Use of X-ray Imaging in the Innovative Development of BP's Leap™ Technology

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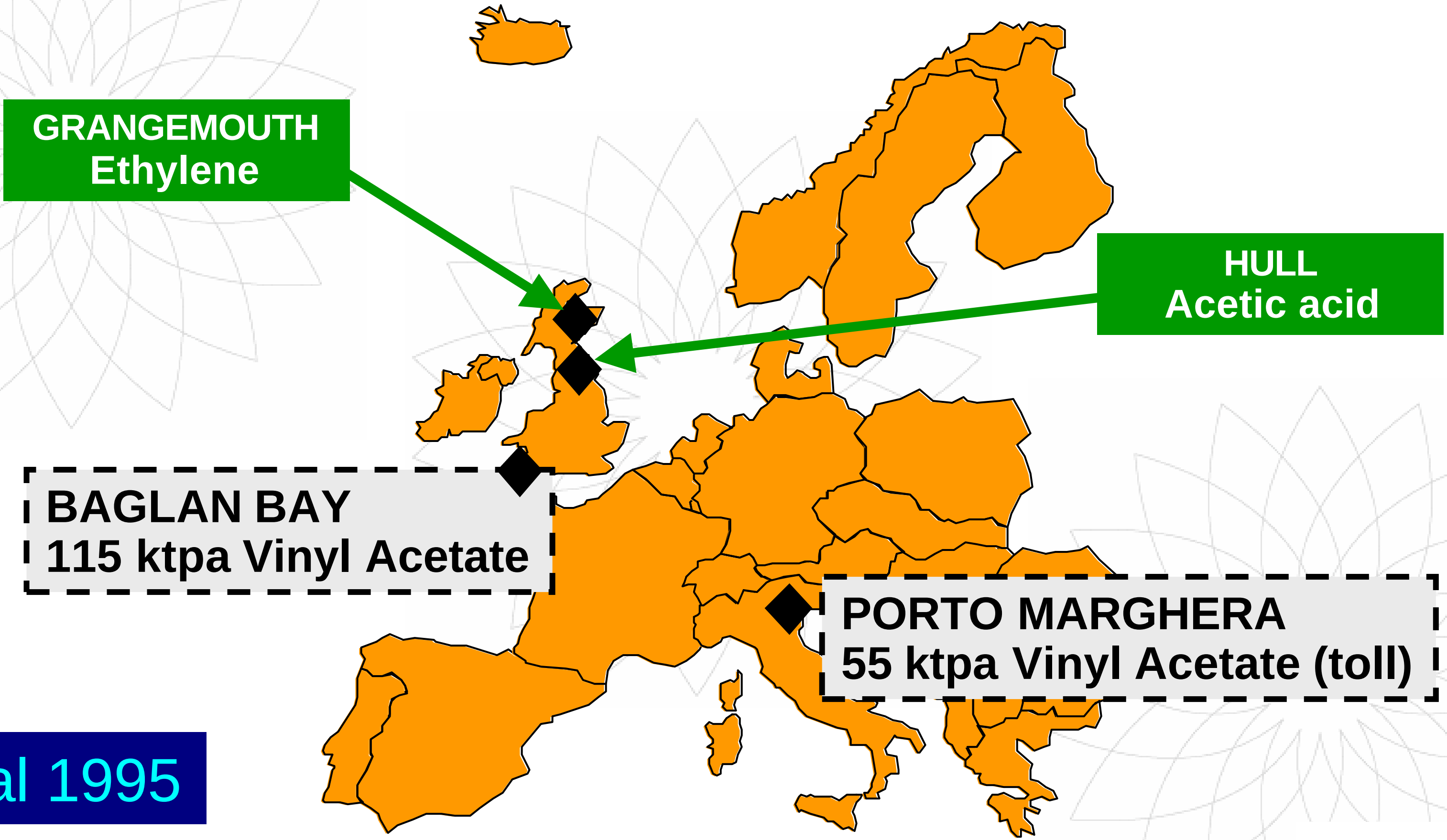
BP European VAM Restructuring

