LEVERAGING CAPE-OPEN FOR ENHANCED MULTIPHASE PUMP DESIGN AND PROCESS SIMULATION

CAPE-OPEN 2025 ANNUAL MEETING

GHENT – BELGIUM

V. CARIES, M. GAINVILLE, V. MOENNE-LOCCOZ

PRESENTATION BREAKDOWN

1. **IFPEN role in CAPE-OPEN**: past contributions & motivations for the current work

2. **Multiphase pump software**: leveraging CAPE-OPEN Python Unit Operation

3. **Conclusions & perspectives**

INTRODUCTION

IFPEN INVOLVEMENT IN CAPE-OPEN ACTIVITIES

Key roles

- Managed CAPE-OPEN and Global CAPE-OPEN projects (1997-2002)
- Co-founded CO-LaN and contributed actively (2001–2011)
- Transitioned to corporate associate member in 2011

Contributions & applications

- Developed a wizard for Unit Operation (UO) in C++
- Developed UO (e.g., Hysipipe for hydrate transportability, Desulfo+ for gas sweetening)
- Introduced CAPE-OPEN support to Carnot, our in-house thermodynamic server
- Extensive use of CAPE-OPEN-supporting tools like COFE, Multiflash®, PRO/II™, HYSYS®…

OVERVIEW OF MULTIPHASE PUMP (MPP) ACTIVITIES

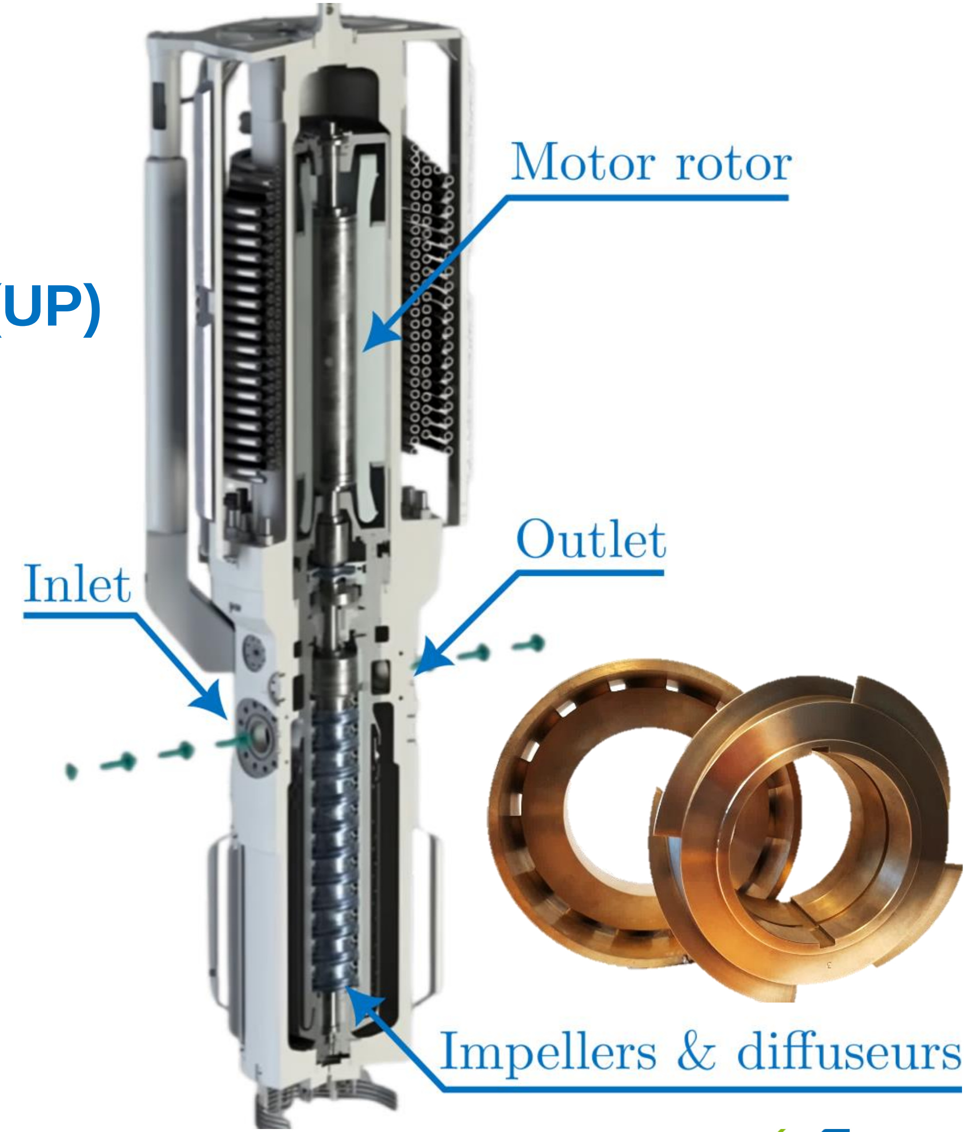
Over 40 years of expertise in MPP design

