achieve outstanding client success

SINCLAIR KNIGHT MERZ
SKM

Leading edge steamfield design
– *After all, the plant is the easy part!*

Paul Quinlivan
March 2010

Introductions

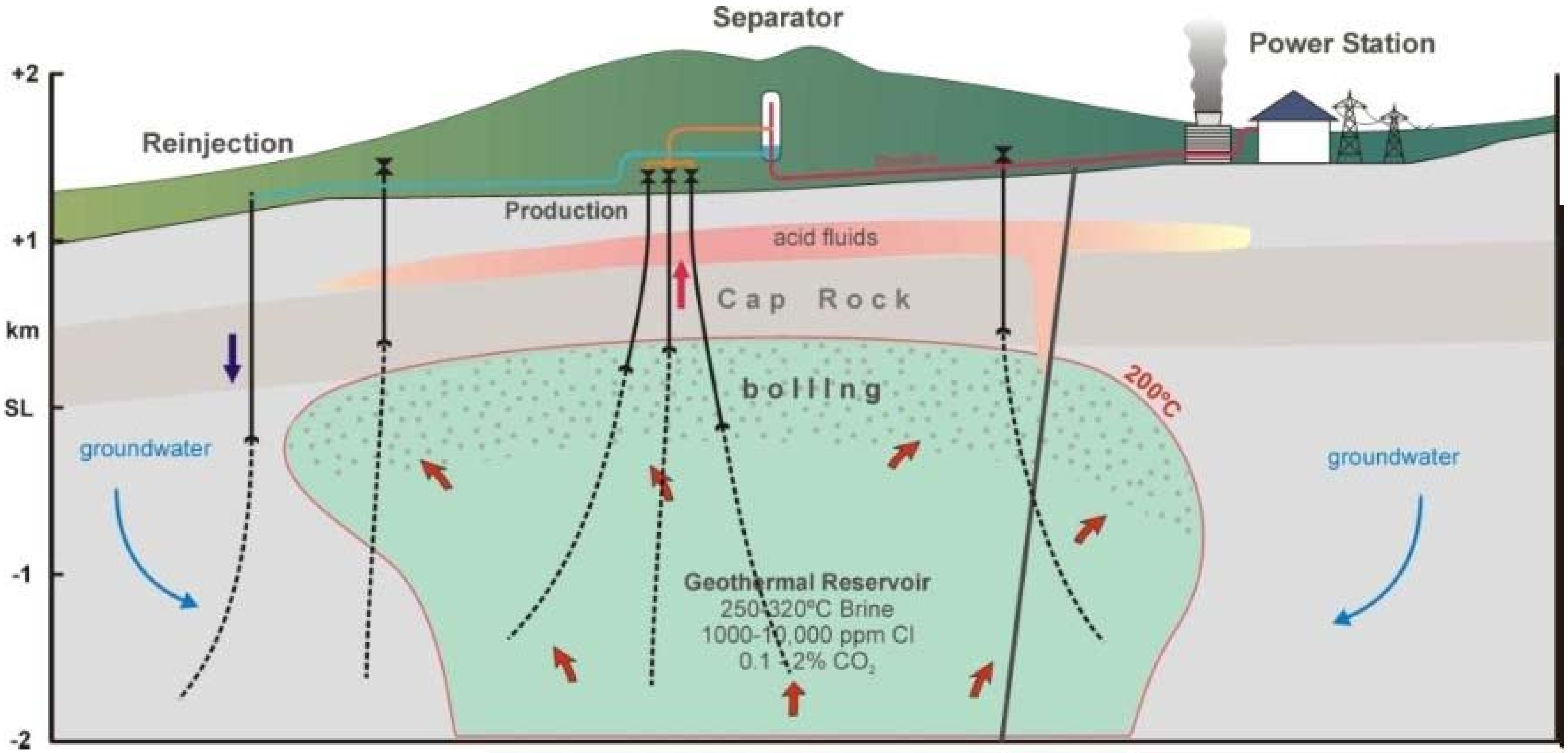
- Sinclair Knight Merz
  - Engineering, science & project delivery services
  - Employee owned
  - 7,000 employees
  - Annual revenue of >1 AUD$billion
- SKM and geothermal
  - 35 years global and local experience
  - A “one-stop-shop” for geothermal
- Myself, Paul Quinlivan,
  - Clean Energy Advisor, Practice Leader Carbon Finance
  - 35 years global and local geothermal experience
  - CDM , clean energy finance and other renewable energy technologies

This Presentation

- Focusses on medium to high temperature, 2 phase geothermal resources, as opposed to simpler:
  - Single phase pumped liquid systems (most new low T US & aspirational Oz projects)
  - Single phase vapour systems (the Geysers)

- Asks: Why is steamfield design important?
- Looks at the way steamfield design has progressed
- Addresses the impact of contracting strategies
- Highlights some leading edge design considerations

Basic Building Blocks of a Geothermal Power Development



Injection Wells

Reservoir & Production Wells

Steam Field

Power Plant

Electricity Sales

Every wellfield is unique

Every steamfield is bespoke

The steamfield cost is 10-20% of the total project cost

How well you:
Design it
Manage it
Operate it

Will have a significant impact on the return on your total project investment

You want me to design & construct a steamfield for a fixed price to connect an uncertain number of wells of uncertain characteristics that you haven’t drilled yet to a power plant you haven’t specified yet!!

