تشير إلى امثل حافرة تم استعمالها لحفر المقطع المحدد و بالتالي يمكن التقليل من تكاليف الحفر الباهظة .

Introduction

In order to break by mechanically or by thermally induced stresses, a sufficient force of energy must be applied to the rock , such that the induced stresses will exceed the rock's strength. Similarly, when fusing rock sufficient heat must be applied to produce local temperatures that exceed the melting temperature at the rock. Once these threshold values of force or energy are exceeded, the amount of energy required to break or remove a unit volume of rock remains nearly constant. This energy parameter, which is a measure of the efficiency of the rock destruction technique , is defined as specific energy [(1)] .
Cutting experiments were carried out to quantify the dependence of the specific energy on the bottom hole pressure and on the pore pressure in shales . The experiments were conducted with an instrument cutting device specially designed to operate inside triaxial cell .This preliminary experimental investigation supports the theoretical findings that the specific energy depends only on bottom hole pressure and not on the differential pressure in shales under conditions when the rock is shear-dilatant .In such cases , specific energy can indeed be expressed as $SE_d = SE_o + mp_m$, where SE_o denotes the specific energy under atmospheric conditions , p_m denotes to bottom hole pressure, and m is a coefficient which is a function of the drilled angle and the internal friction angle of the shale [(2)] .
The drilling specific energy SE_d is a very significant measure of drilling performance .It is directly compatible with cost/meter , because it relates the amount of energy required to penetrate rock .SE_d can also be used to quantify the efficiency of rock working processes and rock hardness during drilling .This relationships between drilling specific energy , drilling rate and the main mechanical rock character [(3)] . Drilling data is summarized in a common format to provide a direct comparison of drilling efficiency , jet pressure and hydraulic power [(4)].It is not easy to make any logical interpretation of raw data i.e., [bit load , rate of penetration , flushing pressure , rotary speed and rotation pressure] and they represent a rather confusing picture . If however , these five parameters are combined in a formula , describing the energy from the drill bit acting on the soil . This formula represents specific energy needed to penetrate one cubic meter of the soil and the different layers of soft and hard soil are clearly visible [(5)].

Theoretical background

Specific energy parameter has defined as follows [(4)] :-

$$SE_d = \frac{W}{Q_r} \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots(1)$$

where , SE_d is the specific energy (J/mm^3) , W is the hydraulic or mechanical power (J) and Q_r is the volumetric rate of rock removal (mm^3)
In another words , the specific energy is defined mathematically as follows [(1)] :-

$$SE_d = \frac{Energy \;\; Input}{Volume \;\; removed} = \frac{P}{d_v / d_t} \qquad \cdots\cdots\cdots\cdots\cdots\cdots(2)$$

$$= \frac{\left[\frac{kW}{cm^2}\right] \cdot \sec onds}{cm} = \frac{kW}{cm^3 / \sec} = \frac{kJ}{cm^3}$$

where :- P = power Input (Watts) , d_v/d_t = Volume time derivative (cm3/sec)
Specific energy may use any consistent set of units .It has been shown that for rotary drilling may calculated from the following equation[(6)] :-

$$SE_d = \frac{E}{V} \qquad \cdots\cdots\cdots\cdots\cdots(3)$$

where :- E = mechanical power lb-in & V = a unit volume of rock in^3
mechanical power can be calculated from the following equation :-

$$E = 2\pi \, N \, W \qquad \cdots\cdots\cdots\cdots\cdots\cdots(4)$$

where N = rotary speed (rev/min) , W = weight on bit (lb)
and volume of rock removed can be calculated from the following equation :-

$$V = \pi \, R^2 \cdot ROP \qquad \cdots\cdots\cdots\cdots\cdots\cdots(5)$$

where :- ROP = rate of penetration (ft/hr) , R = bit radius (in)
and now substituting equ.(4) and (5) into equation (3) produces the following :-

$$SE_d = \frac{2\pi NW}{\pi R^2 \cdot ROP} \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots(6)$$

and replacing R with D i.e.; (hole diameter) , and according to that the data are not all homogeneous to be used into equ.(6) , so conversion factors used to get the following modified equation :-

$$SE_d \quad = \quad 20 \ \frac{W \cdot N}{D \cdot ROP} \quad \cdots\cdots\cdots\cdots\cdots\cdots(7)$$

where :- N = RPM or rev / min , W = ib , D = in , ROP = ft / hr and
SE_d = ib – in / in^3 .

