



ACCURATE FEA SIMULATION ALLOWS 2.5X HIGHER BURST PRESSURE RATES COMPARED TO CONSERVATIVE METHODS

Asset owners often rely on overly conservative methods for their integrity evaluations. Despite the inconvenience of using excessive safety factors when assessing infrastructure integrity, many continue to do so as part of their risk management strategy because conservative methods are simpler to deploy in the field and well-understood by the workforce.

However, in the context of aging infrastructure, asset owners face more pipelines requiring inspection and repair than their available human and financial resources can manage. To cope, they must prioritize and address only necessary repairs, while avoiding unnecessary work.

In other words, asset owners must focus their efforts where it matters most.

Level I, II, and III Assessments

Asset owners decide to comply with Levels I, II, or III based on the complexity and accuracy required to assess the asset's condition and the associated costs and time constraints.

Level I for Quick and Conservative Assessment

In a Level I analysis for burst pressure, asset owners use simplified equations with built-in conservative assumptions, requiring minimal data. This level is chosen when a fast, conservative screening is needed to determine if the pipeline can continue operation without further detailed analysis.

To Use for: Early-stage assessments or when the pipeline defect is straightforward and conservative assumptions suffice.

Level II for More Detailed Evaluation with Refined Estimates

Level II provides a more refined analysis, typically involving more accurate data from measurements and material properties. When calculating burst pressure, this level allows the owner to reduce some of the excessive conservatism present in Level I, resulting in more accurate pressure estimates, though it still uses simplified methods.

To Use When: Defects are more complex or critical, and a detailed yet moderately conservative analysis is required to refine the safety margin.

Level III for the Most Accurate Burst Pressure Calculation Using Advanced Tools like FEA

For Level III assessments, advanced methods such as Finite Element Analysis (FEA) are used, enabling the most precise calculation of burst pressure. This level is chosen when the pipeline is critical, the defect is complex, or when the margin for error is low. It provides the most accurate estimate of burst pressure, accounting for exact material properties, geometry, and load conditions.

To Use For: Complex, high-risk pipelines where precision is critical, and failure could have significant safety, environmental, or financial consequences.

Comparison of Burst Pressure Calculation: FEA Simulation (Level III) vs. B31.G Standards (Level II)

How do burst pressures calculated with B31.G standards compare to those from FEA simulations?

Creaform set out to answer this question by measuring the burst pressure of four pipeline samples. The maximum operating pressures of these pipeline samples were then calculated using five techniques, ranging from the most conservative with simplified models and larger safety factors to the least conservative with advanced methods, more accurate models, and fewer safety factors.

1. B31.G Standard
2. B31.G Modified Standard
3. B31.G Standard - Effective Area
4. PSQR
5. FEA Simulation

Logically, the less conservative the technique, the more precise and realistic the burst pressure estimation is, as it reflects the pipeline's actual structural response to stress rather than relying heavily on simplified assumptions and larger safety margins. Let's see the results Creaform obtained by comparing these five techniques on four samples.

		Échantillon 1 (MPa)	Échantillon 2 (MPa)	Échantillon 3 (MPa)	Échantillon 4 (MPa)
MÉTHODE D'ANALYSE DE LA PRESSION D'ÉCLATEMENT	VXintegrity- B31G	4,27	5,19	3,37	3,17
	VXintegrity- B31G modifié	6,15	6,68	4,42	4,22
	VXintegrity- B31G zone effective	7,98	7,77	5,28	5,11
	VXintegrity- PSQR	8,85	8,04	5,63	5,57
	VXintegrity- FEA-Niveau III	15,17	15,35	10,68	10,17

Burst Pressures with B31.G Standards Compared with FEA Simulation

Method for Burst Pressure Analysis

1. B31.G Standard

The B31.G standard focuses on evaluating the severity of metal loss due to corrosion and other defects and helps pipeline operators determine whether a pipeline can continue to operate safely or if repairs or replacements are necessary. It provides guidelines for calculating the remaining strength and safe operating pressure of corroded pipelines that have experienced wall thinning or corrosion damage.

The B31.G method calculates a “safe operating pressure” based on factors such as:

- Size and depth of the corrosion defect
- Original wall thickness and diameter of the pipeline
- Material properties of the pipe

The B31.G standard is integrated into VXintegrity’s Pipeline module.

The results obtained with the B31.G standard show very conservative burst pressures, between 3.17 Mpa and 5.19 Mpa, for the four samples.

