# Continued System Efficiency Improvements for Airlift Pumping System

## Executive Summary

Airlift Services International (ASI), a Division of Energy, Inc., is an Indiana-based oil service company. ASI, now in the initial marketing phase, is the first company to successfully and economically pump oil and other fluids using compressed air and natural gas. To date, ASI has successfully pumped more than 175,000 barrels of fluid from wells in four states including deliquification of three gas wells. The Airlift Oil Pumping System (Airlift) is designed to increase profits for owners of marginal or stripper wells by increasing well production through the reduction of maintenance costs and increase of uptime and efficiency.

Airlift Services International was the recipient of a grant awarded by the Stripper Well Consortium in 2006. This grant was for "Increased Pumping Capacity and Depth for Airlift Pumping System" (42098R). The work was done in conjunction with Taylor University in Upland, Indiana. This grant provided for computer simulation of the current design, a prototype build of an optimized design as quantified by the computer model, and validation of the simulation model in a working oil well. Then the model was used to define an optimized design in an effort to define an airlift pump capable of pumping 100 barrels per day at 3000 feet. Modeling to date has shown significant performance benefits of making the following changes:

1. Increase in the size of the airlines. The model has also shown that airlines should be varying lengths to better optimize flow as fluid is moved up the system.
2. Use helium or other inert gases as the driving gas in the system to improve system efficiency.
3. Develop a closed loop system to improve efficiency.
4. Lower operating pressures improve system efficiency.

Significant material changes will be required to implement the indicated changes. The model has been used to predict the fluid flow from a 3000-foot well. An ASI 1400-foot test well is being used to continually validate the accuracy of the system model. Incrementally implementing the improvements indicated by the model will provide a more cost competitive and superior performing pump for marginal wells.

Public Executive Summary

Energy usage of oil in the US will increase by 30% by the year 2020. Natural gas demand is on course to double in the next two decades. Current striper well domestic production of oil meets ~ 28% [~ 324 M barrels/ yr in 2002] of the nations needs. Natural gas production from domestic stripper gas wells produces ~ 8% [1 TCF equivalent/yr. = 8%] of current US consumption needs.

Over the past two decades in the Appalachian basin, several tens of thousands of shallow oil and gas wells [1000' – 3500'] have been completed using open hole techniques with multiple zones notched, fractured and produced. The foci for these open hole wells is Pennsylvania, West Virginia and New York. These wells are often configured with 7.0" to 8 5/8" steel surface casing cemented through the water table aquifers, then open rock hole well bore [6.25" to 7 7/8"] to the total depth of well. These wells follow a similar production performance history as their predecessor-cased wells. Several months of flush production are followed by decreasing well pressure and yield of oil/ gas. These wells quickly fall into the category of stripper well production. Down hole pressure in these wells declines to a point where the well is no longer able to lift the fluid in an unassisted manner to the surface. Often time in these multi-zone completion wells an up hole zone [s] acts as a thief for down hole higher pressure zones further confounding their operation & production. In on going stripper well production from these wells 'Beam Pumps', tubing velocity strings, small diameter tubing and plungers are often employed with some finite success. Most of these techniques do not allow the well to produce itself down to with in several tens to a hundred psi of the Fm. pressure. The result is non-captured reserves & higher operation cost for hydrocarbon produced.

This project will select and refit two- [2] existing 6.25"or larger gas or oil and gas, open hole stripper wells with a re-fit well system, 1 comprised of a slip lined 3.0" ID spooled non –metallic tubing, metal to non metal connectors, open hole packer assembly, casing stand /stop, and modified G.O.A.L. PetroPump with unique variable diameter seal cups to automatically lift fluids. The second system will be equipped with slip lined conventional steel casing and a GOAL tool system. The operating system will be designed and constructed to allow shallow up well, low pressure, gas to produce off the back side of the casing above a packer. The non- metallic spoolable tubing system coupled with modified 'GOAL Tool' with new flex diameter cups will afford automatic and regularly lift of fluids to the surface and foster improved gas and fluids production. Comparison of pre system and post system use production and cost for both the spooled synthetic tubing and referred steel casing will be developed to project applicability and upside impacts on the stripper well industry.

