Exhibit No: ________________

Date: August 11, 2014

ALJ: John Wong

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

Application of Pacific Gas and Electric Company Proposing Cost of Service and Rates for Gas Transmission and Storage Services for the Period 2015 – 2017 (U39G).	Application 13-12-012 (Filed December 19, 2013)
And Related Matter.	Investigation 14-06-016

REDACTED

PREPARED DIRECT TESTIMONY ON

RISK MANAGMENT OF

JONATHAN A. LESSER, PH.D.
AND
CHARLES D. FEINSTEIN, PH.D

ON BEHALF OF

THE INDICATED SHIPPERS

AUGUST 11, 2014

Table of Contents

I. INTRODUCTION, QUALIFICATIONS AND PURPOSE OF TESTIMONY

Q. PLEASE STATE YOUR NAME, TITLE, AND BUSINESS ADDRESS.

A. My name is Jonathan A. Lesser. I am the President of Continental Economics, Inc., an economic consulting firm that provides litigation, valuation, and strategic services to law firms, industry, and government agencies. My business address is 6 Real Place, Sandia Park, New Mexico, 87047.

My name is Charles D. Feinstein. I am Associate Professor of Operations Management and Information Systems at the Leavey School of Business, Santa Clara University, and the CEO of VMN Group, LLC, a quantitative consulting company specializing in development of optimization solutions and software.

Q. ON WHOSE BEHALF ARE YOU OFFERING YOUR TESTIMONY?

A. The Indicated Shippers, which for the purposes of this proceeding include Aera Energy LLC, Chevron U.S.A. Inc., Occidental Energy Marketing, Inc., Phillips 66 Company, Shell Oil Products US, and Tesoro Refining & Marketing Company LLC. Each of these companies transports natural gas on PG&E's transmission system, as end-use customers and/or natural gas marketers.

Q. DR. LESSER, PLEASE DESCRIBE YOUR PROFESSIONAL QUALIFICATIONS, EMPLOYMENT EXPERIENCE, AND EDUCATIONAL BACKGROUND.

A. I am an economist with substantial experience in market analysis in the energy industry. I have 30 years of experience in the energy industry working with utilities, consumer groups, competitive power producers and marketers, and government entities. I have provided expert testimony before numerous state utility commissions, as well as before the Federal Energy Regulatory Commission (FERC), state legislative committees, Congress, and international venues. I have attached a copy of my curriculum vitae as Exhibit JAL/CDF-1.

Q. DR. FEINSTEIN, PLEASE DESCRIBE YOUR PROFESSIONAL QUALIFICATIONS, EMPLOYMENT EXPERIENCE, AND EDUCATIONAL BACKGROUND.

A. I have more than 30 years of experience in research, teaching, development and application of mathematical methods and mathematical modeling. My areas of expertise include optimization, decision analysis, system dynamics, and systems analysis. I have taught courses on operations research, operations management, investment science, systems analysis and design, linear and nonlinear programming, dynamic optimization and optimal control, and probability and statistics, at both the undergraduate and graduate levels. I have attached a copy of my curriculum vitae as Exhibit JAL/CDF-2.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. Our testimony addresses Pacific Gas and Electric Company's (PG&E or the Company) general approach to managing risk and reliability, as set forth in the testimony of its witnesses in this proceeding. Our testimony also provides support for the conclusions Dr. Lesser reaches in his separate testimony regarding the prudence of PG&E's proposed expenditures for the 2015 – 2017 period, which are based, in part, on the Company's Asset Management Plans (AMPs).[1]

[1] The specific AMPs were provided in response to TURN-1-001, which is attached to PG&E's Supplemental Testimony as Attachment B. Some of these documents are listed as confidential by PG&E, while others are not.

II. EXECUTIVE SUMMARY

Q. PLEASE SUMMARIZE YOUR CONCLUSIONS.

A. We commend PG&E on the administrative changes it has made to improve accountability and promote a "safety culture" throughout the Company, including its recent PAS 55 and ISO 55001 certification. These administrative changes, however, do not guarantee a safer system and cannot justify the extraordinary rate shock that would result from PG&E's proposed 107% increase in revenue requirement by 2017 and additional capital spending of $2.6 billion. To justify this level of spending, and the accompanying impact on its non-core and core customers, it is imperative that PG&E demonstrate that the Company has selected the most cost-effective measures that provide ratepayers with the greatest possible safety enhancements at the lowest possible cost, in other words the best value for ratepayer money.

The risk management approach that PG&E's Application presents is not capable of achieving this objective because it is fundamentally flawed in the following ways:

- Lacks transparency. The principles that support the specific computations made using the methodology are not stated clearly. The assumptions required to implement the methodology are not stated clearly. No independent third-party could apply what PG&E claims to have done and reproduce the same answers;
- Does not consider any specific budget constraints in the process of selecting risk mitigation strategies and instead relies on an undefined concept of ratepayer "affordability." Therefore, the methodology cannot provide an optimal solution to the constrained budget allocation problem;
- Does not identify any minimum overall risk tolerance objectives, making it impossible to determine whether the proposed measures achieve the desired risk reductions;

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- Does not measure the corresponding value of the risk reductions that will be achieved through risk mitigation measures, making it impossible to determine whether the risk-reduction measures selected will provide ratepayers with the best value for their money;

- Is internally inconsistent between the different stages of identifying and determining which risks PG&E will address, including an inherent circularity in the initial scoring and ranking process of the Company's relative risk methodology;

- Relies on statistically flawed calculations of the likelihood of failure (LoF), a key variable in the Company's determination of risk, and incorrectly treats likelihood and probability as the same thing;

- Relies on inaccurate and statistically flawed calculations of the consequences of failure (CoF), the other key variable in the Company's determination of risk; and

- Does not provide any forecasts or estimates of future performance of the assets assuming that the investments PG&E proposes are actually made. In particular, the amount of risk reduction and the consequences of such risk reduction over time cannot be determined using PG&E's methodology. Therefore, what will be achieved by granting PG&E's requests is unstated, unspecified, and never estimated.

We discuss each of these failures and demonstrate their impact on PG&E's Transmission Pipeline AMP.

PG&E'S failure to successfully implement a risk management approach forecloses a finding by the Commission that the Company's proposals will achieve its safety and reliability goals at affordable rates, and provide the greatest value for ratepayers. Consequently, as discussed in the separate testimony of Dr. Lesser, the Commission has no basis for full pre-authorization of PG&E's requested revenues and capital spending.

Q. PLEASE SUMMARIZE YOUR RECOMMENDATIONS.

A. The Commission should require PG&E to justify its approach and method of choosing specific risk management programs before approving the Company's proposed spending on those programs over the 2015 – 2017 GT&S timeframe. To justify its approach requires PG&E to obtain information on the condition of its assets to improve its ability to assess current and future risks to its system and to correct the methodological flaws we identify.

While PG&E collects and compiles additional information about the condition of the Company's pipeline assets, the Commission should require PG&E to implement a transparent analytical methodology that addresses the fundamental errors of the Company's current "relative risk" methodology, either by correcting the Company's current relative risk methodology or using a probabilistic methodology. Then, the Commission should require PG&E to develop a new risk management plan: (i) which the Company can demonstrate achieves known risk reduction objectives and (ii) provides the best value to ratepayers. This risk management plan should specify not only the nature and timing of asset management investments but also a forecast of the observable consequences of those investments. Only then should the Commission preauthorize PG&E's proposed expenditures. With this solid foundation, both the Commission and PG&E ratepayers can be assured that the Company's programs will create a safer system at affordable rates.

If the Commission declines to take these steps in this proceeding, it should direct PG&E to prospectively implement these changes. In the interim, however, the Commission should require PG&E to:

- Identify the specific constraints, including budget and resource availability, the Company believes will affect the types of programs that can be undertaken for the three-year GT&S period;

- Identify the risk tolerance goal and the time needed to achieve it that PG&E believes is appropriate and feasible, and the basis for the Company's conclusions;

- Identify how each of the Company's proposed risk management programs set forth in testimony will reduce risk and whether the programs will achieve PG&E's risk tolerance goal;

- In the short-run, implement a multi-attribute approach to optimize risk management activities that correctly weighs different attributes that encompass the consequences of asset failure under the relative risk methodology, and move towards development of a full probabilistic methodology within the next two years;

- Adopt a suite of ratemaking measures to limit the rate shock and imprudent spending that would result if PG&E's Application were approved (These ratemaking measures are the subject of separate testimony of Dr. Lesser); and

- Require PG&E to base its asset management decisions on the actual conditions of the assets. If information on asset condition is not presently available in PG&E data, the Company should be required to observe the condition of the assets and integrate those observations correctly into the asset management decision process.

For the short term, it is better to improve the flawed methodology than to proceed on an incorrect basis.

Q. DOES YOUR TESTIMONY SUGGEST THAT PG&E SHOULD NOT MAKE INVESTMENTS IN ITS GAS TRANSMISSION AND DISTRIBUTION SYSTEM TO IMPROVE SAFETY?

A. No. PG&E should be <u>commended</u> for its demonstrated commitment to improving gas operations safety. We agree with PG&E witness Stavropoulos that the Company has made a tremendous effort to establish a new corporate culture that emphasizes safety and ensures a clear organizational structure providing direct responsibility for risk management activities.[2] The breadth and depth of PG&E's accomplishments so far in this regard are impressive.

Rather, the focus of our testimony is on how PG&E determines which specific risk reduction investments to undertake and in what order. These choices are crucial because risk can never be eliminated completely. Moreover, we all recognize that resources – money, manpower, equipment – are limited. PG&E witness Stavropoulos states that, "[r]isk reduction has to be balanced with other considerations, including resource availability and affordability."[3] We agree. Because it is impossible to undertake every possible action to reduce risk simultaneously, it is important to ensure that PG&E's spending on risk management activities is as economically efficient as possible so as to secure the best value for ratepayer money.

Q. CAN YOU EXPLAIN THE DIFFERENCE BETWEEN ASSET MANAGEMENT AND RISK MANAGEMENT?

A. Yes. Asset management can be thought of as a comprehensive process that is designed to find a strategy that maximizes an asset's economic value to an organization over the asset's entire life. Risk management can be thought of as a component of asset management because risk management has a more restricted objective. The focus of risk management to find a strategy that addresses and controls the risks associated with an asset's failure. Risk assessment can be thought of as the process of estimating the likelihood and consequences of an asset's failure. Risk assessment does not include identifying a strategy to manage risks.

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2 *See generally* PG&E Direct Testimony, Vol. 1, Ch. 1.

3 *Id*. at 1-9, lines 26-27.

Q. HOW IS YOUR TESTIMONY ORGANIZED?

A. Our testimony is organized in six sections:

- Section I provides an introduction and Section II an executive summary.
- Section III discusses the role of PAS 55, ISO 55000, and ASME B31.8S as high-level guidance in PG&E's journey to a safer system. It concludes that these general standards alone cannot ensure a reasonable asset management strategy. These standards are noteworthy, however, in their focus on two critical elements of a strategy – asset condition information and optimization – lacking in PG&E's asset management plan.
- Section IV sets out the general requirements underlying development of a risk management strategy, including the importance of asset condition information, what is meant by an "optimal" risk management plan that provides the best value for ratepayers, and the correct methods for undertaking the type of "multi-attribute" or "multi-objective" analysis that PG&E has presented in this proceeding.
- Section V presents a detailed analysis of the fundamental mathematical and statistical flaws in PG&E's application of what is called the "relative risk methodology," including the failure to identify the degree to which the Company's proposed programs will actually reduce risk, the failure to identify and quantify specific constraints, including budget and labor and equipment availability constraints, and the Company's opaque and circular process for selecting risk management projects.
- Section VI presents our conclusions, including how PG&E can implement a robust probabilistic methodology that will provide ratepayers with the best value for the money they will be asked to spend to reduce risk on PG&E's pipeline transmission system.

III. THE ROLE OF PAS 55, ISO 55000 and ASME B31.8S

Q. WHAT ARE YOUR CONCLUSIONS REGARDING PG&E'S USE OF PAS 55, ISO 55000 AND ASME B31.8S?

A. PAS 55 and ISO 55000 provide general organizational guidelines on asset management and the key principles of a well-designed Asset Management Plan.[4] For example, PAS 55 states that, "[t]he organization shall establish and maintain an organizational structure of roles, responsibilities and authorities, consistent with the achievement of its asset management policy, strategy, objectives and plans."[5] ASME B31.8S deals specifically with pipeline integrity.[6] Like PAS 55 and ISO 55000, ASME B31.8S focuses on an overall approach to managing pipeline integrity, including guidelines on gathering sufficient data and classifying different types of risk.

However, simply following the PAS 55, ISO 55000, and ASME B31.8S guidelines does not mean that an organization has an optimized risk management plan. ASME B31.8S, for example, discusses the importance of data collection, but it does not say how to collect data nor how information gleaned from such data should be used. ASME B31.8S discusses the need to address different types of constraints that can affect pipeline management, such as the availability of skilled employees but, again, does not set out specific methods to do so. Thus, while PG&E has made great strides in adopting the organizational and managerial principles embedded in PAS 55, ISO 55000, and

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4 *See, e.g.*, PAS 55:2008-1, viii. "An asset management system is primarily designed to support the delivery of an organizational strategic plan in order to meet the expectations of a variety of stakeholders (see Figure 4). The organizational strategic plan is the starting point for development of the asset management policy, strategy, objectives and plans."

5 *Id*. at 10.

6 "Managing System Integrity of Gas Pipelines," The American Society of Mechanical Engineers, ASME B31.8S-2012 (2012).

ASME B31.8S, the Company's overall analytical methodology and approach to select various risk management projects violates fundamental principles of optimization and is not capable of identifying a set of strategies that provide the best value for ratepayers.

Q. WHAT ARE YOUR RECOMMENDATIONS?

A. PG&E should continue to implement PAS 55 and ISO 55000, and should correctly use ASME B31.8S principles as part of a larger risk management approach.

A. PAS 55 and ISO 55000[7]

Q. WHAT ARE PAS 55 AND ISO 55000?

A. Both PAS 55, and its successor ISO 55000, are management guides that were developed and published by the Institute of Asset Management (IAM), in collaboration with the British Standards Institution (BSI). The purpose of PAS 55 and ISO 55000 is to provide companies with a set of principles on how to manage physical assets. As stated in the introduction to PAS 55:

> This PAS is specifically intended to cover the life cycle management of the assets and, in particular, the assets that are core to an organization's purpose, such as utility networks, power stations, railway or road systems, oil and gas installations, manufacturing and process plants, buildings and airports. An asset management system is therefore vital for organizations that are dependent on the function and performance of their physical assets in the delivery of services or products, and where the success of an organization is significantly influenced by the stewardship of its assets.[8]

PAS 55 and ISO 55000 can be thought of as guidebooks that identify generally accepted practices that an organization can adopt in order to best manage their assets. Both discuss the activities companies <u>should</u> do to manage assets properly, such as by designating

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[7] The ISO 55000 series consists of British Standards (BS) ISO 55000:2014, BS ISO 55001:2014 and BS ISO 55002:2014. For ease of exposition, we refer to this series as ISO 55000.

[8] PAS 55-1:2008, p. vii.

specific individuals who will be directly responsible for specific aspects of asset management activities. However, in terms of asset management, neither PAS 55 nor ISO 55000 specify any analytical methodologies that companies should use to optimize the value of their assets. Thus, while identifying the activities companies must perform to manage their assets, neither PAS 55 nor ISO 55000 provides any guidance as to <u>how</u> to implement those activities.[9]

Q. DO PAS 55 AND ISO 55000 PROVIDE GUIDANCE ON ANY SPECIFIC RISK MANAGEMENT METHODOLOGIES?

A. No. Neither are "how-to" guides for any analytical methodologies. Instead, they set out managerial prescriptions only, that is, what management must do to be consistent with PAS 55 guidelines. As stated in PAS 55-1:

> It is important to note that the requirements of this PAS are prescriptive only to the extent that they define what has to be done, <u>not how to do it. The method of achieving each requirement is for the organization to determine, in accordance with its assessed needs.</u> Guidelines for the application of the requirements within PAS 55-1 are provided in PAS 55-2. However, it is also important to note that the purpose of PAS 55-2 is to provide guidance only and does not add any further requirements to those contained in PAS 55-1.[10]

In this respect, PAS 55 is similar to the language in SB 705, which requires utilities to develop safety plans that are "consistent with best practices in the gas industry." SB 705 does not specify what those "best practices" are, nor does it state how utilities are to meet the various objectives, e.g., how to "[i]dentify and minimize hazards and systemic risks in order to minimize accidents, fires, and dangerous conditions, and protect the public and the gas corporation workforce.

