Allocation in Long Pipelines

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Perth, Australia

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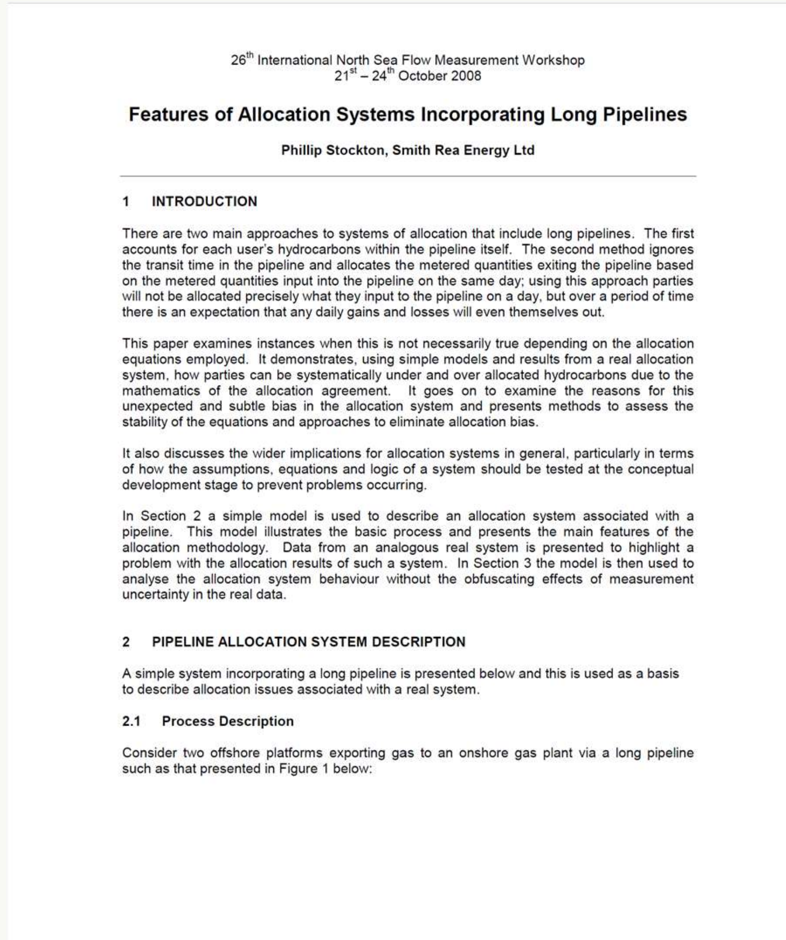
Presentation outline

- Background
- Case studies
- Observation
- Why does it occur?
- Real example
- What is the significance?
- Can this be avoided?
- Conclusion

Background

- ❑ A detailed and comprehensive study by Phil Stockton, Accord Director and Co-Founder
- ❑ Based on a genuine allocation problem with real data from an operational allocation system for a pipeline network
- ❑ Presented in the North Sea Flow Measurement Workshop in 2008, and followed up in 2018 when he managed to mathematically proof the situation, not just in numbers
- ❑ May not be among the most recent discovery but the relevance never go away – *equitable CO2 allocation?*
- ❑ The paper itself is self-explanatory – this presentation is from my own observation after I attempted creating my own model to prove it

Link to technical paper:
[Features of Allocation Systems Incorporating Long Pipeline]



26th International North Sea Flow Measurement Workshop
21st – 24th October 2008

Features of Allocation Systems Incorporating Long Pipelines

Phillip Stockton, Smith Rea Energy Ltd

1 INTRODUCTION

There are two main approaches to systems of allocation that include long pipelines. The first accounts for each user's hydrocarbons within the pipeline itself. The second method ignores the transit time in the pipeline and allocates the metered quantities exiting the pipeline based on the metered quantities input into the pipeline on the same day; using this approach parties will not be allocated precisely what they input to the pipeline on a day, but over a period of time there is an expectation that any daily gains and losses will even themselves out.

This paper examines instances when this is not necessarily true depending on the allocation equations employed. It demonstrates, using simple models and results from a real allocation system, how parties can be systematically under and over allocated hydrocarbons due to the mathematics of the allocation agreement. It goes on to examine the reasons for this unexpected and subtle bias in the allocation system and presents methods to assess the stability of the equations and approaches to eliminate allocation bias.

It also discusses the wider implications for allocation systems in general, particularly in terms of how the assumptions, equations and logic of a system should be tested at the conceptual development stage to prevent problems occurring.

In Section 2 a simple model is used to describe an allocation system associated with a pipeline. This model illustrates the basic process and presents the main features of the allocation methodology. Data from an analogous real system is presented to highlight a problem with the allocation results of such a system. In Section 3 the model is then used to analyse the allocation system behaviour without the obfuscating effects of measurement uncertainty in the real data.

2 PIPELINE ALLOCATION SYSTEM DESCRIPTION

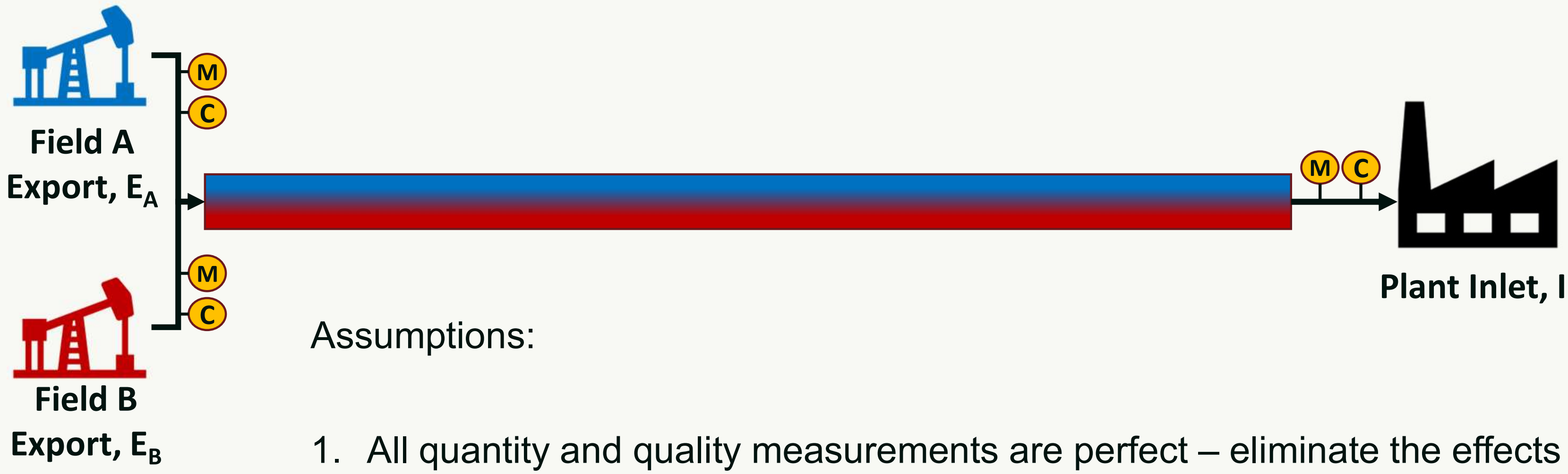
A simple system incorporating a long pipeline is presented below and this is used as a basis to describe allocation issues associated with a real system.

