

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

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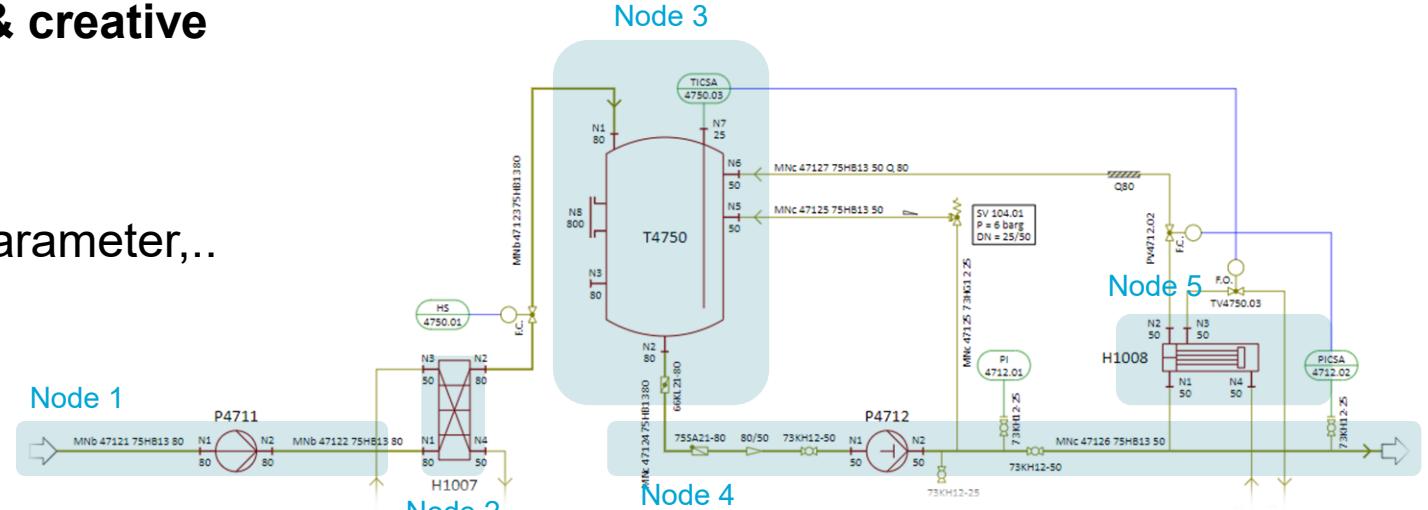
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HAZOPs – a systematic safety review [1, 2]

- 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.

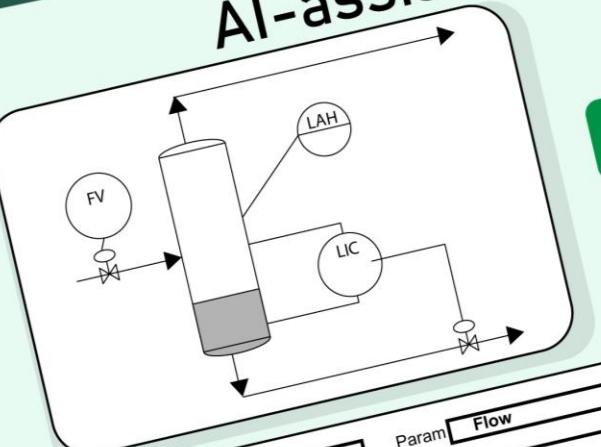
[3] Baybutt, Paul. "A Critique of the Hazard and Operability (HAZOP) Study." *Journal of Loss Prevention in the Process Industries* 33 (January 2015): 52–58. <https://doi.org/10.1016/j.jlp.2014.11.010>.



AI-assisted HAZOP



Generate HAZOP



Guide Wrk
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 Potential hydrocarbon release.
- 3