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[9] *Id*. at xi.

[10] *Id*., (emphasis added).

Q. DOES PG&E RECOGNIZE THE LIMITATIONS OF PAS 55?

A. Yes. In response to Data Request IP-2-008, PG&E states that PAS 55:

> [i]s not a plan or methodology to use to safely manage the integrity of a pipeline system. Rather, it is a rigorous globally recognized certification that … requires an asset owner to <u>holistically and systematically manage</u> all aspects of the life cycle of assets in a risk-based manner.[11]

Although PG&E identifies this limitation, the Company never explains how it will "holistically and systematically manage all aspects of the life cycle of assets in a risk-based manner" in a plan that provides the greatest value for ratepayers.[12] There is no way to determine the value of PG&E's approach to selecting specific risk-management programs.

Q. HOW DOES ISO 55000 DIFFER FROM PAS 55?

A. ISO 55000 is a follow-up to PAS 55 that uses standardized language common to other ISO guidelines. Like PAS 55 before it, ISO 55000 is simply a guidebook, and does not provide any recommendations on the use of specific analytical methodologies to optimize asset value. In some cases, the guidelines set out in PAS 55 are retained, but described in slightly different language. For example,

- The PAS 55 requirements for optimization (between costs, risks and performance, and between short-term and long-term impacts) in planning and decisionmaking are retained but are described differently. For example, ISO 55000 discusses the need for companies to adopt methods and criteria for making decision and prioritizing resources that provide the best value for the money, and to apply those methods and criteria to address conflicting objectives.[13] While ISO 55000 does not label this process optimization, the concepts are the same.

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[11] GTS-RateCase2015_DR_IP_02-Q008, attached as Exhibit JAL/CDF-3(emphasis added).

[12] *Id.*

[13] ISO 55000:2014, p. 2.

- In PAS 55, the term "*asset management strategy*" includes both the actual strategies to manage assets themselves and strategies to improve the asset management process. In ISO 55000, these are split into discrete requirements.[14]

- ISO 55000 no longer refers to asset management strategies, but instead uses a new term: *strategic asset management plan*.[15]

Q. HOW DOES PAS 55 DESCRIBE ASSET MANAGEMENT STRATEGIES?

A. PAS 55 states that an "asset management strategy is a long term optimized and sustainable direction for the management of the assets, to assist in delivery of the organizational strategic plan and apply the asset management policy."[16] In other words, an asset management strategy is the <u>optimal</u> asset management plan.

Importantly, PAS 55 does not identify any specific methodologies for determining the optimal maintenance strategy. Thus, the scope of PAS 55 is limited and managerial:

> It is emphasized that a review against PAS 55-1 is not a substitute for the implementation of the <u>structured, systematic approach</u> to asset management and adoption of continual improvement processes as described in 4.6 and 4.7 (of the PAS 55 specifications).[17]

Q. DOES PAS 55 DISCUSS THE NEED FOR DEVELOPING "OPTIMAL" ASSET MANAGEMENT PLANS?

A. Yes. PAS 55-1:2008 refers to "optimized life cycle asset management" and its principal benefits including, among others, "the ability to demonstrate best value-for-money within a constrained funding regime."[18] PAS 55 also discusses management of physical assets, stating, "Delivering the best value for money in the management of

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[14] *Id*. at 2-4.

[15] *Id*. at 6.

[16] PAS 55-1:2008, p. x, Figure 5.

[17] *Id*. at 3 (emphasis added).

[18] *Id*. at v.

physical assets is complex and involves careful consideration of the trade-offs between performance, cost and risk over all stages of the assets' life cycles."[19] Thus, PAS 55 calls for organizations to develop a strategic plan that includes optimal asset management. As PAS 55 states:

> The organizational strategic plan is the starting point for development of the asset management policy, strategy, objectives and plans. These, in turn, direct the <u>optimal</u> combination of life cycle activities to be applied across the diverse portfolio of asset systems and assets (in accordance with their criticalities, <u>condition</u>, performance and chosen risk profile of the organization).[20]

Q. DO PAS 55 AND ISO 55000 DEFINE WHAT IS MEANT BY "OPTIMIZE?"

A. Yes, in broad terms. PAS 55 defines optimize as "achieve by a quantitative or qualitative method, as appropriate, the best value compromise between conflicting factors such as performance, costs and retained risk within any non-negotiable constraints."[21] PAS 55 also discusses the role of optimization in asset management plans, including importance of maintaining assets and documenting "the specific tasks and activities (actions) required to optimize costs, risks and performance of the assets and/or asset system(s)."[22] Again, however, while stating that companies should optimize the costs associated with managing their assets, neither PAS 55 nor ISO 55000 define specific methodologies with which that should be done.

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[19] *Id*. at vii.

[20] *Id*. at viii (emphasis added).

[21] *Id*. at 4.

[22] *Id*. at 8.

Q. HAS PG&E DETERMINED OPTIMAL ASSET MANAGEMENT STRATEGIES?

A. No. As discussed in Section V, PG&E's asset management strategies are based on flawed implementation of a relative risk methodology and an opaque decisionmaking process. <u>PG&E's described asset management strategies are not optimal and therefore cannot provide ratepayers with the best value for the money PG&E is requesting to address pipeline system risks</u>.

Q. DO PAS 55 AND ISO 55000 RECOGNIZE THE IMPORTANCE OF ASSET CONDITION IN DEVELOPING ASSET MANAGEMENT STRATEGIES?

A. Yes. PAS 55 states that "adequate information and knowledge of asset condition" is "essential for the successful implementation of [PAS 55] principles."[23]

Q. DOES PG&E HAVE SUFFICIENT KNOWLEDGE OF THE CONDITION OF ITS ASSETS TO ENSURE AN OPTIMIZED ASSET MANAGEMENT STRATEGY?

A. No. As we discuss in Section V, PG&E's strategy lacks crucial information about the condition of its assets. The methodology PG&E has implemented also fails to address the role of future asset condition, which is another fundamental aspect of developing optimal asset management strategies.

B. ASME B31.8S

Q. WHAT IS ASME B31.8S?

A. American Society of Mechanical Engineers (ASME) B31.8S is a management document regarding gas pipeline integrity that PG&E has used for components of its risk management process, including using ASME B31.8S classification of different types of risk.[24] ASME B31.8S also provides the basis for PG&E's risk assessment approach.

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[23] *Id.* at v.

[24] ASME B31.8S-2012, p. 5.

Q. HOW DOES ASME B31.8S DIFFER FROM PAS 55 AND ISO 55000?

A. ASME B31.8S focuses solely on managing pipeline integrity, which is defined as the "capability of the pipeline to withstand all anticipated loads …."[25] In that regard, ASME B31.8S, unlike PAS 55 and ISO 55000, contains prescriptive requirements, such as the minimum frequency of different forms of pipeline inspection,[26] the types of data that must be gathered to perform risk assessments,[27] and the types of risk assessment approaches.[28]

The current version of ASME B31.8S, which was issued on January 11, 2013, also provides general guidelines on how to prioritize (not optimize) risks and states that the highest risk segments "shall be assigned a higher priority when deciding where to implement integrity assessment and/or mitigation actions."[29] In other words, "fix the riskiest stuff first."

Q. DOES PG&E USE THE CURRENT VERSION OF ASME B31.8S?

A. No. In response to IS-06-03,[30] PG&E implies that it uses the 2004 version of ASME B31.8S (2004 ASME), which was issued on January 14, 2005.[31]

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25 *Id*. at 38.

26 *Id*. at 14.

27 *Id*. at 10.

28 *Id*. at 13.

29 *Id*. at 16.

30 GTS-RateCase2015_DR_IS_06-Q003. Attached as Exhibit JAL/CDF-4.

31 A complete copy of this 2004/2005 version of the ASME B31.8S-2004 standards can be downloaded at: https://law.resource.org/pub/us/cfr/regulations.gov.docket.03/asme.b31.8s.commentary.pdf.

Q. DOES THE 2004 ASME DISCUSS THE IMPORTANCE OF RECORDKEEPING?

A. Yes. The 2004 ASME states, "Complete records of material, design, and construction for the pipeline are essential for the initiation of a good integrity management program."[32] Identical language appears in the most current version of ASME B31.8S.[33]

Q. ARE THERE ANY SIMILARITIES BETWEEN ASME B31.8S, PAS 555 AND ISO 55000?

A. Yes. Like PAS 55 and ISO 550000, Table 5.6.1-1 of ASME B31.8S directs the minimum requirements for collection of asset condition data. Similar asset condition data collection minimum requirements are shown in Table 3 of the 2004 ASME.

Q. IS THERE ANYTHING WRONG WITH ASME'S DIRECTION TO FIX "THE RISKIEST STUFF" FIRST?

A. In the short term, there is nothing wrong with this approach. However, that reflects short-term tactical management and, in our view, is distinct from the life-cycle asset management strategies and strategic asset management plans discussed in PAS 55 and ISO 55000. PG&E has taken this tactical approach, rather than a long-term strategic approach.

Q. DOES ASME B31.8S DISCUSS HOW THE FUTURE CONDITION OF PIPELINE ASSETS SHOULD BE ADDRESSED WHEN DEVELOPING A PIPELINE INTEGRITY MANAGEMENT PROGRAM?

A. Not specifically. ASME B31.8S recognizes that some threats, such as corrosion, are time-dependent, that is, threats that are related to an asset's age.[34] However, in

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[32] ASME B31.8S-2004, pp. 1-2.

[33] ASME B31.8S-2012, p. 1.

[34] *Id*. at 5.

prioritizing risks, ASME B31.8S focuses solely on *current* asset conditions as the basis for prioritizing risk management activities.[35]

Q. WHY IS FOCUSING ONLY ON <u>CURRENT</u> ASSET CONDITION NOT SUFFICIENT FOR OPTIMIZING ASSET VALUE?

A. A key component of a pipeline integrity assessment process includes obtaining data on the current conditions of pipeline assets. But it is also crucial to determine how those conditions are likely to <u>change</u> over time.

Q. HOW IS THIS RELEVANT TO PG&E'S APPROACH?

A. PG&E defines the risk of an event as the product of the event's likelihood and its consequences. Whereas the likelihood of an event affecting an asset (e.g., a pipeline rupture) can depend on an asset's condition, the consequences of the event do not. Therefore, the consequences of an event, by themselves, do not determine optimal strategies without also considering how changing asset condition over time also affects the risk of asset failure. As an asset's condition changes over time, so may the likelihood of an event (e.g., a pipeline rupture). Thus, evaluating the future condition of an asset through testing is an integral component of an optimal risk management strategy.

Q. DOES ASME B31.8S CONSIDER THE IMPACTS OF BUDGET CONSTRAINTS ON INTEGRITY MANAGEMENT PROGRAMS?

A. ASME B31.8S considers budget limitations only peripherally. That's not surprising because budget limitations, as well as other constraints (e.g., available equipment and manpower) are likely to be both pipeline-specific and change over time. Under these circumstances, it would be impossible for a guideline like ASME B31.8S to

[35] *Id*. at 13.

develop rules that could address all of the possible variations in budget, labor, and equipment constraints. Yet, all of these constraints are key issues in this proceeding.

Q. DOES ASME B31.8S DESCRIBE DIFFERENT RISK ASSESSMENT APPROACHES?

A. Yes. ASME B31.8S describes four approaches companies can use to measure risk: (1) subject matter experts (SMEs), who determine the most important risks to address based on their intuitive knowledge; (2) relative risk assessment models, which rank different risks based on their predicted impacts; (3) scenario-based models that describe a series of events that lead to specific levels of risk (e.g., an earthquake ruptures certain transmission pipe in a high consequence area); and (4) probabilistic models.[36] The risk management process will then use the results of the risk assessment process to determine a strategy to address the measured risks.

Q. ARE THERE ANY COMMON ASPECTS OF THESE FOUR RISK ASSESSMENTAPPROACHES?

A. Yes. All four approaches — SMEs, relative risk assessment, scenario-based models, and probabilistic models — require knowledge about the condition of the assets to be managed. All four evaluate the likelihood of asset failure and the potential consequences of failures. All of them permit (but do not mandate) risk ranking.

[36] These four methods are all described on p. 12 of ASME B31.8S-2004.

Q. HOW DO ASME'S FOUR APPROACHES TO RISK ASSESMENT DIFFER?

A. Besides the obvious differences in implementation, the four approaches differ in the amount of data required, their analytical complexity and, depending on how implemented, their accuracy.

To understand the differences, let's consider them in the context of the risk that a pipeline compressor engine will fail. First, we could employ a SME, such as one of the mechanics who is responsible for maintaining the compressor. Based on his knowledge of the compressor engine, he could examine it, check for leaks, and then tell us the likelihood of failure of specific engine components.

The relative risk assessment would include both the mechanic's inspection to determine the condition of the compressor engine's components, plus any additional information about especially problematic issues, such as knowledge about specific engine parts that could fail in certain circumstances and lead to interruptions in service. Combining the mechanic's inspection and additional knowledge of components, an assessment of the overall risk of compressor engine failure could be made.

Under a scenario-based approach, our SME-mechanic might tell us that, *if* the compressor is operated at too high a pressure, and *if* the engine is leaking oil, and *if* natural gas flows through the system are at a certain level, the compressor engine would be highly likely to fail. The main problem with a scenario-based approach is that the likelihood of the scenario is rarely specified directly.[37] Moreover, the likelihood actually decreases as more components are added to the scenario.

[37] ASME B31.8S-2012 states that scenario-based models sometimes incorporate decision trees (p. 13). True decision trees assign probabilities to different conditions (e.g., rain or no rain) that may affect what we choose to do. Thus, we can estimate the probability of a scenario

A complete probabilistic model for the compressor engine would incorporate various potential failures and their likelihoods. For example, we could estimate the probability of the compressor engine failure based on both its current condition and how that condition changes over time. Thus, if the engine has been leaking oil and those leaks have not been repaired, we can develop a model to predict the likelihood of an engine failure over time. Such a model is called a *hazard function*. Moreover, the hazard function itself depends on the condition of the asset: a well-maintained compressor engine will have a lower likelihood of failure over time than a poorly maintained one. Based on such *condition-dependent hazard functions* and the predicted consequences of failure, we could then determine an optimal maintenance strategy.

Q. WHICH OF THESE APPROACHES WERE USED BY PG&E TO PREPARE THE COMPANY'S VARIOUS ASSET MANAGEMENT PLANS?

A. PG&E seems to have used an amalgamation of approaches in a four-step process. As discussed in the Supplemental Testimony of PG&E witnesses White and Krannich, the steps were:

(1) Threat and risk identification, which relied on SMEs;

(2) Calculation of relative risk values in what PG&E calls a "risk register" that ranks the different risks based on calculated LoF and CoF values that are based on different attributes that define "failure;"

(3) A second relative risk ranking process by PG&E's Investment Planning group which calculates a new set of LoF and CoF values using a different set of CoF weights and attributes and calculates "Program and Project Risk Scores;" and

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(cont.)

that incorporates multiple probabilistic events. However, if we are going to bother doing that, we might as well jump to the full probabilistic model to assess risk.

(4) Various meetings with different groups, culminating in final approval of specific risk-management plans, the "Executable Investment Plans," by PG&E's senior management.[38]

The first two steps focus on risk assessment and are part of PG&E's "Session D" process. The third step is part of what PG&E calls the "Session 1" process that produces an initial Strategic Plan to manage risk. Thus, this third step incorporates both additional risk assessment and risk management. The last step reflects what PG&E refers to as the "Session 2" process and is focused solely on risk management, determining what risk management programs will be implemented based on the constraints and legal requirements identified by PG&E.[39]

Q. HAS PG&E CORRECTLY IMPLEMENTED THE ASME B31.8S RISK ASSESSMENT APPROACHES IT IS USING?

A. No. As we discuss further in Section IV below, PG&E's relative risk assessment and SME approaches, which are also described in the 2004 version ASME B31.8S, must be implemented correctly if they are going to provide reasonable and consistent results. And, as we will demonstrate, PG&E has not correctly applied these approaches.

