VDN Engineering Ltd

IRZ

SUBMERSIBLE PUMP WITH LINEAR PERMANENT MAGNET MOTOR (SPLM)

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October 2021

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ARTIFICIAL LIFT SOLUTION FOR INCREASED PRODUCTION AND DECREASED LIFTING COSTS

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SPLM

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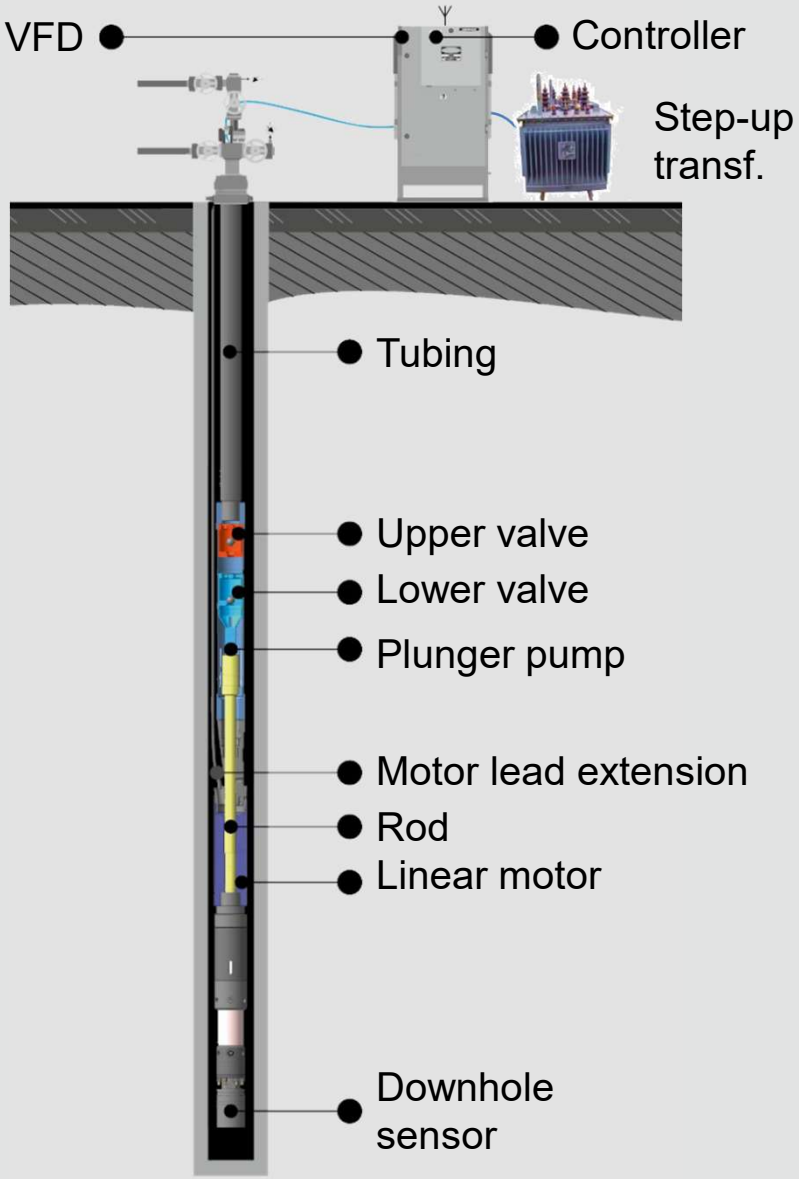


The system

SPLM is an artificial lift system based on a plunger pump. The pump is driven by a reciprocating linear permanent magnet motor installed below the pump.

Application

SPLM was developed to improve the efficiency of production in vertical, horizontal or deviated wells with production rate up to 652 bpd (103 m^3/day) and depth down to 13700 ft (4190 m).

SPLM Advantages

In wells with low production rates, SPLM has the following advantages if compared to other pumping systems (SRP, ESP, PCP):

SPLM allows to decrease

- **energy consumption by 5-80 %**
- **maintenance costs** compared to SRP by **up to 50 %**

and to increase

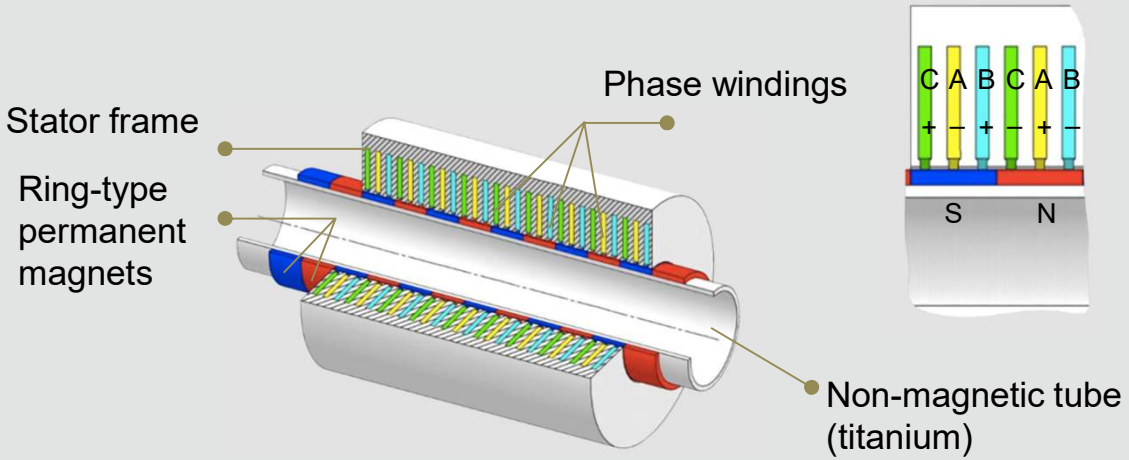
- oil **production rates by 10-50 %**
- **MTBF** in wells with hard conditions **by 2 times**

