Technical Reviewers' Rating Summary

Proposal Number G-030-01 Application Title Reduction of Flares and Ca Submitted By Bakken Western Services, I Request For $390,000.00 Total Project Costs $790,000.00

Section A. Scoring

Statement	Weighting Factor	G-30-01A	G-30-01B	G-30-01C	Average Weighted Score
1. Objectives	9	**3**	**4**	**3**	**27**
2. Achievability	7	**3**	**5**	**3**	**21**
3. Methodology	8	**1**	**3**	**3**	**16**
4. Contribution	8	**2**	**3**	**2**	**16**
5. Awareness / Background	5	**2**	**4**	**2**	**10**
6. Project Management	3	**3**	**3**	**3**	**9**
7. Equipment / Facilities	2	**2**	**4**	**3**	**6**
8. Value / Industry - Budget	4	**3**	**5**	**3**	**12**
9. Financial Match - Budget	4	**2**	**3**	**3**	**8**
Average Weighted Score		**115**	**188**	**137**	**146**
	Total: 50				**250 possible points**

OVERALL RECOMMENDATION

FUND		**X**	
FUNDING TO BE CONSIDERED			**X**
DO NOT FUND	**X**		

Section B. Ratings and Comments

1. The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Oil and Gas Research Council goals are:

   Primarily an economic project versus research project as proposed.
   - Reviewer: G-30-01A
   - Rating: 3

   The goals and objectives of this project are consistent with those of the NDIC/OGRP. If successful, the project will increase the profitability and efficiency of ND's oil and gal wells. I strongly agree that there should be no negative environmental impacts and there may be some positive impacts resulting from the project. I was pleased to see that local ND firm is being considered to manufacture the vortex tools and that a local firm would do the installation. This meets the objective of aiding economic growth locally.

- Reviewer: G-30-01B
- Rating: 4

The financial aspect and the reference to reduced flaring are stated clearly. Knowledge of existing ND production facilities and marketing challenges may be understood, but it really wasn't clear to me from what was provided.
- Reviewer: G-30-01C
- Rating: 3

We would Like to add an additional comment in regards to the research part of the Vortex System in Bakken Wells: The Following are some recent conversations with one of our operators that provided some interesting insight into reduced CO2 and H2S problems. Black powder (H2S) in flow-lines discussion: Texas customer confirmed that they have a minor H2S problem in some of their lines. On flow-lines where they have to pig the line (as opposed to using Vortex), they are seeing black water being discharged to the tanks and this is a black powder reaction problem due to water dropping out and accumulating in the lines. Slugging of black powder can cause problems with filters. On all pipelines where Vortex technology is deployed, they do not have any black water problem, since water remains en-trained and does not drop-out at low points in the line. On all production tanks where Vortex is used to spin vapors to liquids at the heater treater, there are no black powder problems. Also, on lines with Vortex, since water vapor and free water are both reduced, there is reduced corrosion inhibitor use and reduced glycol use. Customer quote: “Because of the addition of Vortex tools, any black powder residue is en-trained in the water and carried to the (production) tanks. Also, because the water and black powder are being transported constantly, as opposed to slugging or pigging, we (customer) are not sending this problem to the pipeline.”

- Applicant

2. With the approach suggested and time and budget available, the objectives are:

No comment
- Reviewer: G-30-01A
- Rating: 3

After an agreement has been reached with the owner/operator of the target wells, the project should be complete within 12 months. A fabrication company ‘in Mandan’ could quickly build the vortex tools because the components are readily available. All other materials needed such as valves, piping and supports are also easily obtained and installed. There are no requirements for electrical and instrument equipment except for testing and measurement. Thus, the greatest time requirements will be dependent on how much testing and equipment revisions will be needed or desired.
- Reviewer: G-30-01B
- Rating: 5

Timeline seems reasonable and being they have done this in Texas already, I would think past experience is guiding them.
- Reviewer: G-30-01C
- Rating: 3

We believe the objectives set forth in the proposal are achievable within the 12 months stipulated in the proposal. The Vortex Tool can be manufactured locally within a short

period of time, requires no special fittings and no independent energy source to operate. Piping, NGL collection tanks, valves, filters and other components are off the shelf equipment, and readily available. This will allow for quick deployment and installation with minimal impact on operations.
- Applicant

