Exhibit No:	
Issue:	**Worn Out or Deteriorated & Bare Steel treated with Cathodic Protection**
Witness:	**David M. Norfleet**
Type of Exhibit:	**Direct Testimony**
Sponsoring Party:	**Spire Missouri Inc.**
Case Nos.:	**GO-2018-0309, GO-2018-0310**
Date Prepared:	**May 13, 2020**

SPIRE MISSOURI, INC.

File Nos. GO-2018-0309, GO-2018-0310

DIRECT TESTIMONY

OF

DAVID M. NORFLEET

MAY 2020

TABLE OF CONTENTS

DIRECT TESTIMONY OF DAVID M. NORFLEET

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is David Matthew Norfleet and my business address is 5777 Frantz Road, Dublin, Ohio.

Q. WHAT IS YOUR PRESENT POSITION?

A. I am presently employed as the Head of Section for the Incident Investigation Section of DNV GL USA, Inc.

Q. PLEASE STATE HOW LONG YOU HAVE HELD YOUR POSITION AND BRIEFLY DESCRIBE YOUR RESPONSIBILITIES.

A. I have been the Head of Section since 2016, approximately 4 years. I am responsible for a section of 21 engineers, scientists, and technicians actively supporting failure and incident investigations, pipeline welding and repair, and research for the oil and gas industry.

Q. WHAT WAS YOUR WORK EXPERIENCE PRIOR TO ASSUMING YOUR CURRENT POSITION?

A. Following graduation from The Ohio State University in 2007, I worked for an engineering firm performing failure investigations for a variety of industries, including oil and gas. In 2011, I joined DNV GL and over the last 9 years I have conducted around 100 investigations for the oil and gas industry and reviewed the analysis of several hundred more.

Q. PLEASE DESCRIBE YOUR PROFESSIONAL EXPERIENCE REGARDING METALLURGY, SPECIFICALLY AS IT PERTAINS TO PIPE MATERIALS.

A. The vast majority of the failure investigations that I and my section have performed for the oil and gas industry pertain to pipelines and specifically to the failure modes and mechanisms associated with line pipe. According to the Pipeline and Hazardous Materials

Safety Administration ("PHMSA"), the largest percentage of failures to the pipeline industry is attributable to corrosion. This is consistent with my observations and the investigations the we have conducted.

Q. HAVE YOU PARTICIPATED IN PROFESSIONAL ORGANIZATIONS THAT FOCUS ON NATURAL GAS SAFETY ISSUES?

A. Yes. They include the National Association of Corrosion Engineers, American Society for Materials, International Pipeline Conference, and Southern Gas Association.

Q. WHAT IS YOUR EDUCATIONAL BACKGROUND?

A. I obtained my Bachelor's, Master's, and Doctor of Philosophy degrees in the area of Materials Science and Engineering (specialization in metallurgy) from The Ohio State University.

Q. HAVE YOU PREVIOUSLY FILED TESTIMONY BEFORE THIS COMMISSION OR ANY OTHER REGULATORY COMMISSION?

A. No.

I. PURPOSE OF DIRECT TESTIMONY

Q. WHAT IS THE PURPOSE OF YOUR DIRECT TESTIMONY?

A. The purpose of my testimony is to address the condition of certain pipe materials that are being replaced as part of the infrastructure system replacement projects being undertaken by Spire Missouri Inc. ("Spire Missouri" or "Company"). I have concentrated specifically on cast iron, bare steel, and bare steel that later had cathodic protection applied.

II. REPORT ON CAST IRON AND BARE STEEL PIPELINE REPLACEMENT

Q. DID YOU CAUSE A REPORT TO BE PREPARED REGARDING THE REPLACEMENT OF CAST IRON AND BARE STEEL PIPE?

A. Yes, I did. That report, which I am sponsoring for purposes of this proceeding, is attached to my testimony as Schedule DMN-1.

Q. PLEASE SUMMARIZE WHAT YOU ADDRESS IN YOUR REPORT.

A. The report addresses concerns and risks, specific to corrosion and corrosion-related graphitization, associated with the continued operation of cast iron and bare steel pipe.

III. CORROSION OF CAST IRON AND BARE STEEL

Q. WHAT IS CORROSION?

A. Corrosion is an irreversible deterioration process of a material resulting from a chemical or electrochemical reaction with its local environment.

Q. HOW IS CORROSION SIGNIFICANT WHEN ASSESSING THE CONDITION OF CAST IRON AND BARE STEEL PIPE?

A. When assessing the condition of cast iron and bare steel pipe, it is important to understand what portion of the pipe's wall thickness is structurally sound. The presence of corrosion reduces the effective remaining wall thickness, and therefore the load carrying capacity of the pipe. Specifically, for cast iron, the presence of corrosion may not be apparent even when excavated and visually examined due to a corrosion process called graphitic corrosion. When a pipe has undergone graphitic corrosion, there is no apparent change in the pipe wall thickness; however, the material's structural integrity has been compromised. It is for this reason that many of the failures associated with cast iron are not related to small leaks through corrosion pits, but rather full guillotine fractures around the entire pipe circumference.

