Fluid dynamics calculations for glycol pipelines in an underground potash mine in the Canada northwest

Based on software simulations and Python coding

María del Pilar Monsalve Correa

Academic internship report submitted in fulfilment of the requirements for the degree of Mechanical Engineer

Advisors

Luis Fernando Córdoba Henao, Magíster (MSc) in Anthropology

Ricardo Zuleta Idárraga (MSc) in Business Administration

Universidad de Antioquia

Facultad de Ingeniería

Ingeniería Mecánica

Medellín, Antioquia, Colombia

2024

Dedication

To Amalia, who is my engine and my life. To Juan José, Felipe, Arturo, Coffee, and Astro for being my home. To my professors who have taught me more about life than academia. To Mamita Eva, my role model engineer. To my family for their unwavering support, no matter the circumstances. To my friends for brightening my days, especially Juan and Mari, without whom none of this would be possible. To Pauli, Ori, and Lilis for taking me beyond what I always dreamed of. To Waltercito, Walter Enrique, Alejo, Diego, and Juan for helping me grow as an engineer and as a person.

Acknowledgments

I thank my mom who brought me coffee in the early morning hours so I could keep studying, and the next day packed my lunch. Thank you, *má*, for being my everything.

Thanks to Juan José who has always listened to me and supported me. Thank you for the endless construction.

Thanks to Felipe for being my best teacher.

I want to thank Coffee and Astro who have accompanied me through more than one all-nighter.

To my aunts and cousins for celebrating every little achievement.

Thanks to my friends who brighten up my studies, projects, and life.

Infinite thanks to my teachers from school, university, and industry, they have shaped who I am today.

Dedicatoria

A Amalia, que es mi motor y mi vida. A Juan José, Felipe, Arturo, Coffee y Astro por ser mi hogar. A mis profesores que me han enseñado más de la vida que de la academia. A la mamita Eva, mi ingeniera modelo. A mi familia por el apoyo siempre, sin importar las circunstancias. A mis amiguitos por iluminar mis días, en especial a Juan y Mari, sin ellos nada de esto sería posible. A Pauli, Ori y Lilis por llevarme más allá de lo que siempre soñé. A Waltercito, Walter Enrique, Alejo, Diego y Juan por ayudarme a crecer como ingeniera y persona.

Agradecimientos

Le agradezco a mi mamá que me llevaba tinto en la madrugada para seguir estudiando, y al otro día me empacaba la coca. Gracias *má* por ser mi todo.

Gracias a Juan José que me ha escuchado siempre, me ha apoyado. Gracias por la construcción infinita.

Gracias a Felipe por ser mi mejor maestro.

Quiero agradecerle a Coffee y Astro que me han acompañado en más de una trasnochada.

A mis tías y primos por celebrar cada pequeño logro.

Gracias a mis amigos que me alegran el estudio, los proyectos, la vida.

Gracias infinitas a mis profesores del colegio, de la universidad y de la industria, ellos han forjado lo que hoy soy.

CONTENT TABLE

TABLE LIST

FIGURE LIST

ACRONYMS, ABBREVIATIONS, AND ACRONYMS

ASME	The American Society of Mechanical Engineers
PFD	Process Fluid Diagrams
PI&D	Piping and Instrumentation Diagram
AFT	Applied Flow Technology
INDISA	Ingenieros Diseñadores Asociados S.A.
HVAC	Heating, ventilation, and air conditioning
GUI	Graphical User Interfaces

I. ABSTRACT

This document presents a comprehensive proposal for conducting pipelines' fluid dynamics calculations using software simulations and Python coding, in the context of an underground potash mine in Northwestern Canada. The work was done as a synergic collaboration between the University and HATCH S.A.S, allowing a huge background both in the academical and technical fields. The study addresses the critical need for efficient glycol transportation systems within potash mines to ensure optimal production and environmental sustainability. Utilizing AFT software and Python coding, the research aims to determine and optimize pipeline sizing, assess pump specifications, and verify the capacity of pipelines to safely transport glycol. The methodology involves a meticulous process of data collection, code programming, simulation modeling, and different scenarios analysis, supported by internal and external piping standards. The anticipated outcomes include operating points and final pipelines characteristics reports, presented as AFT simulations, technical documents, Excel data tables, and formal slides, which will facilitate a comprehensive evaluation of the different proposed solutions. And as additional value, a web application developed using Python language and designed to organize the huge amount data of the simulations, would be presented as an extra outcome.

This work is both an academic deliverable and a procedure-sheet about how the calculations and determinations are taken into the project.

Keywords — Potash, fluid-dynamic, piping, calculations, AFT (Applied Flow Technology), pump system, Python.

II. INTRODUCTION

Since 1955, Hatch has evolved into a distinguished enterprise that extends its reach far beyond mere technical work. Founded by Gerry Hatch in Canada, the company has maintained a constant focus on its workforce, viewing its employees as integral components of a big and interconnected network dedicated to looking for a better world [1]. Operating in three key sectors (metals and mining, energy, and infrastructure) Hatch boasts a global presence along 15 countries across the Americas, Europe, Asia, and Australia, with more than 11000 employees.

Here, in Medellín-Colombia, Hatch arrived in 2016 after making a trade agreement with INDISA, and since that date, many engineers and professionals have enrolled into the company. Also, the enterprise aims to train young professionals and students through different programs such as internships. Nowadays, Hatch Medellín is one of the biggest offices in South America, and specially piping discipline, is the biggest. This team centers most of the time on mining projects, of which 90% are international projects and a small quantity are national. One of these projects is a potash mine located in northwest of Canada.

The project emerged as a response to today's shortage of potash that the world is experiencing, due to political, social, and environmental factors that have significantly reduced its extraction, processing, and post-treatment levels [2]. As the global population grows, arable land becomes scarcer, and dietary habits improve, potash plays a crucial role in promoting sustainable agriculture. Especially now, when fertilizers enriched with potash are vital for ensuring food security [3]. As a result, the current potash producers understand the importance of extending its scope but now, with the challenge of ensuring environmental conservation. As a mining process, it involves various engineering disciplines, one of which is piping, overseen by mechanical engineers responsible for ensuring fluid transportation throughout the mine [4]. This means that without proper piping designs, the mine would not operate efficiently, resulting in low production levels and limited accessibility to fertilizers for all.

To guarantee an efficient piping design, hydraulic calculations are fundamental, particularly for pump systems. As they are the basis of all the engineering labors, it is fundamental to guarantee precision and reliability on each calculation, using different tools as software, which have increasingly become the cornerstone of hydraulic computations. AFT software stands out from others as it is solely focused on physics analysis, supported by mathematical background based on differential equations which iterates until reach the result where they converge. As the software developers state "It is a fluid dynamic simulation software for engineers, used to calculate pressure drop and pipe flow distribution in liquid and low-velocity gas piping and ducting systems" [5].

One of the main fluids used in industrial processes is glycol, which oversees cooling and anti-freezing equipment and areas, to guarantee a specific temperature by heat exchangers systems. In mining contexts, glycol primarily cools equipment experiencing substantial temperature elevation and prevents freezing in chillers. Additionally, when operational site temperatures are critical, glycol facilitates processes within an acceptable temperature range [6]. In this potash mine, glycol is the principal agent for ensuring temperatures ranges in a mill building, and it works throughout a two-pumps system.

In consideration of prep, this work aims to show and explain the calculation of glycol pipelines designed for a potash mine, considering that all the system is buried and focused on two principal items: optimization and sustainability. The calculations are based on software simulations, specifically using AFT Fathom for compressible fluids.

The deliverables consist of investigation summaries, technical reports and vendors quotes, which are going to be illustrated along the document as complementary activities to develop the solution for the project. All the above was made with the purpose of understanding the fluid dynamics phenomena, its mathematical bases and a large state of the art that allowed a holistic view of pump systems in mining industry.

In addition, a web application programmed in Python language, was developed as an important tool to facilitate the management of the huge amount of information taken from simulations. The idea emerged as a technological response to a common industrial issue that is the deficiency in effective data management, by combining the current surge in artificial intelligence (AI) capabilities, and the strategies form computing science.

Hydraulic calculations and analysis, pipeline design criteria, material and fluid characterization, data analysis and treatment, fluid dynamics considerations, and other related concepts will be discussed in this document. These concepts, rooted in mechanical engineering principles, serve as the mathematical foundation and practical basis for the final implementation of the pipelines.

III. PROBLEMATIC

Fluid-dynamics calculations are fundamentals for pipelines systems because they oversee determining the operational points of the different components, especially pumps. On mining processes, pipping is a fundamental discipline which defines how the fluids transportation would be worked to connect processes and machines, and its mathematical basis is essential.

Different fluids with huge variations of characteristics are studied in all cases, for that reason, each situation requires its own calculations and considerations. For this report, glycol is the studied fluid around all the pipeline of a mill building. Characterizing glycol (understanding its chemical and physical properties) is pivotal crucial to ensure the system's correct operation

In addition, the large amount of data difficult how the final operating points are defined, and the conventional ways to do it (Excel sheets, dynamic tables, etc.) are inefficient and most times generate reprocessing.

Considering all: What is the most optimal method for establishing the permissible operating point of a glycol pipeline?

A. Background

Pipes have been an essential part of human civilization for thousands of years, serving as conduits to transport fluids (both liquids and gases) from one location to another.

The earliest evidence of piping can be traced back to ancient civilizations such as the Egyptians, Greeks, and Romans. These civilizations utilized rudimentary piping systems made from materials like clay, stone, and wood for irrigation, water supply, and sewage disposal [7]. During the Industrial Revolution in the 18th and 19th centuries, advancements in metallurgy and manufacturing techniques led to the widespread adoption of metal pipes, particularly wrought iron and later steel. The 20th century allowed the introduction of materials such as cast iron, ductile iron, copper, and various alloys expanded the range of applications for piping systems [8]; while in the latter half of the 20th century and into the 21st century, advancements in materials science, engineering design, and construction techniques have revolutionized the field of piping. Plastic piping materials such as PVC, CPVC, PE, and PEX have gained prominence due to their affordability, corrosion resistance, and ease of installation [4] (Figure 1).

