Plasma Pulse Technology (PPT)
A Reservoir Treatment Technology for Enhanced Hydrocarbon Recovery
Enhanced Recovery Goals

- Increase production and improve recovery factor
- With minimal capital outlay
- Without damaging the wellbore
- In an environmentally friendly way
- With a proven technology
Plasma Pulse Technology Offering

- Increased recovery of oil in place through treatment of the entire reservoir leading to increased production through enhanced permeability & reduced oil viscosity
- A variety of payment models available which are much less than most other forms of EOR
- Cleans perforations and aids in reduction of skin factor with no damage to casing or cement
- Treatment uses no water or chemicals thus no need for EPA permitting
- Proven technology – Over 350 wells successfully treated globally
How PPT Works

*Plasma Pulse: A powerful instantaneous discharge of super ionized energy per pulse propagating a series of shock waves*

- Plasma Generator ionizes a metal filament creating a coronal discharge. This powerful discharge emits a series of non-linear acoustic waves that resonate throughout the reservoir.

- The propagation of these waves excites the fluid molecules and the natural resonance in the reservoir.

- The high frequency waves open the perforations and clean the near wellbore skin.

- The lower frequency waves travel deep into the reservoir increasing its natural resonance opening pore spaces and reducing the oil viscosity.
Increased Production

- Increased Permeability through opening of pore spaces and the creation of micro fractures
- Lower Oil Viscosity up to 20%
- Perforation tunnel and Skin clean up
- Oil molecules wetting rock are released
- Effects of treatment last up to one year

Perforated channels are closed by sedimentation | Formation of plasma accompanied by a compression wave | Wave penetrates the drainage area and deep into the reservoir | Sedimentation gone, pressure forces oil to flow again

Before | After
The treatment duration and number of pulses stimulating the formation are determined by the OIP, production interval parameters and geological characteristics of the deposit.
Tool Specifications

- Presently only for vertical wells (< 50° deviation), Horizontal system coming in 2016

- Sizes Available:
  - 4.02" (102 mm) OD, 9.02 ft. (2750 mm) length available now
  - 3.50" (89 mm) OD, 9.4 ft. (2865 mm) length final testing in ongoing
  - 2.00" (64 mm) OD, 9.96 ft. (3036 mm) length available Q1 2016

- Maximum BH Temperature = 203° F (95° C)

- Maximum BH Pressure = 5800 psi (40000 kPa)

- Minimum 50 ft. fluid head required above tool during treatment

- Minimum 4 SPF (13 SPM) perforations

- Wireline requirements: Standard US/Canada
Unsupported cement is not debonded off test target during plasma pulsing.

The perforations become unplugged and open to allow fluid entry post pulsing.

Simulated blocked perforated casing target before pulsing

Target post pulsing
Well Selection and Operational Procedure

- Operator provides all required well data including historical production, past remedial and stimulation, well logs, fluid level, perforation interval, PLT, BHT, BHP, etc.
- Well parameters evaluated by Novas Energy Team
- If deemed candidate a Treatment Plan is prepared & agreed upon
- Treatment is scheduled preferably in coordination with scheduled well maintenance
- Operator prepares well for treatment by removing pump and pulling completion
- Arrival on site with wireline, wireline crew, Novas Energy tools and crew
- Administer treatment per plan
- Perform post-treatment evaluation including production data sharing (oil, gas, condensate, water)
- Implement ongoing field treatment plan
Well Specific Treatment Plan

Scope of Work Planning

1. The number of spots to be treated depends on:
   - Type of reservoir
   - Capacity of productive interval
   - Rock saturation properties
   - Influx profile
   - Oil-water contact
   - Gas-oil contact

2. The required number of pulses is affected by:
   - Perforation density
   - Rock permeability
   - Existing production casing
   - Cement properties
   - Influx profile
   - Rock saturation properties

3. Forecast of potential production is based on math simulation models and operating time statistics
Case Studies
## Select US Treatments