Linear Motor of SPLM

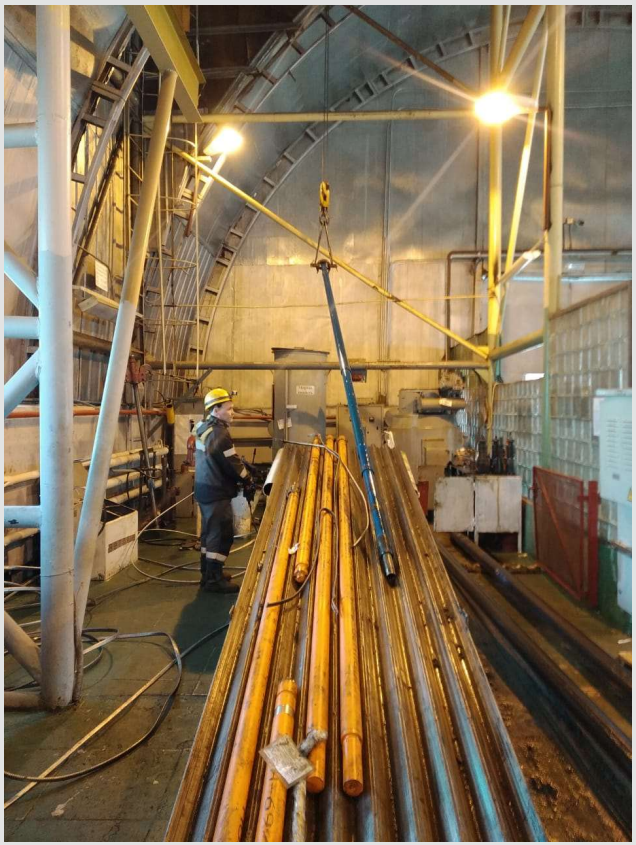
Operating principle

Unlike ESP, the submersible **linear PM motor** is reciprocating

Coils in the stator generate a travelling magnetic field that induces an electromotive force to move the magnetic slider which pushes the plunger pump rod