Historic testing of GOAL PetroPump alone under SWC subcontract #2052-BEDC-DOE-1025, jointly sponsored by NYSERDA and SWC in standard J-55 steel cased-perforated stripper wells has shown 1.5 to 3 fold improved production at a fraction of the service needed to operate other stripper well systems. Similar improvement is expected in these 2 re-fit wells. [Figures 1, 2 & 3]

This system of modified GOAL Pump, new variable diameter cups, packer assembly, metallic to non-metallic connection of spoolable tubing is unique for maximizing yield through re-completion of large diameter and or open hole wells. Coupling non metallic spoolable tubing with a new flex wall cup accommodates passage with out pressure and or fluid loss across diameter changing transitions in tubing. This simple elegant design of the GOAL tools valve control allows it to free travel with in the re-fitted well bore. The new system will allow the re-fitted wells to "pump themselves" despite declining down hole pressures. The system is "smart" in both directions, dropping down hole when pressure at the well head is low/ reduced by down hole fluid accumulation & is "smart" up hole using below tool formation pressure to lift tool and fluid [oil/brine] to the surface. The tool free floats in the well head lubricator allowing down hole pressure/ gas to flow to the process unit. At such time as pressure has declined below system control pressure, the system will once again repeating the automatic pumping cycle.

Successful application of the outlined system will have positive economic impact on the 10,000+ existing potential candidate wells. Open hole well re-fit cost at $30,000- $49,000/ well could be offset in a 1 to 1.5 year period at achievable 1.5 X to 3 X increase yield on target wells.

Public Executive Summary -

The design, manufacture and demonstration of a very low cost booster compressor based upon a unique regenerative compression process is proposed. The compressor concept and design configuration is termed the Polyvane Compressor, and its intended application is within the marginal or stripper well market.

The objective is to demonstrate a lower cost method of extracting natural gas from small, low pressure wells through the use of the proposed Polyvane Compressor, independent of any other compression means, or to increase production by use in series with existing or newly installed reciprocating or rotary positive displacement compressors.

The goal is to demonstrate the potential to manufacture the Polyvane booster at a cost that equals existing small horsepower reciprocating compressors, but at three (3) times the flowrate. Additionally, the booster compressor is to provide reliable operation, efficient performance, three year operation before expected overhaul and be field serviceable.

A secondary goal is to demonstrate the use of the Polyvane Compressor as a means to significantly decrease the cost of compressors required for higher discharge pressures, by supercharging the suction pressure of these compressors and thereby lowering the size and cost required to achieve needed volume flowrate.

The Polyvane Compressor, a dynamic compressor, employs an innovative internal flowpath that allows exceptionally simple machining and construction. The operating constraints and design configuration suggests that the compressor can be fabricated largely out of non-metallic materials, thereby allowing low cost production techniques to be employed.

The methodology proposed to demonstrate attainment of project goals consists of detail component design, creation of manufacturing drawings, development of manufacturing processes for the prototypes, manufacture of prototypes, assembly of prototypes, laboratory performance and endurance testing and field trials. The project is to demonstrate proof of concept and to provide practical field experience. The resultant product of this proposed project is the preliminary hardware and technical knowledge to continue commercialization and ultimate product introduction.

**Impact Technologies LLC**
**2007 Proposal to the**
**Stripper Well Consortium**

# Novel Low Rate, Electric Plunger Pump System


***PUBLIC EXECUTIVE SUMMARY***

Stripper wells, both oil and gas, need to lower costs as production decreases over time to maintain their economic life. Many stripper oil wells produce very low volumes (1-15 barrels per day) of liquid (crude oil plus water) and need only a low volume pump to produce these volumes to the surface. Many stripper gas wells need to remove low volumes of liquid out of the wellbore to maintain gas production. These processes must be done cleanly, efficiently, with low capital and operating cost and be environmentally friendly. Most of these well depths are less than 5000 ft and only require about one horsepower for these volumes. Such pumps for deeper wells are also needed.

To lift these low volumes of liquids out of these stripper wells, a downhole electric driven plunger pump is proposed. This unique pump will also have a unique deployment method. The pump will be installed through the tubing in the well, set in a fixed seat at the bottom of that production tubing all by a wireline which also serves as the electric power line. This pump can also be deployed inside casing or on the end of a coil tubing string (steel or composite). It will be pulled by the same wireline or coil after its productive life is over. Installation and retrieval will be by a coiled reel instead of a conventional service rig. Retrieval and "fishing" options will also be provided. Simple pump off controls will be deployed to start-stop the motor based on the fluid level in the casing to save pump life. Simple displays at the surface will provide performance readings as to pump/ motor stroke speeds and down times. Small (1/8) inch stainless steel tubing can be attached to the wireline for chemical injection (paraffin, scale, corrosion, etc…) at/through the pump. Pump designs will be optimized to minimize gas and solids interference through the pump.