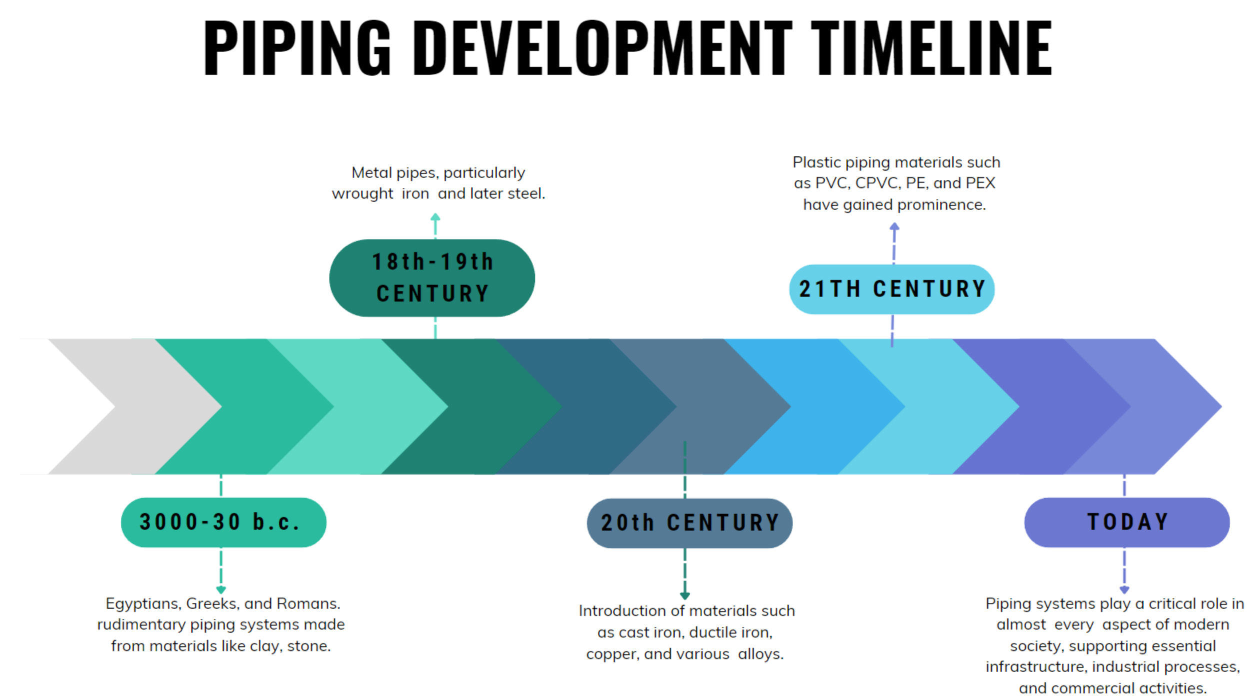


Figure 1. Piping Development Timeline

Today, piping systems play a critical role in almost every aspect of modern society, supporting essential infrastructure, industrial processes, and commercial activities. Ongoing research and development.

Talking now about glycol pipelines, it is important to say that glycol is an organic compound belonging to the alcohol family [9]. Its beginnings registered with nitroglycerin discovered during XIX century, which was useful for understanding the potential of organic nitrate compounds. The first uses of glycol as we know it nowadays, were for coal industry in mines during wars periods. Then, its uses were globally expanded because of its benefits working with chillers as cooler and anti-freeze fluid [10].

Now, it is fundamental to talk about the project's background itself. The potash mine comprises two stages: the first, engineered since 2016 and currently under construction, and the second, slated to begin in 2023 with planned completion by late 2026. Upon full development, this project will rank among the world's largest potash mines, producing approximately 8.5 million tonnes annually. Considering this, the background for calculations is extensive, due to stage 2 taking a lot of information from stage 1. However, it's crucial to note that not all background documents or data can be disclosed in this work due to confidentiality concerns.

Going deeper into potash mines backgrounds, is pivotal to say that Canada is the largest producer, and other countries as Ethiopia, Russia and Belarus (Figure 2), also count with important potash deposits [11]. All potash deposits are naturally buried deep below surface and are normally rich in potassium chloride (KCl), sodium chloride (NaCl) and other salts and clays and are typically obtained by conventional shaft mining with the extracted ore ground into a powder [12]. This is not the exception for the current project, because its main base of operation is shaft mining.

IV. JUSTIFICATION

This research project aims to address the critical need for efficient fluid dynamics calculations and reliable Python coding techniques tailored specifically for glycol pipelines within underground potash mines in the Canadian northwest. With the increasing demand for potash globally and the unique challenges posed by underground mining environments, ensuring the safe and optimal operation of glycol pipelines is fundamental. By taking advantage of advanced software tools and Python coding methodologies, this study pretends to enhance the understanding of the complex fluid dynamics within these pipelines, optimize operational parameters, and ultimately contribute to the safety, efficiency, and sustainability of potash mining operations in the region.

V. OBJECTIVES

Considering all the previous contextualization, specifically the problematic, the main objective of this work that determines its scope, is:

A. *General objective*

To establish the most optimal methodology using software simulations and Python coding for determining the permissible operating point of a glycol pipeline validated by internal and external quality standards.

To achieve the general objective, is fundamental to follow some steps that are guided by the following milestones as specific objectives:

B. *Specific objectives*

- To execute fluid dynamics calculations using software simulations.
- To develop a web application using Python coding for optimizing data management.
- To calculate operating conditions suitable for being included in pump specifications as NPSHA (Net Positive Suction Head Available), NPSHR (Net Positive Suction Head Required), pressure, power, etc.
- To verify piping class running hydraulic simulations for glycol services.
- To issue technical and detailed reports analyzing simulations' results, for showcasing optimum operational points calculated.
- To compare different hydraulic models based on simulations results, for choosing the most accurate.
- To validate vendor information through direct comparisons, for ensuring optimal decision of pumps.

VI. THEORETICAL BACKGROUND

Fluid dynamics plays a pivotal role in the design and operation of pipeline systems, particularly in industries where the efficient transport of fluids is essential. In the context of underground potash mining in the Canadian northwest, fluid dynamics calculations for glycol pipelines are crucial for maintaining operational integrity and efficiency. Understanding fluid flow characteristics such as velocity profiles, pressure drops, and viscosity changes due to temperature fluctuations is fundamental to optimizing pipeline design. These factors not only impact the performance of glycol pipelines but also influence operational costs and safety considerations in harsh underground environments. By employing rigorous fluid dynamics analysis, engineers can predict and mitigate potential issues related to flow stability, heat transfer, and fluid behavior under varying operational conditions.

Glycol pipelines are extensively utilized in underground potash mining operations to regulate temperatures and prevent freezing of essential equipment and infrastructure. The deployment of glycol as a heat transfer medium requires careful consideration of its thermophysical properties, including thermal conductivity and specific heat capacity, which directly influence its effectiveness in maintaining operational temperatures. Challenges arise from the dynamic thermal environment within underground mines, where ambient temperatures can fluctuate significantly, necessitating precise fluid dynamics calculations to ensure glycol flows adequately and uniformly through the pipeline network. Moreover, the operational constraints imposed by confined spaces and structural limitations in underground mines amplify the importance of accurate fluid flow predictions to optimize pipeline performance and ensure operational reliability.

A. Mine context

Due to the project is planned to be one of the biggest potash mines in the world, the numbers that describes its magnitude are highly considerable:

- The total mine's extension (both the buried and surface part) spans approximately 400km² by 800km², translating to a staggering 320,000 km². To put this into perspective, this area is nearly one-third the size of Colombia, whose total extension is approximately 1,141,748 km² [13].
- The project is scheduled to be completed in two phases: basic and detailed engineering are anticipated to conclude around 2026, with plant operations commencing around the first half of 2029 [13].
- The plant is projected to yield an annual output of 8.5 million tonnes per annum (Mtpa) metric tons [13].

B. Mathematical resources

For conducting hydraulic calculations, is important to consider many mathematical inputs as pipelines length based on Equation 1, pump sizing taken from Equation 2, piping losses based on Equation 5 and others specific characteristics based on Equation 3 and Equation 4.

- **Continuity equation:** this one ensures that throughout all the pump system the mass is going to be conserved independently of sections, accessories or equipment. It shows that the amount of fluid entering a region is equal to the amount leaving it [14]. It is described as:

$$A1 * v1 = A2 * v2 \ (1)$$

Where:

A1 and A2 are the cross-sectional areas at two different points in the system.

v1 and v2 are the corresponding fluid velocities.

- **Pump power calculation:** as pump is the one in charge of ensuring a constant flow rate and specific pressure on the system, its calculation is fundamental for ensuring the processes [14]. It is defined as:

$$\frac{\rho\ g\ Q\ h}{\eta}\ (2)$$

Where:

P is the pump power in kilowatts (kW).

ρ is the fluid density (kg/m³).

g is the acceleration due to gravity (approximately 9.8 m/s²).

Q is the volumetric flow rate (m³/hr).

h is the pump head (meters) or the differential pressure across the pump.

- **Bernoulli's Equation:** describes the conservation of energy along a streamline. Bernoulli's equation is based on the principle that the total energy (*kinetic energy + potential energy + pressure energy*) remains constant along a streamline in an ideal, non-viscous, and incompressible fluid flow. It is commonly used in fluid mechanics, aerodynamics, and hydraulics to analyze flow behavior [14].

$$P + \frac{1}{2}\rho\, v^{2}\ + \rho g h = cte$$

Where:

P is the pressure (Pa).

ρ is the fluid density (kg/m³).

v is the fluid velocity (m/s).

g is the acceleration due to gravity (m/s²).

h is the elevation (m).

- **System Curve and Pump Performance Curve:** The system curve represents the relationship between pump head and flow rate for a specific system. The pump performance curve shows how the pump head varies with flow rate. The intersection of these curves determines the operating point of the pump within the system.

- **Reynolds number:** is a dimensionless quantity used in fluid dynamics to predict the flow regime of a fluid. It characterizes the relative importance of inertial forces (due to fluid velocity) to viscous forces (due to fluid viscosity) [14]. The formula for Reynolds number is:

$$Re = \frac{\rho\, v\, D}{\mu} \quad (4)$$

Where:

ρ is the fluid density (kg/m³)

v is the fluid velocity (m/s)

L is a characteristic length (e.g., diameter of a pipe or channel) (m)

μ is the dynamic viscosity of the fluid (Pa·s or N·s/m²)

- **Darcy Weisbach equation:** describes head loss (pressure drop) in a pipe due to friction. It is commonly used in fluid mechanics and hydraulic engineering.

$$hf = f\, \frac{L\, v^2}{2\, g\, D}$$

Where:

hf is the head loss (pressure drop) in meters.

f is the Darcy friction factor (dimensionless).

L is the length of the pipe in meters.

D is the diameter of the pipe in meters.

v is the fluid velocity in meters per second.

g is the acceleration due to gravity (approximately 9.8 m/s²).

Considerations:

a) The Darcy friction factor ((f)) depends on the Reynolds number and the pipe roughness.
b) This equation describes the losses produced by accessories as bends, fittings, etc.
c) The equation accounts for energy losses due to pipe friction.
d) It is commonly used to calculate pressure drop in pipelines, water distribution systems, and HVAC systems.
e) Remember that the Darcy-Weisbach equation helps engineers analyze fluid flow and design efficient piping systems.

To propose the simulations, not just mathematical assumptions are needed. It is fundamental to understand how a section and discharge pump system looks like (Figure 1). They are mainly composed of a reservoir, valves, accessories, pump and final-arrived equipment.

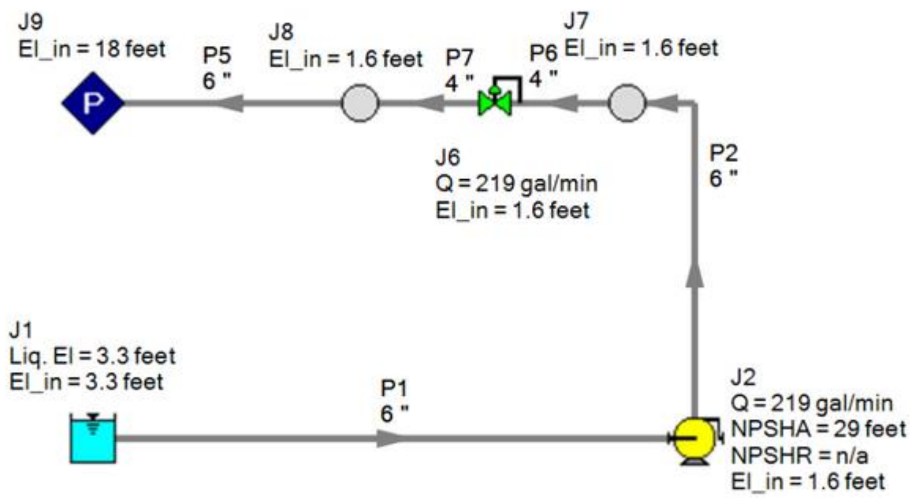


Figure 2. Typical Pump System in AFT Fathom

C. Standards

It is fundamental to base all the calculations and assumptions on international allowable standards and on project's own design criteria's. In this case, the project was based on two principal piping international standards:

- **ASME B31.3 - Process Piping [15]:** ASME B31.3 provides comprehensive guidelines for the design, materials, fabrication, installation, inspection, examination, and testing of process piping systems.

