TR A4975

Use of electric high power equipment during well intervention with DC current

Horst Förster

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TECHNICAL REPORT

SUBJECT/TASK (title)

USE OF ELECTRIC HIGH POWER EQUIPMENT DURING WELL INTERVENTION WITH DC CURRENT

CONTRIBUTOR(S)

Horst Förster

CLIENT(S)

Schlumberger Offshore Services N.V.

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RESULT (summary)

USE OF ELECTRIC HIGH POWER EQUIPMENT DURING WELL INTERVENTION WITH DC CURRENT

Investigation to confirm that there not will occur dangerous voltage drops in the platform construction during wire line operations with a voltage up to 1500 V and 25 A DC.

Wire line cables used to well intervention consist of a steel wire with inlaid conductors. The return path of the current is mainly the construction and earth system of the platform. This is not according to the prevailing regulations.

The results of the voltage measurements confirm that it is safe to do well operations with currents up to 25 A DC, if the recommendations for the electrical equipment and the earth connections to the grease injection head are fulfilled. According to the regulations (FEA-M 1990 and others) the limit for low voltage is 1500 V DC.

At a current of 15 A the voltage drop in the platform construction was 60 mV and it will be about 100 mV at 25 A.

The present report is a supplement to EFI report TR A4596 "Bruk av enlederkabel under brønnintervenering", november 1997. EFI TR A4596 approaches in principle the same problem but using an AC power supply.

Similar conditions as to wire line operation exist when coil tubing is used with electrical tools. In this case the same safety requirements has to be fulfilled. Instead to the grease injection head the earth connection is to the upper bushings where the coil is entering the slipper.

* Rapporten er omklasifisert til åpen 27/1-04 etter oppdragsgivers ønske.

KEYWORDS

SELECTED BY AUTHOR(S)		
	Offshore	Well intervention
	Wire line	Safety

TABLE OF CONTENTS

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1 BACKGROUND AND APPROACH TO THE PROBLEM

For efficient well operation it is necessary with well intervention such as measurements and performing perforations, plugging, etc. The transmission of measured signals and power requires cables with as little cross section as possible to overcome the pressure of the well.

Wire line cables consist of one conductor or several conductors, usually connected in parallel during high power operations, inlaid in a steel wire. The operating current uses the casing of the well and the earth system of the platform as return path. Due to practical and technical problems it is not possible to fulfil the requirements of the regulations. The wire line cables would get a large diameter due to the necessary copper cross section which would lead to problems to overcome the pressure in the well. To avoid potential differences in the ground system of the platform an earth connection was implemented between the power supply and the grease injection head as a compensating effort.

According to the regulations for electrical equipment a cable shall consist of:

- conductors with insulation
- common metallic screen, which has to be grounded, operating current is not allowed in the screen
- an insulating layer on the outside of the screen

In addition the earth system shall not carry operating currents.

The intentions of this investigation is to prove that there is no danger with respect to contact voltage for the personnel and ignition of explosive gas mixtures, although the regulations are not fulfilled.

2 REGULATIONS

References to regulations:

"Regulations relating to electrical installations in the petroleum activities", issued by the Norwegian Petroleum Directorate 08. January 1991, last amended 25 February 1998 with references to:

"Regulation for electrical installations - Maritime installations- FEA-M" 1990 and "Regulation for electrical installations of buildings etc." 1991, both issued by The Norwegian Directorate for Product and Electrical Safety.

IEC Publication 60079-11 "Electrical apparatus for explosive gas atmospheres, Part 11: Intrinsic safety "i", 1991-11.

IEC Publication 61892-7 "Mobile and fixed offshore units- Electrical installations, Part 7: Hazardous areas, 1997-05.

3 MEASUREMENTS AND RESULTS

The measurements were performed on Snorre TLP during a patchflex operation using a DC power supply. The maximum voltage and current are specified by the manufacturer:

Max. no load output voltage: 1410 V
Max. output current: 21 A

During the patchflex operation the maximum voltage and current were 923 V and 14,8 A.

The maximum voltage drop at accessible current-carrying parts of the power supply is between the earth point of the voltage source (Drillflex container) and the cable at the well head where the wire line cable enters the grease injection head.

The maximum voltage difference between the wire line cable at the grease injection head and the earth point of the power supply at the Drillflex container was < 60 mV at 14,8A. There was only a very low current (<0.05A) in the steel armour of the accessible part of the cable. Figure no.1 in Appendix 1 shows a schematic diagram of the earth connections.

The voltage drop in the earth system was continuosly logged during the whole Patchflex operation. The figures nos. 2-4 in Appendix 1 show the results of the voltage measurements.

Channel 2 in these records shows the voltage drop between the cable and the flow tubes in the grease injection head. Low voltage (<100 mV) is required to make sure that heat spots will not occur between the armour and the grease tubes which could reduce the mechanical strength of the cable.

Channel 3 in the records shows the maximum voltage drop in the earth system.

Peaks on the voltage measurements occurring each 15 min. are due to electromagnetic noise. Each 15 minutes the power supply was switched off to do temperature measurements and the switched on again. If necessary the value of the current was adjusted.

