Initial Engineering Design of a Post-Combustion CO_2 Capture System for Duke Energy's East Bend Station Using Membrane-Based Technology:

DE-FE0031589

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Sr. Technical Leader

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Program Manager

NETL CO_2 Capture Technology Review Meeting
August 16th, 2018

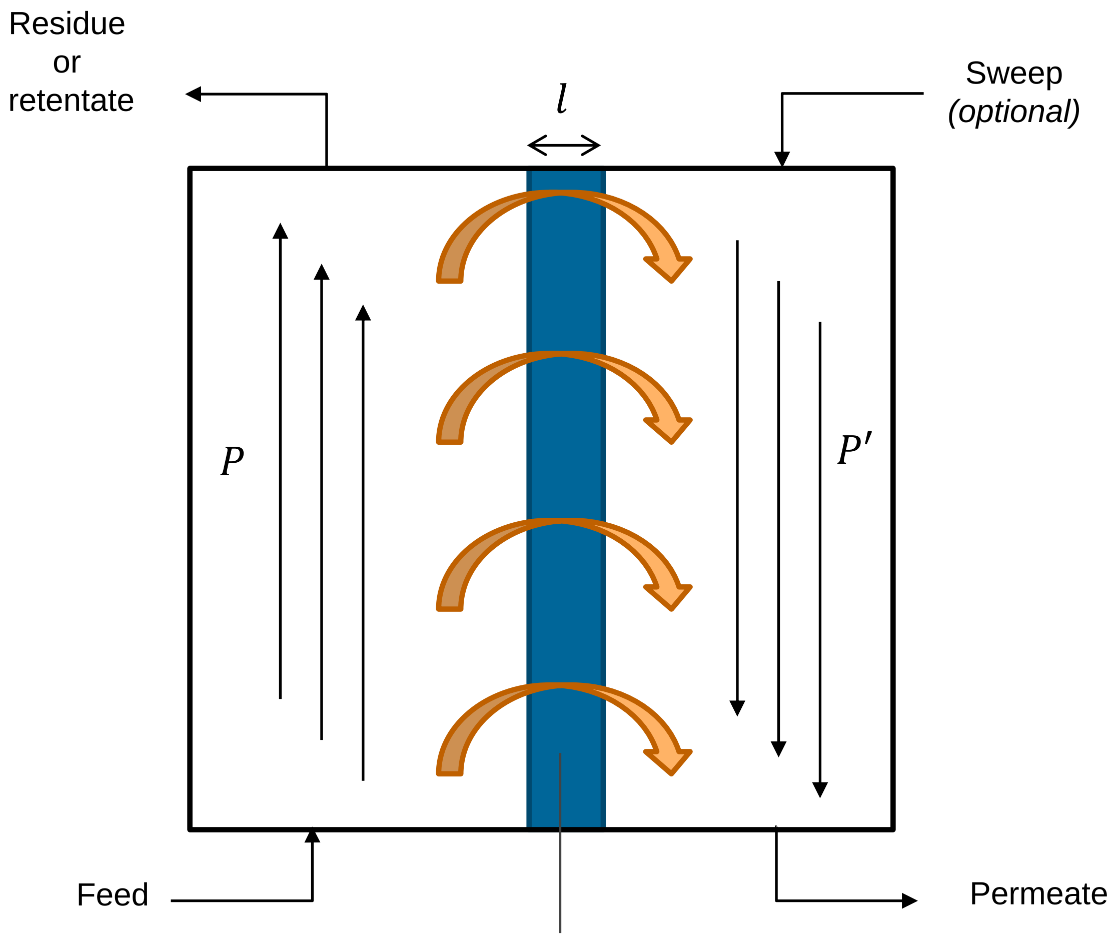
Project Overview

- **Funding**
  - Federal Share: $ 1,625,244
  - Non-Federal Share: $ 406,485
  - TOTAL $ 2,031,729
- **Project Performance Dates**
  - 04/06/2018 to 3/31/2020
- **DOE Project Manager**
  - Dr. Sai Gollakota
- **Project Participants**
  - **Prime:**
    - Electric Power Research Institute
  - **Sub-contractors:**
    - Membrane Technology and Research
    - Nexant Inc.
  - **Site Host:**
    - Duke Energy

- **Project Objective**
  - Perform an initial engineering design & cost estimate for a commercial-scale, membrane-based, post-combustion CO_2 capture system retrofit to Duke Energy's 600MWe coal-fired East Bend Unit.