<table>
<thead>
<tr>
<th>Well Location</th>
<th>Formation Type</th>
<th>Before PPT Oil (bpd)</th>
<th>After PPT Oil (bpd)</th>
<th>% Increase</th>
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</thead>
<tbody>
<tr>
<td>Caddo Co, LA</td>
<td>Limestone</td>
<td>1</td>
<td>3</td>
<td>300%</td>
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<tr>
<td>Kay Co, OK</td>
<td>Limestone</td>
<td>5</td>
<td>12</td>
<td>240%</td>
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<tr>
<td>Creek Co, OK</td>
<td>Sandstone</td>
<td>1.5</td>
<td>5.5</td>
<td>367%</td>
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<tr>
<td>Creek Co, OK</td>
<td>Sandstone</td>
<td>1</td>
<td>57</td>
<td>5700%</td>
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<td>44</td>
<td>4400%</td>
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<tr>
<td>Creek Co, OK</td>
<td>Sandstone</td>
<td>1</td>
<td>20</td>
<td>2000%</td>
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<tr>
<td>Sedgwick Co, KS</td>
<td>Limestone</td>
<td>2.4</td>
<td>4.8</td>
<td>200%</td>
</tr>
<tr>
<td>Natrona Co, WY</td>
<td>Sandstone</td>
<td>5</td>
<td>22</td>
<td>440%</td>
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<tr>
<td>Natrona Co, WY</td>
<td>Sandstone</td>
<td>1</td>
<td>8</td>
<td>800%</td>
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<tr>
<td>Safford Co, KS</td>
<td>Limestone</td>
<td>2</td>
<td>40</td>
<td>2000%</td>
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<tr>
<td>SW CO</td>
<td>Shale</td>
<td>25</td>
<td>80 initial, 106 now</td>
<td>424%</td>
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</table>
# Results from Oil Producing Wells

<table>
<thead>
<tr>
<th>Oil Field</th>
<th>Depth (ft)</th>
<th>Oil Bpd</th>
<th>% Watercut</th>
<th>Oil Bpd</th>
<th>% Watercut</th>
<th>Oil, Bpd Increase</th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hvojnoe</td>
<td>9364</td>
<td>0.00</td>
<td>43</td>
<td>119.20</td>
<td>15</td>
<td>119.2</td>
<td>100</td>
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<tr>
<td>Shkapovskoe</td>
<td>N/A</td>
<td>2.24</td>
<td>97</td>
<td>12.67</td>
<td>96.6</td>
<td>6.7</td>
<td>113</td>
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<td>Fedorovskoe</td>
<td>N/A</td>
<td>5.22</td>
<td>12.5</td>
<td>19.37</td>
<td>18.7</td>
<td>14.2</td>
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<tr>
<td>Shkapovskoe</td>
<td>N/A</td>
<td>5.96</td>
<td>20</td>
<td>38.00</td>
<td>21.5</td>
<td>32.0</td>
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<tr>
<td>Vasilovskoe</td>
<td>N/A</td>
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<td>79</td>
<td>14.90</td>
<td>61</td>
<td>8.2</td>
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<tr>
<td>Pashninskoe</td>
<td>4756</td>
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<td>75</td>
<td>29.80</td>
<td>69</td>
<td>22.4</td>
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<td>Sovetskoe</td>
<td>5904</td>
<td>7.45</td>
<td>85</td>
<td>81.95</td>
<td>70</td>
<td>67.1</td>
<td>450</td>
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<tr>
<td>Djudushevskoe</td>
<td>11808</td>
<td>14.90</td>
<td>66</td>
<td>89.40</td>
<td>77</td>
<td>59.6</td>
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<td>Krapivinskoe</td>
<td>9315</td>
<td>33.53</td>
<td>2</td>
<td>88.66</td>
<td>2</td>
<td>55.1</td>
<td>164</td>
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<td>Severnoye</td>
<td>9184</td>
<td>43.96</td>
<td>74</td>
<td>104.30</td>
<td>39</td>
<td>60.3</td>
<td>137</td>
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<tr>
<td>Tevlinskoe</td>
<td>10922</td>
<td>52.15</td>
<td>18</td>
<td>163.90</td>
<td>2</td>
<td>111.8</td>
<td>214</td>
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<tr>
<td>Pervomajskoe</td>
<td>9610</td>
<td>201.15</td>
<td>20</td>
<td>305.45</td>
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<td>104.3</td>
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## Injection Well Results

