

# Enhancing Section Milling Efficiency in High-Angle P&A Wells Using PBL® Split-Flow Technology.

Petronas Tinggi Field – Malaysia

## CHALLENGE

Efficient debris removal during section milling in highly deviated wells is critical to prevent swarf accumulation and BHA pack-off during plug and abandonment operations.

During the Petronas Carigali (PCSB) Tinggi Plug & Abandonment campaign, several high-angle wells (A23, A24 and A28) required section milling and underreaming operations as part of structured abandonment activities.

These wells presented significant operational challenges due to high deviation and large volumes of metal swarf generated during casing milling. In previous operations, swarf accumulation led to pack-off while tripping out of hole, ultimately resulting in the loss of the BHA.

Additionally, the underreamer assembly had a hydraulic limitation that restricted flow through the BHA to approximately 280 GPM, limiting the ability to increase pump rates for effective debris removal.

The combination of high well deviation, long milling intervals, and large swarf generation created a challenging hole-cleaning environment where conventional circulation methods were insufficient to reliably transport debris out of the wellbore. Improving swarf evacuation and maintaining hole cleaning efficiency were therefore critical to ensure safe and efficient section milling operations.

## SOLUTION

DSI deployed the PBL® Split Flow system to improve circulation efficiency while maintaining safe hydraulic limits for the milling BHA.

The tool was configured with a 50/50 flow split, allowing total surface pump rates to increase significantly while maintaining acceptable flow through the milling assembly. This configuration enabled the operator to increase total pump rates to approximately 550 gpm, while limiting flow through the BHA to  $\leq 280$  gpm, protecting the downhole tools from fluid erosion.

By diverting part of the flow through bypass ports, the system increased annular velocity and enhanced swarf transport without compromising milling performance. Hydraulic modelling confirmed that the Split Flow configuration would maintain optimal bottom hole pressure while improving debris transport efficiency in the highly deviated well sections.

# EXECUTION

The PBL® Split Flow tool was integrated into the section milling BHA used during the Tinggi abandonment campaign.

Key operational parameters included:

- Milling interval: 606.9 m – 615.46 m
- Total metal swarf recovered: 2190 kg
- Pump rates during operation: up to 550 gpm surface flow
- BHA flow maintained below 280 gpm

The Split Flow configuration enabled operators to circulate at higher overall flow rates while maintaining optimal hydraulic conditions for the milling assembly.

The improved circulation efficiency supported continuous milling operations while ensuring effective debris transport from the milling interval to surface.

# RESULTS & BENEFITS

The PBL® Split Flow system significantly improved debris transport and hole cleaning efficiency during the campaign.

Key outcomes included:

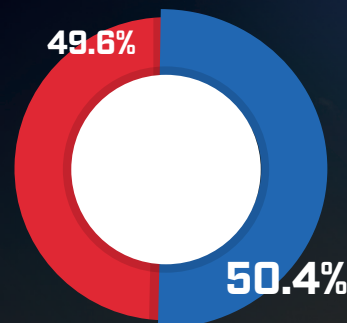
- Successful completion of section milling and underreaming operations across multiple wells.
- No swarf-related pack-off incidents during the campaign.
- Increased circulation rates while maintaining safe BHA hydraulic limits.
- Improved swarf evacuation in high-angle well sections.
- Enhanced operational confidence during P&A activities.

The successful deployment demonstrated the ability of the Split Flow system to overcome hydraulic limitations in complex well environments, enabling higher effective circulation rates while protecting sensitive downhole tools.

This deployment represents the first application of Split Flow technology in a P&A campaign in Southeast Asia, further validating DSI's advanced hydraulic solutions for challenging well abandonment operations.

1	Circulation sub is located at	674.40	(m)
2	Total flow rate	550	(gpm)
3	Sideway port nozzle TFA	0.301	(in2)
4	Downward port nozzle TFA	0.442	(in2)
5	Bit nozzle TFA	0.426	(in2)
6	Pump pressure	2957	(psi)
7	Bottom hole pressure (BHP)	1394	(psi)
8	Bottom hole ECO	1.440	(S.G)
9	Flow split - sideway (%)	50	(%)
10	Flow split - downward (%)	50	(%)
11	Flow rate - sideway	277	(gpm)
12	Flow rate - downward	273	(gpm)
13	Pressure drop - sideway port	703	(psi)
14	Pressure drop - downward port	316	(psi)
15	Pressure drop - bit	340	(psi)

## FLOW RATE DISTRIBUTION [%]



Sideway: 50%

Downward: 50%