The polymerisation record data sheets of the operation shown in Tables 1 and 2 in Appendix 1 allow a correlation between operating current and voltage drop.

The maximum voltage drop between the earth point at the Drillflex container and the cable at the grease injection head did never exceed 60 mV.

4 EVALUATION OF SAFETY ASPECTS

The following requirements to electrical installations are not fulfilled when using wire line cables during well intervention:

- The cable screen (the steel armour) can carry some operating current
- The cable has no insulating sheath

Under such conditions it is possible that:

- personnel may come in contact with live parts of the power supply
- unintended connections may occur between the cable and the deck, for example due to tools or other metallic objects. This may lead to electric sparks if the voltage and current are high enough

The maximum values for currents in the steel armour of the cable and for voltage differences are < 100mA respectively 100mV at the limits given introductorily (1500V, 25A, DC).
Under such condition no danger with regard to contact voltage exists.

To evaluate danger of ignition of explosive gas mixtures Table no. 1 compares the measured values of current and voltage with the limits for intrinsic circuits given in FEB,1991,§808.7.4.3 and IEC Publication 60079-11, 1991.

Table no. 1 compares measured values of voltage and current with the limits given in different regulations. Appendix 2 contains detailed references to regulations and standards.

Table no. 1: Comparison of measured values and the limits in different regulations and standards.

	Requirement in FEB 1991	Requirement in IEC 60079-11 (*1)	Measured values (*2)
Voltage	<1.2 V	< 24 V	< 100mV
Current	< 100 mA	< 950 mA	< 100mA
Power	<25 mW		< 10 mW

(*1) Assumption
- The inductance of the circuit given by the wire line cable and the platform does not exceed 100 μH. It is realistic to assume an inductance of 1 μH per m^2 of the loop between the cable and the deck.
- The gas mixture is corresponding to group II A.

(*2)
- The values in the table are extrapolated from measured values at 14.8 A operating current to expected values at the maximum current of 25 A.

5 ROUTINES ON USING WIRE LINE CABLES

To secure correct electrical installation and safe performance of well intervention these recommendations has to be fulfilled:

- Earth points performed according to the regulations have to be installed at the collector ring box at the winch and at the power supply.
- The terminal of the power supply which is connected to ground may not have an independent fuse.
- An earth cable with a min. cross section of at least 70 mm^2 (Cu) has to be installed from the nearest earth point of the power supply to the grease injection head. (At coil tubing to or nearby the upper bushings) If the length of the cable does exceed 50 m, the cross section of the earth cable has to be increased corresponding to the resistance of the cable.
- The power supply has to fulfil relevant recommendations for short circuit currents and breaking time.

All installations have to be in accordance with relevant regulations for electrical installations off shore.

6 CONCLUSIONS

Due to practical problems it is difficult to meet the requirements of the regulations for electrical equipment during wire line operations. The measurements prove that no danger for personnel touching the wire line cable or for ignition of explosive gas – air mixtures exists, provided that the procedures mentioned in clause 5 are met. The measurements show that the values for voltage and current in accessible parts of the construction do not exceed the limits for intrinsic circuits in classified areas.