Safeguards

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

Action / Actions

- 1 Limiting flow orifice, smart check valve.
- 2 Set-up vessel inspection.
- 3

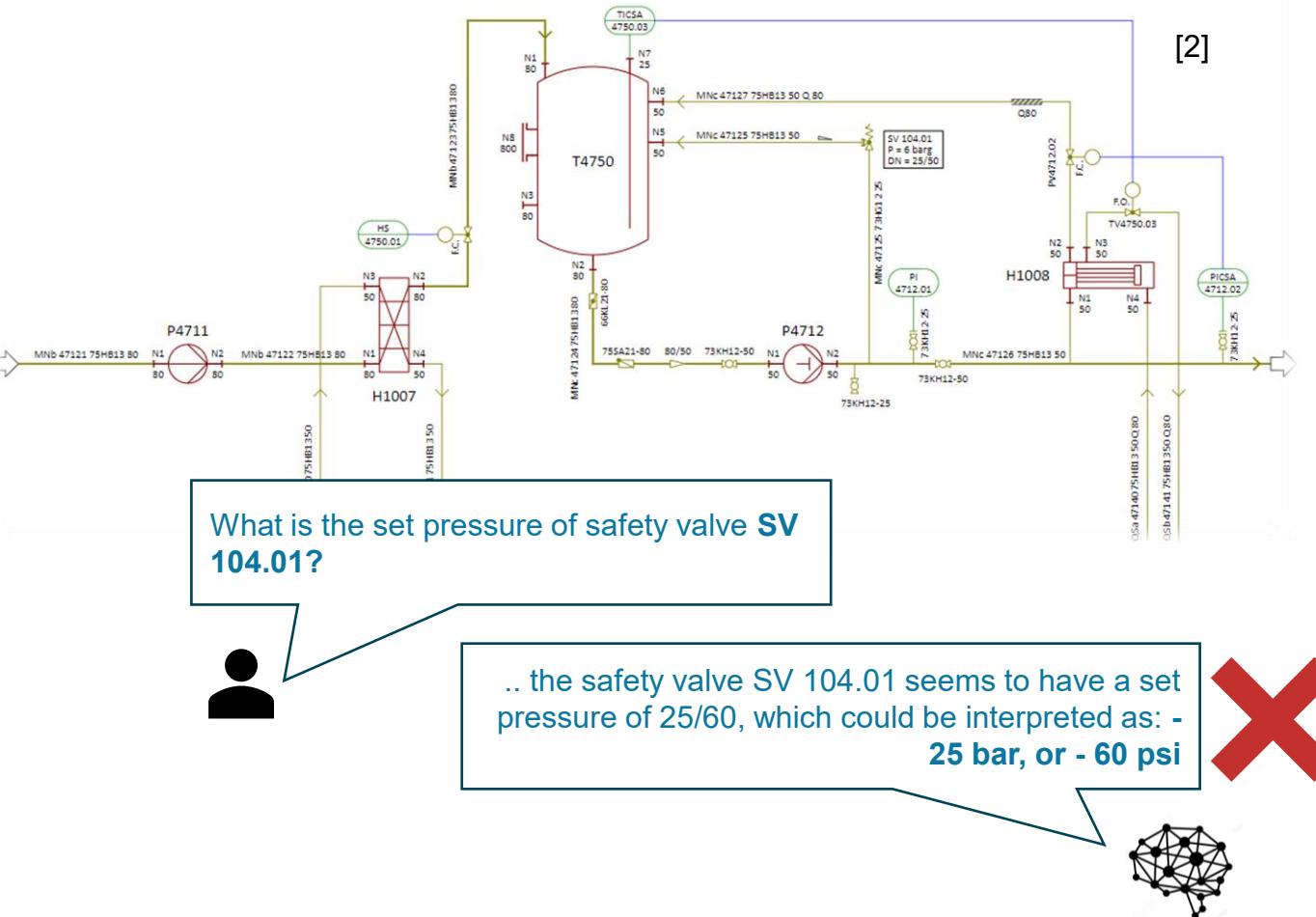
Automate data query from P&ID

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.



