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Witness: Robert F. Allen
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Case No.: EA-2014-0207
Date Testimony Prepared: September 15, 2014

MISSOURI PUBLIC SERVICE COMMISSION

CASE NO. EA-2014-0207

REBUTTAL TESTIMONY

OF

ROBERT F. ALLEN

ON

BEHALF OF

ROCKIES EXPRESS PIPELINE LLC

Braintree, Massachusetts
September 15, 2014

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REBUTTAL TESTIMONY

OF

ROBERT F. ALLEN

CASE NO. EA-2014-0207

I. INTRODUCTION

Q. Please state your name and business address.

A: Robert F. Allen, 639 Granite St., Suite 200, Braintree, MA 02184

Q. What is your position with ARK Engineering?

A. I am the founder, CEO and principal engineer.

Q. Please describe your educational and professional background.

A. I have a bachelor's degree in electrical engineering (BSEE) from Northeastern University in Boston, Massachusetts and a master's of business administration (MBA) from Bryant University in Smithfield, Rhode Island. I am a member of and am certified by the National Association of Corrosion Engineers (NACE) as a cathodic protection specialist and as a senior corrosion technologist. I am also a member of the Institute of Electrical & Electronic Engineers (IEEE), the American Society of Mechanical Engineers (ASME) and the Instrument Society of America (ISA). I have worked in the power and oil refining industries as a system engineer responsible for design and integration of power distribution systems; as a principal pipeline engineer and senior technical services engineer responsible for implementing cathodic protection and corrosion control monitoring programs for pipeline facilities; and as a principal engineer in the pipeline industry responsible for development and implementation of corrosion control systems, supervision of groundbed installations, and supervision of the analysis, design, installation and commissioning of electromagnetic, AC and DC interference mitigation systems. I have also published articles in industry publications, presented technical papers at industry conferences, and taught college courses related to pipeline and energy topics. A copy of my resume is attached as Schedule RFA-1.

Q. Have you previously testified as an expert witness?

A. Yes. In 2013, I was an expert witness for Florida Power & Light Co. on the expansion of the FPL Turkey Point Plant in Miami, FL. This involved AC interference effects to the Miami Metro Rail system as a result of additional AC electric transmission circuits originating from the Turkey Point Plant.

In the 1990's, I was an expert witness for the State of New Hampshire on the proposed routing of High Voltage AC electric transmission circuits and their effect on existing pipelines and other structures near the proposed rights-of-way.

In the mid-1980's, I was involved in a study performed for Texas Eastern Transmission Pipeline Co. analyzing possible HVDC interference effects of a proposed HVDC transmission line in Vermont.

II. PURPOSE AND SUMMARY OF TESTIMONY

Q. What is the purpose of your testimony in this proceeding?

A. The purpose of my testimony is to explain certain conditions that should be imposed on Grain Belt Express Clean Line LLC ("GBX") as part of any grant of a certificate of convenience and necessity ("CCN") to GBX for its proposed high voltage, direct current (HVDC) transmission circuit and converter stations in Missouri, in order to ensure that the construction and operation of the GBX HVDC line does not interfere with, or jeopardize the safety of, the existing Rockies Express Pipeline LLC ("REX") 42-inch diameter natural gas pipeline in Missouri. GBX has indicated in response to data requests in this case that it will perform "necessary studies" and identify "necessary mitigations," but it indicated in response to REX data request #005 that exact pole/structure locations must be known before GBX can determine what studies and mitigation is required. It is my opinion that it is possible, even without knowing the exact final locations of HVDC poles and structures, to identify studies and mitigation required to minimize the serious negative impacts that HVDC circuits can have on underground steel pipelines. Therefore, it is my opinion that certain specific conditions regarding studies and mitigation can and should be imposed before any CCN is granted to GBX.