Creating a world class Acetyls asset for the 21st century

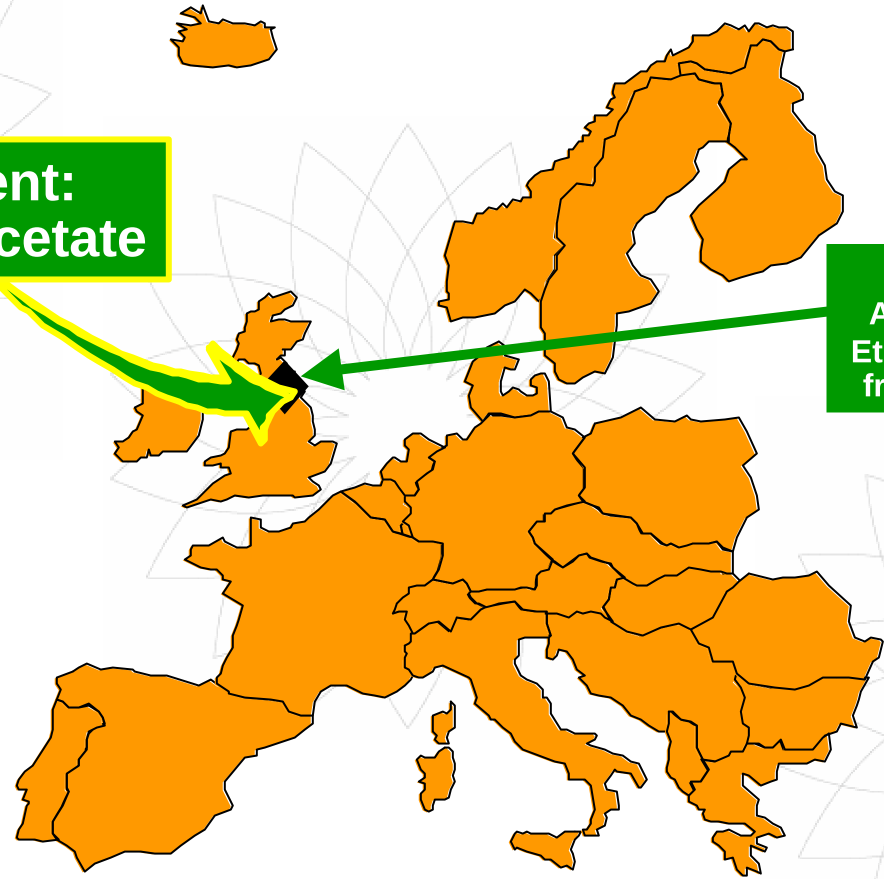


Actual 1995

BP European VAM Restructuring

Creating a world class Acetyls asset for the 21st century

New Investment:
250 ktpa Vinyl Acetate

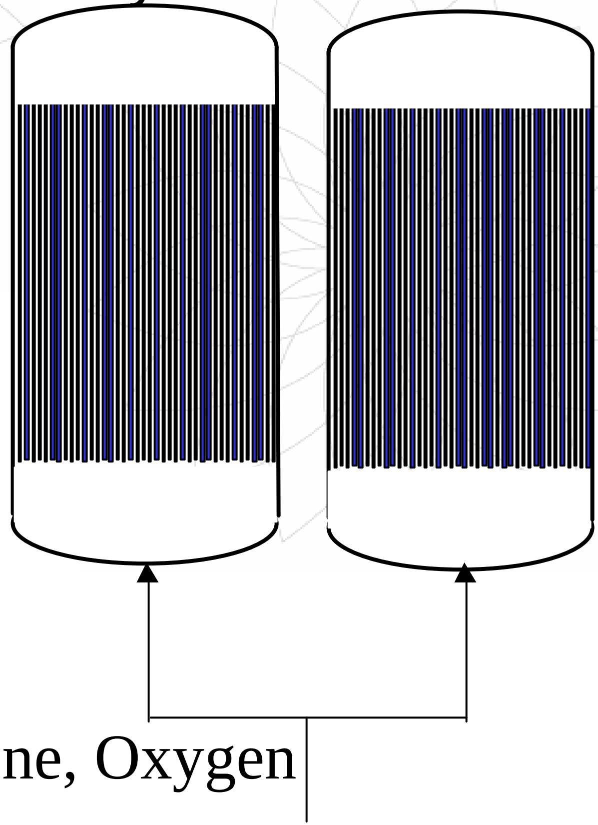


HULL
Acetic acid on site
Ethylene via pipeline from Grangemouth

Vision 2001

The Technology Challenge 1995

- Conventional ethylene-based fixed-bed VAM technology first used commercially in the late 1960's
  - multiple reactors required for world-scale plant
  - Not commercially attractive



The Technology Challenge 1995

- New fluid-bed process being developed by BP (“**Leap™**”) shows potential to overcome the disadvantages of fixed bed designs and generate significant business value

BUT

- Leap technology demonstrated only at microreactor scale
- Conventional scale-up via Demonstration Plant (small commercial unit) would cost $20-30m and add 3-4 years to development schedule
- **Must have commercial plant on-stream in 2001**

Fluid-bed Process Scale-up

Fluid-bed processes are notoriously difficult to scale up :

- ⇨ No proven theoretical predictions : **PC Models** O
- ⇨ Small scale data not representative : **Pilot Plants** O
- ⇨ Determination of fluid dynamics at process conditions is critical to performance : **Glass/Perspex Studies** O
- ⇨ Need to minimise scale-up costs and time to commercialisation : **Large Demonstration Plants** O

The Solution

- Build on existing knowledge
- Virtual-team set up with BP technologists
  - Hull and Sunbury in the UK,
  - Warrensville (and later in Naperville) in the USA,
  - Expertise also drawn from BP's acrylonitrile and polyethylene businesses.