Scope:

a. Covers piping systems used in chemical, petroleum, pharmaceutical, textile, paper, semiconductor, and other industries.
b. Addresses high-temperature, high-pressure, and corrosive fluid services.

Key Features:

a. Defines allowable stresses, material selection, and design criteria.

b. Includes requirements for welding, flanges, fittings, valves, and supports.
c. Ensures safety, reliability, and efficiency of process piping systems.

- **ASME B31.9 - Building Services Piping [16]:** ASME B31.9 focuses on piping systems within industrial, institutional, commercial, public buildings, and multi-unit residences.

Scope:

a. Covers piping systems for building services (e.g., HVAC, fire protection, water supply, drainage).
b. Excludes large industrial facilities covered by ASME B31.1.

Key Features:

a. Prescribes requirements for design, materials, fabrication, installation, inspection, and testing.
b. Addresses piping systems within the building or property limits.
c. Serves as a companion to other ASME B31 codes.

- **Project's Design Criteria:** This document illustrates all the design considerations which must be taken in piping design. The document contains a lot of information related to documentation requirements and standards, general information as units and language, sustainability in design and the most important part for the project, the design requirements. To develop a piping system in AFT software, the most important data extracted from design criteria document, are the velocities in the pipelines.

D. Research bases

Previous research and studies have contributed valuable insights into fluid dynamics within pipeline systems, offering methodologies and empirical data that inform the design and operational strategies for glycol pipelines in mining environments. During the elaboration, many documents in which computational tools have been applied to calculate fluid-dynamics systems in potash mines were reviewed, but there are some especially used during this document elaboration:

- **Thesis - numerical modelling of ground penetration radar for potash mine safety [17]**

This thesis develops a software tool to simulate the geological stratigraphy of a potash mine using gprMax, a Ground Penetrating Radar (GPR) simulation software. The tool helps evaluate auto-picking algorithms by simulating GPR responses from clay seams in the mine's roof. The study compares an industry-standard auto-picking algorithm with a new one, Clustered Ratio Derivative (CRD), and utilizes cloud computing for execution.

This document was fundamental to correlate academic work with an industrial necessity in the same case as a potash mine. Even if the contexts and applications are very different, the compression which the author did between common industrial tools and his development, was extremely helpful to find an propose of Python application developed.

- **Diseño y simulación hidráulica del sistema de refrigeración en una planta de procesamiento de spodumene a hidróxido de litio: análisis de escenarios representativos y filosofía de operación [18]**

This thesis designs and simulates the cooling system for a lithium processing plant using AFT Fathom. It models equipment and pipe hydraulics based on process flow and piping diagrams. A suitable pump was selected, and different scenarios were simulated to optimize valve operation and system behavior under pressure changes. The study aimed to find the best pump performance and improve system efficiency, providing reliable data for final design decisions.

In this case, the content, distribution and focus of the thesis, was fundamental to understand how hydraulic calculations are applied, as an academic development, in the industrial context of a mine or plant. In addition, the software used was the same implemented in this work, so also its calculations representation, assumptions and results, were important to do a comparative approach.

- **A mechanical model to determine upheaval buckling of buried submarine pipelines [19]**

This study addresses the risk of buckling in submarine pipelines due to thermal loads. It introduces a simple mechanical model to predict the axial buckling load of buried pipelines, considering both transverse soil resistance and axial compressive forces. The model, validated against non-linear finite element analysis, accurately captures upheaval buckling behavior, crucial for assessing pipeline integrity under high-pressure conditions.

In this case, the analysis focus was completely different, but the document was important due to its studies related with buried pipelines, as in the potash mine are calculated. The study, planning and calculations of buried pipelines, are very different due to the chemical and physical conditions which they face, which generates special requirements to be considered during engineering calculation process.

E. Python resources

The development of a Python application for facilitating data management and analysis of simulation results involves understanding various theoretical concepts in software development, graphical user interfaces (GUIs), and data processing. This section gives an overview of these concepts, laying the groundwork for implementing the tool.

- **Graphical User Interfaces (GUIs):** Tkinter is the standard GUI library for Python. It provides a robust and platform-independent way to create GUI applications. In the provided code, Tkinter is used to create the main application window and various widgets for user interaction. The application leverages Tkinter's capabilities to provide a user-friendly interface for loading and displaying simulation data.
- **Data Handling and Analysis:** Pandas is a powerful data manipulation library in Python, widely used for data analysis tasks. The application uses Pandas to read Excel files, filter and process data, and compute statistical measures like means. This simplifies handling complex datasets and performing necessary calculations efficiently.
- **Data Visualization:** Tabulate is a Python library used for creating simple ASCII tables. It allows for easy formatting of DataFrames or lists into plain text tables that can be displayed in the console or GUI. In the code, Tabulate is used to format the processed data into readable tables that are displayed within the Tkinter application, providing users with clear and organized output.
- **Image Processing:** Pillow is a Python Imaging Library that adds image processing capabilities to Python. It allows for opening, manipulating, and saving various image file formats. In the application, Pillow is used to load and resize an image

(logo) for display within the Tkinter window, enhancing the visual appeal of the GUI.

By applying these theoretical concepts, the application provides a comprehensive tool for managing and visualizing simulation results, improving the efficiency of data analysis tasks.

VII. METHODOLOGY

This methodology section details the processes and techniques used to perform fluid dynamics calculations. The study involves software simulations and Python coding to analyze the fluid flow characteristics and ensure efficient pipeline operation under the mine's specific conditions.

A. Fluid dynamics calculations

To obtain the calculations and mathematical-theorical assumptions, a subsequent process must be developed, adhering strictly to each stage. This workflow involved collecting all necessary data and verifying its accuracy, creating the simulation model and setting up boundary and initial conditions, running the simulations and monitoring for convergence and accuracy, using Python scripts to analyze simulation results and perform additional calculations, and finally, documenting all procedures, findings, and insights in the report.

It is important to considerate that the project is divided into two stages: the first is already operating in the Canada-northwest potash mine, and the second one, is undergoing basic engineering processes. Given this context, a significant volume of information has been provided, primarily pertaining to the first stage of the project.

Firstly, it was fundamental to filter the data, which was collected from multiple sources, including detailed blueprints and schematics of the mine's provided by the enterprise, information on the physical properties of glycol, including density, viscosity, specific heat capacity, temperature and pressure conditions, sourced from process databases, and operational parameters such as flow rates, pressure drops, and temperature variations obtained from the historical data from the first stage of the project.

Several assumptions were made during the study, including assuming steady-state conditions for the fluid flow, simplifying complex geometrical features to reduce computational load, and considering glycol properties to be constant and not varying with temperature or pressure.

Each system calculated needed a document package specific for each zone composed by:

- A design criteria document, utilized for determining allowable velocities throughout the pipeline and roughness permissible.
- Distance measurements extracted from the Smart Plant 3D model deliverable, provided as coordinates.
- All Process Flow Diagrams (PFDs), which offer a general overview of the process.
- A specifications document (piping class) outlining the characteristics of specific materials.
- All Piping and Instrumentation Diagrams (P&IDs) relevant to the system.
- Excel data table detailing fluid property.

However, finding these documents is not as easy as a normal information search due to the high quantity of zones that the project has. To identify a specific zone, the project utilizes a site plan containing unique equipment identification numbers. These numbers are then cross-referenced with an equipment data manager to ascertain the route to the requisite documentation. With all necessary information in hand, a model is simulated using the AFT software, following these steps illustrated in Figure 3.

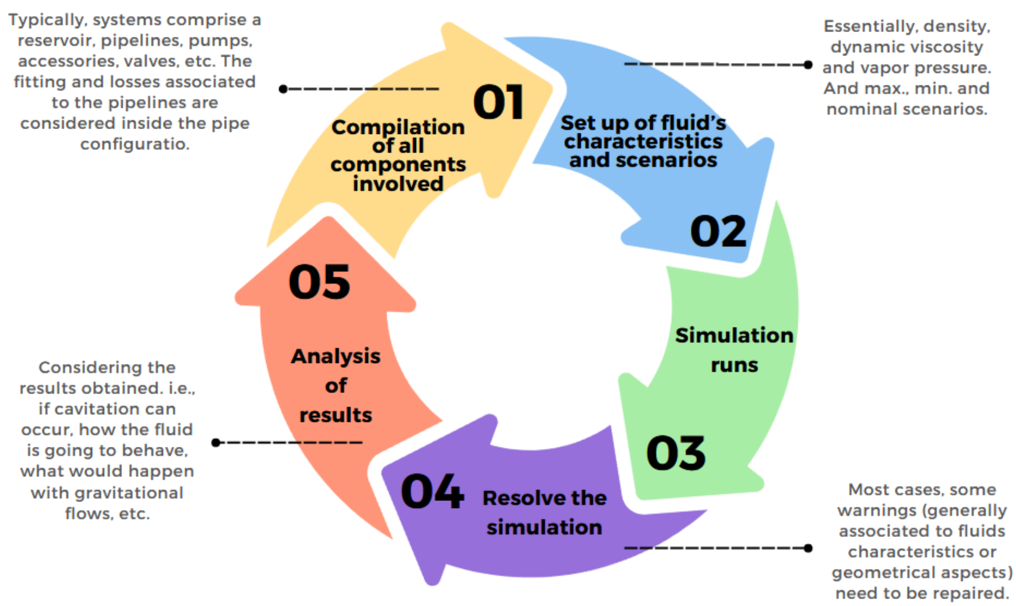


Figure 3. Process to run simulations

B. *Glycol system*

For the specific case of glycol distribution, is important to clarify that the system collects waste heat generated during equipment operation and repurposes it for various applications within the plant, including air preheating for glazing, product dryers, submerged combustion heaters, and reagent water preheating. The system consists of:

- 6 air compressors with their manual valves *(cold to warm)*
- 1 reagent HX *(hot to tempered)*
- 3 slimes tailings centrifuge with their control valves *(cold to warm)*
- 2 salt tailings centrifuge with their control valves *(cold to warm)*
- 6 product centrifuges with their manual valves *(cold to warm)*
- 1 control valve balancing *(warm to tempered)*
- 4 product dryer air preheaters with their manual valves (*warm to tempered)*
- 2 product dryer 1 scrubber with its manual valve *(cold to warm)*
- 1 expansion tank
- 1 control valve balancing *(cold to tempered)*
- 1 principal pump
- 3 reclaim heat exchangers with their manual valves *(tempered to cold)*
- 8 compactors each one with 3 lines. Each line composed by: 3 gear box cooling *(cold to warm)* with their control valves, 2 roller with their control valves *(cold to warm).*
- 2 glazing dryer air preheaters with their control valves *(warm to tempered).*
- 4 product coolers with their control valves *(cold to warm).*
- Back up: 1 heat exchanger, 1 secondary pump and 1 tank.

The system works as follows: the heat recovery system consists of two cooling glycol circulation pumps, one operating and one standby. It recirculates a constant glycol flow through the hot equipment to collect the waste heat for some air and water preheating applications. The cold glycol collects waste heat created by compactors, product dryer scrubber heat exchangers, product coolers, centrifuges and air compressors; then the hot glycol is sent to the preheating applications include air preheating for glazing dryers and product dryers and water preheating for reagent preparation; and then the tepid glycol returns and is pumped to the three glycol cooling heat exchangers, two glycol-brine heat exchangers and one glycol-water heat exchangers.

