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Agenda:

OPEX Review

Throughput & Efficiency

Major Projects

Using DRA to aid pipeline sustainability

T. Rudd

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How can we operate sustainably?

- Operators are often under pressure from regulators, shareholders, community stakeholders, activists etc. to integrate sustainability into their operations.
- UN defines sustainability as *"meeting the needs of the present without compromising the ability of future generations to meet their own needs"*
- Safe, Reliable, Affordable energy is a need of the present & the future
- **How can we, as operators, apply this?**
  - Waste Hierarchy a good place to start
- Prevent, Reduce & Reuse
  - Prevent is key – "Keep it in the pipe!"
- We can also reduce our footprint
  - Reduce materials & energy consumption
- We reuse our long life assets
  - We reuse them a lot & can re-purpose them
  - Town gas ➔ Natural gas ➔ Hydrogen?
- We can achieve sustainable operations by making real changes today, rather than grand promises for the future

What's the link?

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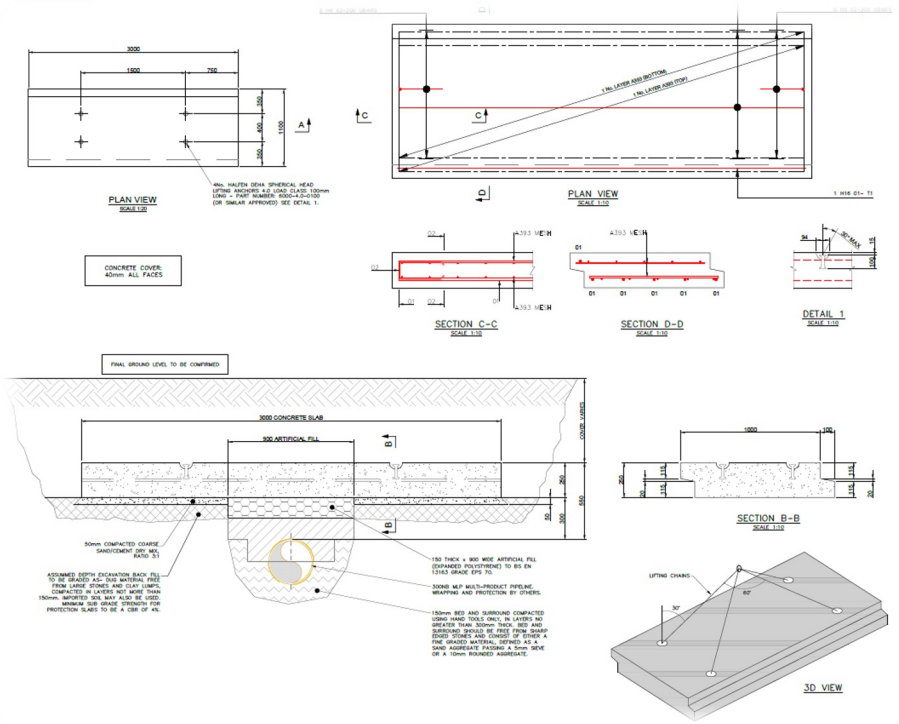

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How can we improve the efficiency of our operations?

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- For liquid operators, pump usage is typically by far largest use of electricity
- How can we reduce this?
- Pump efficiency – impellor optimisation
  - Expensive, requires downtime, difficult to optimise for all scenarios, relatively low % gains
- Motor efficiency – VFD/VSD etc, newer motors
  - Highly CAPEX intensive for minimal gains – motors are generally fairly efficient with only incremental improvements from updating.
  - VFD/VSD's require significant engineering works to install and are very expensive. With careful optimising they can produce significant benefits.
- Operational efficiency – optimising pressures, flowrates for efficiency. Minimise wasted energy (head pressure).
  - No/minimal CAPEX cost but requires significant resources/time for optimisation and a need to challenge all operating assumptions.
  - Sometimes, physical constraints of the system or scheduling demands can hinder operational efficiency.
- Valve philosophy – throttle with pumps, not valves

Operational efficiency

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- Running a pipeline with pressures higher than needed is like carrying liquid up a hill for no reason

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How can we reduce pressures & optimise our systems?