Collection of data

Drilling data had been collected from Baroid oil company for a selected oil well sample in South of Iraq (west Qurna no.15 in Basrah).
Table (1) showed the data which includes depth , rate of penetration , rotary speed , hole diameter , weight on bit , bit type and lithology .

Table (1)

Drilling data collected from Baroid company

Depth	Bit type	ROP (ft/hr)	Rotary speed (rpm)	Hole diameter (in)	WOB (1000 lb)	Formation	Lithology
2932	**JD4**	**2.874**	**90**	**12.25**	**20**	**Nahr Umr**	**Interbeded shales & sandstone**
3005	**JD4**	**4.921**	**90**	**12.25**	**19**	**Shuaiba**	**Dolomite with minor limestone**
3102	**JD4**	**5.624**	**90**	**12.25**	**18**	**Zubair**	**Limestone with minor shales**
3187	**533**	**4.233**	**80**	**12.25**	**18**	**Zubair**	**Shales with minor sandstone**
3312	**J33**	**3.185**	**60**	**12.25**	**18**	**Zubair**	**Interbeded mudstones and shales**
3338	**JD4**	**2.66**	**65**	**12.25**	**18**	**Zubair**	**Shales & interbeded sandstone**
3407	**JD4**	**2.73**	**80**	**12.25**	**21**	**Ratawi**	**Shales with limestone**
3417	**J33**	**2.813**	**65**	**12.25**	**20**	**Ratawi**	**Shales with limestone**
3455	**J33**	**4.921**	**60**	**12.25**	**20**	**Ratawi**	**Shales with limestone**
3475	**J33**	**3.227**	**70**	**12.25**	**20**	**Ratawi**	**Shales with limestone**
3502	**J33**	**2.97**	**70**	**12.1875**	**20.25**	**Ratawi**	**Limestone**
3550	**C20**	**3.579**	**85**	**12.1875**	**9**	**Yamama**	**Limestone with interbeded shales**
3622	**C20**	**2.008**	**80**	**12.1875**	**10**	**Yamama**	**Limestone**
3637	**C22**	**2.316**	**104**	**8.437**	**9.5**	**Yamama**	**Limestone**
3713	**JD4**	**5.625**	**104**	**12.25**	**9**	**Yamama**	**Limestone**
3857	**FS5 KJ**	**2.316**	**84**	**8.375**	**20**	**Sulaiy**	**Limestone with thin interbeds of**

							anhydrite
3896	**LM6**	**1.848**	**50**	**8.375**	**14**	**Sulaiy**	**Limestone with thin interbeds of anhydrite**
3932	**J33**	**1.405**	**50**	**8.375**	**14**	**Sulaiy**	**Limestone with thin interbeds of anhydrite**
3992	**J33**	**1.839**	**50**	**8.375**	**17**	**Sulaiy**	**Limestone with thin interbeds of anhydrite**
4000	**J3**	**2.073**	**50**	**8.375**	**17**	**Sulaiy**	**Limestone with thin interbeds of anhydrite**
4100	**J3**	**2.187**	**50**	**8.375**	**18**	**Sulaiy**	**Limestone with anhydrite**
4117	**J3**	**4.825**	**55**	**8.375**	**19**	**Sulaiy**	**Limestone with thin interbeds of anhydrite**
4200	**J3**	**1.357**	**60**	**8.375**	**13**	**Gotnia**	**Anhydrite with thin interbeds of limestone & salt**
4210	**J3**	**24.607**	**55**	**8.375**	**13**	**Gotnia**	**1st cycle of salt**
4247	**J3**	**26.25**	**65**	**8.375**	**13**	**Gotnia**	**1st cycle of salt**
4275	**J3**	**1.789**	**45**	**8.375**	**18**	**Gotnia**	**Anhydrite with limestone and salt**
4302	**J3**	**13.124**	**100**	**8.375**	**18**	**Gotnia**	**2nd cycle of salt**
4307	**J3**	**3.281**	**100**	**8.375**	**15**	**Gotnia**	**2nd cycle of salt**
4315	**J3**	**10.35**	**100**	**8.375**	**15**	**Gotnia**	**2nd cycle of salt**
4320	**J3**	**13.1**	**100**	**8.375**	**13**	**Gotnia**	**2nd cycle of salt**
4372	**F4**	**1.383**	**60**	**5.625**	**5.25**	**Gotnia**	**Anhydrite with limestone & salt**
4378	**F4**	**3.937**	**59**	**5.625**	**7.3**	**Gotnia**	**3rd cycle of salt**
4387	**F4**	**21.8**	**75**	**5.625**	**7**	**Gotnia**	**3rd cycle of salt**
4392	**F4**	**1.789**	**42**	**5.625**	**5.5**	**Gotnia**	**Anhydrite with limestone**
4402	**F4**	**5.403**	**42**	**5.625**	**6.5**	**Najmah**	**Limestone**
4443	**F4**	**1.405**	**55**	**5.593**	**5.7**	**Najmah**	**Limestone**
4451	**HTC J33**	**1.48**	**55**	**5.875**	**4.5**	**Najmah**	**Limestone**
4463	**J33**	**1.640**	**64**	**5.875**	**6**	**Najmah**	**Limestone**
4498	**LM 9J**	**2.072**	**65**	**5.875**	**6**	**Najmah**	**Limestone with sandstone**
4512	**J33**	**2.46**	**64**	**5.875**	**6**	**Najmah**	**Limestone with salt & anhydrite**
4563	**OVB**	**1.613**	**120**	**5.843**	**6**	**Najmah**	**Limestone with salt & anhydrite**
4615	**OVB**	**6.057**	**110**	**5.843**	**6**	**Najmah**	**Limestone**