These three cooling heat exchangers are normally two operating and one standby. In summertime, the glycol-water heat exchanger can be run in series with one of the glycol-brine heat exchangers to cool part of the glycol further down if needed. This scenario with unequal flows automatically balanced by the resistances in the piping & heat exchanges was used for pump sizing in JS1 calculation.

A previous model made for the first stage of the project was used as a base. This model was pretty like the one needed for the new stage, but some new users (equipment or zones which require the supply of the fluid) are considered. New users were added due to the implementation of new compactors into the processing sequences of the mineral. After the AFT model were modeled with new users (Fig 5), the process was completed by:

- The principal objective of the calculation process was to determine the values of glycol flow to guarantee optimal operation of all the users (equipment), and to verify if the two pumps (one operating and the other one standby) can supply glycol for all users. The calculation also checks different values in pipes and pumps.
- As inputs, two kinds of data were considered: process data which clarified chemical and physical properties of glycol and limits of operation; and hydraulic inputs which described how the system would work during its normal operation. A summary of both could be seen in Table 1 and in Table 2.

TABLE 1

SUMMARY OF PROCESS INPUTS

Property	Value	Units
Glycol SG	1.06	N.A.
Max. temperature	60	°C
Min. temperature	5	°C
Nominal temperature	38	°C

TABLE 2

HYDRAULIC INPUT DATA

Stream #	Users	Flow Control	Flow Scenarios (m3/h) Two Product Lines Operating																						Equipment Pressure Rating or MAWP	Allowable Pressure drop	Pressure drop	Equivalent K calculated for Fathom Model
			max	min	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12	Case 13	Case 14	Case 15	Case 16	Case 17	Case 18	Case 19	Case 20	kPag	kPa	kPa	
7000	Compactors line 1	33.1m^3/h per compactor, 3 Compactors per Line	99,3	0,0	66,2	66,2	99,3	99,3	66,2	99,3	99,3	66,2	66,2	99,3	99,3	99,3	66,2	66,2	66,2	66,2	0,0	0,0	66,2	66,2	Roll: **758** Lube: 1034 Gear: 1034	n/a	135 at 3.4m3/h 70 at 12.7m3/h 16 at 6.8m3/h	60.6 13.6 10.8
7020	Compactors line 2	Manual throttling for Roll, 2-way control for lube oil cooler and gearbox cooling	99,3	0,0	66,2	66,2	99,3	99,3	66,2	99,3	99,3	66,2	66,2	99,3	99,3	99,3	66,2	0,0	0,0	0,0	66,2	66,2	0,0	0,0				
27040	Glycol to CP7/8		66,2	0,0	0,0	0,0	66,2	66,2	0,0	66,2	66,2	0,0	0,0	66,2	66,2	66,2	0,0	0,0	66,2	66,2	66,2	66,2	66,2	66,2				
7002	Product centrifuge line 1	Manual throttling. Flow /3	13,5	7,5	13,5	13,5	13,5	13,5	7,5	13,5	13,5	13,5	13,5	7,5	13,5	13,5	7,5	7,5	7,5	13,5	13,5	13,5	13,5	13,5	1034,0	n/a	15 @ 4.5m3/h	23,1
7032	Product centrifuge line 2	Manual throttling. Flow /3	13,5	7,5	13,5	13,5	13,5	13,5	7,5	13,5	13,5	13,5	13,5	7,5	13,5	13,5	0,0	0,0	7,5	13,5	13,5	13,5	13,5	13,5	1034,0	n/a	15 @ 4.5m3/h	23,1
7004	Air compressors	Manual throttling. Flow /4	77,6	67,5	77,6	77,6	77,6	77,6	67,5	67,5	77,6	77,6	77,6	67,5	77,6	77,6	67,5	67,5	67,5	67,5	77,6	77,6	77,6	77,6	1103,0	n/a	79.43 @ 16.875m3/h	152,8
7006	Salt & Slimes centrifuges	Manual throttling. Flow /5	8,8	0,0	0,0	0,0	8,8	8,8	3,1	8,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,1	0,0	8,8	8,8	0,0	0,0	**500,0**	n/a	15 @ 4.5m3/h	3,8
7011	Product dryer scrubber HX 1	Flow constant confirmed at 61m^3/h. Manual throttling	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	1076,0	n/a	25.18 @ 60.85m3/h	11,0
7031	Product dryer scrubber HX 2	Flow constant confirmed at 61m^3/h. Manual throttling	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	61,0	0,0	0,0	61,0	61,0	61,0	61,0	61,0	61,0	1076,0	n/a	25.18 @ 60.85m3/h	11,0
7009	Product coolers	Flow varies with 2 way control valves, Flow /2	249,1	31,1	249,0	249,0	31,1	31,1	173,2	34,1	34,1	249,1	249,1	34,1	34,1	34,0	31,1	86,6	248,9	249,1	248,9	248,9	249,1	249,1	**700,0**	n/a	105 @ 62.5m3/h (Flow split into two)	43,7
		Total cooling flow required	**616,7**	**288,8**	**608,1**	**608,1**	**531,4**	**531,4**	**513,4**	**524,3**	**525,6**	**608,2**	**608,2**	**503,6**	**525,6**	**525,4**	**299,5**	**288,8**	**588,9**	**598,1**	**616,7**	**616,7**	**608,1**	**608,1**				
		Primary bypass flow	**342,2**	**14,3**	**22,9**	**22,9**	**99,6**	**99,6**	**117,6**	**106,7**	**105,4**	**22,8**	**22,8**	**127,4**	**105,4**	**105,6**	**331,5**	**342,2**	**42,1**	**32,9**	**14,3**	**14,3**	**22,9**	**22,9**				
7018	Glyco to Brine HXs	Manual throttling																							**960,00**	n/a	54.31 @312m3/h	71,5
	Glycol to Water HX	Manual throttling	308,4																						1017,00	n/a	49.52 @312m3/h	65,2
	Cooling Glycol Circulation Pump	Pump flows required with min 17.2m3/h recirculation flow assumed		**631**																								
923	Product dryer air preheater 1	Flow constant confirmed at 129m^3/h, Manual throttling	129,0	129,0	**129,0**	**129,0**	129,0	129,0	129,0	129,0	129,0	129,0	129,0	129,0	129,0	129,0	94,7	122,4	129,0	129,0	129,0	129,0	129,0	129,0	1200,0	70,0	30.69 @ 51m3/h (Flow split into two)	19,2
934	Product dryer air preheater 2	Flow constant confirmed at 129m^3/h, Manual throttling	129,0	129,0	**129,0**	**129,0**	129,0	129,0	129,0	129,0	129,0	129,0	129,0	129,0	129,0	129,0	0,0	0,0	129,0	129,0	129,0	129,0	129,0	129,0	1200,0	70,0	30.69 @ 51m3/h (Flow split into two)	19,2
922	Glazing dryer air preheater 1	Flow constant confirmed at 55.5m^3/h - Manual throttling	55,5	0,0	55,7	55,7	55,7	55,7	55,7	55,7	55,5	55,5	55,5	55,5	55,5	0,0	55,7	55,7	55,7	0,0	55,7	55,7	55,7	55,7	1200,0	120,0	104.4 @ 55.47m3/h	283,9
912	Glazing dryer air preheater 2	Flow constant confirmed at 55.5m^3/h - Manual throttling	55,5	0,0	55,7	55,7	55,7	55,7	55,7	55,7	55,5	55,5	55,5	55,5	55,5	0,0	0,0	0,0	55,7	0,0	55,7	55,7	55,7	55,7	1200,0	120,0	104.4 @ 55.47m3/h	283,9
987	214 HX reagents	2 way control valve	74,5	67,5	**74,5**	**74,5**	74,5	74,5	67,5	67,5	67,5	67,5	67,5	67,5	74,5	67,5	67,5	67,5	67,5	67,5	74,5	74,5	67,5	67,5	996,0	n/a	10.78 @ 74.4m3/h	16,3
		Total preheating flow required	**443,9**	**217,9**	**443,9**	**443,9**	**443,9**	**443,9**	**436,9**	**436,9**	**436,5**	**436,5**	**436,5**	**436,5**	**443,5**	**325,5**	**217,9**	**245,6**	**436,9**	**325,5**	**443,9**	**443,9**	**436,9**	**436,9**				
		Seondary bypass flow	**272,6**	**43,2**	**164,2**	**164,2**	**87,5**	**87,5**	**76,5**	**87,4**	**89,1**	**171,7**	**171,7**	**67,1**	**82,2**	**199,9**	**81,6**	**43,2**	**152,0**	**272,6**	**172,8**	**172,8**	**171,2**	**171,2**				
Product Cooler Preheater Skid																												
7626	Product cooler glycol preheat heater skid	Manual throttling									45,4														1034,0	n/a	65 @ 45.4m3/h	51,2
7628	Product cooler glycol preheat Exchanger	2 way control valve									72,8														1034,0	n/a	33 @ 72.8m3/h	10,1

In addition to hydraulic inputs, it is important to say that most of the users will have a manual throttling valve to balance the flows during commissioning. The flow will be controlled by a temperature control valve.

The excess cold glycol flow pumped will be bypassed through the primary bypass control valve, which will maintain a constant pump discharge pressure. And the excess hot glycol will be bypassed through the secondary bypass control which will maintain enough pressure for those preheaters. See the simplified system control diagram below.

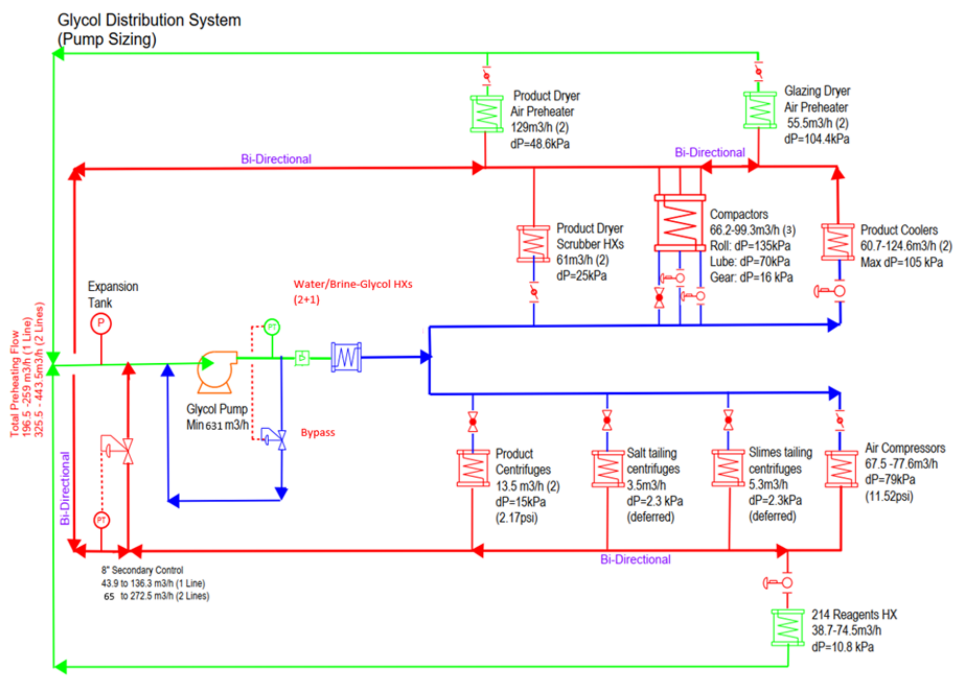


Figure 4. Simplified control system diagram

1. As in all calculations, some assumptions were considered to achieve a satisfactory simulation. Some of them were:
    - The material of pipes was assumed to be Carbon Steel, ASME B16.5 Class 150.
    - Friction factor allowance of 1.1 included for all the piping and fittings.
    - Site Atmospheric Pressure is 94.8 kPa(a).
    - Fluid is considered Newtonian.
    - No inner diameter reduction due to scaling.