Appendix 1: The earth system and results of the measurements

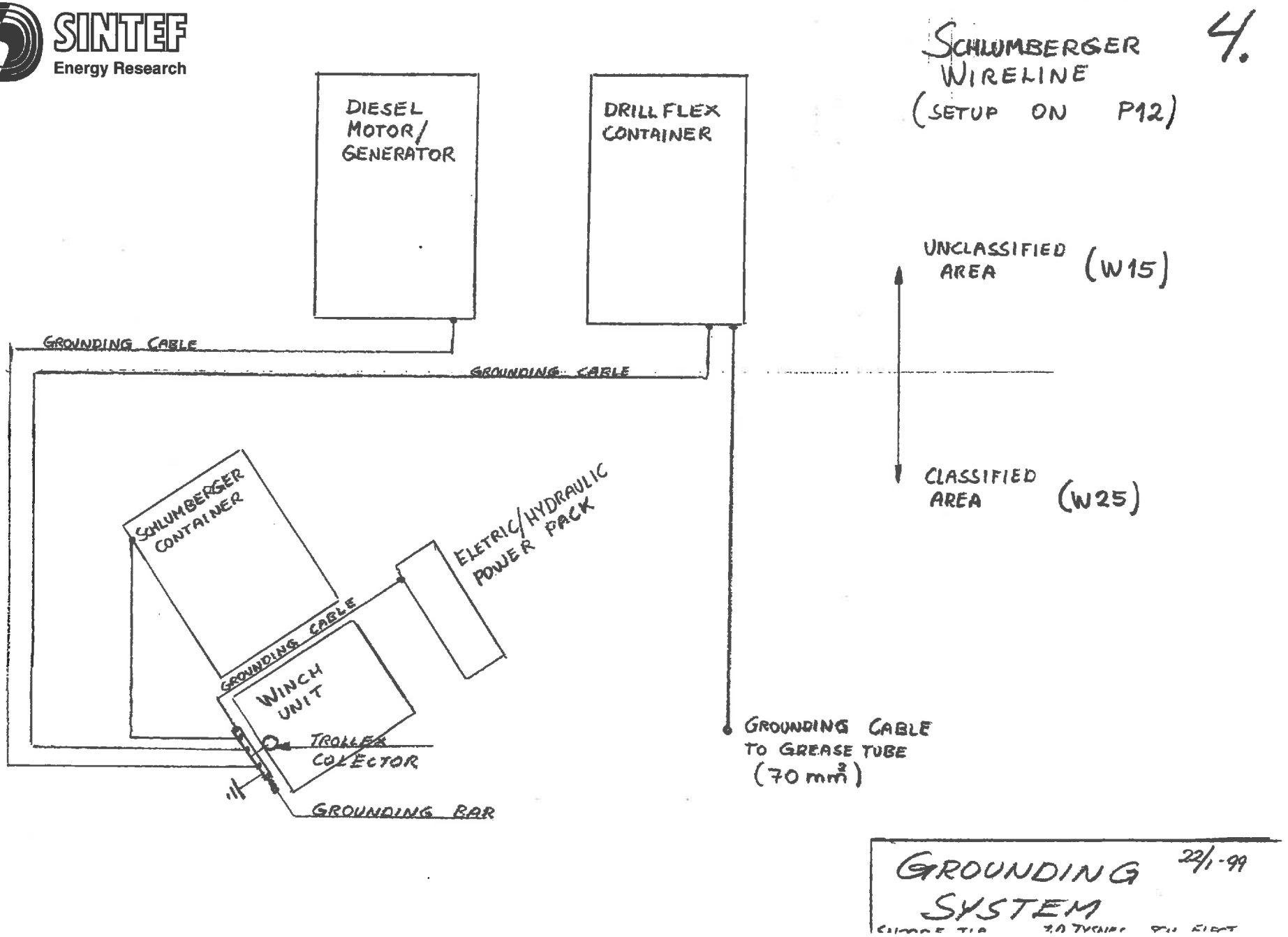
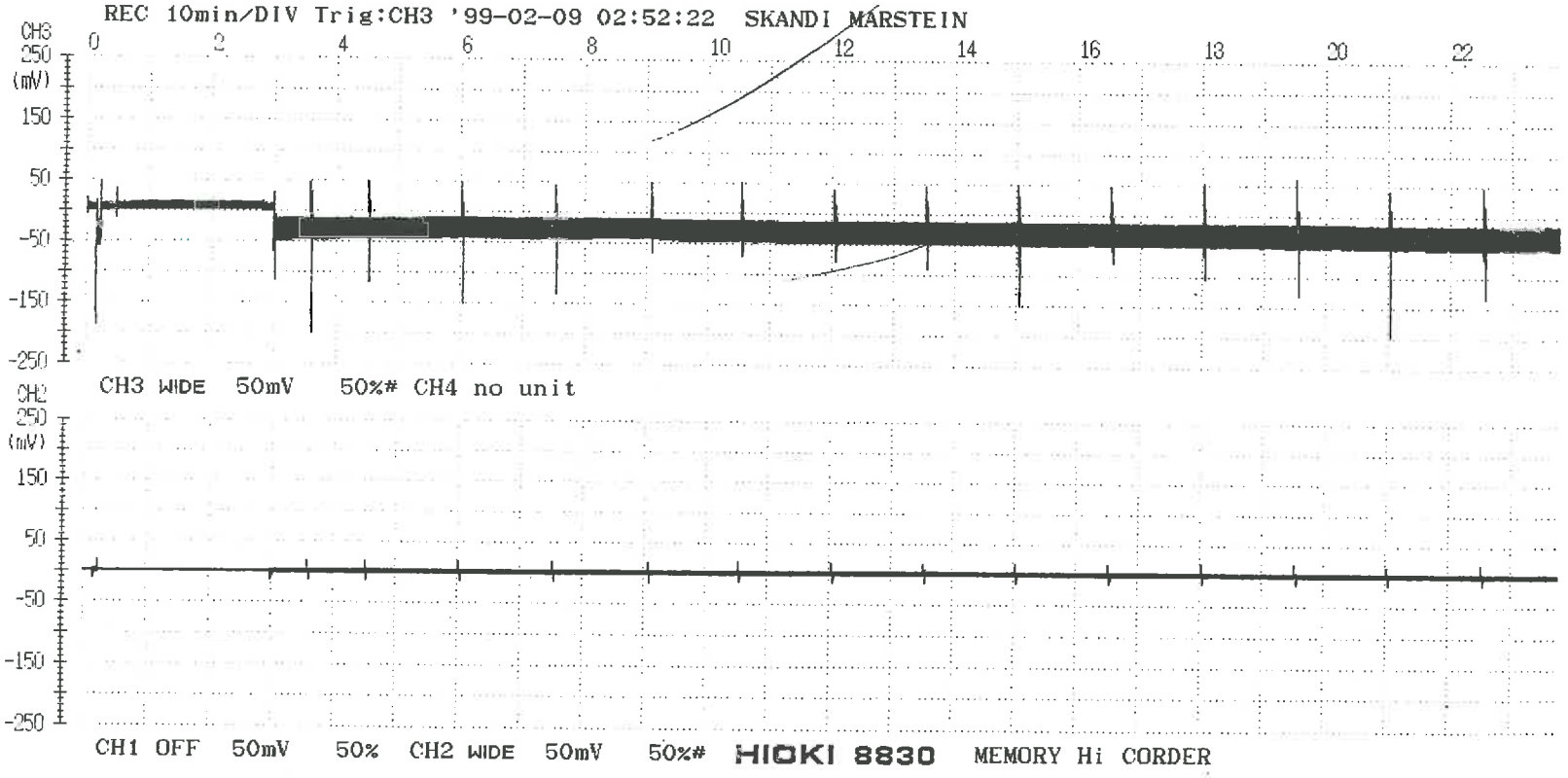