IV. DEVELOPING AN OPTIMAL RISK MANAGEMENT STRATEGY

Q. IS PG&E'S SELECTION OF METHODOLOGIES CONSISTENT WITH THE ASME?

A. Yes. PG&E's use of SMEs and a relative risk ranking methodology is consistent with the ASME. However, PG&E's ultimate determination of risk management programs is flawed.

[38] PG&E Supplemental Testimony, Chapter 2A, p. 2A-1 – 2A-8.

[39] Constraints can include not only resource limitations but system constraints.

Q. WHAT ELEMENTS OF AN OPTIMAL RISK MANAGEMENT STRATEGY GUIDED THE DEVELOPMENT OF YOUR TESTIMONY?

A. Our testimony focuses on the role of three critical elements for an optimal risk management strategy: (1) current and future asset condition, (2) optimization that addresses all of the specific constraints that are in play (e.g., budget limitations, labor availability, a need to achieve a specific risk reduction target, etc.) and (3) a *correct* approach to multi-attribute analysis when the risk of asset failure has multiple consequences. This section describes these elements, which form the basis of our critique of PG&E's approach in Section V.

A. The Role of Asset Condition Information

Q. WHAT DO YOU MEAN WHEN YOU USE THE TERM "ASSET CONDITION"?

A. "Asset condition" is a summary description of the fitness of an asset for its intended use. Asset condition describes an individual asset and distinguishes one asset from another. Asset condition is based on a set of observable and measurable characteristics. Asset condition should be expressed and measured in a consistent way across all assets. For example, a pipeline system includes many types of equipment including pipe, compressors, regulators, and valves. If we ask, "What is the condition of the pipeline?" we would examine the pipe for corrosion, valves for their difficulty operating, compressors for their efficiency, and so forth. These characteristics — corrosion, operational ease, efficiency — are the observable and measurable characteristics we would use to describe the overall condition of the pipeline. Thus, we need to identify the different characteristics for different types of equipment to develop consistent measures of the pipeline's condition.

Q. WHY IS A CONSISTENT MEASURE OF ASSET CONDITION IMPORTANT?

A. We need consistent measures of asset condition to enable us to compare assets that are in different condition and determine appropriate asset management strategies. For example, tire tread depth is a consistent measure of a tire's condition; the greater the remaining tread depth, the better the tire's condition, holding everything else the same. Thus, if Tire A has one quarter inch of tread depth remaining and Tire B has no tread depth, all else equal, we could conclude that Tire A's condition was "better" than Tire B's.

Q. WHAT ROLE DOES ASSET CONDITION PLAY IN EFFECTIVE RISK MANAGEMENT?

A. Asset condition plays a crucial role in effective risk management because asset condition determines the probability that an asset will fail. Asset condition is a dynamic variable. As an asset's condition changes over time, the probability that it will fail also changes. Thus, determining an optimal risk management strategy must not only account for the current condition of assets, but also the future consequences of decisions that are made.

We previously referred to this probability as the hazard function or hazard rate. If asset condition is not known, then all similar asset classes (e.g., all pipe, all compressors, etc.) are assumed to be equally likely to fail, governed by a single hazard function. However, if we know the conditions of the assets within an asset class, we can adjust the probability of failure to reflect the different conditions. This adjustment is specified by the *condition-based hazard rate*.

The default variable that is used to determine the hazard rate is asset age. Clearly, two pipes can be the same age but in very different conditions, depending on their operating environments and other factors. Hence, two equally aged pipes need not have the same likelihood of failure. But if we do not know the conditions of the two pipes, then we must assume each has an equal likelihood of failure. Without knowing the condition of assets, and how those conditions are likely to change over time, it is impossible to determine an optimal strategy to manage those assets over their lifetime. PG&E cannot pursue risk management activities that provide ratepayers with the best value for their money because PG&E does not currently have sufficient information about the conditions of the Company's pipeline assets.

For example, replacing pipe or regulators when they reach a defined age, regardless of their actual condition, is unlikely to be an optimal strategy. Instead, it is important to test their current condition and, with that knowledge, determine the likelihood of the assets' future failure. This is the condition-dependent hazard function concept we discussed previously. The current condition, combined with estimates of the likelihood of failure in the future, can then be used to determine what assets should be replaced today, what should be repaired, and when and what assets should be tested again.

Q. DOES KNOWING THE CURRENT CONDITION OF AN ASSET SUFFICE FOR DEVELOPING A RISK MANAGEMENT STRATEGY?

A. No. In addition to information about the current condition of an asset, we need to know how that asset's condition is likely to change over time. For example, as with any piece of equipment, a pipeline compressor's condition over time depends on how it is maintained and how it is used.

Finally, we need to understand whether there are interdependencies between the condition of different assets that can affect safety and reliability. For example, suppose we replace an existing pipeline compressor with a more powerful and efficient one, without also determining the condition of the pipe. If the pipe is severely corroded, the higher pressure provided by the new compressor could increase the likelihood of a pipeline rupture. Therefore, in determining an optimal strategy to manage compressors, we need to know the condition of the pipe and how that condition is likely to change over time, with and without a different compressor.

Q. HAS PG&E ACQUIRED THE NECESSARY ASSET CONDITION INFORMATION TO ASSURE AN EFFECTIVE OUTCOME OF THE COMPANY'S RISK MANAGEMENT PLAN?

A. No. Much of PG&E's testimony discusses the need to obtain additional information about the condition of the Company's pipeline assets, including information that the Company admits has been lost or misplaced. For example, PG&E is unable to provide corrosion data records before 2009.[40] Similarly, in reference to measurement and control (M&C) station data, PG&E witness White testifies:

> For M&C assets in particular, there is currently limited readily available condition-based performance information by the various station types (i.e., terminals, complex and simple) to assist in the assessment of the condition of these assets. There is limited tracking of the age of critical assets within the M&C asset family. Furthermore, PG&E has not applied a <u>consistent</u> quantitative risk-based methodology for assessing condition and criticality of stations, systems or major components.[41]

Thus, whereas PG&E witness Stavropoulos testifies that Gas Operations "is pursuing a best practice asset management certification offered by the British Standards Institute

[40] *See, e.g.*, GTS-RateCase2015_DR_IS_10-Q005; GTS-RateCase2015_DR_IS_10-Q003, attached as JAL/CDF-5.

[41] PG&E Direct Testimony, Vol. 1, Ch. 6, p. 6-25, lines 17-23 (emphasis added).

under its [PAS] 55,"[42] PG&E is not following all of the PAS 55 guidelines, because it does not have adequate asset condition information to develop an optimal strategy to improve pipeline safety. The Company has also clearly failed to meet the 2004 ASME's conclusion regarding the essential need to have complete records to develop a good pipeline integrity management plan.

Q. IS "ASSET CONDITION" THE SAME AS "ASSET HEALTH"?

A. No. PG&E uses the term "asset health" throughout its testimony, but it is not the same thing. Definitions of "asset health" often combine several distinct characteristics, such as age and near-term failure likelihood, into a single measure, and then apply that measure to different types of assets. A "healthy" compressor is not the same thing as a "healthy" pipe, just as a healthy heart is not the same thing as a healthy tire.

PG&E appears to use asset health as a substitute for asset condition. For example, PG&E witness Stavropoulos testifies that one of the Company's goals is to achieve "reliability through better understanding of the health of the asset base and developing a plan to improve performance and manage risk to achieve optimal asset health."[43] PG&E never explains what it means by "optimal asset health." Does it mean that all of the pipeline equipment will be in like-new condition at all times? Does it mean that compressors will be allowed to operate until they fail, and then be replaced? Does it mean that all valves will be inspected every month? Simply asserting that PG&E will achieve "optimal asset health" does not answer any of these questions.

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[42] PG&E Direct Testimony, Vol. 1, Ch. 1, p. 1-7, lines 28-30.

[43] *Id*. at 1-8, lines 22-24.

Q. HAS PG&E DEVELOPED SPECIFIC ASSET HEALTH THRESHOLDS TO DETERMINE PIPELINE RISK MANAGEMENT PROGRAMS?

A. No. According to the Company's response to IS-9-007, no asset health thresholds have been as yet developed.[44]

Q. HOW WILL THESE AS YET UNDEVELOPED ASSET HEALTH THRESHOLDS HELP IDENTIFY AN OPTIMAL RISK MANAGEMENT PLAN?

A. We cannot say, because PG&E has not developed them. However, if PG&E uses these asset health thresholds to adopt simple risk management rules of the type, "If asset X is found to have health Y, then replace X," such policies are almost certain not to be optimal. The reason is that these types of simple rules cannot take account of multiple constraints that can change over time. Furthermore, they cannot account for the behavior of asset condition over time.

Q. HAS PG&E USED ASSET CONDITION INFORMATION CORRECTLY IN ITS RISK ASSESSMENT METHODOLOGY?

A. No. We discuss this issue further in Section V.

B. The Role of Optimization

Q. WHAT DO YOU MEAN WHEN YOU USE THE TERM "OPTIMIZATION"?

A. "Optimization" can be best thought of as ensuring that you search for the best (optimal) possible strategy to accomplish a goal or objective, given the different constraints that are in place. In this proceeding, the optimal asset management strategy for PG&E is one that reduces pipeline system risk in a way that provides the best value

44 GTS-RateCase2015_DR_IS_09-Q007, attached as JAL/CDF-6.

for ratepayers' money, subject to different constraints including affordability, labor availability, and parts availability, among others.[45]

Q. WHAT ROLE DOES OPTIMIZATION PLAY IN RISK MANAGEMENT STRATEGY?

A. How to find the best asset risk management strategy can be formulated as an optimization problem as recognized in PAS 55, ISO 55000, and ASME B31.8S. Optimization's role is to find a risk management strategy that addresses all of the different constraints as effectively as possible. For example, as discussed previously, one possible risk management strategy is to replace and rebuild PG&E's entire gas transmission pipeline system with new equipment and do so sufficiently frequently so that all of the equipment is in "like-new" condition. That's clearly one strategy, but it is almost certainly not an optimal strategy. Why not? Because, not only would the cost be prohibitive, but there is almost surely neither enough skilled labor nor available equipment to implement such a strategy.

Q. WHAT ARE THE KEY FACTORS IN DEVELOPING AN OPTIMAL PIPELINE RISK MANAGEMENT STRATEGY?

A. There are at least four key factors that guide in the design of an optimal pipeline risk management strategy. These are:

1) <u>Pipeline assets are long-lived, requiring an optimal strategy to be specified over time.</u>[46] In other words, although we need to know what actions to take today, we must also determine what actions to take over time, because the consequences of taking an action today will affect risk today and into the future.

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[45] Optimization is one facet of applied mathematics, in which problems are specified in different ways and, depending on the specification, different methods to solve these problems are applied.

[46] In solving optimization problems involving long-lived assets, the time horizon is typically assumed to be infinite.

2) The time at which a pipeline asset will fail is unknown and the future consequences of failure are uncertain. While the consequences of failure today may be known, the consequences of failure at an unknown time in the future are not. That uncertainty must also be taken into account.

3) The condition of pipeline assets change as the pipeline is operated; so at any point in time, the condition of individual assets is uncertain. Asset condition is important for solving the asset management problem because the probability that an asset fails depends on the condition of the asset. Hence, the cost of operating an asset at any time depends on its condition. As highlighted in Section III above, PAS 55 recognizes the importance of including asset condition data in any successful asset management methodology.

4) Testing to determine an asset's condition provides useful information, but the value of that information varies, depending on asset condition. Also, no asset condition test is perfectly accurate and, therefore, an asset's condition based on test outcomes is also uncertain. In the case of pipelines, there are numerous federal regulations[47] that prescribe *minimum* testing requirements. But, based on the conditions of a pipeline's assets, it may make sense to test some of those assets more frequently or perform additional tests.

Q. ARE THERE ANY OTHER CONSIDERATIONS THAT AFFECT THE DETERMINATION OF AN OPTIMAL PIPELINE RISK MANAGEMENT STRATEGY?

A. Yes. Interdependencies among the assets themselves must be considered. In other words, an optimal strategy will address instances where the condition of pipeline asset A affects the condition of asset B. Any strategy that treats the future conditions and probabilities of failure for assets A and B independently, when in fact the conditions and probabilities of failure are not independent, will not be optimal.

[47] 49 CFR Part 192.

Q. CAN YOU BRIEFLY EXPLAIN THE DIFFERENCE BETWEEN PRIORITIZION AND OPTIMIZATION WHEN APPLIED TO SPECIFIC ASSET MANAGEMENT PROBLEMS, SUCH AS MANAGING RISK?

A. Yes. The most important difference is that prioritization and optimization will each tell you to adopt different risk management strategies. Prioritization typically ranks projects individually in terms of a simple measure, such as a benefit-cost (B/C) ratio. All projects are selected until there either is no more money or some other constraint (e.g. no additional manpower) is reached. (Clearly, if resources were unlimited, there would be no need to rank projects at all.)

Optimization, however, selects an entire portfolio of projects in the presence of multiple goals and constraints. For example, an electric utility in California will develop a portfolio of generating assets that, among other things: (1) can meet customer demand for electricity at all times; (2) supports grid reliability, (3) meets the state's requirements for resource diversity and (4) has the lowest expected cost. Determining what such a portfolio of generating assets looks like is an optimization problem that provides (1) – (3) at the lowest expected cost (4). Ranking generating resources by benefit-cost ratios cannot provide an optimized portfolio when faced with multiple requirements, and when the generating assets themselves are of different size, have different lifetimes, and so forth.

In terms of risk management, a prioritization exercise might determine the following ranking of maintenance measures from greatest to least benefit for an automobile: install new engine, install new brakes, install new tires, install new transmission, repack the wheel bearings, check tire pressure, check engine oil, and check coolant level. Suppose you have only $500 available to spend on maintenance. In that case, the priority ranking will do little good if you cannot afford the highest-ranked measures. Instead, the problem must be formulated as: what set of maintenance measures will provide the greatest improvement in your vehicle's reliability, given that your budget is $500? Moreover, other issues must be addressed, including the remaining risk after the selected maintenance is completed, other ways of achieving the same reduction in risk, and interdependencies between the different maintenance choices.

Q. WHY IS THE DIFFERENCE BETWEEN PRIORITIZATION AND OPTIMIZATION SO IMPORTANT IN THIS PROCEEDING?

A. The difference is important because, if PG&E is asking its ratepayers to fund risk management activities to improve pipeline safety and reliability, ratepayers have a right to expect that the money they are asked to provide will be spent as efficiently as possible. In other words, ratepayers have a right, and PG&E has a duty, to ensure that the money the Company intends to spend for risk management will achieve the greatest possible benefit. As PAS 55 articulates the concept, the plan must provide "the best value for the money." [48] Whatever combination of minimum acceptable reductions in risk and maximum amounts of money ratepayers can afford to pay is determined, the risk management strategy meeting those constraints should be the one that provides the most value.

Q. CAN AN ASSET MANAGEMENT STRATEGY BASED ON PRIORITIZATION EVER BE OPTIMAL?

A. Yes. A prioritization strategy, such as one based solely on Benefit/Cost (B/C) ratios, can yield an optimal strategy under very limited conditions. These are: (1) there can be only one constraint, typically a budget constraint; (2) the projects must have the

[48] PAS 55-1:2008, p. vii.

same expected lifetime, or can be replicated multiple times so that all projects are compared over the same time period; and (3) the projects must all have the same initial cost.[49] If these conditions are not present, prioritizing based on a B/C ratio will not yield an optimal strategy.

Q. DOES PG&E'S ASSET MANAGEMENT PLAN RELY ON OPTIMIZATION OR PRIORITIZATION?

A. PG&E's AMPs rely on some type of prioritization, although not one based on a risk-reduction per dollar type of B/C ratio. The AMPs identify and rank risks (incorrectly, as we discuss in Section V), but PG&E's explanation of how the Company actually selected a portfolio of risk management activities is opaque. For example, Attachment 13 of PG&E's response to TURN-1-001 discusses a process that is based on flawed rankings followed by various committee meetings "to analyze the portfolio and make any adjustments to the portfolio to ensure that the work plan is risk-based." That description does not provide any insight into the basis of PG&E's evaluation.[50] Moreover, PG&E states that it never determined the degree to which specific AMPs would reduce risk from the (erroneously calculated) current levels.[51] Thus, it is impossible for PG&E to have optimized asset management activities and programs if the Company never estimated the risk reductions those activities and programs would

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[49] For a discussion of B/C ratios and there problems, see Richard Zerbe and Dwight Dively, *Benefit-Cost Analysis in Theory and Practice*, (New York: Harper Collins 1994), pp. 189-194.