Breaking up the problem

- Key technical challenges identified in development of process:
  - Formulation of precious metal catalysts in fluid bed form
  - Establishing reaction kinetics and optimum conditions
  - Establishing the fluid dynamics and reactor design criteria
  - Constructing all embracing models

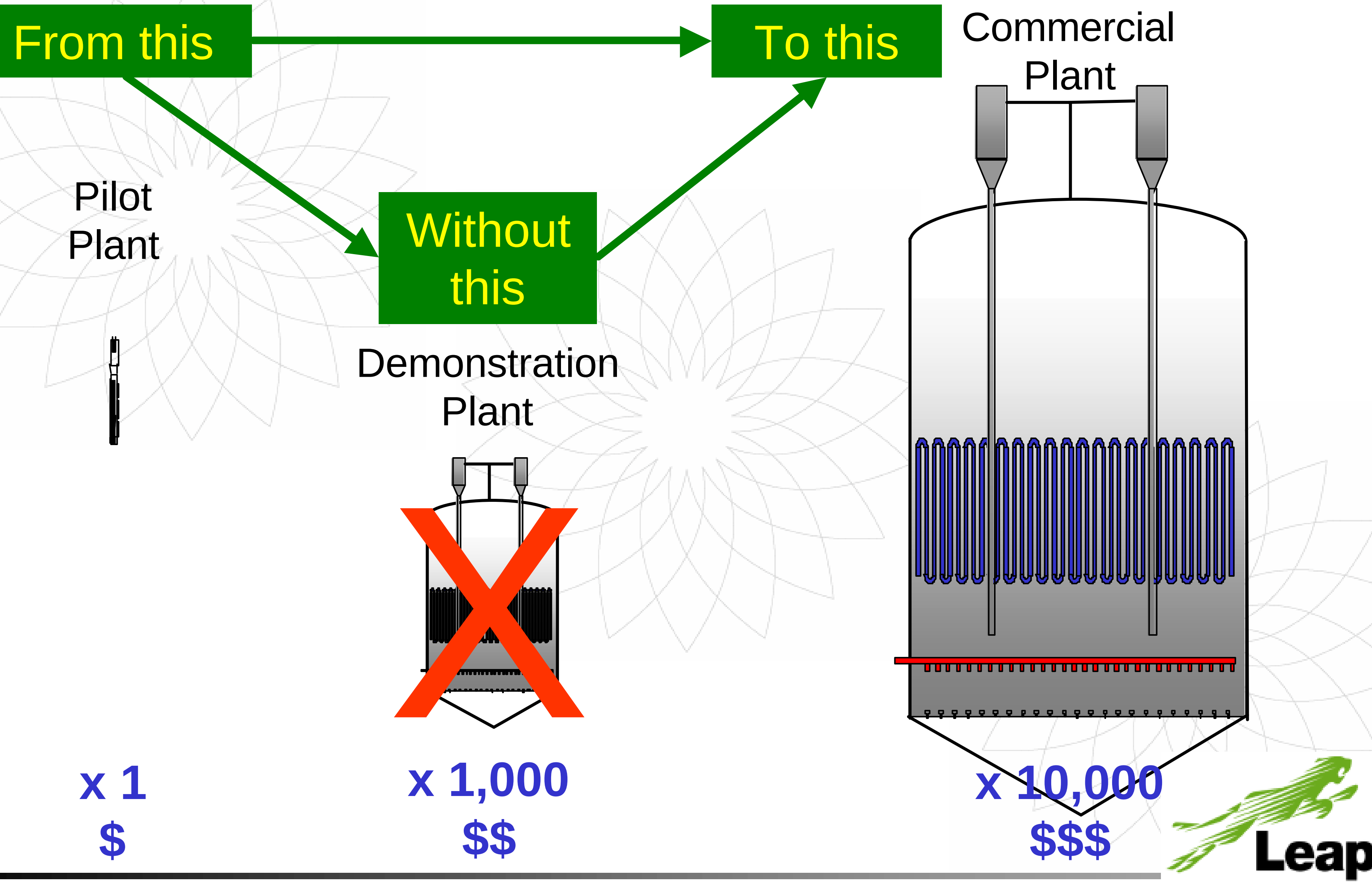
Establishing Fluid Dynamics

- How do we
  - ⇨ establish fluid dynamics of a fluidised bed?
  - ⇨ design the internals for the reactor?
- It would be easy if you could see inside a reactor

 - We can!