2.1 Process Description

Consider two offshore platforms exporting gas to an onshore gas plant via a long pipeline such as that presented in Figure 1 below:

Case Study:

The Long Pipeline (PL1000)*

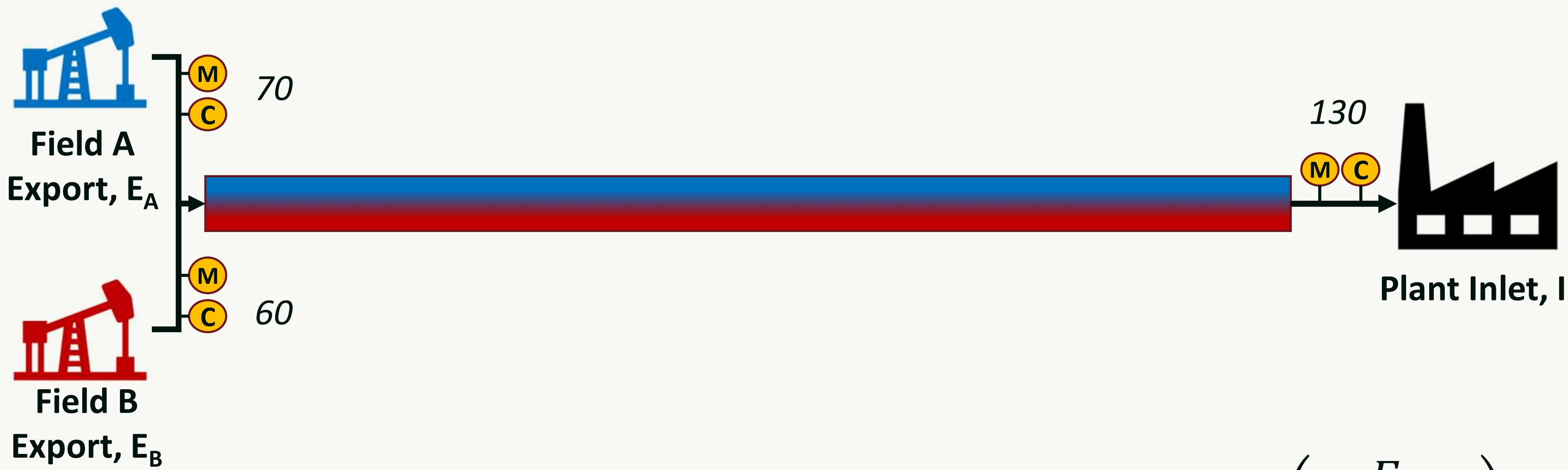


Assumptions:

1. All quantity and quality measurements are perfect – eliminate the effects of metering uncertainties
2. Plug flow of incompressible fluid in pipeline (no axial mixing as today's production displace pipeline contents by equal amount)
3. Gas arriving plant is previous day's production
4. Field A and B have different compositions and flow rates
5. No leaks / loss within the pipeline system

*Not a real name

Imagine this: Day 1



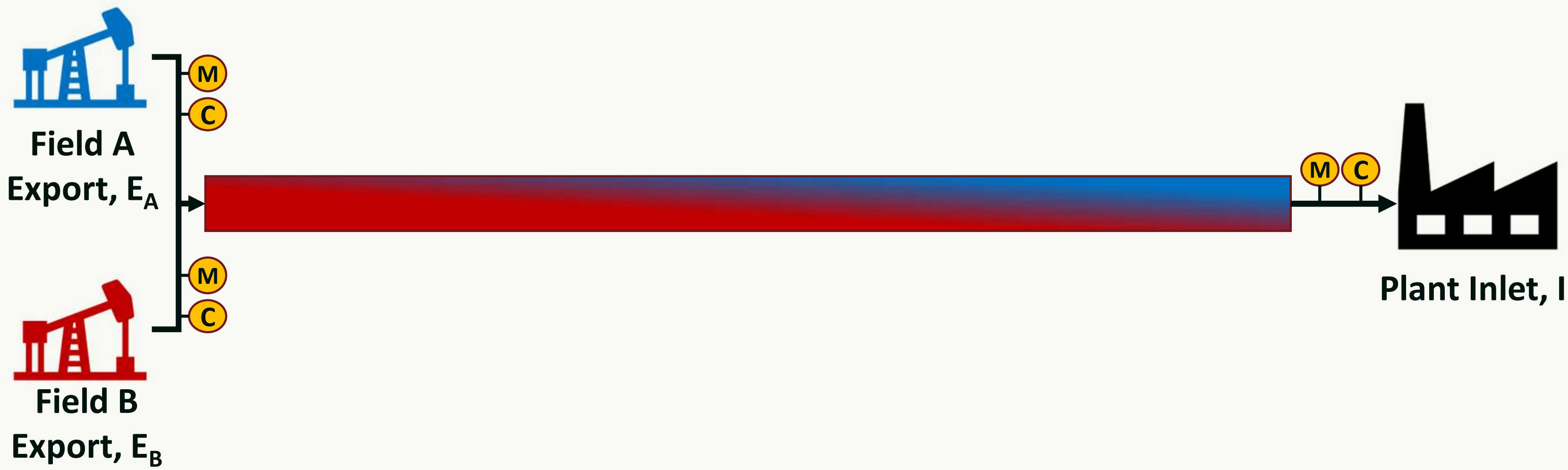
- ❑ Both fields produce at stable rates and fill up the pipeline in a *steady state* mode
- ❑ Pro-rata basis allocation on molar or mass basis
- ❑ Field A and Field B get allocated proportionally of the component that was exported