3. The quality of the methodology displayed in the proposal is:

Project describes various applications (flowing well, pumping well, flared wells, gas connected wells, ect.) Each will have unique mechanical/operational constraints. Unclear how project will address all the variables.
- Reviewer: G-30-01A
- Rating: 1

Compared to other proposals I have reviewed, I find the proposed methodology to be average. This ranking is due to the items not listed or described in the proposal. For example, there are no specifics as to the parameters that are to be observed or measured or how that will take place. There also is no statement regarding the time duration of a test. Further, no indication is given of flow or mass quantities that will be processed during the test period. The proposer lists items that will determine standards of success. They talk about increases/decreases, but no hard targets or estimates are given. It would be great to have at least a couple.
- Reviewer: G-30-01B
- Rating: 3

Based on the fact this has been done in another state, I think the method to install and try it in ND is understood. I would like to see more on the marketing issues that may arise from this, who will address them, the Producer/client or the company providing the technology?
- Reviewer: G-30-01C
- Rating: 3

The Project Manager will define the Operator and the site. Once defined, a site visit will follow and the necessary engineering data will be gathered to determine the Vortex Tool size and the supporting equipment requirements. Performance variables will be identified before work is commenced and performance objectives will be set with the customer (if applicable). Our initial focus is on the stranded gas and other flared wells. Tests will be conducted with a 45 – 60 day or longer duration at a single site and plans are to conduct tests continuously. Comparisons with or without the Vortex Tools will be easily quantified by installing a simple bypass around the Vortex Tool at the required points of measurement. Data will be collected before and after the Vortex Tool deployment and will include gas volume and composition, Btu measurements before and after the gas flash, temperature variables, volume and composition of liquids recovered, corrosion impact, bs&w levels, line pressures and any maintenance and down-time issues being reported. Empirical data collected together with anecdotal benefits identified by the Operator will be recorded and the results will be tabulated and shared with the NDIC and the Operator. Upon completion of the initial tests, the same testing protocol will be used and any required changes and modification will be adopted and implemented. The Vortex equipment will then be deployed to another installation. Vortex Tools have been designed for use directly at the wellhead (after the tree) on pumping, gas lift and flowing wells. The Tools are also designed for use on flared wells as well as for deployment in the pipeline for wells connected to gas gathering systems. Our plans include utilizing a 2” to 4” flare line

and our ideal target installation is a stranded well currently flaring 250 MCF/day of gas or more. In this application, the test program is designed to use single and/or multiple Tools. We have larger Tools that can easily handle volumes up to 10 MMCF/day, but such installations are less likely to be flaring stranded gas and fall into later targets of opportunity as the Vortex solution is more widely deployed. Tools are available in a wide range of sizes, pipe ratings (150 ANSI and higher) and can be configured with different fittings and connections (hammer unions, flanged, etc). In addition, Vortex Tools can also be designed to minimize vapors at the production tanks, reducing water vapors and consequently reducing glycol use, improved filter life and disposal by reducing free liquid hydrocarbons in the gas stream. An example of the economic positive impact of a Vortex Tool installation was in Texas where the Tool was deployed at the tree, prior to entering a test separator or Heater/Treater, and documented that clean, merchantable oil can be put in the tanks earlier in the test cycle. The well, flowing 24 MMCF/day, 4,000 BOPD and 3,000 barrels of drilling mud and cuttings per day, was able to produce oil product to sales after four hours instead of three days. This saved the Operator $500,000 in product that would have been flared along with the attendant emissions. Additionally, the operator noted that prior to the Vortex Tool installation; chokes and flow lines suffered erosion from the abrasive mud. This same Vortex Tool has been used in flow backs for two years (on 12 wells), without repair or replacement. The operational and sales model adopted in Texas integrated the liquids recovery system into the automated Supervisory Control and Data Acquisition (SCADA) reporting system in existence at the Operator facility. Monitoring of levels on the NGL tanks were set to trigger the call for a tanker truck to collect the recovered liquids from the propane tank and were then sold through existing distribution channels at spot market prices. The marketing and sales of NGLs in North Dakota is available through several companies and facilities. The Aux Sable Palermo truck facility is currently contracting for NGL’s from several gas processing plants for shipment to their facilities in Chicago. Also, ONEOK recently announced the completion of the Bakken NGL pipeline that transports unfractioned NGL’s from the Williston Basin to their fifty percent owned Overland Pass pipeline that extends from Southern Wyoming to Conway, Kansas. A local company, Montana Dakota Resources, has several subsidiaries that are involved in the processing and sale of natural gas NGLs and oil production. Other NGL pipeline plans are under consideration. We will work the above mentioned companies, local energy trading companies and the Operator to sell NGL’s into the marketplace. Success of the project will also be measured on the beneficial impact on production volumes, product sales and the positive environmental impact through the reduction in pollution.
- Applicant