Figure A1: Grounding system for wire line set up at Snorre TLP, Patchflex operation at P12 from Schlumberger



09. 02. 1999 Skandi TLP

Figure A2: Record of the voltage measurements, the first 210 minutes

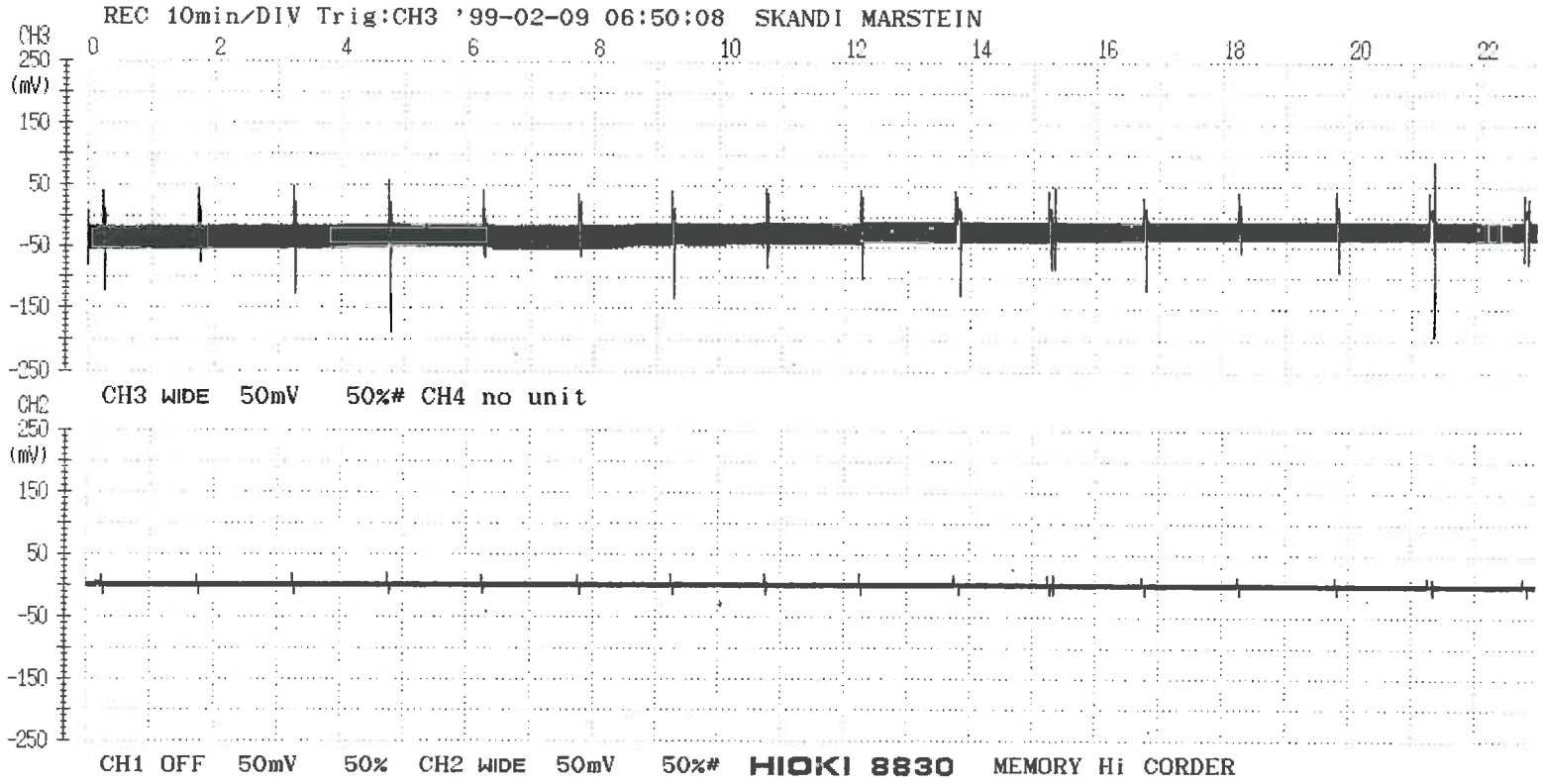


Figure A3: Record of the voltage measurements, from 210 to 440 minutes

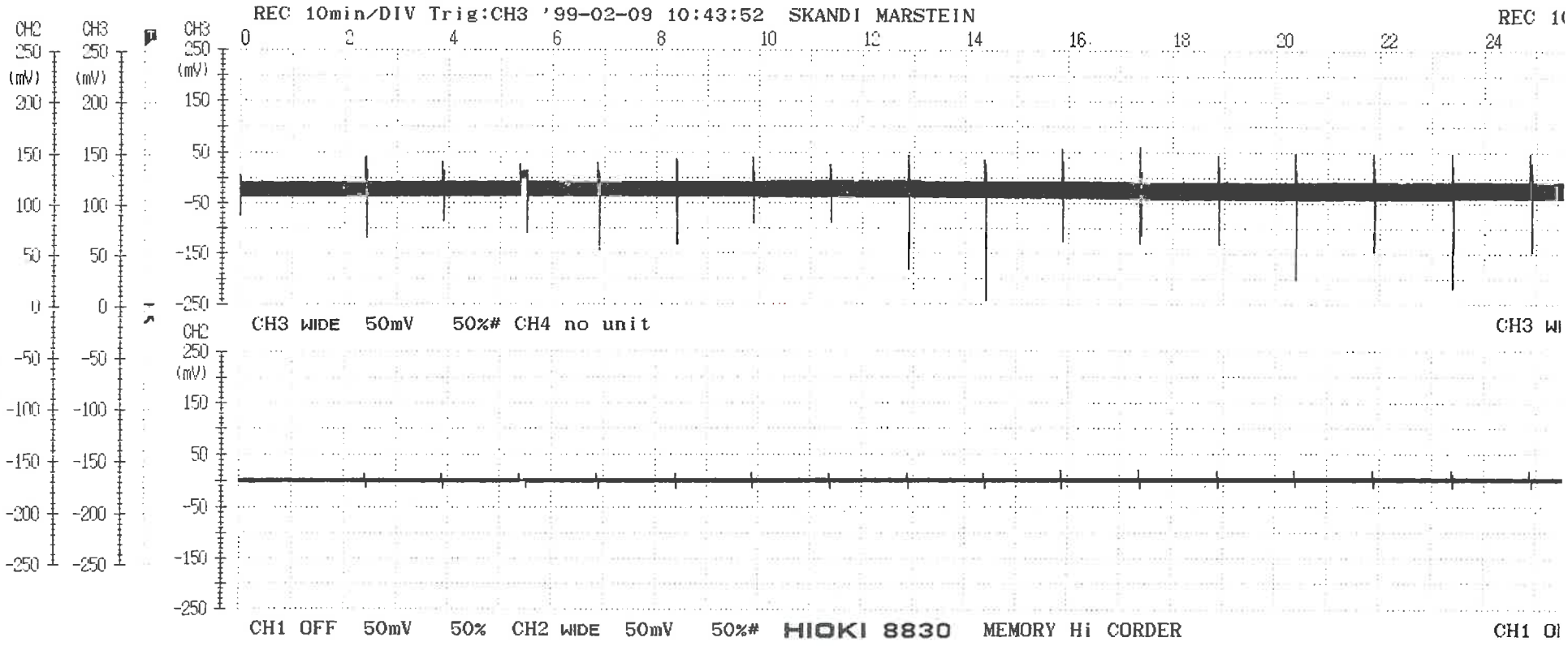


Figure A4: Record of the voltage measurements, from 440 to 700 minutes

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POLYMERISATION RECORD DATA SHEET

Software release: V 2.3
Compagny SAGA
Field: Snorre
Well: 34/7 P12
Patch-Flex: 112
Job date: February 1998