- Carbon steel pipe roughness 0.04572mm and fluid viscosity 4.22 cP as per Fathom data.
- To estimate the power for information, the overall pump efficiency assumed as 75%.
- For Tees and Wyes, the laminar correction was not used to prevent non-applicable warning in the Fathom model.

2. Then, the AFT Fathom model was configurated by creating each scenario. The scenarios methodology consists of a principal model with nominal configurations which is replicated all the times needed until considering all the possible operational points that the system could have. Each of those “copies” are the scenarios simulated and analyzed. The values of the scenarios are determined by Table 2.
3. After that, each case ran into the AFT Fathom conditions.
4. Most of the cases, the scenarios present problems which are related with warnings or critical conditions, or even could be, mathematical problems. For example, it could happen that the system doesn’t converge, or the thermodynamic conditions don’t do it. All these problems required extra configurations until the system worked properly. The problems encountered during the simulations principally were:
   - **These results do not represent a converged solution:** this is a mathematical problem very common in one of the cases. The problem was generated by the losses correction applied inside pipes, which means that the system considers extra losses to prevent any lack of flow, which makes the system more exigent with a volumetric flow that never would be reached. As the flow requirement was higher, the system could not find a solution, so to solve this problem, it was just necessary to disable that correction (but still it complies with all the normal corrections for pipelines as K factor and roughness losses).
   - **Junction X Had Reverse Flow - Pump Head Could Not Be Predicted:** this error just appears in pumps systems and occurs when the flowrate goes backwards through the pump, becoming the software unable to predict the pump head accurately due to this unexpected flow direction. To solve this, it was just necessary to adjust the flow in the control valve balancing.

- **Static pressure lower than vapor pressure at inlet/outlet of pipe/junction X:** indicates that the pressure at a specified location in the system has dropped below the fluid's vapor pressure. This can lead to cavitation, which is the formation of vapor bubbles within the liquid due to low local pressures. What was generating this was an error in the vapor pressure inlet data defined in the fluid properties, so it was just necessary to adjust to the real value and then, it was not a problem anymore.

5. Finally, the results were saved as a normal report and then, the calculation deliverable as a report is made by the engineering group in charge of that zone and reviewed by all the checkers in charge of (normally 3 checkers).

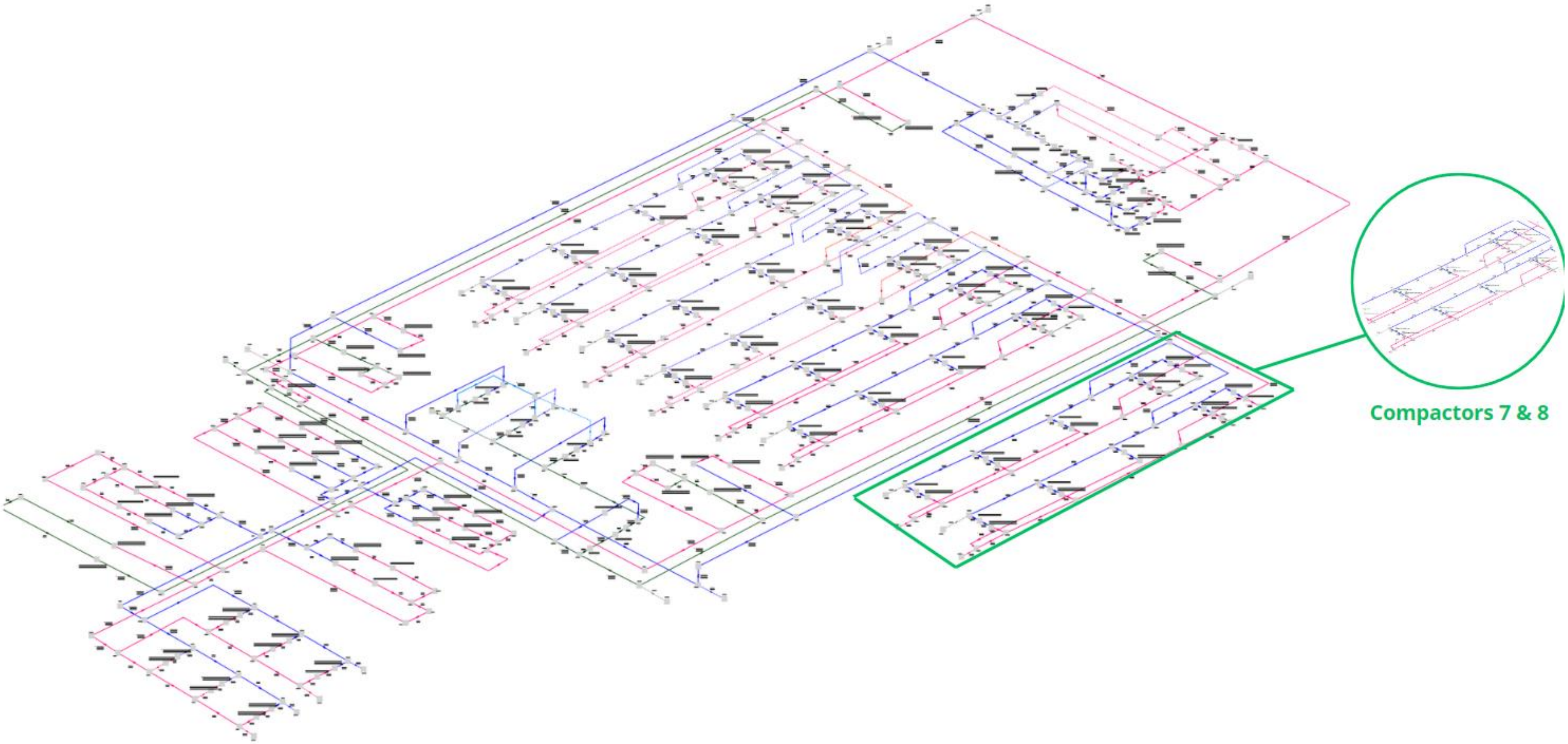


Figure 5. Piping system layout

C. *Python coding*

Until this part, the normal methodology has been run, however, during the calculation report elaboration, a problem was identified: the large amount of data difficulted a lot the construction of tables and diagrams. For that reason, the python app was developed, to manage the data and facilitate the information management.

First, to understand how the program works, it is fundamental to know the information flow along it, for that purpose, the Figure 6 shows the code's flow diagram.

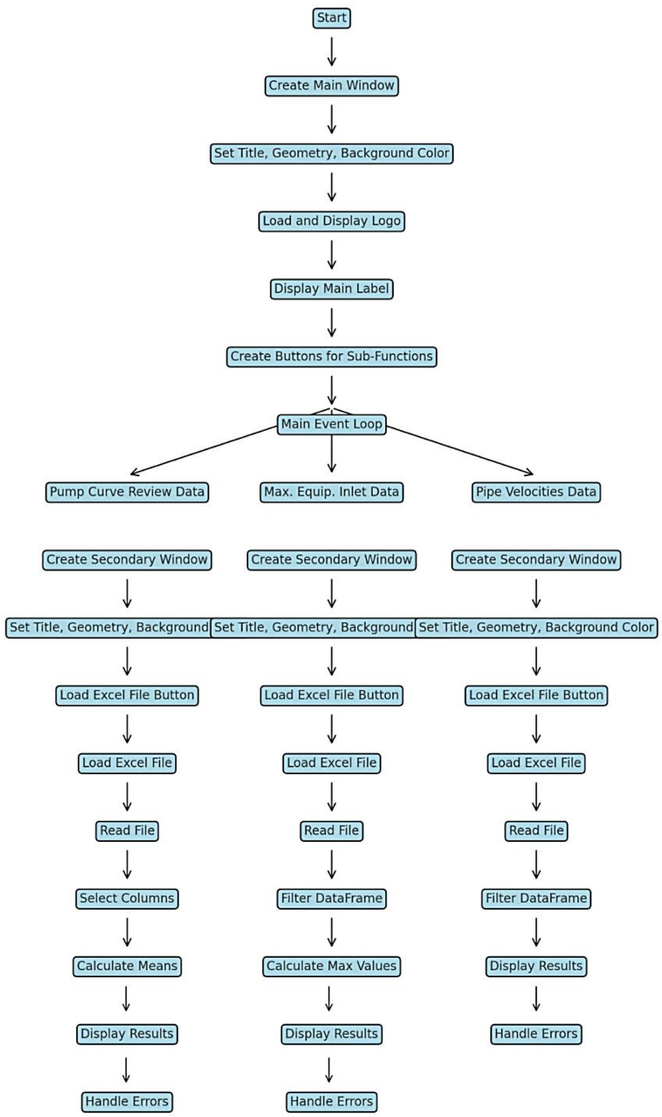


Figure 6. Flow diagram

As the code is very long to be explained here, a simplified model is explained in Figure 7.

Figure 7. Code description

This Python code structure was used to create a graphical user interface (GUI) for processing and displaying data from Excel files using the Tkinter library. The code begins by importing necessary libraries, including Tkinter for the GUI, pandas for data manipulation, PIL for image handling, and tabulate for table formatting. The *from_rgb* function is defined to convert RGB color tuples into hexadecimal color strings for customizing the GUI appearance. Three main functions *max_equipments_inlet*, *pump*, and *pipes* are defined to handle specific data processing tasks, each opening a secondary window for user interaction. The main window of the application is configured with a title, size, and background color, and it includes a logo image at the top. User interaction is facilitated through buttons that trigger the secondary windows, allowing users to load and process Excel files, search for specific data, and display results in a text area. The main event loop runs the application, making it responsive to user actions.

D. Methodology close-up

The methodology outlined above encapsulates the rigorous approach taken to ensure the accuracy and reliability of fluid dynamics calculations for glycol pipelines in the underground potash mine. Each stage of the process, from data collection and simulation setup to the analysis and documentation of results, was meticulously executed to align with engineering standards and project requirements.

By leveraging advanced software simulations and Python coding, the study provided a comprehensive understanding of the fluid flow characteristics within the pipeline system. The iterative nature of the simulation process, coupled with thorough validation against operational data from the first stage of the project, underscored the robustness of the methodology. This methodological rigor ensures that the findings and recommendations presented in this report are not only scientifically sound but also practically applicable, paving the way for enhanced pipeline efficiency and reliability in the challenging environment of an underground potash mine.

VIII. RESULTS AND ANALYSIS

After going through all the steps outlined in this document, we can summarize the following results and analyze them.

A. *Fluid dynamics calculation*

The primary objective of the simulation was to determine optimal glycol flow values for all users (equipment) and verify whether the two pumps (one operational and the other on standby) could adequately supply glycol. To achieve this, the Table 2 and the simulation results to establish glycol flow rates for each user were analyzed. However, during the simulation simulations, issues or warnings appeared constantly, demanding a thorough review of the flows. Adjustments were made to ensure optimum operation in all cases and to adhere to fluid dynamics limits. The final glycol flow rates for each user are summarized in Table 3.