[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

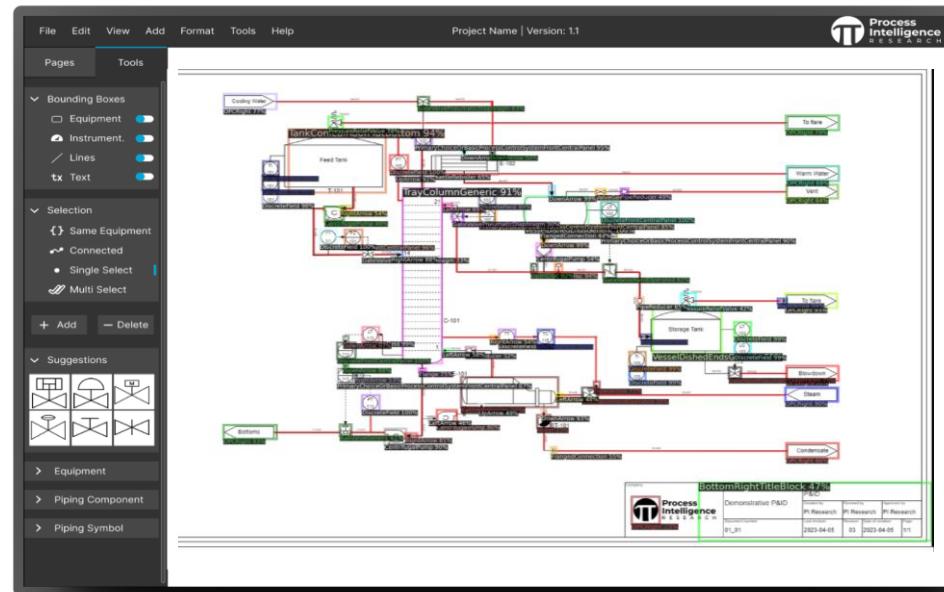
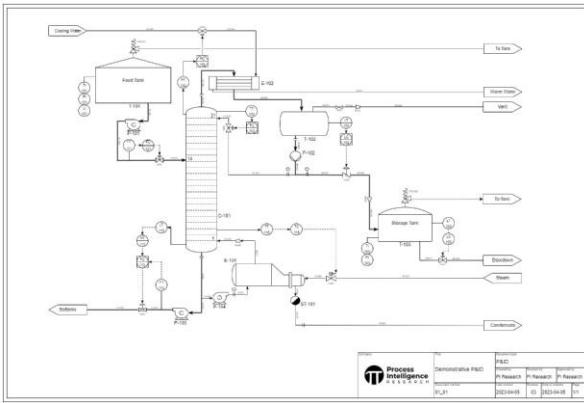
representation
P&IDs

tools integration
LLMs

workflow for
HAZOP

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

DigiCo: Digitization Companion



Smart P&ID
Export



Sign up today!