Hey, no problem Lone Ranger, I’ve got a few silver bullets.

This Presentation

- Will look at:
  - History of separator design
  - Higher pressure, multi-flash
  - Larger units
  - Other challenges
  - Newer challenges
  - Pressure control

Nga Awa Purua – 147 MW Gross – Single Casing Steam Turbine

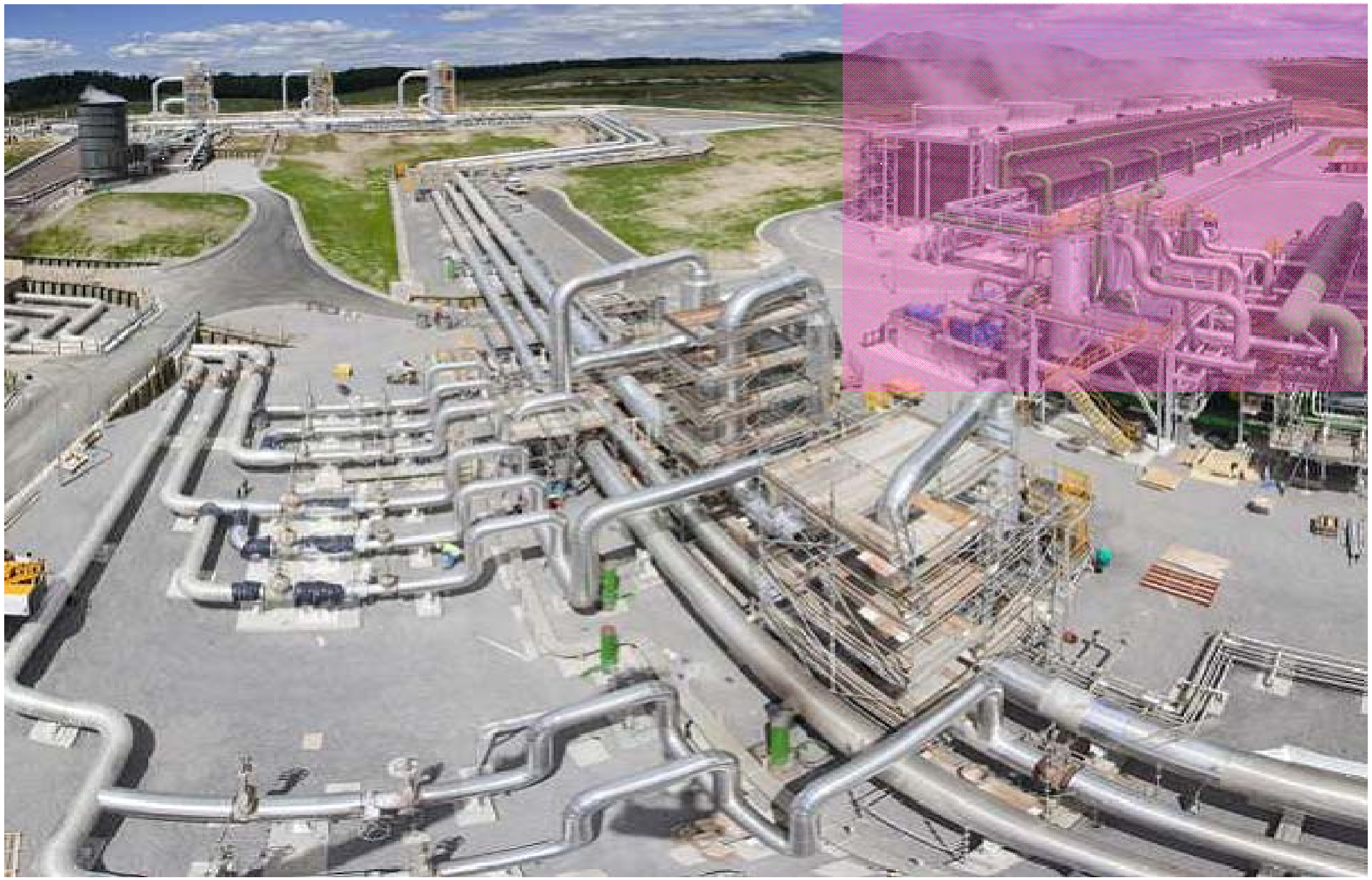


Photo credit: Tauhara North No. 2 Trust & Mighty River Power (Mar ‘10)

Nga Awa Purua – 147 MW Gross – Single Casing Steam Turbine

Photo credit: Tauhara North No. 2 Trust & Mighty River Power (Mar ‘10)

Why is steamfield design important?