Q. Please summarize your testimony and conclusions.

A. When an HVDC circuit (s) are located in proximity (within 1,000 feet or less) to an underground steel pipeline, both normal and abnormal operation of the HVDC circuit can compromise the operation and integrity of the pipeline system. Depending on the proximity and location (parallel or crossing) of the HVDC line to the pipeline, the HVDC system must be constructed, monitored and operated in specific ways so as to mitigate the following threats to the safe operation and integrity of the pipeline system: pipeline coating damage, pipeline corrosion, loss of cathodic protection, damage to corrosion control equipment and damage to corrosion monitoring equipment. When these threats are not properly mitigated, the HVDC line and its grounding system can cause pipeline operations to reduce operating efficiency by the reduction of operating pressure and delivery capacity, can necessitate costly and disruptive (to REX and landowners) repairs to the pipeline, and can even lead to pipeline rupture. I recommend that the Missouri Public Service Commission impose the specific conditions set forth in this testimony in order to adequately mitigate the threats to the safe operation and pipeline integrity that the HVDC circuit and system poses.

III. REX'S STEEL PIPELINE

Q. Please give a brief overview of the Rockies Express Pipeline.

A. Rockies Express Pipeline is a FERC-regulated, steel, 42-inch diameter, 1,698-mile long, underground natural gas pipeline that stretches from northwestern Colorado to eastern Ohio. The pipeline has 1.8 billion cubic feet per day of long haul design capacity. The pipeline passes through the following Missouri counties: Buchanan, Clinton, Caldwell, Carroll, Chariton, Randolph, Audrain, Ralls and Pike.

IV. CORROSION – THE ENEMY OF STEEL PIPELINES

Q. Please describe the corrosion threat to the safety and integrity of underground steel pipelines.

A. One threat to the safety and integrity of underground steel pipelines is the mechanism of corrosion. Corrosion is an electrochemical process that causes the loss of metal from steel pipelines, and other structures, if such structures are not effectively monitored and protected.

Q. What is pipeline corrosion?

A. Pipeline corrosion is the gradual destruction of the pipeline steel by an electrochemical process (reaction) with its environment. Corrosion degrades the useful properties of pipes and structures including strength, appearance and permeability to liquids and gases. Pipeline corrosion can be concentrated locally to form a pit or crack, or it can extend across a wide area more or less uniformly corroding the surface. Because corrosion is a diffusion-controlled process, it occurs on exposed (non-coated) surfaces. As a result, methods to reduce the corrosion activity, such as coatings and cathodic protection are effective to retard corrosion effects.

Q. **What steps are taken to prevent corrosion?**

A. To prevent corrosion and keep the pipeline safe, it is essential to use a coating system and cathodic protection to protect the pipeline from interaction with the soil. In addition to a fusion bonded epoxy coating system, REX's pipeline utilizes an impressed current cathodic protection system consisting of numerous rectifiers and ground beds spaced along the pipeline route to achieve a polarized potential of -850mV DC or more (the level mandated by Department of Transportation regulations). With a polarized potential of greater than -850mV "impressed" on to the pipeline, external corrosion on the pipeline can be practically eliminated.

Q. **What can happen when REX's cathodic protection system or pipeline coatings experiences DC interference from external sources?**

A. DC interference effects to the pipeline can cause upsets (negative or positive variances from the optimal -850mV polarized potential) and can result in damage to the pipeline and its cathodic protection systems. Positive variances from the optimal polarized potential can cause corrosion to occur on the pipeline system. Negative variances can damage rectifier components and cause these rectifier systems to be inoperative, and can also damage pipeline coating and cause pipeline coating to disbond from the pipeline, thereby initiating corrosion effects.

V. DC INTERFERENCE AND RECOMMENDATIONS FOR MITIGATION

Q. Do HVDC electric transmission circuits pose a particular concern with respect to the safety and integrity of steel pipelines?