Plunger Pump of SPLM

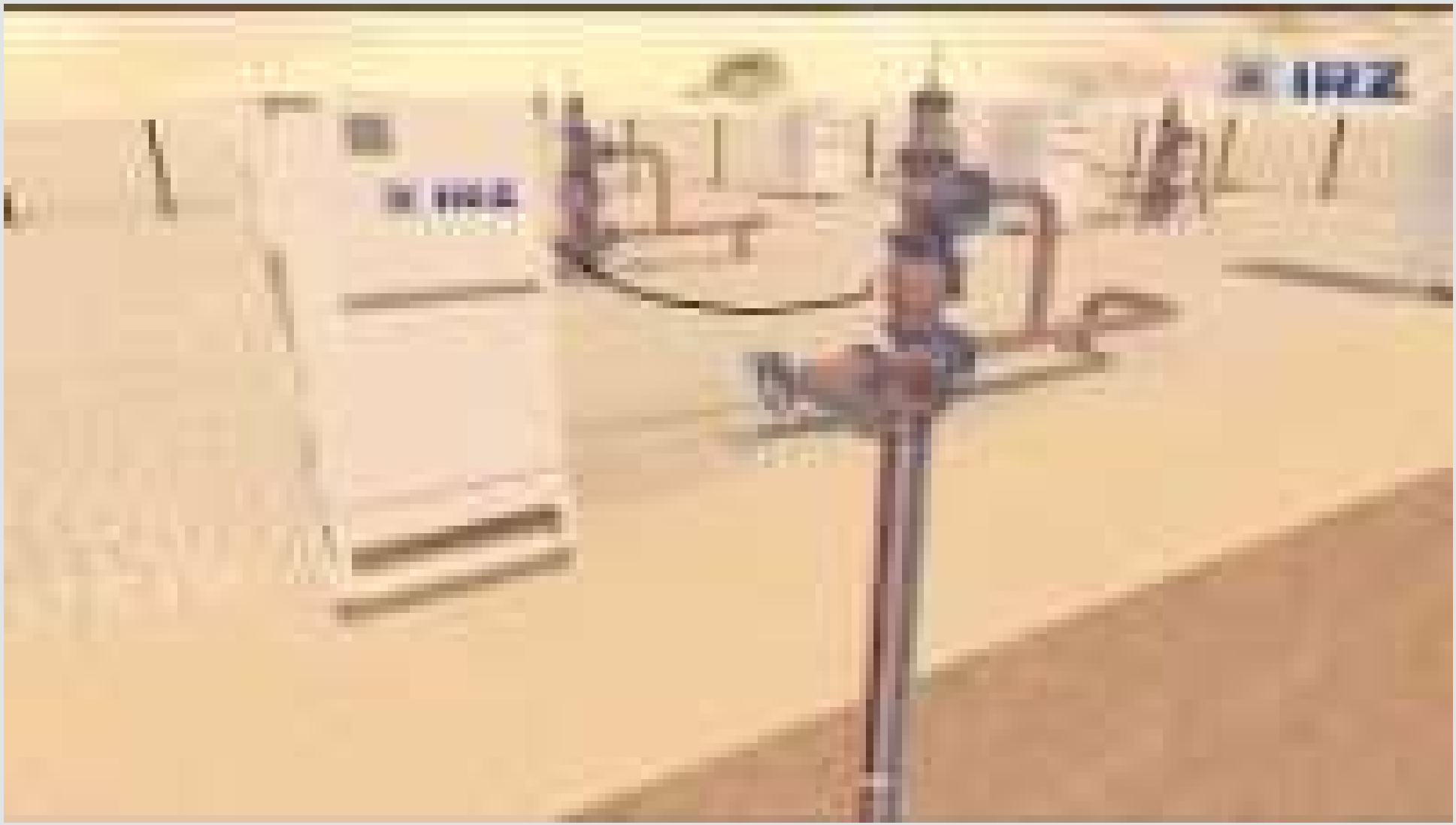


*In SPLM, a **plunger pump is** driven by a submersible permanent magnet motor*

The plunger pump is a modified reversed sucker rod pump

For each specific well it is reasonable to select the exact type of pump, filter and gas separator which proved good performance in such well

SPLM Operation



ESP Downhole Sensor – Main Features

DISCHARGE / INTAKE PRESSURE
- Standard 5800 psi
- **High pressure 8700 psi**
- 316L hydraulic line

INTAKE TEMPERATURE
- Temperature 150 °C
- **Hi-temp version 175 °C**

VIBRATIONS
- XYZ

ELECTRONICS
- **Dual Backup**
- Hi-rel components
- Overvoltage protection
- Supports induction and PM Motors

BOTTOM
- Box thread 2-3/8 8RD EUE or Customized flange

MOTOR OIL TEMPERATURE
- max 250 °C
- Pin sensor
- Thermocouple J-type / K-type and/or pin-sensor

TOP
- 6-bolt flange
- Customizable motor cross-over

SEALING
- Rubber o-rings or metal-to-metal

HOUSING
- OD 81, 95, 103, 117 mm
- CS with coating, 13Cr stainless steel or Monel/Inconel

The specific feature of SPLM downhole sensor is that its downhole part is doubled for run life up to 5 years: while one subset of electronics is operating, the second subset is off; in case of a fault in the main subset the system switches to the redundant one automatically or manually.

Production since
1998

+ 60 000
sensors put in operation

ESP/PSP Variable Frequency Drives

CONTROLLER
- 6’’ graphic screen
- Pump protection functions and automatic restart
- Service modes for variety of production scenarios
- Smart control algorithms for well production optimization
- USB-port

CABINET
- Resistant to severe environment IP43, IP54 OR HIGHER

IEEE 519 COMPLIANT
- Output sinus filter
- 6-pulse with optional external harmonics filter
- 12-,18-pulse
- Active front end

INTERFACES
- Communication with downhole sensors of any vendor by MODBUS protocol RS232/RS485 interface
- SCADA support
- Optional GPRS-modem
- RS232/RS485 interfaces
- Ethernet

POWER SUPPLY
- Supply voltage 480 V

FREQUENCY INVERTER
- In-house inverter
- Inverter bypass option

Features

Compatible with induction & PM motors

Suitable for ESP and PCP

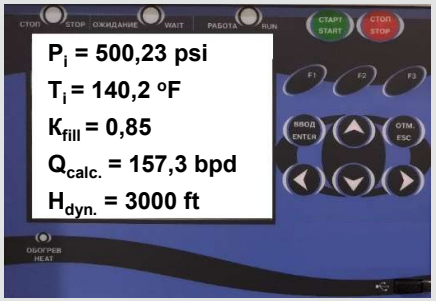
Power of connected motor: up to 1200 h.p.

Operating temperature – 60… +50 °C

Smart Modes

Controller

Power consumption and current vs piston position



Calculated parameters:
- load at up- and down-stroke of the piston
- pump fill
- flow rate
- dynamic level

Smart modes and protections:

1. Maintaining pump fill
2. Operation at max. allowable pump fill
3. Maintaining required flow rate
4. Operation at max. allowable flow rate
5. Maintaining required intake pressure
6. Motor overheating protection
7. Protection against overloads at up- and down-strokes
8. Protection against pump “dry running”

SPLM Specification

Power	20 kW	50 kW
Traction force	1.9 ton	2.4 ton
Voltage	660 V	900 V
Maximum output current	40 A	
Pump flow rate range	3-652 bpd	
Overall dimensions (motor +pump +dh sensor)	Ø 4.6" * 52 ft *(Ø 117 mm * 15.8 m)*	Ø 4.6" * 56 ft *(Ø 117 mm * 17 m)*
Slider stroke	4.03 ft *(1230 mm)*	
Operating temperature	0…+ 150 °C *(0 … 300 °F)*	

Currently IRZ TEK manufactures two models of SPLM motors:
- 20 kW motor with traction force of 1900 kg and operating voltage of 660 V.
- 35 kW motor with traction force of 2400 kg and operating voltage of 900 V.