- You want to **maintain the electricity revenue stream** ∴ you want to:
  - Minimise downtime (maximise time between scheduled major maintenance outs)
  - Minimise steam turbine output decline

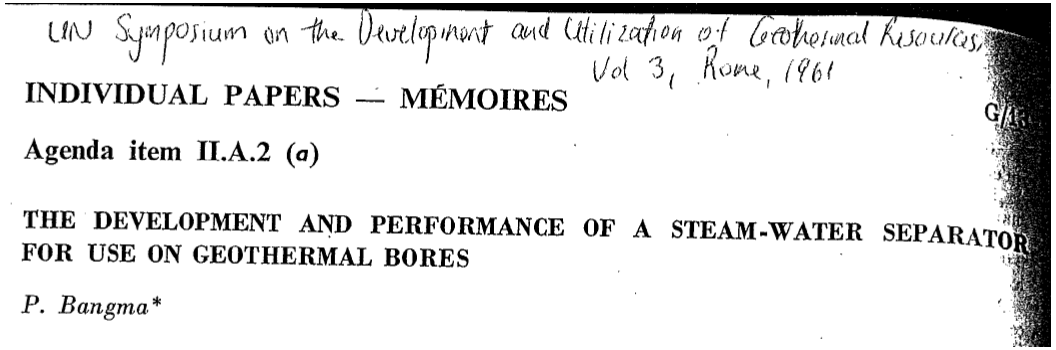
- How?
  - Maximise steam purity
  - Maximise steam quality
  - Don’t scale your pipelines and wells

- Steamfield is approximately 10-20% of overall project cost
  - So its important to get the design and operation right

- What does this require?
  - Maximising separator efficiency
  - Reliable brine pumping design
  - Minimise pressure losses and resource fluid usage

History of separator design

- 1961 Bangma



UN Symposium on the Development and Utilization of Geothermal Resources, Vol 3, Rome, 1961

INDIVIDUAL PAPERS — MÉMOIRES

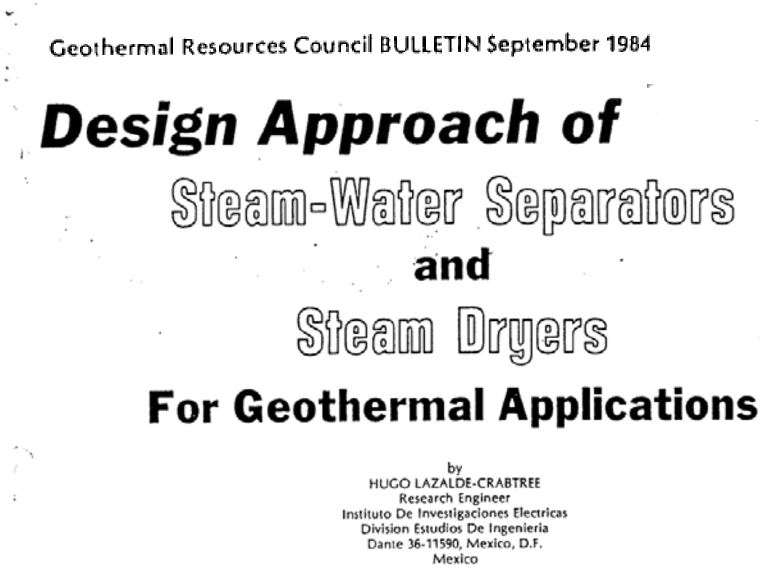
G/

Agenda item II.A.2 (*a*)