Deep Learning Models



Object detection



Connectivity detection



Text recognition

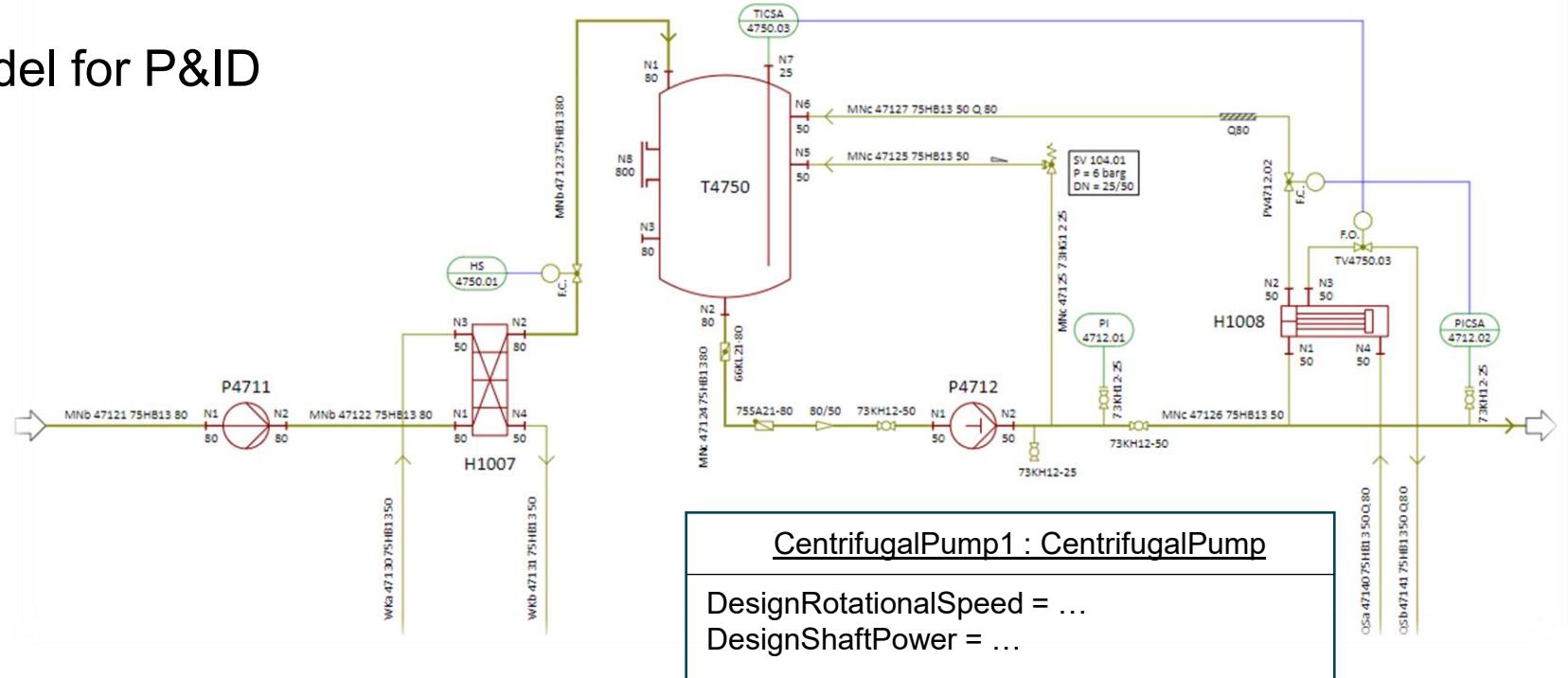


Table extraction

digitization-companion.com

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

