

Towards AI-Assisted HAZOP: A Knowledge Graph and Agentic AI Route

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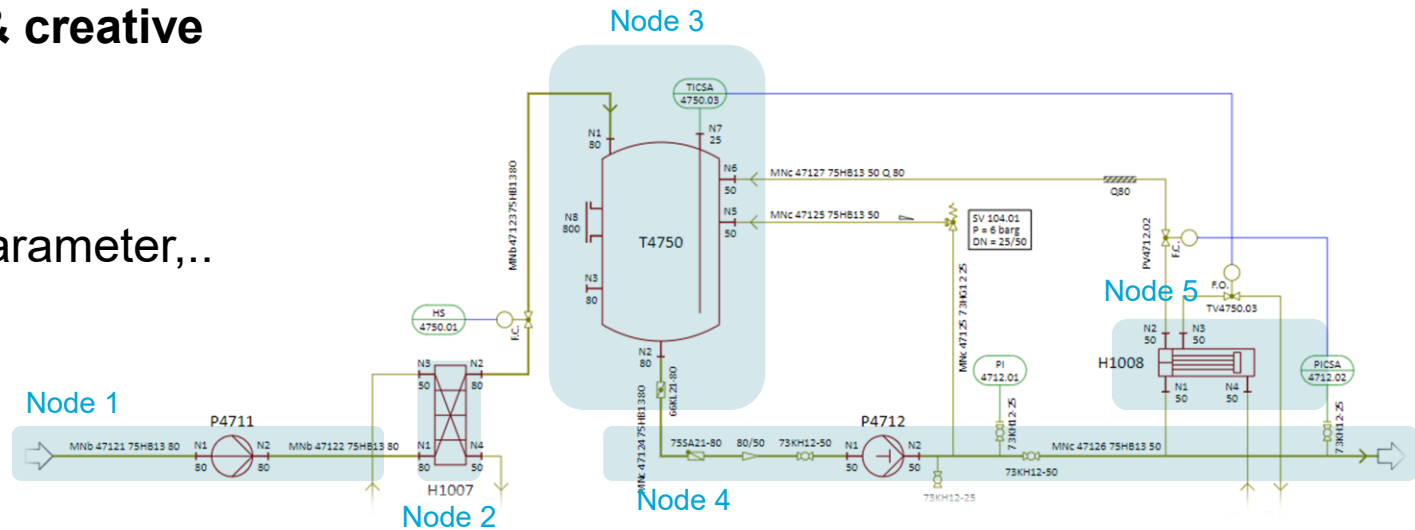


**Process
Intelligence**
RESEARCH

Aachen, December 2025

HAZOPs – a systematic safety review [1, 2]

- We love HAZOP for its **systematic & creative** approach.
- **But, extensive scope**^[3]:
 - Permutation: node, guideword, parameter,..
extensive analysis
- **Manual work with P&ID**
- **Lengthy study time** :
 - 2-6 weeks ^[2]
 - Personnel stamina & budget



Systematic & Creative Brainstorming

Design Intent				
Deviation	Cause	Consequence	Safeguard	Action

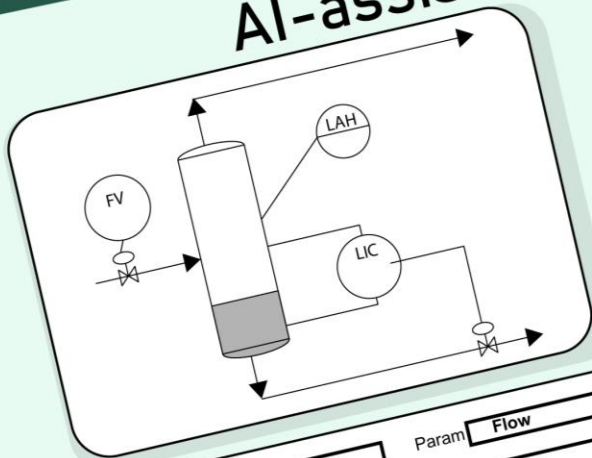
[1] Center for Chemical Process Safety. *Guidelines for Hazard Evaluation Procedures*. 1st ed. Wiley, 2008. <https://doi.org/10.1002/9780470924891>.

[2] Crawley, Frank, and Brian Tyler. *HAZOP: Guide to Best Practice: Guidelines to Best Practice for the Process and Chemical Industries*. Third edition. Amsterdam: Elsevier, 2015.

[3] Baybutt, Paul. "A Critique of the Hazard and Operability (HAZOP) Study." *Journal of Loss Prevention in the Process Industries* 33 (January 2015): 52–58. <https://doi.org/10.1016/j.jlpi.2014.11.010>.