SPLM Application Matrix

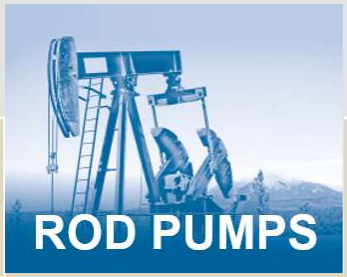
		PLUNGER DIAMETER. STROKE LENGTH 4 FT (1230 mm) 12/16 STROKES PER MINUTE					
		1 1/16 ‘’ (*27 mm*)	1 1/4 ‘’ (*31.8 mm*)	1 1/2 ‘’ (*38.1 mm*)	1 3/4 ‘’ (*44.5 mm*)	2 1/4 ‘’ (*57.2 mm*)	2 3/4 ‘’ (*69.9 mm*)
35 kW / 24 kN Pump setting depth (m) at maximum tractive effort	ρ = 1 t/m^3	4190 (13700 ft)	3020 (9900 ft)	2100 (6880 ft)	1540 (5050 ft)	930 (3050 ft)	625 (2050 ft)
	ρ = 1.5 t/m^3	2790 (9150 ft)	2015 (6600 ft)	1400 (4590 ft)	1030 (3370 ft)	620 (2030 ft)	410 (1240 ft)
Production rate (m^3/day) at filling factor 1 (ideal conditions)		12.1m^3/ 16.2m^3 (72.6 / 97.2 bpd)	17m^3/ 22.8 m^3 (102/ 136.8 bpd)	24m^3 / 32.1m^3 (144 / 192.6 bpd)	32.3m^3 / 43m^3 (193.8/ 258 bpd)	54.6m^3 / 72.8m^3 (327.6 / 436.8 bpd)	81.5 m^3 / 108.7 m^3 (489 / 652.2 bpd)
20 kW / 19 kN Pump setting depth (m) at maximum tractive effort	ρ = 1 t/m^3	3320 (10885 ft)	2390 (7830 ft)	1660 (5440 ft)	1220 (4000 ft)	740 (2430 ft)	495 (1620 ft)
	ρ = 1.5 t/m^3	2210 (7250 ft)	1590 (5210 ft)	1110 (3640 ft)	810 (2650 ft)	490 (1600 ft)	330 (1080 ft)
Production rate (m^3/day) at filling factor 1 (ideal conditions)		12.1 m^3 / 16.2m^3 (72,6 / 97,2 bpd)	17 m^3 / 22.8 m^3 (102/ 136.8 bpd)	24 m^3 / 32.1 m^3 (144 / 192.6 bpd)	32.3 m^3 / 43 m^3 (193.8 / 258 bpd)	54.6 m^3 / 72.8 m^3 (327.6 / 436.8 bpd)	81.5 m^3 / 108.7 m^3 (489 / 652.2 bpd)

SPLM Operational Constraints

	STANDARD PUMP	HIGH-RESISTANT PUMP
Max. fluid density	1500 kg/m^3	
Production water hydrogen ion concentration (pH)	4-8.5	
Max. water cut	0-99 %	
Max. dynamic viscosity (for max efficiency)	0.025 Pa*s (*25 cP*)	0.05 Pa*s (*50 cP*)
Max. content of H_2S	50 mg/l	500 mg/l
Max. gas content at intake	10%	95% (incl. gas separator)
Max. fluid temperature	150 °C (*300 °F*)	
Max. content of solids	1300 mg/l	1500 mg/l
Solids hardness	<7 points Mohs scale	>7 points Mohs scale
Well deviation angle	0-90 °	
Inside diameter of casing	Not less than 5.0''- 6.0''	

This slide shows operation limits of SPLM with a common plunger pump and with a special-purpose pump for heavy environment.
In general, the operational constraints, such as fluid viscosity, solids, gas content and temperatures range are the same as for a pump of a beam-pump unit.

SPLM Compared to Other Pump Systems

	 PCP	 ROD PUMPS	 ESP	 SPLM
Construction	Rod (Abrasion)	Rod (Abrasion)	Motor Rotary	Rodless (no Abrasion)
Suitable for deviated or horizontal wells	no	no	yes	yes
Wellhead infrastructure installations	required	required	not required	not required
Production	<400 bpd (*<60 m³/day*)	<1200 bpd (*<200 m³/day*)	>190 bpd (*>30 m³/day*)	<652 bpd (*<103 m³/day*)
Operating mode	continuous	continuous	periodic	continuous
Running depth	< 4900 ft (*<1500 m*)	<6400 ft (*<2000 m*)	<13700 ft (*<6000 m*)	<13700 ft (*<6000 m*)
Specific energy consumption (kW/ton)	2.56 kWh/barrel (*16 kWh/ton*)	3.2 kWh/barrel (*20 kWh/ton*)	1.6 kWh/barrel (*10 kW/ton*)	1.28 kWh/barrel (*8 kW/ton*)

- Like ESP, SPLM has no rods and is free from problems related to rod wear or damage and can be used in deviated or horizontal wells (unlike PCP or SRP)
- SPLM can be installed at higher depths than PCP or SRP
- Like ESP, SPLM does not require surface foundation or mechanical drives
- SPLM can be used at very low production rates, while ESP is used at rates over 200 b/day and has to be used in periodic or underload modes
- SPLM features the lowest specific energy consumption than any of the rest ALS methods

Benefits of SPLM Compared to Sucker-Rod Pumps

- SPLM is **rodless** → there is no downtime caused by rods loosening, rods/tubing wear, corrosion or damage,
- SPLM can be used in **deviated** and **horizontal wells** and **at higher depths to 4000 m**
- SPLM pump has **higher volume efficiency** as there are no variations of rods length and the pump plunger can stop for better cylinder filling
- Pump **plunger stroke and number of strokes per minute** can be **steplessly regulated**
- N**o need surface foundations**
- There is **no downtime caused by repairs and maintenance** of surface equipment (drive oil replacement, belt tensioning, etc.), **no need in regular inspections**
- **Low** specific **energy consumption**
- **SPLM motor heats fluid and viscosity of fluid at pump intake is lower**

