



ESDU-SPF-M6-1

Apr.08: Annulus flow tests (status report on tube and annulus flow rig development)

**Unamended
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**Imperial College
London**

EPSRC RESEARCH PROJECT: “FOULING IN HEAT EXCHANGERS OF CRUDE DISTILLATION UNITS”

SUB-PROJECT F

ANNULUS FLOW TESTS

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SUMMARY

- 1. Introduction, Crude oil supplies**
Prof. Denis Dugwell
- 2. Rig design, construction and commissioning**
Dr. Colin Hale
- 3. Safety considerations**
Dr. Harrison Shumba
- 4. Operational considerations**
Mr. Jerzy Pental
- 5. Dynamic Gauging probe**
Dr. J. Chew, Ms. T. Gu

OBJECTIVES OF SUB-PROJECT F

GENERAL:

TO STUDY THE EFFECTS OF FOULING ON HEAT TRANSFER AND PRESSURE DROP IN AN ANNULUS TEST SECTION SIMULATING FLOW IN A SHELL-AND-TUBE HEAT EXCHANGER

SPECIFIC:

CONTINUOUS MONITORING OF HEAT TRANSFER RATE BETWEEN HEATED SURFACE AND FLOWING CRUDE OIL -- HENCE RATE OF BUILD-UP OF FOULING RESISTANCE

CONTINUOUS MEASUREMENT OF PRESSURE DROP

CONTINUOUS IN-SITU MEASUREMENT OF FOULING LAYER THICKNESS BY NOVEL DYNAMIC GAUGING TECHNIQUE

LINKAGE WITHIN PROJECT

PROVIDE ASPHALTENE DEPOSIT SAMPLES FOR CHEMICAL/
RHEOLOGICAL CHARACTERISATION - AS A FUNCTION OF POSITION,
TIME, FLOW CONDITIONS, OIL TYPE etc. **[SUB PROJECTS A & B]**

PROVIDE FACILITY FOR THE TESTING OF FOULING CONTROL
AND MITIGATION STRATEGIES - SURFACE MODIFICATION; THE USE
OF CRUDE OIL ANTI-FOULING ADDITIVES; CLEANING STRATEGIES
[SUB PROJECT G]

INVESTIGATE POSSIBLE LINKAGE BETWEEN ANNULUS FLOW RIG
FOULING MEASUREMENTS AND SIMILAR MEASUREMENTS FROM
THE STIRRED CLOSED VESSEL TEST RIG **[SUB PROJECT E]**

CRUDE OIL SUPPLY

- PETRONAS
 - Oil supplies – 5 litres each of 5 selected crudes, plus crude properties + blending ratio. Also 5 litres of post de-salter sample air freighted
 - 9 barrels of post de-salter crude delivered to Imperial College
 - Blend API ~30
- BP
 - Oil samples – range of small samples from various sources.

Imperial College
London

Rig design, construction and commissioning

Sub-Project F Annulus Flow Tests
Dr. Colin Hale
8th April 2008

TEST PARAMETERS

CRUDE OIL INLET TEMPERATURE - max. 300°C [200 - 270°C]

CRUDE OIL PRESSURE: max. 30 BAR

TEST SURFACE TEMPERATURE: 250 - 350°C [oil plus 120°C max.]

HEAT FLUX TO BE IMPARTED TO OIL: 20 – 100 kW/m²

FLUID HYDRODYNAMICS:

