ESP Mechanical Shaft Seal Run-Life Extender Performance Enhancements

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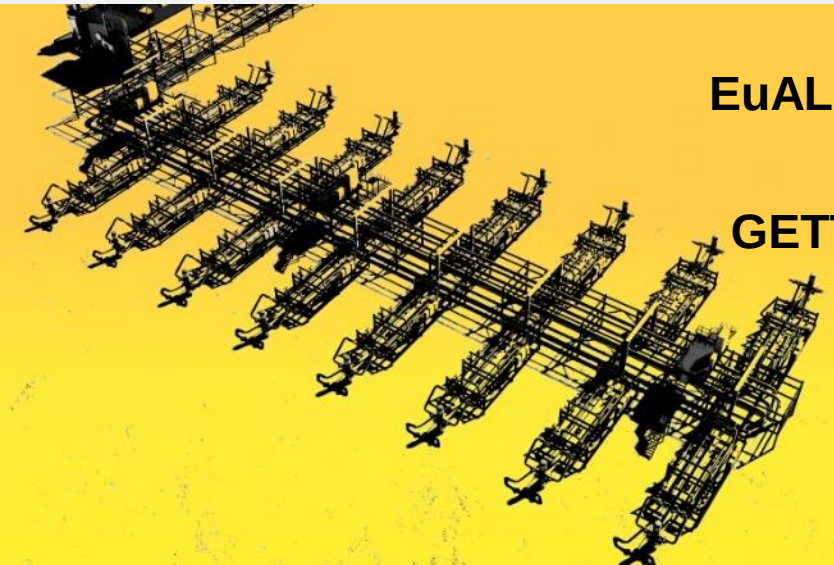

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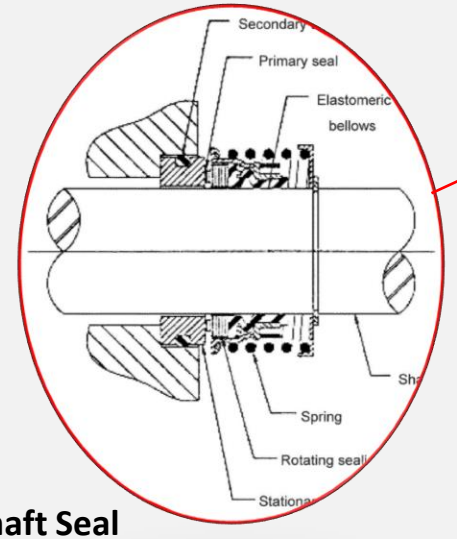
11 FEBRUARY 2021

CONTENT

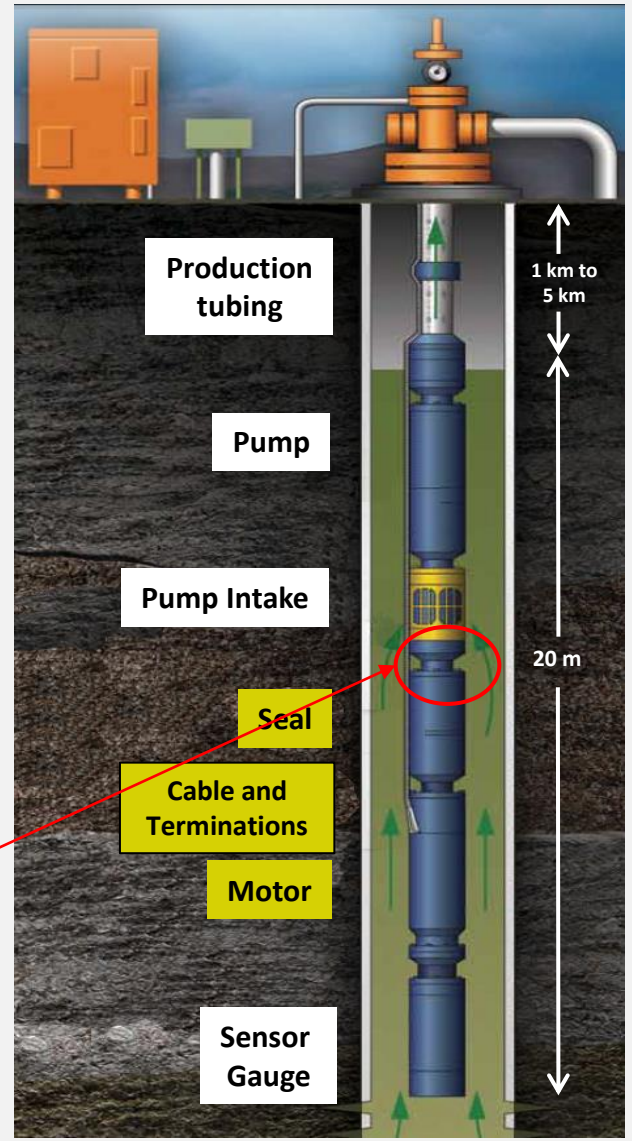
- Introduction
- The mechanical seal, a reliability challenge
- The solution – the “Mechanical Seal Protector”
- Product development and validation
- Field trial status
- Design Enhancements and further characterisation
  - Fluid flushing enhancement
  - Performance with solids and gas
  - CFD flow profile at pump intake
- Future developments
- Q&A

INTRODUCTION

- The seal section is a critical component of an ESP
- While the failures seem to relate to number of start and stops …. the prevalent root cause is solids impact on mechanical shaft seals
- The industry uses redundancy by means of multiple seal sections to deal with the challenge increasing complexity and CAPEX
- New remedies/prevention methods are required ….. preventing solids getting to the seal in the first place