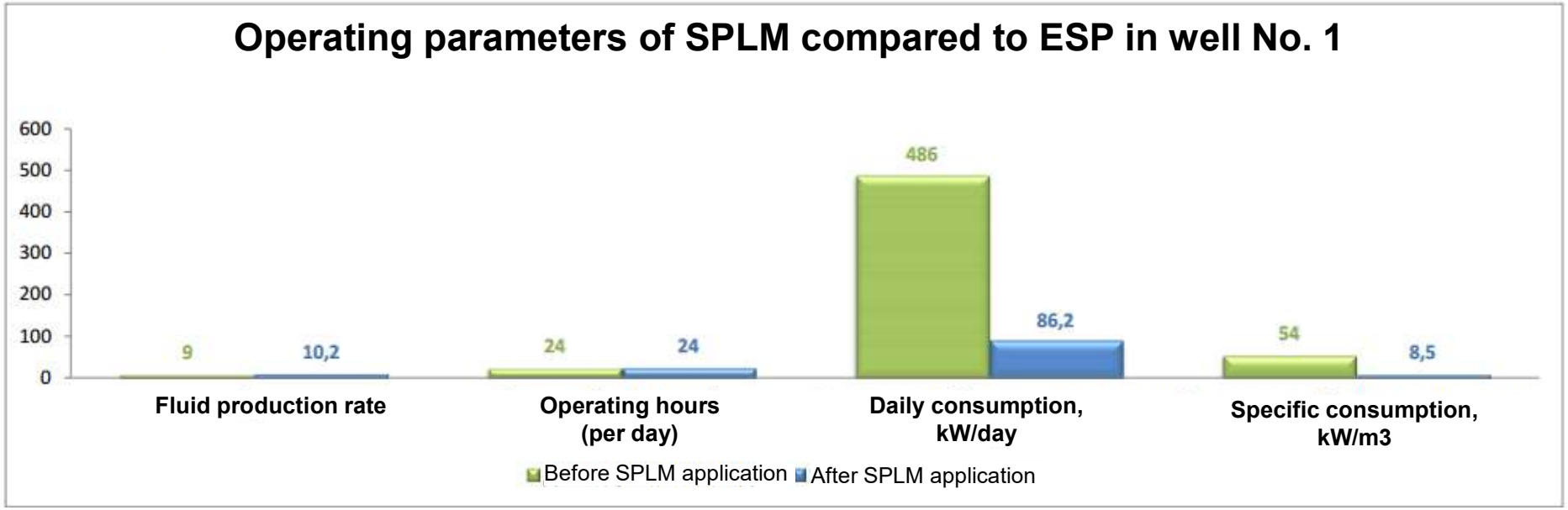
SPLM Target Applications

In certain conditions, SPLM is the best choice compared to other technologies and in some cases is the only alternative. These conditions are:

- **low production rate up to 652** bpd
- **pump setting depth up to 13700ft** (*4190 m*)
- **wells with complex geometry** (use of rods leads to breakage of the rods or tubing)
- highly **deviated wells** and **horizontal wells**