Results & discussion

SE_d calculations:

The data collected used to calculate SE_d using equation (7) .
The obtained values of SE_d shown below in table (2)

Table (2)

SE_d calculated vs. Depth

Depth (m)	SE_d [(lb-in)/in^3] *1000	Depth (m)	SE_d [(lb-in)/in^3] *1000
2932	1022.538	4117	517.21
3005	567.27	4200	1372.7
3102	470.246	4210	69.38
3187	555.341	4247	76.873
3312	553.619	4275	1081.297
3338	662.881	4302	327.531
3407	1004.724	4307	1091.782
3417	754.5	4315	345.761
3455	398.089	4320	236.984
3475	708.322	4372	809.872
3502	788.85	4378	388.981
3550	350.764	4387	85.626
3622	653.808	4392	459.107
3637	700.063	4402	179.658
3713	394.429	4443	797.81
3857	1184.307	4451	569.292
3896	904.568	4463	796.854
3932	1189.869	4498	640.709
3992	1103.322	4512	531.395
4000	979.206	4563	1527.689
4100	982.747	4615	372.909

Now after SE_d calculations, we sketch SE_d vs. depth. The resulted graph shown in fig.(1) .

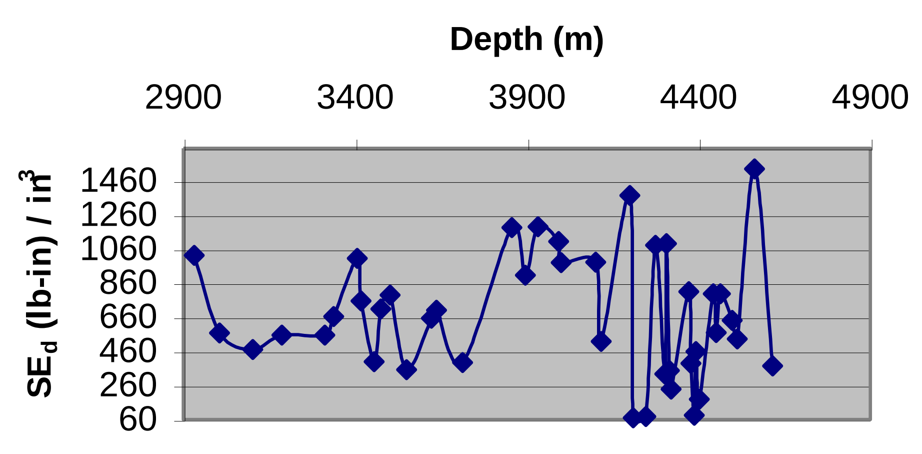


Fig.(1) Relation of SE_d vs. depth

We notice that each point on the graph represent bit performance regardless the trip time , rig cost , and other parameters that effects the cost per foot (CPF).We will show later how the best bit performance carried lowest values of SE_d values .