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

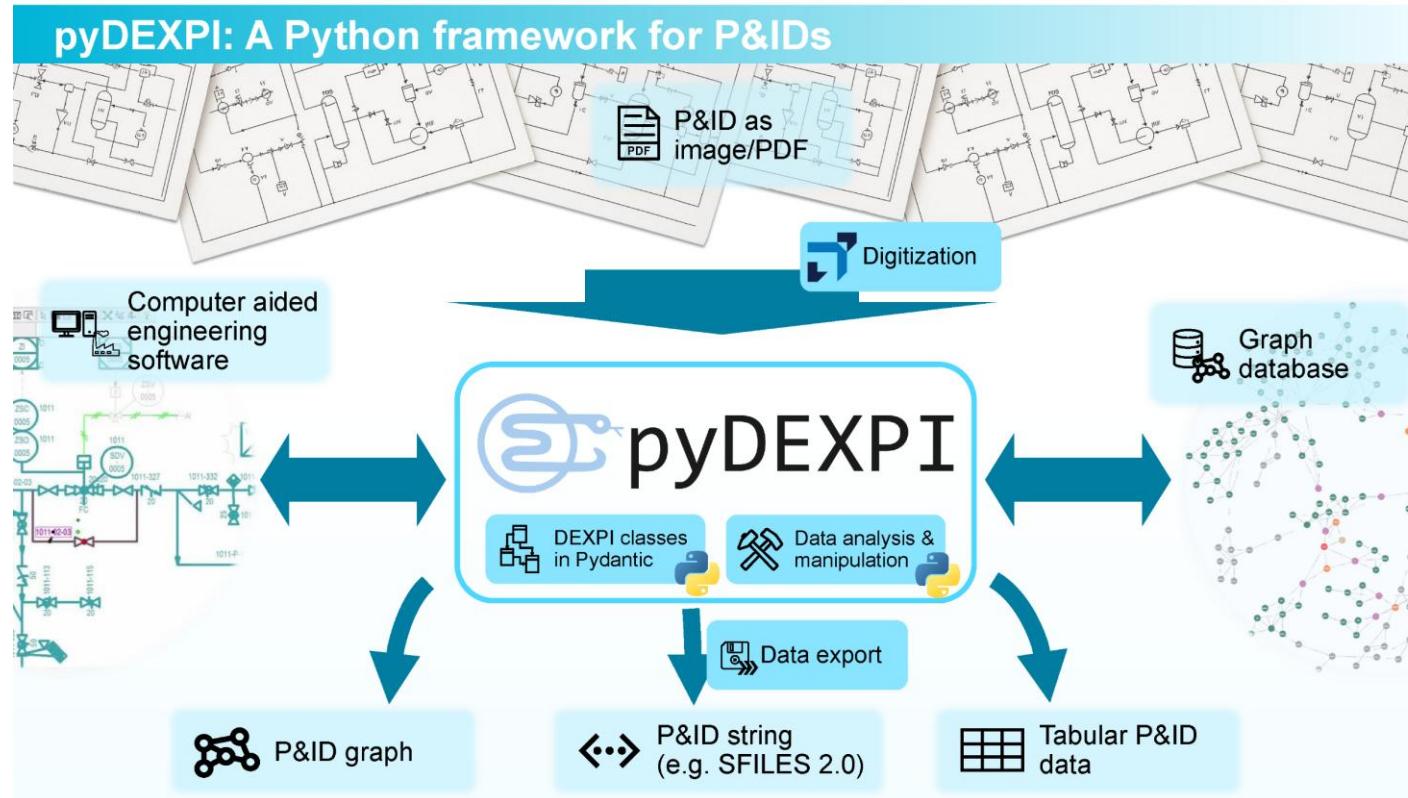


[1] Theißen, Manfred, and Michael Wiedau. “DEXPI P&ID Specification 1.3,” 2021.

[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.