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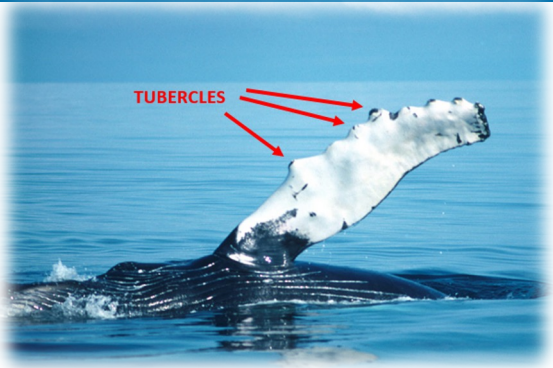
- We can't control pipeline elevations or fluid density
- We have some control over frictional drag
  - Faster flowrates increase turbulence, which wastes energy & generates drag through frictional losses
  - Pipeline roughness induces micro turbulence/drag – rougher pipes have a higher Reynolds Number.
- In nature and in other industries (e.g. aviation, Formula 1) small eddies are often used to prevent formation of larger eddies
- We see this in planes, F1 cars and whale fins
  - The "Tubercule effect"
- How can we apply this to pipelines?



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DRA – Drag Reducing Agent

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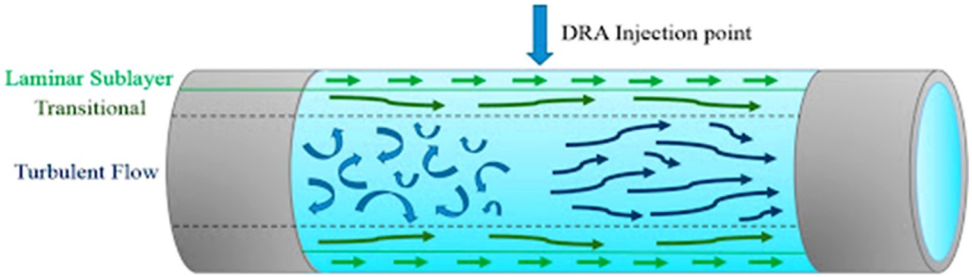
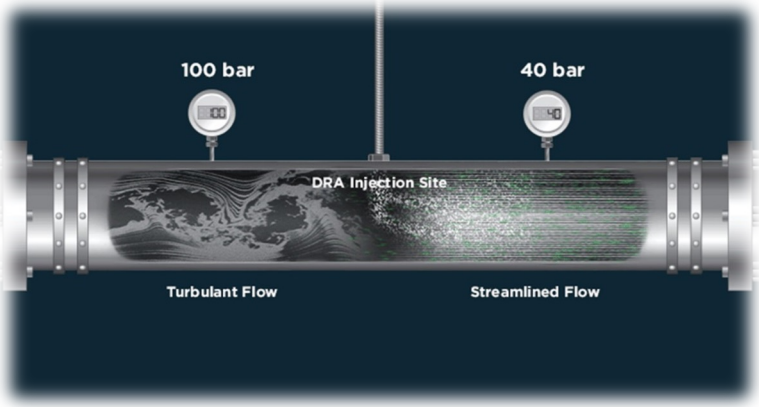
- DRA is made from long-chain hydrocarbons injected into the pipeline
- They align along edges of pipe and prevent small eddies forming/growing
  - They don't cling to the metal or film; they flow & exit with the fuel
  - Shear stresses from pumps, impellors, changes in direction break down the molecules.
- The long-chain molecules align along the edges of the pipe & produce a sub-layer of laminar flow. This reduces friction from turbulent flow & moves the laminar:turbulent boundary out or eliminates it.
- Laminar flow ➔ less energy wasted in turbulence ➔ efficient operation
- Effectively, DRA makes a pipeline slippier so reduces drag, thereby reduces pump effort/head needed to overcome it
- Steady-state operation can be maintained at lower pressures.
- OR: enhanced throughput at original pressures – reducing need to build/upgrade equipment or lay more pipe





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What kind of gains are achievable?