THE DEVELOPMENT AND PERFORMANCE OF A STEAM-WATER SEPARATOR FOR USE ON GEOTHERMAL BORES

*P. Bangma**

- 1984 Lazalde-Crabtree

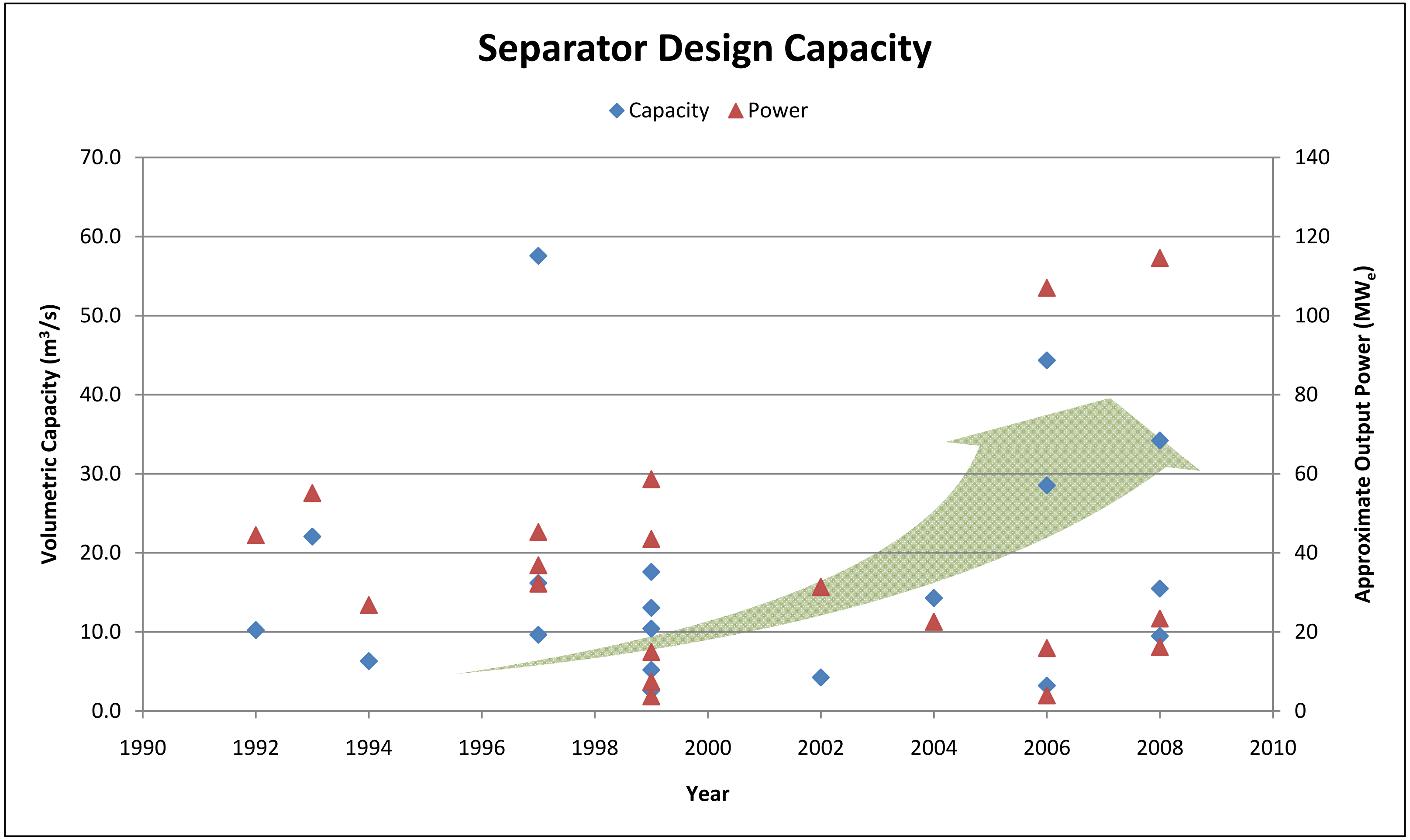


Geothermal Resources Council BULLETIN September 1984

Design Approach of
Steam-Water Separators
and
Steam Dryers
For Geothermal Applications

by
HUGO LAZALDE-CRABTREE
Research Engineer
Instituto De Investigaciones Electricas
Division Estudios De Ingenieria
Dante 36-11590, Mexico, D.F.
Mexico

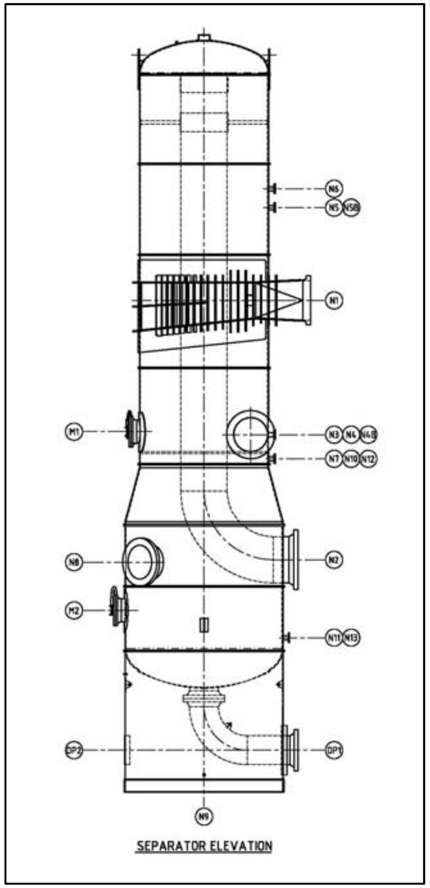
SKM's history of separator design



Higher pressures lead to higher unit sizes

- 20 years ago the standard size was 55 MW (2 x 55)
- 10 years ago saw the advent of 100 MW (2 x 100)
- Present designs up to 150 MW (but this requires higher inlet pressures)
- And this has lead to other mechanical design challenges
  - Height/brine storage
  - Structural considerations/vibration
  - Vessel internals