$$I_A = \left(\frac{E_A}{E_A + E_B}\right) I$$

$$I_A = \left(\frac{70}{70 + 60}\right) 130$$

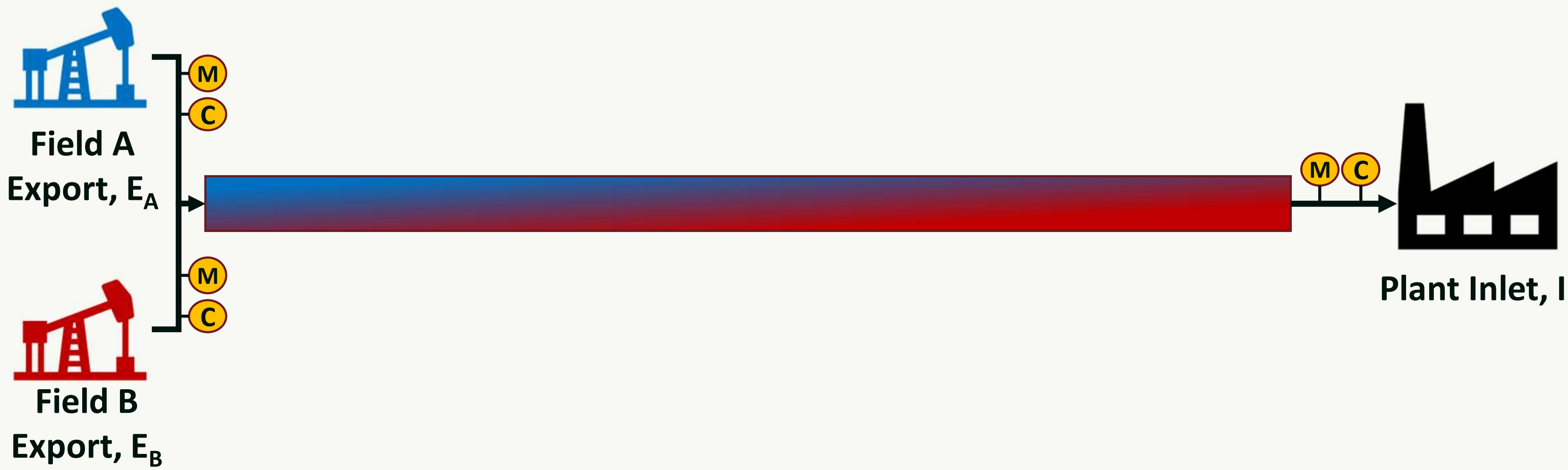
$$I_A = 70$$

Imagine this: Day 2



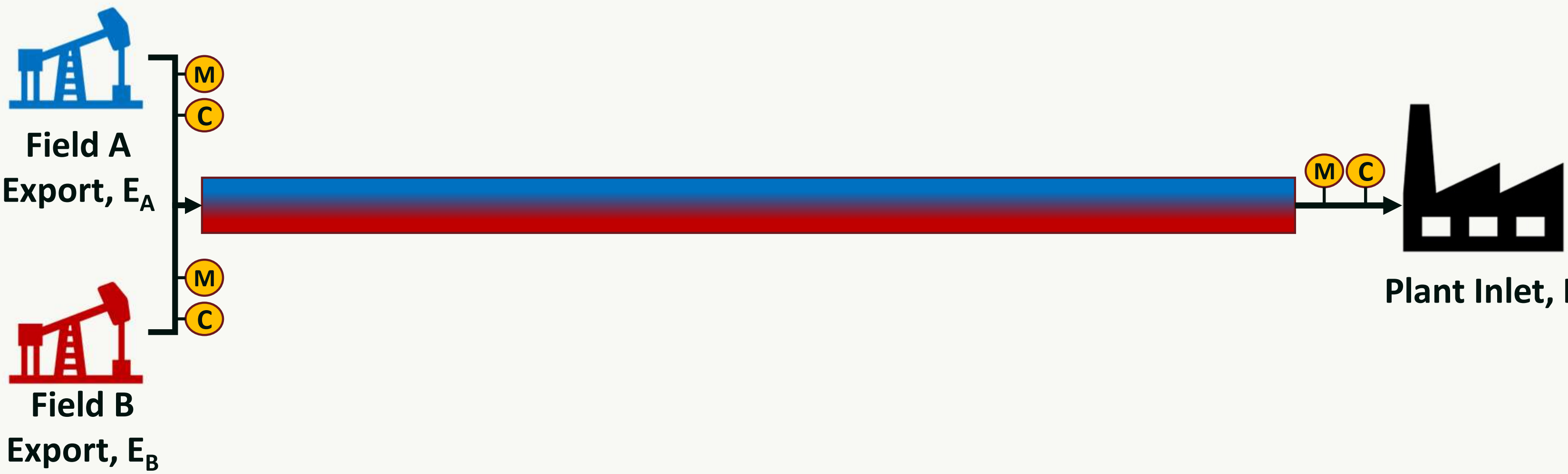
- Field A shuts down
- Plant receives the displaced volume from Day 1
- Only a portion of pipeline volume is filled with today's production from Field B
- Field B get allocated mixture of Field A and Field B composition as measured at Plant inlet

Imagine this: Day 3



- ❑ Field A starts up again
- ❑ Plant receives the displaced volume from Day 2
- ❑ Field A and B get allocated mixture rich in Field B composition

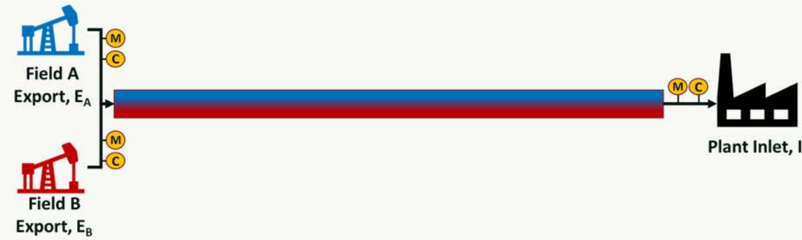
Imagine this: Day 4 …. n^{th}



- ❑ Field A and B start up, shut down, ramp up and down independently at various occasions
- ❑ Plant receives the displaced volume from previous day(s)
- ❑ Different percentage of pipeline volume being displaced on daily basis
- ❑ Field A and B get allocated mixture from previous day(s)

How to model this situation…

Let’s throw in some numbers..

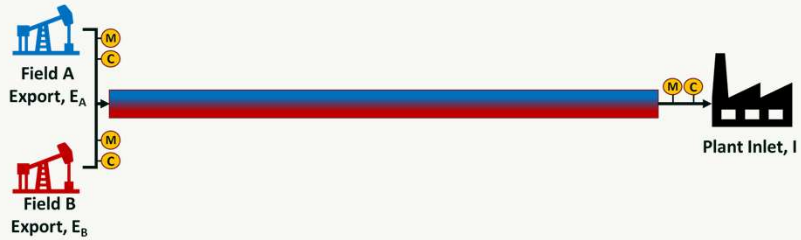


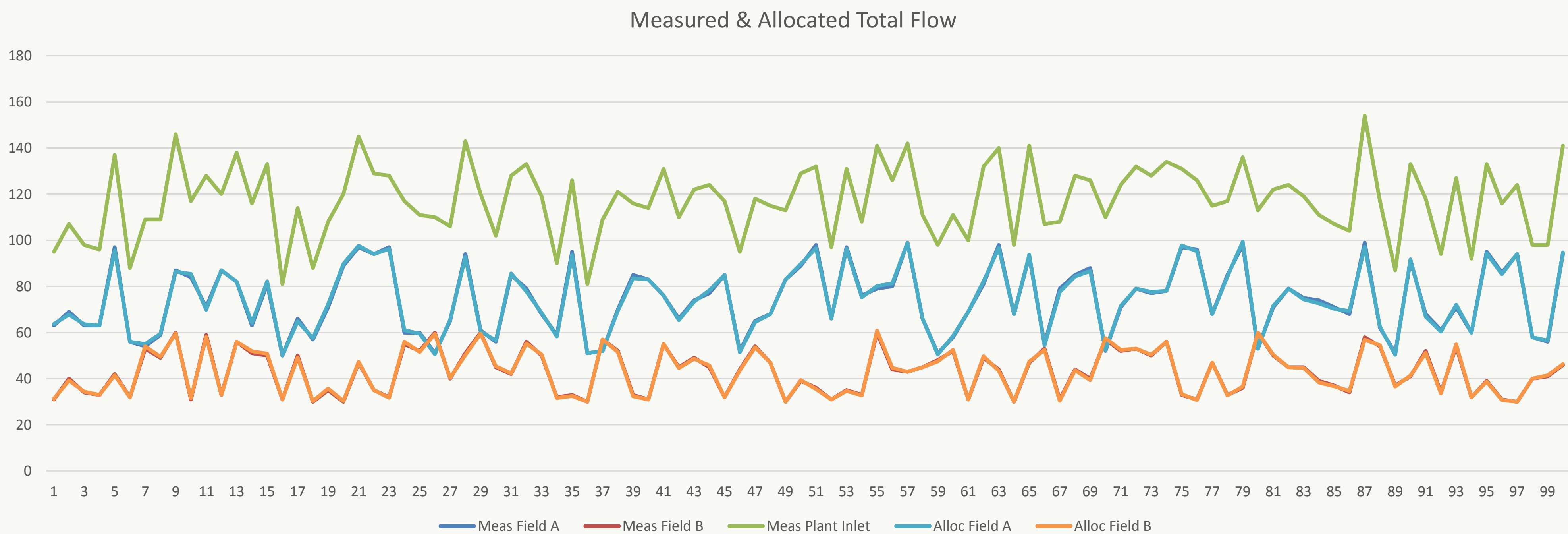
- Start with total mass approach
- Allocation is done in mass, units are arbitrary
- Field A and Field B total flow vary randomly between 70 to 100 and 30 to 70 respectively
- Plant Inlet measured receipt vary randomly between +/- 2% of Field A plus Field B to represent the stock fluctuations in the pipeline