A. When HVDC transmission circuits and pipelines are in proximity to (within 1,000 feet of) each other, either in parallel or crossing, DC interference may occur. DC interference effects to the pipeline is the pickup of DC current from a foreign source at one location and the discharge of DC current at another location along the pipeline. At the point where the DC current discharges from the pipeline, the DC current will remove metal from the pipeline in the form of corrosion effects on the pipeline. As mentioned above, DC interference can also cause damage to pipeline coating and cause the coating to disband from the pipeline. These DC interference effects to the pipeline can occur during normal operations of the HVDC circuit and also during abnormal operations (during a fault situation). This situation can negatively affect the pipeline and related equipment and monitoring system facilities. An abnormal operation or fault situation on the HVDC system that causes a DC voltage rise of over 2.0 volts, at any location on the pipeline can cause coating damage or structural damage to the pipeline, and damage to the corrosion control system and cathodic protection monitoring system. Depending on the electrical characteristics of the HVDC current, and depending on the fault current available at a HVDC system tower, a fault condition on an HVDC transmission circuit could result in fault current voltages transferred to the pipeline in the <u>tens</u> or <u>hundreds</u> of volts.

Q. What do you mean by normal and abnormal operation of the HVDC system?

A. Normal or stead-state conditions on the HVDC circuit are operations of the circuit up to its maximum design capacity.

An abnormal condition on the HVDC circuit is any upset or condition that causes the circuit to function in a different capacity than it was designed for. This may be caused by a failure of internal circuit equipment or outside forces such as a lightning strike or damage due to weather or animals, etc. In an abnormal condition, large amounts of DC current may flow into the soil at various locations as the system tries to correct itself or shut down.

Q. You said DC interference can have negative effects on the pipeline and related facilities. Please describe what you mean.

A. The effects can include the following, which are of particular concern to REX:

Coating damage—damaged coating can lead to corrosion of the pipeline steel in the area of the damage.

Corrosion to the pipeline—at an existing coating holiday (where coating is absent), the corrosion process can be accelerated.

Loss of cathodic protection—cathodic protection systems protect the pipeline from corrosion effects by impressing DC current on to the pipeline so that the pipeline reaches at least the -850 mV DC level outlined above to retard corrosion effects. If that cathodic protection system level is lost or reduced, corrosion mechanisms, of varying degrees, can begin immediately to affect the pipeline steel.

<u>Damage to corrosion control equipment</u>—equipment (anodes, rectifiers, etc.) are part of the corrosion control system. During an abnormal condition, DC interference can shorten the life of (deplete) anodes and can "fry" the electrical components of rectifiers.

<u>Damage to corrosion monitoring equipment</u>—equipment required to monitor the corrosion system (remote monitors, remote computers) can also be "fried" by DC interference effects during an abnormal condition.

Q. Are REX's pipeline, cathodic protection systems or monitoring devices likely to be affected by HVDC during normal operation of the HVDC line or abnormal operation?

A. If the HVDC circuit is located close to the REX pipeline, there may be possible DC interference effects to the pipeline during normal operation. This is unknown until a final route is determined and an interference analysis is completed. During abnormal operation of the HVDC circuit, there may be various effects to the REX pipeline. The effects will be based upon location and crossings of the HVDC circuit and the REX pipeline and the conditions and locations of these abnormal conditions. These issues would be amplified if the system were to operate in a ground return mode.

Q. How long might a fault condition last?

A. I can't tell you that for certain. GBX stated in response to REX's data request #005 that during a fault condition, de-energization of the HVDC line would occur within less than a second, but GBX has not disclosed how it will ensure this effective shutdown with no effects to the pipeline. In general, the greater the magnitude and duration of the fault current situation, the greater the potential damage to the pipeline facilities in the area of the fault condition.

Q. Does the proximity of the HVDC line to the pipeline make a difference?

A. Yes. Generally, the further the distance between the HVDC transmission circuits and the pipeline, the less DC interference effects will be experienced by the pipeline system. There are a number of factors, such as distance, fault current magnitude and duration, grounding, and alignment of the pipeline with respect to the HVDC circuit which will influence the effects to the pipeline at any particular location.