Relation of ROP with SE_d :

First of the distinguished part of the graph is that we notice very low value of SE_d i.e. 69.38 lb-in / in3 at depth 4210 m .
If we return to penetration rate at that depth , it was 24.607 ft / hr .
The same thing , it has been realized at depth 4247 m , the calculated SE_d was 76.873 corresponding to rate of penetration equals to 26.25 ft /hr .
If we get benefit of the lithology at depth between (4120-4400 m) , it refers to Gotnia formation , and particularly at depth between (4204-4252 m) the 1st cycle of Gotnia salt encountered . The presence of salt at that formation increases the rate of penetration & consequently decreases the value of SE_d calculated according to equ.(7) .
Also we realize the same thing at depth between (4300-4358 m) & particularly at depths 4315 &4320 m where , the second cycle of Gotnia salt , but SE_d here are so low like the first Gotnia salt i.e. 345.761 & 236.984 (lb-in) / in^3 respectively .
Final effect of Gotnia salt encountered at depth 4387 m where the third series Gotnia salt and the value of SE_d at that depth was 85.625 (lb-in) / in^3 , so we realize that at very high ROP SE_d will be low.

Bit performance:

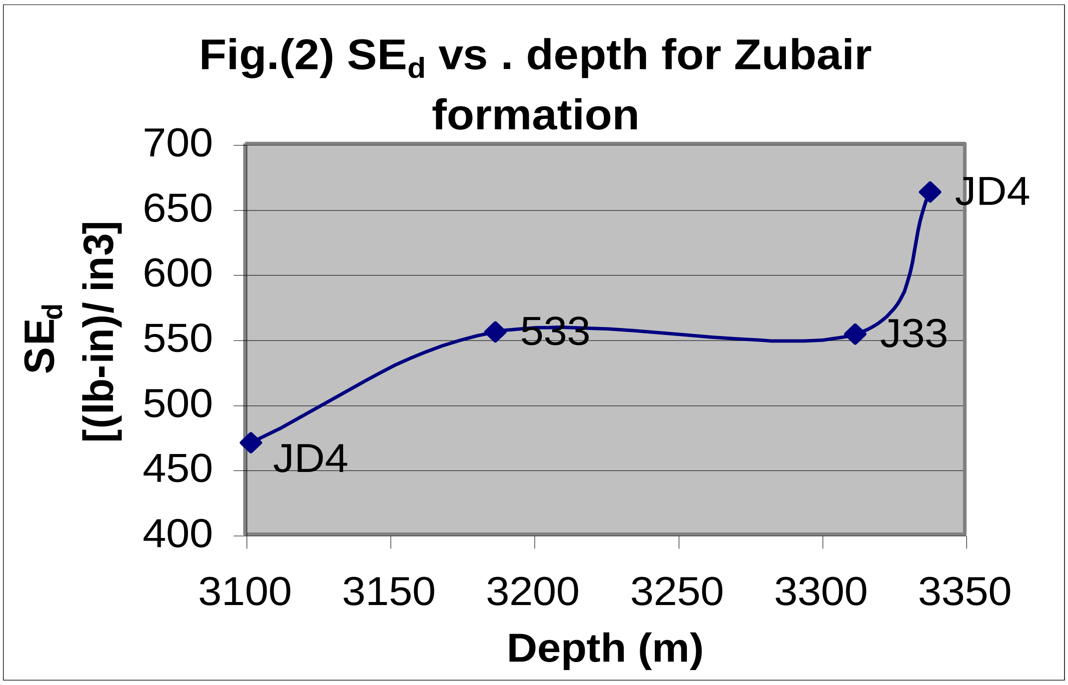
Using various bits to drill each formation as shown in table1 (1) produces various graphs of SE_d vs. depth as following :-

Nahr Umr and Shuaiba formations:

For both above formations , we have only one point of readings for bit record and consequently one point of SE_d for each formation , so it is insufficient to apply SE_d technique for these formations .