Mechanical Shaft Seal

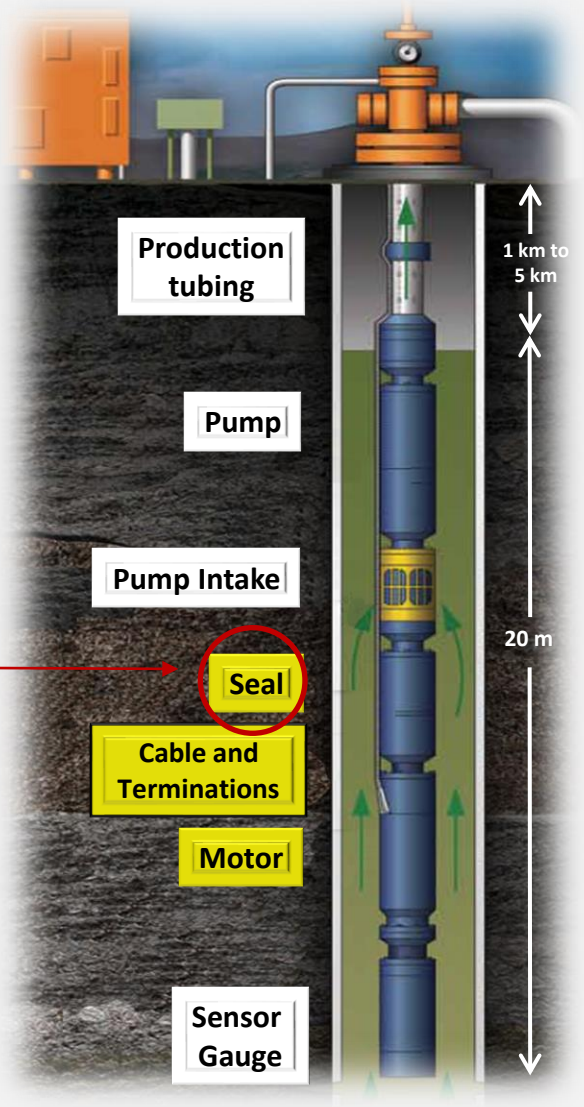


SEAL SECTION RELIABILITY – INDUSTRY KEY CHALLENGE

Failure analysis in current SAGD ESP Systems

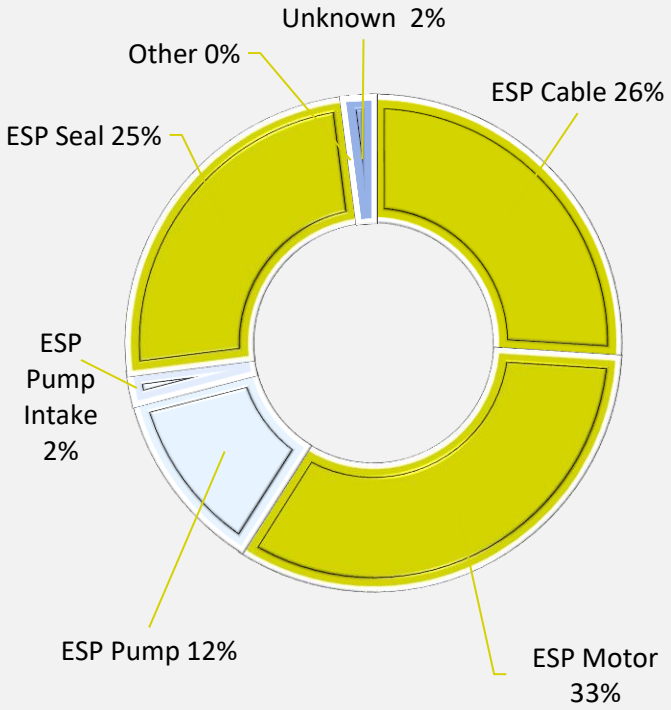
- **Seal failure** because of sand ingress (25%)
  - Of which 54% are Mechanical Shaft Seal
- **Cable damage** contributes to an average (26%)
- **Motor failure** including consequential damage of seal failure (33%)
- **Resulted in 84% of all failures**

Mechanical shaft Seal is responsible for (13.5%) of all failures



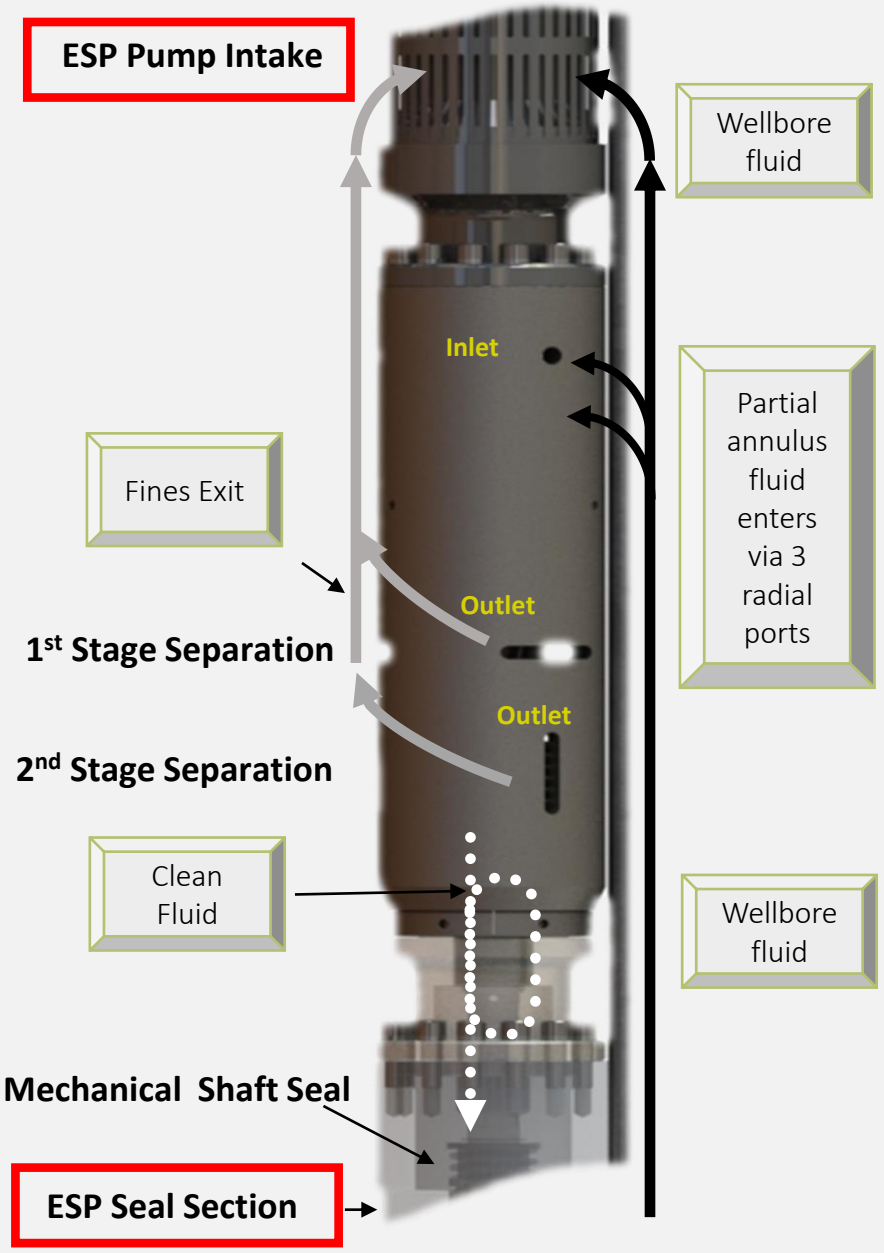
Source:
5 Yr. Data for 3 Major SAGD Operators actual reliability data [2013-18]