<u>Recommendation #1</u>

Q. Do you have a recommendation about the proximity of GBX's proposed HVDC line to REX's pipeline?

A. Yes. Ideally, where the HVDC line parallels REX's pipeline, it should be located 1,000 feet or more away from the pipeline. If it is located within 1,000 feet of the pipeline, additional DC voltage monitoring systems (discussed in relation to pipeline crossings in Recommendation #7) may be required.

Q. Have you reviewed the proposed route for the HVDC line that GBX included in its application?

A. Yes.

Q. Does it appear that the proposed route for the HVDC line may come within 1,000 feet of, or closer to, REX's pipeline?

A. Yes.

Recommendation #2

Q. Is there a way to predict what the DC interference effects might be, if the HVDC line is closer than 1,000 to REX's pipeline?

A. Yes. A DC interference analysis can be conducted using calculations and modeling software to simulate the operation of the HVDC circuit and determine the DC interference effects to the pipeline. This analysis can determine what mitigation measures are required to prevent the effects outlined above. I recommend that GBX be required, after an exact route for the HVDC line is determined and prior to the commencement of construction, to conduct a DC interference analysis to determine the mitigation measures necessary to prevent the negative effects to the pipeline and related facilities that I outlined. The analysis should model conditions where the HVDC line will parallel REX pipelines as well as where it will cross REX's pipeline, to determine the DC interference effects to the pipeline and related facilities based on maximum operating parameters of the HVDC circuit and simulated abnormal operations, to determine what additional mitigation methods or monitoring systems are required on the pipeline or related systems to reduce these DC interference effects on the pipeline and its related systems and monitoring equipment.

Recommendation #3

Q. Is it important that detailed and accurate information about REX's pipeline and related facilities be used in the DC interference analysis?

A. Yes. I recommend that GBX be required to confirm all data or other assumptions about REX's pipeline system including routing, soil resistivity, cathodic protection systems and pipeline facilities, coating type and condition, wall thickness, and other technical parameters with appropriate REX personnel before engaging in the DC interference analysis. Every location where the HVDC line may be sited within 1,000 feet of the pipeline or may cross the pipeline must be analyzed separately, as proximity and other relevant conditions (such as soil resistivity or the particular cathodic protection systems in place) may vary from location to location along the pipeline route. For example, if the HVDC line is sited within 500 feet of the pipeline for 20 miles, then is sited further than 1,000 feet from the pipeline for 30 miles, then comes back and crosses the pipeline, the effect of the siting within 500 feet must be analyzed separately from (in addition to) the effect of the crossing. If inaccurate data about REX's pipeline system is used, the modeling results may misrepresent or underestimate the interference effects to the pipeline system.

Q. You mentioned crossings. Does it appear that the HVDC line may cross over REX's pipeline?

A. Yes.

<u>**Recommendation #4**</u>

Q. Do such crossings raise additional concerns?

A. Yes. If an abnormal (fault) condition occurs at a crossing, the fault current may enter the ground at the closest tower and travel through the soil to the pipeline. This could result in coating damage or damage to the pipeline steel if the fault current is large enough. If the DC current is able to get on to the pipe through a coating holiday, it can travel along the pipe and possibly damage equipment at some remote location.

Even in normal conditions, I recommend that all crossings of the HVDC line over the REX pipeline be required to be at 90 degree angles, plus or minus 10 degrees.

This is because minimal DC interference effects occur to structures that are at a 90 degree angle to the DC line.

Recommendation #5

Q. Do you have a recommendation regarding the location of any GBX towers in relation to crossings?

A. Yes. I recommend that GBX not be permitted to construct towers closer than 300 feet from the pipeline. This would place the pipeline mid-span, considering a span of at least 600 feet between towers. This is recommended because in a fault current scenario, the fault current can flow down the towers closest to where the fault occurs and into the earth to the pipeline. As a result, mid-span is the safest position for a pipeline crossing of an HVDC circuit.