Q. IN YOUR EXPERIENCE, WHEN CATHODIC PROTECTION ("CP") HAS BEEN APPLIED TO BARE STEEL DECADES AFTER THE BARE STEEL WAS FIRST INSTALLED IN THE GROUND, IS CORROSION STILL AN ISSUE FOR THESE PIPES?

A. Yes. I agree with the witnesses for the Office of the Public Counsel ("OPC") and the Company that corrosion on bare steel pipe generally begins immediately after such pipe is installed so over that length of time it is almost certain that some portions of the pipe have deteriorated due to corrosion.

Q. DOES THE APPLICATION OF CP DO ANYTHING TO REVERSE THIS CORROSION-RELATED DETERIORATION?

A. No. While the application of CP will attempt to mitigate the pace of further corrosion it does nothing to reverse corrosion that has already occurred. Moreover, it is important to note that successful corrosion mitigation is typically obtained when cathodic protection is applied on a well-coated pipe. Bare steel pipe has a very large surface area that requires protecting in comparison to well-coated pipe, which only needs protection at locations where the coating is compromised, a condition sometimes referred to as "holidays". The large surface area can create challenges in applying uniform protection across the pipe. For example, on bare pipe, large areas of anodic and cathodic regions may be remote to one another. The consequence is the formation of macro-cells that generate current flow along the pipeline, also known as long-line currents. The presence of these currents can make achieving proper cathodic protection very difficult.

In addition, there is the possibility of rocks or other debris shielding cathodic protection from reaching the pipe surface. On a well-coated pipe, shielding is only of concern if a

rock or other debris has caused a holiday in the pipe coating. Therefore, the presence of a bare pipe increases the probability of having local areas that are shielded from cathodic protection.

Lastly, pipe that has exhibited some amount of corrosion prior to the application of cathodic protection, may exhibit mounding of corrosion products that can create a higher resistance path for the current to penetrate and reach the pipe surface. Therefore, even following the application of CP on bare pipe that has been in the ground for some time, complete mitigation of future corrosion is difficult to achieve. This makes bare pipe, even with CP applied, a high risk for corrosion and eventual leaks.

Q. IN YOUR REPORT, YOU DISCUSS THE INFLUENCE SOIL HAS ON CORROSION RATES. DID YOU HAVE THE OPPORTUNITY TO REVIEW ANY OF THE SOIL DATA IN SPIRE MISSOURI'S SERVICE TERRITORY?

A. Yes, I did. As I explained in my report, published literature was reviewed to identify historical data from seventeen (17) counties comprising of Spire's East and West service territories. . Soil data consisting of 527 different data points were identified from locations within the counties in order to determine general pH ranges. The pH of soil is important because the lower the pH level and more acidic the soil, the more conducive the soil is to causing corrosion, and a specific form of corrosion in cast iron called graphitic corrosion.

Q. WHAT DID YOUR REVIEW OF THE DATA TELL YOU ABOUT THE RATE OF CORROSION AS IT APPLIES TO THE CAST IRON AND BARE STEEL PIPE IN SPIRE MISSOURI'S SERVICE TERRITORY?

A. The samples reveal that the soil fosters an environment for corrosion of both cast iron and bare steel. Specifically, as it pertains to cast iron, the majority of the soils tested in both

Spire East and Spire West were acidic or slightly acidic (<pH 7), which indicates that the soils support conditions where graphitic corrosion is likely to occur.

IV. RELEVANCE OF AGE AS IT PERTAINS TO CAST IRON AND BARE STEEL

Q. IS AGE A FACTOR IN DETERMINING THE CONDITION OF CAST IRON AND BARE STEEL PIPE?

A. Yes. The age of pipe is a highly relevant factor in assessing the condition of cast iron and bare steel.

Q. DO YOU KNOW THE AGE OF THE CAST IRON AND BARE STEEL PIPE IN SPIRE MISSOURI'S SERVICE TERRITORY?

A. Yes. Based on the information I reviewed from the Company regarding the pipes it has replaced as part of its 2018 and 2020 replacement programs, the age of the cast iron and bare steel pipes in Spire Missouri's service territory range from roughly 50 to over 110 years old.

Q. PLEASE EXPLAIN WHY AGE IS A RELEVANT FACTOR WHEN ASSESSING THE CONDITION OF CAST IRON AND BARE STEEL PIPE.

A. Corrosion is a time-dependent process, the rate of which is dependent on many variables, including the local environment. Older pipe provides more time and opportunity for corrosion to manifest and persist.