Benefits of this unique pump include lower capital requirements since no pumping unit and no rods will be required, lower horsepower with no gear and rod losses, smaller surface foot print and profile than beam pumping units, no tubing wear and will work in bad casing. While it will be more expensive to purchase and operate (requires electrical power) than plunger lift systems, it will be more reliable and allow lower reservoir pressures to be obtained for extended well life and reserves. It will also work with less gas production than required by plunger lift systems. It can be reduced to fit in microholes or increased for higher production rates and/ or for deeper wells.

Such benefits will allow many of the 400,000+ stripper wells in the United States a longer productive life and provide significant additional gas and oil reserves for the public good.

SWC 2007 PAAL. LLC. “PAL” CASING PLUNGER
“HYBRID CASING PLUNGER FOR MULTIPLE ZONE STRIPPER WELLS”

## EXECUTIVE SUMMARY

This proposal offers to extend the efficiency of recently developed innovations in casing plungers into the critical application of stripper gas well production from multiple production zones. Current casing plunger applications are limited to fluid removal above the top perforations of any well bore. A plunger cycle starting at the bottom perforation would lose critical pressure as it ascends into the higher perforations, especially perforated sections longer than the casing plunger length. The essential pressure would leak around the casing plunger, out into the reservoir and back into the casing above the plunger through higher perforations disabling further assent. Producers and casing plunger manufacturers have steadfastly refused to attempt such casing plunger applications. Even conventional tubing plungers experience this same limitation. Consequently, many stripper gas wells with multiple producing zones remove fluid accumulations with generally cost ineffective rod pumps and jacks. Small volumes of fluid are removed through the tubing and gas sales occur through the tubing/casing annulus.

Most producers co-mingle all producing zones permitted by statute. Producers see the cost benefit, and subsequent production increases, of fluid removal from the lower production zones. Producers frequently inquire at technical seminars, trade shows, and casing plunger presentations if casing plungers can be used below the top perforation to remove fluid from lower production zones.

This proposal will address this critical need in the stripper well industry. Tools will be designed and fabricated that will permit the removal of fluid from the lower perforations. Such tools will be capable of being set and retrieved with conventional wire line equipment. Further, such tools will permit the production of the fluid from lower perforations to be accumulated and held briefly above the top perforation. Subsequent cycles of a conventional casing plunger would further remove the fluids to the surface separation equipment. This cost effective method will permit the anticipated increase in production from stripper wells and enable better utilization of lease assets. Provisions will be included to record down hole pressures during the complete flow cycle for better technical evaluation of optimum performance.

**RTA Systems, Inc.**
**2007 Proposal to the**
**Stripper Well Consortium**

# New Class of Novel Paraffin Inhibitors


***PUBLIC EXECUTIVE SUMMARY***

A potentially new class of novel paraffin inhibitors will be investigated for their performance in treating wells with severe paraffin problems. The expected benefits of this work are lower cost and environmentally friendlier paraffin treatments that will not contribute to downhole equipment corrosion. Paraffin problems impact many of the 435,000 stripper wells in the U. S. and occurs in every region where oil and gas is produced. When paraffin builds up in a well or flowline it can restrict or completely shut off oil and gas production causing lost revenues and expensive 'stripping' well pulling jobs. This novel copolymer technology is expected to function as paraffin crystal modifiers. This in-sight comes from exceptional performance behavior with crude oils and refined distillates in other application areas. The proposed research is directed toward the replacement of the conventional polyalkylmethacrylate monomers often copolymerized with anhydrides or carboxylates which suffer from high concentrations requirements, high cost, or the tendency to contribute to corrosion. These new copolymers fall under the "green chemistry" logo and some have FDA approval for certain other applications involving food contact. These products should not interfere with refinery operations.