TABLE 3

GLYCOL FLOW RESULTS PER EQUIPMENT

Equipment	**Flow [m3/h]**
Air compressors	72.55
Reagent HX	74.5
Slimes tailings centrifuge	5.95
Salt tailings centrifuge	5.95
Product centrifuges	10.5
Control valve balancing	111.76
Product dryer air preheater	129
Product dryer scrubber	61.8
Control valve balancing	191.17
Gear box cooling	6.8
Roller	3.4
Glazing dryer air preheater	55.5
Product cooler	140.1

From the last table is important to mention that the values were taken as average values from all the 20 cases analyzed.

In Table 3 is evidenced that users as air compressors, control valve balancing and product coolers, are the principal glycol-demanding equipment, because of its function. In the case of air compressors, glycol is fundamental to collect heat of compression process, and in the case of product coolers, the fluid is the one in charge of its main function of removing heat based on the great thermal conductivity that glycol has. And in the case of control balancing, glycol passes through it depending on the needs of other users, for that reason it registers the highest glycol flow.

For the second part of the principal objective, was possible to determine the capacity of the two pumps to supply glycol for all users. In this point, is important to remember than the base of the calculation was a system used for the first stage of the project, which was different from the current one, so even if the set up was already confirmed, was fundamental to check if all the system's values were suitable.

To confirm that the system is suitable, a comparison between pump's operation pump curve and system curve, was done in Figure 8.

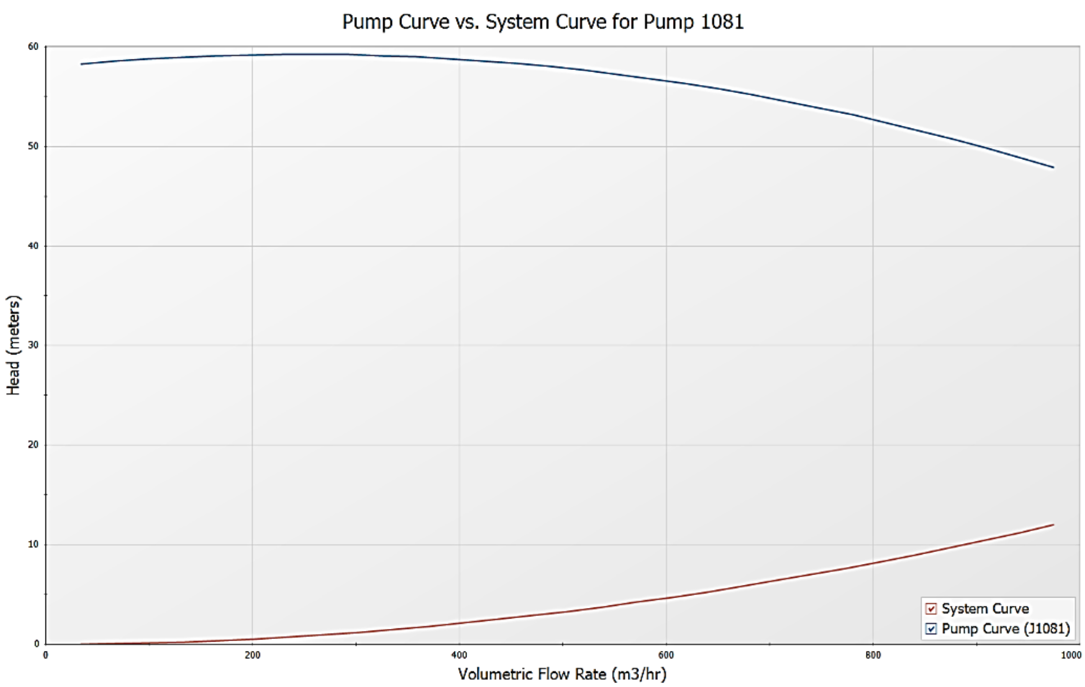


Figure 8. Pump curve comparison

Figure 8 shows a typical pump curve VS. system curve chart, which is a graphical representation used to show the relationship between the performance characteristics of a pump and the requirements of the system in which it operates. In this case, the pump analyzed is the principal which operates all time. The graph is composed by two axes: the x-axis represents the volumetric flow rate (m^3/hr), and the y-axis represents the head (m), which is the pressure the pump needs to overcome. Between them, two curves are drawn:

- **Pump Curve (Blue Line):** This curve shows the relationship between the head and the flow rate for Pump 1081. As the flow rate increases, the head decreases. This is typical for centrifugal pumps, indicating that at higher flow rates, the pump cannot generate as much pressure.
- **System Curve (Red Line):** This curve represents the relationship between the head and the flow rate required by the system. It typically increases with flow rate due to frictional losses and other system resistances.

For the specific curve, the operating point could not be seen because the intersection point is not showed, however, is possible to determine that the operating point is around 1300 m3/hr, which is great if we compare it with the actual value of the pump's flow rate (Figure 9).

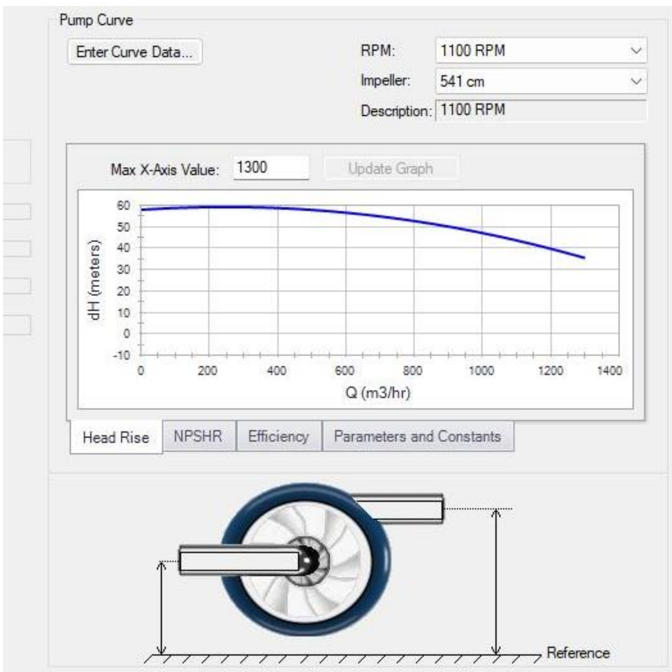


Figure 9. Input values for the pump

After all the simulations, was possible to say that the two pumps considered could supply glycol for all the system with any issue or lack of fluid. In addition, the pumps were already characterized by the vendor, so with the simulations made, the enterprise can confirm that the pumps already selected are completely suitable for the system.

In addition to the listed results, others values important for the system were considered and analyzed, these were:

- **Pump outputs:** although the simulation results indicated that the pumps were sufficient to ensure glycol supply, it remains crucial to examine the numerical values for their key characteristics. These include flow rate, head, pressure rise, pressure stagnation discharge, pump efficiency, power, NPSHa (Net Positive Suction Head Available), and NPSHr (Net Positive Suction Head Required). Given the 20 cases of interest, Table 4 displays the results for all scenarios.

TABLE 4

PUMP OUTPUT

	Scenarios		Flow	Head	Pressure Rise	P Stag. Disc.	Pump Efficiency	Power	NPSHA	NPSHr
	Case	Condition	m3/h	m	kPa	kPag	%	kW	m	m
Two Product Lines in Operation	Case1	2 HXs in Parallel. Line N°1 and N°2 of compactors working +	822	52,2	550,9	920,3	87	144,4	44,3	6,1
	Case2	2 HXs in Serie. Line N°1 and N°2 of compactors working +	822	52,2	550,9	920,3	87	144,4	44,3	6,1
	Case3	2 HXs in Parallel. Line N°1 and N°2 of compactors working.	813	52,4	553,4	923,0	87	143,7	44,3	6,0
	Case4	2 HXs in Serie. Line N°1 and N°2 of compactors working.	813	52,4	553,4	923,0	87	143,7	44,3	6,0
	Case5	N°2 of compactors working + compaction 7/8	810	52,5	554,1	923,7	87	143,5	44,3	6,0
	Case6	2 HXs in Parallel. Line N°1 and N°2 of compactors working +	812	52,4	553,7	923,2	87	143,6	44,27	6,0
	Case7	N°2 of compactors working + compaction 7/8	812	52,4	553,6	923,2	87	143,6	44,3	6,0
	Case8	2 HXs in Parallel. Line N°1 and N°2 of compactors working.	822	52,2	550,9	920,3	87	144,4	44,3	6,1
	Case9	2 HXs in Serie. Line N°1 and N°2 of compactors working.	822	52,2	550,9	920,3	87	144,4	44,3	6,1
	Case10	2 HXs in Parallel. Line N°1 and N°2 of compactors working +	809	52,5	554,4	924,1	87	143,4	44,27	6,0
	Case11	N°2 of compactors working + compaction 7/8	812	52,4	553,6	923,2	87	143,6	44,3	6,0
	Case12	N°2 of compactors working + compaction 7/8	812	52,4	553,6	923,2	87	143,6	44,3	6,0
Only One Product in Operation	Case13	2 HXs in Parallel. Line N°1 and N°2 of compactors working.	723	53,3	563,2	933,4	86	140,7	44,3	5,8
	Case14	2 HXs in Parallel. Line N°.1 of compactors working.	773	53,3	563,3	933,4	86	140,7	44,3	5,8
	Case15	2 HXs in Parallel. Line N°.1 of compactors working +	823	52,2	550,8	920,2	87	144,4	44,3	6,1
	Case16	2 HXs in Parallel. Line N°.2 of compactors working +	824	52,1	550,5	919,9	87	144,5	44,3	6,1
	Case17	2 HXs in Parallel. Line N°.1 of compactors working	771	53,4	563,6	933,8	86	140,6	44,3	5,8
	Case18	2 HXs in Serie. Line N°.1 of compactors working	771	53,4	563,6	933,8	86	140,6	44,3	5,8
	Case19	2 HXs in Parallel. Line N°.2 of compactors working +	825	52,1	550,2	919,6	87	144,6	44,3	6,1
	Case20	2 HXs in Serie. Line N°.2 of compactors working +	825	52,1	550,2	919,6	87	144,6	44,3	6,1

In the latest table, is possible to observe that despite variations in the configuration of the heat exchangers (whether in series or parallel distribution), the glycol flow remained stable at approximately 810 m³/h (maximum flow values reached around 825 m³/h, while the minimum was approximately 723 m³/h). Additionally, critical parameters such as head (52 m), pressure rise (554 kPa), pressure stagnation discharge (924 kPa), pump efficiency (87%), power (143 kW), NPSHa (44 m), and NPSHr (6 m) exhibited remarkable consistency across all studied cases.

- **Pipe velocities:** according to the system's Design Criteria document, one of the primary limitations pertains to the fluid velocities within the pipelines. High velocities can result in significant losses within the pipe network. Therefore, it is crucial to assess the critical velocities associated with glycol flow in the pipelines (Table 5).