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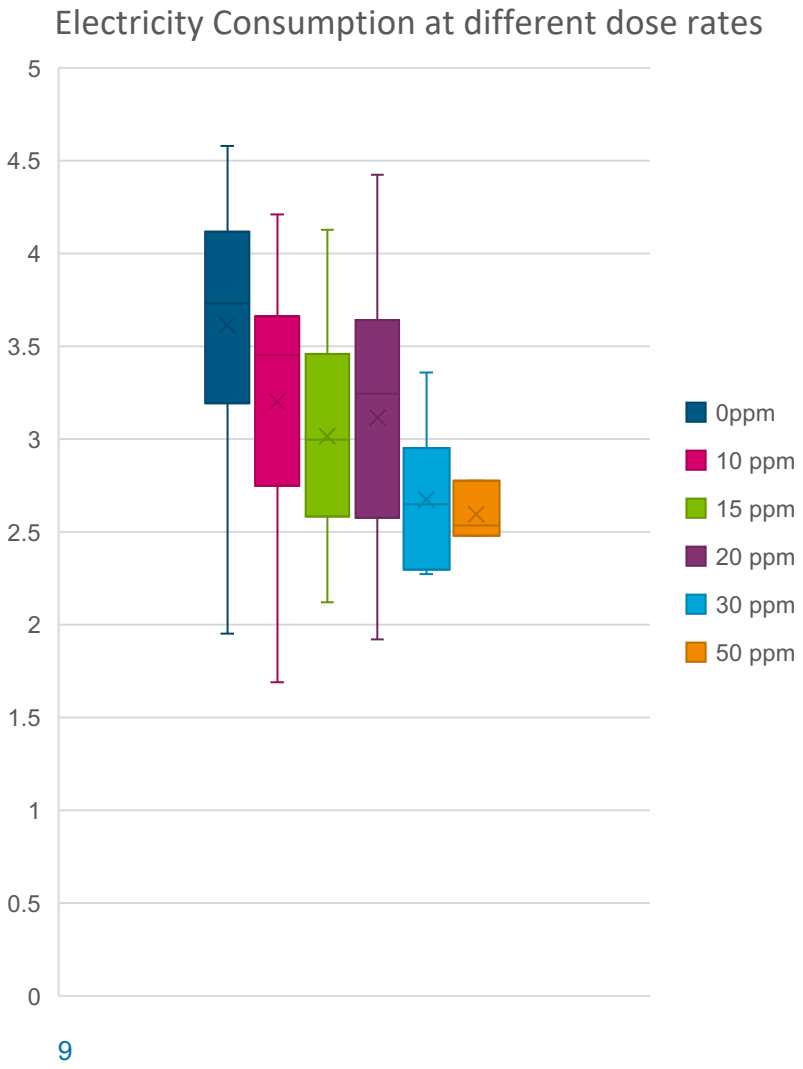
- Tested on MLP Welsh Leg
  - ~160 mile, 16” diameter, multifuel line bifurcating to 2x12” lines.
- During trials a significant reduction in steady-state operating pressure was noted
  - >10 reduction bar in some locations at equivalent flowrate
- Could be used to significantly increase flowrates/throughput with existing pump set
  - > 35% increases in maximum flowrate achievable
- We were able to achieve same flowrate with 1 less pump running
- Generated measurable electricity savings of over 20%
  - Varies with dose rate, flowrate etc.
- Although chemistry is expensive, dosage rate is relatively low (ppm) giving economic benefits even in low electricity environment
- Estimate 430 tonnes annual CO_2 savings from reduced electricity
  - Enough for the Ford Kuga to drive 2.6 Million KM or 1.65 million miles driving - around the world 66 times, or 242 years of average UK mileage!

Is DRA always optimal?



What do you need to consider when evaluating DRA?

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- Specialist chemistry is expensive
- Not many UK suppliers (even fewer with approved product in Diesel and Gasoline)
- Economics may vary in lower electricity pricing scenario, particularly at lower flow rates
- Chemical is highly viscous and can be difficult to handle, requiring specialist injection equipment
- Can't be used in Jet – need to consider interlocks and buffers either side to avoid risk of contamination or bleedback etc.
- Highly flammable mixing agents - >10 tonnes on site ➔ COMAH notification
- Needs a specialist injection skid & safe storage for chemistry
- Learning curve – how do you optimise?
  - Typically need extensive trials to optimise dose rate & confirm no contamination risk
- Changes operating regime of pipeline, so Operators need time for training & familiarisation
- Can increase transmix/interface in multi-product pipelines – need to optimise and balance costs from this with electricity savings and other benefits.
  - There is a cost & environmental downside from more transmix/interface generation unless it can be reprocessed or another use found for it
- PQ concerns – test regime, contamination risks, need to ensure long-chain molecules are broken down before entering engines.