						Delta (Alloc - Meas)		Cumulative Delta	
	Meas Field A	Meas Field B	Meas Plant Inlet	Alloc Field A	Alloc Field B	Field A	Field B	Field A	Field B
Day 1	63	31	95	63.67	31.33	0.67	0.33	0.67	0.33
Day 2	69	40	107	67.73	39.27	-1.27	-0.73	-0.60	-0.40
Day 3	63	34	98	63.65	34.35	0.65	0.35	0.05	-0.05
Day 4	63	33	96	63.00	33.00	0.00	0.00	0.05	-0.05
Day 5	97	42	137	95.60	41.40	-1.40	-0.60	-1.34	-0.66
Day 6	56	32	88	56.00	32.00	0.00	0.00	-1.34	-0.66
Day 7	54	53	109	55.01	53.99	1.01	0.99	-0.33	0.33
Day 8	59	49	109	59.55	49.45	0.55	0.45	0.21	0.79
Day 9	87	60	146	86.41	59.59	-0.59	-0.41	-0.38	0.38
Day 10	84	31	117	85.46	31.54	1.46	0.54	1.08	0.92

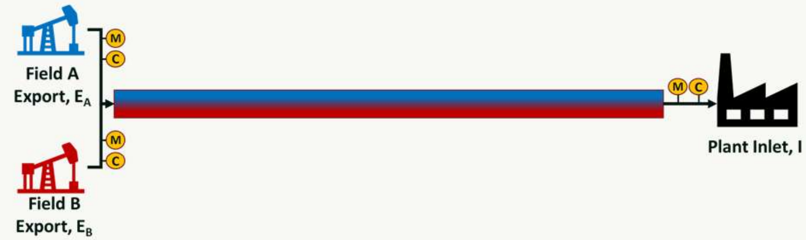
Extend this to 100 days..

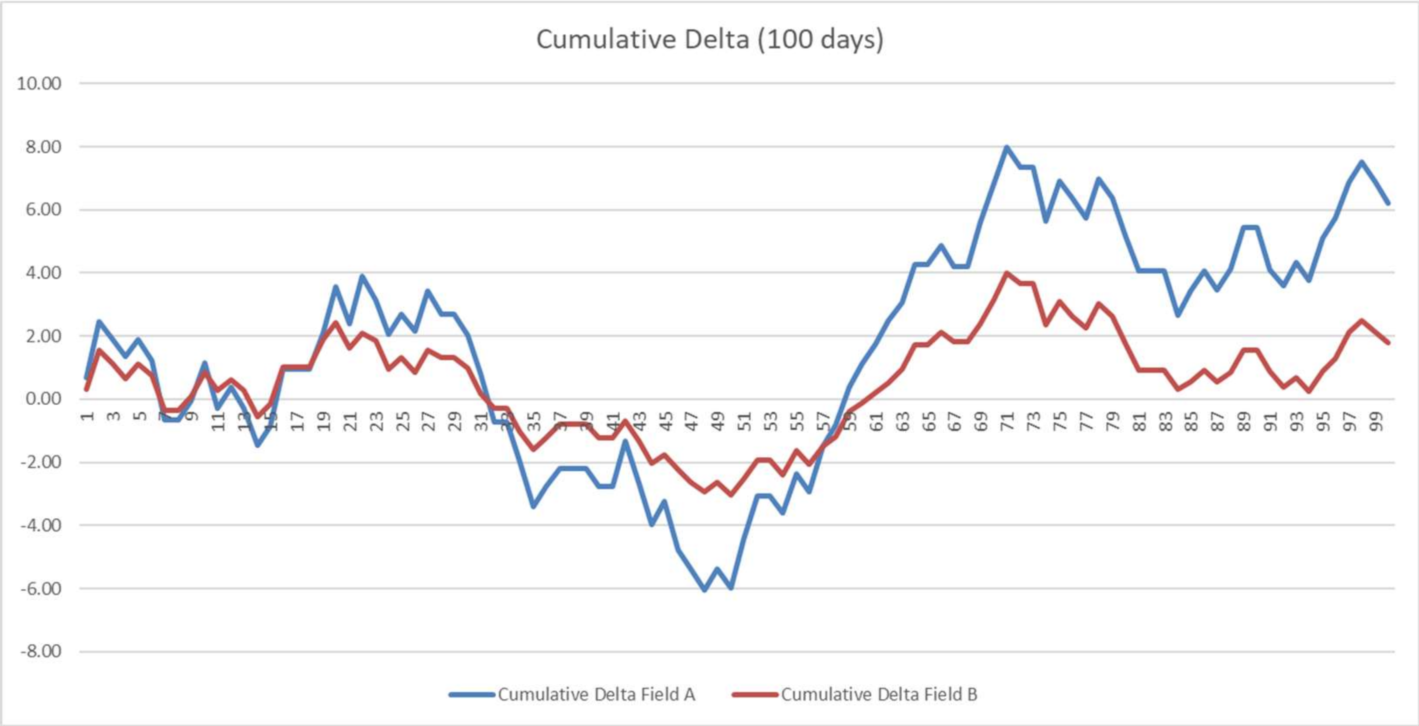
Seems perfect?



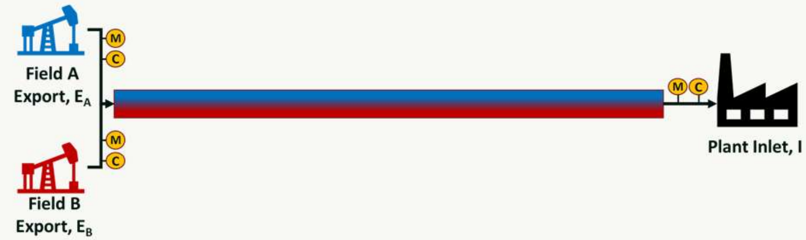


Will the differences even out eventually?

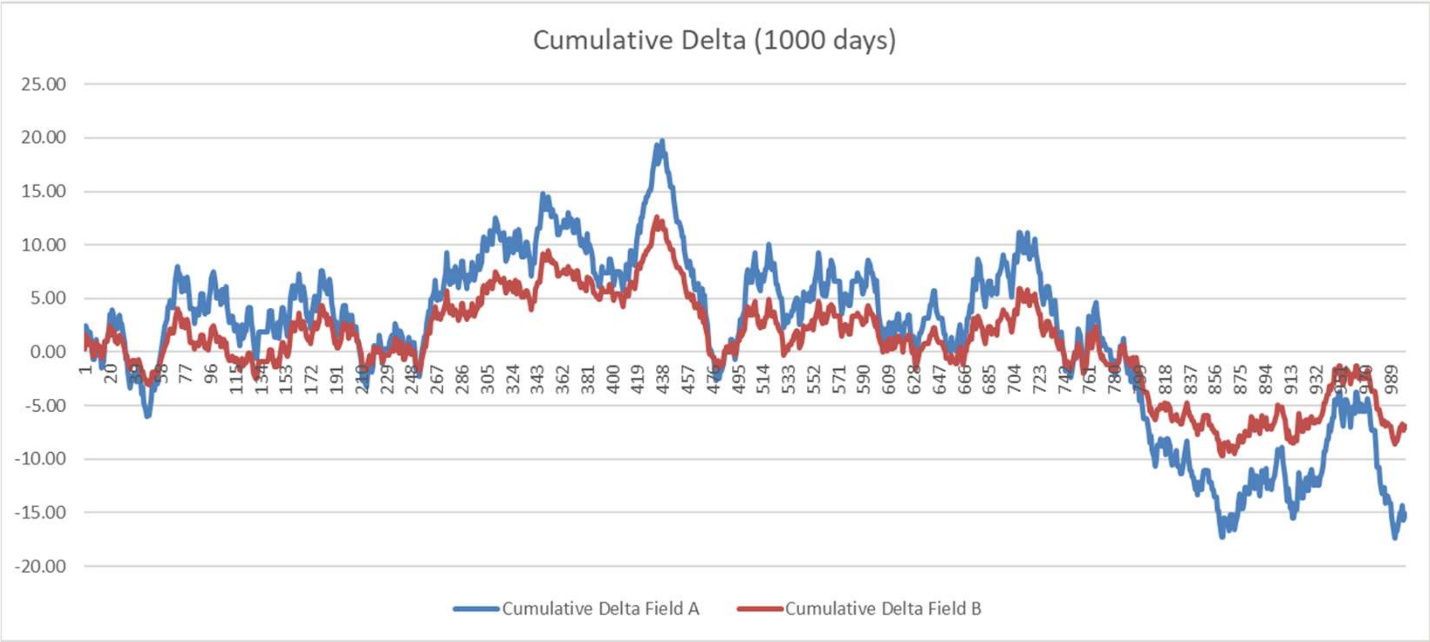




1000 days?