We use X-ray imaging at the VIPA centre

Fluidised Bed Scale-Up

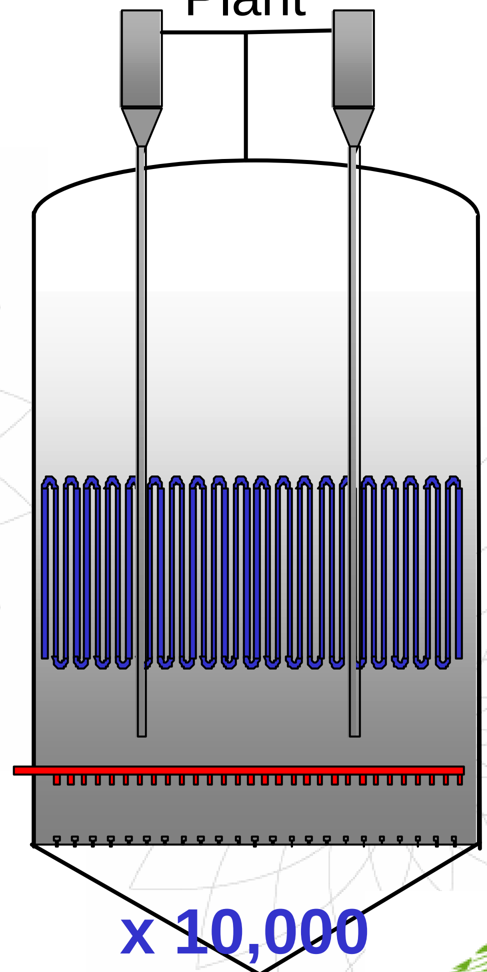


Fluidised Bed Scale-Up

From this

To this

Commercial Plant



Pilot Plant

With this

Visualisation

Imaging

&

Process

Analysis

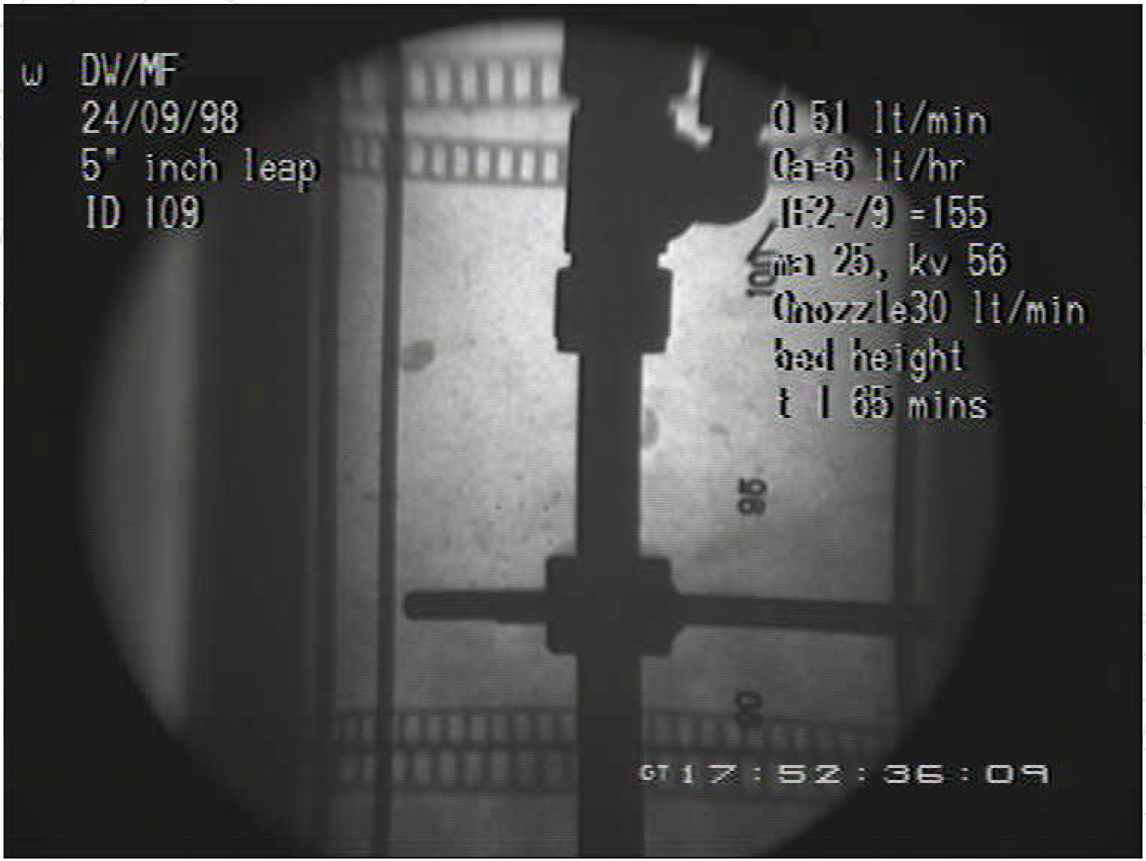
x 1

$

x 10,000

$$$

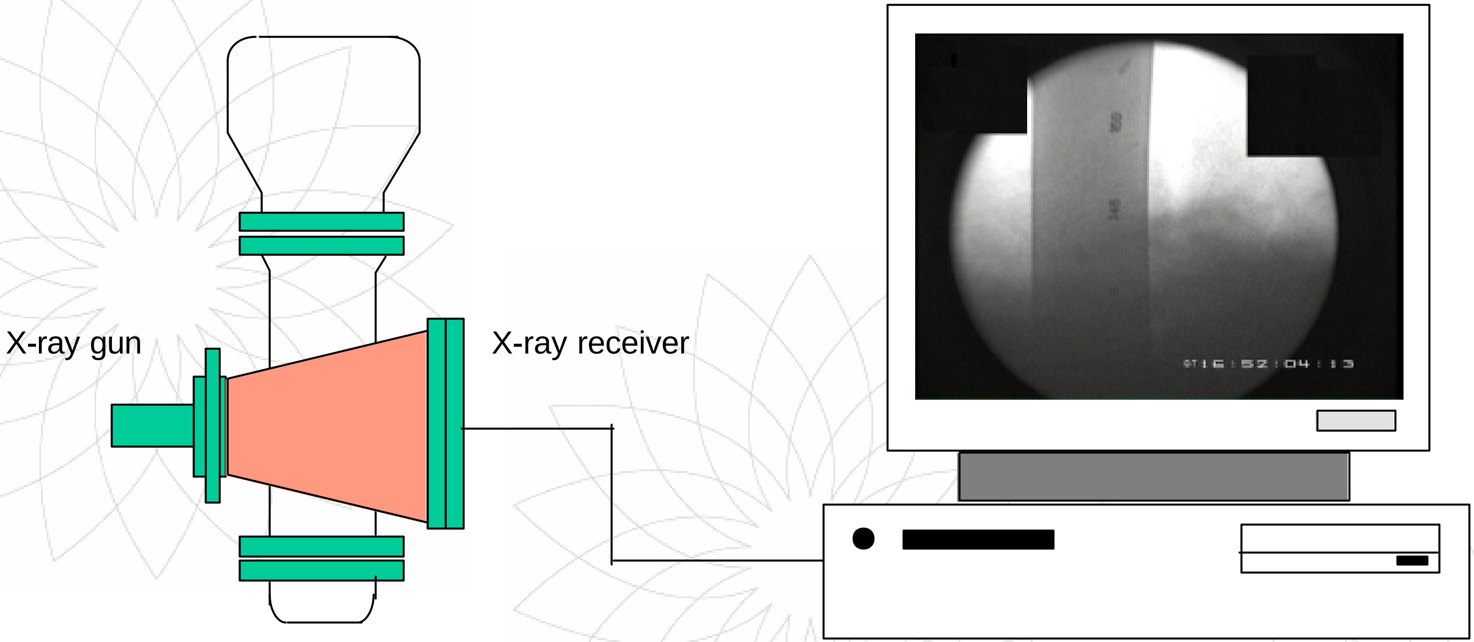
Visualisation Imaging and Process Analysis



What does it do ?

- Uses imaging and fluidisation techniques to observe behaviour of fluidised process within a reactor
- Studies processes under full temperature and pressure conditions
- Uses data to accelerate process development and optimise engineering designs

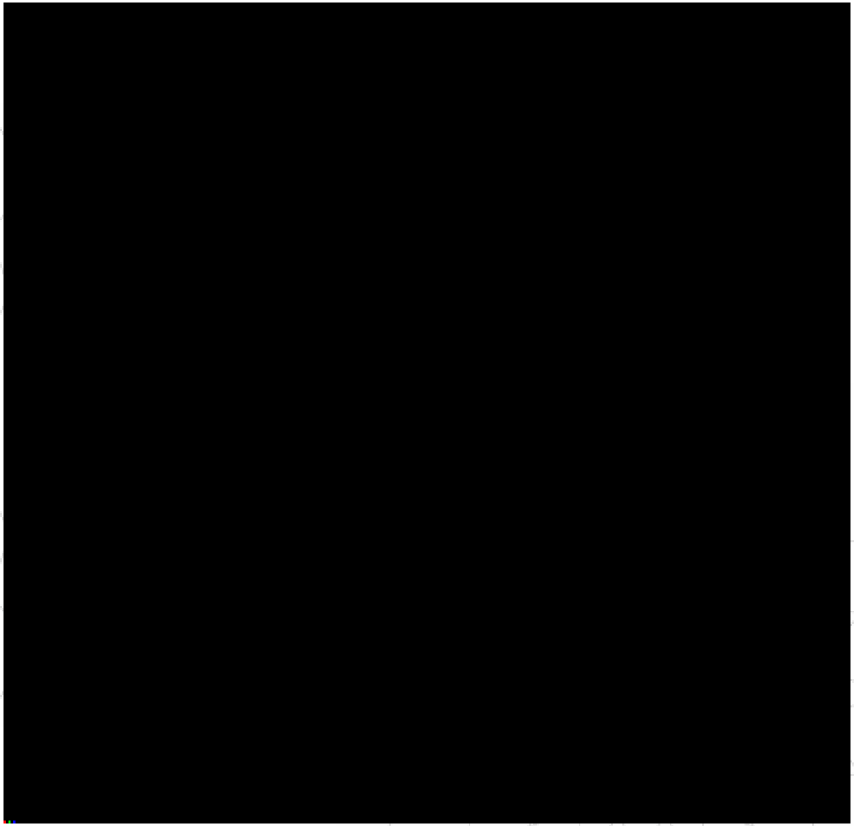
X-Ray Imaging



- X-Ray gun and receiver mounted on fully programmable suspension system which can be moved in 3-D around a hydrodynamic test rig.
- Very high powered X-Ray pulsed through reactor, and videos taken of the images received

X-Ray Imaging

- The ability to see inside a reactor in real-time at actual operating conditions
- Housed in purpose built lead cell.
- X-Ray can be targeted at any aspect of the reactor
- Can be used to look at specific fluid dynamic features
- Unique technology allows movies to be taken from multiple locations
- Measures distances and time durations of events
- On this large scale, this capability is believed to be totally unique



Catalyst development

- **Fluidised catalysts**
  - ⇨ Incorporate catalytically active material
  - ⇨ Require high porosity and surface area
  - ⇨ Physically robust
  - ⇨ Good fluidisation properties