AI-assisted HAZOP

Generate HAZOP



Guide Word **High**

Param **Flow**

Dev'n **High Flow**

Possible Causes

- 1 FV-1 Wide open
- 2 Line break.
- 3

Consequences

- 1 High level in KO pot with liquid carry-over to compressor with serious damage to rotor. Potential hydrocarbons release.
- 2
- 3

Safeguards

- 1 High level alarm LAH-1
- 2 High level alarm HHLA - 1 shutdown.
- 3 Vessel inspection yearly.

Actions

- 1 Limiting flow orifice, automatic shutdown.
- 2 Determine extent of typical hydrocarbon release.
- 3 Set-up vessel inspection.

Respib	By	Date
1	JB	01-Jan-24
2	PM	15-Jan-24
3	FD	30-Jan-24

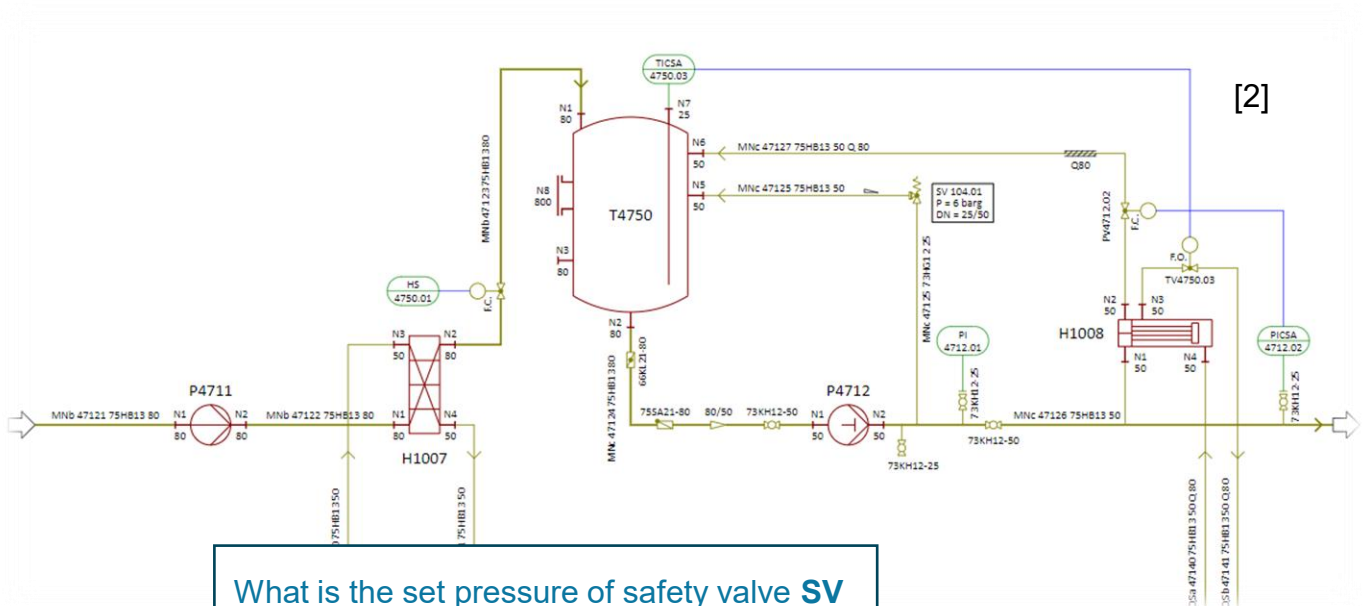
Automate data
query from P&ID

Assist us with
safety analysis

Manage
documentation

Has AI worked with P&IDs?

- Today AI can read flowsheet as image “**directly**”.
- But:
 - Accuracy only **59-74%**.^[1]
 - Poor information density, expensive
 - Difficult to edit or interact with
- We need a better **representation** for P&ID and better way to **integrate** with LLMs & HAZOP.



What is the set pressure of safety valve **SV 104.01**?



.. the safety valve SV 104.01 seems to have a set pressure of 25/60, which could be interpreted as: - **25 bar**, or - **60 psi**



[1] Internal testing from various multimodal LLMs (OpenAI, Anthropic)

[2] Theißen, Manfred, and Michael Wiedau. "DEXPI P&ID Specification 1.3," 2021.