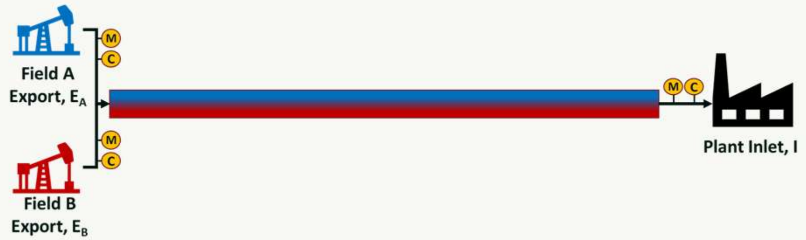


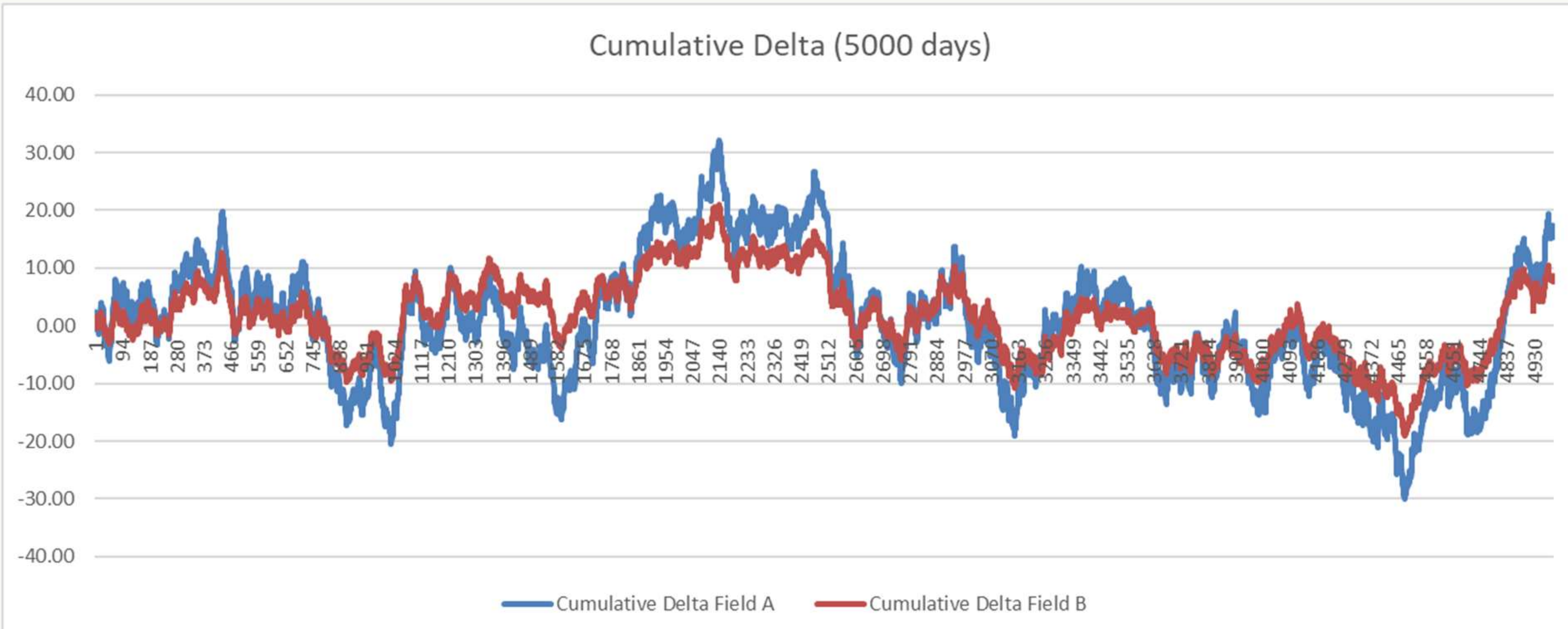
Field A
Export, E_A
Field B
Export, E_B
Plant Inlet, I
M
C



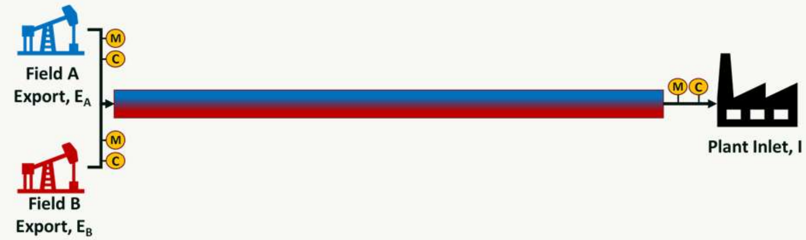
Cumulative Delta (1000 days)
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
Cumulative Delta Field A
Cumulative Delta Field B

5000 days?


Field A
Export, E_A
Field B
Export, E_B
Plant Inlet, I


Cumulative Delta (5000 days)
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
Cumulative Delta Field A
Cumulative Delta Field B

What about at component level?



Let’s model these scenarios:

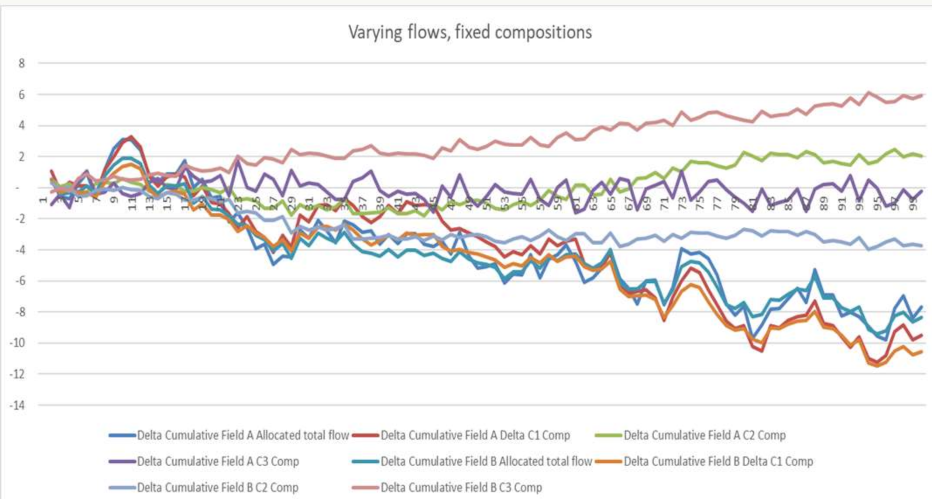
- ❑ Case 1. Field A and B vary total flow while composition is fixed
- ❑ Case 2. Field A and B vary composition while total flow is fixed
- ❑ Case 3. Field A and B vary both total flow and composition
- ❑ Case 4. Only Field A vary both total flow and composition