Ttop 1700
Tbottom 20000

Thermal capacity of ground	Cp =	1700	J/kg,K
Lambda of Outer Skin		0.31	W/m,K

See Note: Cas favorable Cp= 910 J/kg,K; Cas défavorable Cp = 4500 J/kg,K

Time of record			MAIN REAL VALUES				EVALUATED INDICATORS			THERMAL SIMULATION RESULTATS					OTHER REAL VALUES						
							POLYMERISATION PROGRESS		HI												
Computer time at begining h:mn	Computer time at end h:mn	Phse polym. duration	I Amps	U Volts	T1 Top °C	T2 Botom °C	Top composite	Bottom composite		Composite temperature simulation	Neces. current Amps	Anticiped voltage Volts	Power per meter supplied w/m	Ground parameter (+ or -)	T3 Electro. °C	T4 Puls °C	before pumping Bar	Pumping Yes or No	P after pumping Bar	Tension tool N	Comments
	0:00	0:00			63.0	62.0				60.0				%	58	59.0	15.0			1664	T1=Bottom; T2=Top
4:35	4:50	0:15	12.4	770	75.2	73.4	0	0		66.8	12.4	715	1000		61	59.0	16.5				
4:50	5:05	0:30	12.4	770	80.8	78.2	0	0		87.2					54	59.0	16.3			1527	
5:05	5:20	0:45	12.4	770	85.6	81.9	0	0		91.9					57	59.0	16.4			1507	
5:20	5:35	1:00	12.4	770	90.3	85.3	0	0		96.0					58	59.0	16.6			1499	
5:35	5:50	1:15	13	809	95.6	89.1	0	0		103.3	13.4	776	1175		58	59.0	16.3			1467	
5:50	6:05	1:30	13.5	839	101.2	93.0	0	0		107.7					59.5	58.8	15.8			1463	
6:05	6:20	1:45	13.5	840	105.7	95.9	0	0		111.6					59.5	58.8	15.8			1449	
6:20	6:35	2:00	13.5	840	110.3	98.4	0	0		115.0					59.6	58.9	16.0			1446	
6:35	6:50	2:15	14.1	877	115.9	101.8	0	0		120.9	14.1	816	1300		59.7	59.0	15.9			1437	
6:50	7:05	2:30	14.1	877	120.8	104.3	0	0		124.8					60	59.0	16.0			1432	
7:05	7:20	2:45	14.1	879	125.3	106.5	0	0		129.2					59.9	59.1	15.6			1409	
7:20	7:35	3:00	14.1	881	129.5	108.5	0	0		131.4					60	59.0	15.5			1411	
7:35	7:50	3:15	14.6	909	134.5	111.1	4	0		136.5	14.6	847	1400		60	59.0	15.4			1410	
7:50	8:05	3:30	14.6	909	138.7	113.0	7	0		139.9					60.3	59.4	15.6			1395	
8:05	8:20	3:45	14.6	909	142.5	114.6	12	0		143.0					60.4	59.4	15.4			1411	
8:20	8:35	4:00	14.6	909	146.0	115.9	17	0		145.9					60.5	60.5	15.3			1395	
8:35	8:50	4:15	14.6	923	149.7	117.7	22	0		149.1	14.5	837	1370		61	60.0	14.4			1400	
8:50	9:05	4:30	14.7	910	152.4	118.6	27	0		150.6					61	60.0	15.3			1389	
9:05	9:20	4:45	14.5	902	154.8	119.1	33	0		152.8					61	60.0	14.2			1408	
9:20	9:35	5:00	14	870	156.0	118.4	39	0		155.0					60	60.0	13.8			1400	
9:35	9:50	5:15	13.5	840	157.7	117.3	45	0		150.6	12.7	733	1050		60.7	59.9	8.6			1395	
9:50	10:05	5:30	12.4	770	157.7	117.3	51	0		150.5					60.7	59.9	8.6				
10:05	10:20	5:45	12.4	770	152.4	112.7	1	0		151.0					60.7	59.8	2.2		12.6	1472	
10:20	10:35	6:00	12.4	771	156.5	114.1	63	0		151.6					60.8	60.0	2.2		13.0	1466	
10:35	10:50	6:15	11.7	731	155.1	112.3	69	0		148.5	11.5	667	870		60.6	60.0	2.2		12.4		
10:50	11:05	6:30	11.5	714	153.8	110.8	74	0		148.1					61	60.0	2.0		14.0	1479	
11:05	11:20	6:45	11.5	715	155.4	110.8	80	0		147.9					60.5	60.0	2.0		14.2	1471	
11:20	11:35	7:00	11.5	714	152.2	109.7	86	0		148.0					61	60.0	2.6		12.5	1473	
11:35	11:50	7:15	11.5	715	151.3	108.2	91	0		148.0	11.5	667	870		61	60.0	2.9		13.1	1455	
11:50	12:05	7:30	11.5	715	150.8	108.0	96	0		148.2											
12:05	12:20	7:45	11.5	715	150.6	107.7	102	0		148.4					60	60.0				1366	
12:20	12:35	8:00	11.5	716	150.6	107.4	107	0		148.6					60	60.0	2.1			1341	
12:35	12:50	8:15	11.5	714	150.0	107.0	112	0		148.9	11.5	667	870		61	60.0	1.0		14.0	1491	
12:50	13:05	8:30	11.5	713	149.2	106.3	117	0		149.2					61	60.0	6.5			1456	
13:05	13:20	8:45	11.5	713	149.2	106.2	122	0		149.6					60.4	59.8	4.6			1434	
13:20	13:35	9:00	11.5	715	149.3	106.4	127	0		149.9					60.5	59.8	4.0			1420	

Notes:

Pour le cas d'un tubing:

- Si la simulation est au dessus (Cas peu probable), la peau extérieure est plus isolante que prévue. Action: augmenter le lambda de la peau extérieure.
- Si la simulation est en dessous, on n'est pas en vrai tubing. Action : Passer en casing avec Cp du sol de l'ordre de 15.000 (à faire varier)
  Lambda peau extérieure autour de 0,31 (à faire varier éventuellement si problème avec Cp sol)

Table A1: Polymerisation record data sheet from Drillflex containing information of values of the operating current, the first 9 hours