Background - Membrane Basic Principles

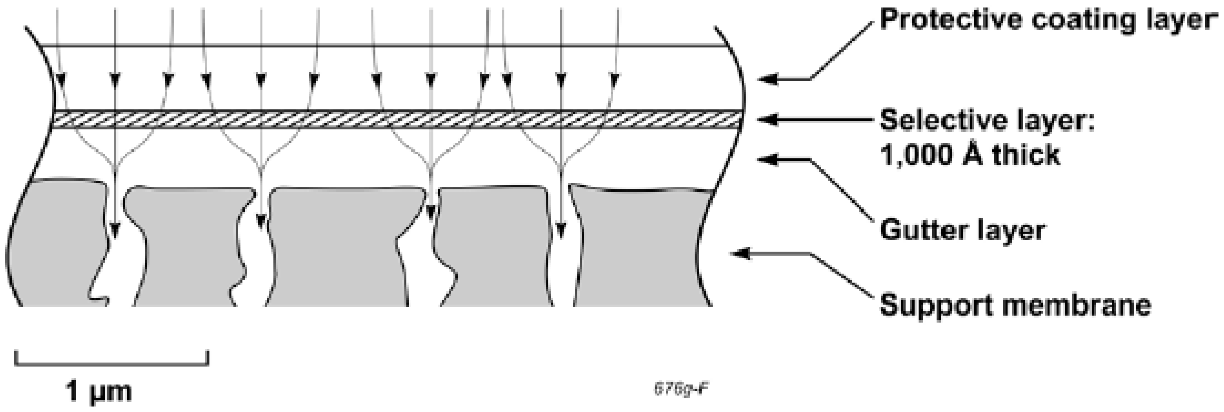
- Polymeric membrane typically operate via the solution-diffusion mechanism
- Gases dissolve into an active layer and diffuse across to the other side
- Permeation is driven by differences in partial pressures

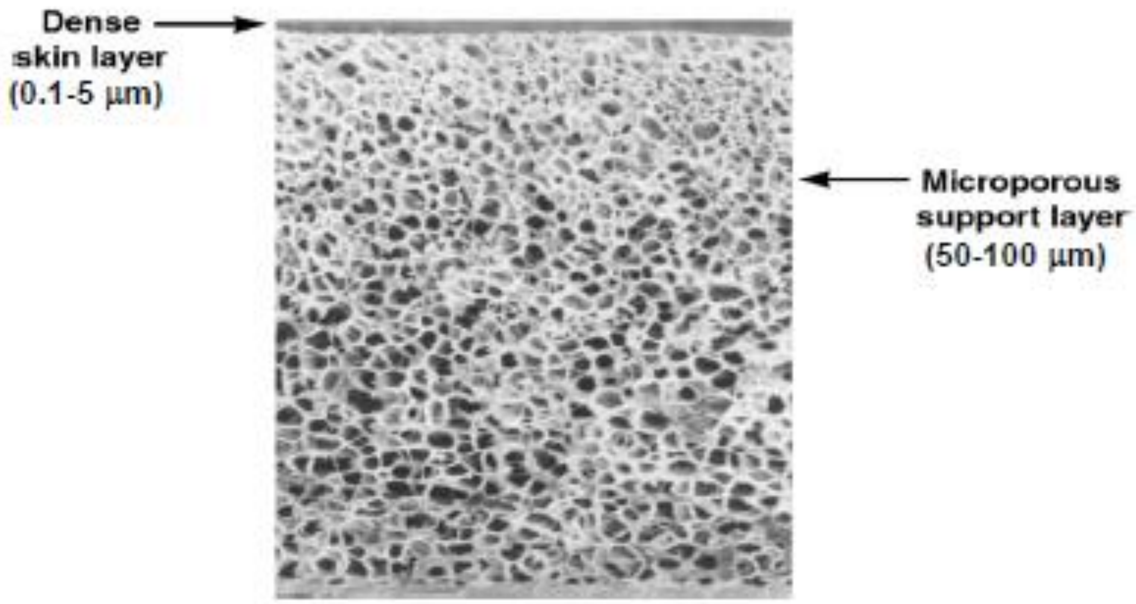


Gases dissolve into the membrane material, diffuse across, and enter the gas on the other side

Background - MTR Polaris Membrane

- MTR has developed a CO_2 selective polymeric membrane material and module - the MTR Polaris membrane
- This provides higher CO_2 permeance for post combustion flue gas applications than existing polymeric membranes