Historical applications in upstream petroleum (UP)

- Wellhead pumps: 100+ units
- Downhole pumps: 1,000+ units

MPP key features

- Gas volume fraction: up to 90%
- Flow rate: up to 400 m^3/h
- Pressure increase: up to 200 bar



Source: SLB OneSubsea

MOTIVATIONS

Ouputs from past UP activities

- Proprietary software for MPP design, performance, and selection
- Proven MPP robustness and reliability derived from extensive UP experience

Leverage MPP potential by expanding its application range

- Lower CAPEX: equipment replacement synergy → compressor + pump = single MPP
- Lower OPEX: maintenance cost reduction & lower downtime

Current needs: evaluation and optimization of MPP integration into new processes

- ➢ Embedding proprietary MPP design code into PMEs (Process Modeling Environments)
- ➢ AmsterCHEM CAPE-OPEN Python UO identified as an ideal framework

LEVERAGING AMSTERCHEM CAPE-OPEN PYTHON UNIT OPERATION

CAPE-OPEN PYTHON UO IMPLEMENTATION: INTRODUCTION

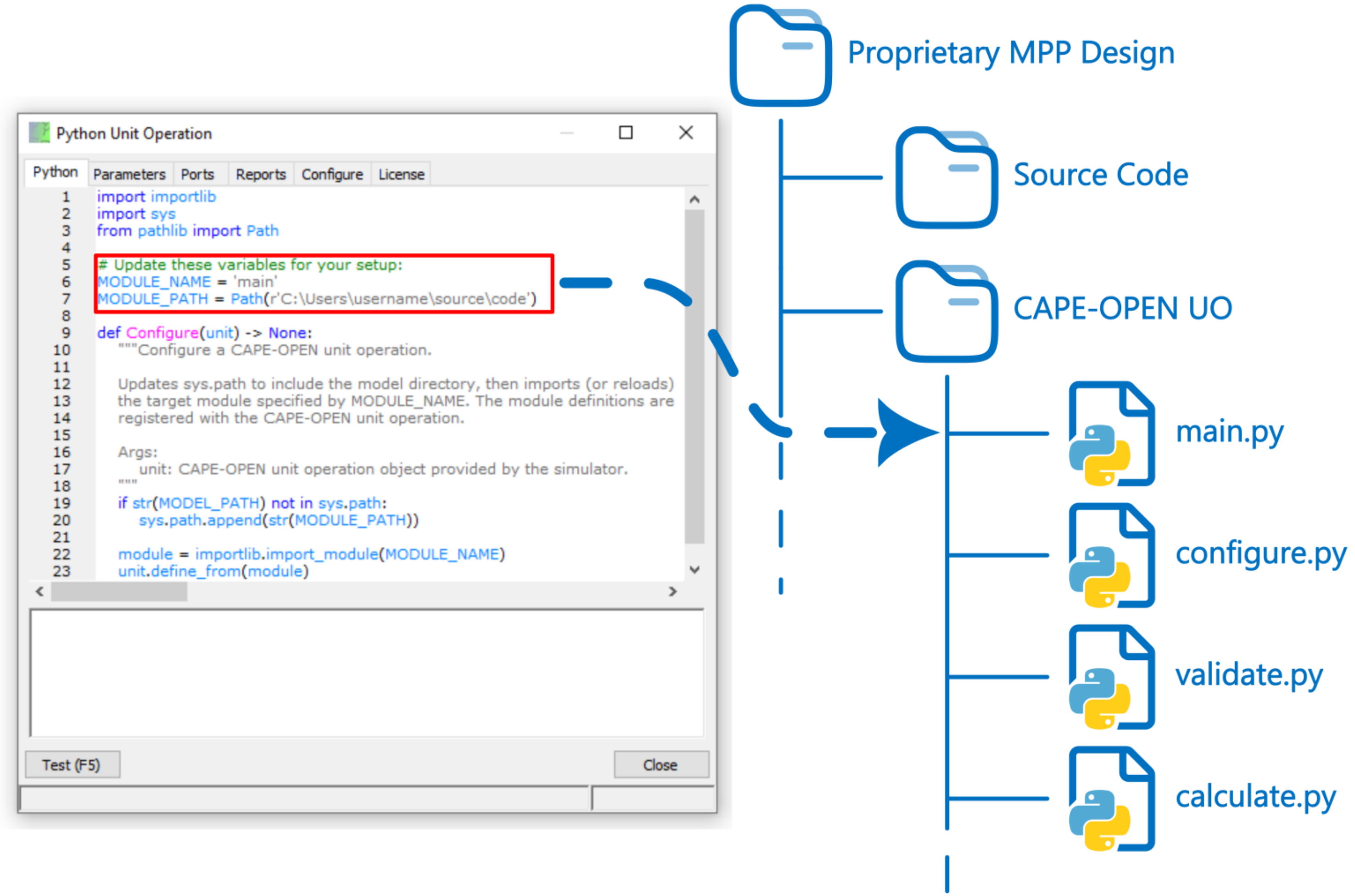
Key drivers

- Ensure thermodynamic model consistency by using the same model as the PME
- Handle complex compositions without further assumptions in the MPP design software
- Execute MPP design software directly through Python to pass the feed object from the PME as the thermodynamic object