Recommendation #6

Q. Do you have a recommendation regarding the grounding of any GBX towers in relation to crossings?

A. Yes. REX anticipates that GBX will ground its towers to achieve a ground resistance of less than 10 ohms per tower. While REX agrees this is the required ground resistance value, the grounding method must not increase possible DC interference effects on REX's pipeline. Therefore, I recommend that as to grounding the towers nearest pipeline crossings, GBX be required to locate (install) any ground rods or other local methods of grounding towers on the side of the tower farthest from the pipeline. If additional grounding methods at towers near crossings are required, only ground rods or ground wells are acceptable. Locating the grounding methods away from the pipeline is required in order to increase the separation distance between the tower grounding conductor and the pipeline during a fault or lightning strike condition. The farther away the tower grounding system is from the pipeline, the less the possible DC interference effects will be on the pipeline. Further, I recommend that GBX not be permitted to use counterpoise methods of grounding in tower spans where the pipeline will be crossing between towers. Counterpoise methods involve the installation of a buried grounding conductor from tower to tower. Using this method at crossings would place a grounding conductor bare cable in close proximity to, only 2-3 feet from, the pipeline and significantly increase the DC interference effects to the pipeline at such locations, therefore, it should not be permitted.

Recommendation #7

Q. Do crossings also raise specific monitoring concerns?

A. Yes. Because of the situation just described, where fault current may travel down a tower and into the earth to the pipeline (in the event of a fault occurring at or near a crossing), I recommend that GBX be required to install a DC voltage monitoring system at each crossing of the HVDC line and REX's pipeline. GBX should be required to provide the specifications and capabilities of any proposed system to REX for REX's prior review and approval. At a minimum, the system must be capable of monitoring (sensitive enough to detect) and reporting any change in voltage levels from -850mV experienced by REX's pipeline and cathodic protection systems during a fault event on the HVDC circuit. The data captured by the monitoring system must be available to REX pipeline operations personnel in real time. Such remote monitoring systems are routinely used in the pipeline industry for monitoring of these situations and other corrosion control functions.

Recommendation #8

Q. Does REX need to be notified only when a fault condition occurs in proximity to REX's pipeline?

A. No. I recommend that GBX be required to immediately notify REX pipeline operations personnel if and when a fault occurs anywhere on the HVDC line, and to disclose the approximate location of the fault condition, the magnitude and duration of the fault current situation, and the time when the system returned to normal operation. This is required so REX personnel are able to review monitoring data to determine if the fault condition has caused any adverse effects to the pipeline system.

Recommendation #9

Q. Do HVDC converter stations pose any specific concerns related to the REX pipeline?

A. Yes. Converter stations increase the potential for DC interference effects on the pipeline because there is more concentration of fault current at converter stations. Therefore, after the exact location of any converter station is determined and prior to the commencement of construction, I recommend that GBX be required to conduct a DC interference analysis with respect to the converter stations. The analysis must determine the distance from the converter station at which DC interference effects may be recorded on a buried steel structure. If the analysis shows that at maximum operating parameters of the HVDC circuit and simulated abnormal operations the converter station would cause REX's pipeline and related monitoring equipment to experience DC interference effects, then GBX must implement mitigation methods and monitoring systems to reduce these DC interference effects on the pipeline and its related systems and monitoring equipment.

VI. SUMMARY OF RECOMMENDATIONS AND CONCLUSION

Q. Have you prepared a summary of your recommendations?

A. Yes. It is attached as Schedule RFA-2.

Q. Does this conclude your testimony?

A. Yes.

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

In the Matter of the Application of Grain Belt Express Clean Line LLC for Certificate of Convenience and Necessity Authorizing it to Construct, Own, Operate, Control, Manage And Maintain a High Voltage, Direct Current Transmission Line and an Associated Converter Station Providing an Interconnection on the Maywood-Montgomery 345 kV transmission line.	) Case No. EA-2014-0207

AFFIDAVIT OF ROBERT F. ALLEN

STATE OF Mass)
) ss
COUNTY OF Plymouth)

Robert F. Allen, being first duly sworn on his oath, states:

1. My name is Robert F. Allen. I work in Braintree, Massachusetts, and I am employed by ARK Engineering & Technical Services as its Principal Engineer.