[50] PG&E Supplemental Testimony, Attachment B, GTS-RateCase2015_DR_TURN_01-Q001. Att. 13, p. 2A-B-518.

[51] GTS-RateCase2015_DR_IS_07-Q002; GTS-RateCase2015_DR_IS_07-Q003, attached as Exhibit JAL/CDF-6.

provide. Instead, PG&E prioritized the Company's proposed risk management activities using unknown metrics.

Q. REGARDLESS OF THE METRICS PG&E USED TO PRIORITIZE ITS RISK MANAGEMENT ACTIVITIES, COULD THOSE METRICS PRODUCE AN OPTIMAL STRATEGY?

A. No. PG&E witness Stavropoulos admits the Company faces multiple constraints, including equipment availability, manpower, and affordability.[52] No prioritization approach can identify the optimal (i.e., greatest economic value) strategy in the face of multiple constraints.

Consider the following example. Suppose that there are seven pipeline maintenance alternatives, each having a specific cost, an estimated benefit, and a specific labor requirement, as shown in Table 1.

Table 1: Pipeline Maintenance Strategy

Project	Cost (1000$)	Benefit (1000$)	B/C Ratio	Labor Required	Benefit/Labor Ratio	NPV (1000$)
1	$100	$300	3.00	5.00	60.00	$200
2	$20	$50	2.50	0.75	66.67	$30
3	$150	$350	2.33	4.00	87.50	$200
4	$50	$110	2.20	1.00	110.00	$60
5	$50	$100	2.00	0.75	133.33	$50
6	$150	$250	1.67	1.50	166.67	$100
7	$150	$200	1.33	1.00	200.00	$50

In Table 1, the seven maintenance projects are ranked in order from highest B/C ratio to lowest, as shown in the fourth column of the table. Suppose that the pipeline has only $200,000 to spend. In that case, choosing projects by their B/C ratio would result in selecting projects [1 and 2]. Suppose, instead, that the only constraint is on available

52 PG&E Direct Testimony, Vol. 1, Ch. 1, p. 1-9, line 27.

labor. For example, suppose there are only 5.75 units of labor available to the pipeline. If the projects were ranked based on their "benefit-to-labor ratio," as shown in the sixth column of the table, the pipeline would select projects [7, 6, 5, and 4]. Therefore, with two constrained variables, the selection process based on prioritization is not well defined. It is worth noting that the two prioritized selections have no common members.

Next, we consider the results of optimization. We can solve three different optimization problems in the preceding example: (1) the optimal group of projects (i.e., the group of projects providing the highest net present value (NPV)) when there is only a cost constraint is [1, 4, and 5]; (2) the highest NPV group of projects with just the labor constraint is [5, 4, and 3]; and (3) finally, the highest NPV group of projects with both the cost and labor constraints in place is [3 and 4]. Thus, in this example <u>the optimal group of projects to select when constraints are present (i.e., the group of projects having the highest NPV) is completely different than either of the prioritized sets of projects</u>. Furthermore, the optimal group of projects depends on which constraints are present.

The example illustrates that prioritization and optimization are <u>not</u> the same thing and can lead to different choices. Another way of expressing that observation is that prioritization is an inappropriate method for solving optimization problems. Therefore, prioritizing projects based on B/C ratios does not provide ratepayers with the best value for their money.

C. The Role of Multi-Attribute Analysis

Q. WHAT IS MULTI-ATTRIBUTE ANALYSIS?

A. Multi-attribute analysis is a method of making decisions with multiple objectives. Within the broader academic literature on decision analysis it is known by its more technical term as *multi-attribute utility analysis*.[53] For example, deciding on a house to buy often involves multiple objectives, including a location near good schools, a minimum number of bedrooms, minimum number of bathrooms, and the size of the yard. Multi-attribute analysis provides a way to systematically and logically address multiple and competing objectives. It is especially important when decisions are made collectively by individuals and groups who have different preferences and, therefore, may not address competing objectives in the same way.

In this section, we present some material taken from Ralph Keeney's book, *Value Focused Thinking*,[54] which we believe provides a good discussion of structuring and solving multi-attribute decision problems.

Q. CAN YOU BRIEFLY DESRCIBE HOW A MULTI-ATTRIBUTE ANALYSIS WORKS?

A. Yes. All multi-objective decision problems begin with identifying the *overall objective*. In this case, we presume PG&E's overall objective is to maximize the safety of its pipeline system with a spending constraint. Starting with that overall objective, the process continues by identifying *fundamental objectives* and creating a hierarchy that ultimately result in a set of *measurable attributes*. Figure 1 illustrates a portion of that hierarchy.

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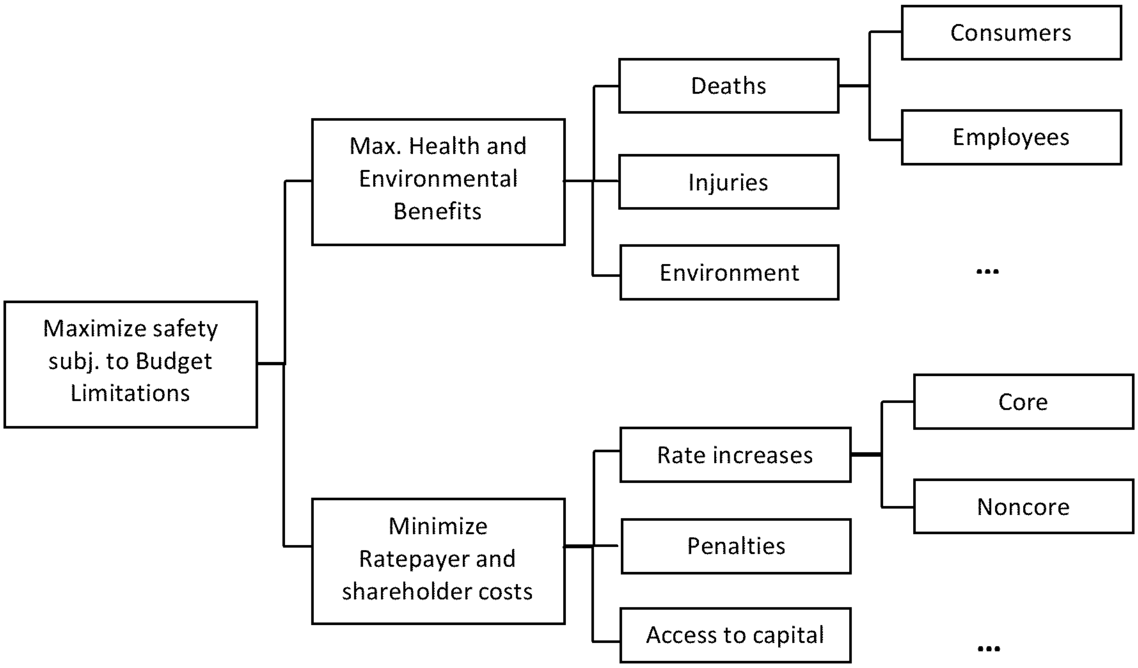
[53] The seminal reference is Ralph Keeney and Howard Raiffa, *Decisions with Multiple Objectives*, (New York: John Wiley 1976).

[54] Ralph Keeney, *Value-Focused Thinking*, (Cambridge, MA: Harvard University Press 1992) (Keeney).

Figure 1: A Fundamental Objectives Hierarchy



In Figure 1, the ultimate objective for all parties is to provide the most safety possible within spending constraints. That ultimate objective is broken down into two sub-objectives: (1) maximizing health, safety, and environmental benefits, and (2) minimizing ratepayer and shareholder costs. Continuing to the right in Figure 1, we break down the two sub-objectives further. Thus, the health and safety objective is broken down in categories of minimizing deaths, minimizing injuries, and minimizing environmental damage. Similarly, the ratepayer and shareholder cost objective is broken down into categories of minimizing rate increases, minimizing shareholder penalties, and ensuring access to capital. Ultimately, the rightmost level of the hierarchy should list measurable attributes.

The measured attributes must be independent of one another, so that the benefit (or cost) arising from the change in the level of one attribute does not depend on the levels of any other attribute. For example, suppose one attribute is the cost to PG&E ratepayers and another is PG&E's reputation. The benefit of a one million dollar reduction in cost to ratepayers cannot depend on whether PG&E's reputation is "good" or "bad." If the attributes are not independent, applying the attribute hierarchy to guide decisions can lead to inconsistent or even nonsensical results.

The fundamental purpose is to measure the relative benefits (and costs) arising from sets of changes in the levels of the attributes. In effect, making an optimal decision means measuring the impact of a program's ability to change the attribute values or, in economists' parlance, the weighted difference in the changes associated with the "utility" of each attribute level. For example, if the impact of a project on one set of attributes implies a "score." If one set of attributes has a score of 10 units and another set of attributes implies a score of 8 units, the only thing that matters is the *difference* between the scores. The key to determining optimal decisions is to determine the decision with the best (maximum) overall score, based on the changes in the attributes and their assigned weights.

Q. CAN YOU PROVIDE A SIMPLE EXPLANATION OF WHAT "UTILITY" MEANS IN THE CONTEXT OF THIS SORT OF DECISIONMAKING?

A. Yes. "Utility" is a concept developed by economists which provides a mathematical representation of how individuals' values affect their choices, including choices about the risks they are willing to take. For example, when you buy a latte from the corner Starbucks, you exchange an amount of money for your drink, presumably because the value you place on the latte is greater than its cost. Or, if you have only limited money, you may choose between a latte in the morning or purchasing a sandwich for lunch. Utility functions provide economists helpful mathematical ways of representing these choices and are therefore integral to multi-attribute analysis.

Q. WHAT ARE THE PROPER PROPERTIES OF A SET OF FUNDAMENTAL OBJECTIVES IN MULTI-ATTRIBUTE ANALYSIS?

A. Keeney identifies nine desirable properties, which are shown in Table 2.

Table 2: Desired Properties of Fundamental Objectives[55]

1.	**Essential:** Required to indicate the consequences in terms of the fundamental reasons for making decisions.
2.	**Controllable**: Required to address consequences influenced by decision alternatives.
3.	**Complete**: Include all fundamental aspects of the consequences of the decision alternatives.
4.	**Measurable**: Required to define objectives precisely and specify the degree to which they are achieved.
5.	**Operational**: Ensure that the amount of information needed is reasonable.
6.	**Decomposable**: Allow for the separate treatment of the different objectives.
7.	**Nonredundant:** Avoid double-counting of possible consequences.
8.	**Concise**: Reduce the number of objectives to the minimum number needed for completeness.
9.	**Understandable**: Facilitate insights for the decision making process.

Q. WHY ARE THESE PROPERTIES IMPORTANT?

A. These properties are essential because objectives must be broken into their logical and separate parts. That is the purpose of breaking down broad objectives, such as those shown in Figure 1, into components that can be defined and measured.

Q. WHY IS CORRECTLY SPECIFYING ATTRIBUTES SO IMPORTANT?

A. The reason specifying attributes is so important is that the benefits and costs of alternative risk management strategies (in this case decisions on replacing, repairing, and testing assets) are measured by *changes* in the attribute values. The *utility* provided by a change in attribute level is measured by a *scale* that converts changes in the natural units of an attribute (for example, the number of customers experiencing a service outage) to a pure number, the *utility* of the change in number of customers experiencing a service outage. The relative benefits provided by changes in different attributes are specified by

[55] Adapted from Keeney, p. 82, Table 3.5.

attribute weights. Thus, the scale measures the benefit of a change in a single attribute's level. The weights measure the benefit of a set of changes in the levels of several attributes at the same time. If the attributes are not specified correctly, the results of the entire analysis will be faulty because the scales and weights will be incorrect.

It turns out that, because the attribute weights measure the relative benefits of specific changes defined by the attribute scales, the weights and the scales are linked. Consequently, <u>one cannot develop the attribute weights and attribute scales independently of one another</u>. It is these specific linkages between weights and changes in attribute values associated with different risk management projects that allow the multi-attribute approach to work correctly. Otherwise, the methodology leads to nonsensical results, as we demonstrate in Section V.

Q. HOW ARE ATTRIBUTE WEIGHTS CORRECTLY DEVELOPED?

A. To develop attribute weights <u>correctly</u>, one must compare <u>changes</u> in the levels of the different attributes. The clearest way to do this is to compare the benefits achieved by changing different attributes from best to worst, one pair of attributes at a time. For example, changing health and safety from its worst level to its best level can be compared to moving PG&E's reputation from its worst level to its best level. Only when all of these pairwise comparisons have been made can a consistent and meaningful set of attribute weights be developed and provide consistent rankings of alternatives. This means that attribute weights cannot be set independently of the attribute values and scales. However, as we discuss in the next section, <u>PG&E incorrectly does this in applying the relative risk methodology to rank risks in its Risk Register</u>.

Q. WHAT DO THE DIFFERENT ATTRIBUTE WEIGHTS MEAN?

A. Attribute weights, such as PG&E's 30% weight for Health and Safety, describe the relative importance of each attribute and thus, how important are changes in each attribute level. Recall the four-step process PG&E used to select projects.

(1) Threat and risk identification, which relied on SMEs;

(2) Calculation of relative risk values in what PG&E calls a "risk register" that ranks the different risks based on calculated LoF and CoF values that are based on different attributes that define "failure;"

(3) A second ranking process by PG&E's Investment Planning group which calculates a new set of LoF and CoF values using a different set of CoF weights and attributes and calculates "Program and Project Risk Scores;" and

(4) Various meetings with different groups, culminating in final approval of specific risk-management plans, the "Executable Investment Plans," by PG&E's senior management.[56]

In Steps (2) and (3), PG&E established attributes and their weights for two different purposes: developing the Risk Register (Step 2) and selecting projects (Step 3). PG&E used different attributes and different attribute weights in steps (2) and (3), and these weights define the CoF values. The use of different attributes and different weights for these two purposes creates inconsistency in PG&E's various relative risk rankings. Most importantly, incorrectly specifying attribute weights leads to inconsistent rankings of project alternatives. In Section V, we show how this is the case using PG&E's "Heat Map" approach.

[56] PG&E Supplemental Testimony, Ch. 2A, p. 2A-1 – 2A-8.

Q. WHAT IF THE ATTRIBUTE WEIGHTS DO NOT REFLECT MY PREFERENCES? FOR EXAMPLE, WHAT IF THE HEALTH AND SAFETY ATTRIBUTE IS TOO LOW? DOES THAT MAKE THEM WRONG?

A. No, the fact that different parties value specific attributes differently does not make those individual preferences wrong. When decisions necessarily involve multiple groups with different preferences, it is important to use a process that can account for those differences in a consistent manner.

For example, suppose we ask PG&E's Chief Risk Officer and the Chair of the CPUC to compare the same changes in attributes and, as a result, we determine the weights they assign to the attributes are not the same. The Chief Risk Officer and the Chair each have different preferences, leading them to make different decisions.

The attribute weights are only "wrong" if there are either additional strategic objectives that have not been identified, or that the attributes used to measure the objectives haven't been scaled properly, or both.

Q. IS IT POSSIBLE TO RECONCILE SUCH DIFFERENCES?

A. Yes. Because reducing pipeline risks involves public policy and private investment decisions, we believe it is important for a "meeting of the minds" to take place. Even if PG&E had used a valid multi-attribute approach, it is entirely likely the attribute weights would differ than if the CPUC were determining appropriate attribute weights. The nature of public policy issues is such that there can, and often are, disagreements about the "best" solutions.

Q. HOW COULD ANY SUCH DISAGREEMENTS IN THIS PROCEEDING BE ADDRESED?

A. Determining the specific attributes and their weights from this type of exercise would benefit from input by both PG&E *and* the CPUC. In fact, one could establish a broader stakeholder process in which this same process was performed and accounted for preferences of PG&E, the CPUC and other stakeholders. Because it is impossible to eliminate all risk while also ensuring ratepayers can afford natural gas transmission service, we believe such a joint exercise would be extremely useful for all parties. This could be undertaken immediately and would help PG&E to design its risk management programs.