SAGD % of Failure Analysis



MECHANICAL SEAL PROTECTOR - APPROACH

- **Mechanical Seal Protector (MSP)** prevent solids getting to the mechanical shaft seal area
- The **MSP** is used in conjunction with the ESP Protector to continuously filter, flush and replenish the fluid in contact with the mechanical shaft seal
  - Only a small portion of fluid enters the inlets to create internal flow needed for mechanical shaft seal protection
  - It has no Screens or filter to plug
  - **Modular design** located between Seal section and Pump inlet
  - **Extends the life** of rotating sealing surfaces in contact with wellbore fluids
  - Exhausts sand particles and fines back into the main flow stream
  - Compatible with the majority of ESPs equipment using **standard interfaces**
  - Sand concentration up to **5% by volume**
  - Material selection applied for **high temperature** and exposure to **abrasive solids**



MECHANICAL SEAL PROTECTOR – PRODUCT DEVELOMENT (538)

- **Small Scale** (1/2 scale)
- Configuration optimized for understanding
- Open Flow loop testing for initial observations

- Progress to **Full Scale** Design
- Understand operation and validate results from ½ scale design and tests performed
- Repeat process and testing in full scale flow loop

- Comprehensive CFD undertaken
- Critical features optimized to enhance flow in/out of mechanical seal area

- Freeze test
- Thermal soak conducted

-40°C ⇕ 290°C

- **Full Scale** testing in closed loop performed routinely

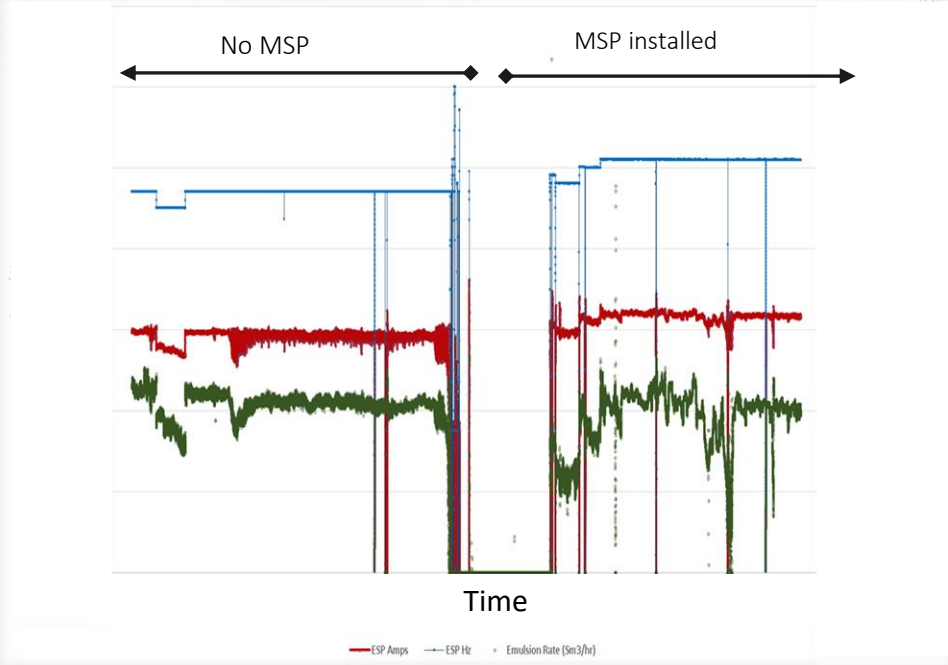
- **SIT Performed** (Site Integration Test)
- Testing at various loads was repeated to compare data of the ESP with and w/o Guardian.
- Visual and NDT Inspection performed on moving parts with no defects observed

MECHANICAL SEAL PROTECTOR - FIELD VALIDATION

The first-generation MSP was deployed in Northern Canada back in February 2019

- **SELECTED WELL**
  - Field deployed as part of an ESP string in a SAGD well known for its high sand production and for shaft seal failures
  - High sanding issues above normal circa ~ >0.5%

- **OBJECTIVE**
  - Integrate the MSP into an ESP string to evaluate if its run life is extended beyond average run life achieved in the same well
- **RESULTS**
  - 1st ESP is still operating ~2 year after successful deployment
  - ESP System has undergone many shutdowns and restarts during this period
  - Amplitude of current draw is much tighter compared to previous ESP systems indicating MSP has additional benefits