Key constraint

- Address the complexity and multiple dependencies of the MPP design code with a modular implementation
- Deploy the AmsterCHEM CAPE-OPEN Python UO on multiple PMEs: COFE, PRO/II™ & HYSYS®

CAPE-OPEN PYTHON UO IMPLEMENTATION: INSIGHTS



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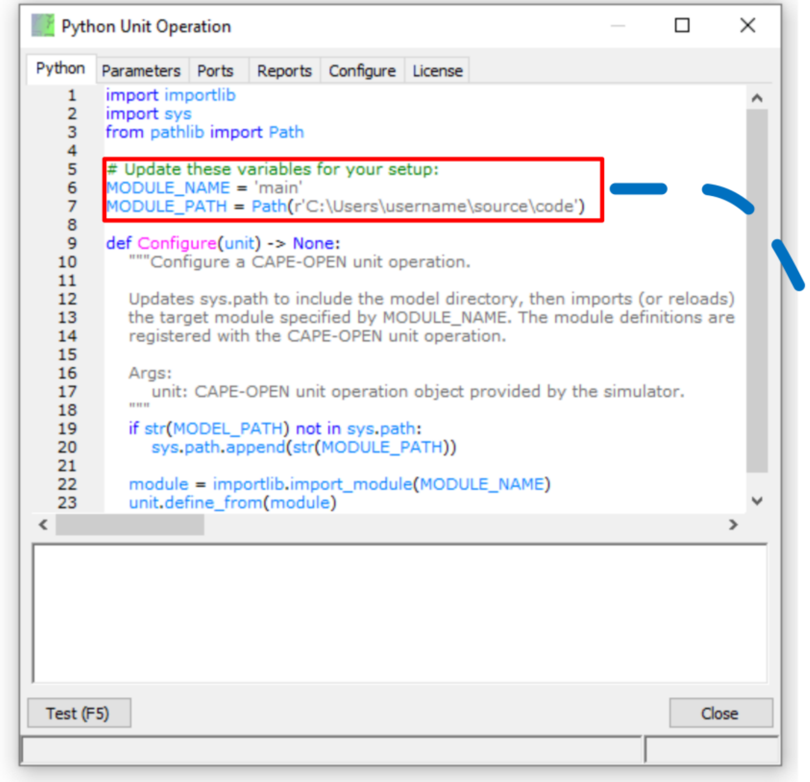
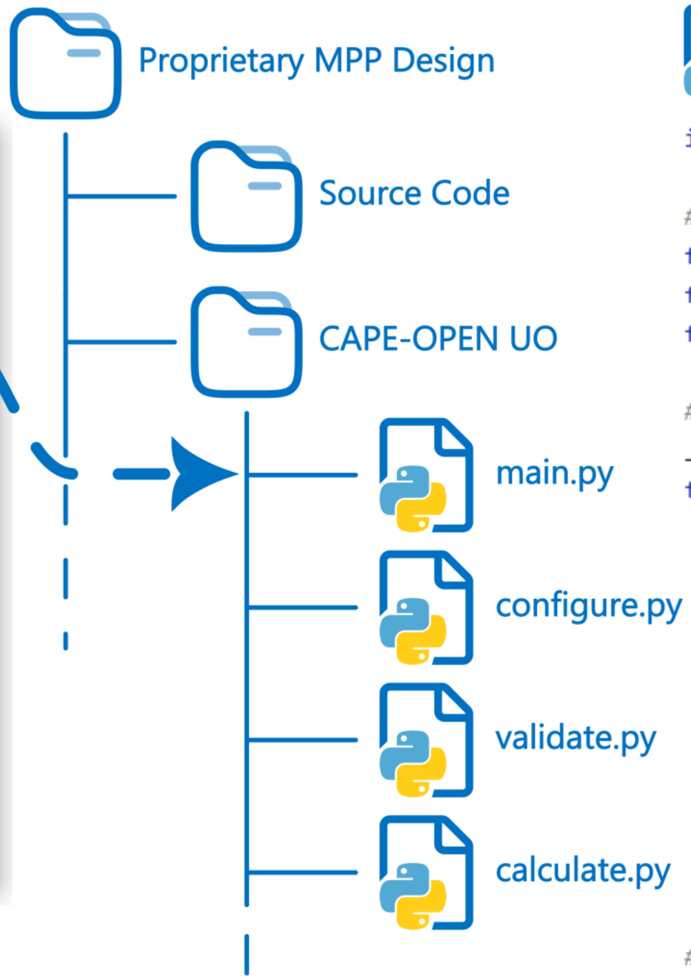