V. CRITIQUE OF PG&E'S APPROACH TO RISK MANAGEMENT

Q. PLEASE SUMMARIZE YOUR CONCLUSIONS REGARDING PG&E'S METHODOLOGY.

A. PG&E has not presented a rational, optimized asset management plan grounded in knowledge of asset condition. PG&E has also incorrectly implemented the "relative risk assessment" methodology that supports its Application. While it is possible to use a relative risk approach to develop and implement a comprehensive pipeline risk management program, as the saying goes, "the devil is in the details."

PG&E's relative risk approach suffers from numerous fundamental mathematical and statistical errors that render it incapable of providing an optimal risk management strategy.

1) PG&E has not applied any known budget constraints.

2) PG&E has not applied any known risk tolerance constraints.

3) PG&E's risk scoring and ranking process is internally inconsistent and circular.

4) PG&E has not estimated the risk reduction value implied by different mitigation programs, nor used those values to select specific mitigation programs.

5) PG&E's calculation of LoF, a key variable in the analysis, is fundamentally flawed.

6) PG&E's calculation of the CoF, another key variable, is fundamentally flawed.

7) PG&E has not properly applied the relative risk methodology.

8) PG&E did not correctly incorporate the condition of assets into its risk-management approach.

We demonstrate these flaws by examining the Transmission Pipe AMP and PG&E's proposed vintage pipe replacement program.

Q. HAS PG&E USED A FORM OF MULTI-ATTRIBUTE ANALYSIS IN RANKING RISKS?

A. Yes. PG&E's risk management strategy involves multiple objectives, as shown in Figure 1, above. These include reducing risks to health and safety, reducing risks to the environment, while ensuring these risk reductions are affordable.

Q. PLEASE SUMMARIZE YOUR RECOMMENDATIONS FOR PG&E'S METHODOLOGY.

A. In light of the fundamental flaws we have identified in PG&E's risk management methodology (and which we discuss below), we recommend that the Commission direct PG&E to correct these flaws *before* allowing the Company to spend additional ratepayer dollars on risk management activities. Because of these flaws, PG&E cannot have produced programs that provide ratepayers with the "best value for the money."

A. Description of PG&E's Relative Risk Assessment Methodology

Q. CAN YOU BRIEFLY SUMMARIZE THE RISK ASSESSMENT METHODOLOGY PG&E USES TO DEVELOP ITS RISK REGISTER?

A. Yes. PG&E is using a relative risk assessment model, similar to what is described in ASME B31.8S and ASME 2004.[57] Under this approach, "risk" is defined as the "likelihood" of an event times the "consequences" of the event.[58] We have placed the word "likelihood" in quotes because PG&E wrongly conflates "likelihood" and "probability." They are not the same thing as will be addressed further below.[59] We have placed the word "consequences" in quotes because PG&E uses it to refer not only to adverse physical impacts (e.g., loss of life and property, etc.), but also other adverse impacts that may occur (e.g., financial losses to PG&E, loss of reputation, etc.). The relative risks of different threats are calculated using PG&E's methodology and ranked to create what PG&E calls its "risk register."

Q. CAN YOU BRIEFLY DESCRIBE THE RISK REGISTER AND ITS PURPOSE?

A. Yes. PG&E explains that the Risk Register "process" includes identification of threats and assessment of the severity of particular threats.[60] This identification and assessment is used to guide selection of operational mitigation measures aimed to lessen risk and allow safer operations. PG&E scores and ranks risks as described above and

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57 *See* ASME B.31.8S-2012, p. 13, Section 5.5(b)(2).

58 *Id*. *See also*, PG&E Supplemental Testimony, Attachment B, GTS-RateCase2015_TURN_01-Q001, Att. 2.

59 Probability is a well-defined mathematical concept satisfying a collection of axioms. *See* Sheldon Ross, *A First Course in Probability,* (New York: Macmillan 1994), p. 32. In particular, PG&E's approach violates the third axiom of probability.

60 *See* PG&E Supplemental Testimony, Attachment B, GTS-RateCase2015_TURN_01-Q001, Att. 4.

uses this ranking to determine mitigation projects. This scoring and ranking process makes up the information contained in the Risk Register.

The Risk Register contains numerous "Heat Maps," which are charts that plot the LoF on the X-axis and the CoF on the Y-axis.[61] PG&E measures both LoF and CoF on 7 point relative scales, with "1" being the lowest value and "7" the highest value.

Under this approach, if two events have the same risk score, i.e., if the LoF x CoF values are the same, they have the same risk. Thus, suppose Event A has a LoF value of 3 and a CoF value of 6, and therefore a risk score of 3 x 6 = 18. If Event B has a LoF value of 6 and a CoF value of 3, its risk score is also 18. Therefore, under this methodology, Events A and B have the exact same risk. This is important because, as we discuss below, in the third step of its risk management process, PG&E uses a different methodology for which this equivalence no longer holds; events with the same LoF x CoF values are no longer considered to have the same risk.

These values are plotted on the heat map and the overall "risk score" of an event (e.g., a pipeline rupture) equals the event's LoF value multiplied by its CoF value (i.e., LoF *x* CoF). This is illustrated in Figure 2 below.

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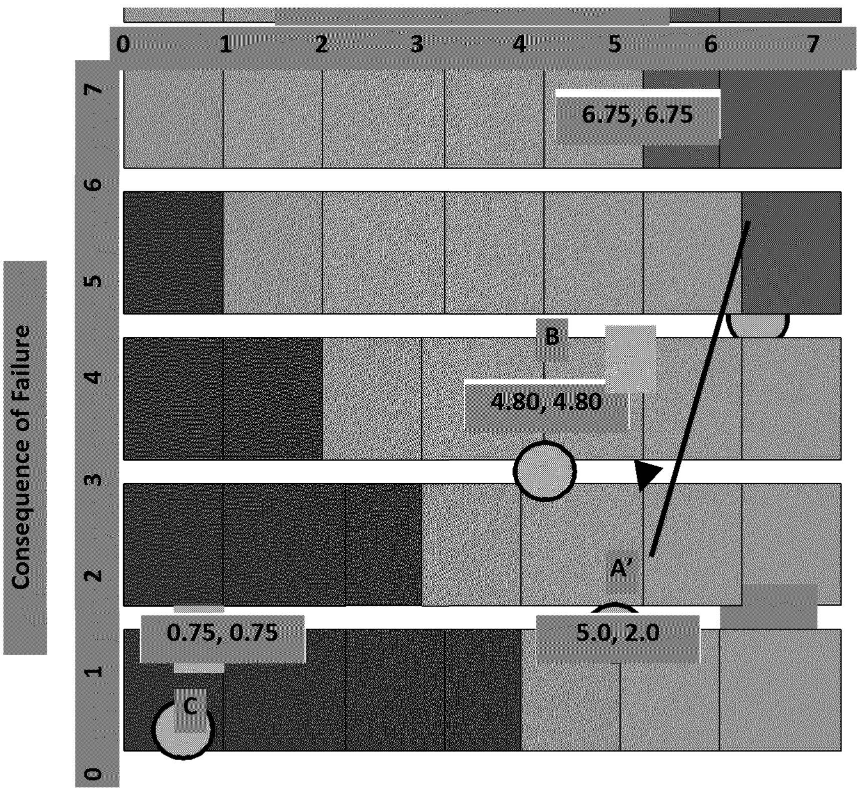
[61] In some PG&E documents, the axes are reversed. *See, e.g.*, slide 8 of PG&E's "Session D" presentation Supplemental Testimony, Attachment B, GTS-RateCase2015_TURN_01-Q001, Att. 4.

Figure 2: PG&E "Heat Map"



In Figure 2, Point A is an event with high consequences and for which there is a high probability that the event will occur. It has a risk score is 6.75 *x* 6.75 = 45.56 out of a maximum 49. Point A is in the "red" zone and is considered "catastrophic" in PG&E's parlance.[62] In contrast, Point C's risk score is just 0.75 *x* 0.75 = 0.56. Point C is an event of minimal consequence and likelihood and is thus in the "green" zone. Point B, with a score of 4.8 *x* 4.8 = 23.04 is somewhere in the middle "yellow" zone. This is what is meant by "relative" risk assessment. The numbers are meaningless in themselves; <u>what is important is how different risks compare and how different risk management strategies will change the initial estimated LoF and CoF values</u>. We cannot overemphasize the

[62] *See e.g.,* GTS-RateCase2015_ORA_17-Q002, Att. 1, p.1, attached as Exhibit JAL/CDF-8. "For example, a health and safety score of 7 is "catastrophic", and is defined as resulting in an event that causes loss of multiple lives."

importance of this latter point. Determining the impact of a mitigation strategy is fundamental to using a relative risk assessment methodology because changes in the risk values should drive the choice of risk management activities.

Q. HOW SHOULD THE "HEAT MAP" OR RELATIVE RISK ASSESSMENT INFORM RISK MANAGEMENT ACTIVITIES IN A PROPERLY DESIGNED SYSTEM?

A. In theory, a relative risk assessment approach would use the changes in risk scores to determine what specific risk management activities to undertake. In a properly designed relative risk assessment, the "benefit" of a risk management action (e.g., replacing a corroded pipe segment) equals the change in the risk score. Again, consider Figure 2 above.

Suppose the "risk" of the event at Point A, as measured by the product of its LoF (6.75) and CoF (6.75) scores, or 45.6, can be mitigated to Point A', such that the likelihood of the event is reduced from 6.75 to 5.0, and the consequence can be reduced from 6.75 to 2.0. Thus, the new risk score for event A is 5.0 x 2.0 = 10.0 and the relative benefit of equals the decrease in the risk score, i.e., 45.6 – 10.0 = 35.6. By itself, the decrease in risk is meaningless because it does not tell us whether we should mitigate the specific risk caused by Event A. It simply tells us that by mitigating the risk posed by Event A, using the strategy that results in the Point A, we will reduce risk by 35.56. To determine whether we should, in fact, mitigate the risk posed by Event A, we must evaluate the mitigation benefits of all of the different risks, determine how they compare in relative terms, an determine which events to mitigate based on all of the constraints we face (e.g., budget, manpower, equipment availability).

Q. WHAT IS THE SIGNIFICANCE OF POINTS B AND C IN FIGURE 2?

A. Points B (4.80, 4.80) and C (0.75, 0.75) illustrate another implication of PG&E's relative risk methodology. Specifically, the risk reduction moving from Point A to Point B is 45.56– 23.06 = 22.5. Similarly, the risk reduction moving from Point B to Point C is 23.06– 0.56 = 22.5. Therefore, PG&E measures the risk reduction value of moving from Point A to Point B is exactly the same as moving from Point B to Point C. Intuitively, however, reducing the consequences from catastrophic to minor will be far more valuable than reducing them from minor to inconsequential. PG&E's nonlinear scaling of CoF is mathematically inconsistent with how it applies linear values to risk mitigation. The reason PG&E's methodology yields such a counterintuitive result is because the Company did not develop attribute weights correctly, using the approach we described above.

Q. HAS PG&E USED A RELATIVE RISK APPROACH PREVIOUSLY?

A. According to PG&E, the Company has used this general approach since 1998. In the testimony submitted with its 2009 Gas Transmission and Storage case, Application 09-09-013, PG&E witness Roy Surges stated:

> In 1998, PG&E developed a pipeline Risk Management (RM) Program to assess the risk of every segment of gas transmission pipeline within PG&E's system. The Chief of the Utilities Safety Branch at the California Public Utilities Commission (CPUC or Commission) approved the program on April 20, 2000. Pipeline risk is determined by assessing two factors: (1) probability or likelihood of failure; and (2) local consequence of failure.
>
> …
>
> Utilizing these characteristics, PG&E developed a risk assessment algorithm:
>
> Risk = (Likelihood of Failure) × (Consequence of Failure)

> PG&E uses these algorithms to derive risk numbers for every unique segment of gas transmission pipe. The pipeline segment risk numbers are then used to help identify, quantify, and prioritize high-risk pipeline segments. PG&E analyzes each high-risk segment and looks for engineering solutions and risk mitigation techniques to reduce pipeline risk. … The RM Program ensures that PG&E is allocating capital safety and reliability dollars and resources to the highest risk pipeline segments and regulating stations within the system.[63]

Given the flaws in PG&E's current use of this relative risk methodology, and the Company's failure to collect data as set out in ASME 2004, it is doubtful that PG&E used the methodology correctly in the past. Given the lack of adequate maintenance and condition records, as discussed in the accompanying testimony of Dr. Lesser, PG&E could not have determined LoF values correctly.

B. Flaws in PG&E's Implementation of Relative Risk Assessment

Q. HAS PG&E PROPERLY IMPLEMENTED THE RELATIVE RISK APPROACH?

A. No. PG&E's implementation suffers from numerous flaws. These include: (1) constraints that are not defined, (2) risk ranking procedures that are circular and inconsistent with one another; (3) a complete failure to estimate the risk reductions associated with different mitigation strategies; and (4) fundamental mathematical and statistical flaws associated with how PG&E calculated the LoF and CoF values used in the relative risk ranking procedures.

[63] A.09-09-13, PG&E Direct Testimony of Roy Surges, p. 6-8, line 18 – p. 6-9, line 4, attached as JAL/CDF-9.

1. PG&E's Budget and Risk Tolerance Constraints are Not Transparent

Q. IS THERE ANY EVIDENCE THAT PG&E BASED ITS CHOICE OF ASSET MANAGEMENT ACTIVITIES ON A GIVEN BUDGET LIMIT?

A. No. In fact, PG&E's response to IS-4-23[64] states that the Company did not use a budget to determine which risk management projects to propose in its application.[65] Although PG&E witness Stavropoulos refers to affordability as a constraint,[66] nowhere in his testimony, nor any other PG&E witness's testimony, nor in any workpapers, does PG&E identify what the "affordability" objective means and how PG&E measured it as part of the Company's relative risk analysis.

Q. IS THERE ANY EVIDENCE THAT PG&E SELECTED PROJECTS BASED ON WHAT WOULD BE AN ACCEPTABLE LEVEL OF REMAINING RISK TOLERANCE?

A. No.

Q. MUST A SPECIFIC REMAINING RISK TOLERANCE LEVEL BE DEFINED WHEN USING THE RELATIVE RISK METHODOLOGY?

A. The answer depends on how an optimum portfolio of risk management actions is selected. If PG&E has specific budget, manpower, and equipment constraints, the objective is to select the portfolio of risk management actions that maximizes the reduction in risk within those constraints. If there are no budget, manpower, and equipment constraints, the optimal portfolio is the one that meets a defined risk tolerance level.

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64 GTS-RateCase2015_DR_IS_04-Q023, attached as Exhibit JAL/CDF-10.

65 In Section V, we explain the components used to calculate the LoF and CoF values.

66 PG&E Direct Testimony, Vol. 1, Ch. 1, p. 1-9, lines 26-27.

Q. IS YOUR CONCLUSION ABOUT THE LACK OF RISK TOLERANCE CONSISTENT WITH THE PRELIMINARY REPORT ISSUED BY THE COMMISSION'S SAFETY AND ENFORCEMENT DIVISION (SED REPORT)?

A. Yes. The SED Report[67] recognizes the absence of risk tolerance constraints in PG&E's methodology. It concludes: "Although the testimony alludes to the concept of risk tolerance, there is no showing of risk tolerance at the corporate level to adequately justify the scope and pace of the proposed programs."[68] The SED Report further proposes consideration of costs in PG&E's decision making, through a cost-benefit or "As Low As Reasonably Practicable" standard.[69]

Q. WHAT IS THE CONSEQUENCE OF PG&E'S FAILING TO EMPLOY A BUDGET OR RISK TOLERANCE IN THE RISK MANAGEMENT PLAN?

A. Without a well-defined budget constraint or a well-defined risk tolerance target, it is mathematically impossible to develop a coherent and logical risk management strategy. PG&E admits it never estimated how the different risk management activities actually reduce risk, relative or otherwise.[70] Thus, PG&E is asking the Commission to approve a $4.2 billion risk management strategy for the next three years for which: (1) the degree to which risk will be reduced is not measured; (2) the selection of projects that will reduce risk by this unmeasured amount is not based on a budget or other constraint; and (3) the projects selected are not based on any known risk reduction goal or tolerance for remaining risk.