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Oil and Gas Research Council goals will likely be:

   - Unclear how project determines which vortex location achieves greater success. - Suggestion that NGL's captured by vortex method has higher economic value then normal gas processing is not validated.
   - Reviewer: G-30-01A
   - Rating: 2

   The concept of a vortex separator or cyclone separator (as some call certain designs) is certainly not new. Separators of this type have been used for decades in removing solids from gases and liquids, and gases from liquids. Some can even be used to separate less dense vapors from higher density vapors. Also the vortex tools described here have been

used by others to entrain fluids to prevent freezing and improve flow characteristics. For example, Schulmerger advertises their vortex tool for use in gas separation processes. As the proposer notes, oil fields in Texas have used their tools successfully. The significance in this case will be to demonstrate the effectiveness of these tools in ND's extreme temperature variations and with the product mix of hydrocarbons coming from a Bakken well. The challenge will be to determine the best sizing and internal vortex design of the tools to achieve the optimum separation or flow characteristics. I am actually surprised that no one has tried this before in ND.
- Reviewer: G-30-01B
- Rating: 3

Would like to have seen more on the science end of the vortex method. Just stating spinning oil vapors back into hydrocarbon products is pretty vague. Even though it can be done, it won't last long and the products will separate again. Does this spinning effect lead to any corrosion/erosion issues in piping/vessels, especially if there are solids present (sand or other proppant from a Bakken frac)?
- Reviewer: G-30-01C
- Rating: 2

In past case studies, Vortex has removed up to 10 times more NGLs from flow lines than traditional methods (drip systems and/or pigging). Higher economic value is attributed to the fact that NGLs sell at a higher price than natural gas, resulting in a better economic and ecological solution than the current method of flaring. An example of capturing highly valued NGLs out of flared gas can be found in an article written by RBN Energy contributor Sandy Fielden, "Set Fire to the Gas – The Fight to Limit Bakken Flaring". He reports that as of May 3, 2013, the weighted average value of the primary NGL constituents (propane, normal butane, isobutene, natural gasoline minus ethane) was $10.22/MMBTU, whereas Rockies Natural Gas was priced at $3.75/MMBTU. His calculations show a value of NGLs of $1.02 per gallon. Further value can be understood that in rich Btu gas lines, liquids typically fall out at low points in the line and as the gas cools this liquid drop-out causes clogging of pipes, pressure spikes, corrosion and hydrates to form. Vortex Tools keep the liquids continually moving with improved liquids recovery, reducing hydrate formation and results in less slugging. The difference between the patented Vortex Tool and vortex separators is significant. Typical separators (and hydrocyclones) use a vortex generator in a hydrocyclone (or series of hydrocyclones) which are volume sensitive and cannot handle wide variances in product composition. This type of hydrocyclone separates one component of a flow from another, typically at discharge and requires an additional and costly energy source. The Vortex Tool does not require a vortex generator to separate the two component fluids. The separation instead takes place in the pipe downstream of the Vortex Tool and once separated the gas and liquids do not combine, as long as discharge tank pressures are above flash pressures of ~120 psi or at atmospheric pressure in the case of standard production tanks. The Vortex Tool can handle wide variances in flow and product mix, from 1% to 100% liquid with minimal impact. Also, because the Tool is velocity (not pressure) dependent, the "organized" flow is developed at low velocities of 5 feet per second or less. No outside pressure enhancement is required, and therefore no additional energy source is required. Further experience and research has shown the Vortex Tool providing beneficial effects regarding the question of corrosion issues and the presence of solids in the lines. For example, in coal bed methane gas wells, coal fines are often present and can drop out and settle in gas lines. With the Vortex Tool in place, the coal fines continue to move and do not drop out. This flow also prevents corrosion from low spot clogging and facilitates the