MECHANICAL SEAL PROTECTOR – FIELD DEPLOYMENT STATUS

- After 1 year of operation, Operators decided to deploy more MSP units into the field
- A total of 21 units are now out in the field with 19 operating in producing SAGD wells
- The oldest running unit has now been operating for 23+ months in in Northern Canada
- To date only one unit was pulled due to the ESP failure after operation for ~7 Months
  - ESP with starting problems on a well with severe scaling

No.	FIELD	FIELD START	Status	ACTIVE MONTHS		ESP PULLED DATE
1	Foster Creek	Feb 16, 2019	Running	23		
2	Foster Creek	Nov 29, 2019	Running	13		
3	Foster Creek	Dec 4, 2019	Running	12		
4	Foster Creek	Dec 12, 2019	Running	12		
5	Christina Lake	Feb 4, 2020	Running	10		
6	Christina Lake	Feb 18, 2020		7	(*)	September 20
7	Long Lake	Dec 16, 2019	Running	12		
8	Long Lake	Jan 5, 2020	Running	11		
9	Firebag	May 22, 2020	Running	8		
10	Firebag	May 1, 2020	Running	9		
11	Surmont	July 2020	Running	6		
12	Surmont	July 2020	Running	6		
13	Firebag	Oct 27, 2020	Running	2		
14	Firebag	Oct 7, 2020	Running	3		
15	Firebag	Nov 3, 2020	Running	2		
16	Firebag	Nov 11, 2020		0	(**)	December 20
17	Firebag	Oct 20, 2020	Running	3		
18	Firebag	Oct 31, 2020	Running	3		
19	Firebag	Nov 15, 2020	Running	2		
20	Firebag	December 16, 2020	Running	1		
21	Surmont	January 2021	Running	< 1		

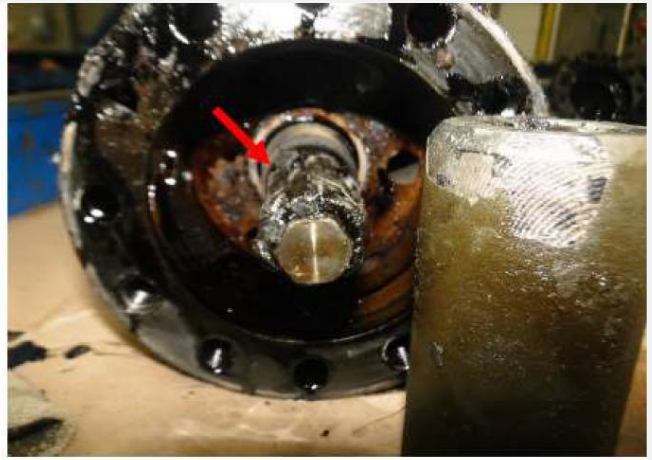
(*) Start problem on a well with heavy scale

(**) ESP Pulled from the well as it did not start. MSP pulled, cleaned and waiting to be put back into service.

MECHANICAL SEAL PROTECTOR – FIELD DEPLOYMENT STATUS

- The MSP was disconnected from the seal section head at the shop and inspected
  - The MSP base showed no sign of sand
  - The MSP turns good. Shaft spline was not twisted and the coupling was in good condition
- Well fluid made it to the guide of the lower tandem seal
- Oil passed dielectric test in the lower tandem seals' upper and lower sections, as well as the motor, a good indicator the MSP is performing its function
- The cause of failure was the potential scale and well debris jamming into the pump, pump intake and the pull was due to a stuck pump
- Overall, the operator was pleased with what he saw on the first pulled MSP

The guardian base showing no signs of sand.

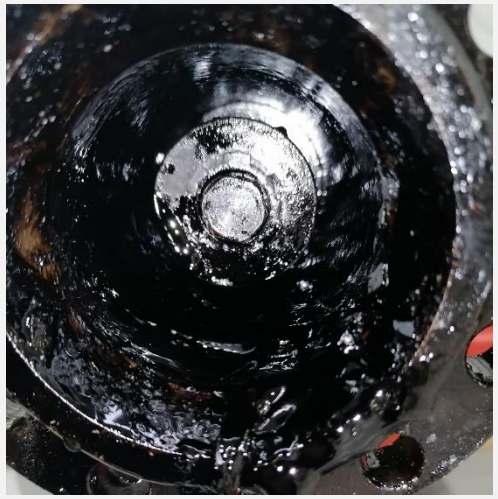


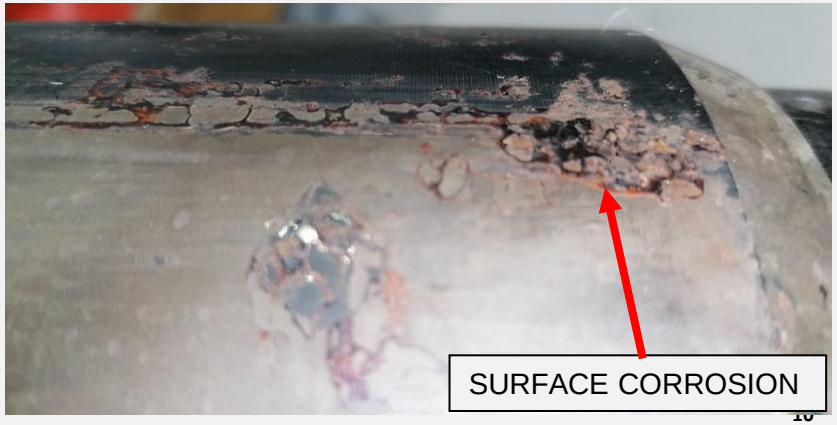
The guardian head was in fair condition.