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[67] Caroline Contreras, Steven Haine, and Suman Mathews, Pacific Gas & Electric Company Proposal for Cost of Service and Rates for Gas Transmission and Storage for 2015-2015 Application 13-12-012, "Preliminary Staff Report," July 18, 2014 (SED Report).

[68] SED Report at 15.

[69] *Id*. at 1, 20, 40-41.

[70] As stated in PG&E's response to GTS-RateCase2015_DR_IS_07-Q002 (a)-(i), attached as Exhibit JAL/CDF-7.

Q. CAN THESE FAILURES BE CORRECTED?

A. Of course. First, PG&E, the Commission, or both must specify an ultimate risk tolerance goal and the time by which this goal should be achieved. Everyone recognizes that risk cannot be eliminated completely and that natural gas transmission service must remain affordable. In determining an optimal set of risk management programs, different residual risk and cost consequences will have to be evaluated until, ultimately, an acceptable combination is reached. That is a public policy decision.

Second, PG&E, the Commission, and other parties can participate in a process in which a consistent set of attributes and attribute weights are developed, so that the relative values of risk reductions provided by alternative programs can be evaluated and compared consistently.

Third, the relative risk reduction values of these programs can then be combined with well-defined budget, equipment, and manpower constraints to determine the set of risk management programs that will provide ratepayers with the best value for the money.

2. PG&E's Risk Scoring Methodology is Internally Inconsistent

Q. WHY DO YOU BELIEVE THE USE OF RISK SCORING BY PG&E IS INCONSISTENT? IS THE DEVELOPMENT OF THE RISK REGISTER CIRCULAR?

A. The Program and Project Risk Scores are developed using a very different process than used to create risk scores in the Risk Register.

Q. PREVIOUSLY, YOU DISCUSSED THE THIRD STEP OF PG&E'S PROCESS: TO DEVELOP "PROGRAM AND PROJECT" RISK SCORES. CAN YOU DESCRIBE THIS STEP IN MORE DETAIL?

A. Yes. As stated in PG&E's Supplemental Testimony:

> The first step [in developing Program and Project risk scores] is to classify the programs or projects to identify key work drivers (such as "compliance" or "customer driven"). Once the work is classified, each program or project is assigned a Program and Project Risk Score <u>based on consequence and likelihood scores for Safety, Environmental, and Reliability. The Program and Project risk scoring process uses a framework to assess consequence and likelihood that is aligned with the framework utilized in the development of the Gas Operations Risk Register</u>. … Once the preliminary investment portfolio is compiled, Investment Planning collects information on constraints to analyze the ability to execute on the portfolio of investments. Constraints include resources required, availability of the gas system to handle the system clearances required, and work execution constraints such as permits, materials and contracts.[71]

Q. DOES PG&E SCORE RISKS FOR THE INVESTMENT PLAN IN THE SAME WAY IT SCORES RISKS FOR ITS GAS OPERATIONS RISK REGISTER?

A. No. Although assessing the consequence and likelihood values is the same process as done for the Risk Register, the methodology by which these values are developed is not the same and, in fact, is inconsistent with the methodology used in the Risk Register process. As PG&E states in the Supplemental Testimony:

> The purpose of the Risk Register Risk Score, a product of consequence of failure and likelihood of failure, is to rank and prioritize risks at the asset level. The purpose of the Program and Project Risk Score is to capture on a relative basis the safety, environment, and reliability risks that each project or program in Gas Operations aims to prevent, based on the worst-

[71] PG&E Supplemental Testimony, Ch. 2A, p. 2A-6, lines 1-19 (footnotes omitted, emphasis added).

case credible event that the project mitigates in each risk category (safety, environmental and reliability).[72]

Unlike the Risk Register scores, the Program and Project Risk Score are based on the highest single score of three categories of consequences: safety, environmental impact, and reliability.

Q. WHY DOES PG&E ESTIMATE PROJECT RISK IN THIS FRAMEWORK BY SELECTING THE ATTRIBUTE WITH THE HIGHEST SCORE?

A. PG&E provides three reasons. These are:

- The consequence and likelihood scales increase along an exponential curve, even though they are represented by the categorical numbers 1 through 7. Therefore, any given risk score could represent a magnitude of risk that is 10% to 300% higher than the magnitude of risk represented by the next lowest risk score (e.g. a risk score of 22 represents a magnitude of risk 50% higher than the magnitude of risk represented by a risk score of 21);
- Aggregating different scores (1-49) into one score would be mathematically incorrect;
- Individual category risk scores are available during prioritization decisions as necessary (e.g. [sic] could decide to prioritize a project with a reliability risk score of 21 and safety risk score of 18 ahead of a project with a reliability risk of 21 and a safety risk score of 1).[73]

Q. ARE THESE THREE REASONS GIVEN BY PG&E VALID?

A. No. In part, the reasons reflect PG&E's incorrect use of multi-attribute analysis. The first reason – nonlinearity of the scales – does not seem to bother PG&E for purposes of ranking risks using the Risk Register process. As we discussed in Section IV, a multi-attribute process does not require that all attributes be ranked using linear scales. The

[72] *Id.* at 2A-7, lines 8-14 (footnotes omitted).

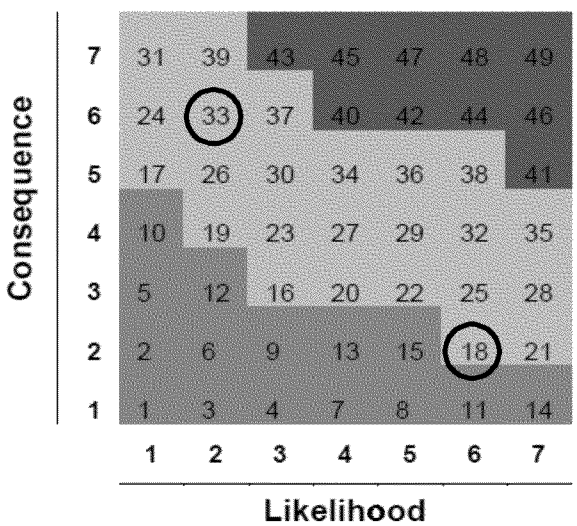
[73] PG&E Supplemental Testimony, Attachment B, GTS-RateCase2015_TURN_01-Q001, Att. 13, p.2A-B-516 – 2A-B-517.

second reason—aggregating scores would be mathematically incorrect—is true, but only if scores are aggregated using PG&E's methodology or some other incorrect methodology. Again, however, all valid multi-attribute implementations aggregate individual attribute values for ranking purposes. The third reason – that individual category risk scores are available during prioritization decisions – is irrelevant. Moreover, the particular example PG&E uses is an example of *dominance*. As long as the weight attributed to "safety" is greater than zero, the first project will necessarily be riskier than the second, as they both have the same reliability risk score.

Q. ARE THESE PROGRAM AND PROJECT RISK SCORES BASED ON THE SAME APPROACH AS THE RISK REGISTER?

A. No. Although they are presented using the same type of LoF x CoF format, as shown in Figure 3 (which reproduces the figure shown on page 3 of TURN-1-001 Attachment 13), and as we discussed previously, the "risk" values are no longer the same. For example, in the Program and Project Risk Scoring process, the risk score for a project with LoF and CoF values of two and six, respectively, is 33, whereas the risk score for a project with LoF and CoF values of six and two, respectively, is 18.

Figure 4: PG&E Program and Project Risk Matrix



Defining risk as the product of LoF and CoF, but assigning different risk values to events having the same risk scores is impossible when using a relative risk methodology. Thus, unlike in the risk register process, PG&E measures risk differently that the Company does for the Risk Register.

Q. DOES PG&E USE THE SAME ATTRIBUTES AND ATTRIBUTE WEIGHTS IN THIS STEP TO DETERMINE CoF VALUES?

A. No. Rather than using six attributes, PG&E uses three attributes and different weights. Then, PG&E ignores the weighted values and simply ranks the risk of an event based on its highest attribute score, which defeats the entire purpose of the multi-attribute approach to evaluating consequences and makes it impossible to determine an optimal risk management strategy.

Q. HOW DOES THE FOURTH STEP OF PG&E'S PROCESS FIT IN?

A. Recall that, in the fourth step, the results of the Program and Project Risk Scoring process is then reviewed by different PG&E committees until a final set of projects is selected and approved by PG&E senior management. How that final set is selected is not clear, because PG&E never identifies the objectives and constraints on which senior management ultimately uses to make the project selection decisions.

Q. WHAT DOES THIS MEAN IN PRACTICAL TERMS?

A. It means that PG&E's entire process is fundamentally flawed and opaque, and that the Company's choice of projects will not, and cannot provide the best value for ratepayers.

Q. CAN THESE FAILURES BE CORRECTED?

A. Yes. We would prescribe the same steps as discussed previously. First, clarify the risk reduction objective and identify the specific budget, manpower, and equipment constraints PG&E must deal with. Second, develop a consistent set of attributes and attribute weights. Third, develop an optimal set of risk management projects consistent with the relative risk reductions they provide and the constraints.

3. PG&E Has Not Estimated the Risk Reduction Value of Potential Mitigation Measures

Q. HAS PG&E EVER ESTIMATED THE RISK REDUCTION VALUE OF POTENTIAL MITIGATION MEASURES?

A. No. To the contrary, PG&E states that it *has not* estimated risk reduction. In PG&E's data response to Data Request IP 07-02, PG&E admitted that the Company "does not numerically quantify risk reduction on a system level" nor does the Company "numerically quantify residual risk at a system level."[74]

PG&E also states that "[t]he Heat Maps do not provide a total quantified level [of] risk reduction."[75] That's true, of course, because PG&E is using a <u>relative</u> risk methodology. However, the most important components of the relative risk methodology are: (1) measuring relative risks and (2) evaluating the relative risk reductions of different risk management strategies so as to determine an optimal strategy. PG&E does neither.

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[74] GTS-RateCase2015_DR_IS_07-Q002 (b), (d), attached as Exhibit JAL/CDF-7.

[75] *Id*. at (e).

Q. WHAT IS THE CONSEQUENCE OF FAILING TO ESTIMATE THE RISK REDUCTION VALUE OF VARIOUS MITIGATION MEASURES?

A. Without estimating the expected reductions in risk associated with different risk mitigation alternatives, whether in relative or absolute terms, there is no analytical basis with which to select from among specific alternatives.

Q. IS YOUR VIEW ON THE LACK OF RISK REDUCTION ESTIMATES CONSISTENT WITH THE SED REPORT?

A. Yes. SED reaches a similar conclusion from a narrower perspective. The SED Report concludes that "PG&E has not made a showing of the incremental risk reduction achieved by the [Risk Control Measures] to justify the proposed scope and pace of implementation." [76] The SED Report also highlights this lack of risk reduction information regarding several of PG&E's proposed risk-management programs. For example, in commenting on the Company's proposed hydrostatic testing program, the SED Report states, "PG&E summarily states that its forecast 'provides the most appropriate risk reduction associated with previously untested pipe' but does not provide detail or quantification of said risk reduction."[77] Similarly, regarding PG&E's proposal to replace 20 miles of vintage pipe per year, the SED Report states that, "there is no basis by which to compare PG&E's determination of the right pace or sufficient surrounding analysis to support its conclusion."[78]

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[76] SED Report at 12.

[77] *Id*. at 14.

[78] *Id*. at 15.

Q. CAN THIS FAILURE BE CORRECTED?

A. Yes. PG&E must be able to determine the change in the LoF and CoF associated with different risk management measures. This is a fundamental requirement for determining which risk management programs to undertake.

4. PG&E's Calculation of Likelihood of Failure is Flawed

Q. PLEASE DESCRIBE THE ROLE OF LOF IN PG&E'S METHODOLOGY.

A. LoF is the first half of the relative risk methodology. As described previously, the risk associated with a given threat is measured as the product of LoF and the consequences of failure (CoF).

Q. PLEASE SUMMARIZE YOUR CONCLUSIONS REGARDING PG&E'S LOF METHODOLOGY.

A. PG&E's methodology lacks any statistical validity. It is simply an arbitrary way of taking event frequencies and converting them to pseudo-probabilities. Specifically, the methodology exhibits the following failures:

- PG&E has wrongly conflated statistical "likelihood" with statistical probability;

- PG&E has wrongly treated different characteristics contributing to the likelihood of failure as mutually exclusive, despite discussing interdependencies that affect the likelihood of asset failure;

- PG&E has wrongly used a "linear probability" model, which is not a probability model at all and which allows for nonsensical results (e.g., probabilities greater than one.)

Q. HOW DOES PG&E DETERMINE THE LIKELIHOOD OF FAILURE?

A. The derivation of LoF is described in Section 8 of PG&E's Risk Management Procedure. PG&E defines LoF as the <u>sum</u> of the "normalized" values (i.e., a value between zero and one) of eight separate "threat" categories:

(1) External corrosion,
(2) Internal corrosion,
(3) Stress corrosion cracking,
(4) Third-party damage,
(5) Weather-related outside forces,
(6) Manufacturing and construction-related risks,
(7) Equipment, and
(8) Incorrect operations.[79]

For each of these categories, PG&E assigns a non-linear occurrence frequency, similar to an "order of magnitude" value used on the Richter scale to measure earthquake severity: once every year, once every ten years, etc. PG&E takes these estimated event frequencies and normalizes the occurrence frequency value to between 0 and 1 for each threat. The LoF is calculated by adding up the normalized scores of all of the different threats. Thus, the possible range of LoF values is between 0 and 8. Nevertheless, the PG&E's Heat Maps show LoF values between 0 and 7.

Q. ARE THESE LOF VALUES THE SAME AS STATISTICAL PROBABILITIES, SUCH AS THE PROBABILITY OF A COIN LANDING ON "HEADS"?

A. No, LoF values cannot be thought of as statistical probabilities. As PG&E states in its response to ORA-17-005 "the categorization, and resulting risk ranking score, is

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[79] *See* GTS-RateCase2015_DR_IP_02-Q085, Att. 1, Section 8.3, attached as JAL/CDF-11.

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not intended to predict the mathematical probability of that specific failure occurring at any given time, but instead, to establish a relative ranking of the likelihood of failure."[80]

Q. CAN YOU DESCRIBE THE STATISTICAL PROBLEMS RAISED BY PG&E'S PROPOSED TREATMENT OF LOF?

A. Yes. PG&E simply adds up the eight categories of threats, so the Company is inherently treating each separate threat category as mutually exclusive. In other words, if a pipe failure results from, say, internal corrosion, it cannot also result from a manufacturing defect. For PG&E's approach to work, the specific causes of a failure cannot interact, that is, they must be mutually exclusive. However, as stated in PG&E's Risk Evaluation Methodology, "Threat interaction is acknowledged in the summations of the individual threat scores. Further evaluation for possible threat interaction is done by examination of combinations of certain threat scores."[81] Thus, PG&E's current approach to account for "threat interaction" by adding up the individual threat scores is not valid.

For example, because external corrosion and internal corrosion interact, the probability that a pipe will rupture is greater if both types of corrosion occur, than if either type occurs by itself. Using PG&E's methodology suppose the probability that either internal corrosion or external corrosion will cause a given pipe to fail are each estimated to be 60%. In that case, PG&E's methodology implies that the probability the pipe will fail in the presence of both internal and external corrosion is 60% + 60% = 120%. Clearly, this is impossible because the probability of failure cannot be greater than 100%, which corresponds to certainty. Although our example may be extreme, PG&E's adding up likelihoods to estimate probabilities is not accurate.

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80 GTS-RateCase2015_DR_ORA_17-Q005, attached as JAL/CDF-12.

81 *See* GTS-RateCase2015_DR_IP_02-Q085, Att. 1, Section 8.3, attached as JAL/CDF-11.

Q. WHY CAN'T PG&E ADD UP THE LIKELIHOODS OF INDIVIDUAL EVENTS SUCH AS INTERNAL AND EXTERNAL CORROSION TO OBTAIN AN OVERALL LIKELIHOOD VALUE FOR FAILURE?