Zubair formation:

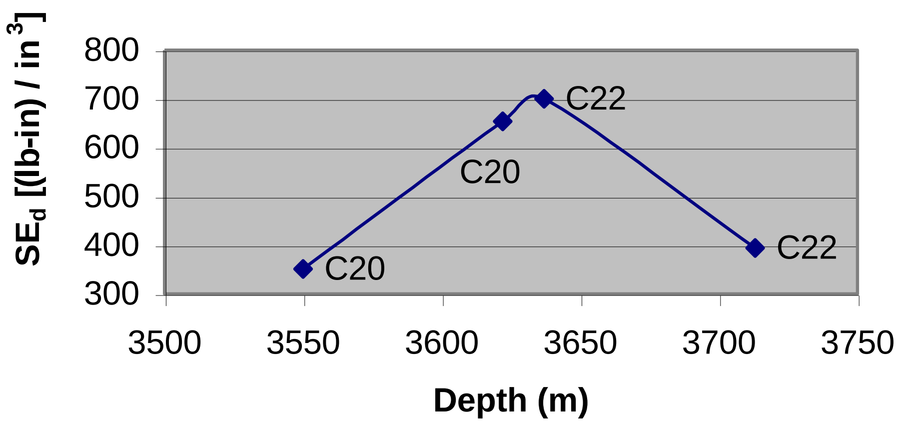
For this formation, and according of it's lithology , which most of it is limestone with little bit of shale, so we see that optimum (best) bit used to drill this section is JD4 because it carries lowest value of SE_d.This conclusion is identical to which used by bit comparison chart [7] where JD4 bits classified under insert medium bits where , medium refers to medium formations i.e. between soft to hard formations & here limestone represent this formation .Fig.(2) illustrates values of SE_d vs. depth for Zubair formation.



Yamama formation :

For this formation we notice that C20 bit carried minimum SE_d which that means it is the best , but unfortunately the bit comparison chart that we used does not include c20 bits into it in order to confirm our choice to use these bits.Fig.(3) illustrates SE_d vs. depth for Yamama formation .

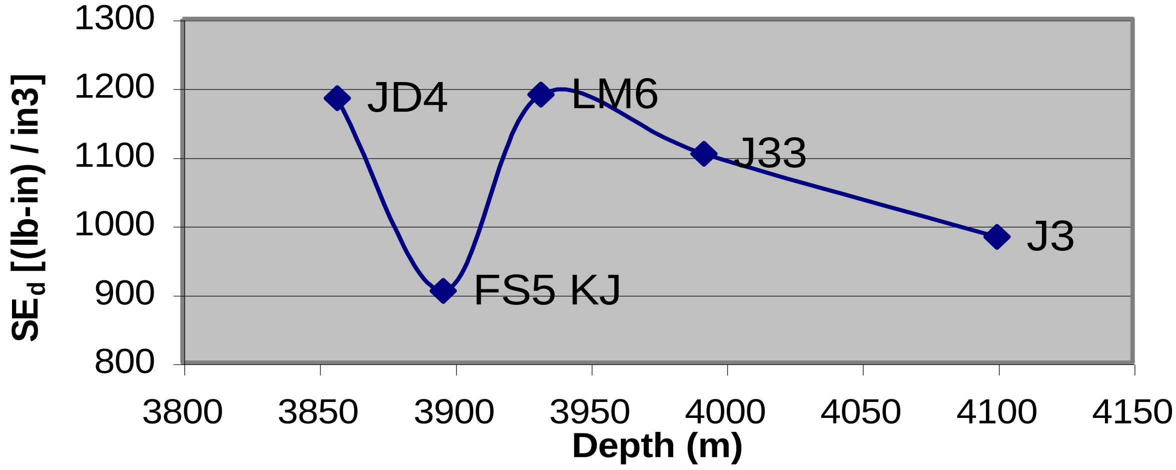
Fig.(3) SE_d vs. depth for Yamama formation



Sulaiy formation :