In addition to general corrosion and graphitic corrosion, which I discussed in my report, there are other types of corrosion that can manifest on older vintage pipe. For example, older vintage pipe manufactured by a welding technique referred to as low-frequency electric resistance welding ("LF-ERW"), can be susceptible to localized corrosion along

the bond line of the longitudinal seam weld. This form of corrosion is called selective seam weld corrosion ("SSWC"). Selective seam weld corrosion results from a faster corrosion rate occurring along the bond line in comparison to the base metal, which creates a notch, or v-shaped groove along the bond line. The longitudinal seam weld runs the entire length of the pipe joint. On a coated pipe, the notch terminates where the coating is not compromised and corrosion cannot occur; however, on a bare pipe the corrosion can persist along the length leaving a long notch that can significantly increase the susceptibility to pipe rupture. The LF-ERW process was heavily utilized in pipe manufacturing from 1920-1970, which suggests that much of the bare steel pipe in Spire's Missouri territory is LF-ERW pipe.

V. WORN OUT OR DETERIORATED CONDITION

Q. HOW WOULD YOU DEFINE "DETERIORATED" AS IT PERTAINS TO PIPE?

A. Focusing on the separate "in deteriorated condition" component of this ISRS requirement, deteriorated pipe would be pipe that has changed (in a negative way) from its original, as-installed, condition. To use the dictionary definition, it means that that the pipe has become inferior in quality or value compared to its original condition.

Q. HAVE YOU REVIEWED THE TESTIMONY OF COMPANY WITNSS JOHN SPANOS AS IT RELATES TO THE AGE OR VINTAGES OF THE FACILITIES THAT WERE RETIRED AS PART OF THE COMPANY'S 2018 ISRS FILING?

A. Yes.

Q. BASED ON YOUR KNOWLEDGE OF HOW CAST IRON AND BARE STEEL CORRODE OVER TIME DO YOU BELIEVE THAT FACILITIES OF THIS AGE WOULD BE IN A DETERIORATED CONDITION?

A. Based on my observations, soil data reviewed, and the samples I have had the opportunity to inspect, I would say that there is a high probability that virtually all of the cast iron and bare steel pipe will have deteriorated to some degree or another. The extent of that deterioration, of course, will vary from location to location, but it would be very rare to find cast iron or bare steel pipe that has not deteriorated over a period of 50-110 years.

Q DOES THIS MEAN THAT SUCH PIPE IS "WORN OUT" TO THE POINT WHERE IT CANNOT BE SAFELY USED?

A. Not necessarily. Worn out is not a term that we would typically use to describe the condition of a pipe. We would typically use the term "fit-for-service," suggesting whether the condition of the pipe meets the performance criteria for continued operation. That is, has it deteriorated to the point where it can no longer safely transport gas. Fortunately, my understanding of the ISRS Statute is that it does not require that utilities wait until pipe has deteriorated to a degree where it cannot be operated safely and represents an immediate threat to public safety. That is why pipe qualifies for ISRS inclusion if it is either "worn out" OR "in deteriorated condition."

Q. DOES THAT MEAN THAT IT IS SAFE TO ALLOW SUCH PIPES TO CONTINUE OPERATING INDEFINITELY?

A. No. In my opinion a utility would not be fulfilling its obligation to provide safe service if it did not have an ongoing program to replace such deteriorated facilities over a reasonable period of time.

Q. AS A MATTER OF SAFETY, SHOULD BARE STEEL PIPE THAT HAS BEEN BARE FOR DECADES BEFORE CATHODIC PROTECTION WAS APPLIED, BE REPLACED?

A. Yes.

Q. PLEASE EXPLAIN.

A. Given the complexity in achieving successful corrosion mitigation on bare pipe, coupled with the likelihood of preexisting corrosion on the pipe prior to the application of cathodic protection, it is likely that there are areas that cannot be adequately protected and active corrosion is occurring. These high-risk assets should be part of a replacement program and removed from service at the earliest possible time.

Q. DO YOU CONSIDER BARE STEEL PIPE THAT HAS BEEN BARE FOR DECADES, BUT CATHODICALLY PROTECTED, TO BE IN A WORN OUT OR DETERIORATED CONDITION?

A. Since, as witnesses for the Company and Staff have acknowledged, bare steel begins to corrode as soon as it is installed, and it appears from the information provided by Mr. Spanos that such bare steel was in the ground for at least two decades or more before CP was applied, I can say with a high degree of certainty that the facilities replaced by the Company were, to one degree or another, in a deteriorated condition.

VI. ANALYSIS OF SPIRE MISSOURI'S PIPE SAMPLES

Q. IS THIS CONCLUSION CONSISTENT WITH YOUR REVIEW OF THE SAMPLES OF CAST IRON AND STEEL PIPE THAT HAVE BEEN REPLACED AS PART OF SPIRE MISSOURI'S PIPELINE REPLACEMENT PROGRAM?