A. Regardless of whether the LoF values are statistical probabilities or not, the underlying analysis must conform to basic statistical properties and constraints, such as the statistical probability of an event not exceeding 100%.[82] To understand this, note that PG&E ties LoF values to the frequency with which an event is expected to occur. For example, suppose that a rupture on a given pipe segment can be caused only by external or internal corrosion. Suppose also that the estimated frequency of a rupture caused either by internal or external corrosion is once per year for pipe in a given condition. One

[82] The reason one cannot add likelihoods the way PG&E's methodology does, is based on a well-known mathematical model that converts the rates at which events occur over time into probabilities. This model is called a "Poisson" process, and is the most common approach to calculating the probability that "events" will take place whenever the average rate at which an event "arrives" are known. A typical example is the number of customers who enter a store each hour to shop. Each arriving customer is an "event." Suppose that the average number of arriving customers is 10 per hour. That does not mean 10 customers will arrive every hour; in some hours, fewer customers will arrive, while in other hours more will arrive. A Poisson process is used to calculate the probability that a specific number of customers will arrive in a given hour. In our corrosion example, we can think of a pipe failure as an "arrival." Thus, the arrival rate is one per year for either an internal or external corrosion event. The expected number of arrivals because of either cause can be found by adding their "arrival" rates, which is two per year. However, the probability of one or the other type of failure occurring in a year is not equal to the sum of the probabilities of each individual type of failure. Nor is the probability of either event occurring in a year proportional to the sum of the individual arrival rates. Yet, this is what PG&E's approach assumes. For a discussion of the Poisson process, *see* Sheldon Ross, *Introduction to Probability Models*, 7th ed. (New York: Academic Press 2000), pp. 256-284.

Ironically, PG&E converts the overall likelihood values into probabilities using a Poisson process, as shown in the spreadsheet provided by PG&E as Confidential Attachment 3 to TURN-1-001, as can be seen in column "L" of the worksheets "Risk Matrix Input" and "Risk Matrix Input (ERM Fin.)" (attached as Confidential Exhibit JAL/CDF-8). Although the probability values shown "Risk Matrix Input (ERM Fin.)" are transferred to another worksheet, "Summary Risk Scores," they are never used in PG&E's analysis. (The probabilities shown in the "Risk Matrix Input" also are not used anywhere else.)

cannot, as PG&E has, add the two likelihoods and conclude that the likelihood of a rupture on the pipe segment is twice per year. This is simply wrong.

Q. ARE THERE OTHER STATISTICAL PROBLEMS WITH PG&E'S APPROACH TO CALCULATING LoF VALUES?

A. Yes. The additive formula and LoF x CoF risk construct used by PG&E to calculate LoF assumes that an asset failure caused by any of the eight separate threats has the same consequence. Thus, if a pipe fails because of a manufacturing defect, the consequences must be exactly the same as a failure caused by corrosion, earthquake, flood, or an improperly trained employee. To use an analogy, a flat tire on your car is a "failed" tire. But a tire "failure" caused by a defective valve that caused a slow leak will have different consequences than if the failure is a sudden blowout on the highway.

Using PG&E's LoF x CoF approach, the CoF values associated with an asset's failure must be the same, regardless of the cause of failure. However, the CoF values defined by PG&E are not always the same, as they must be. For example, PG&E's response to IS-2-019(p)[83] references a spreadsheet that was provided as Confidential Attachment 3 to TURN-1-001. The worksheet "Transmission" in that spreadsheet provides both the LoF and CoF values used by PG&E for its risk matrix.[84] Each risk shows six CoF data values, associated with the six consequence categories used in PG&E's Heat Map Methodology.[85] As can be seen, the CoF values for the different

[83] PG&E Supplemental Testimony, Confidential Attachment 2A, Volume 1, Confidential GTS-RateCase2015_DR_TURN_01-Q001. Att. 3.

[84] *Id.*

[85] *Id.* at Att. 4. We discuss derivation of the CoF values themselves in the next section.

types of pipeline threats assumed by PG&E are not exactly the same. Therefore, the identical consequence requirement for PG&E's additive LoF construction is violated.

Q. ARE THERE ANY OTHER PROBLEMS WITH PG&E'S DERIVATION OF LoF VALUES?

A. Yes, PG&E states that the Company uses a scaling process in order to use a "linear probability distribution" to ensure all of the resulting "probability" values are between 0 and 1, instead of LoF values between 0 and 7.[86] The entire process is superfluous when using a relative risk methodology because that methodology does not rank different threats based on their absolute statistical risk.

Q. IS THIS SCALING PROCESS USED TO CREATE ACTUAL STATISTICAL PROBABILITIES?

No. While the LoF values may look like statistical probabilities, the entire process has no statistical validity. The conversion process for LoF values does not create statistical probabilities at all, such as the probability of a fair coin landing on "heads." It is simply an approach to rescale PG&E's estimated likelihood values, apparently to create the *appearance* that the analysis creates statistically valid probabilities of various events, such as pipeline ruptures caused by an earthquake. The result is the creation of values that look like probabilities because they are scaled to values between 0 and 1.[87]

For example, using PG&E's scaling process, the "pseudo-probability" of Event A, which is expected to occur 10 times each year, would be calculated as 85.7%. The pseudo-probability of Event B, which is expected to occur once every 100 years, would

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[86] As we discussed previously, PG&E's normalized LoF scores could actually fall between 0 and 8 (eight factors, each with values between 0 and 1, that are added up), but PG&E's Heat Maps show LoF values between 0 and 7.

[87] This scaling process is described in PG&E Supplemental Testimony, Attachment B, GTS-RateCase2015_DR_TURN_01-Q001. Att. 4, p. 3.

be calculated as 42.9%. Thus, under PG&E's scaling approach, the "probability" of Event B, even though it is expected to occur at 1/1000th the frequency of Event A, has a "probability" of about half that of Event A.

This scaling leads to nonsensical results. For example, suppose that Events A and B have the same consequences. Then, because risk is defined as the product of LoF and CoF, then based on this scaling process, Event A will have just twice the risk of Event B, even though, on a probabilistic basis, the expected cost of Event A is 1,000 times greater than the expected cost of Event B.

If the relative-risk methodology is to have any grounding in reality, it must be able to provide a reasonable relative ranking of expected losses. To develop an optimal risk management strategy, we must do more than simply determine that Event A has a greater relative risk than Event B; one must also be able to determine how much higher risk does Event A have relative to B (a lot? a little?). However, PG&E's transformation of LoF values, which are themselves problematic, into a different scale of values between 0 and 1 does not do this accurately.

Q. CAN PG&E'S LOF CALCULATIONS BE CORRECTED?

A. Yes. PG&E can adopt a probabilistic methodology that calculates statistical probabilities from likelihood values using the Poisson process discussed in footnote 74.

5. PG&E's Calculation of Consequences of Failure is Flawed

Q. PLEASE DESCRIBE THE ROLE OF COF IN PG&E'S METHODOLOGY.

A. CoF is the second half of the relative risk methodology because, as described previously, the risk associated with a given threat is measured as the product of LoF and CoF.

Q. PLEASE SUMMARIZE YOUR CONCLUSIONS REGARDING PG&E'S CoF METHODOLOGY.

A. We conclude that PG&E's CoF calculations lack any statistical validity. It is simply an arbitrary way of taking the characteristics of different events (e.g., loss of service) and converting them into values. Specifically:

- The PG&E methodology treats equal *numerical* reductions in CoF as equally valuable. Not only does this violate common sense, it is inconsistent with the nonlinear way in which PG&E determines the LoF and CoF values associated with different events.
- The six attributes PG&E uses to determine an overall CoF score are inconsistent and duplicative.
- The weights that PG&E uses for the six attributes that determine an overall CoF score are not anchored to measureable, real-world changes.
- As discussed previously regarding multi-attribute models, because PG&E specified these weights independently and because the scaling factors PG&E used do not correspond to actual changes in real attribute levels, the CoF values, as defined, do not, and cannot, reflect the true value of real changes to actual attributes.

Q. CAN YOU EXPLAIN HOW PG&E DETERMINES THE CONSEQUENCES OF FAILURE?

A. Yes. The methodology is set out in PG&E's Heat Map Methodology. Recall that, in the second step of PG&E's process to create the Risk Register, CoF values are calculated as weighted averages of six identified attributes.[88] The specific attributes and the weights PG&E assigns them are shown in Table 2.

[88] PG&E Supplemental Testimony, Attachment B, GTS-RateCase2015_DR_TURN_01-Q001. Att. 2, p. 2A-B-6.

Table 2: CoF Factors and Weights

Category of Impact	Percentage Weight
1. Health and Safety	30%
2. Regulatory Compliance	5%
3. Environmental Impact	5%
4. Reliability	30%
5. Reputation	25%
6. Direct Financial Damage	5%

Under PG&E's approach, categories 1 – 3 are all considered "Safety" related, while categories 5 and 6 are considered "Financial."[89]

Q. IS THIS AN EXAMPLE OF A MULTI-ATTRIBUTE OR MULTI-OBJECTIVE ANALYSIS?

A. Yes. PG&E's development of multiple CoF categories, and weights for those different categories, as part of its relative risk assessment is just an application of multi-attribute utility analysis that we described previously in Section IV. PG&E attempts to trade off many different objectives in the presence of multiple constraints.

Unfortunately, PG&E violated fundamental principles of multi-attribute analysis by failing to select a valid set of attributes and valid attribute weights, based on the requirements we previously described. PG&E also failed to provide measures of the changes in attribute values, which belies the entire purpose of this type of analysis. If one does not calculate the changes in the attribute values, it is impossible to measure the benefit of doing so, and thus impossible to select an optimal set of actions.

[89] *Id.*

Q. DOES PG&E STATE HOW THE CoF WEIGHTS WERE DETERMINED?

A. Yes, but PG&E provides conflicting responses with no analytical basis. For example, PG&E's response to ORA-17-001 states that the weights were approved by the Company's Chief Risk and Audit Officer.[90] The Heat Map Methodology document states that the weighted scoring method itself was developed by PG&E's Energy and Risk Management (ERM) department.[91]

Nowhere does PG&E provide any analytical basis for determining the weights. Instead, according to PG&E's response to ORA-17-006:

> PG&E's Risk Evaluation Tool was designed to produce a priority list of risks that are aligned with the company's objectives. This meant the tool needed to place an emphasis on the top risks that could threaten PG&E's ability to deliver safe, reliable, and affordable gas and electric service. To achieve this, Safety related consequences in the risk register, and listed in Table 2 of the Method for Calculating Weighted Risks and Determining the Heat Map, are weighted at 40% by adding Health and Safety at 30%, Environment at 5%, and Regulatory Compliance at 5%. Reliability consequences are weighted at 30% between Reliability at 25% and Reputation at 5%, and finally, Financial consequences are weighted at 30%. The weighting of these factors mirror the weighting of the same factors included in PG&E's short term incentive plan (STIP) (Safety – 40%, Reliability – 30%, and Financial – 30%), which also are aligned with management's goal of delivering safe, reliable and affordable gas and electric service (*emphasis added*).[92]

In addition to the analytical flaws associated with arbitrarily selecting these weights, as we discuss below, the quoted explanation reveals that the determination of "top" risks is fundamentally circular. The "top" risks are those that mirror the Company's objectives,

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90 GTS-RateCase2015_DR_ORA_17-Q001, attached as Exhibit JAL/CDF-13.

91 PG&E Supplemental Testimony, Attachment B, GTS-RateCase2015_DR_TURN_01-Q001. Att. 2, p. 2A-B-7.

92 GTS-RateCase2015_DR_ORA_17-Q006, attached as JAL/CDF-14.

but the Company's objectives reflect only a qualitative determination of how different types of risks will affect it, rather than the structured analytical basis required for multi-attribute analysis. Ultimately, the "top" risks are "top" because the Company says they are, not because of any objective analysis of consequences based on an appropriate weighting scheme.

Q. CAN YOU EXPLAIN WHY PG&E'S RELATIVE RISK RANKINGS CANNOT BE CORRECT?

A. Yes. To understand this, recall that PG&E defines "risk" as LoF *x* CoF. Therefore, the benefit of mitigating a given risk equals the <u>difference</u> between the risk value before mitigation and the value after mitigation:

$$\textbf{Risk Mitigation Benefit} = (\textbf{LoF}\ x\ \textbf{CoF})_{\textbf{BEFORE}} - (\textbf{LoF}\ x\ \textbf{CoF})_{\textbf{AFTER}}.$$

Mitigation can change LoF, CoF, or both. Moreover, recall that the LoF and CoF scales PG&E has used are not linear, but reflect order of magnitude differences. For example, a CoF value of 2 is not twice the consequence of a CoF value of 1, but is 10 times the consequence. The LoF scale increases in the same way.

Recall also that PG&E established weights for the CoF attributes independently of the attribute values themselves, contrary to what is required for a multi-attribute analysis. PG&E's *nonlinear* scaling of CoF is mathematically inconsistent with how it applies *linear* values to risk mitigation.

For example, suppose PG&E designs two risk mitigation projects, A and B, to reduce the consequences of an earthquake. Let's suppose further that the likelihood of an earthquake is estimated to have a value of 2 on PG&E's 1 to 7 scale. Project A reduces the consequences of an earthquake from 7, the highest possible value, to 6. Project B reduces the consequences from 2 to 1, the lowest possible value. Thus both projects reduce the consequences of an earthquake by 1 point on PG&E's 7- point scale and both projects will have the same Risk Mitigation Benefit, with a value of 2.[93]

Intuitively reducing the consequences from catastrophic to severe will be far more valuable than reducing them from minor to inconsequential.

Not only does the equality of the two mitigation programs' benefits violate common sense, PG&E's weights, shown previously in Table 2, make the equal valuation impossible. The only reason PG&E's methodology leads to equality is because the weights chosen are not anchored to real-world measures.

Q. WHY DO YOU BELIEVE PG&E'S WEIGHTS ARE NOT ANCHORED TO REAL-WORLD MEASURES?

A. Recall from Table 2 that PG&E assigns Health and Safety (H&S) and Direct Financial Damage (Fin) equal weights of 30% each. This means that a risk mitigation action that moves Health & Safety from its worst level (7) to its best level (1) provides the same risk reduction value as an asset management action that moves Financial Damage from its worst level (7) to its best level (1). Given how PG&E itself defines these two attributes, <u>this equivalence means that PG&E considers avoidance of large loss of life and injuries to have no greater priority than saving lots of money</u>.

[93] For each project the mitigation benefit = LoF *x* (CoF_{BEFORE} – CoF_{AFTER}) = 2 *x* (1) = 2.

Q. HOW DOES PG&E DEFINE THE FINANCIAL DAMAGE ATTRIBUTE?

A. According to PG&E's response to IS-2-003(a)(v):

> Shareholder risk is implied in the Financial consequence category of the Risk Register, but the focus of the Asset Family Owners and the subject matter experts in preparing the Risk Register was on the potential financial cost itself. See GTS-RateCase2015_DR_IndicatedProducers_002-Q003Atch01, page 3, for the PG&E enterprise risk management definition of financial consequence.[94]

PG&E defines Financial Consequence as the "Probability of loss inherent in the methods used in financing an organization that may impair its ability to provide adequate return."[95] These financial consequences are can take on three values: High (H), Medium (M), and Low (L), as shown in Figure 4.[96]

Figure 4: Financial Consequences Definitions

Corporate Objective: Finance (30%)

Impact Assessment Categories	Impact	Impact Criteria
Financial (30%)	H	Potential fine/impact > $100 million
	M	Potential fine/impact between $100 and $50 million
	L	Potential fine/impact < $50 million

Thus, under PG&E's approach, avoiding a major financial impact would have the same value as avoiding an event that results in loss of life or serious injuries.

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94 GTS-RateCase2015_DR_IP_02-Q003(a)(v), attached as Exhibit JAL/CDF-7.

95 GTS-RateCase2015_DR_IP_02-Q003, Att. 1, p. 3, attached as Exhibit JAL/CDF-7.

96 *Id*. at Att. 1, p. 4.

In fact, PG&E recognizes this as an issue with its weighting methodology. Therefore, as explained on page 2 of PG&E's Heat Map Methodology document, the Company states that:

> [T]his results in a dilution due to the weighting factors and to a dissatisfying and contra-intuitive result as the overall risk is lower than the original Health and Safety value. To compensate for this effect, the result is divided by the health and safety weight factor.[97]

Thus, PG&E admits that the weighted risk score provides results that are inconsistent with reality, which means that the weights and methodology used to estimate consequence values are methodologically flawed.