Road to AI-Augmented HAZOP

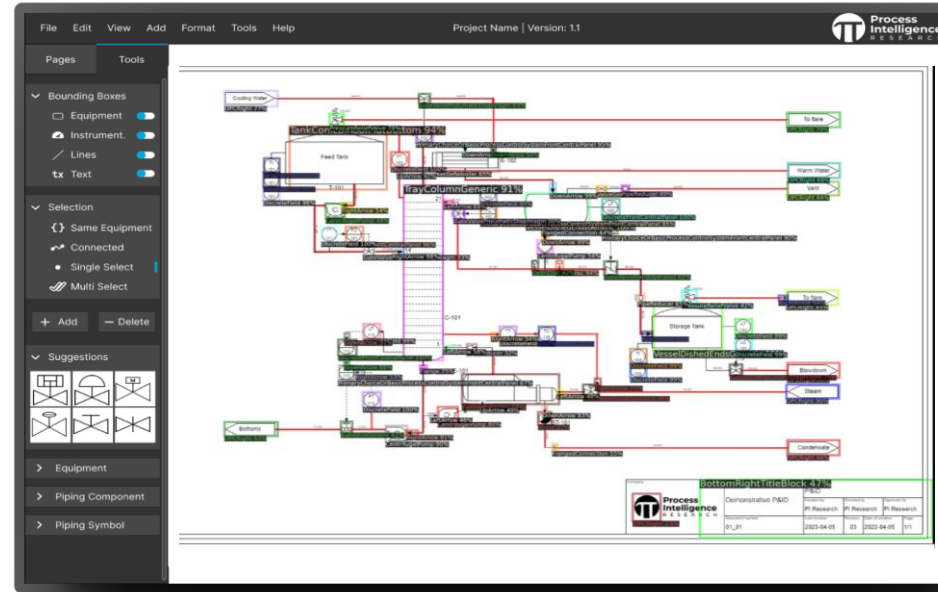
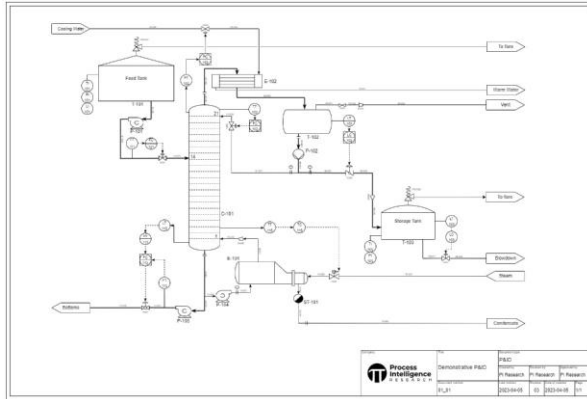
representation
P&IDs

tools integration
LLMs

workflow for
HAZOP

- **Digitize** the P&ID
- **Interoperable** format for P&ID
- **Graph representation** of P&ID.