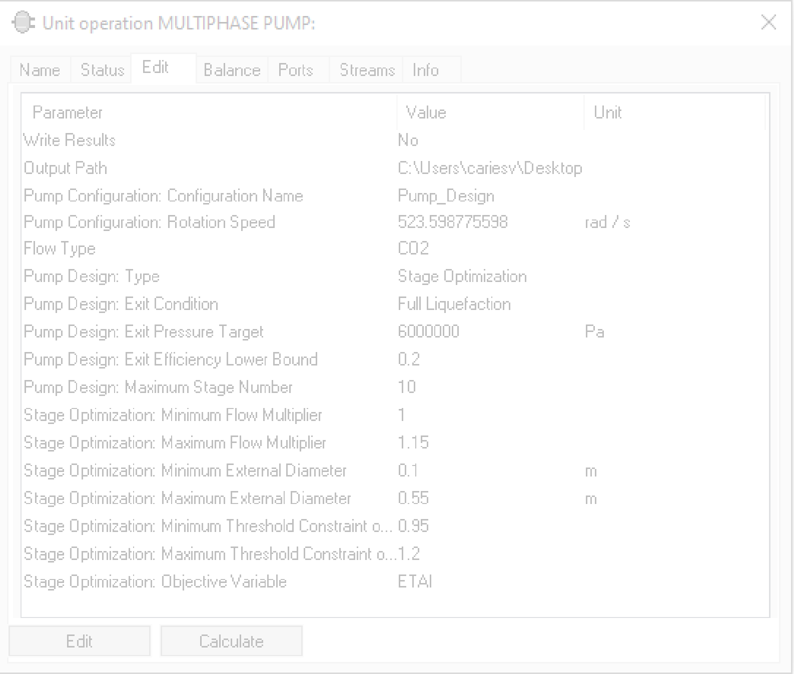


main.py Expose all public functions from local scripts, including Configure(unit), Validate(unit), and Calculate(unit)

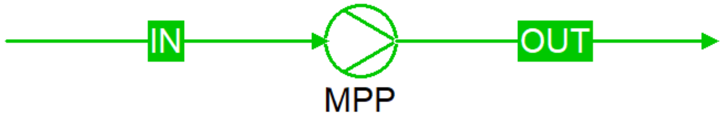
```python
import sys

# Importing core functionalities
from configure import *
from validate import *
from calculate import *

# Generate __all__ by inspecting the module's public functions
__all__ = []
for module in ['configure', 'validate', 'calculate']:
    try:
        module_obj = sys.modules[module]

    except KeyError:
        raise ImportError(f'Module {module} not found.')

    # Expose public functions for CAPE-OPEN Python Unit Operation
    public_items = [name for name, obj in inspect.getmembers(module_obj)
                    if not name.startswith('_')]
    __all__.extend(public_items)

# Ensure __all__ only contains unique entries
__all__ = list(set(__all__))
```