2. Attached hereto and made a part hereof for all purposes is my Rebuttal Testimony on behalf of Rockies Express Pipeline LLC consisting of 15 pages, and 2 schedules, all of which have been prepared in written form for introduction into evidence in the above-referenced docket.

3. I hereby swear and affirm that my answers contained in the attached testimony to the questions therein propounded are true and correct.

Robert F. Allen
Robert Allen

Subscribed and sworn to before me this 15th day of Sept, 2014.

Linda P. Turbell
Notary Public

My commission expires:

LINDA P TURBELL
NOTARY PUBLIC
COMMONWEALTH OF MASSACHUSETTS
My Commission Expires July 22, 2016

ENGINEERING & TECHNICAL SERVICES, INC.

Robert F. Allen

Current Position

Founder & CEO

Experience

ARK Engineering & Technical Services, Inc. Braintree, MA
Vice President / Principal Engineer / Founder
Founded the company in 1991, present responsibilities include:

Project management, client relations, budget, technical marketing, fee and contract negotiations, operations manager, and expert witness.

Corrosion control design, installation, testing and commissioning.

Supervision of groundbed installations.

Supervise analysis, design, installation, and commissioning of electromagnetic interference mitigation systems.

AC & DC interference analysis and mitigation system designs.

Coordinator and principal speaker for Corrosion Control and AC Interference Seminars.

Expert Witness

Algonquin Gas Transmission Company Boston, MA
Principal Pipeline Engineer / Senior Technical Services Engineer
Analyze, design, plan, and coordinate electrical and electronic control and instrumentation projects for measurement of natural gas in pipeline system.

Implement computer based cathodic protection and corrosion control monitoring programs for all pipeline facilities.

Project Manager for technical projects related to pipeline operations, cathodic protection, and corrosion control including:

In-Line Inspection of pipelines for corrosion.

Chief Inspector for pipeline replacement projects.

Gas quality measurement.

Electrical interference effects of nearby high voltage power lines to pipelines.

Microwave communications.

Member of the Operations Division Technical Training Staff conducting training for company personnel.

The Foxboro Company Foxborough, MA
System Engineer
- Ensure proper technical design and integration of Foxboro's line of process control computer systems used in the power and oil refining industries.
- Design, implement and test custom options needed for specific customer applications such as power distribution systems, backup computer and peripheral switchover systems.
- Technical project Team Leader.
- Point of Contact for customers on technical issues.
- Conduct presentations and demonstrations.

Professional Activities

Southern New Hampshire University — Manchester, NH
Adjunct Professor
Instructor for distance education program college course on "Energy and Society".

New Hampshire College — Manchester, NH
Adjunct Professor
Instructor for distance education program college course on "Energy and Society".

Appalachian Underground Corrosion Course — West Virginia University
Instructor
Course Committee Member

Coordinator and principal speaker for Corrosion Control and AC Interference Seminars.

Professional Registration

National Association of Corrosion Engineers (NACE) certified:
Cathodic Protection Specialist – Certification # 5677.
Senior Corrosion Technologist – Certification # 5677.

Education

Bryant University — Smithfield, RI
MBA – Management

Northeastern University — Boston, MA
BSEE

Publications

"Testing and Monitoring of AC Mitigation and Cathodic Protection on Pipelines in Joint Facility Corridors" – *Materials Performance*, Published April 2002.

"Knowing the Basics Eliminates Intimidation From AC Mitigation" – *Pipeline & Gas Industry*, Published August 2001.

"Determining the Effects On Pipelines Built in Electric Transmission ROW" – technical paper presented at National Association of Corrosion Engineers (NACE) Conference, Houston, Texas, March 2001.

"Determining the Effects On Pipelines Built in Electric Transmission ROW" – *Pipeline & Gas Journal*, Published February 2001.

"Cathodic Protection & AC Mitigation Techniques in Joint Facility Corridors" – technical paper presented at the American Gas Association Operations Conference, San Francisco. Library of Congress Catalog Number 20-19797, A.G.A. Catalog Number X59407.