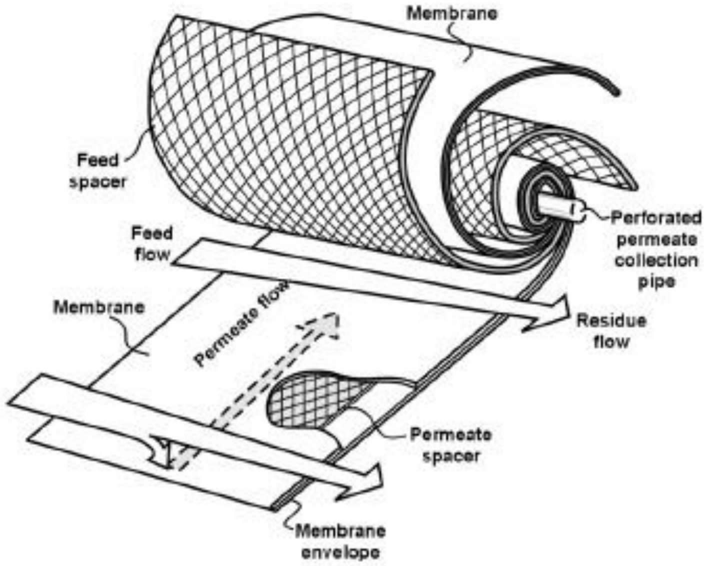




Images Courtesy of MTR

Background - Membrane Module

- Compact modular system design using high permeance membranes reduces CAPEX and overall system pressure drop
- Membranes are widely used for desalination and natural gas sweetening
- The largest existing systems are similar in scale to those required for a 550MWe coal fired power plant



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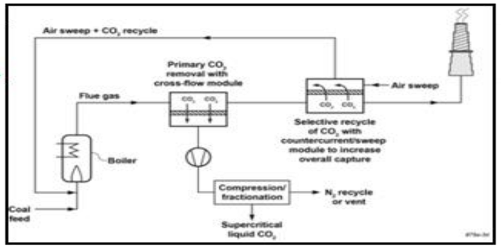
MTRs CO_2 Capture Development to Date

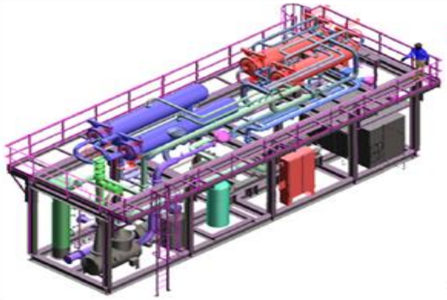
Feasibility study (DE-NT43085)
- Sweep concept proposed
- Polaris membrane conceived



APS Red Hawk NGCC Demo
- First Polaris flue gas test
- 250 lb/d CO_2 used for algae farm

APS Cholla Demo (DE-FE5312)
- First Polaris coal flue gas test
- 1 TPD CO_2 captured (50 kW_e)

NCCC 1 MW_e Demo (DE-FE5795)
- 11,000 hours of 1 TPD system operation
- 1 MW_e (20 TPD) system operation



Low Pressure Mega Module (DE-FE7553)
- Design and build a 500 m^2 optimized module