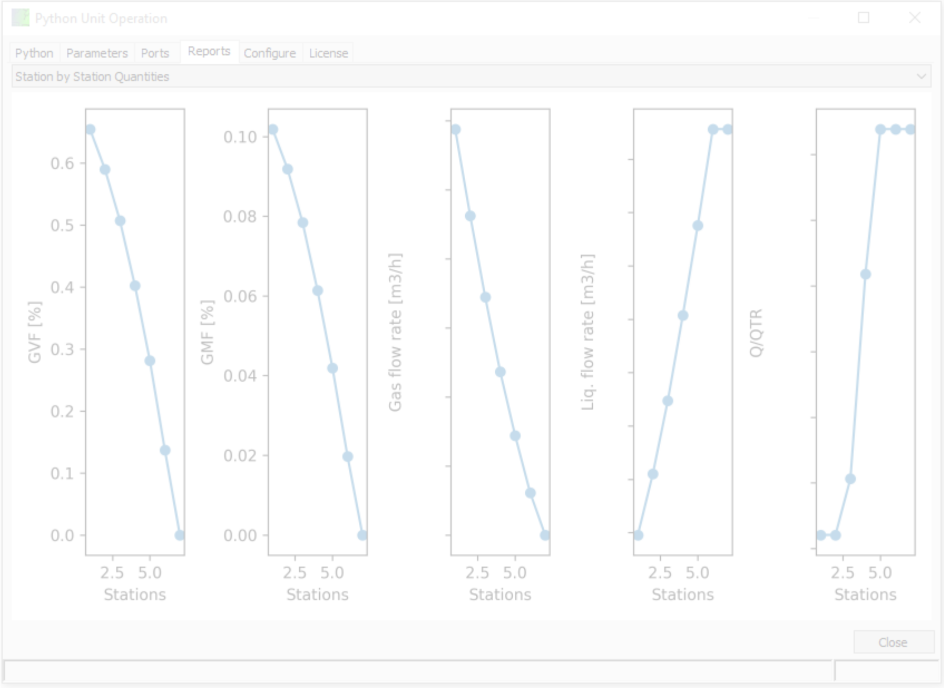

CAPE-OPEN PYTHON UO IMPLEMENTATION: FEATURES

- Calculation applied to CO_2 with impurities conditioning with a Multiflash® model
- Facilitates rapid and interactive analyses through the integrated CAPE-OPEN GUI
  - ✓ Fully customizable input settings
  - ✓ Provides direct user access to output visualization through the Reports tab



Stream	IN	OUT	Unit
Pressure	25	47.75	bar
Temperature	-20	-0.8751	°C
Flow rate	20	20	kg / s
Mole frac CARBON DIOXIDE	0.97	0.97	
Mole frac NITROGEN	0.015	0.015	
Mole frac ARGON	0.01	0.01	
Mole frac OXYGEN	0.0025	0.0025	
Mole frac WATER	0.0013	0.0013	
Mole frac CARBON MONOXIDE	0.0012	0.0012	
Vapor phase			
phase fraction	0.1058		
Liquid phase			
phase fraction	0.8942	1	





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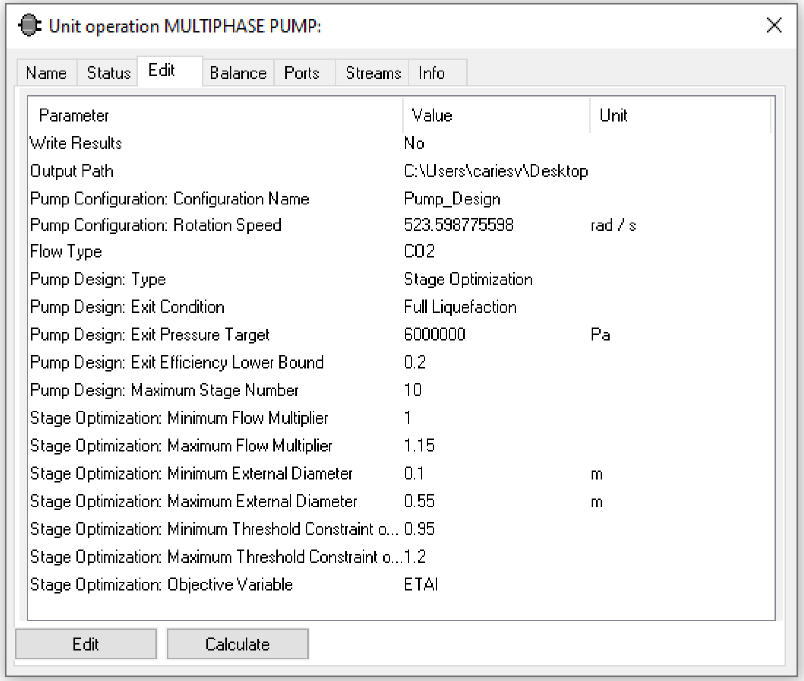

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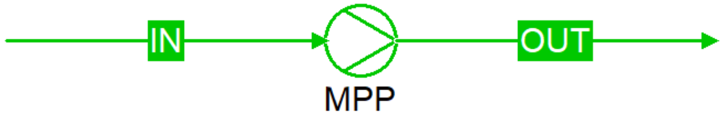