DigiCo: Digitization Companion



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Export



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 Deep Learning Models



Object detection



Connectivity detection



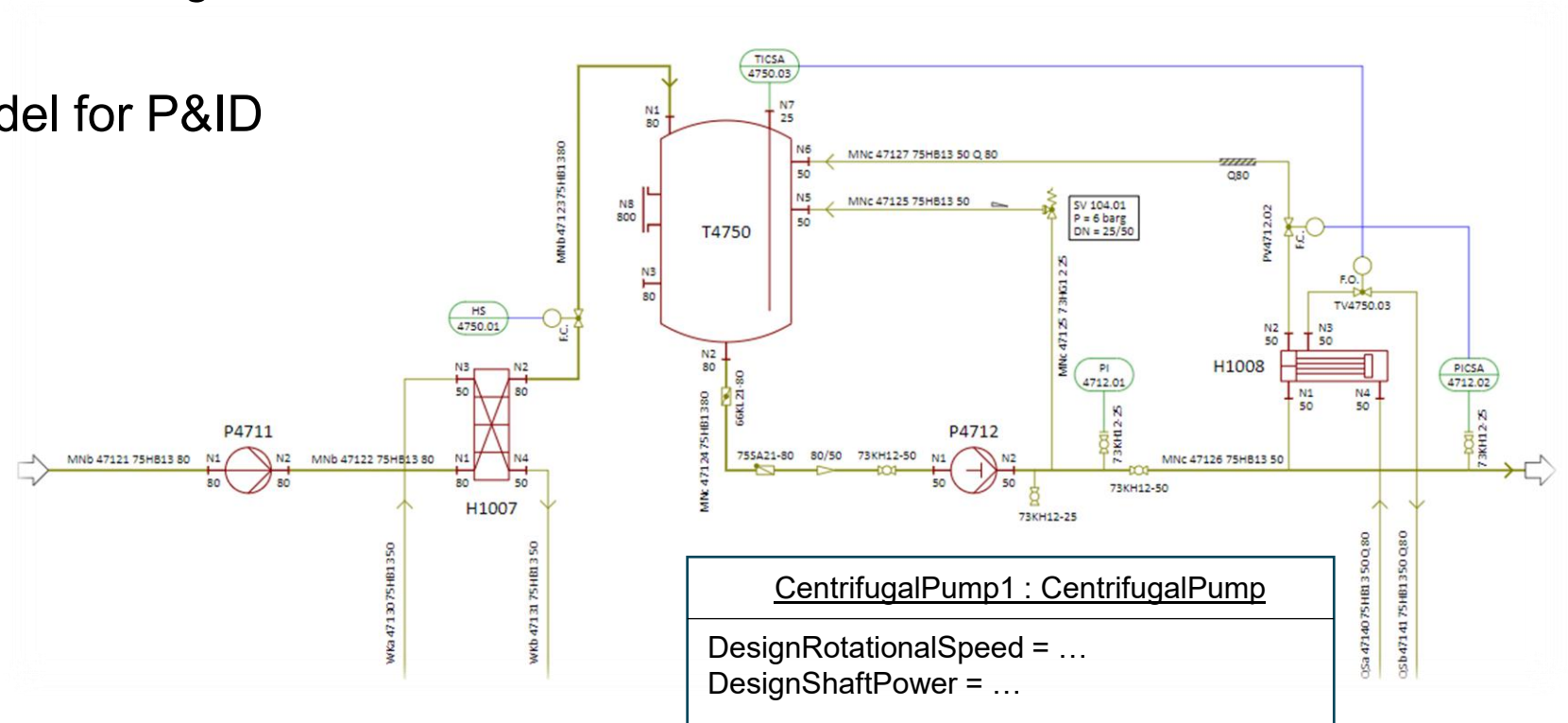
Text recognition



Table extraction

DEXPI[®] = P&IDs + database + interoperable [1]

- DEXPI stands for “*Data Exchange in the Process Industry*”
- **Standardized** data model for P&ID documents.

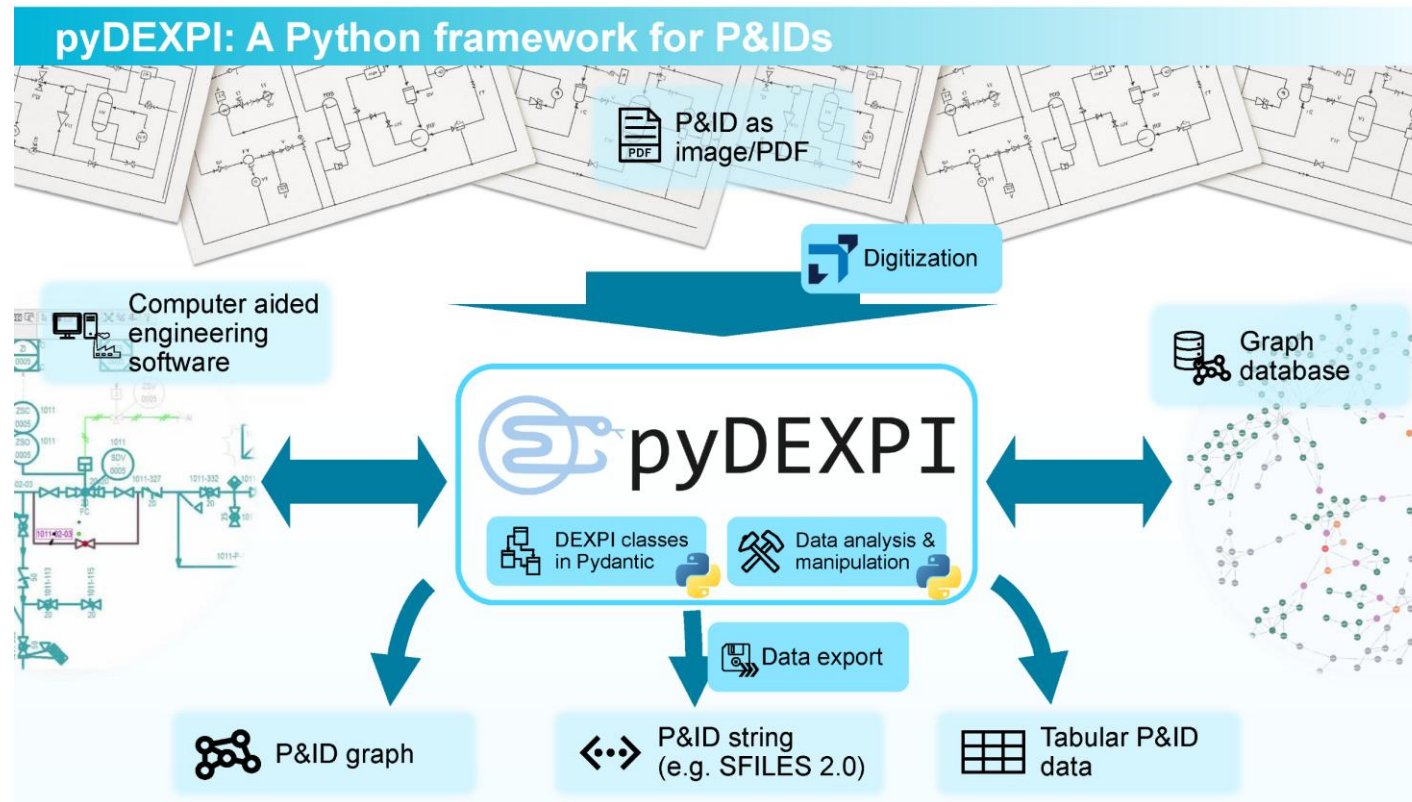


[1] Theißen, Manfred, and Michael Wiedau. “DEXPI P&ID Specification 1.3,” 2021.