deployment of anti-corrosive chemicals. These liquid corrosion chemicals, traveling down the pipeline in a rifling spiral, allow direct contact with the pipe, and improve the effectiveness of the chemical treatment. The scientific explanation of the Vortex Tool offered by a research engineer, David Simpson, P.E. Muleshoe Engineering, is as follows: "As a stream of gases and liquids enters the (Vortex) flow modifying device, it is forced by a 'bluff body' in the flow stream to spin rapidly. The high angular acceleration slings the heavier liquid towards the pipe wall. As this spinning flow moves through the device, the configuration allows the spin angle to relax to a very efficient value. This efficient helix-angle will propagate very long distances. The consequence of the liquid moving (like the rifling on a gun barrel) is that the no-flow boundary at the edge of the central gas flow is moving, resulting in a lower differential velocity between the bulk flow and the outer edge of the flow, which yields a lower shear force and a lower pressure drop due to friction. A second benefit is provided by eliminating the slip between liquid droplets in the flow and the gas stream. Removing this slip force reduces the amount of work the gas must do as it moves – reducing the total pressure drop."
- Applicant

5. The background of the principal investigator and the awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is:

    No comment
    - Reviewer: G-30-01A
    - Rating: 2

    The backgrounds and knowledge level of the principal investigator and other personnel associated with conduct of the project would appear to be more than adequate to conduct the project. The references to the Texas well test results indicate Vortex Tools, LLC has tested and experimented with vortex tools. Evidence was also found on their website indicating they have read at least a few other research and test project reports.
    - Reviewer: G-30-01B
    - Rating: 4

    Didn't see a lot on research or published literature, just references to what has been done in another area.
    - Reviewer: G-30-01C
    - Rating: 2

    Vortex Tools, LLC, the owner of the patented process, has over 1,500 Tools in operation worldwide and the personnel associated with the NDIC proposed project has collectively over 50 years of oil & gas operational experience. Most of the installations prior to 2010 were focused on the elimination of water from gas and improving performance in producing gas wells (surface and downhole). Over the years of working closely with the Operators, the Company also saw the need and value in directing its attention to oil vapors and the recovery of NGLs from low-value rich gas. Several case studies and white papers have been published describing the test results and benefits obtained through the use of the Vortex Tool in a number of applications and are attached. One study, published by the Society of Petroleum Engineers (SPE), focused on the benefits of the Vortex technology in the wellbore. The study noted that the Tool was able to lower the pressure drop, resulting in increased production and recovery from the gas wells. Another study that was conducted on the Vortex technology describes the benefits of reduced freeze-ups and

increased performance in low temperatures and was published by RMOTC in 2007. Also attached is a white paper presented at the Texas Tech University Short Petroleum Course in April 2012. The paper discusses a Texas test trial conducted in a series of 5 gathering systems (10 wells) over a 15-month period. The Texas trial in 2010 and 2011 represented the first major deployment of this solution that shows the Vortex Tool causing liquids to be transported 6.5 miles without slugging and without line freeze ups down to 9° F ambient temperature.
- Applicant

6. The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any, is:

No comment
- Reviewer: G-30-01A
- Rating: 3

It appears that the proposer can handle the finances on their side. The communications internally should be okay since the proposer is using 'in house' procurement and installation personnel. The proposal is weak in describing communications between the proposer and the OGRP.
- Reviewer: G-30-01B
- Rating: 3

More of a list of what needs to be done and what month it would happen, but it covers what needs to be accomplished.
- Reviewer: G-30-01C
- Rating: 3