RTA Systems has made a significant discovery of a new polymer type that has a preference for paraffinic crude oils and distillates that has unique absorbent properties in the environmental products arena, surpassing the performance of competitive products. From the literature search, a copolymer of similar chemical stochiometry, but significantly different chemical structure was identified as having significant paraffin inhibition properties in crude oil and pour point depressing abilities in refined petroleum cuts. Because the performance mechanism for the environmental application is different from the accepted mechanism for paraffin crystal modifiers, it is plausible this potential new family of paraffin inhibitors may inhibit paraffin deposition in crude oil operations to a higher level of performance than the commercially available products.

Laboratory tests will be conducted to screen the various polymers for pour point and cloud point suppression in petroleum or refined products. From this screening, the laboratory effort will focus on the best products for cold finger testing in five crude oils with the experimental polymers and known paraffin commercial inhibitors. A study will be conducted to select the best solvent system and mixing requirement for that system to provide the best results by cold finger testing. Core testing will be conducted to establish the best methods of application. Well information will be obtained from selected wells for possible field treatments and laboratory tests will be made to determine the optimal treatment plans. Three field treatments will be conducted from these choices. The results will be monitored for performance and the benefits obtained.

## Executive Summary

## Stripper Well Characterization with Low-Cost Micro-Electronic Linked Probe

This grant is a continuation of stripper well research at the Taylor University Center for Research and Innovation (CRI), in conjunction with Airlift Services International (ASI). In previous work, we have successfully modeled the ASI compressed air pumping system using computational fluid dynamics programs and an advanced diagnostic probe module in a down-hole environment.

In this grant we plan to leverage our data module probe experience to characterize stripper wells with much greater detail and at much lower cost so that proper action can be readily taken regarding well viability, re-stimulation, advanced well-logging, new perforations, or ultimate plugging (AIP E3). The problem exists that low-cost well information is not readily available to make a decision to either invest or plug a well while the alternative outcomes many times result in environmental damage, project standstill, or improper abandonment (orphan wells).

The overall project objective is to provide vital data for stripper well and reservoir characterization in a low-cost (~$5K) and easily deployable package that will help improve the efficiency and profitability of oil and gas production. The overall method employed is to advance the down-hole environment sensing using inexpensive and miniature technologies developed for our previous SWC grant, for NASA and Air Force Nanosatellites and for high-altitude balloons. A further innovation includes a small coil reel to tether the probe with a real-time communication link to the surface for rapid data processing and focus on regions of interest. The proposed characterization probe has broad applicability in the energy industry and can also be used for down-hole seismic, advanced well logging tools, pump control and diagnostics.

This proposal will focus on two areas: an advanced instrumentation probe and a communication link between the down-hole probe environment and the surface ground control. The proposed instrumentation will include development of low-power, ruggedized down-hole electronics for data acquisition, storage, and telemetry, including mechanical design of the data module probe. Multiple sensors will be evaluated in a trade-off matrix, a working probe will be developed and tested, and a real-time tether link will be connected to ground control. Instruments for well characterization and well logging include a digital image and video camera, 3-axis flux gate MEMS magnetic field sensor, temperature, EM waves, and Gamma/X-ray detection (similar to nanosatellite designs). Water quality pH, conductivity, sampling and well conductivity and resistivity will also be measured.

We also are part of the Airlift Systems International 2007 grant proposal, “Expanding a New Technology for the Cost Effective Re-Completion of Stripper Wells”, as a $30,000 subcontract to the Stripper Well Consortium. For this effort we will be improving pump design by using the AmeSim fluid dynamic software and data module to help model and optimize the system.

The PI, Co-I and proposed team are highly qualified, experienced, and have the manpower to carry out the design and construction, to safely complete and operate this new development project, and document, assess, and publish the initial results. Undergraduate student participation encourages interest and education in novel gas and oil technologies and careers.

# Executive Summary

**Low Cost Downhole Power Generator for Downhole Gauges in Plunger Lift Wells**

Optimization of the processes required to produce hydrocarbons constitutes an on going strategic concern and a major goal in the oil and gas industry. The goal of this project is to develop a low cost downhole power generator for downhole gauges in plunger lift wells application to achieve the following: monitor the rod pump lifting process in wells, transmit well production information in real time from downhole to the surface, lower gauge costs, improve pump reliability and monitor water levels during the production of hydrocarbons. The purpose of monitoring the rod pump process is to optimize the production and to minimize the amount of down time and lost production from wells. This new system will generate power downhole to operate a wireless gauge also deployed inside the well. The generator will have a coil assembly mounted as part of the tubing string, a rod which will be assembled as the lower section of the rod assembly and a power harvest system. The rod will be composed of permanent magnets that will be placed on the outside of the rod. The up and down motion of the rod and magnets through the coil assembly will generate electricity that will power the gauge downhole. There will be no cables from downhole to the surface and the entire installation can be done within a fraction of the time that it now takes to deploy a gauge in a rod pump well. This project will research, develop and test a low cost, high reliability power generator using the plunger lift as the means to generate the power. This system will help reduce well down time, increase hydrocarbon production and reduced OPEX.