Q. DID PG&E ATTEMPT TO CORRECT THIS METHODOLOGICAL FLAW?

A. Yes. To overcome this serious methodological flaw, PG&E divides all of the weights by 0.30.[98] In its response to ORA-17-008(c) PG&E justifies this approach, stating:

> Dividing the health and safety weight factor by 0.3 assures that the final consequence score is at least as high as the normalized Health and Safety score. Since safety is the most important of the consequence categories, it makes sense that a final consequence score would at least result in a Health and Safety consequence score that matched the normalized Health and Safety scores. PG&E believes this conservative approach is appropriate.
>
> In addition, when viewing the risk register, there is a difference in the consequence values shown on the "Risk Matrix Input Data" and the "Risk Matrix Input Data (ERM Fin)" tabs. The reason for this difference is to further apply conservatism when comparing Financial and H&S consequence scores with the expectation that the final risk ranking places H&S consequences above Financial consequences. Although PG&E

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[97] PG&E Supplemental Testimony, Attachment B, GTS-RateCase2015_DR_TURN_01-Q001, Att. 2, p. 2A-B-7.

[98] *Id.*

> weights consequence scores at 30% for each Health and Safety and Financial, PG&E prioritizes Health and Safety over Financial consequences. PG&E adjusted consequence scores where the Financial consequence score could cause the risk to rank higher than one with an equal or greater Safety and Health consequence score.[99]

Q. IS PG&E'S "CONSERVATIVE APPROACH" REASONABLE?

A. No. Rather than arbitrarily rescaling all of the weights, PG&E should have asked why the weights and scales it was using gave "contra-intuitive results." Quite simply, PG&E should have asked *why* the results were inconsistent with reality.

PG&E did not do this. Instead, the Company simply made the overall result cosmetically pleasing, so that the results would not appear absurd. Had PG&E specified the weights and scales based on the relative benefits of actual changes to well-defined attributes, this kind of "contra-intuitive" result cannot occur. As we discussed in Section IV, when a multi-attribute value function is specified correctly, the weights and scales are continually updated with reference to reality and are cross-referenced with respect to the different values.

Q. WHAT ARE THE IMPLICATIONS FOR PG&E'S RELATIVE RISK APPROACH IF THE ATTRIBUTE WEIGHTS ARE NOT CREDIBLE?

A. If the weights are not credible and the components are not anchored in reality, the entire procedure proposed by PG&E is not theoretically valid. As such, the methodology cannot justify any risk management actions.

Real world asset management actions, including risk management actions, have measureable and predictable, although uncertain, consequences. Those consequences can be expressed in terms of changes to the six attributes that PG&E specifies. However, to

[99] GTS-RateCase2015_DR_ORA_17-Q008, attached as Exhibit JAL/CDF-15 (footnote omitted) (emphasis added).

be valid (and useful), a risk measurement scheme must translate those attribute changes into measurements of value that can be compared and added together. In other words, we must be able to specify which of two proposed changes in two different attributes' levels is more valuable. As we have shown, PG&E's method cannot do this with any credibility.

Q. ARE YOU SUGGESTING PG&E NOT EVALUATE THE IMPACTS OF DIFFERENT RISKS AND ESTABLISH PROGRAMS TO MANAGE THOSE RISKS?

A. Of course not. Fundamentally, economic resources are limited. Therefore, it is imperative that the different risks be evaluated and programs be designed to maximize the overall value of asset management decisions that reduce these risks in ways that maximize the value of the resources devoted to risk reduction. However, because of its fundamental flaws, PG&E's methodology cannot do this in any reasonable and consistent manner. Therefore, PG&E's methodology cannot determine the risk reduction strategies that maximize benefits and will not result in risk management actions that provide the best value for the ratepayer money the Company is requesting.

Because accurately addressing competing factors of risk, cost, and value are imperative, and because PG&E's multi-attribute analysis is so fundamentally flawed, we recommend the Company redo the analysis entirely using correct procedures.

Q. CAN THIS FAILURE BE CORRECTED?

A. Yes. As we have discussed previously, PG&E can implement a multi-attribute approach consistent with the approach we describe in Section IV.

C. Illustrating PG&E's Failures: Transmission Pipe AMP

Q. WHAT DO YOU CONCLUDE ABOUT THE MITIGATION MEASURES IDENTIFIED IN THE TRANSMISSION PIPE AMP?

A. [redacted]

Q. WHY DID YOU SELECT THE TRANSMISSION PIPELINE AMP FOR THIS EXAMPLE?

A. [redacted]

[100] PG&E Supplemental Testimony, Att. B, Confidential GTS-RateCase2015_DR_TURN_01-Q001. Att. 11 (Transmission AMP).

[101] Confidential Transmission Pipe AMP, p. 38, Tables 8 and 9.

[redacted]

[redacted]

Q. DOES THE TRANSMISSION PIPE AMP IDENTIFY ITS OVERALL OBJECTIVE?

A. [redacted]

[redacted]

[redacted]

[102] PG&E Direct Testimony, Vol. 1, Ch. 3, p. 3-7, lines 6-10.

[103] *Id.* There are no expense estimates for 2016 and 2017.

[104] PAS 55:1- 2008, p. vii.

Q. HAS PG&E CORRECTLY CALCULATED THE LoF WHEN DEVELOPING THE TRANSMISSION PIPE AMP?

A. [redacted]

Q. DID PG&E PROPERLY USE THE RELATIVE RISK MODEL?

A. [redacted]

Q. DID PG&E PROPERLY IDENTIFY RISKS?

A. [redacted]

Q. [redacted]

A. [redacted]

Q. DID PG&E PROPERLY SELECT RISK MITIGATION PROJECTS?

A. [redacted]

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[105] Using PG&E's own definition of "risk" as LoF *x* CoF, what PG&E defines as "risks" are actually events.

[106] *See* Confidential Transmission Pipe AMP, Figure 7, p.20.

[107] *Id.* at 20.

Q. [redacted]?

A. [redacted]

Q. [redacted]

A. [redacted]

Q. DOES THE TRANSMISSION PIPE AMP SET OUT AN OPTIMAL RISK MANAGEMENT APPROACH THAT PROVIDES THE BEST VALUE FOR RATEPAYERS?

A. [redacted]

[108] *Id. at 12.*

Q. DOES THIS AMP IDENTIFY WHAT THE CONSTRAINTS ARE?

A. [redacted]

Q. DOES THE AMP DISCUSS DATA REGARDING THE CONDITION OF PG&E'S TRANSMISSION PIPE?

A. [redacted]

Q. DOES THE AMP SHOW HOW THESE CONDITION DATA ARE USED TO DETERMINE LoF VALUES?

A. [redacted]

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[109] Transmission Pipe AMP, p. 14.

[110] PG&E Direct Testimony, Vol. 1, Ch. 1, p. 1-8, line 25.

[111] PG&E Direct Testimony, Vol. 1, Ch. 2, p. 2-15, lines 14-15.

[112] Confidential Transmission AMP, Table 3, pp. 21-22.

[redacted]

Q. WHY DOES KNOWING THE CONDITION OF VINTAGE PIPE MATTER?

A. There are two reasons. First, an optimal program designed to replace vintage pipe will, one hopes, replace all pipe that is in poor condition. Second, an optimal program will not replace pipe that is in good condition and does not require replacement. In statistics, these are known as Type 1 and Type 2 errors, respectively.[113] By not knowing the true condition of the assets to be replaced, both types of errors are inevitable.

Q. ARE YOU SUGGESTING THAT PG&E SHOULD NOT COLLECT ADDITIONAL INFORMATION ABOUT PIPELINE ASSET CONDITIONS?

A. Of course not. An integral part of an optimal asset management strategy includes developing an optimal testing strategy. That is why one of our recommendations to the Commission is to have PG&E focus on collecting data on the condition of its system and develop condition-dependent hazard functions.

Q. DOES THE TRANSMISSION PIPE AMP DISCUSS MITIGATION PROGRAMS?

A. [redacted]

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[113] In statistical parlance, a Type 1 error refers to rejecting the null hypothesis (i.e., the pipe is in good condition) when it is true, or "convicting the innocent." A Type 2 error refers to not rejecting that null hypothesis when it is false, or "releasing the guilty." In other words, a Type 1 error replaces good pipe whereas a Type 2 error leaves bad pipe in the ground.

[redacted]

[redacted]

[redacted]

[redacted]

Q. WHAT DOES PG&E PROPOSE TO SPEND ON VINTAGE PIPE REPLACEMENT?

A. [redacted]

[114] PG&E Direct Testimony, Vol. 1, Ch. 3, p. 3-12, Table 3-3, line 4.

[redacted]

Q. HOW MUCH VINTAGE PIPE DOES PG&E STATE IT WILL REPLACE?

A. According to the testimony of PG&E witness Barnes, "We determined that 20 miles of pipeline replacement per year is the right pace for reducing risk for these interacting threats during the rate case period because we are able to reduce risk to 90 percent of the population in the vicinity of our pipelines."[115]

Q. DID PG&E PROVIDE ANY EVIDENCE ON HOW IT DETERMINED THAT REPLACING 20 MILES OF PIPE PER YEAR WAS "THE RIGHT PACE?"

A. No. We found no evidence for the 20 mile per year replacement decision, in Mr. Barnes's testimony, the workpapers for Chapter 4A, or in the Transmission Pipe AMP. Moreover, in its response to IS-9-006,[116] PG&E simply referred back to Mr. Barnes's testimony quoted above.

Q. BUT ISN'T REDUCING THE THREAT TO 90% OF THE POPULATION LIVING NEAR PG&E'S PIPELINES REASONABLE?

A. It may be. Then again, it may be that an optimal risk management strategy would include replacing 30 miles of pipe each year, rather than 20 miles. It may be that that only 10 miles of pipe should be replaced per year, or that none of the pipe should be replaced.

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[115] PG&E Direct Testimony, Vol. 1, Ch. 4A, p. 4A-55, lines 17-20.

[116] GTS-RateCase2015_DR_IS_09-Q006, attached as Exhibit JAL/CDF-16.

PG&E says that it will reduce risk to 90% of the population, but never specifies by how much. The quantity of risk reduction, as measured by PG&E's relative risk approach, is the key missing piece of data, and thus it is impossible to compare the risk reduction benefits of PG&E's 20-miles-per-year VPR program with alternative replacement rates or with other risk management programs. Thus, PG&E's analysis provides no empirical support whatsoever for any of the Company's decisions. Because PG&E's Heat Map analysis is so fundamentally flawed and because the Company never estimates the risk-reduction benefits, it is simply not possible to determine what an optimal risk management program would be.

Q. HAS PG&E DEMONSTRATED THAT THE OTHER PROPOSED MITIGATION STRATEGIES SET FORTH IN THE TRANSMISSION PIPE AMP WILL PROVIDE OPTIMAL VALUE FOR RATEPAYERS?

A. No. Given the methodological flaws and the contradictory statements, as well as the lack of any analysis that even shows the predicted risk reductions of the programs, PG&E has clearly failed to demonstrate that the proposed programs provide ratepayers with the most value for the ratepayer funds requested by PG&E.

VI. CONCLUSIONS AND RECOMMENDATIONS

Q. WHAT ARE YOUR CONCLUSIONS?

A. As demonstrated above, PG&E's risk management approach is fundamentally flawed and does not result in an optimized risk management plan.

Q. WHAT ARE YOUR RECOMMENDATIONS?

A. The most effective solution would be to direct PG&E to correct the fundamental flaws in its methodology before proposing additional spending on risk management activities. Alternatively, the Commission could direct PG&E to correct the flaws prospectively and limit preauthorization of additional spending until PG&E has properly implemented risk management methodology. While its relative risk assessment methodology can be fixed to serve its intended purposes, in the long run, PG&E ratepayer and California residents would benefit most from implementation of a probabilistic methodology.

Q. PLEASE LIST THE CHANGES THE COMMISSION SHOULD REQUIRE PG&E TO MAKE TO FIX THE FLAWS YOU HAVE IDENTIFIED.

A. The Commission should require PG&E to do the following:

- Identify the specific constraints the Company believes will affect the choice of programs that can be undertaken for the three-year GTS period;
- Identify the risk tolerance goal PG&E believes is appropriate, and the basis for the Company's belief;
- Identify how each of the Company's proposed risk management programs set forth in testimony will reduce risk and whether the programs will achieve PG&E's risk tolerance goal; and
- Implement a correct multi-attribute approach to optimize risk management activities under the relative risk methodology.

The Commission should also consider the potential benefits of using a full probabilistic methodology in the future.

Q. CAN YOU DEFINE WHAT YOU MEAN BY A PROBABILISTIC APPROACH?

A. Yes. The structure of the probabilistic approach is described in our article, "Opening the Black-Box: A New Approach to Utility Asset Management," which was published in the January 2014 issue of *Public Utilities Fortnightly*.[117] The methodology described in the article contains three key components:

(1) The approach recognizes that the condition of an asset today is a key factor in determining the probability of its failure. More importantly, however, it considers how an asset's condition will change over time, using a "condition dynamics model." Given the long-term nature of pipeline assets, any analysis seeking to determine an optimal risk-management strategy must consider a sufficiently long time horizon.

(2) The condition of an asset over time influences, along with external events (e.g., an earthquake), the likelihood that the asset will fail. In technical terms, this is called a "state-dependent hazard rate model." Although the terms sounds complex, it is a straightforward concept. For example, suppose we want to estimate the likelihood that the front tires on our car will suffer a blowout on the highway. That likelihood will depend not only on the tires' condition today (e.g., good tread, bad tread, bald), but whether the tires are inflated properly, rotated at appropriate intervals, and so forth. Over time, the likelihood of a blowout will change, depending on how their condition changes.

(3) Observing the condition of the asset can be accomplished at any time by a testing procedure. Test accuracy is described by a set of likelihood functions. The approach to convert the test outcome to a probability statement about asset condition is described in the paper. Testing is a key part of the optimal asset management strategy.

Given these three components, the risk management problem is formulated as an optimization problem. In order to specify the optimization problem, we define the objective of the asset management strategy. One possible objective is to minimize the risk associated with operating the assets over the foreseeable future. The risk can be defined as LoF x CoF, with those two components correctly specified and related to the dynamic behavior of the assets, with particular attention to asset condition. The optimization problem is solved using well-known algorithms. In the paper, we illustrate the solution method using a decision tree. All these elements together – asset condition,

[117] This article is attached as Exhibit JAL/CDF-17.

condition-dependent hazard rates, testing accuracy, minimum risk objective — determine an optimal strategy for each class of assets, including an optimal testing strategy, based on asset condition and the condition-dependent hazard rate function.[118] Our article discusses each of these topics in further detail.

Q. WHY DO YOU THINK RATEPAYERS AND CALIFORNIA RESIDENTS WOULD BENEFIT FROM IMPLEMENTATION OF A PROBABILISTIC METHODOLOGY?

A. Unlike PG&E's current approach, ratepayers will benefit from an approach that provides the best value for the money they are being asked to provide. A full probabilistic approach can determine an optimal strategy incorporating asset replacement, asset repair, and optimal testing strategies. This can provide PG&E ratepayers with additional safety for their money, a lower cost to achieve the risk reductions that PG&E's proposed programs will achieve, or both.

Q. HAVE OTHER UTILITIES IMPLEMENTED THIS APPROACH?

A. Yes.

Q. COULD PG&E IMPLEMENT THE PROBABILISTIC APPROACH YOU HAVE OUTLINED IN THIS SECTION?

A. Yes. The approach would require PG&E to obtain additional information about the condition of its pipeline assets, but the Company is doing so in any case. Perhaps the most complex aspect – but also the most crucial to identifying optimal risk management strategies, is developing condition-dependent hazard rates. However, with PG&E's subject matter experts, there is no reason the Company cannot do this.

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[118] In formal mathematical terms, the problem is formulated as an optimal control problem with dynamic state variables and uncertainty. The appendix to the article contains an overview of the modeling structure, where we determine the decision strategy having the lowest expected present value cost.

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Q. WHAT WOULD BE THE OUTCOME OF THE PROBABILISTIC APPROACH OUTLINED IN THIS SECTION?

A. The outcome of the probabilistic approach we have set out would be an optimal asset management strategy that would provide ratepayers with the best value for their money.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes.