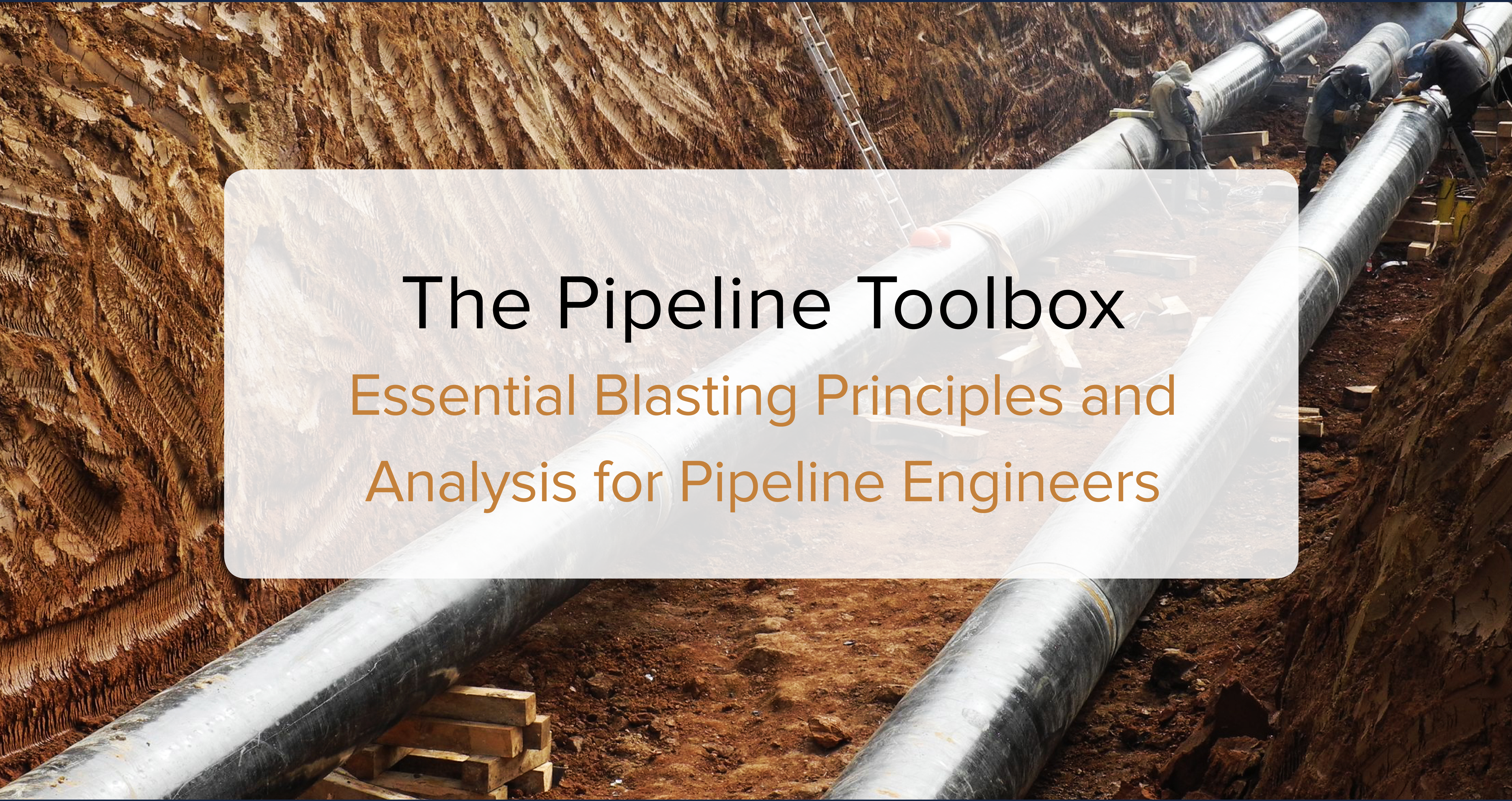

The Pipeline Toolbox

Essential Blasting Principles and Analysis for Pipeline Engineers

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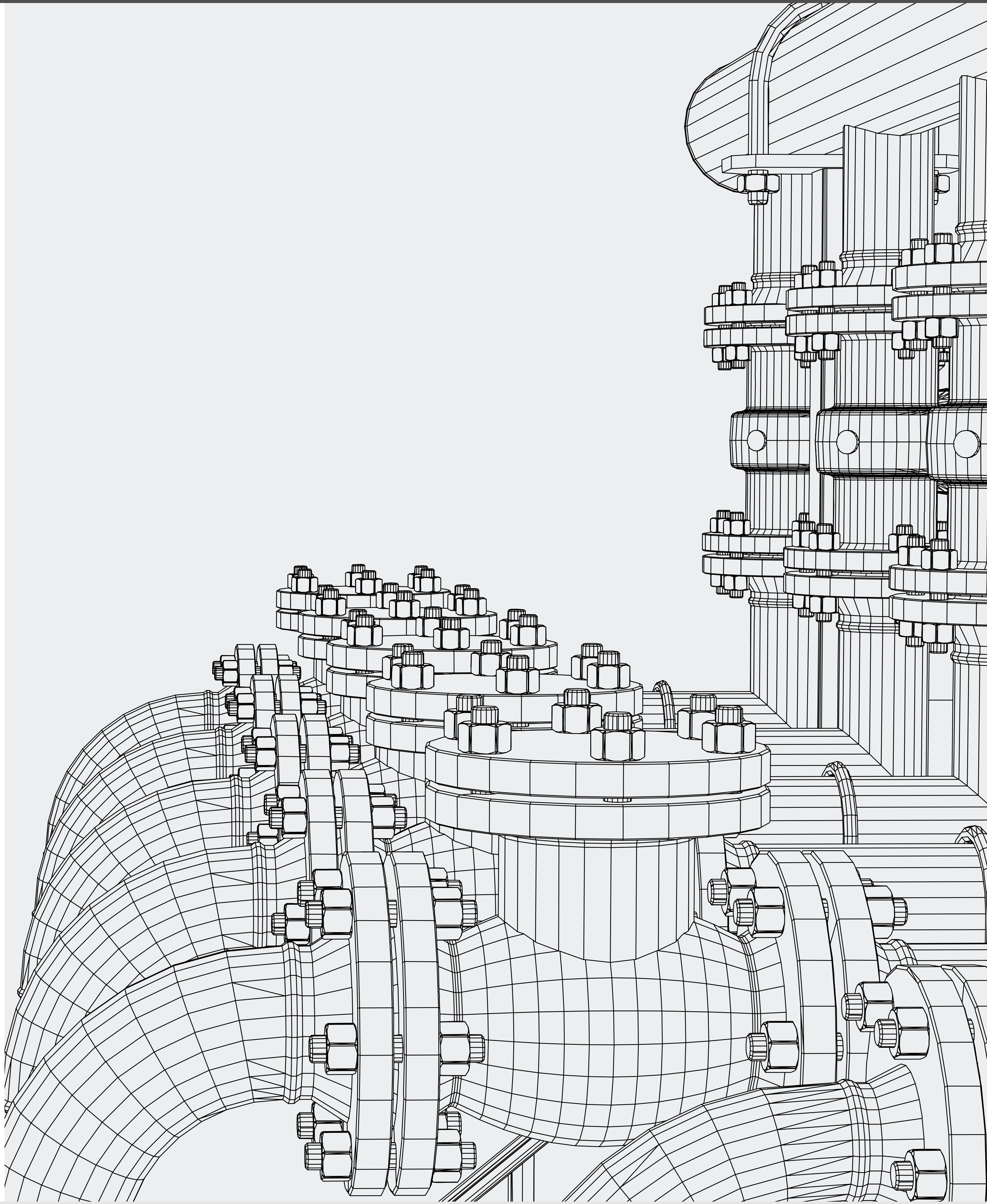


Overview

This eBook accompanies the Pipeline Toolbox Webinar about the Impact of Blasting on Buried Pipes! Technical Toolboxes created the webinar and eBook in collaboration with our expert on the subject, Dr. Benjamin Zand.

Blasting is not something that most pipeline engineers encounter every day. Unless your pipeline right-of-way is adjacent to a busy minerals-extraction operation, blast load assessment probably sounds like an off-the-wall analysis.

More development means more encroachment on pipeline right-of-ways and so more activities that involve blasting. When land-use changes, awareness of the requirements is vitally important when a blasting notification arrives. Sometimes it's mining and quarrying activities, but more likely scenarios arise as a result of demolition and construction parallel to pipeline right-of-ways.

As a pipeline engineer, you may pass through your career without ever having to address such a situation, but you have to get the calculations right when you do. Determining ground strain for pipelines in the intended blast area and all associated safety parameters is vital to safety and uninterrupted production. As a matter of best practice, pipeline companies should maintain contingency planning to respond to explosive blasts' potential stresses and strains.

In this age, when pipeline operators face so many challenges, there is a forceful tension between mitigating risk and minimizing cost. The potential hazards of an oil spill or gas release could be ruinous. Not all companies in the industry have the resources to overcome events like the Deepwater Horizon disaster.

Midstream operators must address the risk, but the mitigation cost cannot be so high as to put your company in jeopardy. As a pipeline engineer, the default practice is to be conservative in calculating ground strain, but that adds cost and increases the constraints, which might cause push-back from the party doing the blasting. You must allow enough uncertainty for risk without overstepping the bounds of cost.

"As a pipeline engineer, you may pass through your career without ever having to address such a situation, but you have to get the calculations right when you do."

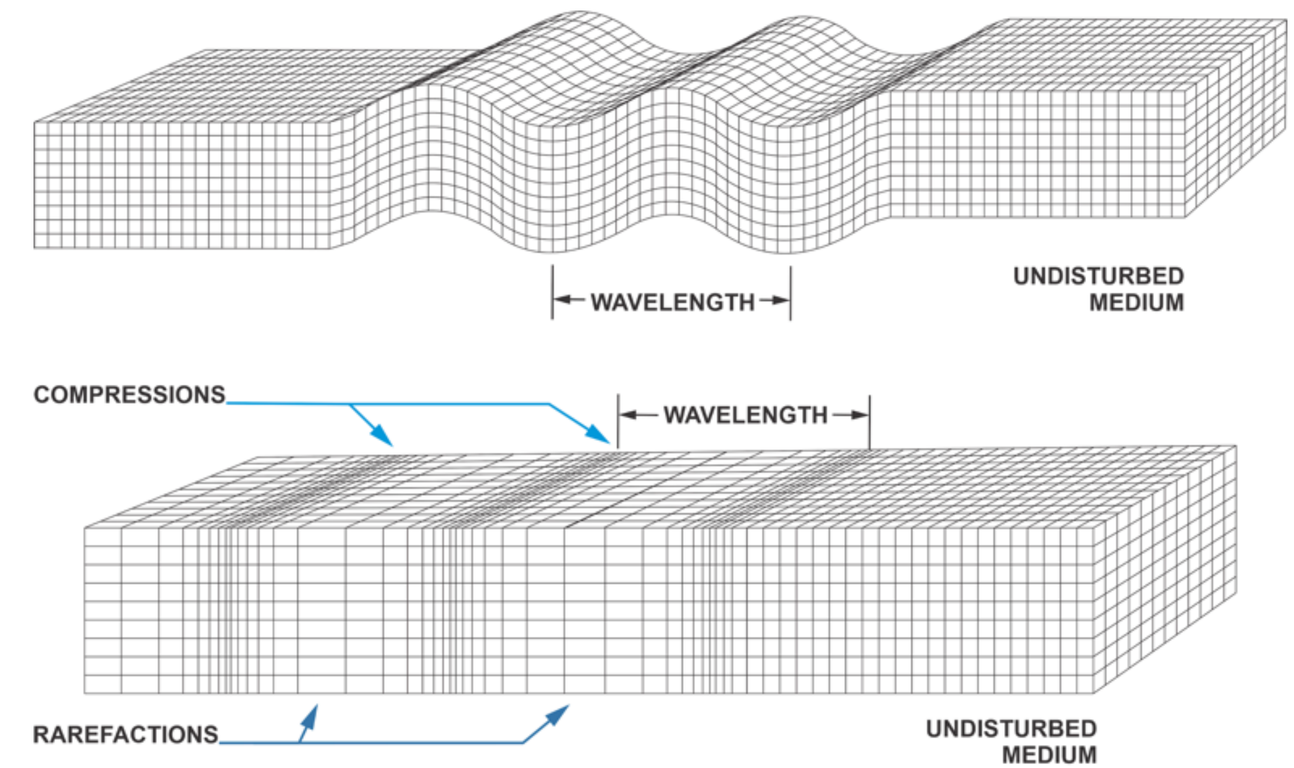
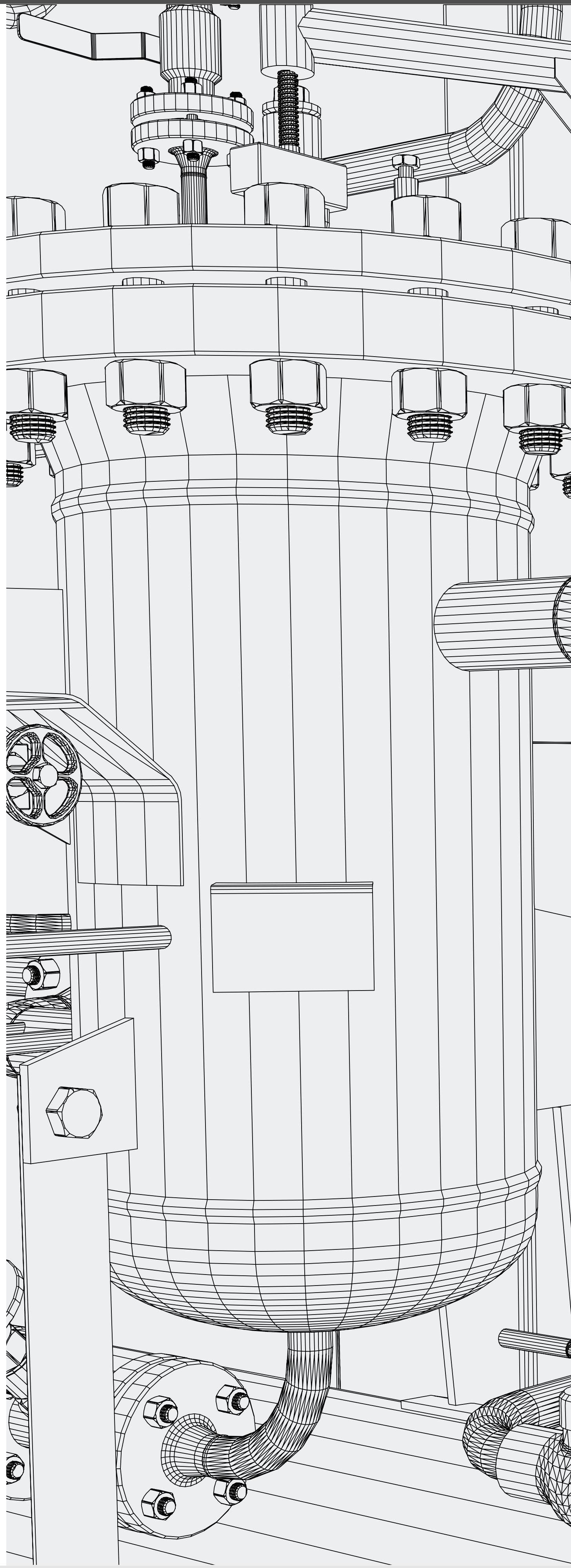


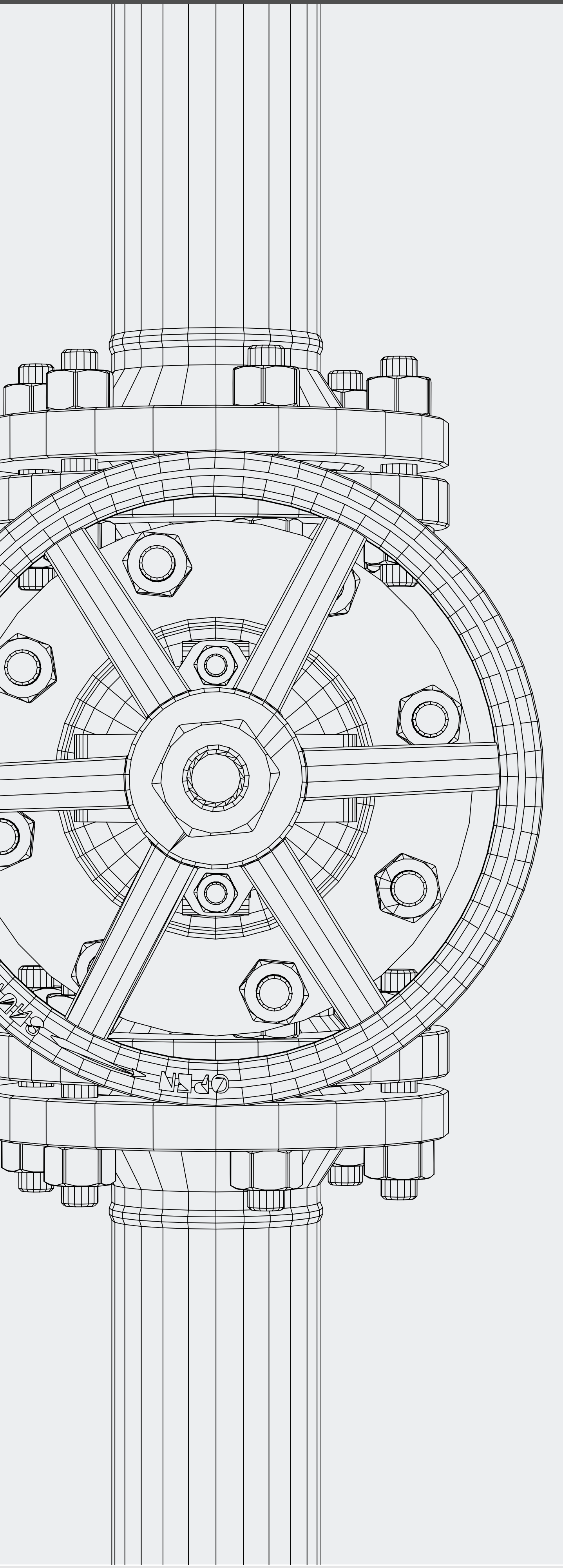
Figure 1 — Shear waves (top) and longitudinal (compression) waves (bottom)

Blasting and Construction Ground Vibrations

The energy from blasting and construction vibrations transmits to the pipeline through wave propagation. These vibrations are a mixture of longitudinal or shear waves, as you see in figure 1.

Buried pipelines suffer the impact of blasting on pipelines based on the size of the blast and distance involved. The degree of risk is based on the stress transmitted through the ground and the strain it causes within the material of the pipe.





Displacement Versus Load Controlled Analysis

Figure 2 shows the ground displacement-controlled situation, i.e., ground settlement, the stress in the pipe is self-limiting. The amount of displacement and shape of the stress-strain curve determines the deformation experienced by a pipe in the affected blast area (see Figure 3). After yielding, stress increases slowly with increasing movements.

In a load-controlled situation, the stress-strain curve does not limit the stress in the pipe. Equilibrium of forces dictates the amount of stress. Before yielding, the response is similar under both displacement-controlled or load controlled situations. When necking occurs in a load-controlled case, the stress increases rapidly, resulting in almost immediate failure of the pipe. After yielding, a small load increment causes a significant displacement increase.

In a displacement-controlled situation, the stress will adjust to the strain of the displacement, and failure does not occur until the strain reaches the failure strain. Engineers perform tensile testing under displacement control.

The takeaway: A load-controlled situation should be approached more cautiously than a displacement-controlled case.

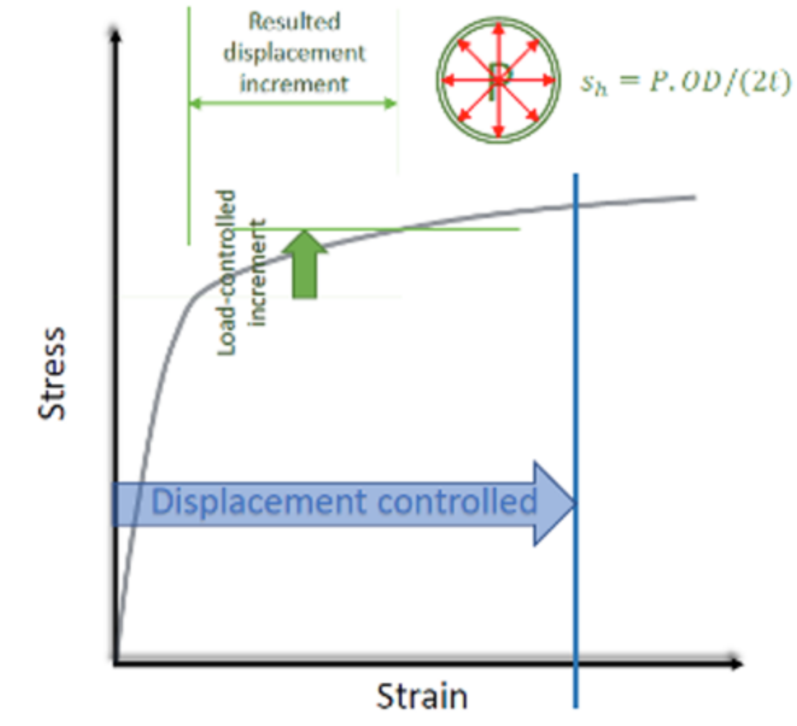


Figure 2 — Displacement controlled versus load controlled

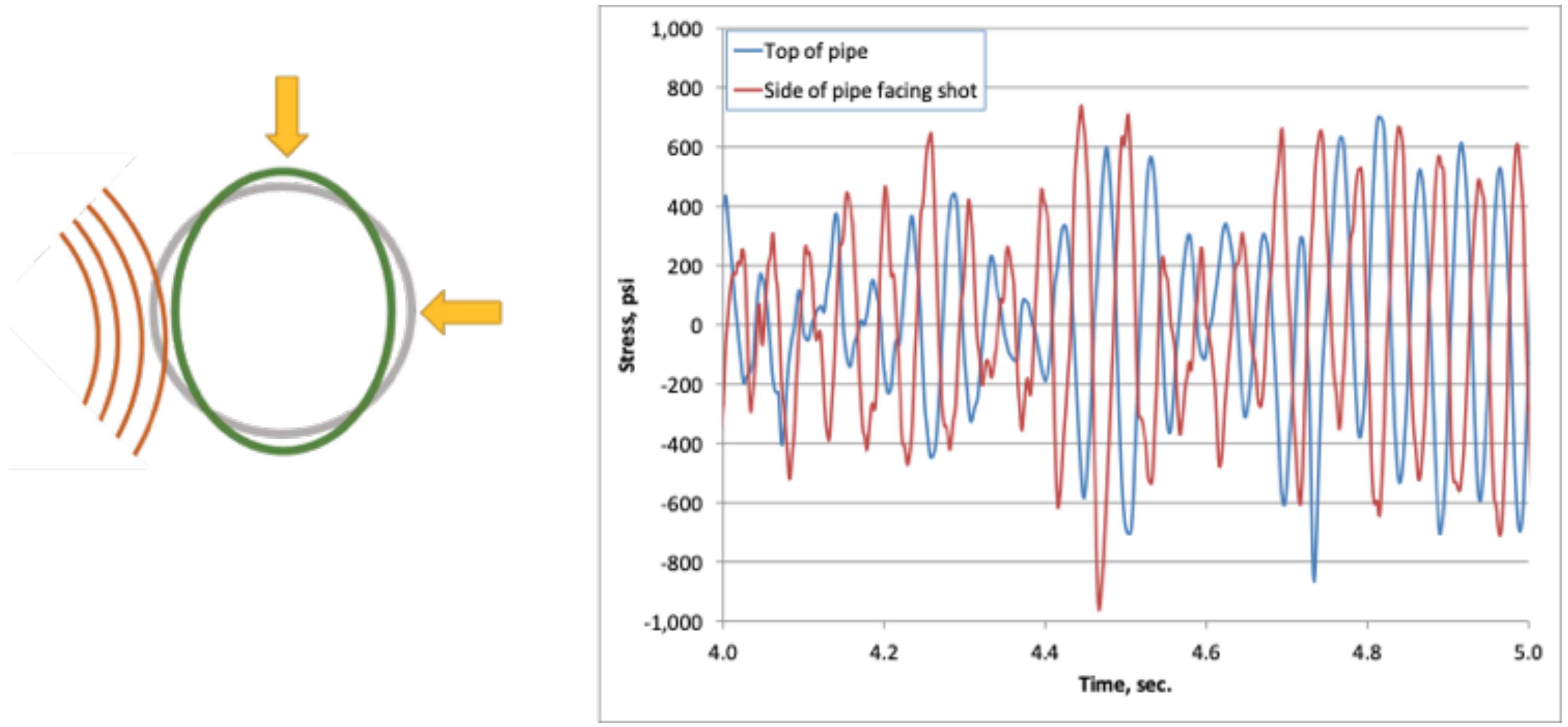


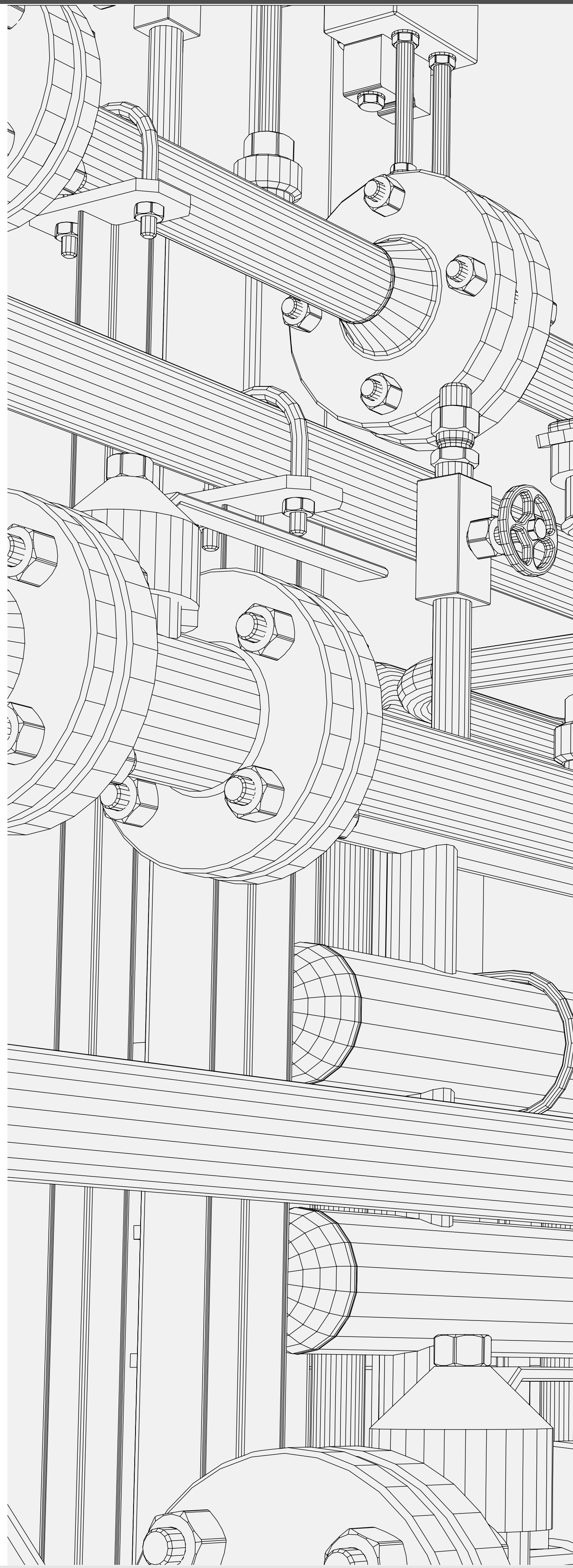
Figure 3 — Blast induced stress in a buried pipe

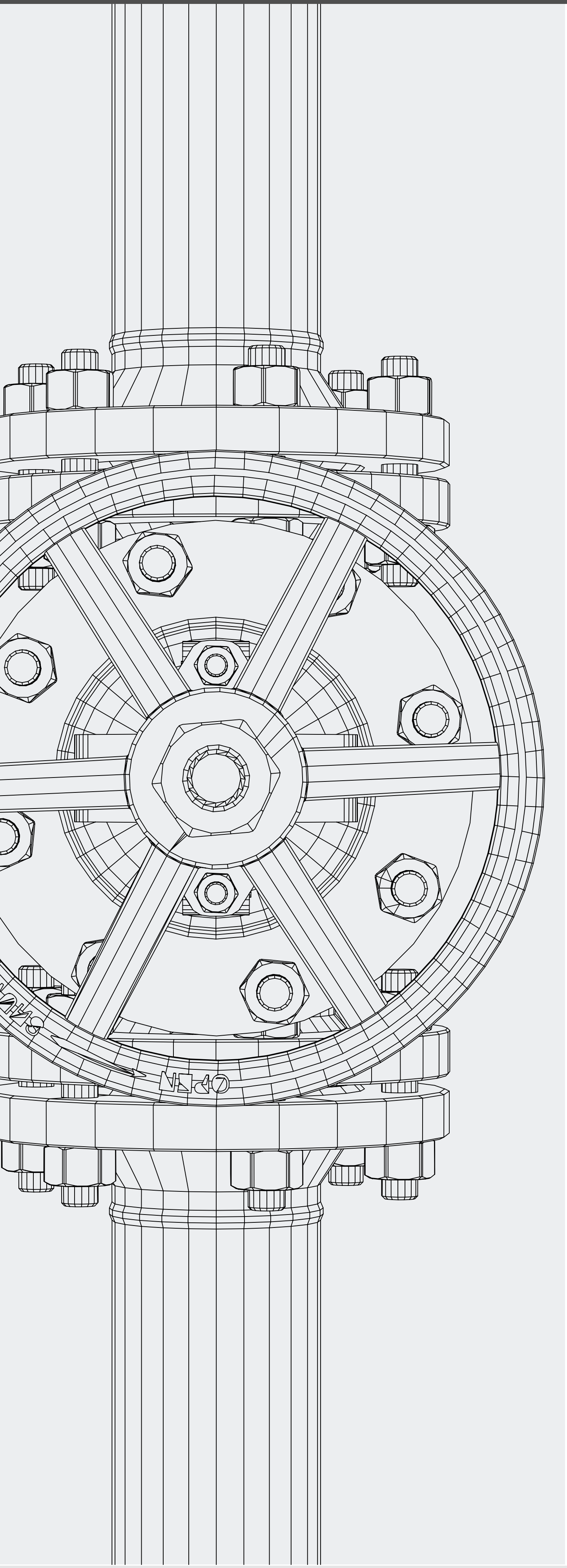
Robert Francini and Benjamin Zand, "ENV2 Procedure for Evaluating the Effects of Blasting on Pipelines Phase 1 Summary Report", PRCI Report No PR-218-104509R, September 24, 2013

Charge Spacing in Time and Geometry

The type, quantity, and spacing of charges, both in detonation timing and geometry, are key decision points when selecting which formulas/methods to employ in your analysis. The general classifications of geometries used include point source, lines, and grids. Depending on the distance from the pipeline to the blast location, as well as the time delay between detonations, lines, and grids of charges can be evaluated using point source formulas.

Luckily, the knowledge transfer capabilities of modern software, like those offered by Technical Toolboxes, help you keep track of both the existence of these decision points and how to make decisions about which correlations fit your specific needs. The Pipeline Toolbox from Technical Toolboxes has calculations for each of these situations.





Point Source Blasting and Ground Particle Velocity

Blasting at an extended distance from the right-of-way can be treated as point charges. For example, quarry blasting is likely to involve large charges at a far distance, and so it's treated as a point detonation.

To evaluate the effect of point source blasts on buried pipelines, the peak radial ground particle velocity using equations developed by Edward Esparza . The Esparza Equation can be restated relative ANFO, as a simplifying benchmark. The equivalent weight is stated as a Powder Factor, as shown in the table in figure 4.

Hoop and longitudinal stresses are usually assumed to be equal. Decision points determined by distance from the pipeline with ±8ms timing separation and proximity to the pipeline. If the timing difference is greater than 8ms, the horizontal and lateral forces and strains must be evaluated separately as point source blasts. However, the sum of the strain produced by the blasts must not exceed the allowable strain on the pipe.

Explosive	Powder Factor
ANFO (94/6)	1.00
AN Low-Density Dynamite	0.99
Comp B (60/40)	1.12
Comp C-4	1.12
HBX-1	0.83
NG Dynamite (40%)	1.05
NG Dynamite (60%)	1.12
Pentolite (50/50)	1.11
RDX	1.16
TNT	0.98

Figure 4 — Typical powder factors for blasting analysis (the ratio of the energy of the explosive to the same weight of ANFO)

Esparza, E, Westine, P. and Wenzel, A. "Pipeline responses to buried explosive detonations" Volume II – Technical Report, Southwest Research Institute, 1981

Lines and Grids of Charges

In addition to calculations for point source blasts, the PipeBLAST in PLTB includes calculations for both lines and grids of charges, both parallel and angled to the pipeline. If the timing of the detonations in lines and grid arrays of blasting charges are simultaneous, i.e., less than 8ms apart, they must be evaluated with specific formulas that account for the variables in each situation. The diagrams in figures 5 through 7 show the layouts of explosives relative to a pipeline. The variables are those that must be included in any analysis of each situation.

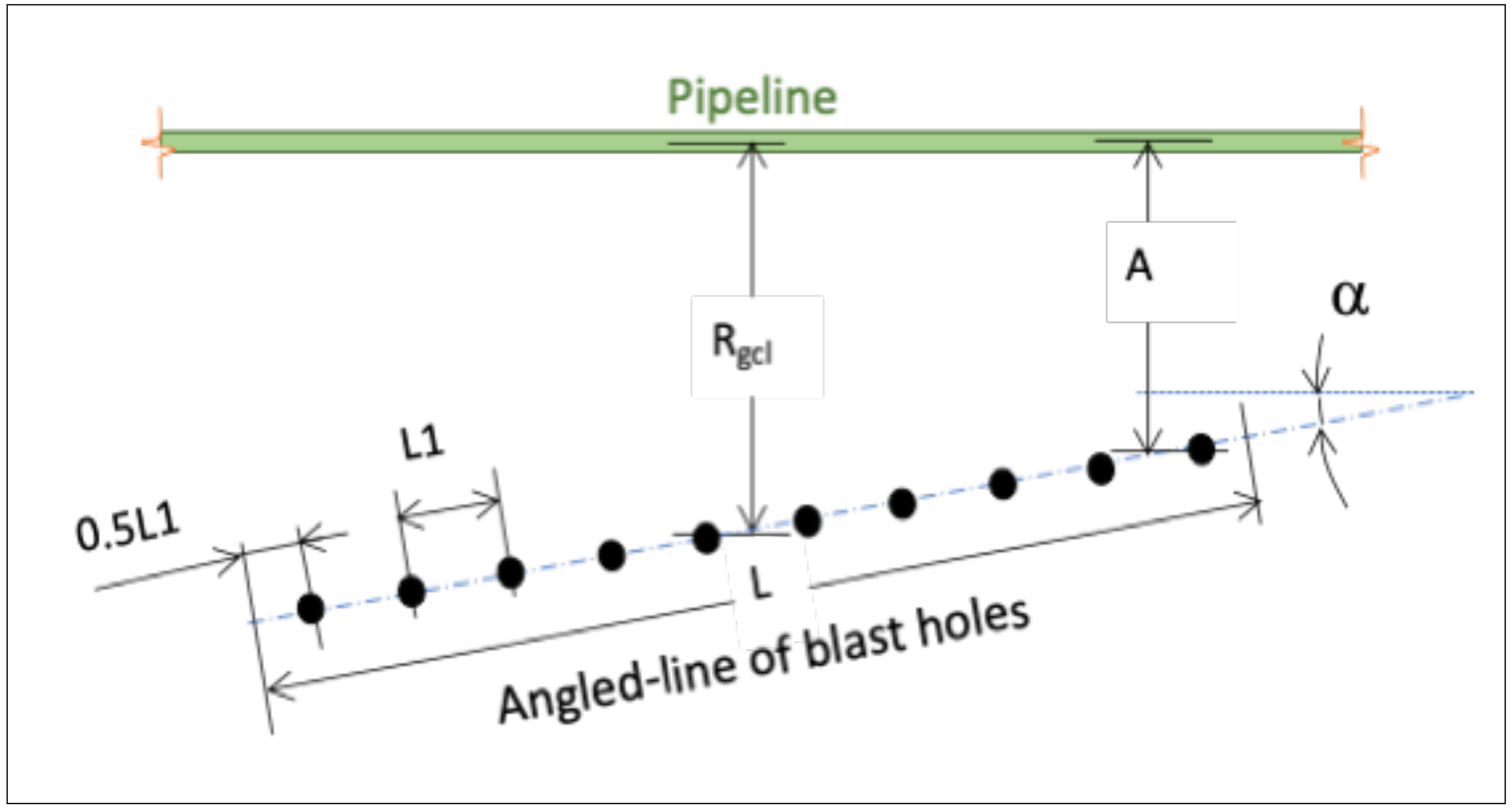


Figure 5 — Angled line of explosive charges with variables for the Esparza Equation or PLTB

Lines of Explosives Angled to The Right-Of-Way

The diagram in figure 5 illustrates a typical configuration, where the key influencers in the analysis include the distance to the nearest charge, the number, weight, and spacing of the explosive charges. The angle α is the angle between the pipeline and the line of explosives. When the line of charges is parallel to the pipe, the angle *α* equals zero, which simplifies the calculation.

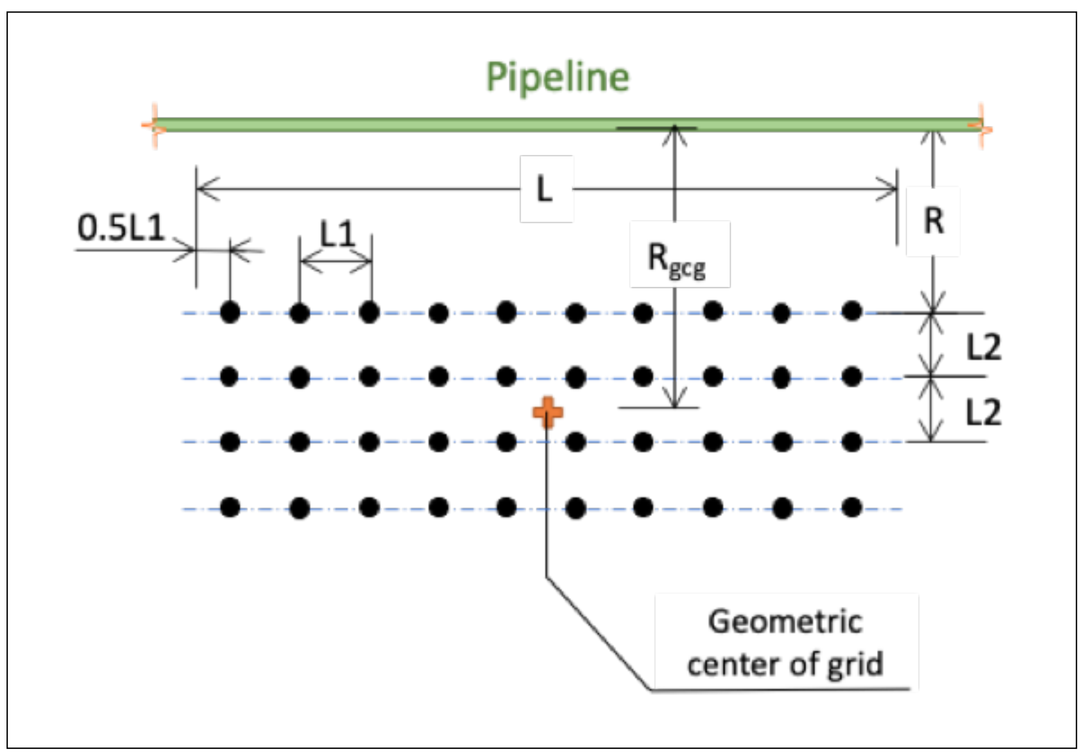


Figure 6 — Grid of explosive charge parallel to the pipeline

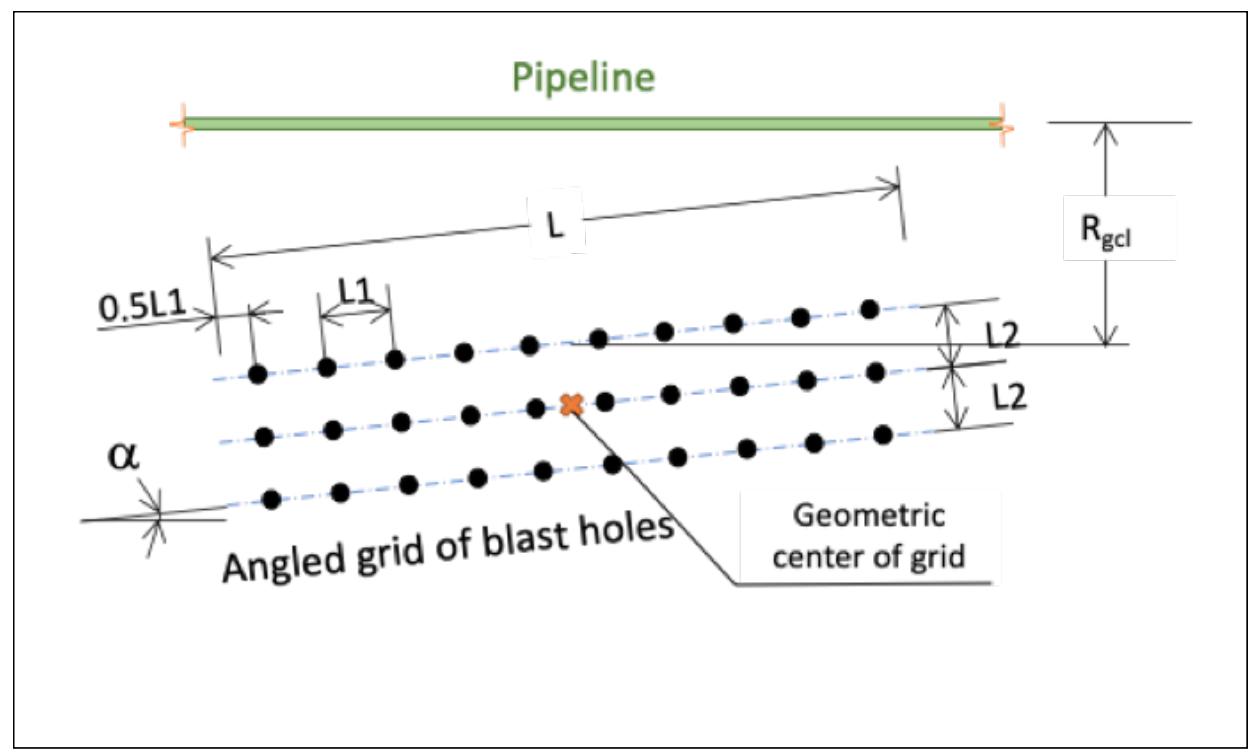
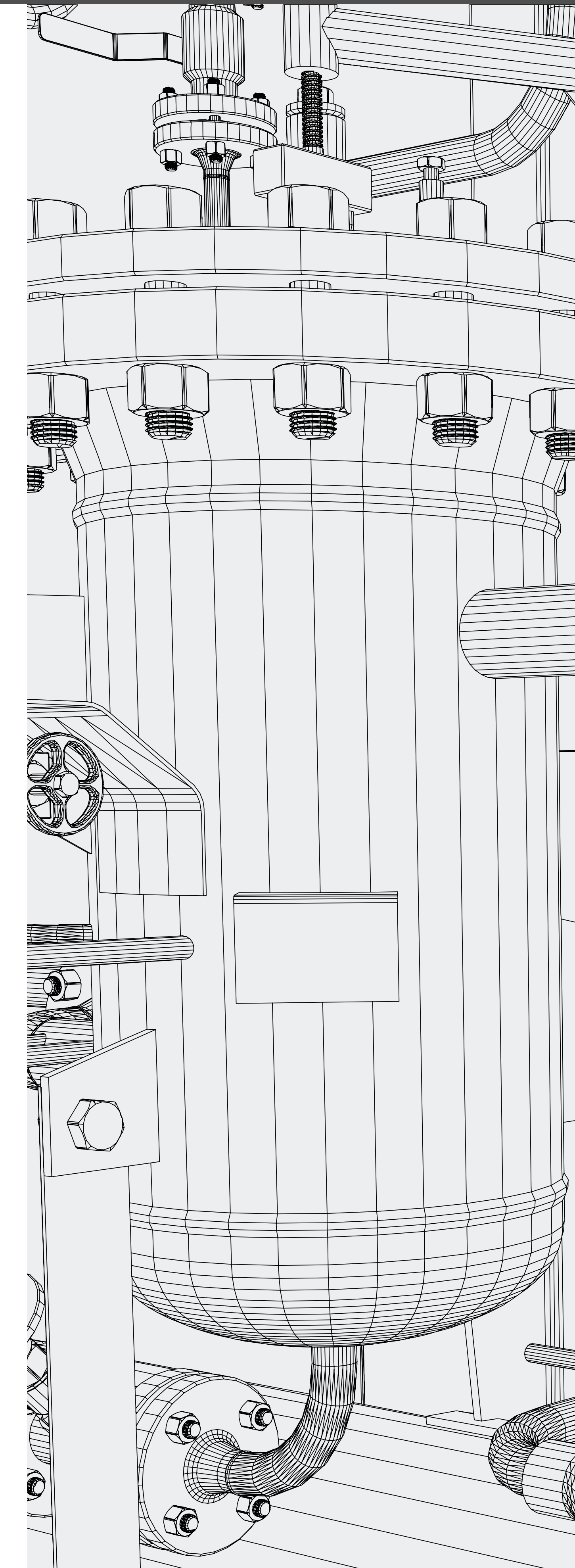
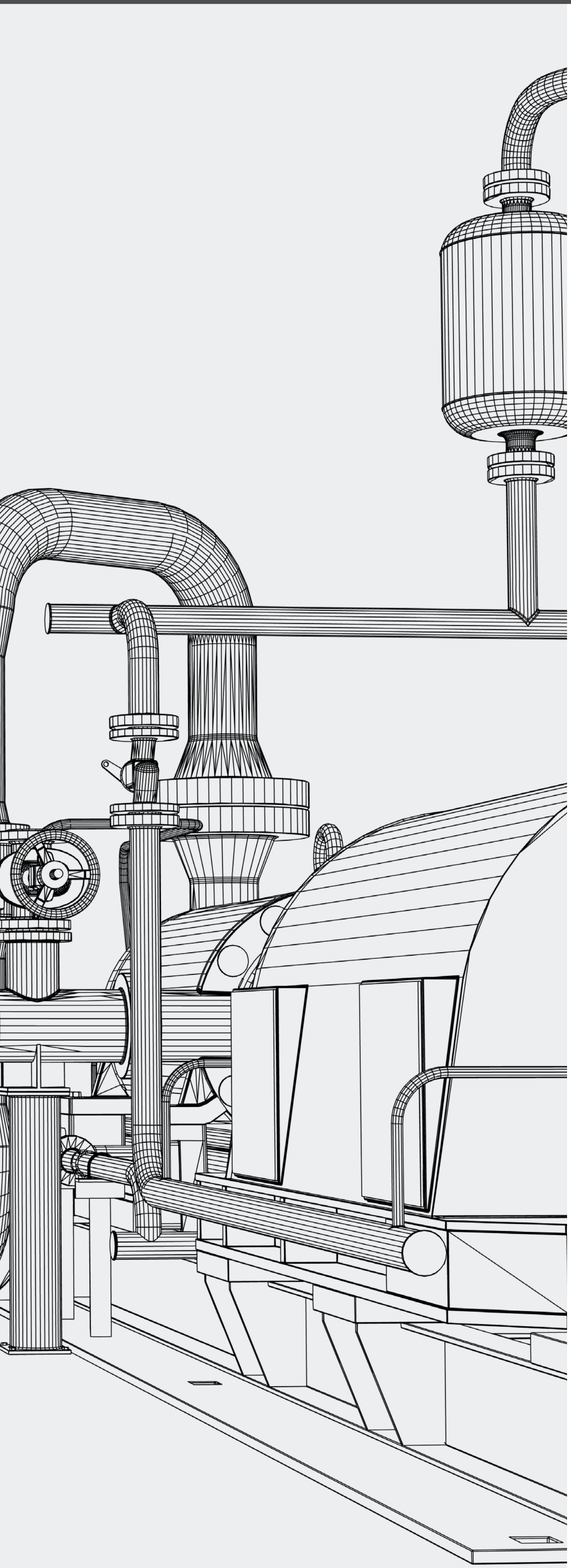


Figure 7 — Grid of explosive charges angled to the pipeline





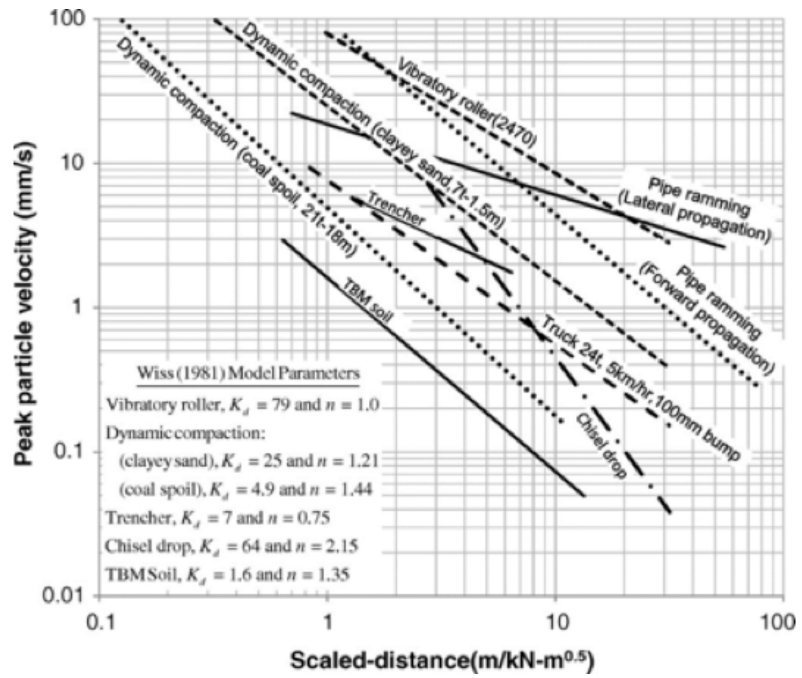


Figure 8 — PPV Attenuation Examples

Tadesse Meskele and Armin W. Stuedlein, "Attenuation of Pipe Ramming-Induced Ground Vibrations" Journal of Pipeline Systems Engineering and Practice, Volume 7 Issue 1 - Feb 2016

"Excavation and construction equipment operating in and around right-of-ways stresses pipelines similar to blasting. "

PPV Attenuation for Heavy Equipment Induced Vibrations

Excavation and construction equipment operating in and around right-of-ways stresses pipelines similar to blasting. Such activity can be analyzed in terms of Peak Particle Velocity, as shown in figure 8.

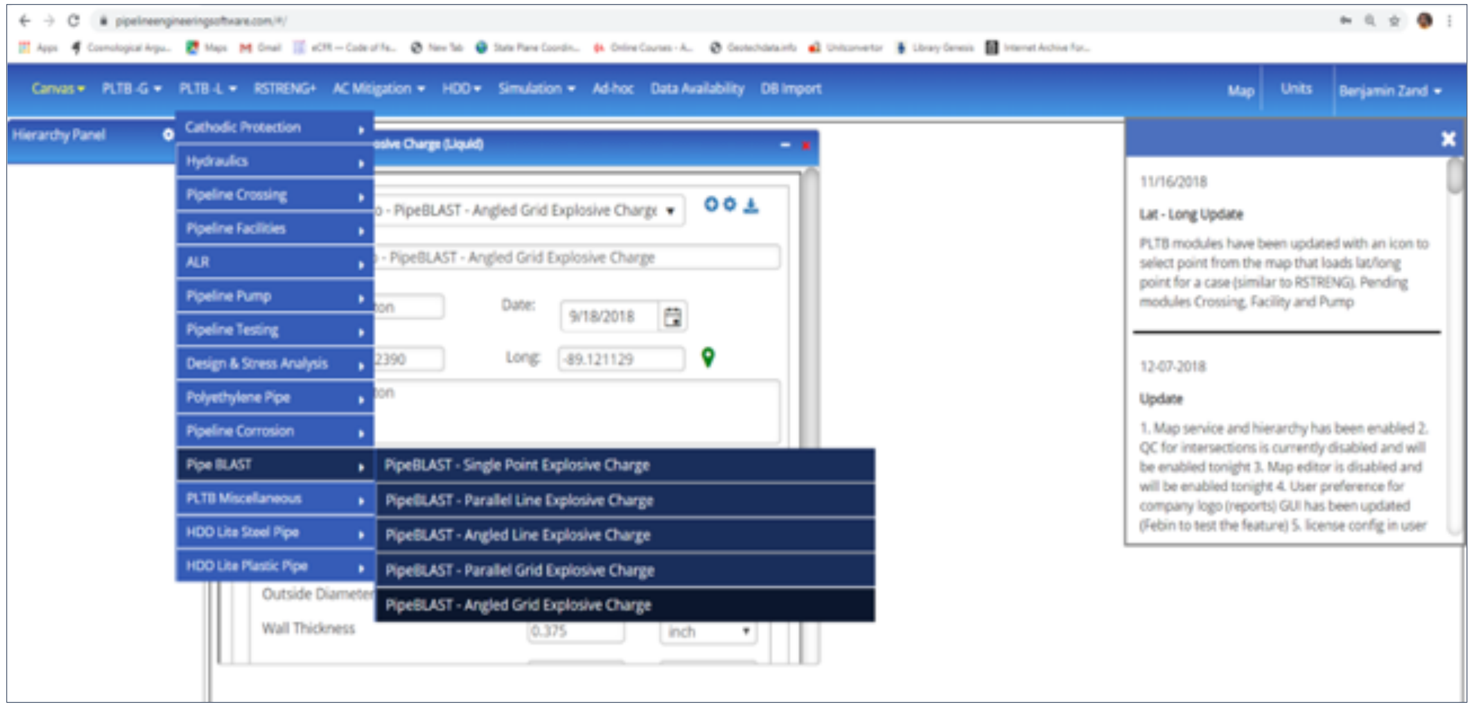


Figure 9 —Showing PLTB-L (liquid) and PipeBLAST with relevant options appearing from the dropdown menu

Software and Training from Technical Toolboxes

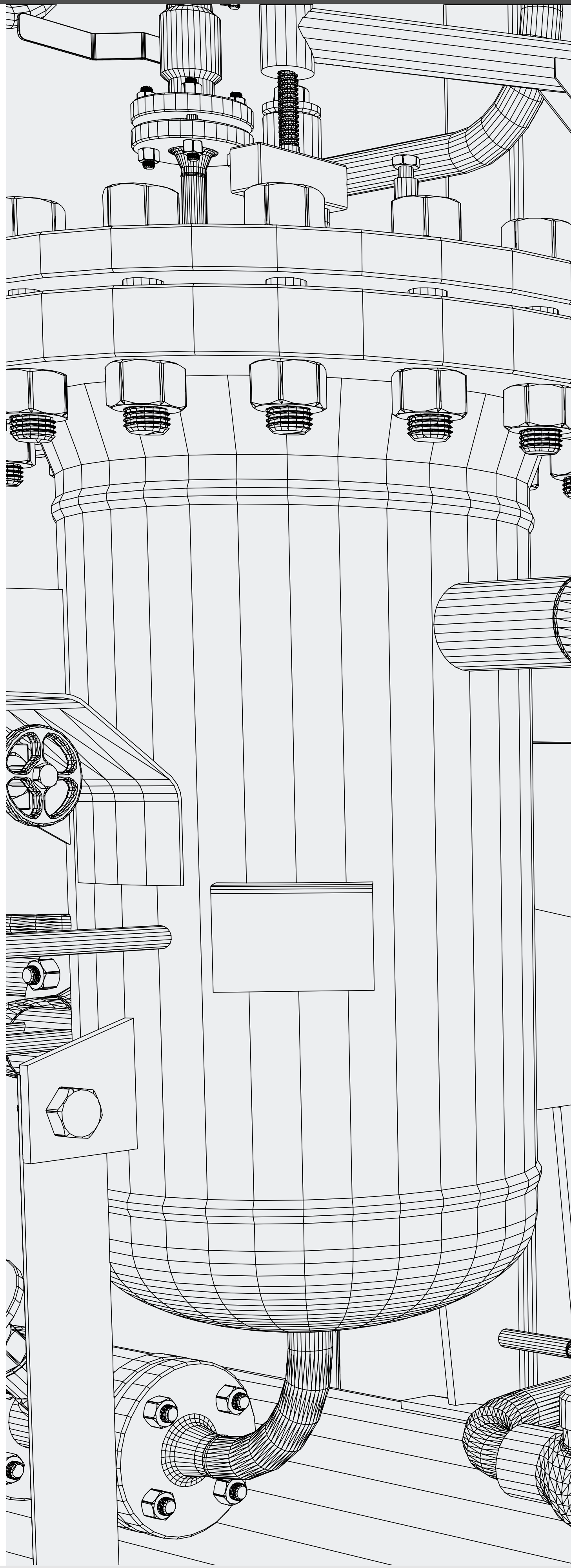
The latest generation of software tools from Technical Toolboxes build on the Pipeline Hub (HUB^PL) Integrated Data Environment. Technical Toolboxes is an Authorized PRCI software reseller and has developed a range of PowerTools designed to maximize pipeline engineering productivity. The company is a thought leader and knowledge resource provider, with live and online training for PDH credit for pipeline engineers.

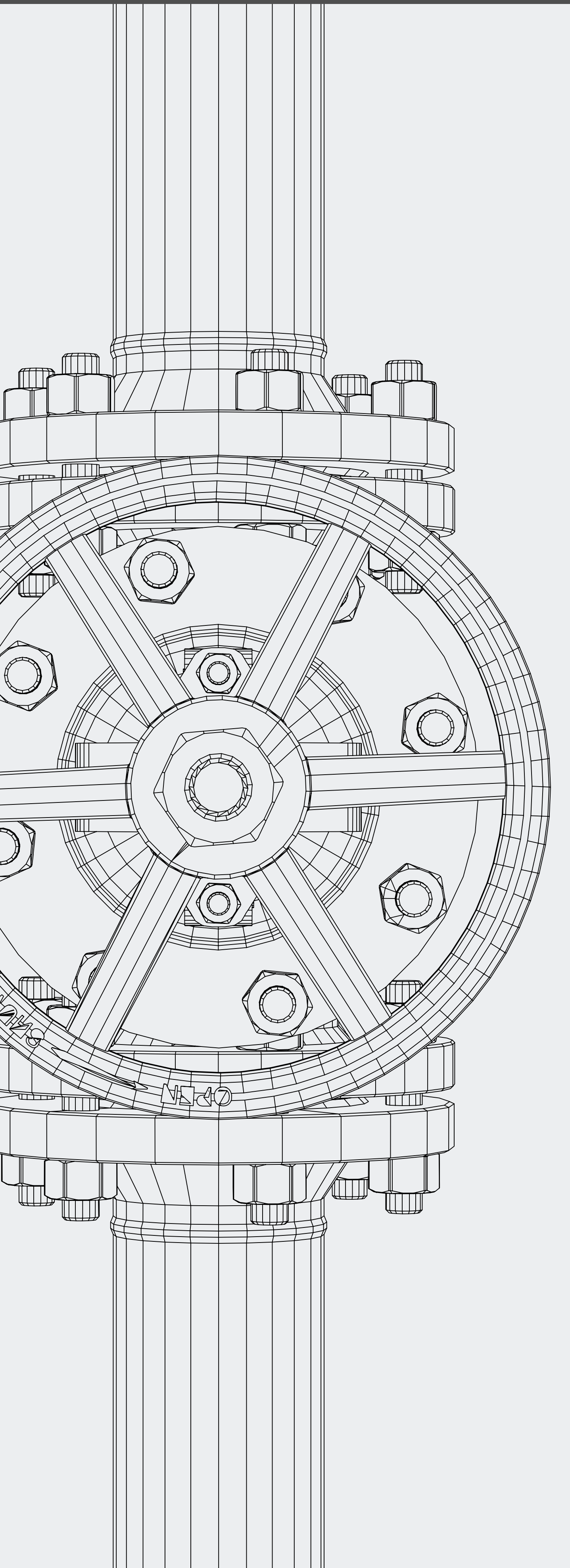
Calculating Blast Effects with the Pipeline Toolbox

The Pipeline Toolbox (PLTB) is a versatile midstream solution with more than 254 engineering applications. In addition to blasting calculations, engineers use Pipeline Toolbox for pipeline design, construction, operations, and integrity.

Now, PLTB integrates into the Technical Toolboxes HUB^PL platform. It paves the way for automating integration and analyses to reveal insights into your assets and infrastructure solutions' design and operational fitness.

HUB^PL filters your calculations through all industry and regulatory standards to ensure your information is compliant. Now you can perform blast assessment within the HUB^PL using PLTB. PipeBLAST (see figure 9) has tools for tensile stress-strain curves, surface loading, span analysis, and blasting vibrations. It calculates blast effects for both gas and liquid pipes.





Looking Forward

At present, key oil and gas industry metrics are at 10-year lows. The midstream sector faces the challenge of losses due to COVID-19. While the crisis is sure to pass eventually, questions remain as to the shape of the post-pandemic world and what impact the changes will force on the industry.

Oil and gas companies keep moving and changing as gas replaces coal and uncertainty creates volatile prices. The potential for market collapse means only the most efficient and productive players are likely to survive. Digital tools are essential components that will enable pipeline engineers to work most efficiently and productively.

“The potential for market collapse means only the most efficient and productive players are likely to survive.”

"The programs that [Dr. Zand] has developed have optimized mitigation and monitoring for pipelines subjected to a broad range of geohazard conditions."

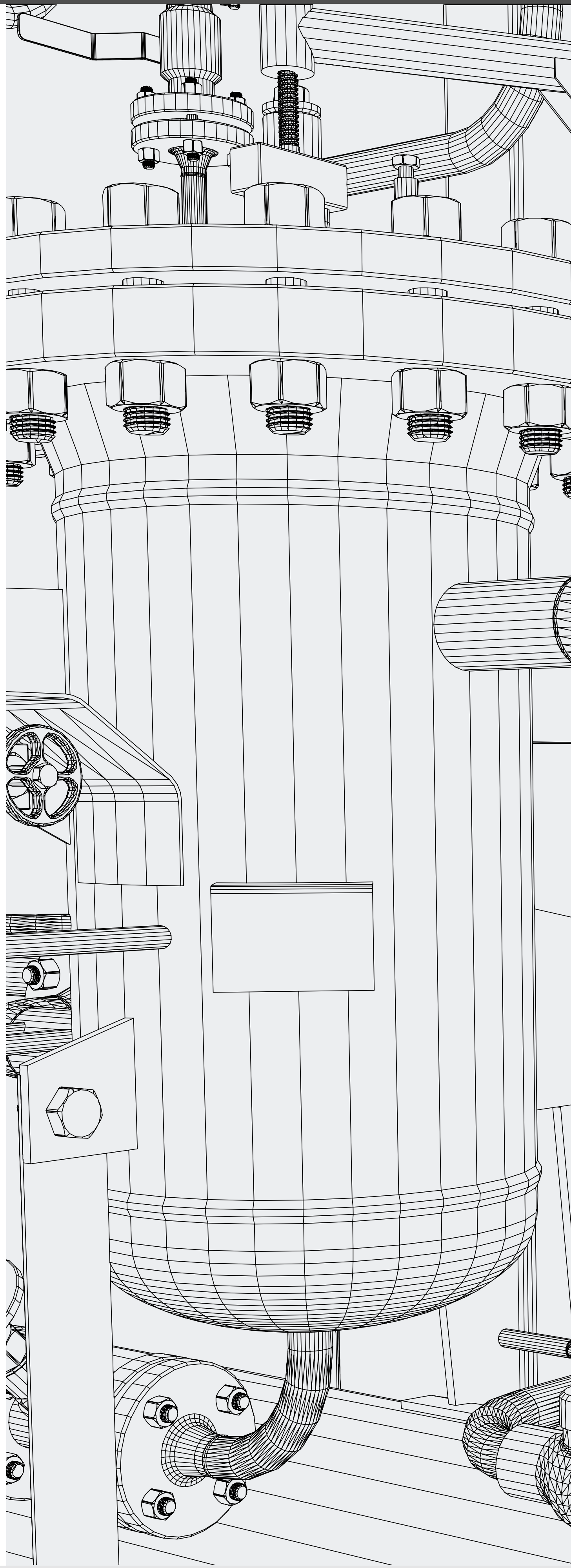
Dr. Benjamin Zand

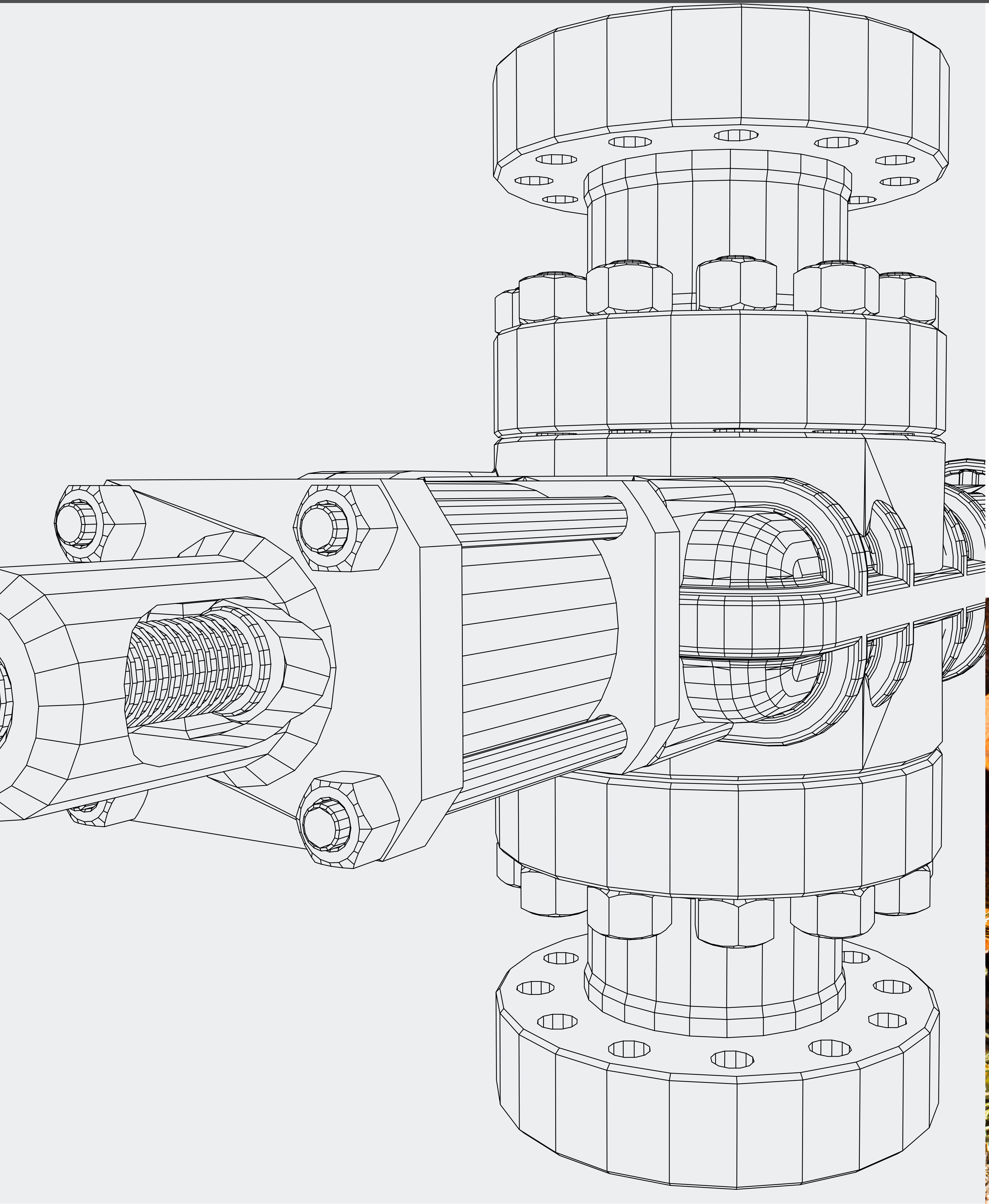
Dr. Zand has 20-plus years of experience in geotechnical engineering, geohazard assessment, stress analysis, pipeline integrity assessment, mechanics of composite material, and mathematical modeling. His expertise includes stress and vibration analysis and monitoring for oil and gas transport pipelines and facility piping. Over the years, he has assisted pipeline operators with geohazard problems such as longwall mining subsidence, ground movement, sinkholes, earthquakes, and fault crossings.

The programs that he has developed have optimized mitigation and monitoring for pipelines subjected to a broad range of geohazard conditions. He created the solutions for numerous pipelines that were subjected to vibration and cyclic loading from blast and construction. After working with Kiefner & Associates, Inc. from 2012 to 2019, he began a position at RSI Pipeline Solutions, LLC He served as an instructor for the Rock Mechanics course at Ohio State University.

On behalf of Technical Toolboxes, Dr. Zand leads such online and live courses as:

- Outside Forces on Buried Pipelines
- Effects of Construction and Blast Vibration on Buried Pipelines
- Pipeline Geohazard Assessment
- Advanced Pipeline Stress Analysis





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Technical Toolboxes leads the midstream oil and gas industry with knowledge-based solutions. Our integrated desktop and cloud-based solutions foster engineering productivity and standardization. Professionals around the world look to our industry-recognized instructors for training and development. To improve efficiency, compliance, and productivity, pipeline engineers look to Technical Toolboxes.