[2] D. P. Goldstein, A. A. Alimin, L. Schulze Balhorn, and A. M. Schweidtmann, “pyDEXPI: A Python framework for piping and instrumentation diagrams using the DEXPI information model,” *Proc. ESCAPE35*, 2025.

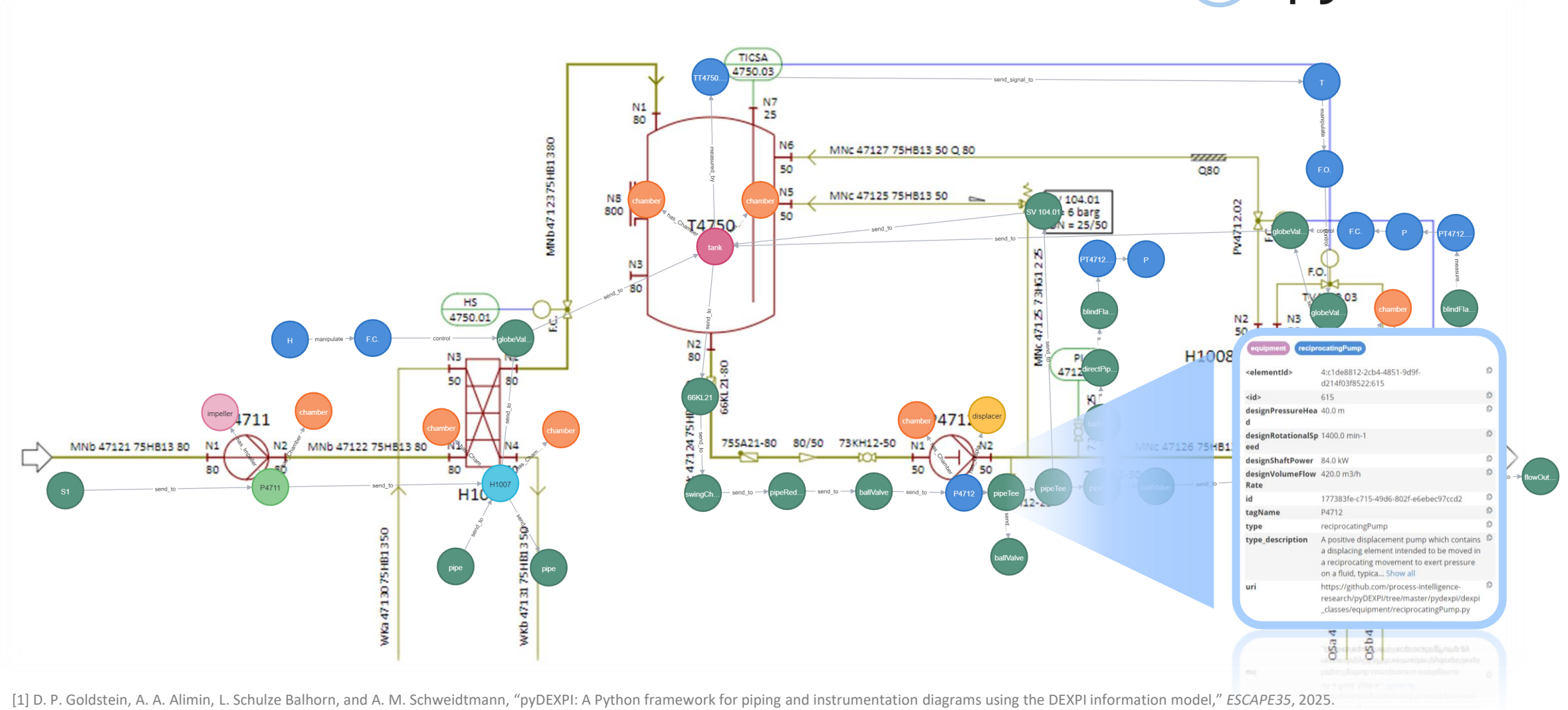
pyDEXPI: Bringing DEXPI to life¹

- Majority of data science/machine learning is happening in python



[1] Goldstein, D. P., Balhorn, L. S., Alimin, A. A., & Schweidtmann, A. M. (2025). pyDEXPI: A Python framework for piping and instrumentation diagrams (P&IDs) using the DEXPI information model. *Systems and Control Transactions*, 1365-1370.

P&ID as *high-level* graph



[1] D. P. Goldstein, A. A. Alimin, L. Schulze Balhorn, and A. M. Schweidtmann, "pyDEXPI: A Python framework for piping and instrumentation diagrams using the DEXPI information model," *ESCAPE35*, 2025.