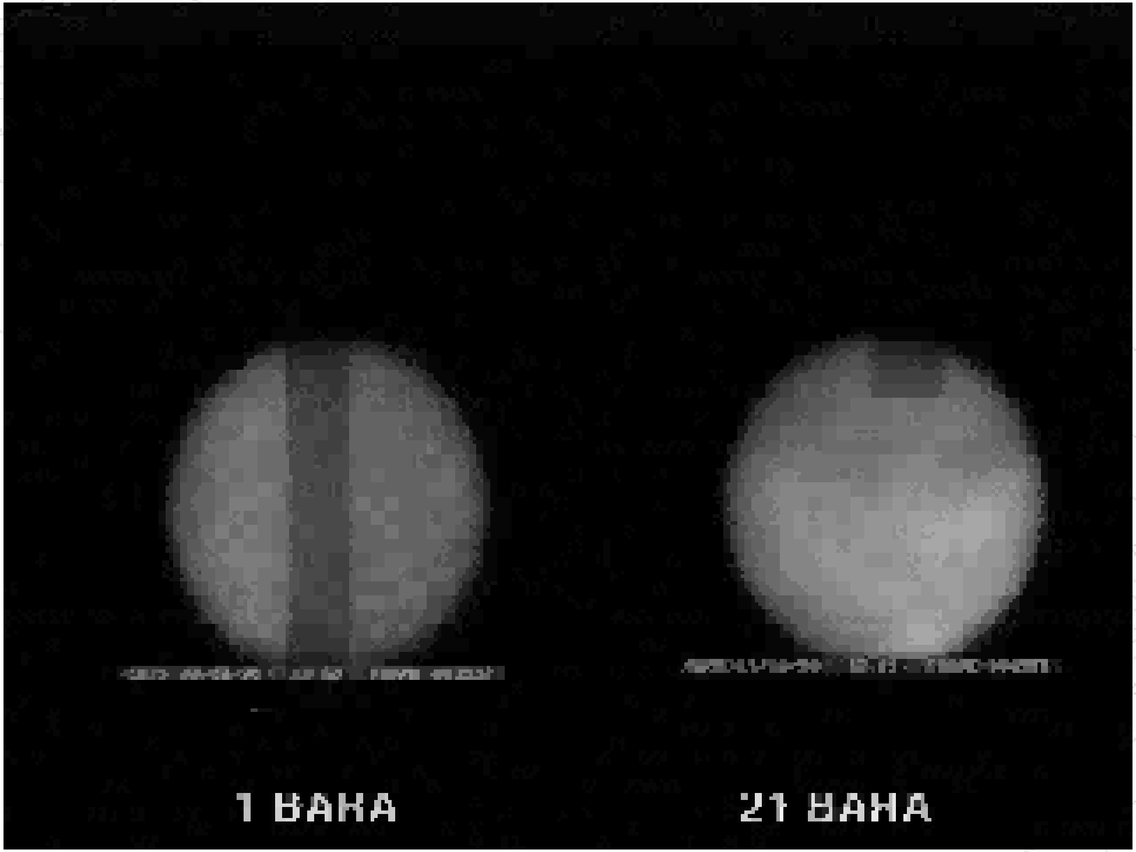
Catalyst development

- **Concurrent development**
  - ⇨ **Small scale pilot plant**
    - ➢ **Reaction kinetics**
    - ➢ **Optimum Operating conditions**
  - ⇨ **X-ray imaging**
    - ➢ **Effect of pressure and temperature**
    - ➢ **Optimum fluidisation properties**
      - – **E.g. Fines distribution**

Leap

Catalyst development- pressure effects

The following clips show the effect of pressure on the fluidisation of a typical powder – the acoustic signal generated by the fluids inside the vessel also gives valuable information