Hybrid Capture (DE-FE13118)
- Membrane-solvent hybrids with UT, Austin

B&W Integrated Test

2006	TRL3	2008	TRL4	2010		2012 (TRL5)		2014	TRL6	2016	TRL7	2018		2020

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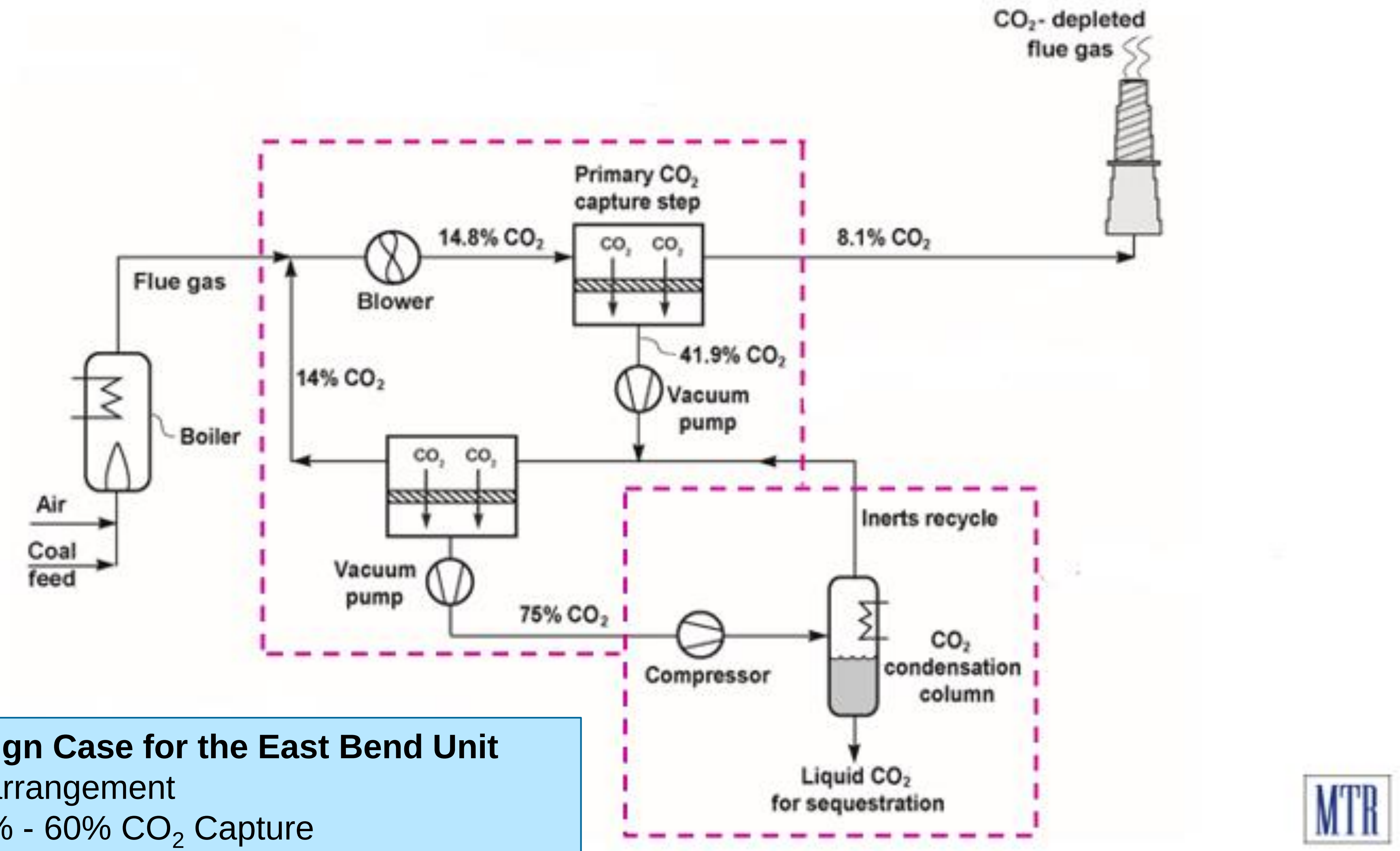
Advantages of the Membrane Capture Process

- Simple, passive operation with no chemical handling, emissions, or disposal issues
- Not affected by oxygen, SOx or NOx; co-capture possible
- Water use is lower than most capture technologies (recovers H_2O from flue gas)
  – No steam use → no modifications to existing boiler/turbines
  – Near instantaneous response; high turndown possible
  – Very efficient at partial capture (40-60%)

Challenges of the Membrane Capture Process

- Develop a design that will **minimize the impact** on the power plant by disrupting as little of the existing facilities as possible.
  - Also shorten the amount of downtime before the plant can resume normal operations
- Develop a design that will **minimize the cost** of each tonne of captured CO_2 while also maintaining the net 600 MW output of the East Bend Station.
  - This will be done by optimizing the percentage of CO_2 captured (~45 to 60%) and by adding a natural-gas-fired combustion turbine (CT) or possibly a combined cycle to offset the new auxiliary loads

Partial CO_2 Capture with 2 Stage Membrane Process



<u>Preliminary</u> Design Case for the East Bend Unit

- 2 membrane arrangement
- Aiming for 45% - 60% CO_2 Capture
- No boiler recycle

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Supplying the Membrane Power Requirements

- Unlike solvent PCC systems - No steam requirement, but power is required to drive the membrane systems fans, blowers, vacuum compressors pumps and CO_2 compression
- 4 ways to supply power will be considered:
  - New natural gas-fired simple cycle,
  - New simple cycle with heat recovery steam generator supplying steam to the coal power plant feedwater heaters
  - New combined cycle
  - Auxiliary power supplied from the existing station
- The technical and economic feasibility of adding a pipeline to supply the required amount of natural gas will be examined.
- The impacts of turning off the PCC during periods of high power demand will be evaluated (if the site has sufficient power export capacity).