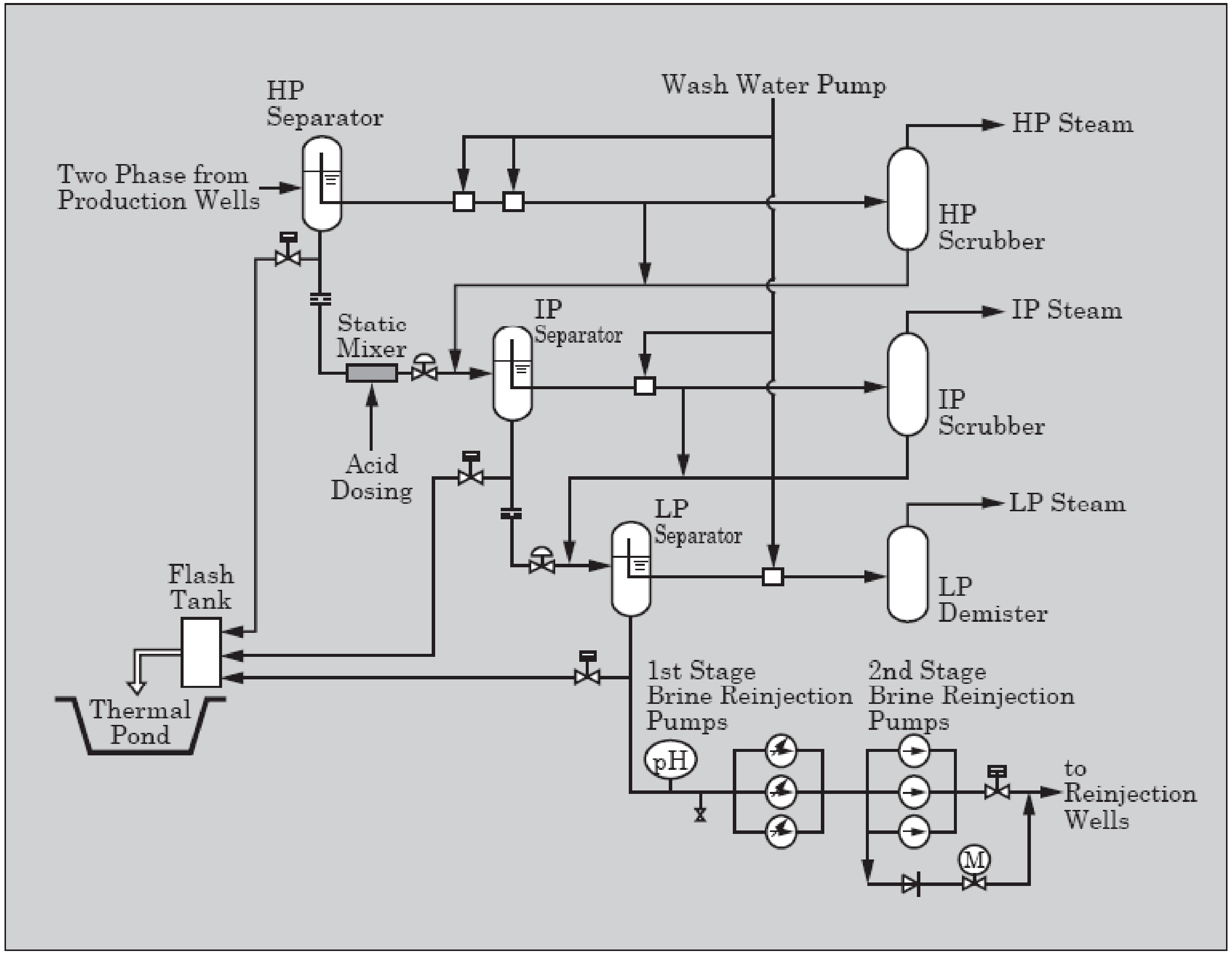
Higher pressures lead to higher unit sizes



How complex is the design?

- Wellhead control valves
- Two-phase piping
- Separators
- Acid dosing – brine pH
- Brine pumps
- Steam piping
- Brine piping – no flashing! Minimum brine flows so wells stay quenched.
- Scrubbers
- Brine dump – brine pond
- Steam vent
- Steam pressure control
- Steam condensate piping, pumping, pH control

How complex is the design?



Reference:
http://www.fujielectric.com/company/tech/pdf/55-03/FER-55-3-080-2009.pdf