TABLE 5

PIPE VELOCITIES DATA

	6" Pipe 837	8" Pipe 853	8" Pipe 1005	10" Pipe 854
Case	Velocity [m/s]	Velocity [m/s]	Velocity [m/s]	Velocity [m/s]
Case 1	0,99	1,126459	1,09	1,047737
Case 2	2,47	0,925831	1,95	0,920439
Case 3	0,99	0,812193	1,09	0,848351
Case 4	2,47	0,926034	1,95	0,920568
Case 5	2,47	0,926429	1,95	0,920819
Case 6	0,99	1,126459	1,09	1,047737
Case 7	2,47	0,927246	1,95	0,921337
Case 8	2,47	0,926429	1,95	0,920819
Case 9	2,47	1,424373	1,95	1,236725
Case 10	0,99	0,569749	0,57	0,361462
Case 11	0,99	1,127265	1,09	1,048248
Case 12	0,00	0	0,00	0
Case 13	0,99	1,641686	1,09	1,374593
Case 14	1,97	1,686474	1,66	1,403008
Case 15	0,99	1,126888	1,09	1,048009
Case 16	0,99	1,126475	1,09	1,047755
Case 17	2,47	0,925831	1,95	0,920439
Case 18	0,99	1,126475	1,09	1,047755
Case 19	1,97	1,686474	1,66	1,403008
Case 20	0,99	1,126904	1,09	1,048027

In Table 6, the velocities of the fourth most critical pipes are displayed. Throughout various cases, the values remain consistent, with minimal deviation. Notably, in Case 12, the velocities are recorded as 0 m/s due to the closure of pipes 837, 853, 1005, and 854, as specified in the input data.

Finally, could be said that considering the admissible limits defined by the design criteria from 1.0m/s to 1.6m/, then the velocities and friction losses within these pipe headers meet the design criteria, thus eliminating the need for any modifications to the pipe sizes.

- **Pressure**

TABLE 6

MAX. OPERATING PRESSURE AT EQUIPMENT INLET

Equipment	Elevation m	Max P Stag. In kPag	Design P or MAWP kPag	Pump Dead Heading P kPag
Reclaim 1-HXST-00007	545.2	890.6	960	1040.2
Reclaim 2-HXST-00003	545.2	890.8	960	1040.2
Water-HXST-00006	545.1	878.7	1017	1041.3
214 Reagents HXST-00009	552.1	431.5	996	967.3
Air Compressors	543.2	640	1103	1061.4
Compactor Gear Box Cooling	550.3	820.3	1034	986.4
Compactor Lube Oil Cooling	549.9	820.3	1034	990.6
Compactor Rolls Cooling	553.9	565.5	758	948.3
Glazing Dryer Air Preheaters	564.3	316.9	1200	838.5
Product Centrifuge Lube Oil Cooler	568.5	546.9	1034	794.1
Product Coolers	557.2	623.5	700	913.5
Product Dryer Scrubber HXs	542.8	569.2	1076	1065.6
Product Dryer Air Preheaters	569.6	233.1	1200	782.5
Salt tailing centrifuges	554	423.7	500	947.3
Slimes tailing centrfuges	756.8	426.3	500	-1195.2
Solex Skid	558	541.2	1034	905.0

From Table 6, is important to note that Maximum Pressure Stagnation at Inlet (Max P Stag. In kPag) represents the highest pressure recorded at the inlet of each equipment piece; it is critical for ensuring the equipment can withstand operational pressure. While MAWP or Maximum Allowable Working Pressure, indicates the maximum pressure that each equipment piece is designed to handle safely. It must be higher than the maximum stagnation pressure to ensure safe operation. So, comparing both values for each equipment, is possible to say that MAWP is lower in all cases, which means that pressures are completely sure for operating based on single characteristics of each equipment.

However, there is a specific case that must be reviewed: the Reclaims. That is because Max P Stag. In is pretty close to MAWP (890.6 and 960 kPa respectively), so is important to ensure that pressure doesn't increment by regular monitoring or a pressure relief system implementation. Finally, is important to mention that based on the piping spec, the pressure/temperature value allowable is 1686 kPag below 85 deg C.

B. *Python coding*

As a result of python coding, the final app beta version is presented. The application consists of a main window (Figure 10) which contains three buttons: “Pump Curve Review Data”, “Max. Operating Pressure at Equipment Inlet Data” and “Pipe Velocities Data”. Each one of those open a secondary window which displays a friendly user interface that allows to input the Excel file to be processed.

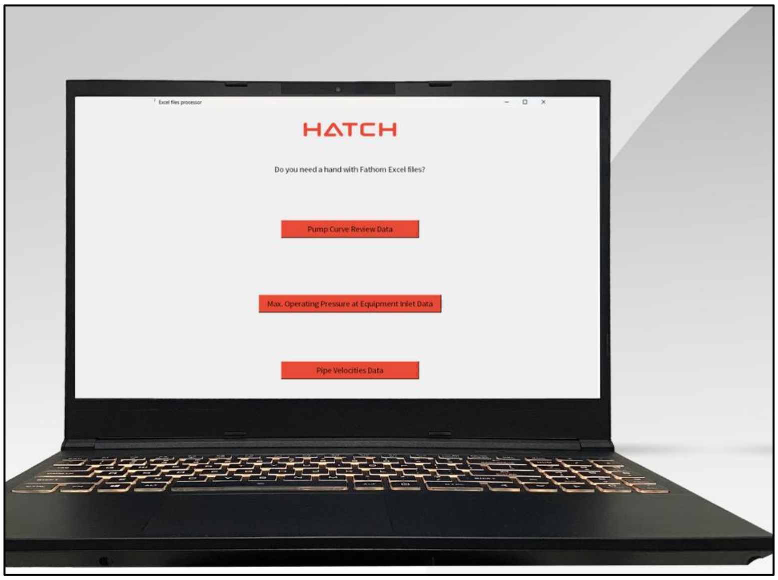
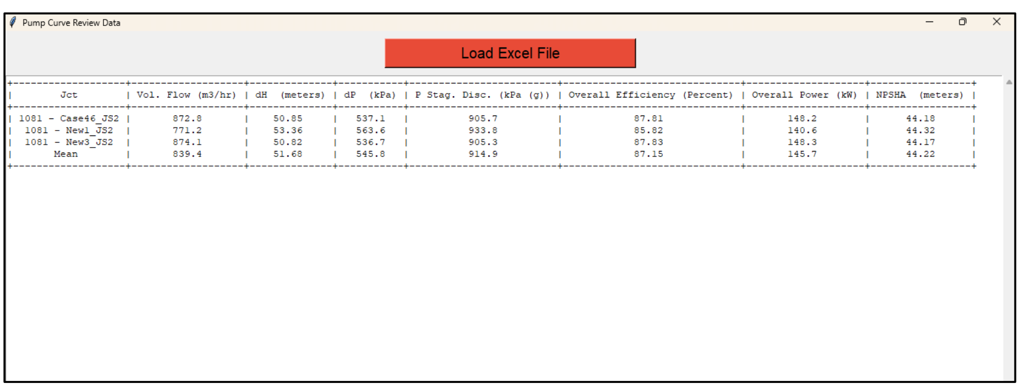


Figure 10. Main app window

- **Pump Curve Review Data:** this option allows the user to load an Excel file with the pump outputs from the AFT Fathom model, then, it takes just the information needed for the report, and organics it in a table. As an additional thing, it calculates the mean of each column to give, an average value of each parameter (Figure 11).



Pump Curve Review Data

Load Excel File

Jct	Vol. Flow (m3/hr)	dH (meters)	dP (kPa)	P Stag. Disc. (kPa (g))	Overall Efficiency (Percent)	Overall Power (kW)	NPSHA (meters)
1081 - Case46_JS2	872.8	50.85	537.1	905.7	87.81	148.2	44.18
1081 - New1_JS2	771.2	53.36	563.6	933.8	85.82	140.6	44.32
1081 - New3_JS2	874.1	50.82	536.7	905.3	87.83	148.3	44.17
Mean	839.4	51.68	545.8	914.9	87.15	145.7	44.22

Figure 11. Pump Curve Review Data window

- **Max. Operating Pressure at Equipment Inlet Data:** this option requires the user to input the number of cases analyzed and to provide an Excel file containing detailed junction information. This functionality is particularly beneficial for pipeline design, as it focuses on the maximum operating pressures at each equipment inlet. The program will display the maximum pressure values and features a search bar that allows the user to locate specific equipment by name (Figure 12).

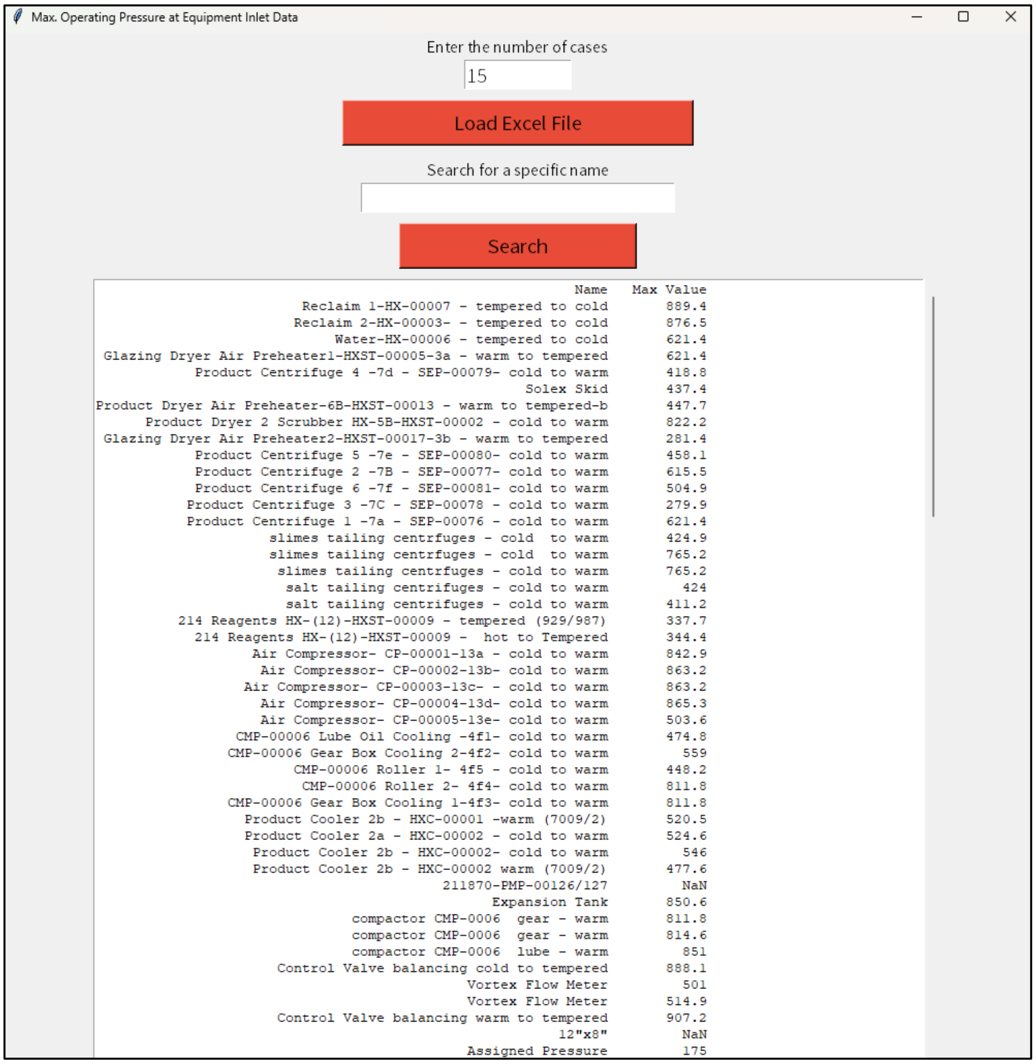
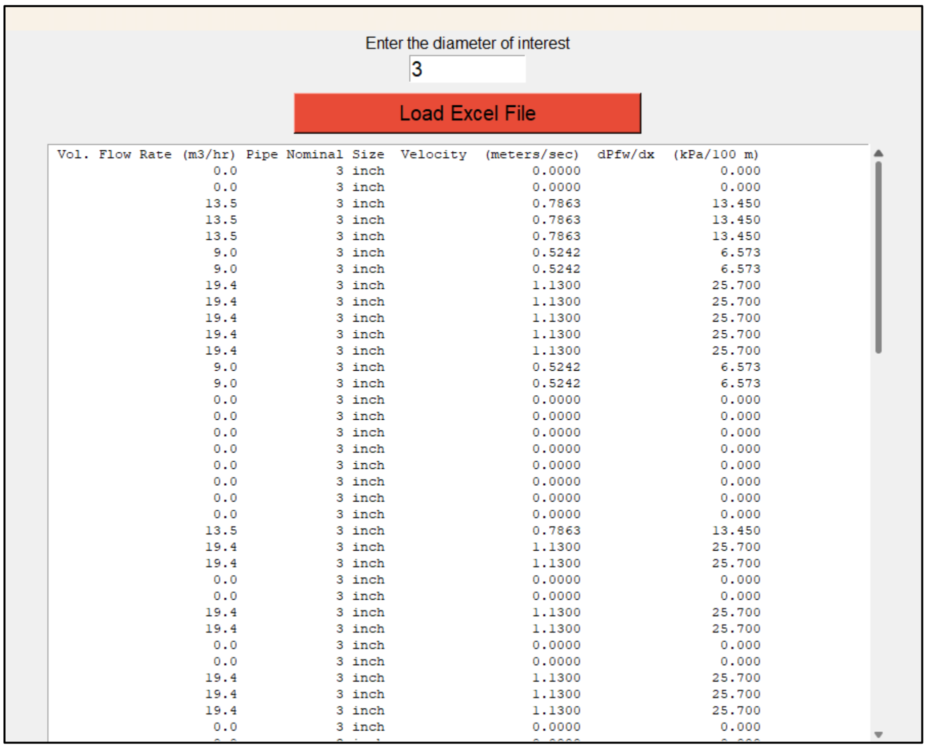