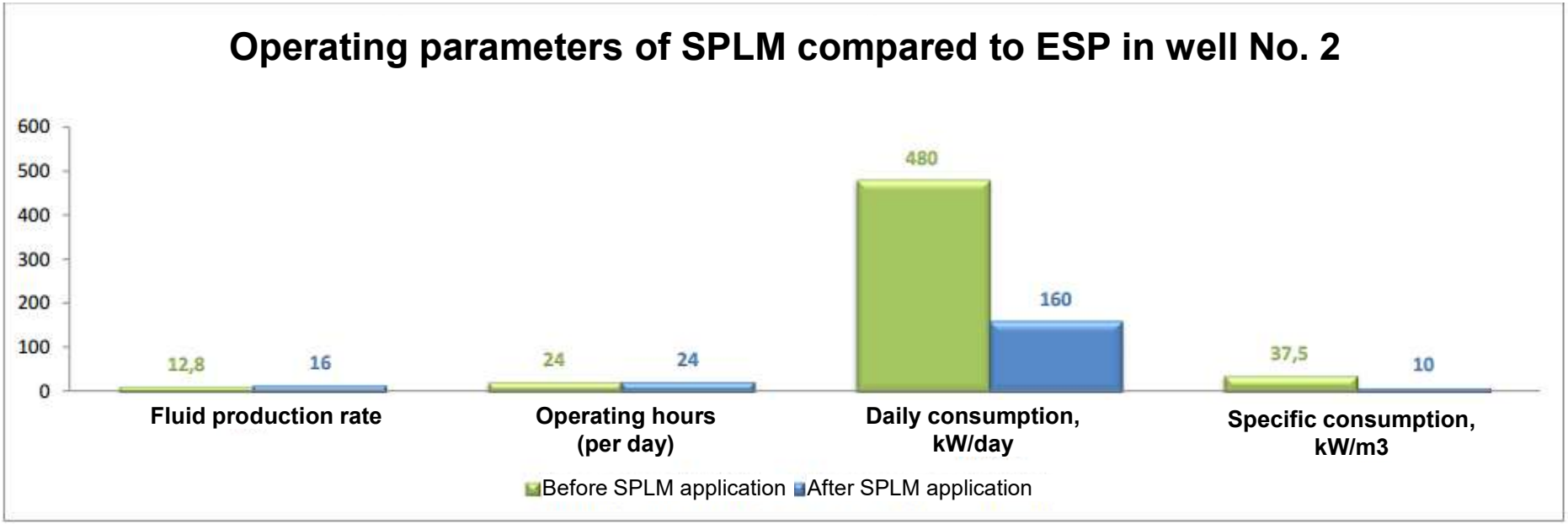
Case Studies

Case Studies
Well No. 1, Perm Region, Russia



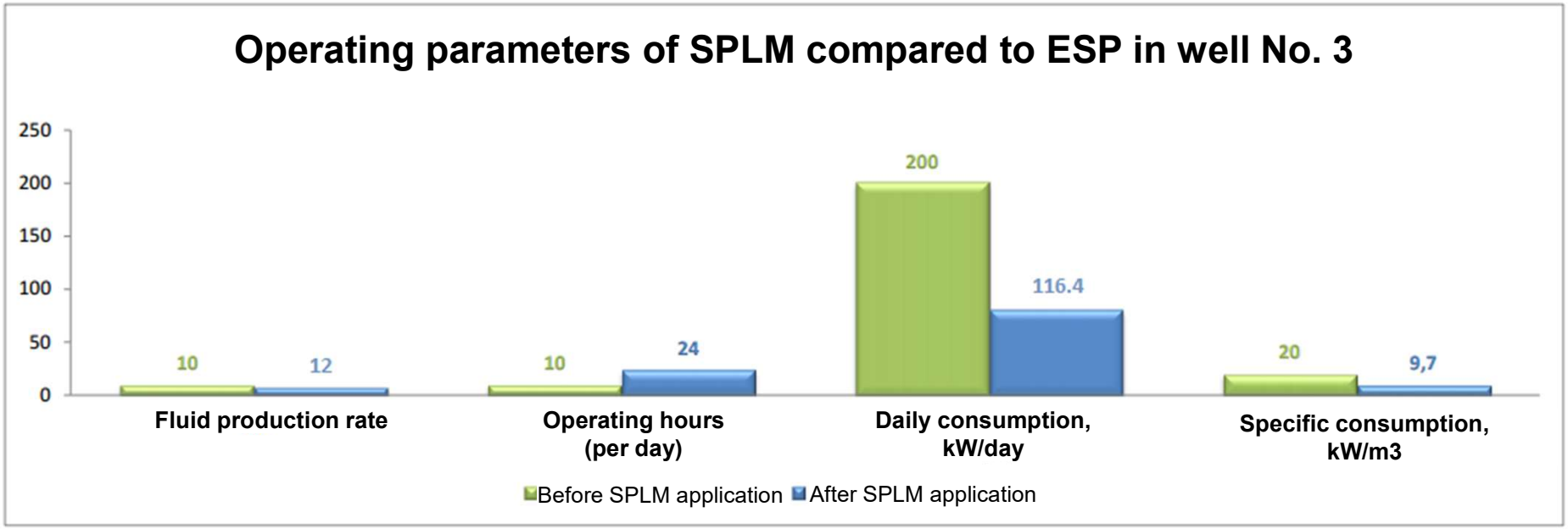
- Before SPLM, in this well electric submersible pump was used. ESP operation mode was not optimal – ESP was underloaded and ran continuously.
- SPLM allowed to increase the production rate from 57 to 64 bpd and decrease specific energy consumption almost six times.

Case Studies
Well No. 2, Perm Region, Russia



As in the previous case, SPLM replaced ESP, and production rate increased by 25% , specific energy consumption decreased almost 4 times.

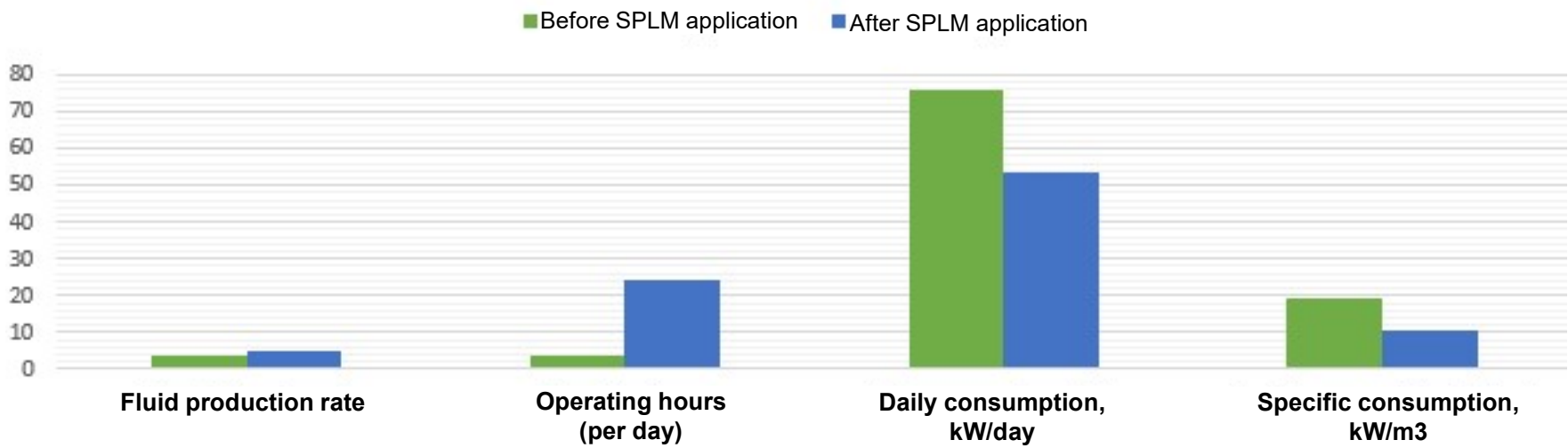
Case Studies
Well No. 3, Perm Region, Russia



- ESP ran in accumulation mode, i.e. it was operated during 10 hours per day and the rest time the pump was shut down.
- SPLM was operated continuously and production rate increased by 20%, whereas energy consumption decreased 2 times.