[2] A. A. Alimin, D. P. Goldstein, L. Schulze Balhorn, and A. M. Schweidtmann, "Talking Like Piping and Instrumentation Diagram (P&IDs)," *Proc. 35th Eur. Symp. Comput. Aided Process Eng. ESCAPE35*, 2025.

Road to AI-Augmented HAZOP

representation
P&IDs

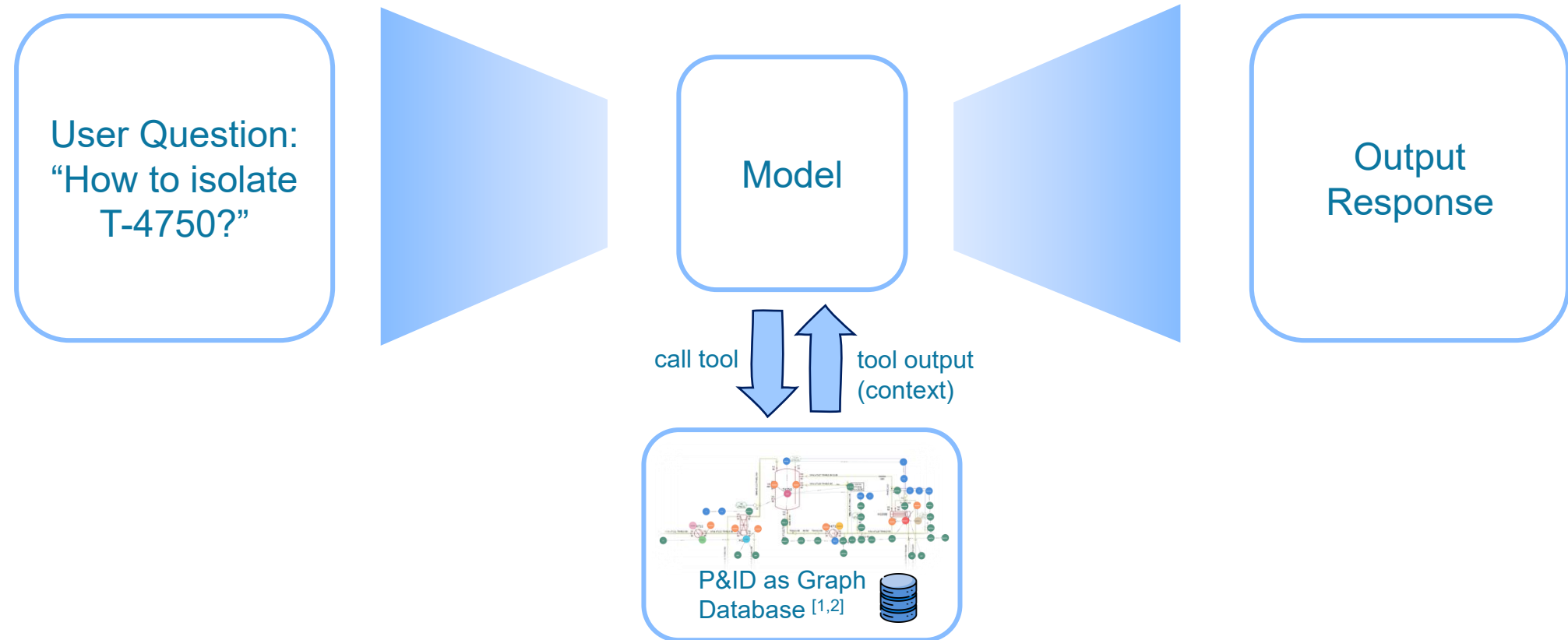
- Digitize the P&ID
- Interoperable format for P&ID
- Graph representation of P&ID.

tools integration
LLMs

- Querying information from P&ID.
- Modify the P&ID.