## EXECUTIVE SUMMARY

Natural gas is marketed on the basis of its heat content (950 BTU/cu ft or higher). U.S. pipeline specifications vary but generally require nitrogen ($N_2$) to be less than 5% resulting in 32 tcf (17% of known reserves) to be categorized as low-BTU "sub quality". $N_2$ is thus a major target for removal to upgrade natural gas to pipeline quality. A significant portion of the nation's $N_2$-rich low-BTU gas is trapped in modest to small fields owned by stripper operators, or isolated behind pipe. These small fields are not amenable to upgrading technologies such as cryogenic separation and conventional pressure swing adsorption (PSA) because these fields cannot usually deliver the large feed volumes necessary for profitable operations of these types of technologies.

In an attempt to encourage economically viable upgrading of low-BTU gas from stripper wells, a demonstration project that encompasses the planning, design, construction, operation, and optimization of an easily built, low-cost, 2-tower micro-scale PSA plant for $N_2$-rejection using non-patented processes and commonly available equipment is proposed. User-friendly public-domain or inexpensive well-analysis software will determine likely feed volumes (anticipated to be from 40 to 200 mcfd) which, in turn, will dictate the size of key components in the plant. The proposed plant will use easily obtained and inexpensive activated adsorbent charcoal. It will be designed to be mobile and scalable, with skid-mounted units being attached or detached depending on input volumes. It will have a small environmental foot print (400 sq. ft) and will produce no volatile organic compounds (VOCs). Labor and maintenance costs for the plant are anticipated to be minimal, for it will have few moving parts (<10) outside the engine and compressor, and will not require more than two daily visits by the operator.

This project is a joint effort by the Kansas Geological Survey and American Energies Corporation (a company that primarily operates stripper wells in Kansas). The project along with technology transfer workshops (to be scheduled upon completion) will show that stripper gas well operators can easily build micro $N_2$-rejection plants for about $100,000, operate it at attractive rates of return (of at least 40%), and significantly add (~1 tcf) to the nation's reserves.

# Best Practices Guide: Reducing Water Production in Coalbed Natural Gas Fields

Matt Accurso, Principle Investigator, WellDog, Inc.; Dr. Steve MacDonald Principal Lead, WellDog, Inc.

## Executive Summary

The purpose of this study is to reduce coalbed natural gas produced water, while maintaining existing gas production levels by using spectroscopic analysis to determine the reservoir parameters of gas content (GC), critical desorption pressure (CDP), and percent saturation on existing leases in the Powder River Basin **(Gleghorn T44N R77W, Mengel T44N R78W)**. The net result from these key reservoir parameters will be the economic feasibility of each well and will be immediately available to guide the producer to more economic areas. More importantly, these parameters will help the producer avoid areas with little or no GC which would otherwise cost hundreds of thousands of dollars in infrastructure and water handling costs while further depleting aquifers that are not economically contributing to gas production in the basin. The study objects are:

- Use WellDog's proprietary technology to determine CDP, GC and percent saturation in 32 wells to help determine which wells have the best economic viability. We anticipate up to 33% of the wells will be uneconomical.
- Use CDP, GC and percent saturation to evaluate the economic production potential of each well, and identify and eliminate wells with a high potential to contribute large volumes of water without economic gas production.
- Document the number of wells that are plugged due to low GC while monitoring water and gas production statistics from the economically feasible wells throughout the duration of the study. These statistics will demonstrate the producer's volume of produced water can decrease while maintaining or increasing gas production.

In 2007, the Powder River Basin surpassed 4,000,000,000 barrels of cumulative water production and as development continues to move west, water production statistics continue to increase. Currently, over 7,300 wells are not economic gas producers and over 2,000 of those have only produced water. In order to decrease the volume of produced water in the PRB, it is essential to employ WellDog technology to identify areas of economic GC and avoid areas that will only contribute needless water production.