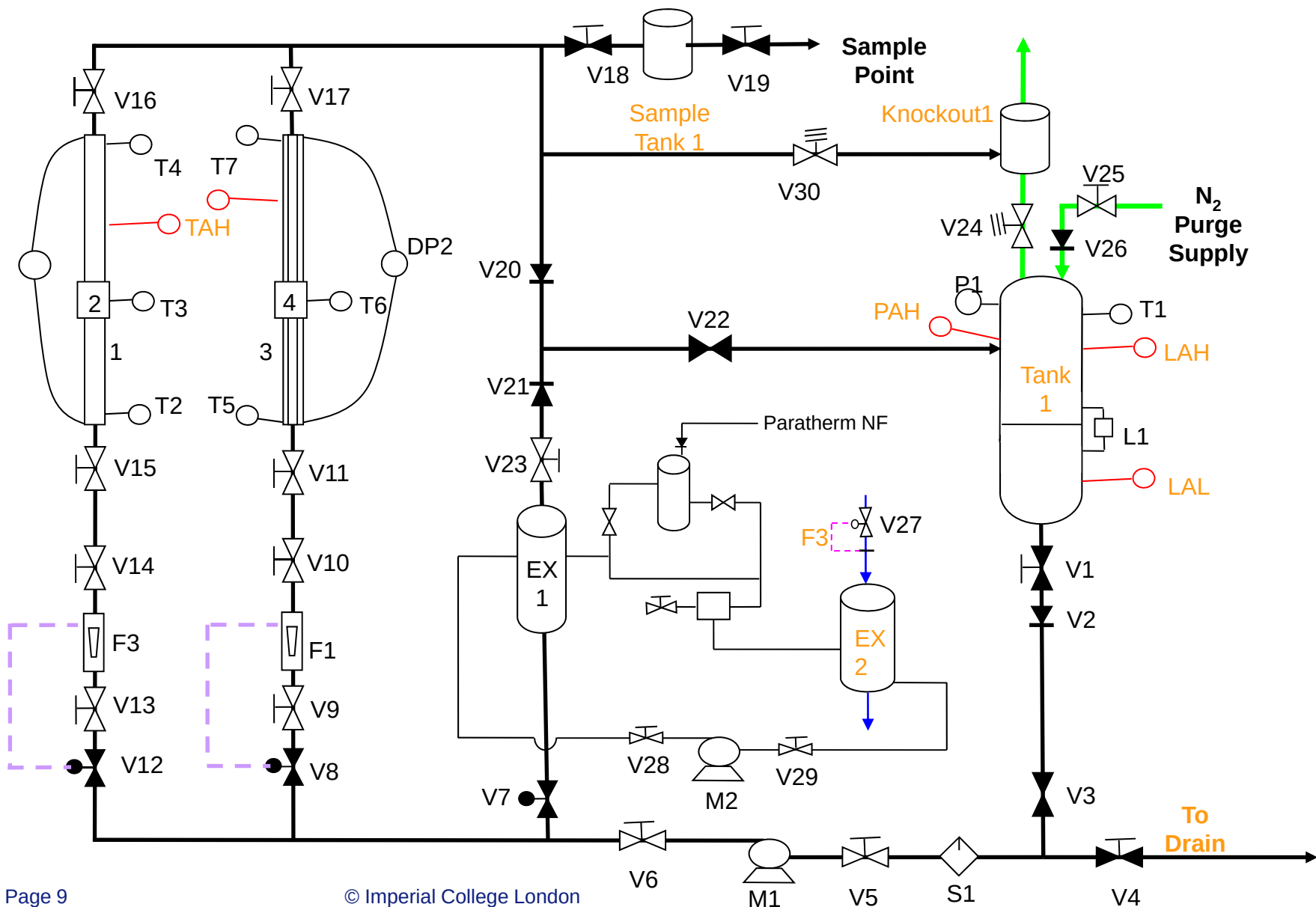
- LINEAR VELOCITY: 1 – 3 m/s
- REYNOLDS NUMBER: max. 20,000
- ANNULUS DIMENSIONS: ~6 mm