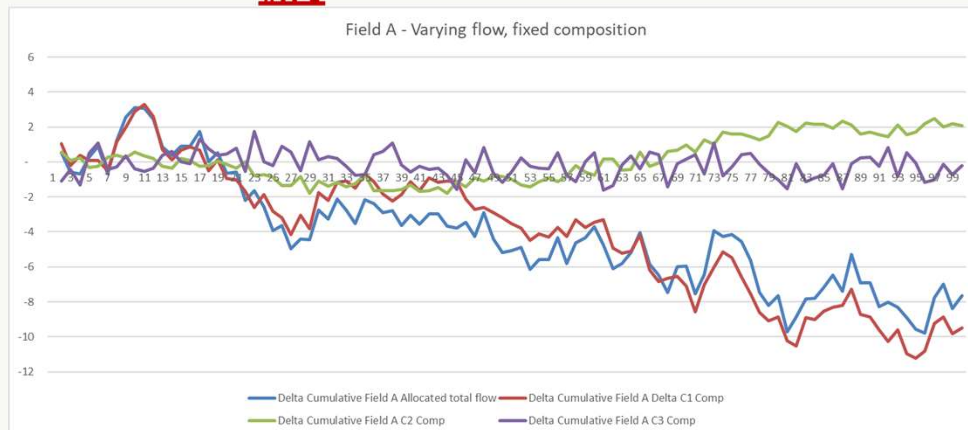
Assumptions:

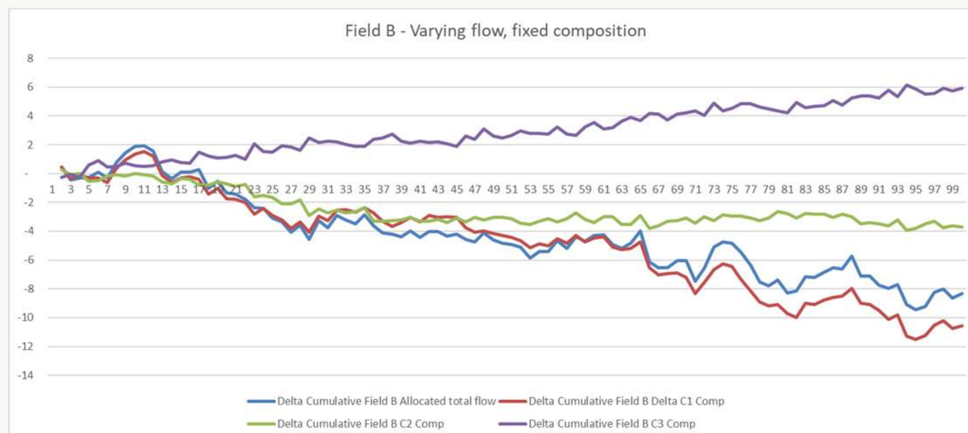
- ❑ Total output flow = total input flow i.e. perfect metering
- ❑ Output composition = yesterday’s combined input composition

	Fixed – Field A	**Fixed – Field B**	**Vary – Field A**	**Vary – Field B**
Total Flow	90	50	70 - 100	30 - 70
C1 %	60	65	55 – 70 %	65 – 70 %
C2 %	15	20	15 – 20%	20 – 25 %
C3 %	25	15	Balance	Balance

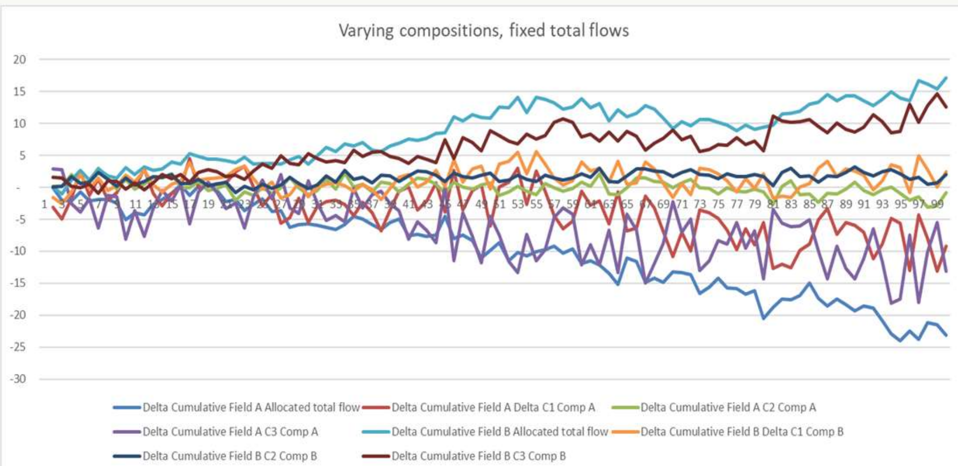
Case 1: Field A and B vary total flow while composition is fixed

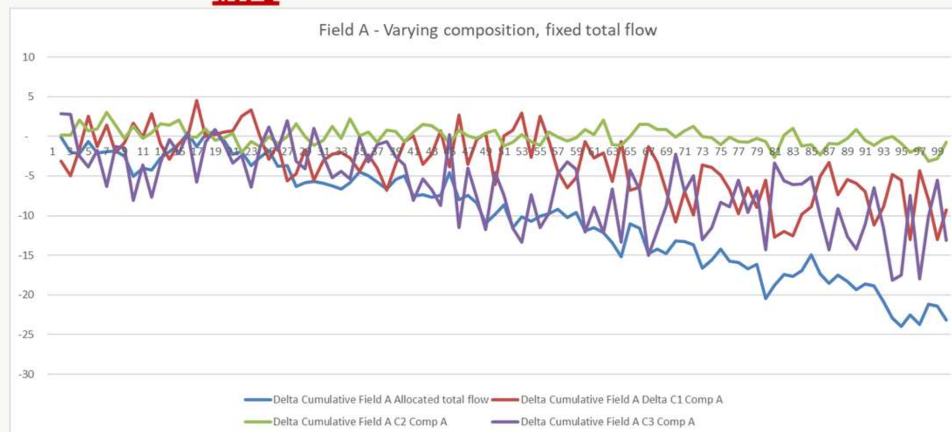


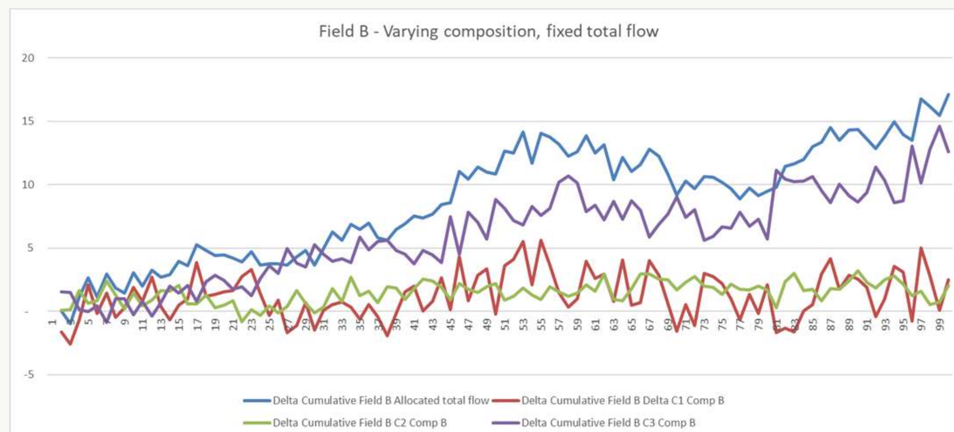




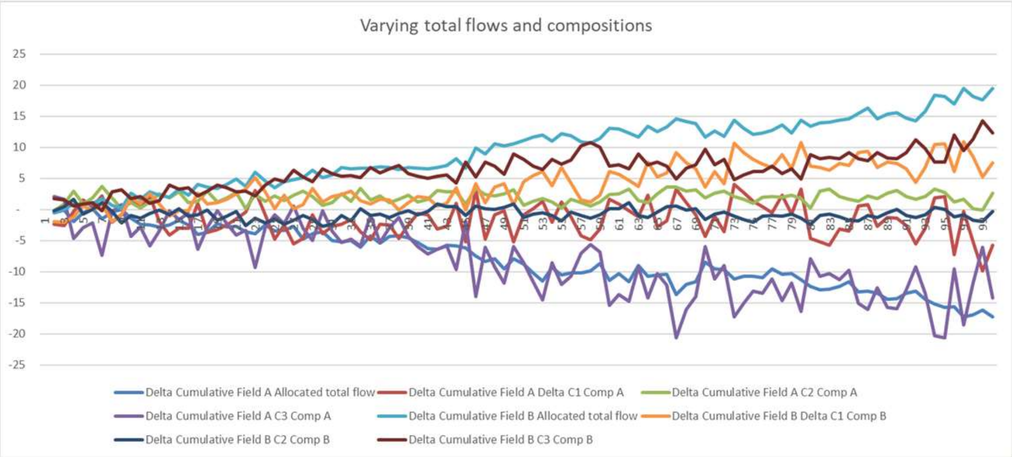
Case 2. Field A and B vary composition while total flow is fixed