Case Studies
Well No. 4, Samara Region, Russia

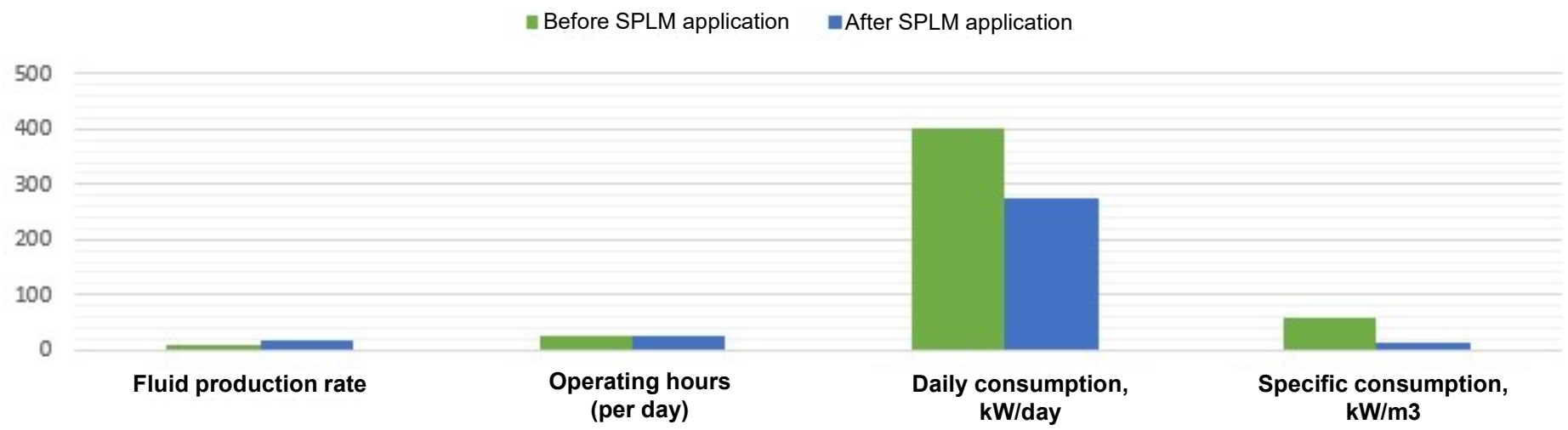
Operating parameters of SPLM compared to ESP in well No. 4



- ESP ran in accumulation mode, i.e. it was operated during 4 hours per day and the rest time the pump was shut down.
- SPLM was operated continuously and production rate increased by 20%, whereas energy consumption decreased 1.5 times.

Case Studies
Well No. 5, Nyagan' Region, Russia

Operating parameters of SPLM compared to SRP in well No. 5



- SRP ran in continuous mode, i.e. it was operated 24 hours per day.
- SPLM was operated continuously and production rate increased by 170%, whereas energy consumption decreased 1.5 times.

Case Studies

Summary table for trial operation in Lukoil-Perm

PARAMETER	Well #1		Well #2		Well #3	
	BEFORE APPLICATION	AFTER APPLICATION	BEFORE APPLICATION	AFTER APPLICATION	BEFORE APPLICATION	AFTER APPLICATION
Fluid production rate	57 bpd (*9.0 m^3/day*)	64 bpd (*10.2 m^3/day*)	80.5 bpd (*12.8 m^3/day*)	100.6 bpd (*16.0 m^3/day*)	62.8 bpd (*10.0 m^3/day*)	72 bpd (*12 m^3/day*)
Oil production rate	13.2 bpd (*2.1 m3/day*)	18.6 bpd (*3.0 m3/day*)	66.6 bpd (*10.6 m3/day*)	84.2 bpd (*13.4 m3/day*)	50.3 bpd (*8.0 m3/day*)	60 bpd (*10 m3/day*)
H_2O	73 %		9.9 %		20 %	
Dynamic fluid level	3914 ft (*1193 m*)	3773 ft (*1150 m*)	3182 ft (*970 m*)	3444 ft (*1050 m*)	4724 ft (*1440 m*)	3727 ft (*1136 m*)
Setting depth	5193 ft (*1583 m*)	5085 ft (*1550 m*)	4609 ft (*1405 m*)	4609 ft (*1405 m*)	6069 ft (*1850 m*)	6551 ft (*1997 m*)
Equipment and operation mode	ESP-25: continuous, underloaded mode	SPLM with motor 35 kW, pump 1.26" (*32 mm*): continuous mode	ESP-25: continuous, underloaded mode	SPLM with motor motor 35 kW, pump 1.49" (*38 mm*): continuous mode	ESP-25: periodic mode: 10 h in operation, 14 h stopped	SPLM with motor 50 kW, pump 1.49" (*38 mm*) : continuous mode
Daily energy consumption	486 kW*h/day	86.2 kW*h/day	480 kW*h/day	160 kW*h/day	200 kW*h/day	74.5 kW*h/day
Date of installation	no data	18.10.2015	no data	19.12.2016	no data	24.12.2016
Date of de-installation	no data	01.05.2016 cable damage	no data	12.2018	no data	09.2020
Mean time between failures, days	700	180	650	730	780	1365