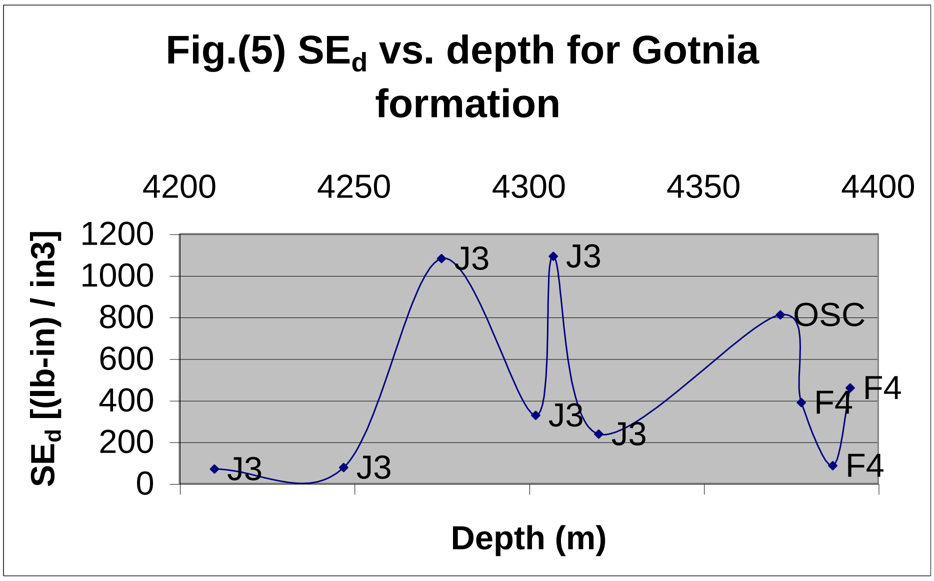
From the lithology for this formation , we realize that most of it is limestone plus Anhydrite , and from fig.(4) we notice that minimum value for SE_d corresponded to FS5 KJ bits ,i.e.; a type of F5 bits which it is classified according to bit comparison chart under insert medium bits where, medium refers to medium formations i.e. soft to hard formations and in this identical to our formation i.e. (Sulaiy formation) .

Fig.(4) SE_d vs. depth for Sulaiy formation



Gotnia formation :

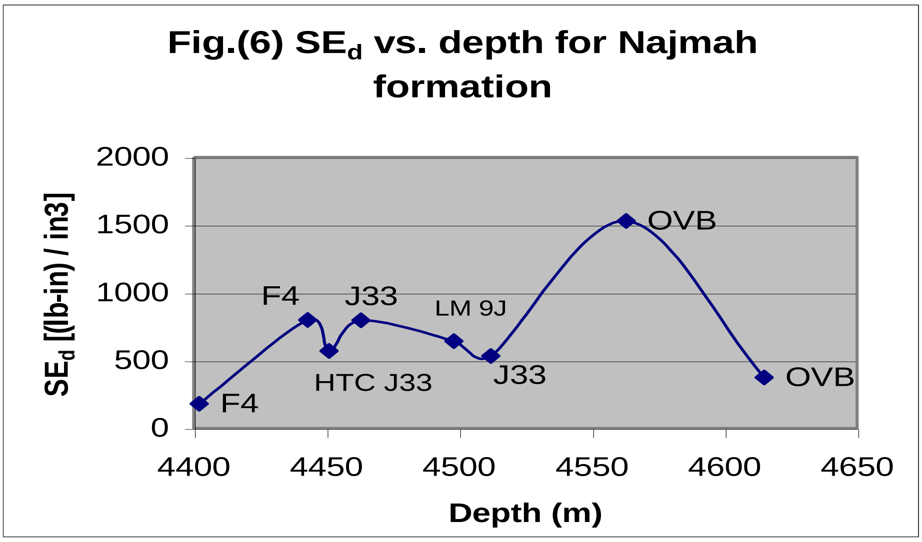
For this formation the best bit is J3 because it carried lowest value of SE_d and according to bit comparison chart these bits classified under milled tooth soft bits which it is used for soft formation , and this is true because most of Gotnia formation is salt and soft anhydrite which considered soft formation .Fig.(5) illustrates his reality .



Najmah formation :

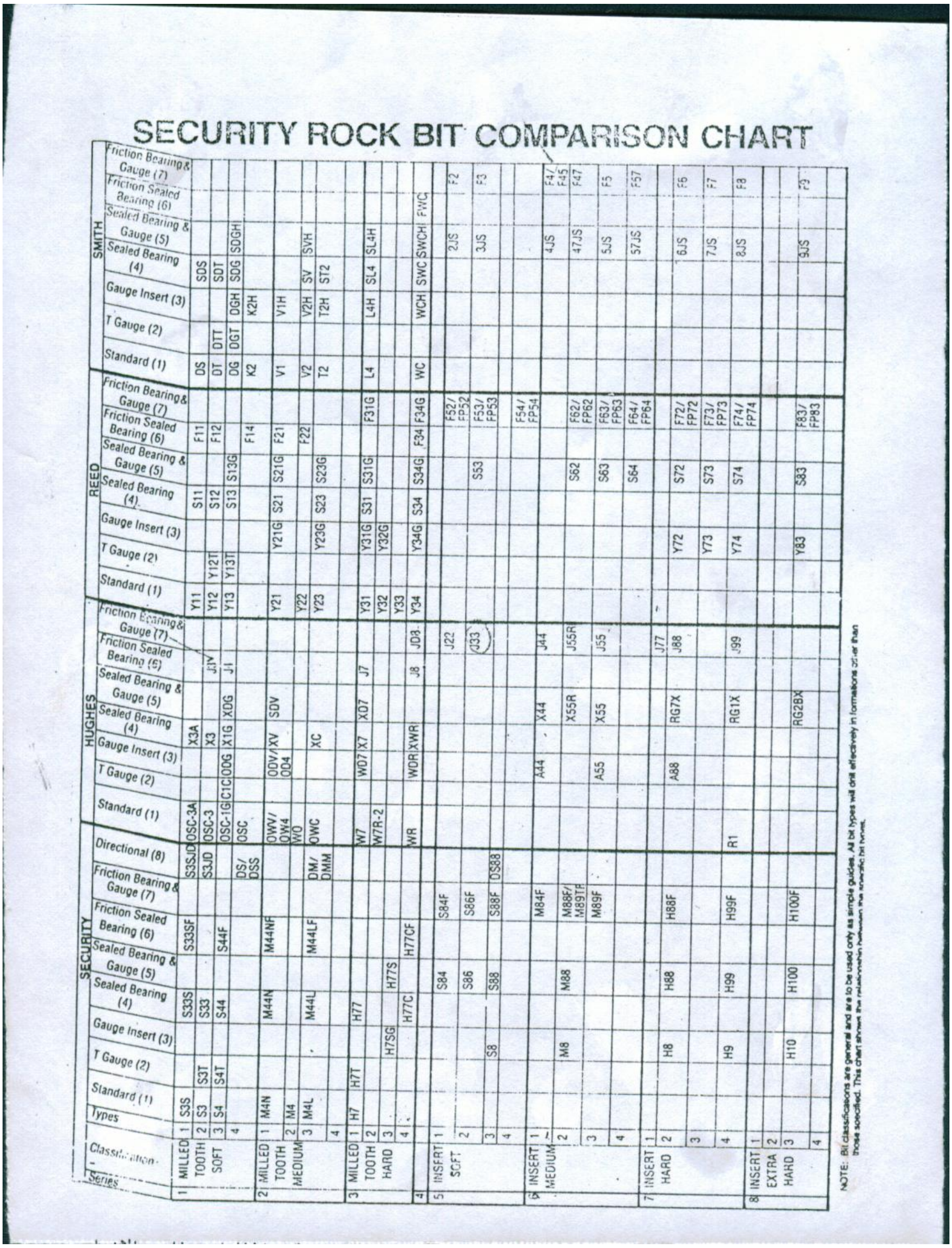
For this case the best bit used is F4 because it carried lowest value of SE_d i.e. 179.658 [(lb-in) / in^3] and according to bit comparison chart these kinds of bits classified under insert medium bits , and from the lithology of Najmah formation which most of it is limestone .

And as known that Limestone considered as medium formation , so it confirms the reality of bit comparison chart. This reality shown in fig.(6) below.



Conclusions :

1- SE_d technique is so useful and economical method to evaluate the drilling bits and bit performance by optimum bit selection .
2- Lowest SE_d occurred at highest rate of penetration .
3- The drilling parameters such as weight on bit , rotary speed and bit size have slightly effect on SE_d rather than rate of penetration .
4- Optimum bits can be selected at each formation by plotting SE_d vs. depth , where bits which carried lowest SE_d are the best or optimum bits and consequently reduces drilling costs .
5- Optimum bit drilled Zubair formation was JD4 bit , while C20 bit for Yamama formation , FS5kJ bit for Sulaiy formation ,J3 bit for Gotnia formation and F4 for Najmah formation .
6- We can apply this technique for the adjacent wells to get optimum bits use to drill similar formations and consequently reducing drilling operation costs.



SECURITY ROCK BIT COMPARISON CHART

Series / Classification	Types	Security Standard (1)	Security T Gauge (2)	Security Gauge Insert (3)	Security Sealed Bearing (4)	Security Sealed Bearing & Gauge (5)	Security Friction Sealed Bearing (6)	Security Friction Bearing & Gauge (7)	Security Directional (8)	Hughes Standard (1)	Hughes T Gauge (2)	Hughes Gauge Insert (3)	Hughes Sealed Bearing (4)	Hughes Sealed Bearing & Gauge (5)	Hughes Friction Sealed Bearing (6)	Hughes Friction Bearing & Gauge (7)	Reed Standard (1)	Reed T Gauge (2)	Reed Gauge Insert (3)	Reed Sealed Bearing (4)	Reed Sealed Bearing & Gauge (5)	Reed Friction Sealed Bearing (6)	Reed Friction Bearing & Gauge (7)	Smith Standard (1)	Smith T Gauge (2)	Smith Gauge Insert (3)	Smith Sealed Bearing (4)	Smith Sealed Bearing & Gauge (5)	Smith Friction Sealed Bearing (6)	Smith Friction Bearing & Gauge (7)
1 MILLED TOOTH SOFT	1	S3S			S33S		S33SF		S3SJD	OSC-3A			X3A				Y11			S11		F11		DS			SDS			
	2	S3	S3T		S33				S3JD	OSC-3			X3		J3V		Y12	Y12T		S12		F12		DT	DTT		SDT			
	3	S4	S4T		S44		S44F			OSC-1G	C1C	ODG	X1G	XDG	J1		Y13	Y13T		S13	S13G			DG	DGT	DGH	SDG	SDGH		
	4								DS/ DSS	OSC												F14		K2		K2H				
2 MILLED TOOTH MEDIUM	1	M4N			M44N		M44NF			OWV/ OW4		ODV/ OD4	XV	SDV			Y21		Y21G	S21	S21G	F21		V1		V1H				
	2	M4								WO							Y22					F22		V2		V2H	SV	SVH		
	3	M4L			M44L		M44LF		DM/ DMM	OWC			XC				Y23		Y23G	S23	S23G			T2		T2H	ST2			
	4																													
3 MILLED TOOTH HARD	1	H7	H7T		H77					W7		WD7	X7	XD7	J7		Y31		Y31G	S31	S31G		F31G	L4		L4H	SL4	SL4H		
	2									W7R-2							Y32		Y32G											
	3			H7SG		H77S											Y33													
	4				H77C		H77CF			WR		WDR	XWR		J8	JD8	Y34		Y34G	S34	S34G	F34	F34G	WC		WCH	SWC	SWCH	FWC	
4																														
5 INSERT SOFT	1					S84		S84F								J22														
	2					S86		S86F								J33							F52/ FP52					2JS		F2
	3			S8		S88		S88F	DS88												S53		F53/ FP53					3JS		F3
	4																						F54/ FP54							
6 INSERT MEDIUM	1							M84F				A44		X44		J44												4JS		F4/ F45
	2			M8		M88		M88F/ M89TF						X55R		J55R					S62		F62/ FP62					47JS		F47
	3							M89F				A55		X55		J55					S63		F63/ FP63					5JS		F5
	4																				S64		F64/ FP64					57JS		F57
7 INSERT HARD	1															J77														
	2			H8		H88		H88F				A88		RG7X		J88			Y72		S72		F72/ FP72					6JS		F6
	3																		Y73		S73		F73/ FP73					7JS		F7
	4			H9		H99		H99F		R1				RG1X		J99			Y74		S74		F74/ FP74					8JS		F8
8 INSERT EXTRA HARD	1																													
	2																													
	3			H10		H100		H100F						RG2BX					Y83		S83		F83/ FP83					9JS		F9
	4																													

NOTE: Bit classificasons are general and are to be used only as simple guides. All bit types will drill effectively in formations other than those specified. This chart shows the relationship between the specific bit types.

Bit Comparison Chart [7]

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