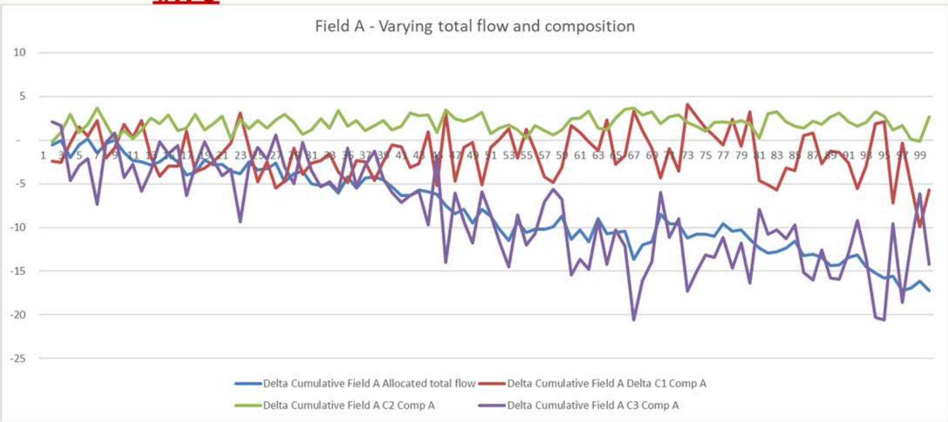


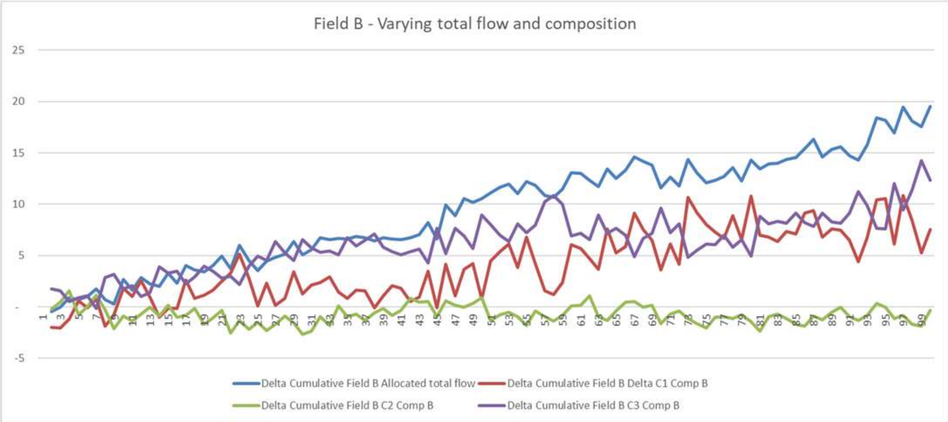




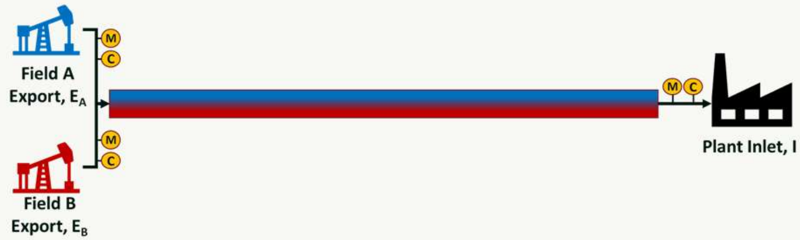
Case 3. Field A and B vary both total flow and composition

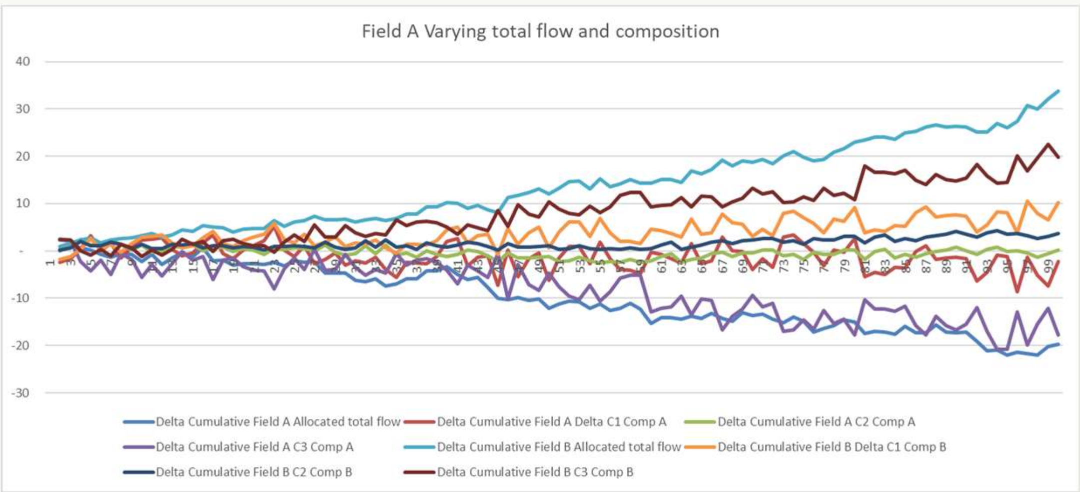


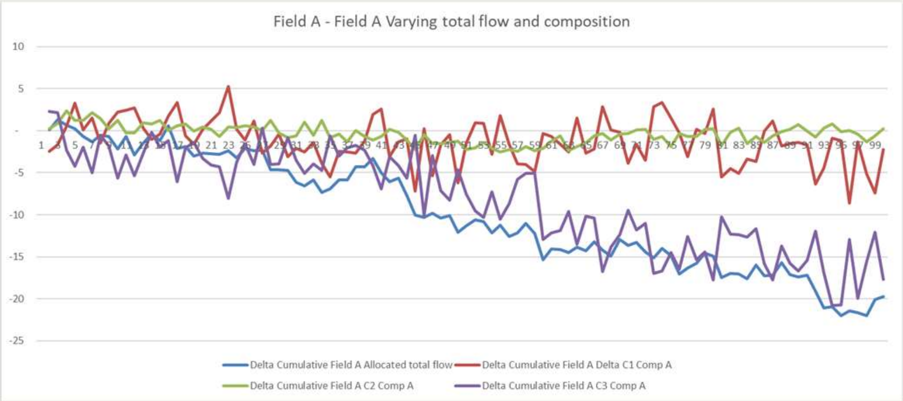


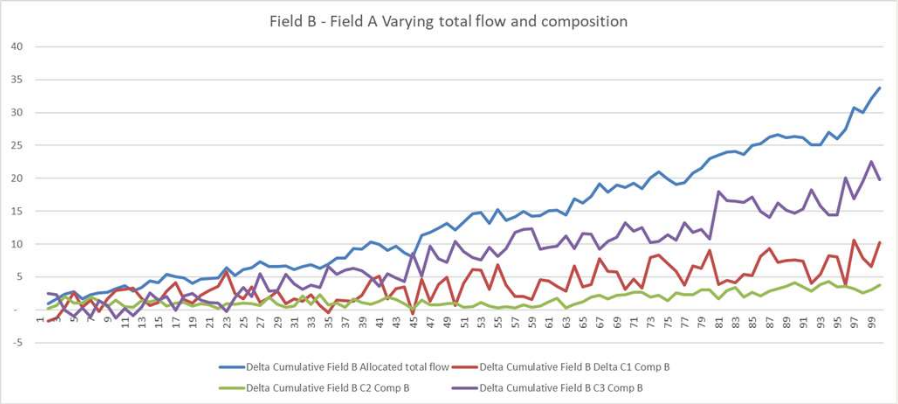


Case 4. Only Field A vary both total flow and composition









Observations

- As this model uses random values within the defined boundaries, the magnitude of cumulative values varies every time the model is refreshed. However, the *trend is rather consistent*
- At a component level, the expectation that you get out what you put in is most likely not correct
- Difference between measured exports and allocated inlets diverges with time more significantly when the composition varies
- The more dissimilar the field compositions the faster the divergence
- The field richer in a component is systematically under-allocated that component