Technical Approach 1/2

- Following a data gathering task that will include a site visit to the EBS, a preliminary process design will be developed for <u>one</u> PCC system which captures CO_2 from the entire flue gas stream of the power plant.
- This preliminary design will then be subjected to a series of analyses to examine various options for minimizing the cost of CO_2 capture on a $/tonne-captured basis.
- The analysis will also examine several options for providing the PCC system's auxiliary power via a CT-based power plant.
- Once an optimized process design has been identified, that design will be documented in a complete Process Design Package (PDP).

Technical Approach 2/2

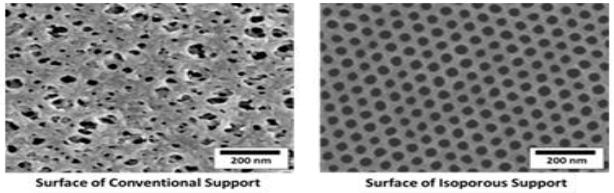
- As part of this effort a HAZOP and constructability review of the design will be conducted.
- The PDP data will be used to carry out a techno-economic analysis (TEA) that will include a +/-30% accuracy capital cost estimate as well as an estimate of the first year cost of electricity and $/tonne cost of CO_2 capture for the retrofitted power plant.
- The marginal operating cost of the retrofitted plant with also be calculated and used in a unit dispatch model to predict how the retrofit will impact how often the coal plant is called on to operate.

Project Schedule

TASK NAME:	DATES:		BUDGET PERIOD 1:												BUDGET PERIOD 2:											
	Start	End	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
TASK 1: Project Management and Planning (EPRI lead)	4/1/2018	3/31/2020																								
1.1 Project and Risk Management (EPRI)			M1	M2							DP															M11
1.2 Financial and Project Reporting (EPRI)						Q1			Q2			Q3			Q4			Q5			Q6			Q7		
1.3 Technology Maturation Plan (MTR)					M3																					
TASK 2: Develop Design Basis document (Nexant Lead)	4/1/2018	6/30/2018			M4																					
TASK 3: Establish Base Case Model (Nexant Lead)	7/1/2018	9/30/2018						M5																		
TASK 4: System analysis of Integration options (EPRI Lead)	8/1/2018	12/31/2018																								
4.1 Opimize CO2 Capture Plant Design (MTR)																										
4.2 Evaluate Options for Aux Power (EPRI, Nexant)																										
4.3 Finalize Design Configuration (EPRI , MTR, Nexant)											M6															
DECISION POINT: Examine and Review Retrofit Options	1/1/2019	15/1/2019										DP														
TASK 5: Finalize Overall Retrofit PC Design (EPRI Lead)	1/16/2019	6/30/2019																								
5.1 Design Package of the Membrane CCS System (MTR)															M7											
5.2 Design Package for BOP & Aux. Power (EPRI & Nexant)																										
5.3 Preliminary HAZOP Review (Nexant, Bechtel, MTR & Duke)																	M8									
5.4 Constructibility Review (Nexant , Bechtel & Duke)																	M9									
TASK 6: Techno-Economic Analysis (EPRI Lead)	7/1/2019	12/31/2019																								
6.1 Capital Cost Estimation of Integrated PCC Design (Nexant)																			M10							
6.2 O&M Cost Estimation of Integrated PCC Design (Nexant, EPRI)																										
6.2 TEA and Dispatch Analysis (EPRI & DUKE)																										
TASK 7: Final Report Preparation (EPRI Lead)	1/1/2020	3/31/2020																								FR

MTRs CO_2 Capture Development – Current Projects

Self-Assembly Isoporous Supports, CA (DE-FE31596)
- Improve gas transport through support layer
- Enables a reduction in membrane area
- Build and test new membrane at NCCC



Pilot Testing at TCM, Norway (DE-FEXXXX)
- 1 MWe - advanced Polaris™ membrane
- Partial capture for low cost-of-capture
- New modular construction

Pilot Testing at TCM, Norway (DE-FEXXXX)
- 1 MWe - Hybrid testing with TDA
- Membrane + solid sorbent for 90% capture
- Selective CO_2 recycle using sorbents

Full-Scale FEED at Duke Energy's East Bend Station, KY (DE-FE31589)
- 460 MWe – using Advanced Polaris™
- Partial capture and modular membrane
- Rapid retrofit deployment

Large-Pilot Testing at WY ITC, WY (DE-FE31587)
- Phase I – Design ~16 MWe pilot; secure host site
- Phase II – FEED and permitting
- Phase III – Fabricate, install and operate

TRL7 TRL8

2018 2019 2020 2021 2022 2023 2024 2025

Courtesy of MTR

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Acknowledgement and Disclaimer

Acknowledgement

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