TEST SECTION LENGTH: ~ 1.5 m heated plus entry section

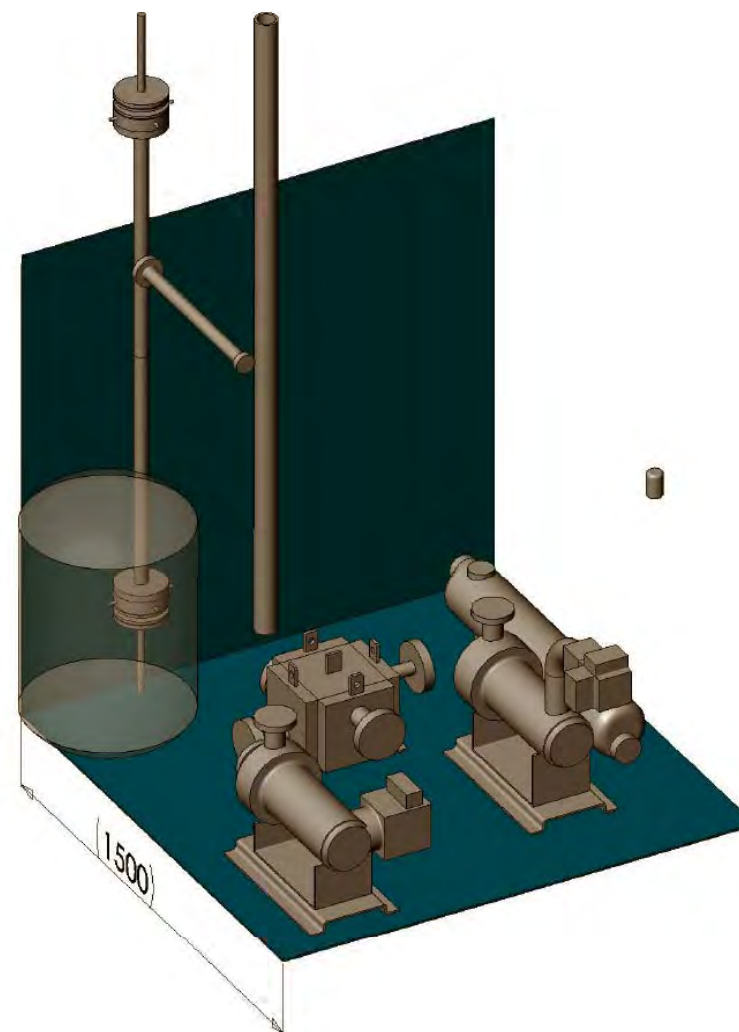
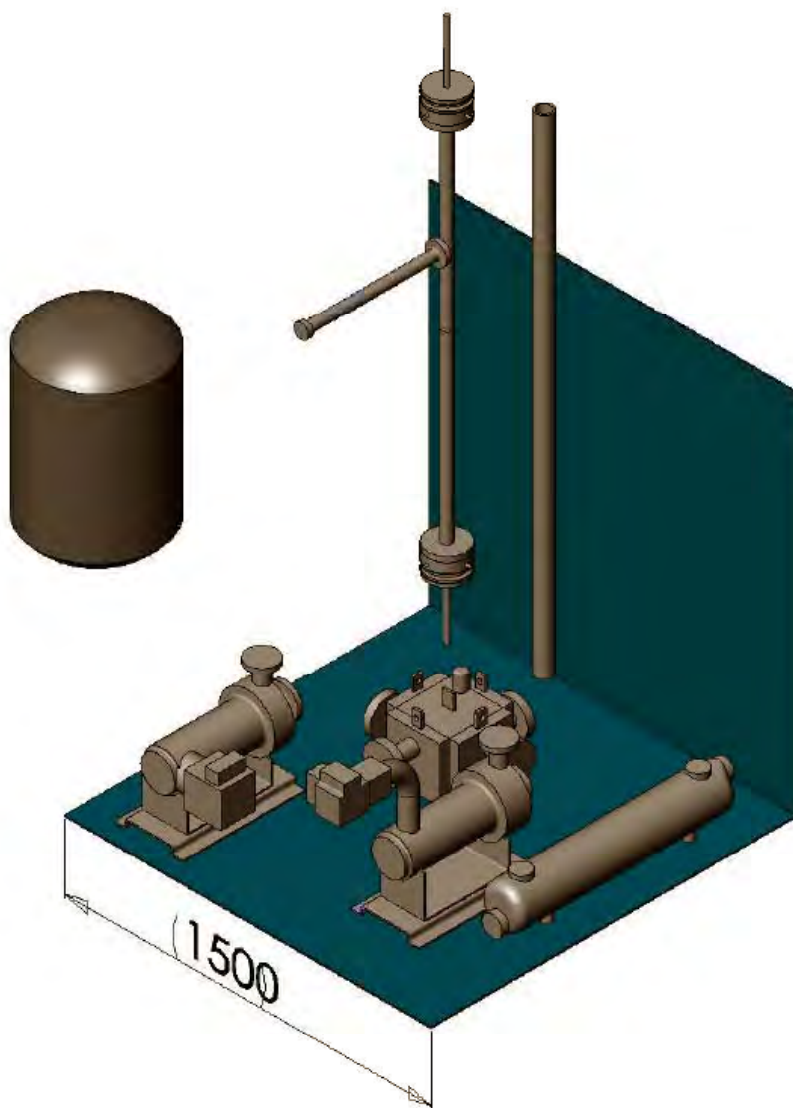
SURFACE PROPERTIES – TYPE OF STEEL, etc