The project organization has been established so that work and cost activities are planned, controlled and monitored; objectives and requirements are met; and work is performed to meet the schedule established. The project will be managed by Bakken Western's Project Manager. The Project Manager will be responsible for the scope of work, and overall management of the site selection, engineering, installation, data monitoring and project reports. The reports will consist of data, including gas flow rates, recovered condensate quantities, operating pressures, flare measurements and observations. Interim reports will be distributed to the NDIC and a final report will be provided at the conclusion of the project. Besides the interim report data, the final report will also include measurable economic and environmental data, observations and any anecdotal information. The Project Manager will also ensure that the project receives management attention and that it will be staffed with adequate resources. He will also assure that the site selection, quality manufacturing, engineering and construction are performed in a timely manner. The Project Manager will work closely with the Operator ensuring that all objectives of the project will be met. Those responsibilities also include the development and management of the project schedule, procurement activities, cost control, and monitoring the construction activities of Operator approved sub-contractors or roustabout crews. The Scope of Work, defined by Bakken Western's management and the Project Manager, includes establishing the project protocol, identifying Operators and target wells, site visit, engineering, manufacturing, installation, data collection, reporting, and NGL sales and marketing. The Scope of Work also includes the methodology of determining the Vortex Tool size, the supporting equipment, performance variables and objectives.
- Applicant

7. The proposed purchase of equipment and the facilities available is:

No comment
- Reviewer: G-30-01A
- Rating: 2

It is relatively straight forward to project the equipment costs associated with this proposal because of the simplicity (aside from the manufacture of the vortex tools). The cost estimates given appear to be reasonable.
- Reviewer: G-30-01B
- Rating: 4

The process is used elsewhere, so it seems like it is known what is needed. One thing I did notice is several references to HP separators in the write-up. Not too many HP separators on ND Bakken wells after initial flowback. I did notice the drawing/sketch layout did not reference HP separators. Would be interested to know if the intention is to try and get in on initial flowback or after that time period is complete or of course, both. Adding a layer of complexity to most field sites with the addition of a tower vessel and bullet tanks. As a former plant manager, this brings a whole host of considerations for fire and leak drainage issues to sites that normally don't deal much with pressurized storage vessels. NGL volume/storage on site can lead to OSHA PSM regulations if the onsite volume is over 10,000 lbs (which isn't that much). Has this been looked into? No Producer will want to start a PSM program for a well site. Adding a tower vessel, a compressor, and bullet tanks is not minimal equipment added to an existing oil well site. It is pretty significant.
- Reviewer: G-30-01C
- Rating: 3

We do understand that HP separators are not typically used on Bakken wells after initial flow-back. In some applications, our intent is to deploy Vortex Tools with a HP separator, before the LP separator (or heater-treater), and remove the HP separator when appropriate. Adding a Vortex Tool on the liquid leg to the heater treater without an HP separator will provide some benefit, but the light NGLs typically flash to gas (and to flare). Use of the HP separator will facilitate a better oil cut and increased recovery of the light ends. We also believe the heater treater can operate at lower temperatures with Vortex, thereby reducing gas use and further reduce pollution. Using Vortex on a new well flow-back can be extremely beneficial. However, the capital investment in a new well increases the burden of proof. Although we have several successful flow-backs in Texas, this remains a much harder "sell" to Operators until Bakken-specific installations are available as reference. The Project Manager is responsible for all OSHA regulation compliance and the OSHA PSM regulations have been reviewed and do not present a challenge as far as we can tell.
- Applicant

8. The proposed budget "value"1 relative to the outlined work and the commitment from other sources is of:

No comment
- Reviewer: G-30-01A
- Rating: 3

This is perhaps the strongest criterion of the proposal. The proposed funding level being requested is $390,000 and the project duration is only 12 months. The economic benefit

may be significant in comparison if the equipment performs as the proposer envisions. This equipment can be installed in parallel with existing piping. The beauty of this ability is the operator can take the test equipment in and out of service easily. One can then do a real process time comparison to the benefits achieved while the test equipment is in place vs excluding the test equipment. When the project is complete, success or failure should be quite identifiable. With this project, millions of dollars and years of time will not have been expended in reaching that determination.
- Reviewer: G-30-01B
- Rating: 5