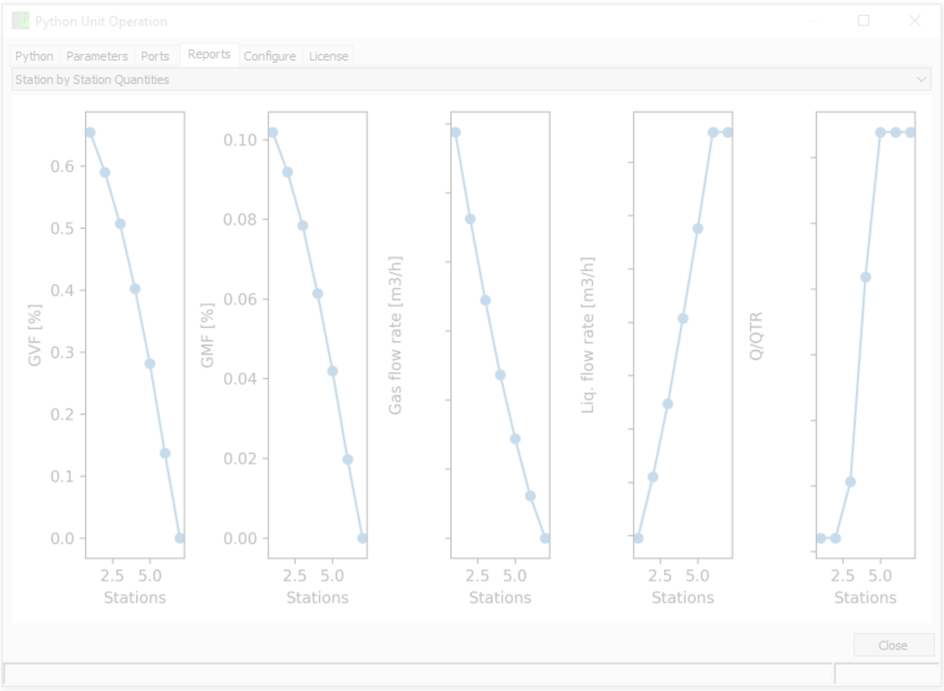

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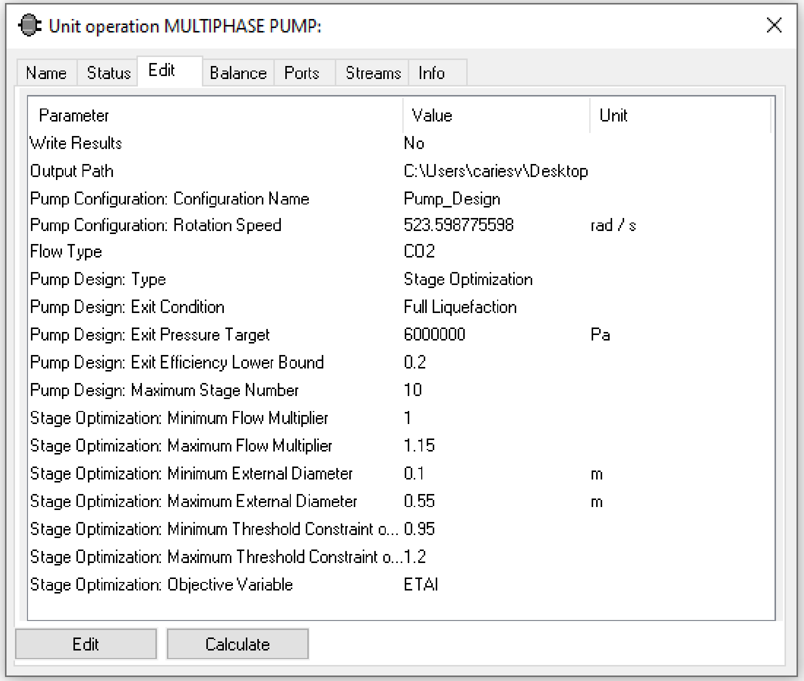

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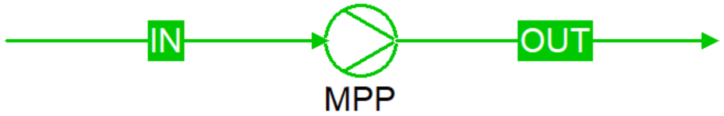