Oil samples collected from the motor:
Head = 16.7 kV, Base = 13.6 kV

MECHANICAL SEAL PROTECTOR – FIELD DEPLOYMENT STATUS

- The returned unit was found to be in good condition
- Minor aesthetic issues (discolouration/corrosion) were found on the carbon steel parts.
- Thin scale like layer found on the shaft exposed to the well bore fluid
- Bearings with some polishing but within tolerance
- The unit was shipped back to go into service





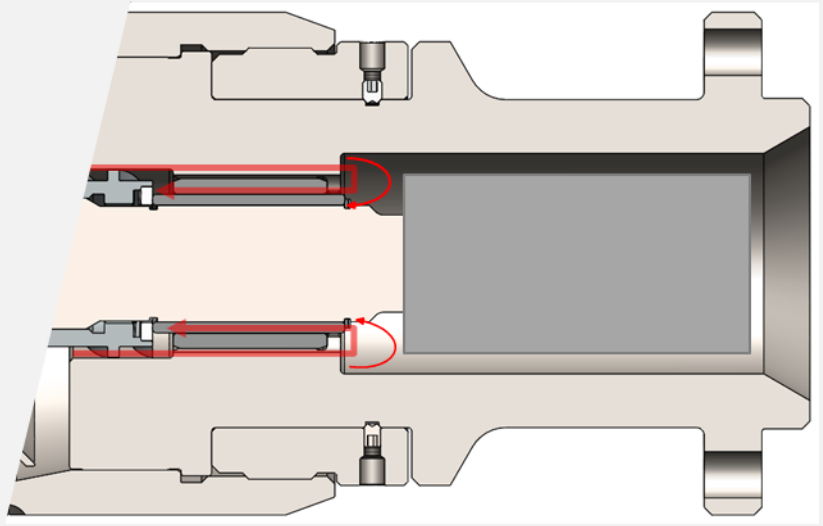
MECHANICAL SEAL PROTECTOR - ENHANCEMENTS

While the first field trial was progressing, we continued to enhance performance and understand operating characteristics of the MSP based on observation from the flow loop, early field trials and from discussions with operators

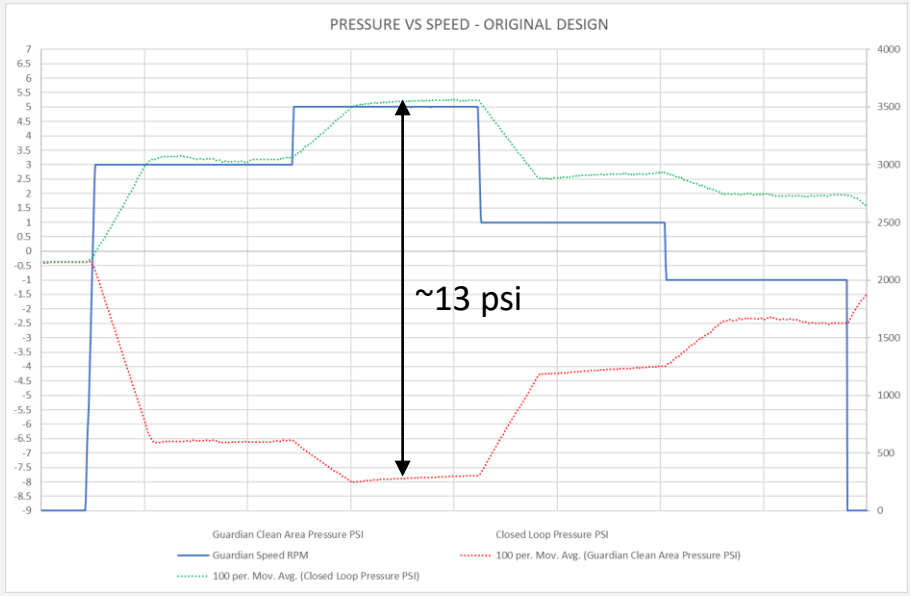
- Enhanced the flushing mechanism to further reduce the likelihood of solids in the clean area: **Generation 2 MSP**
- Characterised the effect of gas in the produced fluid in MSP operation
- Undertook flow simulations to understand the characteristics of the flow into the pump intake using CFD