Seems reasonable.
- Reviewer: G-30-01C
- Rating: 3

One reviewer states that our proposed budget "values" relative to the outlined work and the commitment from other services is perhaps the strongest criteria of the proposal. We agree with this statement and the reviewer further comments that "the economic benefit may be significant in comparison if the equipment performs as the proposer envisions". The NDIC data indicates that oil production, in February 2013, increased to 779 MM barrels/ day and the associated natural gas produced increased to 850 MM cubic feet/day. The data further indicates that about 30.4% or 258 MM cubic feet/day was flared. The University of North Dakota reports that there is an average of four gallons of NGL's/MM cubic feet of natural gas. At this rate, a total of 1,032,000 gallons/day or more than 376 MM gallons of NGL's/year are burned in the flare gas. At an estimated NGL value of $1.00/gallon, this represents a huge financial target for the Vortex System of offered savings along with the environmental benefits that will occur when the NGL's are recovered. As a result of a meeting with Frank Morehouse, President, Montana Dakota Utilities, who has extensive interests in gas collection and transmission pipelines, oil and gas production along with a fifty percent interest in a natural gas cleaning plant, Mr. Morehouse agreed to express his Company's interest in our Vortex proposal by writing a letter of support to the NDIC. We fully expect that the information provided from the Vortex Tool installations under this proposal will provide the industry with the knowledge and the opportunity to add millions of dollars in additional revenue, while sharply curtailing the environmental emissions caused by the flaring at the oil wells.
- Applicant

9. The "financial commitment"2 from other sources in terms of "match funding" have been identified:

   Applicants "in-kind" share for principals appears high. Combining the principals expensive and "bullet" tank expense - these two items represent nearly half (43%) of project expenses.
   - Reviewer: G-30-01A
   - Rating: 2

   As stated earlier, the budgeted cost estimates appear reasonable. As such, the proposer is putting up 50.6% of the total costs and just barely meeting the match funding criteria.
   - Reviewer: G-30-01B
   - Rating: 3

   Seems reasonable.
   - Reviewer: G-30-01C

- Rating: 3

As stated in our proposal, Bakken Western is fully committed to the project and will be providing funding from its own resources. The bullet tank is the largest component expense and is necessary as it allows the collection of the NGL's which are separated from the gas flow by the Vortex Tool. The Vortex Tool System also includes piping, valves, gauges, and other supporting equipment. Alternative configurations are also planned that will allow for testing different Vortex locations, and will include more than one Vortex Tool. The proposal further provides for support by consulting engineers. Operator approved subcontractors and roustabout crews will be used for the initial installation as well as the subsequent configurations and changes as trial opportunities are identified.
- Applicant

1 "value" – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar. A commitment of support from industry partners equates to a higher value.

2 "financial commitment" from other sources – A minimum of 50% of the total project must come from other sources to meet the program guidelines. Support less than 50% from Industrial Commission sources should be evaluated as favorable to the application; industry partnerships equates to increased favorability.

General Comments

No comment
- Reviewer: G-30-01A

Again, I find it surprising that no one has tried this technology in the patch. Having said that, I find this project interesting and of value. Given the relatively low cost and time duration vs potential benefits, the proposal should be given consideration. The proposal could have been much stronger by adding a few points. I felt the methodology section in particular and the standards of success section to a lesser extent, should have been expanded and provided more detail.
- Reviewer: G-30-01B

1) Would like to know more about where the markets are for the ngl liquids collected in the bullet tanks. Where are they going to be sold? Is the plan to sell them to local plants, etc. (which there aren't many selections). Do the plants have truck unloading facilities? The only one I know of is Aux Sable's plant in Palermo. We've always known there are ways to capture ngls on field locations, but you have to be able to market them effectively from there to be of real value. 2) Have crude oil marketing issues been discussed with any clients or oil purchasers? Selling Bakken crude oil is already a challenge due to the high vapor pressures encountered, especially when 70+% is currently moved by rail in ND. Methods which would put more ngl type products in the crude would not be helpful. In my prior job, we were already experiencing problems unloading rail cars at their destination points due to the high vapor pressures and considerations were being made to build large crude stabilization facilities to alleviate this problem (remove the light ends). Price deducts and in some cases not being able to unload the rail cars and sending those back 1,100 miles were the results of this. 3) Also, this would add more trucking to an area already grossly overloaded by oilfield trucking. Hauling from bullet tanks and maintaining the pressure requires a pressurized truck or you just lose the product to vapors (potential of a lot more danger in a vehicle accident).
- Reviewer: G-30-01C