Pipelines are the most sustainable way of transporting liquid products

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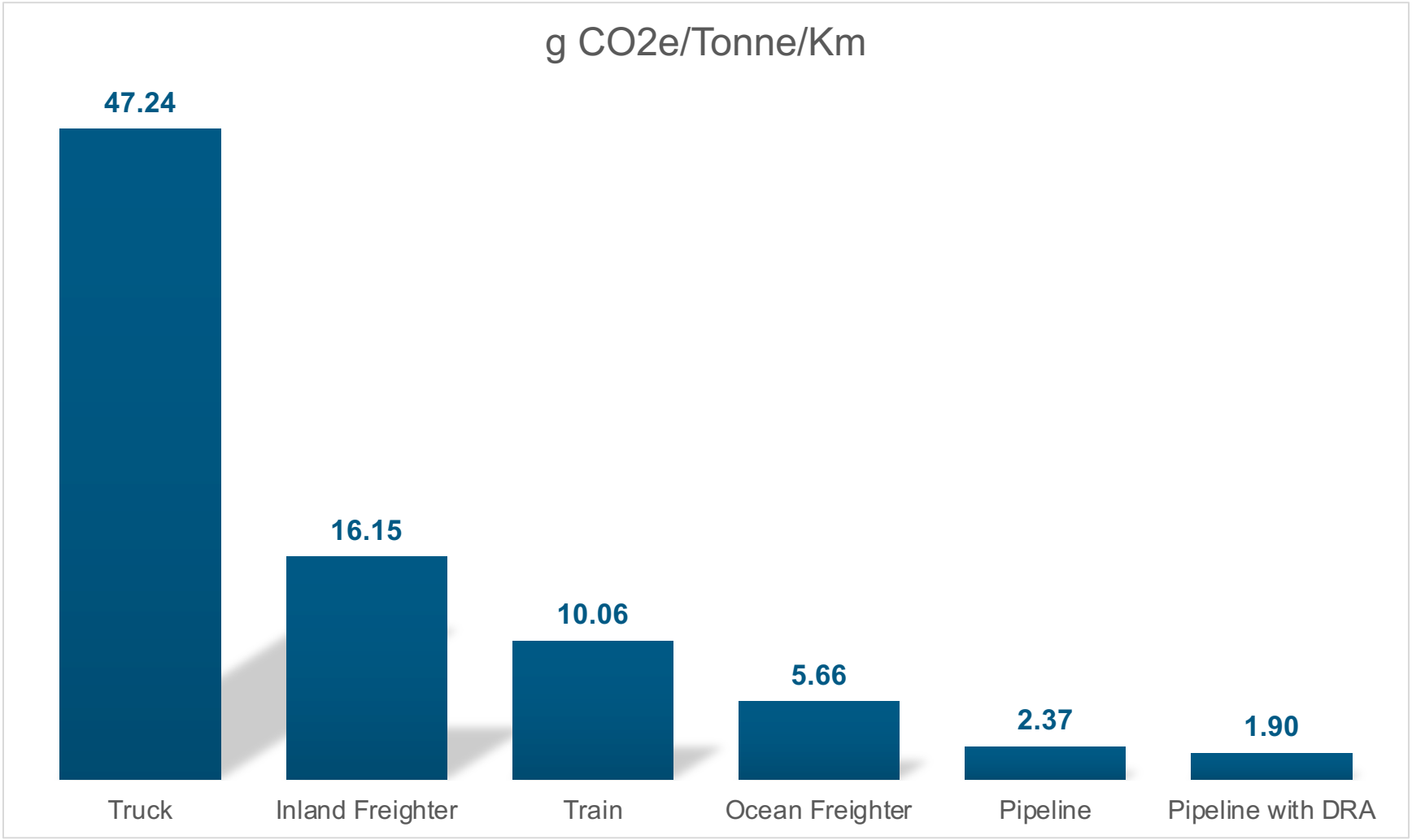

1. https://www.carboncare.org/en/co2-emissions-calculator
2. https://www.edie.net/what-did-the-uks-electricity-generation-mix-look-like-in-2022/#:~:text=The%20carbon%20intensity%20of%20the%20generation%20mix%20in%20February%20was,continues%20to%20hold%20the%20crown.