MECHANICAL SEAL PROTECTOR - DESIGN ENHANCEMENTS

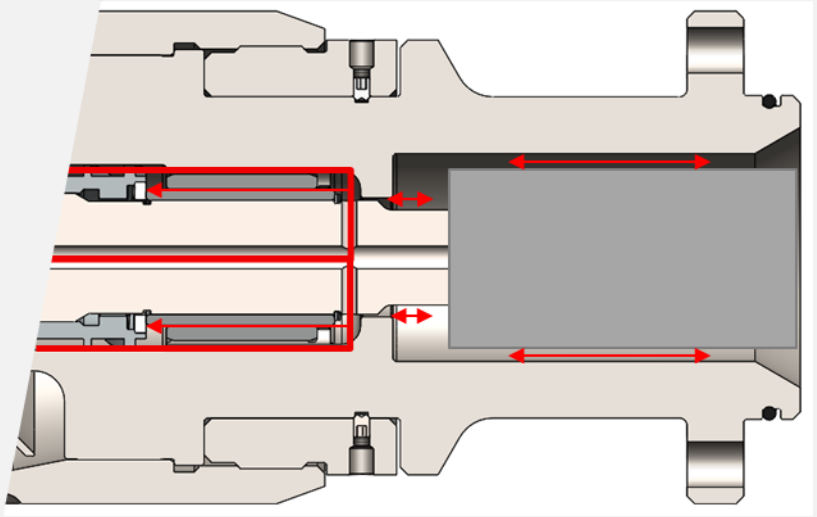
ORIGINAL DESIGN



- Recirculation through bearing gap only

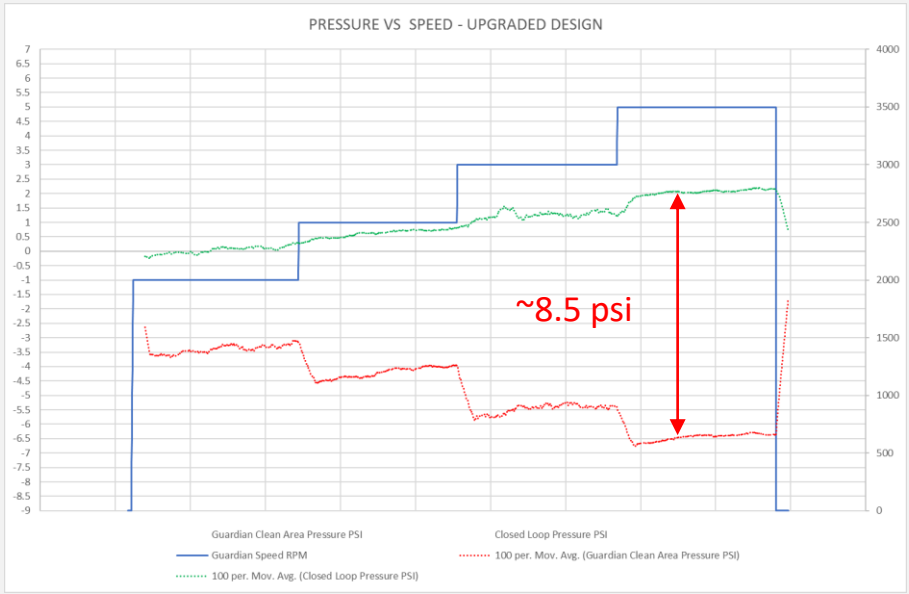


UPGRADED DESIGN



- Recirculation through the shaft and partially through bearing gap

PRESSURE DIFFERENTIAL BETWEEN ANNULAR AND CLEAN AREA IS REDUCED



Patent Pending

MECHANICAL SEAL PROTECTOR - DESIGN ENHANCEMENTS

ORIGINAL DESIGN

ORIGINAL DESIGN – 8 HRS
~0.2% of total solids

- Total accumulated time: 8 hrs
- Significant amount of macerated solids (sludge)
- Speed: 3000 rpm

UPGRADED DESIGN

UPGRADED DESIGN – 16 HRS
Traces of solids

- Total accumulated time: 16 hrs
- Speed: 3000 rpm
- Less maceration observed (more un-broken glass beads)

MECHANICAL SEAL PROTECTOR – EFFECT OF GAS

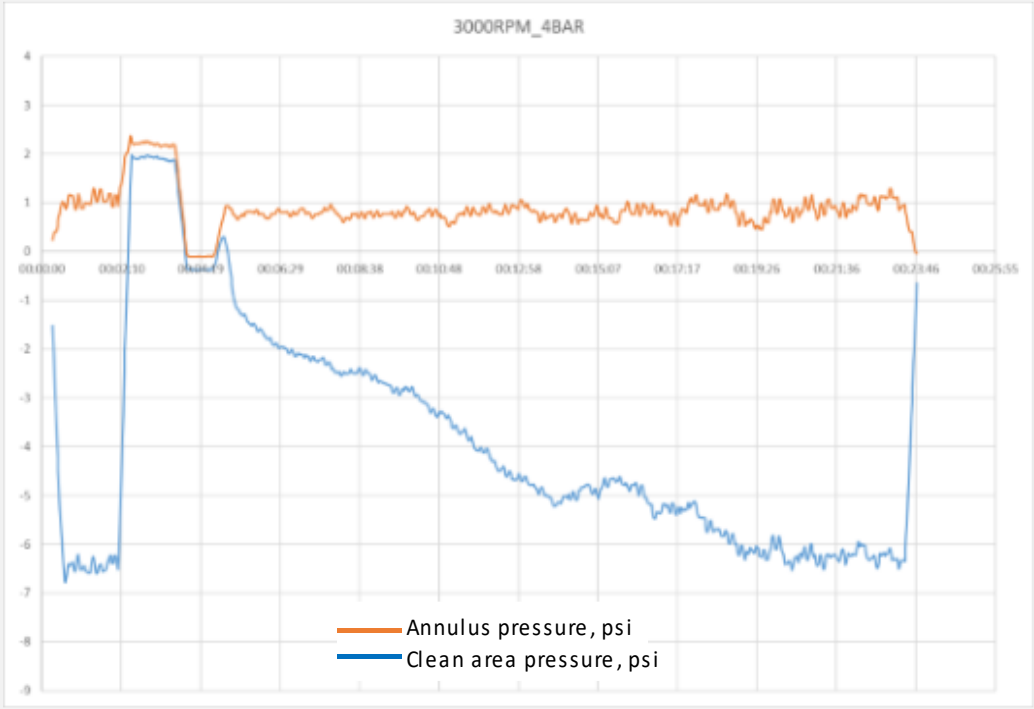
- Test setup upgraded to be able to combine both solid and gas injection
- Test conducted with Generation 2 MSP with 5% solids per volume in the presence of gas of up to 50% GVF
- After 16 hrs of cumulated run with gas and solids, the amount of solids found in the clean area was 0.08% of the initial volume of solids , a better performance than Gen 1