CLEANING STRATEGIES, ADDITIVES, SURFACE MODIFICATION

FOULING MEASUREMENT TEST LOOP



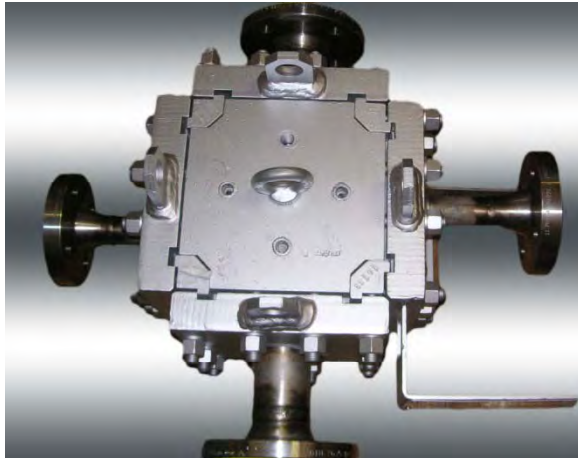
FOULING MEASUREMENT TEST LOOP



KEY FEATURES: 1

- STORAGE VESSEL
 - Volume: 120 litres
 - Heated
 - Nitrogen blanket
- TEST SECTION (x2, Vertical, Joule heating)
 - ANNULUS:
 - INNER TUBE $\frac{1}{2}$ ", Schedule 40
 - OUTER TUBE $1 \frac{1}{4}$ ", Schedule 40
 - 6.87 mm annulus gap
 - Flow area: 609 mm²
 - TUBE:
 - Tube 1", Schedule 40
 - 26.64 mm ID
 - Flow area: 557 mm²

KEY FEATURES: 2



- COOLING LOOP

- Crude Oil / Paratherm exchanger
 - COMPABLOC – ALFA LAVAL
 - High Pressure (up to 40 barg)
 - High Temperature

- Paratherm / Water exchanger

- Shell and Tube – E.J. Bowman (Birmingham) Ltd
- Lower pressure
- Lower Temperature



- Paratherm loop pump

- Canned motor pump -TEIKOKU
- Electrical dry run protection relay
- Lower probability of leaks
- 8m³/hr

KEY FEATURES: 3

- Main Feed lines
 - $\frac{3}{4}$ ", 316L Stainless Steel
 - Lower propensity to fouling
- Test-section heaters
 - Programmable supply – COUTANT LAMBDA Ltd
 - 10/15KW
- Crude oil pump
 - Canned Motor Pump - Teikoku
 - High temperature (max 350 deg C)
 - Electrical dry run protection relay
 - Lower probability of leaks
 - $\sim 6\text{m}^3/\text{hr}$