workflow for
HAZOP

Querying information from graph

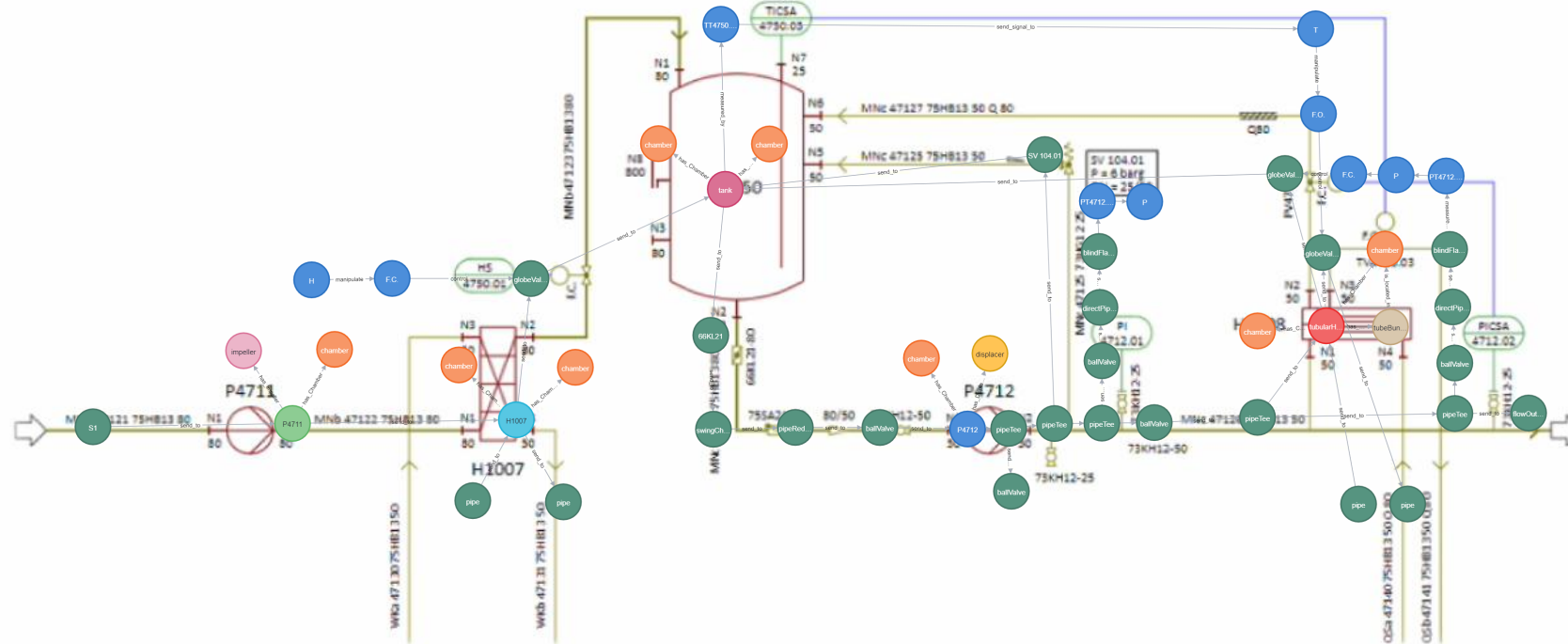


[1] D. P. Goldstein, A. A. Alimin, L. Schulze Balhorn, and A. M. Schweidtmann, "pyDEXPI: A Python framework for piping and instrumentation diagrams using the DEXPI information model," ESCAPE35, 2025.

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New
Session

Graph
Abstract



Process Flowsheet

How to Isolate Tank T4750

Tank T4750 is a process vessel with a 4.0 m cylinder length that has multiple inlet and outlet connections. To properly isolate T4750, follow this procedure:

1. Inlet Isolation

- Close valve HV4750.01 (Globe valve on the inlet line from heat exchanger H1007)
 - This valve is controlled by actuating function HV4750.01 with fail-close (F. C.) action
 - The valve is operated from a central control location

2. Outlet Isolation

- Close valve 66KL21 (Butterfly

Ask me about the process flow diagram...



[1] A. A. Alimin, D. P. Goldstein, L. Schulze Balhorn, and A. M. Schweidtmann, "Talking Like Piping and Instrumentation Diagram (P&IDs)," Proc. 35th Eur. Symp. Comput. Aided Process Eng. ESCAPE35, 2025.

Road to AI-Augmented HAZOP

representation **P&IDs**

- **Digitize** the P&ID
- **Interoperable** format for P&ID
- **Graph representation** of P&ID.

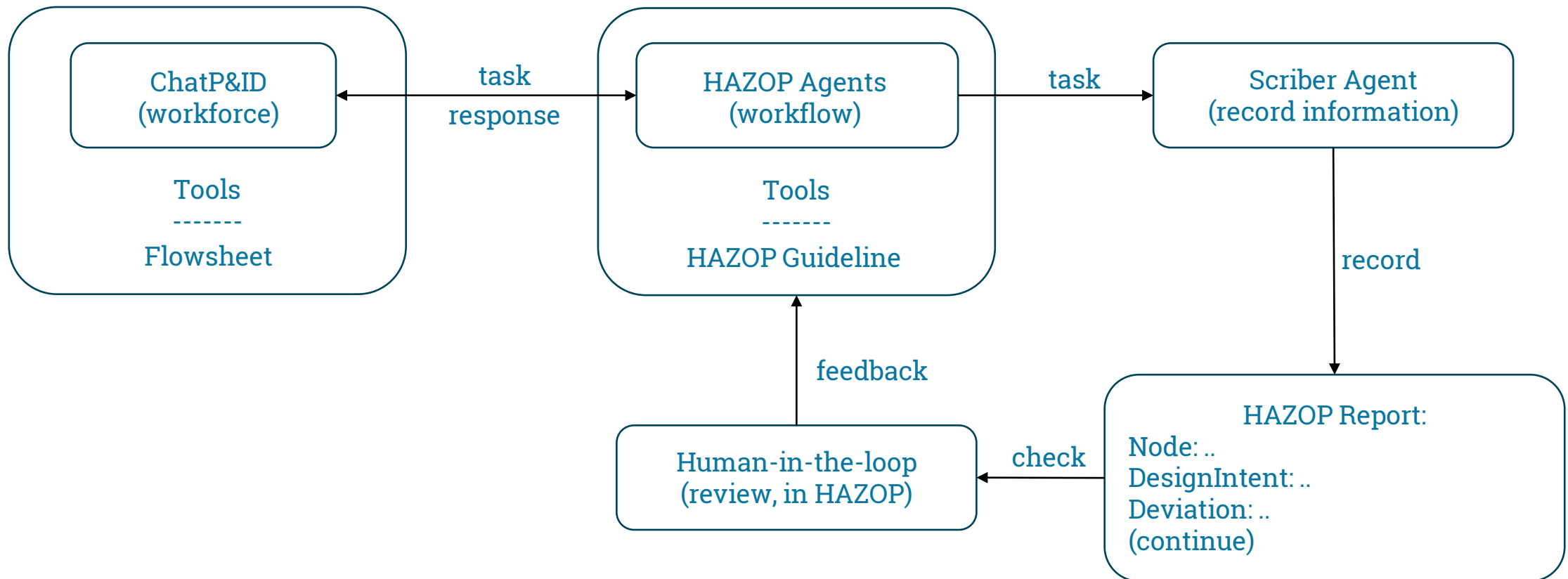
tools integration **LLMs**

- **Querying** information from P&ID.
- **Modify** the P&ID.

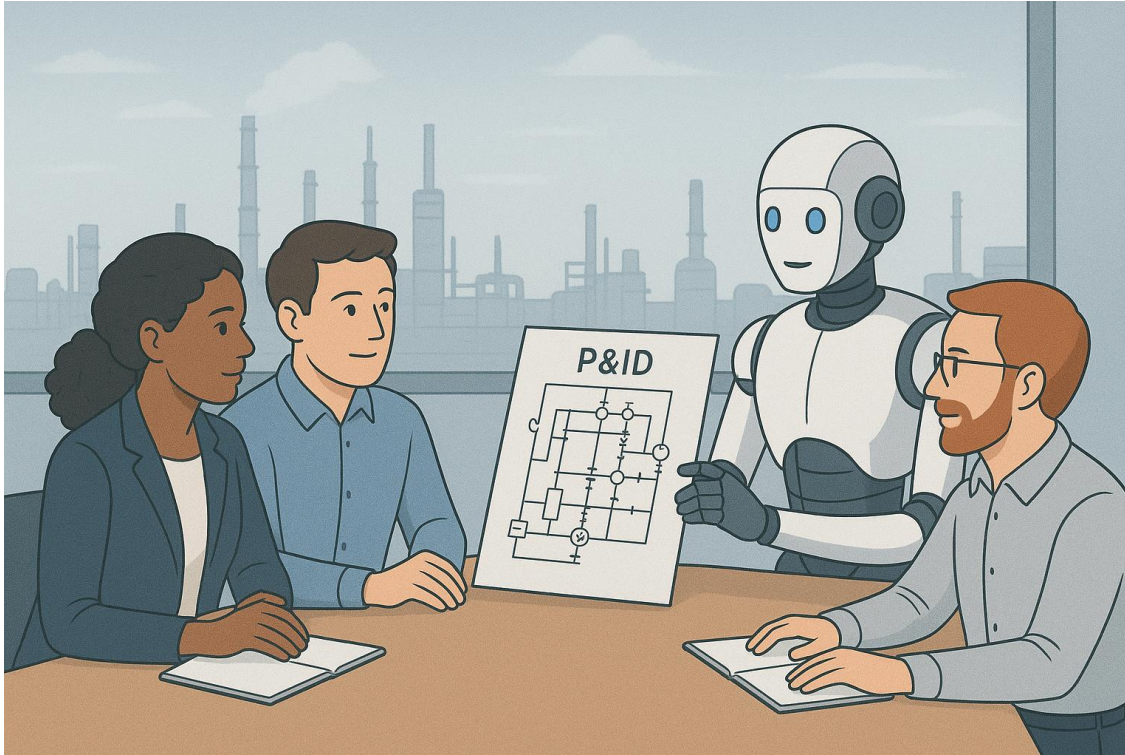
workflow for **HAZOP**

- **Transparent** generation & traceability
- **Configurable** and adaptable
- **Human-in-the-loop** decision making.

Multi-agent workflow for HAZOP



Conclusion



- **Digital engineering data** is key for future AI applications
- **Agentic workflow** (LLM with tools) significantly improve the performance of the LLMs.
- **GenAI** has the **potential** to transform process safety engineering, but require further research.

Acknowledgement



Thank you very much for your attention!