<table>
<thead>
<tr>
<th>Oil Field</th>
<th>Bbls/Day Before</th>
<th>Bbls/Day After</th>
<th>Increase</th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lomovoe</td>
<td>119</td>
<td>728</td>
<td>609</td>
<td>511</td>
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<tr>
<td>Poludennoe</td>
<td>314</td>
<td>942</td>
<td>628</td>
<td>200</td>
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<td>Sutorminskoe</td>
<td>157</td>
<td>1080</td>
<td>923</td>
<td>588</td>
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<tr>
<td>Sutorminskoe</td>
<td>63</td>
<td>345</td>
<td>282</td>
<td>450</td>
</tr>
<tr>
<td>Tajlakovskoe</td>
<td>31</td>
<td>376</td>
<td>345</td>
<td>1100</td>
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<tr>
<td>Arlanskoe</td>
<td>31</td>
<td>138</td>
<td>107</td>
<td>340</td>
</tr>
<tr>
<td>Turchaninovskoe</td>
<td>125</td>
<td>546</td>
<td>421</td>
<td>335</td>
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<tr>
<td>Muravlenkovskoe</td>
<td>1727</td>
<td>4396</td>
<td>2669</td>
<td>155</td>
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</tbody>
</table>
Increase in the Well Production Rate

- **Well #:** C-7
- **Oil field:** Russia, Dyusushevskoye
  LLC Polar Lights Company
- **Reservoir:** Carbonate
- **Well Type:** Production Well

**DFL** before treatment – 2250
DFL after treatment – 1817

**Formation** – D3fm

**Operating capacity** – 8.6 m

**PI** before treatment – 0.09
PI after treatment – 0.33

DFL = Dynamic Fluid Level, PI = Productivity Index

![Graph showing changes in oil and water production over time](Image)
Increase in the Well Production Rate

Well #: 70
Oil field: Russia, Zapadno-Sikhoreyskoe LLC Polar Lights Company
Reservoir: Carbonate
Well Type: Production Well

DFL before treatment – 2245
DFL after treatment – 1373
Formation – D3fm
Operating capacity – 16,2 m
PI before treatment – 0,55
PI after treatment – 1,84

DFL = Dynamic Fluid Level, PI = Productivity Index
Increase in the Well Production Rate
Well № XXX8 Vatyaganskoe Field
Increased Productivity After Plasma Pulse Treatment
(IN HYDRO-FRACKED FORMATION)

Well #: 753
Oil field: Vatyoganskoye
Reservoir: Tight Sand
Object: Enhance Oil Recovery
Permeability: 3 mD

Dynamic Fluid Level (ft)
- May: 5938
- June: 4970
- July: 5052
- August: 4856
- September: 4856
Increased Productivity After Plasma Pulse Treatment
(IN HYDRO-FRACKED FORMATION)

- **Well #:** 9138
- **Oil field:** Vatyoganskoye
- **Reservoir:** Tight Sand
- **Object:** Enhance Oil Recovery
- **Permeability:** 10 mD
Decline Curve Before and After PPT

Downward production trend before PPT and after PPT
Terrigenous deposit, Taylakovskoe oil field, Megionneftegaz

bbl/d

0 50 100 150 200 250 300 350

Nov-07  Apr-08  Sep-08  Feb-09  Jul-09  Dec-09  May-10  Oct-10  Mar-11  Aug-11  Jan-12  Jun-12  Nov-12  Apr-13  Sep-13  Feb-14  Jul-14

PPT  Fracking  Poly. [PPT]  Expon. [Fracking]