Case Studies

Deep wells (>8700 ft) installations in Rosneft

PARAMETER	Well #1	Well #2
Production rate	60 bpd (*9 m³/day*)	60 bpd (*9 m³/day*)
GOR	64 m³/m³	64 m³/m³
Water cut	7 %	18 %
Solids	176 mg/l	352 mg/l
Buffered pressure	15 bars	16 bars
Asphaltene, resin and paraffin deposits removal	Once per 3 days	Once per 3 days
Dynamic fluid level	7400 ft (*2250 m*)	7700 ft (*2350 m*)
Setting depth	8700 ft (*2650 m*)	9500 ft (*2900 m*)
Linear motor power	50 kW	50 kW
Pump inside dia	1.26“ (*32 mm*)	1.49” (*38 mm*)
Nr. of pump cycles per minute	8	7
Energy consumption	192 kWh/day	156 kWh/day
Specific energy	3.4 kWh/barrel *(21.3 kWh/m³)*	2.8 kWh/barrel *(17.3 kWh/m³)*
Fill factor	0.8	0.7
Date of installation	2018	2018
Date of de-installation	2019	2020
Mean time to failure	350 days	424 days

This is a case study of the first application of SPLM in Russia in wells deeper than 8700 ft

The continuous oil production from the well and helped to avoid wellhead freezing in a winter period and maximize oil recovery with the minimum energy consumption.

Case Studies

Trial operation in Zarubezhneft and Nyaganneftegaz

PARAMETER	Well №14G Zarubezhneft	Well № 6704 Nyaganneftegaz
Production rate	26.4 bpd (*4.4 m^3/day*)	108 bpd (*18 m^3/day*)
GOR	29.7 m^3/m^3	157 m^3/m^3
Water cut	1 %	9 %
Solids	32 mg/l	46 mg/l
Buffered pressure	6 bars	7 bars
Asphaltene, resin and paraffin deposits removal	-	-
Dynamic fluid level	4328 ft (*1320 m*)	5246 ft (*1600 m*)
Setting depth	4410 ft (*1345 m*)	7540 ft (*2350 m*)
Linear motor power	35 kW	50 kW
Pump inside diameter	1.26“ (*32 mm*)	1.26” (*32 mm*)
Nr. of pump cycles per minute	3.5	18
Energy consumption	46,9 kWh/day	297.9 kWh/day
Specific energy	3.4 kWh/barrel *(10,6 kWh/m^3)*	2.8 kWh/barrel *(16.6 kWh/m^3)*
Fill factor	0.93	0.78
Date of installation	Dec 2020	Feb 2021
Date of de-installation	continue	continue
Mean time to failure	>270 *days*	>225 *days*

This is a case study application of SPLM in Russia in wells with continuous operation mode.

The continuous oil production helped to avoid wellhead freezing in a winter period and maximize oil recovery with the minimum energy consumption.

FAQs

1. *What is the maximum achieved run life of SPLM?*

- **Over 900 days**, the wells are running at the moment

2. *What is the max. production rate of SPLM?*

- SPLM production rate depends on pump size and setting depth. At pump diameter of 2-3/4" (69.9 mm), SPLM production rate reaches **652 bpd** (108 m^3/day) (for fill factor 1 and nr of strokes 16 per minute). The company is developing models for higher rates

3. *What is the max. setting depth of SPLM?*

- The design max. setting depth for SPLM is over **13700 ft** (4190 m). At present, SPLM are being operated at depths up to **9508 ft** (2900m)

4. *Can SPLM be remotely controlled?*

- SPLM surface VFD **has inbuilt modem** for remote control and online data monitoring

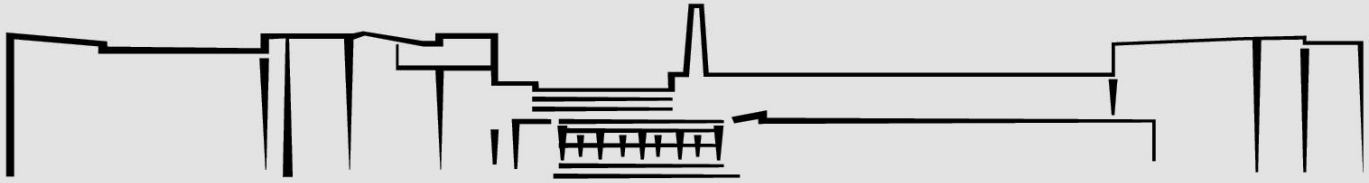
5. *Does SPLM require regular maintenance and repair?*

- If properly selected, the **plunger pump** features time to failure is not less than **720 days**. The pump does not require regular maintenance during operation. After pull-out, the pump can be repaired in workshop conditions (parts replacement).
- The **linear motor** is maintenance-free and has run life not less than **5 years**.

6. *How is the downhole cable connected to the linear motor? Making cable splicing in field reduces reliability of the connection and is time-consuming!*

- SPLM has a **male connector** for mating with the downhole cable. No in-field cable splicing is required

Contact Us



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