A. The Company provided me with seven pipe samples; two (2) cast iron and five (5) bare steel that were replaced during recent ISRS projects, including four (4) samples from projects included in this ISRS case, specifically work order numbers 15307244, 17611805, 17612824, and 14450752.

Q. PLEASE DESCRIBE HOW THE PIPE WAS TESTED AND ANALYZED.

A. I performed a visual inspection of the seven provided pipe sections. Small ring sections were removed from three bare steel pipe sections for metallographic analysis. Small cross-sections were then removed from each of the three ring sections, mounted in an epoxy resin, and polished to a mirror finish for examination. The metallographic mounts were examined under a light microscope at magnifications up to 500x to evaluate the corrosion morphology, depth of corrosion, and microstructure of the steel.

The remaining pipe sections were cleaned with a brush and/or grit blasted. The cut ends of the pipe sections were ground to facilitate inspection for evidence of graphitic corrosion.

Q. PLEASE DESCRIBE THE RESULTS OF YOUR ANALYSIS.

A. All samples exhibited external corrosion along their respective lengths. Three (3) of the seven (7) pipe sections exhibited through-wall corrosion. For the three pipe sections where metallography was performed, the deepest area of corrosion resulted in a remaining wall thickness of 0.073 inches (48.7% of the maximum measured wall thickness [MMWT]) for Sample 1, 0.000 inches (0% of MMWT) for Sample 2, and 0.082 inches (54.6% of MMWT) for sample 3. One of the pipe sections (Sample 2) exhibited two large through-wall holes, with the largest measuring approximately 2 inches axially by 0.8 inches circumferentially, with additional areas of significant corrosion, as well as evidence of through-wall SSWC at a location that visually did not appear to be through wall.

The two cast iron pipe sections each exhibited wall loss resulting from corrosion and graphitic corrosion.

Q. ARE THE RESULTS OF YOUR ANALYSIS REGARDING THE DETERIORATION OF BARE STEEL CONSISTENT WITH YOUR EXPECTATIONS, BASED ON YOUR TESTIMONY IN THE SECTONS ABOVE?

A. Yes.

VII. CONCLUSION

Q. BASED ON YOUR EXPERIENCE AS A METALLURGIST, AND THE INFORMATION YOU HAVE OBTAINED REGARDING SPIRE MISSOURI'S CAST IRON AND BARE STEEL PIPE REPLACEMENTS, WHAT IS YOUR EXPERT OPINION REGARDING THE CONDITION OF THESE PIPES?

A. The cast iron and bare steel pipes in Spire Missouri's territory are undoubtedly in a deteriorated condition to one degree or another given the length of time that the forces of corrosion have had to work on them. The challenge in identifying the presence of graphitic corrosion in cast iron and cathodically protecting bare steel pipe increases the risk of operating assets fabricated from these materials. Based on my observations of some of the pipe removed from their system, additional challenges due to the welding process also increase the risk and the potential for a rupture.

Q. WHAT IS YOUR EXPERT OPINION REGARDING SPIRE MISSOURI'S BARE STEEL FACILITIES WHERE CATHODIC PROTECTION WAS LATER APPLIED?

A. Given the complexity in achieving successful corrosion mitigation on bare pipe, coupled with the likelihood of preexisting corrosion on the pipe prior to the application of cathodic

protection, it is likely that there are areas that cannot be adequately protected and active corrosion is occurring and has occurred. These high-risk assets should be part of a replacement program and removed from service at the earliest possible time.

Q. **DOES THIS COMPLETE YOUR DIRECT TESTIMONY?**

A. Yes.

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

In the Matter of the Application of Spire Missouri Inc. to Establish an Infrastructure System Replacement Surcharge in its Spire Missouri East Service Territory	))))	**File No. GO-2018-0309**
In the Matter of the Application of Spire Missouri Inc. to Establish an Infrastructure System Replacement Surcharge in its Spire Missouri West Service Territory	))))	**File No. GO-2018-0310**

AFFIDAVIT

STATE OF OHIO)
) SS.
COUNTY OF FRANKLIN)

David M. Norfleet, of lawful age, being first duly sworn, deposes and states:

1. My name is David M. Norfleet. I am Head of Section for the Incident Investigation Section of DNV GL USA, Inc. My business address is 5777 Frantz Road, Dublin, Ohio.

2. Attached hereto and made a part hereof for all purposes is my direct testimony on behalf of Spire Missouri Inc.

3. Under penalty of perjury I hereby swear and affirm that my answers contained in the attached testimony to the questions therein propounded are true and correct to the best of my knowledge and belief.

David M. Norfleet

This 13th day of May 2020.