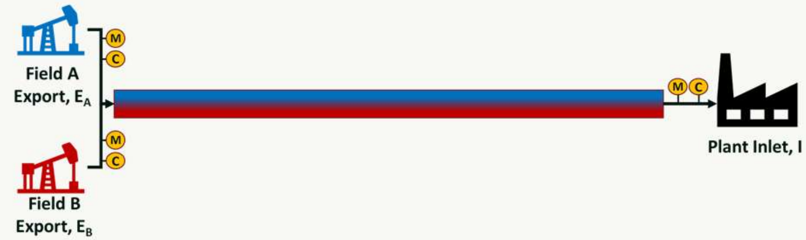
Why does it occur?

- Fields production can vary in both measured total flow and compositions – most likely scenario
- Each field maybe allocated different quantities of a component at inlet compared to outlet, depending on the movement in field's pipeline stock of that component
- Pipeline stocks fluctuate from day to day therefore can be added or subtracted from each field's current day production
- Generally, the allocation algorithms are preferably simple and straight forward
- Therefore, here is the problem…

Allocation algorithm <u>assume steady-state behavior</u> – what you put in of a component is what you get out – making it <u>mathematically unstable</u>

Allocation should be simple… but not too simple

Real Data Example



Allocated Pipeline Stock

	Field A kg	Field B kg
N2	166,786	255,147
CO2	**-504,728**	4,816,148
C1	5,206,866	14,366,841
C2	3,977,723	2,397,806
C3	2,785,383	**-812,473**
IC4	751,988	202,924
NC4	1,552,043	102,636
IC5	328,169	412,012
NC5	410,196	57,509
C6	**-849,384**	236,605
C7	**-163,564**	296,035
C8+	354,973	300,008
Total	14,016,451	22,631,198

	Field A wt%	Field B wt%
N2	1.2%	1.1%
CO2	**-3.6%**	21.3%
C1	37.1%	63.5%
C2	28.4%	10.6%
C3	19.9%	**-3.6%**
IC4	5.4%	0.9%
NC4	11.1%	0.5%
IC5	2.3%	1.8%
NC5	2.9%	0.3%
C6	**-6.1%**	1.0%
C7	**-1.2%**	1.3%
C8+	2.5%	1.3%
Total	100.0%	100.0%

Typical Export Composition

Field A wt%	Field B wt%
1.8%	0.5%
9.9%	12.8%
48.7%	61.7%
14.6%	11.6%
14.4%	7.2%
1.9%	1.1%
5.0%	2.4%
1.1%	0.7%
1.3%	0.8%
0.8%	0.8%
0.2%	0.4%
0.1%	0.1%
100.0%	100.0%

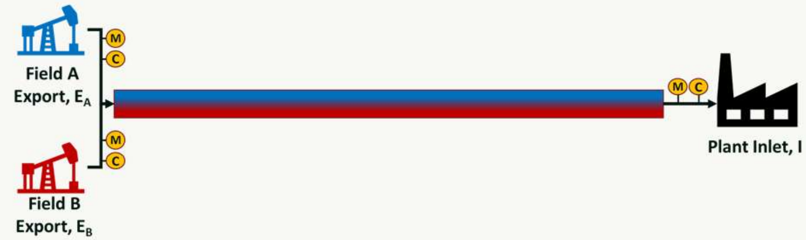
Plant Inlet

Total kg	wt%
421,933	**1.2%**
4,311,420	**11.8%**
19,573,707	**53.4%**
6,375,529	17.4%
1,972,910	5.4%
954,912	2.6%
1,654,679	**4.5%**
740,181	2.0%
467,705	**1.3%**
-612,779	-1.7%
132,471	0.4%
654,981	1.8%
36,647,649	

Potential causes:

- ❑ ***GC and/or meter uncertainty?***
- ❑ ***Allocation algorithm?***

What is the significance?



- We may have assumed that it won't happen or there will be no material exposure to our operation, but have we given a deeper look? The real case example 'only' happened after many years of operations

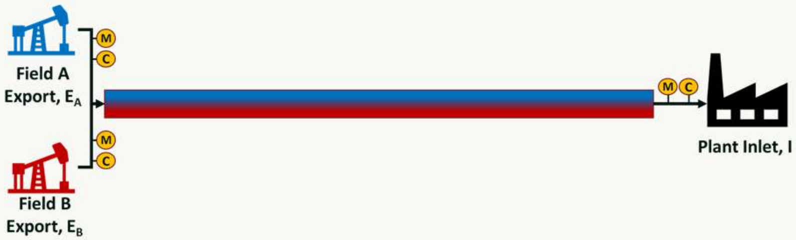
- This situation can happen in various applications and more severe in certain scenarios, e.g.
  - Sluggish flow with significant presence of liquid in a gas pipeline
  - Significant amount of inert gas from a particular producer(s) in the network
  - Any highly variable producers into a pipeline system with significant transit time

- Equitable?

- Over time, the subtle differences can easily add up to be a millions of dollars loss (or gains?)

- Or we are dealing with much more pressing matters that this risk *does not matter?*

Can this be avoided?

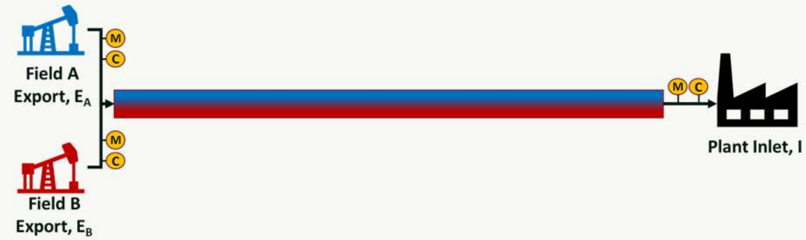


- ❑ Change in mathematical approach – substitute the export component with change in pipeline stock in the allocation algorithm
  - ✓ Small change in daily allocated quantities
  - ✓ Incorporate feedback mechanism
  - ✓ Remains stable over time

- ❑ Analyze the allocation model before implementation
  - ✓ Construct simplified models to test allocation logic
  - ✓ Mathematical techniques – stability analysis
  - ✓ Tools are available

- ❑ Periodic review of allocation system performance during operations
  - ✓ Validate the assumptions – especially on compositional analysis
  - ✓ Proper maintenance and verification of the measurement system – *goes without saying*

Conclusion



- Preference for simple transparent allocation systems
- However, even in simple systems get unexpected results
- Discovered a subtle and unexpected consequence of allocation system design
- Potential to occur in a range of pipeline allocation systems
- Can apply to other aspects of allocation systems as a whole
- Illustrates the need for rigorous mathematical testing at concept stage
- A problem with pipeline stocks may not be due to metering issues – give metering some break!

ACCORD

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Thank you