New “funnel” tank
Ensures effective solid distribution and circulation

Air Injection Hose

Tests at 50% GVF

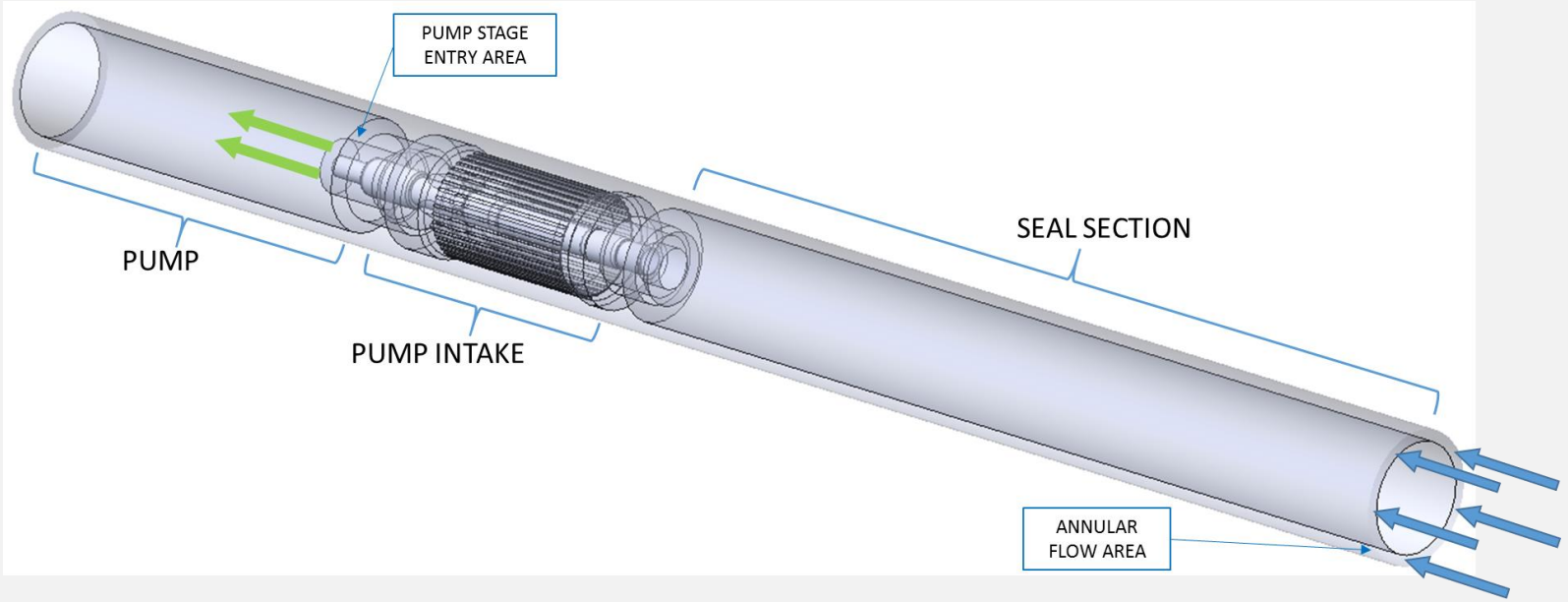
MECHANICAL SEAL PROTECTOR – EFFECT OF GAS



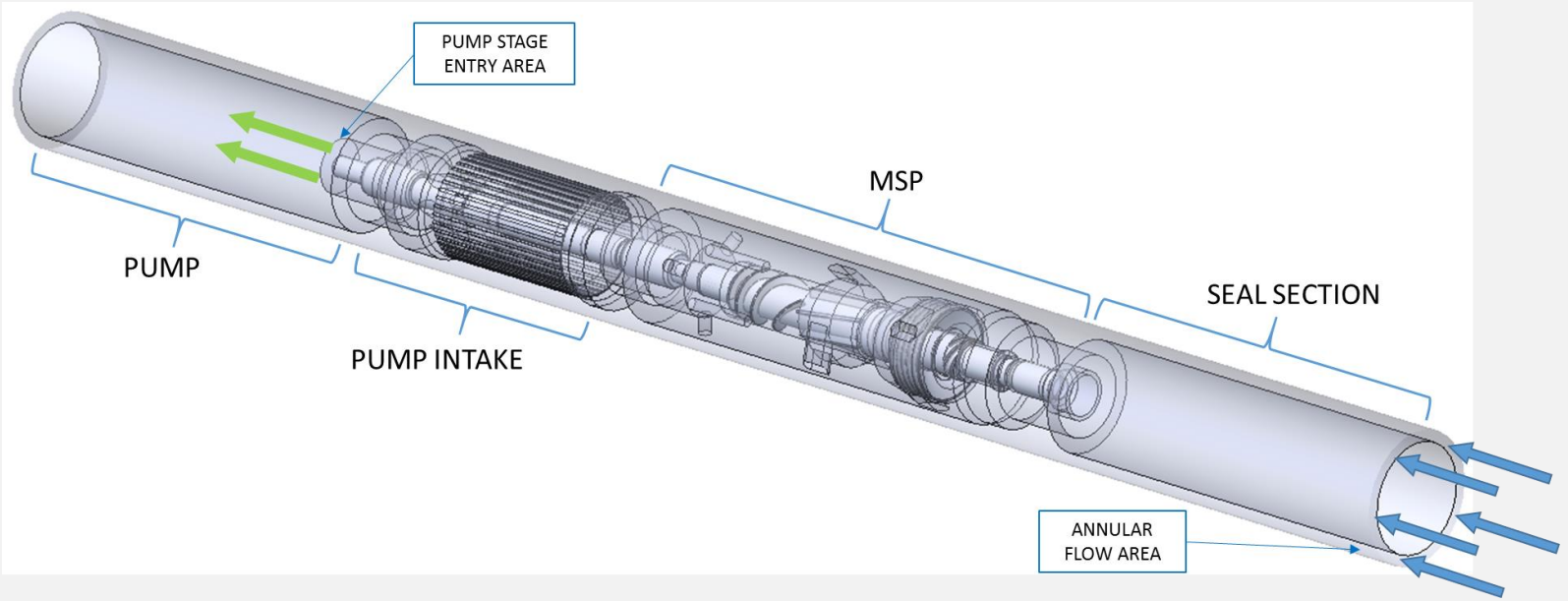
- Injected air volume : up to 50% of volume
- Pressure change due to air observed in clean area
- Pressure in the clean area recovered in less than 30 minutes after air injection stopped

