TPS

51ST TURBOMACHINERY & 38TH PUMP SYMPOSIA

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AN ALTERNATIVE OPTION TO PROVIDE SEAL GAS FOR DRY GAS SEALS WHICH WAS USED DURING THE FIRST START UP OF PIPELINE BOOSTER COMPRESSORS

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- Salman Mirza is currently a Unit Head – Pipelines Project Management for Saudi Arabian Oil Company, worldwide working experience with oil & gas exploration and production Companies (BP Middle East & South Asia, BP Canada, Saudi Arabian Oil Company);

- Leonardo Baldassarre is currently Engineering Executive Manager for Compressors, Turboexpanders and Electric Systems with Baker Hughes, in Florence, Italy;

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- Eric William Brown is currently an independent Engineering Consultant and Director of Eric Brown Consulting Ltd , founded in 2009. He was previously an Engineering Consultant on Compressors, Turbines, Expanders, and Gears for Saudi Aramco Consulting Services where he worked from 1978- 2009;

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- Luigi Barbato is currently Product Safety Leader at Baker Hughes, in Florence, Italy. He is responsible for managing Product Safety team for the turbomachinery engineering organization;

OVERVIEW

- This case study covers the initial start up (“black” start up) of a centrifugal compressor at a pipeline station located in a remote desert environment in Saudi Arabia, focusing on the issue that the suction and discharge header pressures were the same.

- No supply of process gas at a higher pressure than the suction pressure was available for use as seal gas.

- In many gas plant or Refinery installations, suitable gas at a higher pressure is often available, but this was not the case for this pipeline application

- The seal gas system configuration studied and described was used to overcome this seal gas supply issue during initial or “black” startup