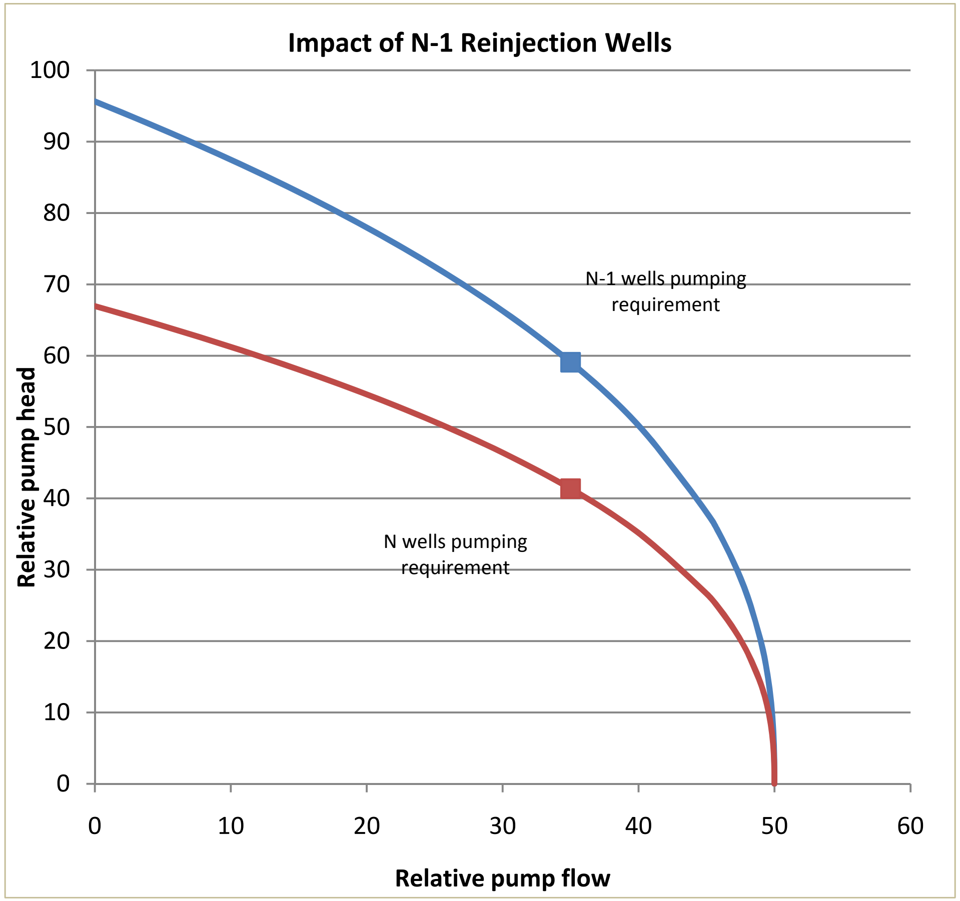
Other challenges

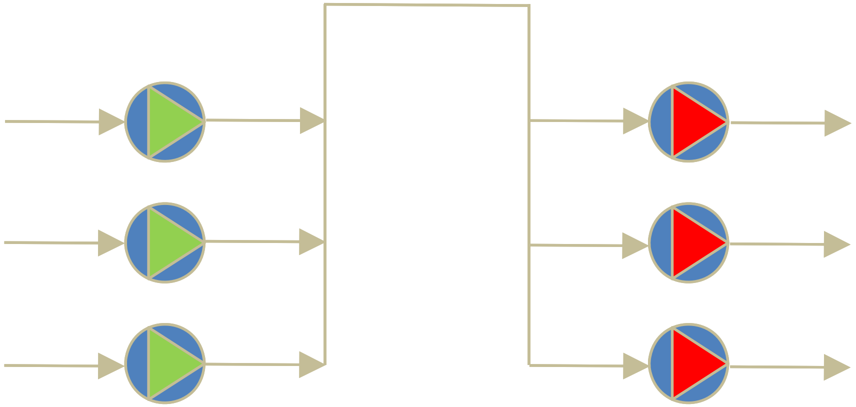
- Multi-flash
  - Higher TDS
  - Acid dosing

- Terrain
  - Forested areas
  - Steep slopes

Newer challenges

- N-1 wellfield philosophy - brine pumping
  - Series & parallel pumping
  - Fixed speed versus variable speed drives





Variable or fixed speed

Variable or fixed speed

Parallel or series or both?

Pressure control

- Brine carryover – minimise disturbances
  - Loop seal isolates water drum
  - In-line pressure control maintains constant separator pressure

- Advanced control to minimise fluid discharge (venting & dumping)
  - Use turbine governor valve in conjunction with vent valves and pressure control valves to:
    - Minimise venting
    - Reduce unrecoverable pressure losses across pressure control valves
    - Reduce separation pressure and increase flash ratio

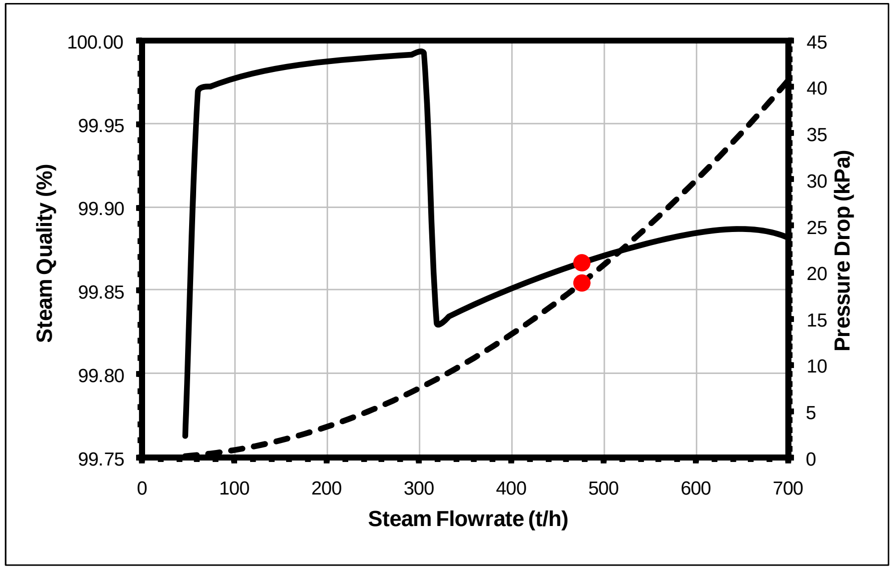
Contracting Strategies

- Traditional
  - Responsibility for steam purity lies with the Owner
  - Owner wants to avoid EPC Contractors claim that the steam purity is not up to specification so tends to over-design
  - cost of losses (pressure and fluid) generally not seen as a cost to the project

- Recent
  - Responsibility for steam purity lies with the EPC Contractor
  - EPC Contractor aims to meet the turbine inlet steam purity at minimum cost so this design tends towards the limit, economies of scale call for larger vessels
  - EPC Contractor wants to minimise losses (pressure and fluid) to maximise plant output

SKM Recent Design Experience

- Increased separator size, centralized stations, closer to PP
  - Obvious benefits in terms of unitisation & economies of scale
  - Increasing height typically in seismically active areas
  - Are traditional methods based on empirical formulae still valid?