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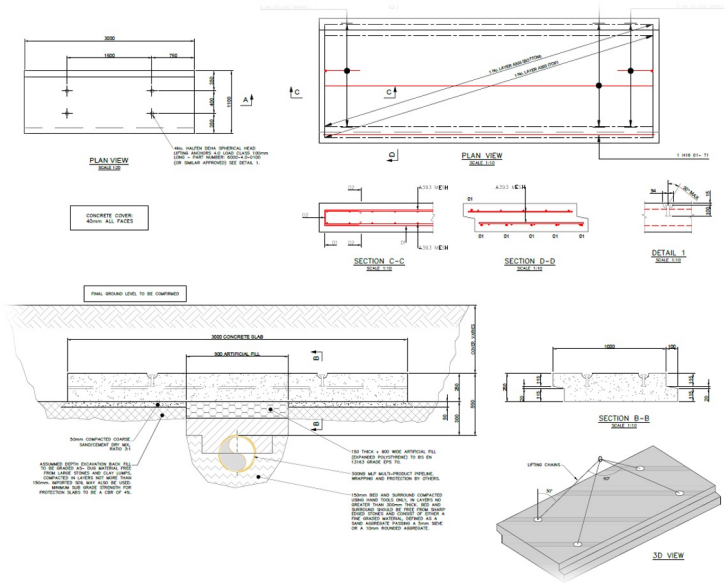
Prevent: Material Reduction

- Installation of reinforced concrete load-bearing slabs at pipeline crossings is relatively common practise.
- Production of reinforced concrete is highly CO_2 intensive – literature indicates approximately 142 kg of CO_2 produced for each tonne of reinforced concrete produced[1]
- Typical reinforced concrete slab (3000x1100x250) has mass of 1900 kg
  - Materials used to manufacture each slab are responsible for 269.8kg of CO_2 (plus transport, installation etc… but we're keeping this simple!)
  - A typical family car (Ford Kuga 2.0 Diesel) has quoted CO_2 emissions of 164 g/km[2]
  - So emissions associated with producing each slab would be equivalent to driving this car 1645 km/1000 miles
- Designing out protection slabs when not needed can have several major benefits:
  - Reduces energy consumption & raw materials in slab manufacture
  - Reduces need for excavation and site works
  - Can reduce cost to operator.



1. https://eprints.whiterose.ac.uk/78456/1/adcr25-0362.pdf
2. https://www.carbuyer.co.uk/reviews/ford/kuga/suv/62527/review/mpg#:~:text=The%20Kuga%20works%20best%20when,of%20144%2D164g%2Fkm.

Sustainability by reducing slabbing

- **Case study:** in a recent pipework protection scheme near a new development MLP challenged our default position of slabbing the entire area
- Instead, we worked with developer to optimise design and set up defined crossings etc. and defined land use types.
- Risk assessment conducted on risk of excavation or significant loadings on each different land type.
  - Near buildings, roadways/crossings, car parking areas, turning areas, green spaces
- Reduced extent of slabbing from 300m to 150m
  - Significantly reduced cost and time duration of scheme – approximately half time on site
  - Generated Savings of 285 Tonnes in raw materials and 40.5 Tonnes of CO_2
  - Equivalent to driving 247,000 km/155,000 miles or around the world 6 times.
  - UK average mileage was 6,800 miles per year – so this is equivalent to 22 years of normal car usage[3]
- **Small changes can add up to have a big difference!**
- Ask the question – do we need to protect it?
- If it needs protection or reduction in loading are slabs the only way to achieve this?
- PIWG looking to develop simple slab loading assessment tool to help assess pipeline loading and determine if slabbing necessary for load protection.
  - NB: Impact protection is a separate risk assessment

1. https://www.leaseloco.com/guides/contracts-and-finance/what-is-the-average-mileage-per-year

A final note

- Despite what the media or environmental activists may claim, we're not the bad guys!
- Pipelines are the cleanest & most efficient way to transport material – we need to make sure people realise this.
  - It's **our** responsibility to educate others
- People oppose pipelines through lack of understanding – but the risks are lower from pipelines than from other transport sources.
- Environmental footprint (both in terms of CO_2 and leaks) are significantly lower by pipeline than by the alternatives available (road, rail or ship)
- We can improve this further by careful optimisation using existing equipment, or by deploying novel techniques such as DRA injection.
- Small changes can make big difference & add up to major savings, both financially and environmentally.