"The Key to Proper Electrical Grounding" – *Electrical Contracting Today*, Published by Associated Builders and Contractors.

Professional Memberships

National Association of Corrosion Engineers (NACE)
Technical Committee Chairman - TG025 - "AC Interference Effects to Pipelines in Joint Facility Corridors"
Technical Committee Member - TG430 - AC Corrosion Causes & Effects"
2003 – 2009 Trustee – Greater Boston Section, NACE
1997 – 98 Chairman – Greater Boston Section, NACE
Institute of Electrical & Electronic Engineers (IEEE)
American Society of Mechanical Engineers (ASME)
Instrument Society of America (ISA)

REBUTTAL TESTIMONY OF ROBERT F. ALLEN

SUMMARY OF RECOMMENDATIONS

Recommendation #1

Where parallel to REX's pipeline, GBX should be required to locate its HVDC line 1,000 feet or more away from REX's pipeline.

Recommendation #2

After an exact route for the HVDC line is determined, and prior to the commencement of construction, GBX should be required to conduct DC interference analysis to determine mitigation measures necessary to prevent negative effects to REX's pipeline and related facilities. The analysis should:

- model conditions where the HVDC line will parallel REX pipelines
- model conditions where the HVDC line will cross REX's pipeline
- determine DC interference effects to the pipeline and related systems and monitoring equipment based on simulated maximum operating parameters of the HVDC circuit
- determine DC interference effects pipeline and related systems and monitoring equipment based on simulated abnormal operating parameters of the HVDC circuit
- determine mitigation methods or monitoring systems required to reduce these DC interference effects on the pipeline and its related systems and monitoring equipment.

Recommendation #3

Prior to engaging in DC interference analysis, GBX should be required to confirm with appropriate REX personnel:

- all data or other assumptions about REX's pipeline system including routing, soil resistivity, cathodic protection systems and pipeline facilities, coating type and condition, pipeline wall thickness, and other technical parameters.

GBX should be required to separately analyze DC interference effects at every location along REX's pipeline route where GBX's HDVC line will parallel or cross REX's pipeline and where conditions relevant to the analysis (such as proximity, soil resistivity or particular cathodic protection systems) vary.

Recommendation #4

GBX should be required to design and construct its HVDC line to cross REX's pipeline at 90 degree angles, plus or minus 10 degrees.

Recommendation #5

At crossings of the HVDC line with REX's pipeline, GBX should be required:

- to construct its towers no closer than 300 feet to REX's pipeline
- to construct its towers such that REX's pipeline is located mid-span between the towers nearest to the pipeline

Recommendation #6

With respect to grounding of GBX's towers nearest crossings of REX's pipeline, GBX should be required:

- to ground its towers to achieve a ground resistance of less than 10 ohms per tower
- to locate (install) any ground rods or other local methods of grounding on the side of the tower farthest from REX's pipeline
- to use as additional grounding methods only ground rods or ground wells

GBX should not be permitted to use counterpoise methods to ground its towers nearest crossings of REX's pipeline.

Recommendation #7

GBX should be required to install a DC voltage monitoring system at each crossing of its HVDC line and REX's pipeline. GBX should be required to provide to REX for REX's prior review and approval the specifications and capabilities of the DC voltage monitoring system that GBX proposes to use. GBX should be required to install a system which, at a minimum:

- is capable of monitoring (sensitive enough to detect) and reporting any change in voltage levels from -850mV experienced by REX's pipeline and cathodic protection systems during a fault event on the HVDC circuit
- makes all data captured available to REX pipeline operations personnel in real time (instantly)

Recommendation #8

GBX should be required to notify REX pipeline operations personnel in real time (instantly) if and when a fault occurs anywhere on the HVDC line, and to disclose, as soon as known:

- the approximate location of the fault condition
- the magnitude of the fault condition
- the duration of the fault current situation
- and the time when the system returned to normal operation