MECHANICAL SEAL PROTECTOR – FLOW PROFILES

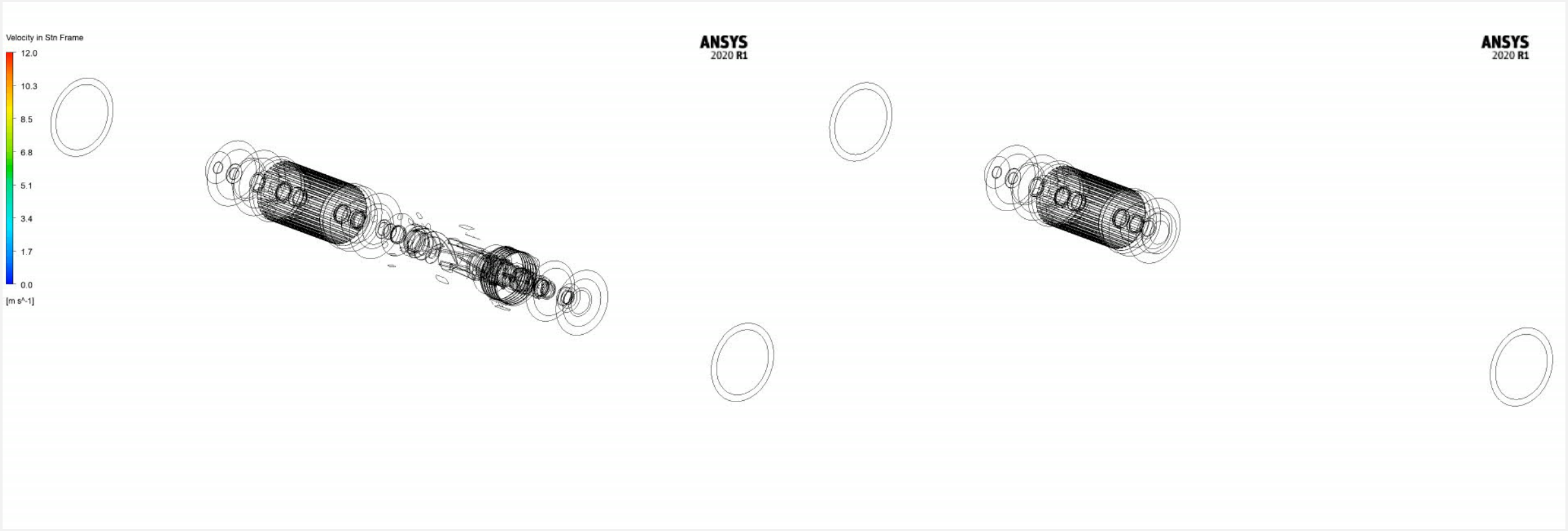
Standard ESP Configuration



ESP with MSP Installed



MECHANICAL SEAL PROTECTOR – FLOW PROFILES

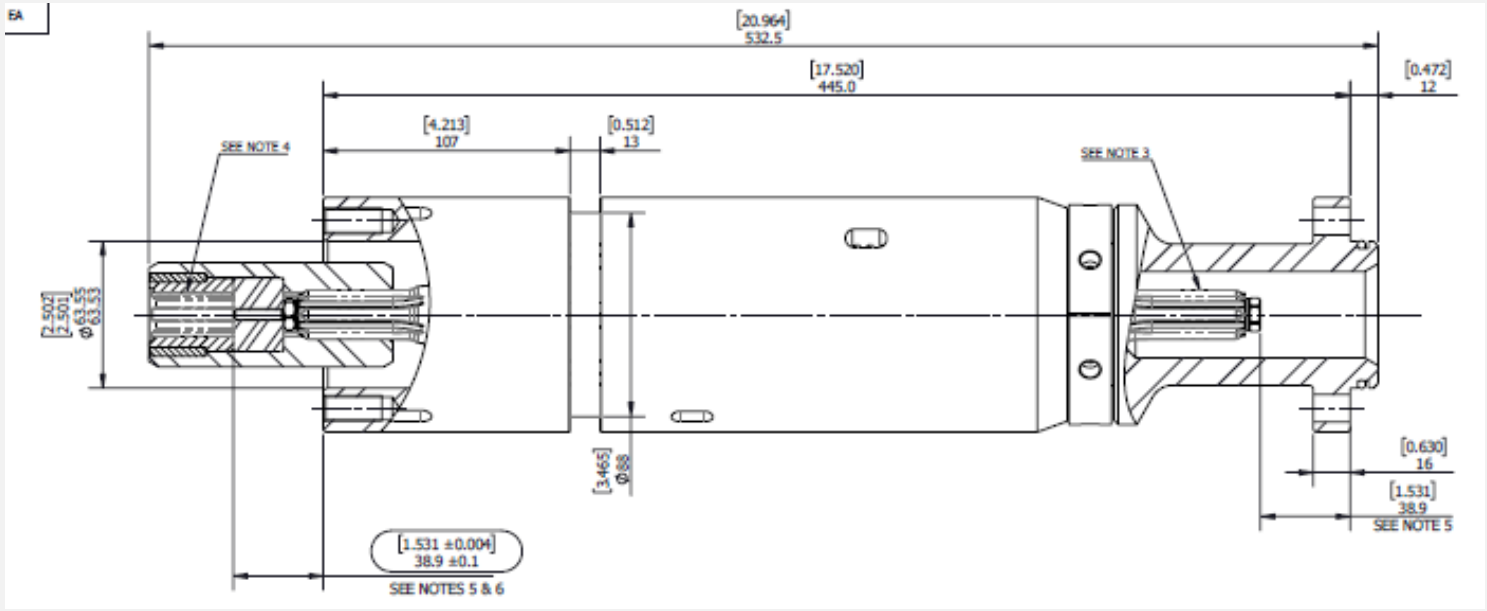


ESP with MSP Installed

Standard ESP Configuration

MECHANICAL SEAL PROTECTOR – 400 SERIES DEVELOPMENT

- 400 series version
- Designed for the general market
- Design complete, Drawings released



- Thank you for your time!
- Any Questions?