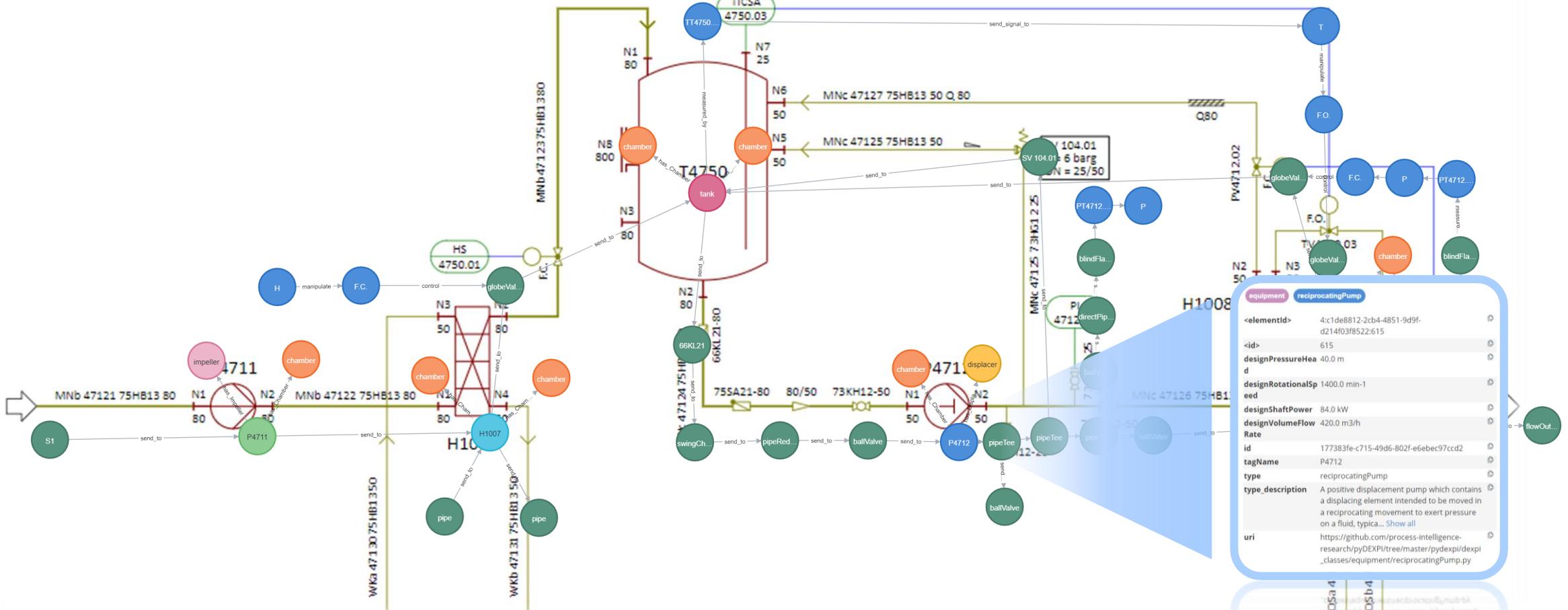
pyDEXPI: Bringing DEXPI to life¹

- 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**

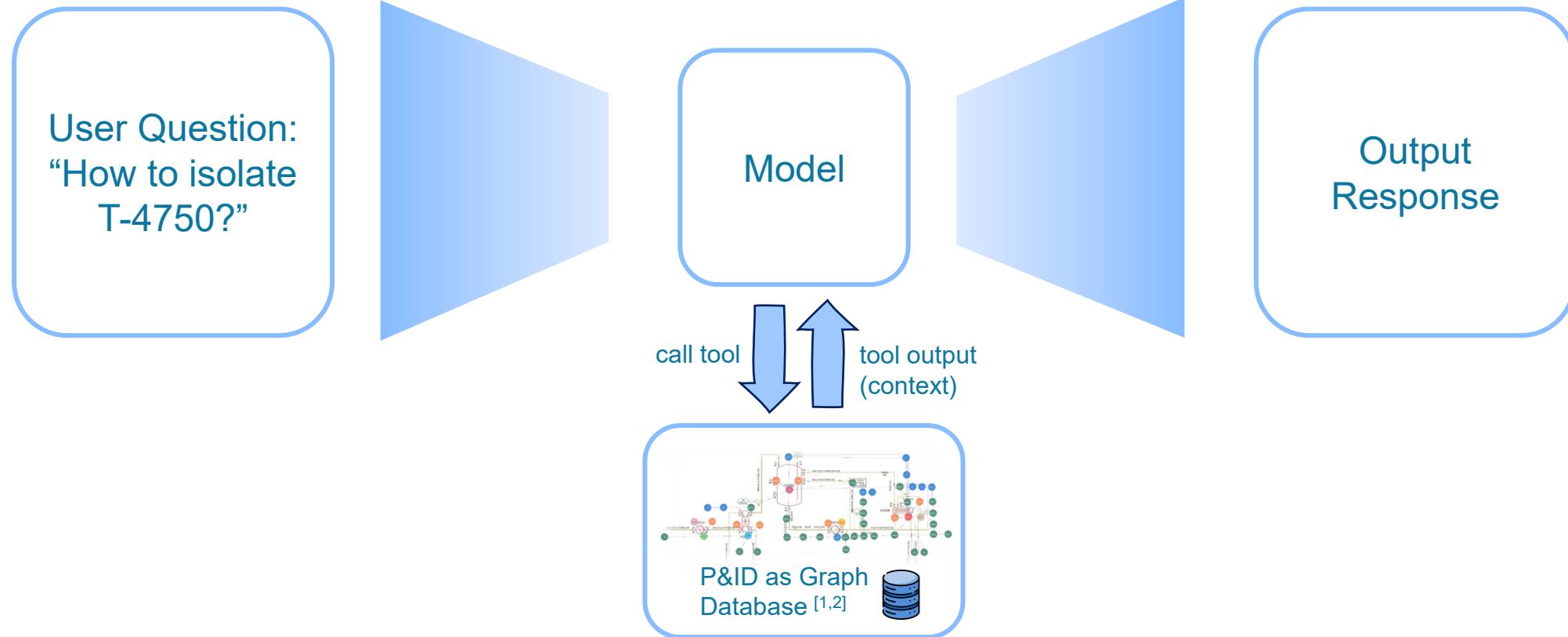
- Digitize the P&ID
- Interoperable format for P&ID
- **Graph representation of P&ID.**

tools integration **LLMs**

workflow for **HAZOP**

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

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.

