An Introduction to Flow Control Devices and the Potential Benefits to Geothermal Applications

Brandon Curkan, Jami DePencier and Wayne Klaczek

C-FER Technologies (1999) Inc.

Presented by: Wayne Klaczek, MSc, PEng
• Introduction

• Overview on Flow Control Devices (FCDs)

• FCD use in the Oil Industry (SAGD)

• Potential Benefits of FCDs to the Geothermal Industry

• Summary
• Uniform Distribution is Vital
  Uniform distribution of injected and produced fluids to & from the reservoir is critical

• SAGD Operators face Similar Challenges
  Oil operators, particularly those who use *Steam Assisted Gravity Drainage (SAGD)* are like geothermal

• FCDs Provide Effective Well Control (Significant Improvements Demonstrated)
  To address reservoir inefficiencies, SAGD operators have begun to employ FCDs as an effective means of *well control* and several operators have reported *significant process improvements*

• FCDs may be a viable solution for Geothermal Wells
  Given the similarities between the challenges faced by SAGD and geothermal operators, *FCDs may be a viable technology* to help mitigate imbalanced reservoir flow in geothermal operations – and something to consider
Overview of Flow Control Devices (FCDs) 
Use in SAGD Wells

• FCDs have been commonplace in conventional oil wells since the early 90's

• Since first being considered in SAGD wells by ConocoPhillips at Surmount – FCDs have now become a standard design element

• FCDs improve Reservoir Conformance in SAGD with a steam blocking effect to:
  - Promote an even liquid level around the production well
  - Improving steam chamber uniformity
  - Stop “short-circuiting” between the injection and production well
In SAGD there are two types of FCDs

- **Outflow Control Devices (OCDs)**
  - Used in Injection Well(s)
  - Promote even distribution of steam, resulting in better steam chamber growth and a reduced Steam Oil Ratio (SOR)

- **Inflow Control Devices (ICDs)**
  - Used in Production Well(s)
  - Promote lateral inflow conformance and improves steam efficiency/recovery

FCDs Deployed in a SAGD Well
(Halliburton)
The underlying operating principle of an FCD is to restrict flow by inducing a pressure drop.

FCDs can be categorized by three primary mechanisms:

- **Channel-style**
  - Frictional Drag
    - Directs flow through helical channels or tortuous pathway

- **Restriction-style**
  - Bernoulli Principle
    - Typically an orifice or nozzle-based design
    - Changes in flow area create instantaneous pressure drops

- **Autonomous**
  - Frictional Drag, Bernoulli Principle, Momentum Effects
    - Hybrid designs that use a combination of restriction and frictional pressure drop mechanisms
• FCDs have been used in conventional wells since the early 1990’s

• FCDs can *delay water or gas breakthrough* in horizontal wells

• High rate of production in a localized zone may draw gas cap or aquifer to the production well ("**Drawdown**")

• Typically, Drawdown occurs at the heel of the well due to frictional pressure loss (i.e. heel-toe effect)
  - However, reservoir characteristics and other factors may cause breakthrough anywhere along the well

*Localized Gas/Water Drawdown in a Conventional Horizontal Production Well* (Halliburton)
A key step in SAGD recovery is the even formation of the steam chamber.

Recently, FCDs have been deployed in SAGD to mitigate localized breakthrough ("Short-circuiting").

FCDs have been successful in lab testing at C-FER and field pilots with:

- Higher production rates, without localized breakthrough
- Reduced Steam Oil Ratio (SOR)
- Improved reservoir conformance
Flow Control Devices in the Oil & Gas Industry

Challenges (and path forward) in SAGD

• Identifying optimal ICD types to maximize performance in a SAGD well is challenging
  - There are few ICDs specifically designed for SAGD

• Other key factors to consider include:
  - Number of FCDs per well (and optimal spacing/deployment)
  - Likelihood of erosion and wear over life of well (15 to 25 years)

• SAGD operators and C-FER have invested significant effort into evaluating FCD technology for SAGD
  - C-FER and ConocoPhillips designed and built a unique high temperature flow loop and Erosion Apparatus
  - They also devised a protocol for characterizing the performance and reliability of ICDs under SAGD-representative conditions
Potential Benefits to Geothermal Applications

**Imbalanced Reservoir Flow**

- There are many parallels when comparing conditions experienced by geothermal operators and SAGD – such as imbalanced reservoirs

- Short-circuiting (or “Flow Channeling”) is a widespread issue in the Geothermal industry; impacting both hydrothermal and EGS operations
  - Chemical precipitates injection is sometimes possible – but in other cases geothermal operators need to drill a new injection well

- Thermal Drawdown is another major issue; it is detrimental to the produced heat capacity of the resource and a factor which may induce thermal stresses in the surrounding rock (i.e. leading to further short-circuits)

- Controlling flow through the reservoir may maximize heat exchange and mitigate Short-circuiting
Potential Benefits to Geothermal Applications

Possible Benefits of FCDs

• Short-circuiting and Thermal Drawdown in the Geothermal industry share many commonalities with SAGD operations

• Considering the similarities between the mechanisms, we suggest FCD technology may help to mitigate Short-circuiting and Thermal Drawdown in geothermal applications
  – OCDs in geothermal wells could promote balanced distribution of injected fluids
  – ICDs in a production well would mitigate Short-circuiting by preventing high rate production from a preferred path; possibly preventing Thermal Drawdown from produced fluid through localized zones

• FCDs may provide increased confidence in new EGS projects
Potential Benefits to Geothermal Applications

Limitations and the Bottom Line

• Although FCDs have been successful in the Oil & Gas industry, there is little information on the use of this technology in geothermal applications.

• Differences between Oil & Gas and geothermal operations may pose challenges to existing FCD designs, including:
  – Higher flowrates (i.e. SAGD operations exhibit lower flowrates than geothermal applications)
  – Scaling/Plugging (i.e. FCDs induce a pressure drop and flashing may lead to increased scaling)
  – Advancing completions (i.e. FCDs require advanced completions such as liners or tubing)

• **Bottom Line:** FCDs have potential but they are an unproven technology in the Geothermal Industry; development and refinement is required.
• FCDs have provided SAGD operators with improved reservoir conformance

• Short-circuiting, flow channeling and thermal drawdown can be critical issues for both SAGD operators and geothermal operators

• Potential challenges remain regarding the implementation of FCDs due to the unique conditions of geothermal wells – but the benefits may be large

Further collaboration between the oil and the geothermal industries would be beneficial to accelerate the understanding of how FCD technology may benefit both groups
This PowerPoint document is protected by copyright and may not be reproduced in whole or in part by any means without the approval in writing of C-FER Technologies (1999) Inc.