2. B31.G Modified Standard

The B31.G modified standard is an enhancement of the original B31.G method for assessing the remaining strength of corroded pipelines. The modified version refines the original approach by providing a more accurate and less conservative estimate of the pipeline’s remaining strength, particularly when dealing with deeper or more extensive corrosion.

In the original B31.G method, conservative assumptions were made to ensure safety, often leading to repairs or replacements even when a pipeline had sufficient strength to operate safely.

The modified version allows for more precise calculations by:

- Considering the actual profile and dimensions of the corrosion defect in greater detail.
- Reducing the level of conservatism in calculating the safe operating pressure of a corroded pipeline, leading to less unnecessary downtime or repairs.

One key improvement in the B31.G modified method is the use of the actual measured dimensions of the corroded area instead of idealized defect shapes. It also better accounts for longer, shallower corrosion profiles, which are less critical than deeper, smaller defects.

The B31.G modified standard is also integrated into VXintegrity’s Pipeline module.

The results obtained with the B31.G modified standard show slightly less conservative burst pressures, between 4.22 Mpa and 6.68 Mpa, for the four samples.

3. B31.G Standard - Effective Area

While B31.G and its modified version focus on relatively simple and conservative assessments, B31.G Effective Area is an iterative method that adds a layer of sophistication.

B31.G - Effective Area provides a more accurate evaluation of corroded areas and a less conservative estimate of the corrosion profile by using a more detailed representation of the defect geometry.

By using different lengths to approximate the corrosion profile and assessing more data points at high resolution, VXintegrity produces a more reliable and consistent assessment.

The data obtained with B31.G - Effective Area shows slightly more permissive burst pressures, between 5.11 Mpa and 7.98 Mpa, for the four samples.

4. PSQR

The Pipeline Stress and Qualification Review (PSQR) method is an approximation technique developed by TransCanada for calculating the burst pressure of pipelines, especially those with complexities not adequately addressed by other methods. It is designed to provide a more accurate and less conservative approach than traditional methods like B31.G.

B31.G is known for its conservative estimates and more straightforward approach, which prioritize safety but can lead to higher costs and material use. PSQR, by contrast, incorporates more nuanced considerations, allowing for a better balance between safety and efficiency.

The PSQR method is also integrated into VXintegrity's Pipeline module.

The results obtained with PSQR show less conservative and more accurate burst pressures, between 5.57 Mpa and 8.85 Mpa, for the four samples.

5. FEA Simulation

The FEA simulation is an advanced computational technique used to predict the pressure at which a pipeline will rupture due to internal stress. This method provides a highly detailed analysis of the pipeline's structural integrity, particularly under internal pressure conditions, material defects, or metal loss due to corrosion.

The FEA simulation accurately calculates the burst pressure by analyzing the pipeline's mechanical response to the internal pressure at the critical failure point.

VXintegrity now offers a streamlined path to FEA simulation, determining residual burst pressure through nonlinear elastoplastic analysis. Customers can simply export the 3D model of a damaged pipeline with a single click and receive a simulation analysis compatible with VXintegrity. With this tool, Creaform obtained the most accurate estimation of burst pressure, between 10.17 and 15.35.

Burst Pressure Result Analysis

Comparing the results obtained with the five techniques on four samples, we can conclude that burst pressures obtained with FEA simulation are 2.5X higher than with the more conservative B31.G and PSQR approaches.

Because FEA simulation provides deeper insights by using more accurate models and factoring in complex geometries, material non-linearities, and precise load conditions, results obtained with FEA simulation align more closely with the pipeline's real burst pressures under real-world conditions.

This means that asset owners who rely on FEA simulation can avoid overly conservative estimates, which often lead to unnecessary repairs or replacements, and instead base their decisions on more realistic assessments of the pipeline's condition. They can save on maintenance costs by focusing on critical areas that actually need attention, leading to more efficient use of resources and reducing unnecessary downtime.

In short, with FEA simulation, pipeline owners can make strategic decisions based on factual, detailed analysis, leading to optimized operations, reduced costs, and better risk management.

Proof of Rigor and Accuracy of the Creaform FEA Simulation

When developing its model, Creaform Engineering compared its FEA simulation to numerous real cases and actual burst pressures.

Here are five pieces of evidence that demonstrate the rigor of the simulation team and the accuracy of the model.

1. Validation with Real Burst Pressure Values

Creaform Engineering aimed to validate the implementation of the triaxiality criterion outlined in the API 579 standard. To achieve this, the team compared the burst pressure values simulated with FEA to actual burst pressure data. They used a thesis from the University of Malaysia⁽¹⁾, which includes a pipeline damage model and real explosion data obtained from experimental tests.