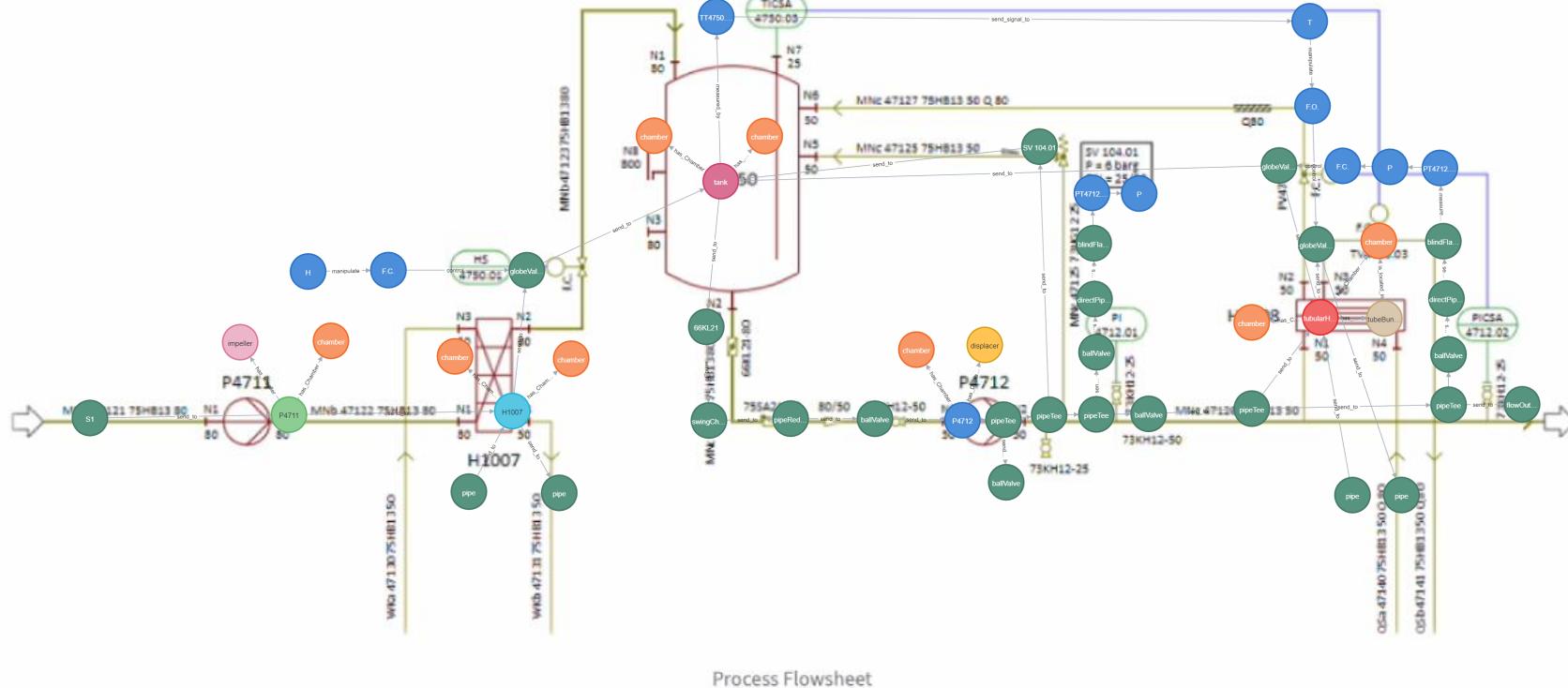
[2] A. A. Alimin, D. P. Goldstein, L. Schulze Balhorn, and A. M. Schweidtmann, "Talking Like Piping and Instrumentation Diagram (P&IDs)," Proc. 35th Eur. Symp. Comput. Aided Process Eng. ESCAPE35, 2025.

ChatP&ID - π

Bridging Flowsheet and AI

New Session

Graph Abstract



Process Flowsheet

[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.

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...