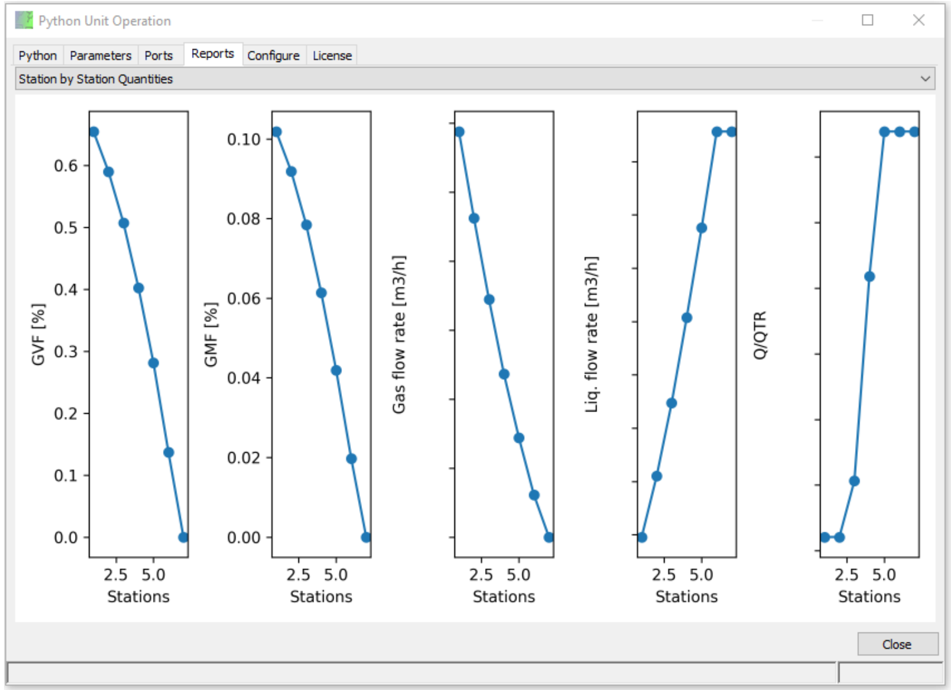

CAPE-OPEN PYTHON UO IMPLEMENTATION: AVAILABLE ON PMEs

COFE

AVEVA™ PRO/II™

Aspen HYSYS®

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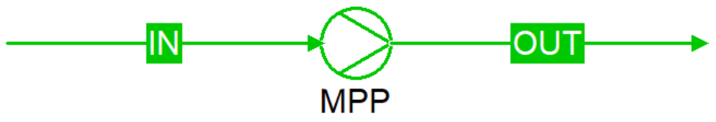
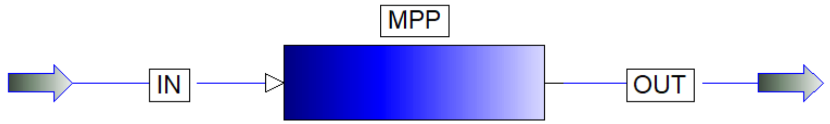
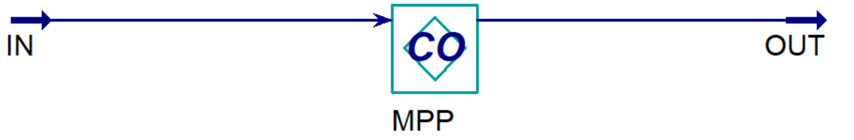


Stream Name Stream Description Phase		IN Mixed	OUT Liquid
Temperature	C	-20,0000	-0,8750
Pressure	BAR	25,0000	47,7469
Enthalpy	M*KJ/HR	-22,9721	-21,3251
Molecular Weight		43,6462	43,6462
Mole Fraction Vapor		0,1058	0,0000
Mole Fraction Liquid		0,8942	1,0000
Rate	KG-MOL/HR	1649,627	1649,627
Fluid Rates	KG-MOL/HR		
CO2		16,4963	16,4963
CO2		1600,1387	1600,1387
N2		24,7444	24,7444
O2		4,1241	4,1241
H2O		2,1445	2,1445
CO		1,9796	1,9796



Material Streams			
		IN	OUT
Vapour Fraction		0,1058	0,0000
Temperature	C	-20,00	-0,8749
Pressure	kPa	2500	4775
Molar Flow	kgmole/h	1650	1650
Mass Flow	kg/h	7,200e+004	7,200e+004
Liquid Volume Flow	m3/h	86,89	86,89
Heat Flow	kJ/h	-6,534e+008	-6,517e+008



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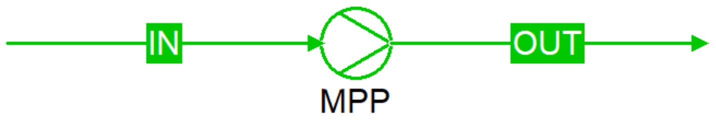

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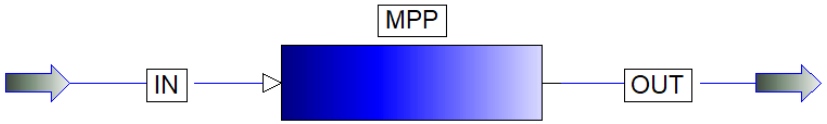

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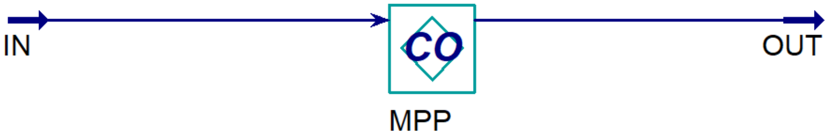

✓ Proprietary MPP design code successfully integrated in COFE, PRO/II™ & HYSYS® using AmsterCHEM CAPE-OPEN Python UO

CAPE-OPEN PYTHON UO IMPLEMENTATION: USER FEEDBACK

Strengths

- User-friendly CAPE-OPEN formalism with easy implementation via clear documentation
- COFE: ideal for prototyping and testing new features

Challenges

- Adding Python virtual environment support would make it easier to address package compatibility challenges in large Python projects
- PRO/II™: missing phase related feed stream properties that should be available
- HYSYS®: requires changing the unit CapeVersion in the registry to 1.1 (misunderstanding of the standard) and lacks essential feed stream properties

Acknowledgments: a big thanks to J. Van Baten for the CAPE-OPEN Python UO 1.0.26.0 release addressing the missing properties issue in PRO/II™ & HYSYS®