Figure 12. Max. Operating Pressure at Equipment Inlet Data window

- **Pipe Velocities Data:** this option enables the user to input the diameter of interest, upon which the program will display key information necessary for characterization: volume flow rate, velocity, and the rate of change of pressure along the X direction. Both velocity and dPfw/dx are critical parameters. The velocity determines the appropriateness of the pipe size, ensuring that it meets design criteria and operational requirements. WhidPfw/dxis is the indicative of pressure losses along the pipeline, which are essential for assessing the efficiency and performance of the system.



Vol. Flow Rate (m3/hr)	Pipe Nominal Size	Velocity (meters/sec)	dPfw/dx (kPa/100 m)
0.0	3 inch	0.0000	0.000
0.0	3 inch	0.0000	0.000
13.5	3 inch	0.7863	13.450
13.5	3 inch	0.7863	13.450
13.5	3 inch	0.7863	13.450
9.0	3 inch	0.5242	6.573
9.0	3 inch	0.5242	6.573
19.4	3 inch	1.1300	25.700
19.4	3 inch	1.1300	25.700
19.4	3 inch	1.1300	25.700
19.4	3 inch	1.1300	25.700
19.4	3 inch	1.1300	25.700
9.0	3 inch	0.5242	6.573
9.0	3 inch	0.5242	6.573
0.0	3 inch	0.0000	0.000
0.0	3 inch	0.0000	0.000
0.0	3 inch	0.0000	0.000
0.0	3 inch	0.0000	0.000
0.0	3 inch	0.0000	0.000
0.0	3 inch	0.0000	0.000
0.0	3 inch	0.0000	0.000
0.0	3 inch	0.0000	0.000
13.5	3 inch	0.7863	13.450
19.4	3 inch	1.1300	25.700
19.4	3 inch	1.1300	25.700
0.0	3 inch	0.0000	0.000
0.0	3 inch	0.0000	0.000
19.4	3 inch	1.1300	25.700
19.4	3 inch	1.1300	25.700
0.0	3 inch	0.0000	0.000
0.0	3 inch	0.0000	0.000
19.4	3 inch	1.1300	25.700
19.4	3 inch	1.1300	25.700
19.4	3 inch	1.1300	25.700
0.0	3 inch	0.0000	0.000

Figure 13**.** Pipes velocities information

IX. CONCLUSIONS

In this study, was comprehensively described the simulation process for determining operational points, specifically applied to a glycol system. After executing all the phases needed, the following conclusions could be considered for understanding the final scope of the work.

- Throughout this work, the entire simulation process for determining operational points was described. Applied to a glycol system, the simulations demonstrated that the current pumps, already purchased, are suitable for the system requirements in terms of flow and pressure. Additionally, the results obtained from the software were fundamental in verifying the final operating point of the pump, pipe velocities, and pressure drops.
- During the purchase and construction phases, it is crucial to ensure specific flows to the various pieces of equipment associated with the glycol system. Since glycol is essential for maintaining operational temperatures across different equipment and zones, determining the flow needed for each user is critical for final calculations such as pipe sizes and control valve setpoints. Consequently, it was possible to determine the flow requirements for each piece of equipment across the 20 cases analyzed.
- For these kinds of systems, it is essential to ensure optimum operation under all possible scenarios, most of which are related to changes in weather or flow requirements. To address this, the system was evaluated in 20 different scenarios, yielding optimal results for each case with the same base setup, with only the flows being adjusted to meet process requirements.
- Python coding proved to be an excellent tool for reducing time and effort in resolving tasks, particularly in data management. Python's powerful capabilities not only organize information but also execute a wide range of tasks, displaying only the necessary information after processing. In this work, Python was fundamental in managing all the data from simulation runs and, beyond just managing it, the code was able to display the new information in a user-friendly interface that could be edited by any user.
- As future work, developing a Python code that allows for comparison between the first and second stages of the project would be highly beneficial. This tool would not only be useful for glycol or pipeline calculations but also for assisting those working in the second stage.

The program should be flexible enough to receive various types of information and provide an interface that users can modify according to their needs.

- As a methodological exercise, it is important to highlight the benefits that the preparation of this document has generated, not just for academic purposes but also for the project's benefit. Reflecting on the normal industrial processes, it is evident that the exercise of analyzing and addressing deep questions is often overlooked due to the multitude of tasks at hand. This work demonstrates that dedicating even a small portion of time to such analysis can make a significant difference in the project by developing new processing tools.

REFERENCES

[1] Hatch, "Celebrating 50 years of service," Hatch. ART INNOV., p. 150, 2005.

[2] M. C. Chrispim, M. Scholz, and M. A. Nolasco, "Phosphorus recovery from municipal wastewater treatment: Critical review of challenges and opportunities for developing countries," J. Environmental Manage., vol. 248, p. 109268, Oct. 2019. Accessed: Jul. 3, 2024. [Online]. Available: https://doi.org/10.1016/j.jenvman.2019.109268.

[3] J. Doe, A. Smith, and B. Johnson, "Potassium Depletion in Agricultural Soils: A Threat to Global Food Security," Nature Food, vol. 5, no. 3, pp. 123-135, Mar. 2023.

[4] J. Penuelas, F. Coello, and J. Sardans, "A better use of fertilizers is needed for global food security and environmental sustainability," Agriculture & Food Secur., vol. 12, no. 1, Mar. 2023. Accessed: Jul. 3, 2024. [Online]. Available: https://doi.org/10.1186/s40066-023-00409-5.

[5] J. M. Galvin, *Ground Engineering - Principles and Practices for Underground Coal Mining*. Cham: Springer Int. Publishing, 2016. Accessed: Jul. 3, 2024. [Online]. Available: https://doi.org/10.1007/978-3-319-25005-2.

[6] "AFT Fathom | Fluid Dynamic Simulation Software," AFT | Pipe Flow Modeling Software for Engineers. Accessed: Jul. 3, 2024. [Online]. Available: https://www.aft.com/products/fathom.

[7] H. Yue, Y. Zhao, X. Ma, and J. Gong, "Ethylene glycol: properties, synthesis, and applications," Chem. Soc. Rev., vol. 41, no. 11, p. 4218, 2012. Accessed: Jul. 3, 2024. [Online]. Available: https://doi.org/10.1039/c2cs15359a.

[8] A. T. Ahmed, F. El Gohary, V. A. Tzanakakis, and A. N. Angelakis, "Egyptian and Greek Water Cultures and Hydro-Technologies in Ancient Times," Sustainability, vol. 12, no. 22, p. 9760, Nov. 2020. Accessed: Jul. 3, 2024. [Online]. Available: https://doi.org/10.3390/su12229760.

[9] N. M. L, Ed., *Piping handbook*, 7th ed. New York: McGraw-Hill, 2000.

[10] G. Johanson, "Toxicity Review of Ethylene Glycol Monomethyl Ether and its Acetate Ester," Crit. Rev. Toxicol., vol. 30, no. 3, pp. 307–345, Jan. 2000. Accessed: Jul. 3, 2024. [Online]. Available: https://doi.org/10.1080/10408440091159220.

[11] L. Stajuda et al., "Composition, features, problems, and treatment related to cooling fluid – a

review," Combust. Engines, Jul. 2023. Accessed: Jul. 3, 2024. [Online]. Available: https://doi.org/10.19206/ce-169185. [11] S. Jasinski, "Potash," U.S. Geological Survey, Mineral Commodity Summaries, January 2022. [Online]. Available: https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-potash.pdf. [Accessed: Jul. 2, 2024].

[12] G. M. Mudd and J. C. Boger, "The Everlasting Potash Debate: What Is The World's True Potash Resource?," in *Proceedings of the 10th International Conference on Mine Closure*, 2015, pp. 1-10. [Online]. Available: https://www.imwa.info/docs/imwa_2015/IMWA2015_Mudd_56.pdf. [Accessed: Jul. 2, 2024].

[13] BHP, "Jansen," BHP, [Online]. Available: https://www.bhp.com/what-we-do/global-locations/canada/jansen. [Accessed: Jun. 2, 2024].

[14] Y. A. Çengel and J. M. Cimbala, *Fluid Mechanics: Fundamentals and Applications*, 5th ed. New York, NY, USA: McGraw-Hill Education, 2022. [Online]. Available: https://books.google.com.co/books?hl=es&lr=&id=LIZvEAAAQBAJ&oi=fnd&pg=PP1&dq=fluid+dynamics+cengel+isbn&ots=4L30MPiWrf&sig=xpd77TyoFoACPbtJWu6jt5nf0gM. [Accessed: Jun. 22, 2024].

[15] ASME, ASME B31.3 - Process Piping, The American Society of Mechanical Engineers, 2020.

[16] ASME, ASME B31.9 - Building Services Piping, The American Society of Mechanical Engineers, 2017.

[17] Okonkwo, Victor & Briggs, Tokini & Paranjape, Raman & Berghe, Matthew. (2019). Numerical Modelling of Ground Penetrating Radar for Potash Mine Safety. 1-7. 10.3997/2214-4609.201902602.

[18] F. Ruiz, "Diseño y simulación hidráulica de sistemas de bombeo para agua potable utilizando herramientas computacionales," M.S. thesis, Universidad de Antioquia, 2023. [Online]. Available: https://bibliotecadigital.udea.edu.co/bitstream/10495/35585/2/RuizFelipe_2023_DisenoSimulacionHidraulica.pdf. [Accessed: Jul. 2, 2024].

[19] P. Teixeira, "Mechanical modeling to determine the influence of adhesion on the mechanical properties of cells," Ph.D. dissertation, Universidad de Antioquia, 2022. [Online]. Available: https://bibliotecadigital.udea.edu.co/bitstream/10495/32781/1/TeixeiraPaulo_2022_mechanicalmodeldetermine.pdf. [Accessed: Jul. 2, 2024].