Road to AI-Augmented HAZOP

representation **P&IDs**

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

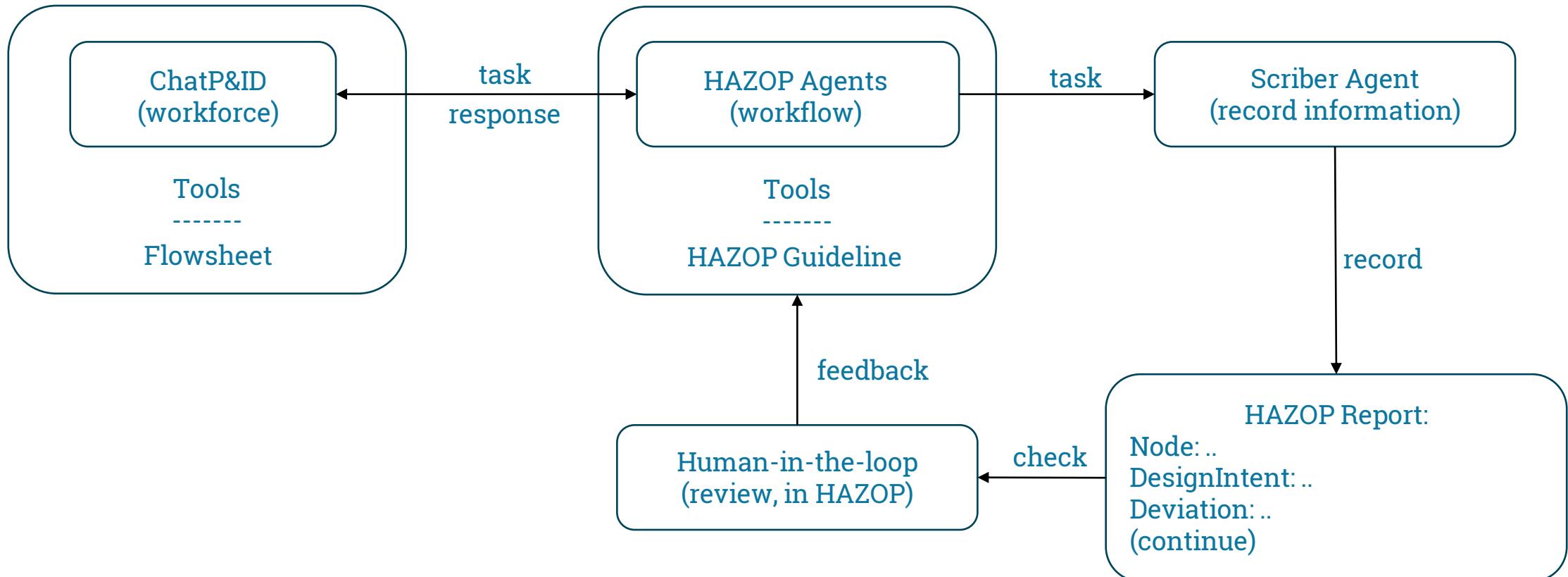
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- Querying information from P&ID.
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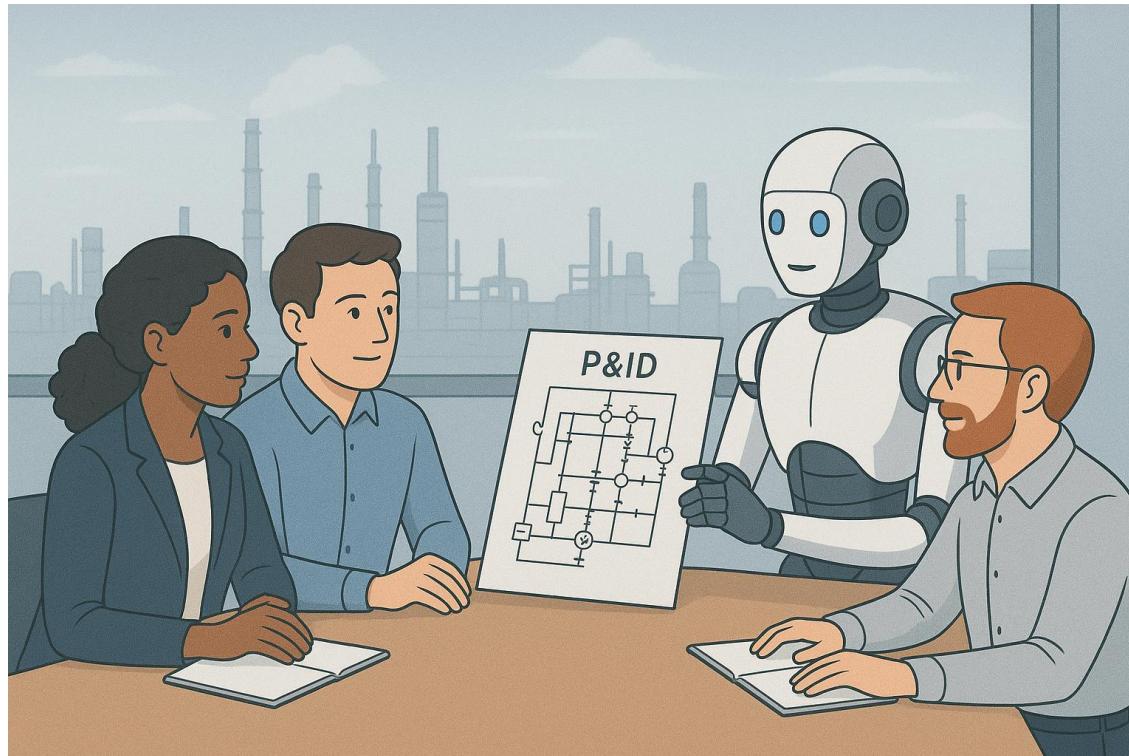
workflow for **HAZOP**

- **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!