(1) Finite Element Analysis on Burst Pressure of Steel Pipe with Corrosion Defects, N.A.Alang, N.A.Razak, K.A.Shafie, A.Sulaiman. Corrosion & Fracture Focus Group, Faculty of Mechanical Engineering, University of Malaysia

The results showed that, in all cases, the burst pressures obtained through FEA simulation were 15-20% more conservative than the experimental values. This indicates that the simulation values maintain a 15-20% safety margin compared to the actual burst pressures observed in testing.

		Testing 1 (MPa)	Testing 2 (MPa)	Testing 3 (MPa)	Testing 4 (MPa)
METHOD FOR BURST PRESSURE ANALYSIS	Experimental	54	61	46	44
	VXintegrity- FEA-Level III	45.35	51.23	37	33.5

Burst Pressure with FEA Simulation Compared with Experimental Tests

2. 3D Scanning Technology

Creaform's FEA simulation model is created by leveraging advanced 3D scanning technology, which offers unique benefits, such as traceability over time, metrology-grade accuracy, and human-independent results.

Unbeatable Accuracy

- Ensure the highest data quality on digital reconstructions
- Get reliable diagnoses and trustworthy inspection results

Infinitely Traceable Data

- Follow and compare damage evolution over time
- Establish trends

Many Users, Same Result

- Obtain the same and unique scan regardless of the technician's skills and experience
- Proceed with data acquisition and analysis with little human intervention

3. Internal Pressure Constraints, Boundary Conditions, and Material Properties Automatically Applied to FEA Simulation Model

Creaform automatically applies internal pressure constraints, boundary conditions, and material properties to the FEA simulation model.

By applying these constraints at key locations and running a non-linear FEA simulation, Creaform can accurately predict rupture points and the combined effect of these forces on the pipeline's integrity. In VXintegrity, these constraints and combinations of forces are applied through advanced material models and boundary conditions, ensuring a comprehensive burst pressure analysis.

4. Triaxiality Used to Find the Pipeline Burst Pressure

Based on API 579, we use the triaxiality criterion for assessing the pipeline burst pressure, especially in regions where stress concentration or defects affect material behavior. Triaxiality is a measure of the ratio of hydrostatic stress (mean stress) to equivalent von Mises stress, and it helps determine how ductile or brittle the material behaves under complex loading conditions.

$$\text{Triaxiality} = \frac{\sigma_m}{\sigma_{vm}}$$

Where:

- σ_m is the **hydrostatic (mean) stress**, which is the average of the principal stresses in all three directions.
- σ_{vm} is the **von Mises equivalent stress**, which represents the deviatoric stress responsible for yielding.

Higher triaxiality reduces the material's ductility, increasing the risk of brittle failure (higher hydrostatic stress) and reducing its ability to undergo plastic deformation. Conversely, lower triaxiality indicates more ductile behavior, meaning the material can undergo significant plastic deformation before failure.

5. Engineers Validate Simulation Analysis

The simulation results obtained by Creaform Engineering make FEA simulation for burst pressure analysis easily accessible for routine inspections. It consists for customers to export a precise 3D model of their damaged pipeline, accessible on-site with VXintegrity. The data transfer, feasible with one click, is safe through cloud services. Then, Creaform Engineering's team runs its FEA simulation models semi-automatically. Using the triaxial strain criteria of API-579, they calculate stress and strain and evaluate the burst pressures and their locations. They generate 3D visual reports of the digitized surface to enable asset owners and service companies to clearly visualize the constraints and limits on their operating pipelines.

With its product offering, Creaform Engineering significantly reduces the time and effort needed to comply with Level III assessment requirements.

FEA Simulation Models So Close to Reality

Instead of relying on overly conservative methods with excessive safety factors, Creaform offers FEA simulation models that closely approximate real burst pressure values. This means that with Creaform's accurate and reliable burst pressure analysis, asset owners get a true representation of the pipeline's performance under pressure, helping them to identify potential failure points before they occur. This proactive approach enhances the overall safety of operations while saving costs associated with unnecessary maintenance, repairs, and inspections.

Creaform's FEA simulation models accurately reflect actual behaviors, enabling better predictive maintenance strategies. This allows companies to perform maintenance based on real performance data rather than conservative estimates, leading to better resource allocation and operational efficiency.

In summary, Creaform's new FEA simulation results allow for more informed decision-making regarding pipeline operations because engineers and management can now base their decisions on reliable predictions rather than cautious estimates.



For an unparalleled experience connect with us at the nearest office located in Canada.

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