SINTEF Energy Research

POLYMERISATION RECORD DATA SHEET

Software release: V 2.3
Compagny SAGA
Field: Snorre
Well: 34/7 P12
Patch-Flex: 112
Job date: February 1999

Thermal capacity of ground Cp = J/kg,K
Lambda of Outer Skin W/m,K
See Note Cas favorable Cp= 910 J/kg,K
Cas défavorable Cp = 4500 J/kg,K

Time of record ⇩

			MAIN REAL VALUES				EVALUATED INDICATORS			THERMAL SIMULATION RESULTATS					OTHER REAL VALUES						
							POLYMERISATION PROGRESS		HI												
Computer time at begining h:mn	Computer time at end h:mn	Phse polym. duration	I Amps	U Volts			Top composite	Bottom composite		Composite temperature simulation	Neces. current Amps	Anticiped voltage Volts	Power per meter supplied w/m	Ground [illegible]	T3 Electro. °C	T4 Puits °C	before pumping Bar	Pumping Yes or No	P after pumping Bar	Tension tool N	Comments
	0:00	0:00								149.9				%	59	59.0	15.0			1504	T1=Bottom; T2=Top
13:35		0:15	12	745.0			133	0		86.9	12.4	715	1000		60.4	59.7	6.3			1430	
13:50		0:30	12	745.0			138	0		87.2					60.8	59.9	6.0			1417	
14:05		0:45	12.4	769.0			143	0		91.8					60.4	59.7	11.1			1356	
14:20		1:00	12.4	771.0			149	0		96.9					60.4	59.7	15.6			1361	
14:35		9:36	12.4	771.0			155	0		101.6	13.0	750	1100		60.4	59.7	15.7			1326	
14:50		1:30	13	809.0			160	0		105.4					60.4	59.7	15.6			1319	
15:05		1:45	13	809.0			166	0		108.9					60.4	59.7	15.6			1315	
15:20		2:00	13	809.0			172	0		112.1					60.5	59.8	15.8			1312	
15:35		2:15	13	807.0			179	0		113.0	12.4	715	1000		60.6	59.8	15.1			1312	
15:50		2:30	12.8	797.0			185	0		115.1					60.6	59.8	14.2			1312	
16:05		2:45	12.4	771.0			191	0		117.3					60.6	59.8	14.1			1305	
16:20		3:00	12	744.0			197	0		119.3					60.6	59.8	1.7			1279	
16:35		3:15	12	744.0			203	0		121.3	12.4	715	1000		60.5	59.8	1.7			1297	
16:50		3:30	12	745.0			209	0		123.1					60.6	59.9	1.6			1296	
17:05		3:45	FIN DE	PHASE			209	0		124.9											
17:20		4:00					209	0		126.6											
17:35		4:15					209	0		132.4	13.5	784	1200								
17:50		4:30					209	0		135.2											
18:05		4:45					209	0		137.6											
18:20		5:00					209	0		139.9											
18:35		5:15					209	0		142.0	13.5	784	1200								
18:50		5:30					209	0		144.0											
19:05		5:45					209	0		145.8											
19:20		6:00					209	0		147.6											
19:35		6:15					209	0		149.3	13.5	784	1200								
19:50		6:30					209	0		151.0											
20:05		6:45					209	0		152.6											
20:20		7:00					209	0		154.1											
20:35		7:15					209	0		155.6	13.5	784	1200								
20:50		7:30					209	0		157.0											
21:05		7:45					209	0		159.3											
21:20		8:00					209	0		159.7											
21:35		8:15					209	0		160.9	13.5	784	1200								
21:50		8:30					209	0		162.2											
22:05		8:45					209	0		163.4											
22:20		9:00					209	0		164.6											

Notes:

Pour le cas d'un tubing:

- Si la simulation est au dessus (Cas peu probable), la peau extérieure est plus isolante que prévue.
- Si la simulation est en dessous, on n'est pas en vrai tubing.

Table A2: Polymerisation record data sheet from Drillflex containing information of values of the operating current, from 09.00 to 12.45 hours

Appendix 2: References to national regulations for electrical installations and international standards

Safety for personnel

The question about danger for personnel which comes in contact with current carrying components was not investigated because the accessible voltages are very low (< 100 mV).

Danger of ignition of explosive gas mixtures

The consideration is based on:

"Regulations relating to electrical installations in the petroleum activities", established by The Norwegian Petroleum Directorate, 1998.
Section 14 "Special technical and operational requirements" in this regulation refers to:

"Regulation for electrical installations – Maritime installations – FEA-M", established by The Norwegian Directorate for Product and Electrical Safety, March 1990 and

IEC Publication 6189 "Mobile and fixed offshore units – Electrical installations –Part 7: Hazardous areas, 1997-05.

When writing EFI TR A4596, the investigation about use of ac power supplies to well intervention the IEC Pub. 61892-7 was not yet available and the consequences of this standard are so far not completely evaluated.

The regulations and standards mentioned above, refer to FEB § 808.7.4.3 or/and to IEC Pub. 60079-11 when giving limits for electrical values as current, voltage, etc. in hazardous areas.

According to FEB 1991, §808.7.4.3 it is not necessary to certify equipment not exceeding following values in areas class I with gasses of group II A:

- voltage: 1.2 V
- current: 0.1 A
- energy: 20 μJ
- power: 25 mW

The maximum current in the steel screen of the wire line cable, which can be short circuited to ground is < 0.1 A and the voltage does not exceed 100 mV. This means that the maximum power is 10 mW.

To exceed the energy of 20 μJ the spark had to last for 2 ms. With this low currents and voltages it will be very difficult, probably impossible to generate a spark at all.

Figure 5 of IEC Pub. 60079-11 gives the lowest limit for ignition current under consideration of the inductance of resistive-inductive circuits with a primary voltage of 24 V DC. To estimate the inductance of a loop in air we may assume an inductance of 1 μH per square meter of the loop. For a loop of 100 m^2 (equivalent to100 μH), the minimum ignition current is 0.95 A for gas mixtures of group II A.

Figure A5 in Appendix 2 shows this curves.

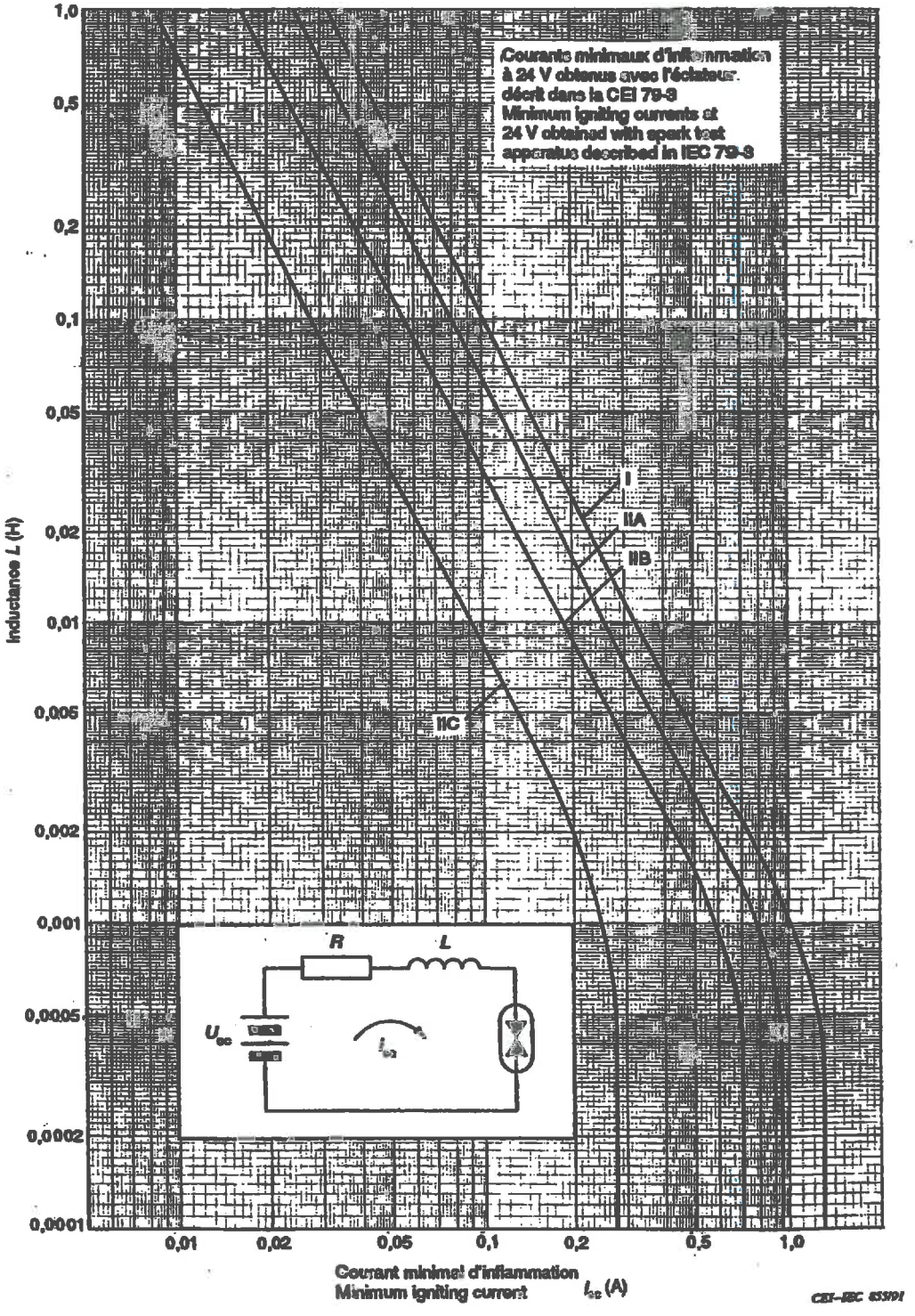

Figure A7: Minimum ignition currents of inductive circuits.

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