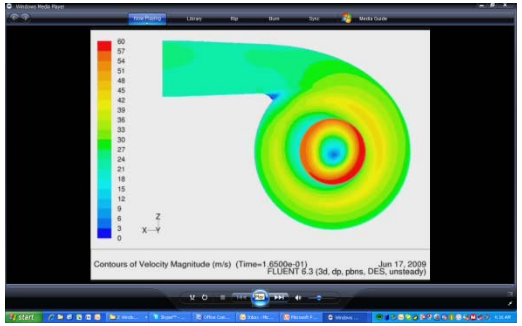


SKM Recent Design Experience

- SKM turned to Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) to:
  - Verify scale-up of empirical approaches
  - Model the separation process
  - Validate the sizing for very large separators and a wide range of fluid conditions
  - Validate the mechanical design and check for potential vibration problems (through Finite Element Analysis)
  - Evaluate some issues with steam tube support guide

SKM’s Recent Design Experience

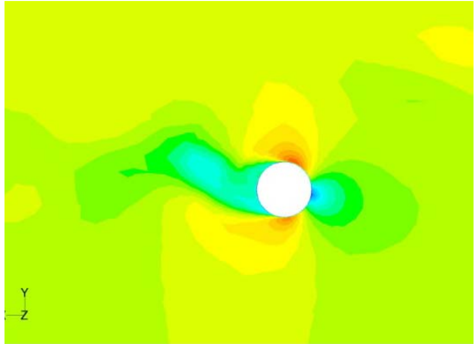
- CFD modelling:
  - provides a detailed analysis and modelling of the flow. Key areas of interest:
    - quantification of time-varying or unsteady flow in the separation vessel and its impact on structural loading and fatigue life
    - impact of design changes, such as entry profiles, on separator performance
    - an effective and computationally-efficient modelling of the basic droplet separation process



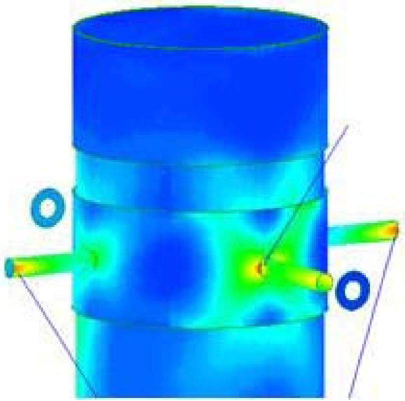
  - Is based on solving the Reynolds-averaged Navier-Stokes (RANS) equations with two-equation turbulence modelling, using the commercially-available CFD software FLUENT, and now using Unsteady Reynolds-averaged Navier-Stokes (URANS) and Detached Eddy Simulation (DES) techniques to better model turbulent flows

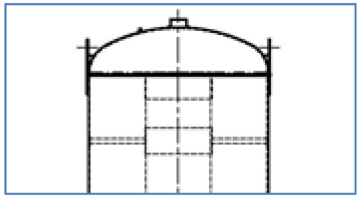
SKM’s Recent Design Experience

- Increased size has lead to challenges in supporting the separator steam outlet pipe
  - Turbulent flow can lead to excitation of vibration modes
  - Used CFD to map time dependent pressure onto surface of steam outlet pipe
  - Then used FEA to estimate effects of pressure forces from CFD
  - HA01195-G6-C7-Relative-Pressure-Z=0.wmv



Vortex Shedding From Steam Tube Support Strut (red contours indicate high velocity; blue contours, low velocity)

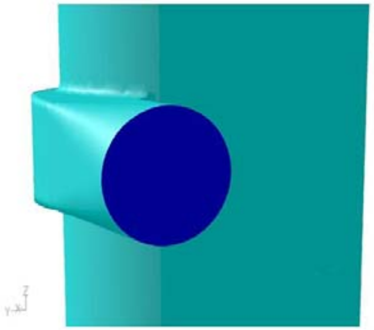


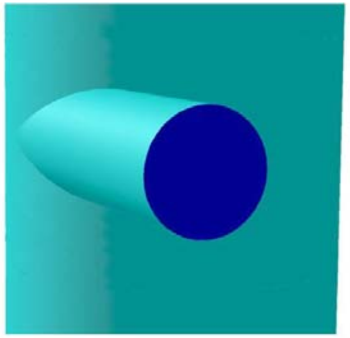


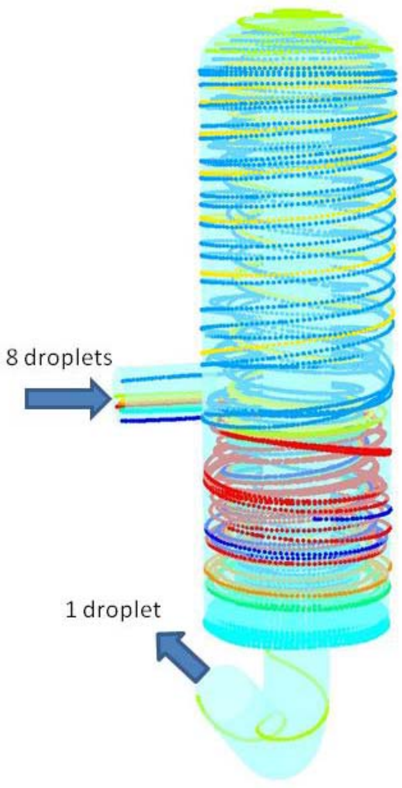
Stress Distribution at Steam Tube Support Assembly (red contours indicate high stress; blue contours, low stress)