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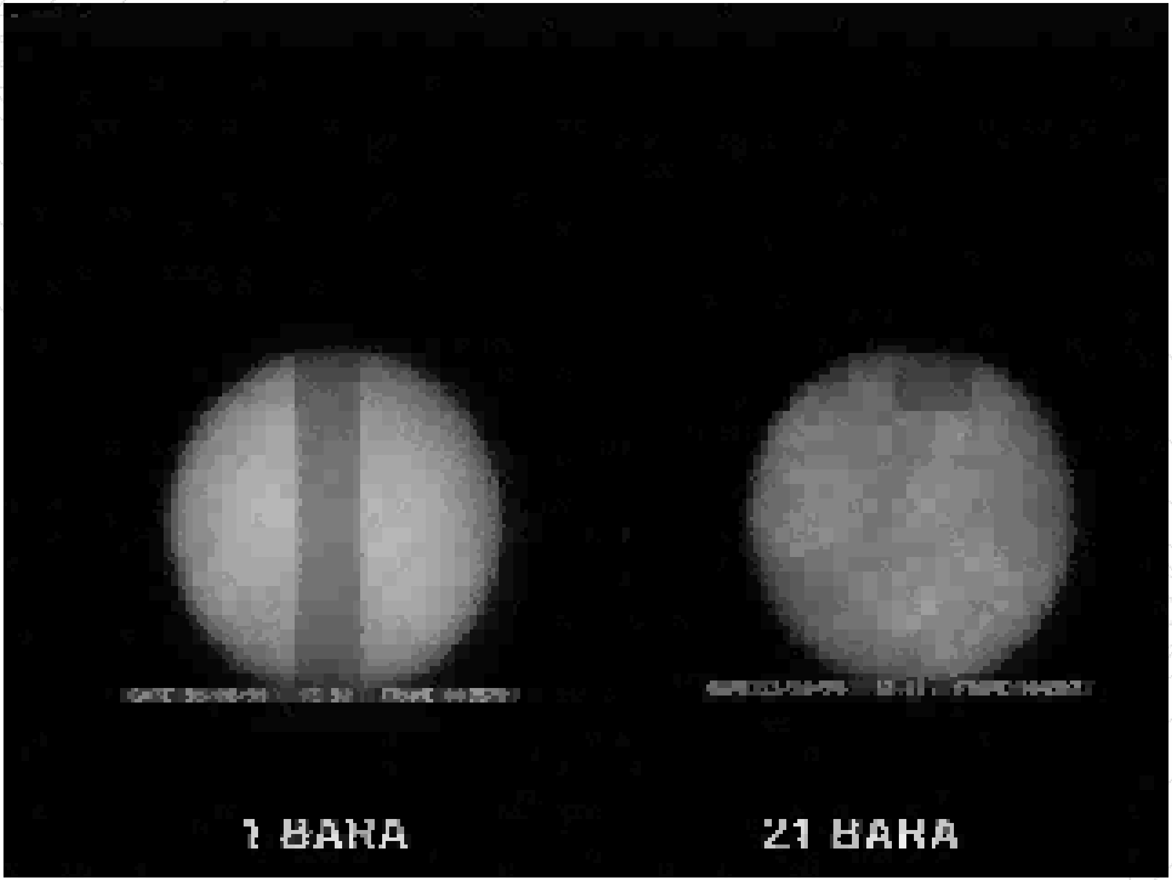
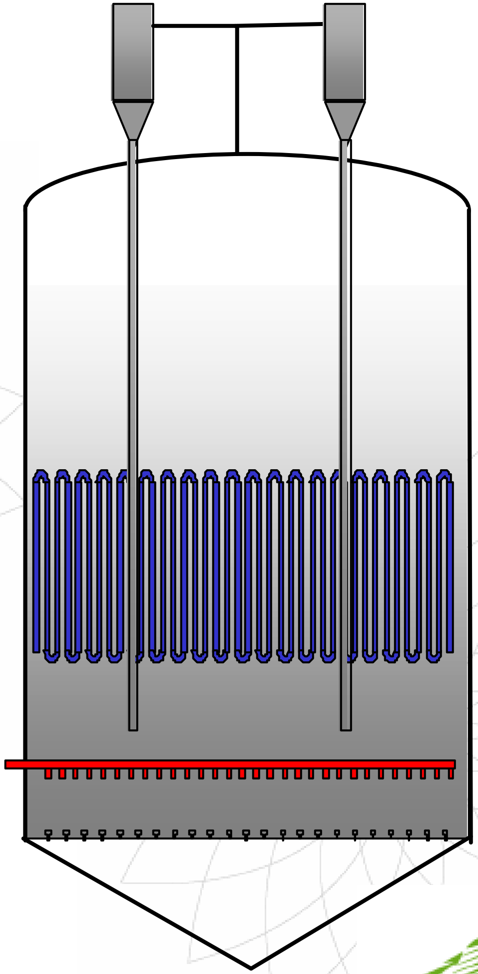