CONCLUSIONS & PERSPECTIVES

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- ✓ **Proprietary MPP design software successfully integrated in COFE, PRO/II™ & HYSYS® using the AmsterCHEM CAPE-OPEN Python UO**
- ✓ **Thermodynamic model consistency**: ensured by being able to use the same model as the PME
- ✓ **Integration into complex process flowsheets**: enabled by treating the MPP as a standard pump component
- ✓ **Easier collaboration** during new process design and exploration phases
- **Enhancing the robustness of the MPP design software** to effectively handle unexplored configurations
- **Improving error handling** between the MPP design software and the CAPE-OPEN standard for smoother operation

REFERENCES

Python Unit Operation license
Version 1.0.26.0
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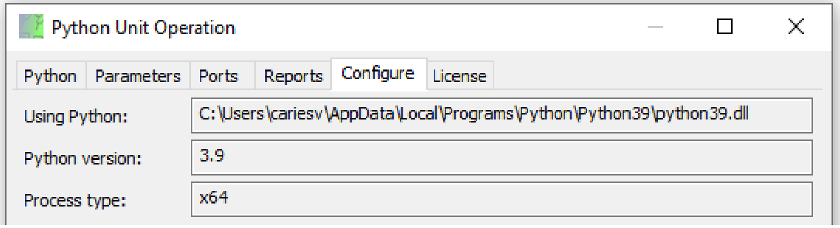

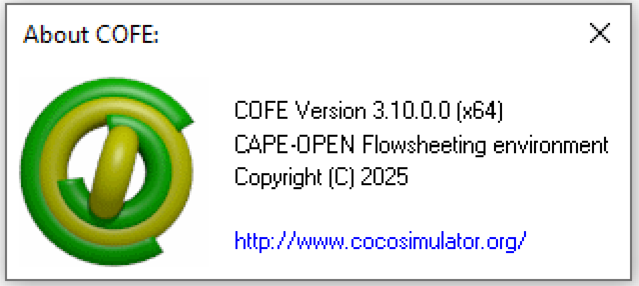

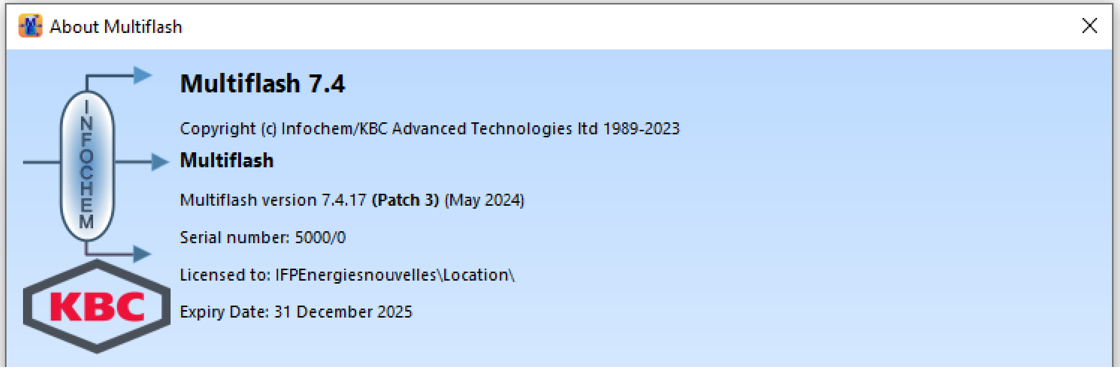

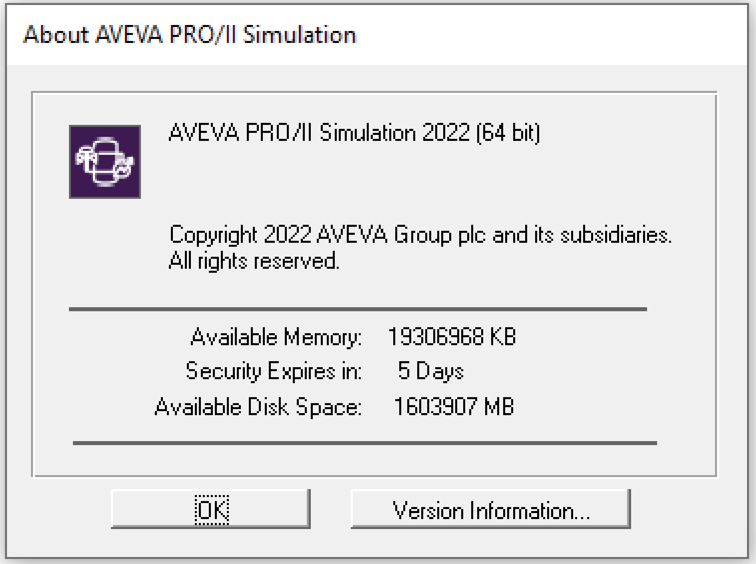

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