SKM Recent Design Experience

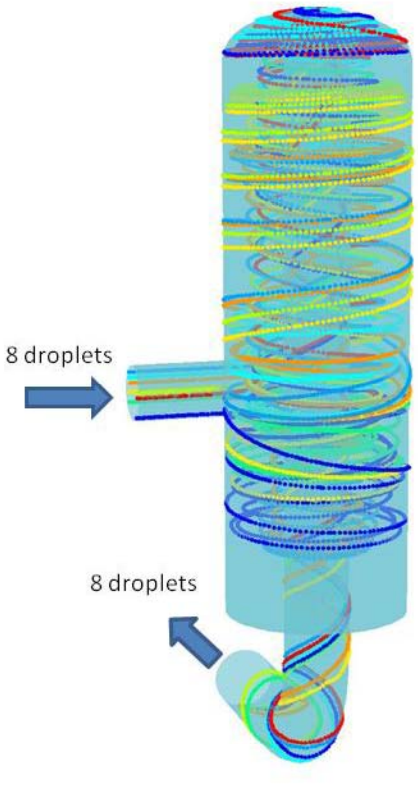
- CFD modelling has been used to evaluate:
  - lemniscate vs tangential entry
  - 8 droplets of 3 micron modelled
  - All 8 exited the tangential model only 1 exited the lemniscate model


Lemniscate entry


Tangential entry



Lemniscate entry



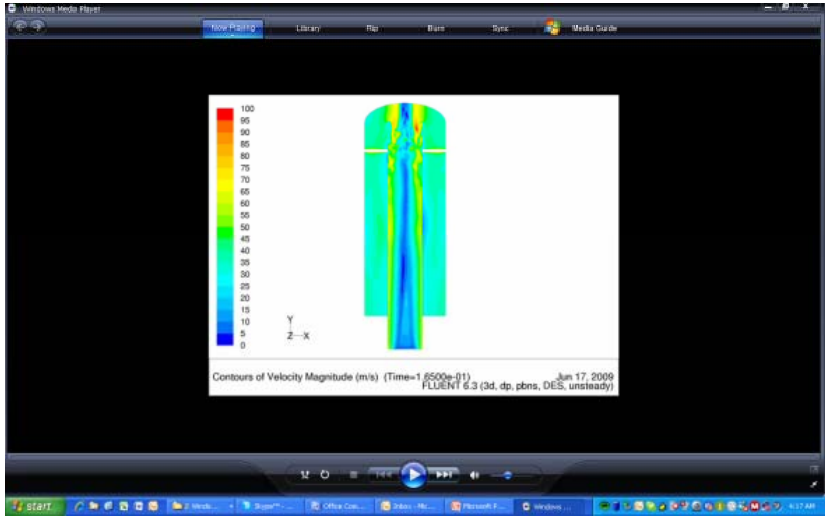
Tangential entry

CFD visualization

- Velocity profiles 0.165 sec duration
  (10 days computing on a dual quad core processor with 32 GB RAM to run 1 sec real time)

- HA01195-G6-C7-Velocity-Z=0.wmv

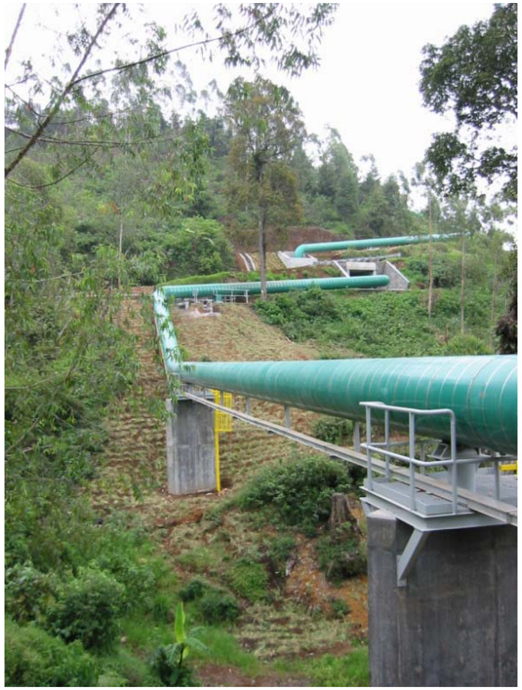
- HA01195-G6-C7-Velocity-Y=4.7.wmv



Contours of Velocity Magnitude (m/s) (Time=1.6500e-01) Jun 17, 2009
FLUENT 6.3 (3d, dp, pbns, DES, unsteady)

ACKNOWLEDGEMENTS

Alan Pointon	SKM Auckland
Tracy Mills	SKM Auckland
Greg Seil	SKM Sydney
Qihong Zhang	SKM Sydney



Computational Fluid Dynamic Techniques for Validating Geothermal Separator Sizing. **Paper presented at 2009 GRC Annual Meeting.**

Thank You
Power Engineers Incorporated
for inviting SKM
and sponsoring this presentation!