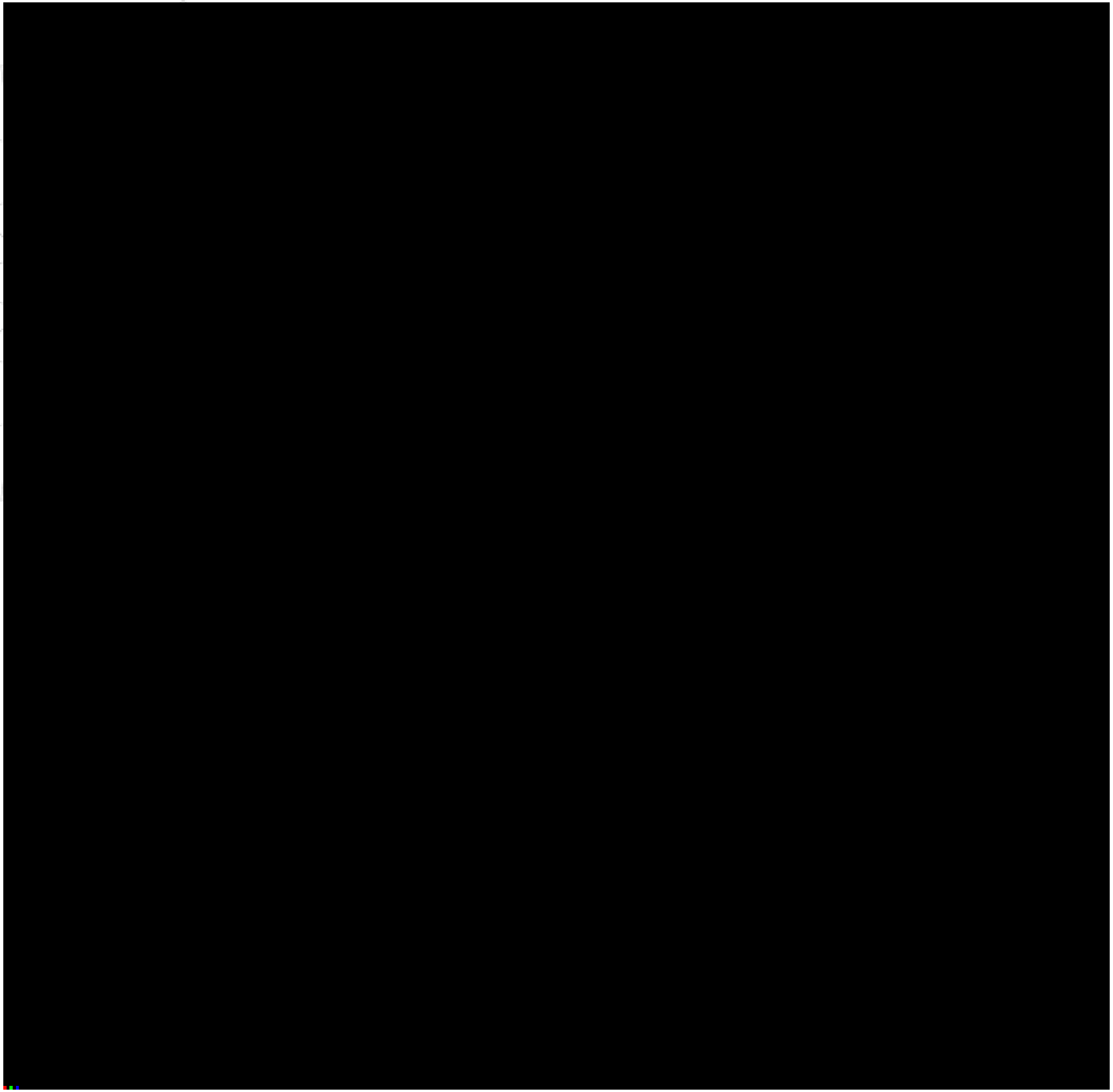
Reactor Design

Main reactor elements for fluidised reactor to provide good fluidisation:

- ➢Grid design
- ➢Reactant distribution
- ➢Cooling cooling design
- ➢Fines recovery



X-Ray Imaging



Imaging was used to look at each individual component.

Leap™ Fluid dynamics test rig

- Contains chosen internals for reactor
- Tests for interactions between internals
- Assures system with catalyst manufactured for plant
- Assesses physical properties
  - Heat transfer coefficients
  - Bed density profile
- Operates 24 hours a day to assess long term effects.

Modelling

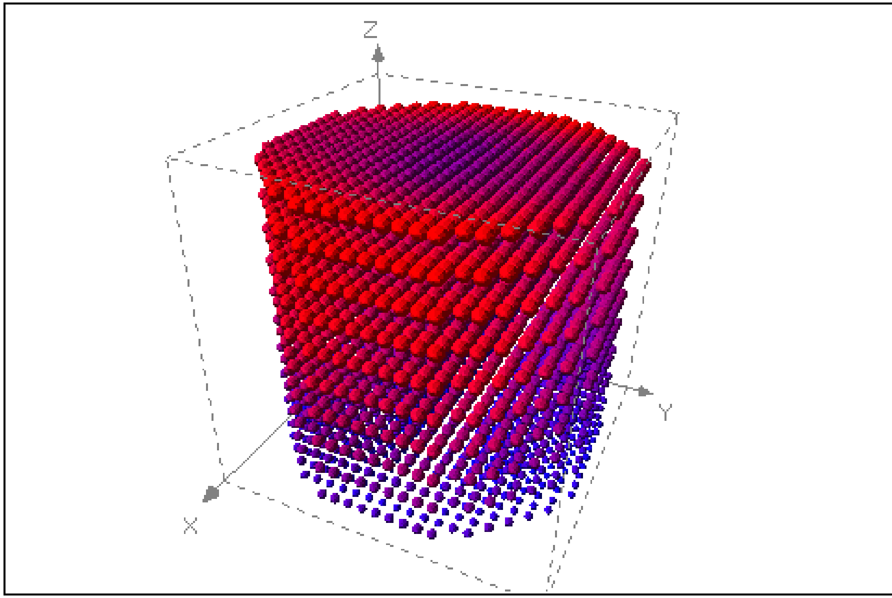
Modelling assessed the combined effect of the chemistry and the process dynamics to determine the shape of the final process.

Models were developed further as new or refined data became available

Models developed included:

- overall heat and mass balance of the process,
- model of the catalyst management strategy,
- Reactor model giving local compositions within the reactor

Product distribution



Leap

The Result

- World's first Leap™ plant commissioned safely and successfully in 2001, meeting or exceeding all its performance expectations and delivering on- specification product reliably and consistently
- Fluidised process saved 30% in capital costs over fixed bed.
- Further Leap™ developments to provide BP with significant platform for growth are well advanced
- Innovative approach and novel techniques developed to fast- track the technology delivery are now being used for other potential developments
- In June 2002, Institute of Chemical Engineers awarded BP the 'Aspentech' award for Business Innovation

Leap™

Generating Business Value through Process Technology & Engineering Innovation