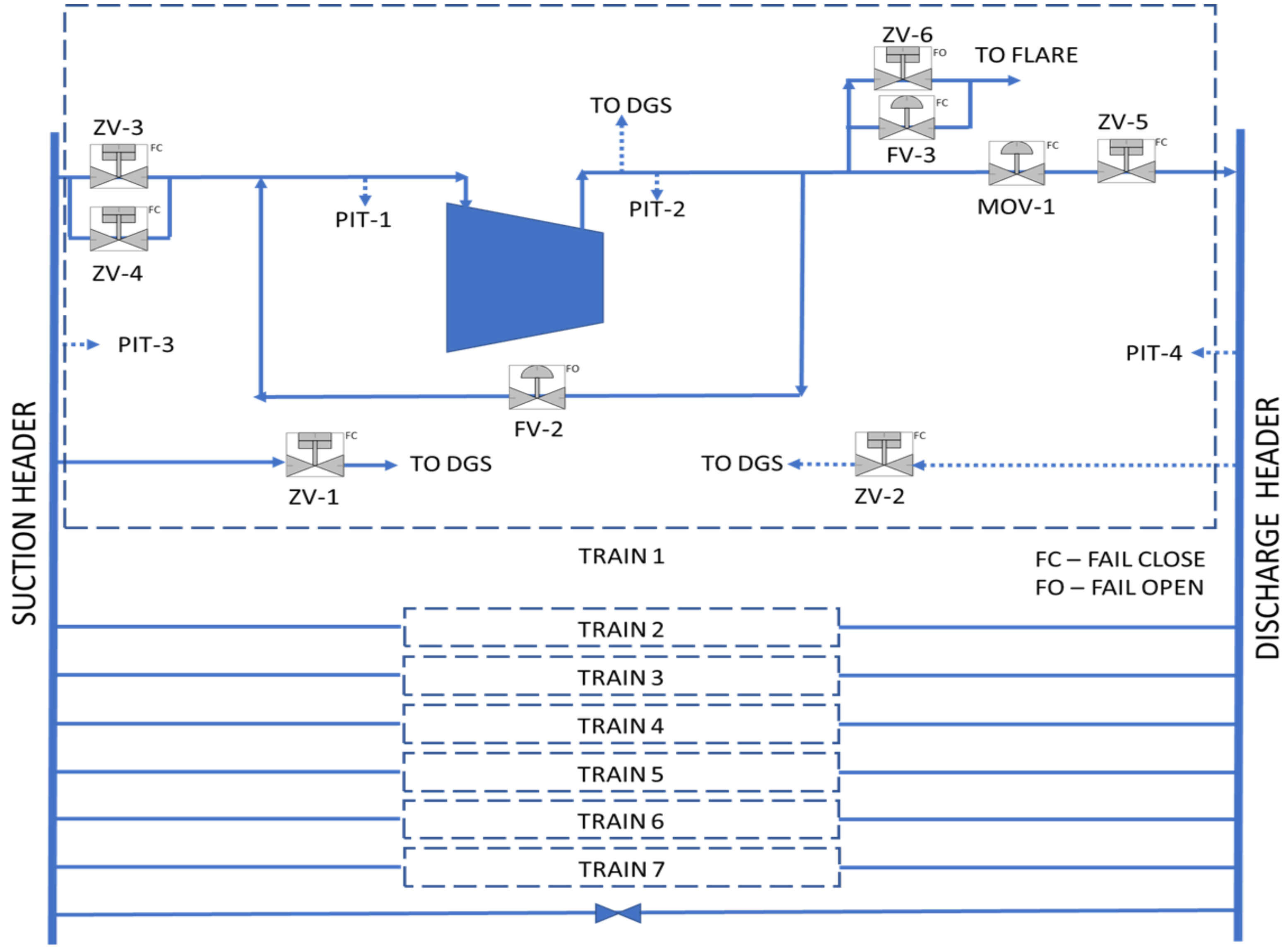
BOOSTER GAS COMPRESSION STATION

STATION OVERVIEW

- Booster Gas Station purpose is to increase the gas pressure to accommodate the pressure losses along the pipeline;
- Pipeline compressor is the key component of each Booster Gas Compression station, together with the Gas Turbine driver and all the auxiliary systems;
- During the startup of each station, the pressures of suction and discharge headers are the same;
- Insufficient delta pressure between headers is available to provide seal gas for the gas sealing.

STATION SCHEMATIC

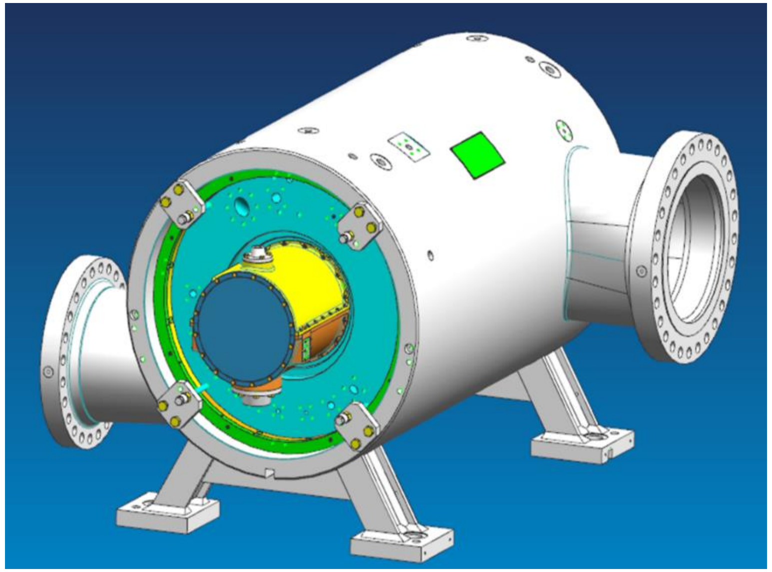
Gas from
Upstream Piping



Cooled higher
pressure Gas to piping

BOOSTER STATION
CENTRIFUGAL COMPRESSOR TRAIN

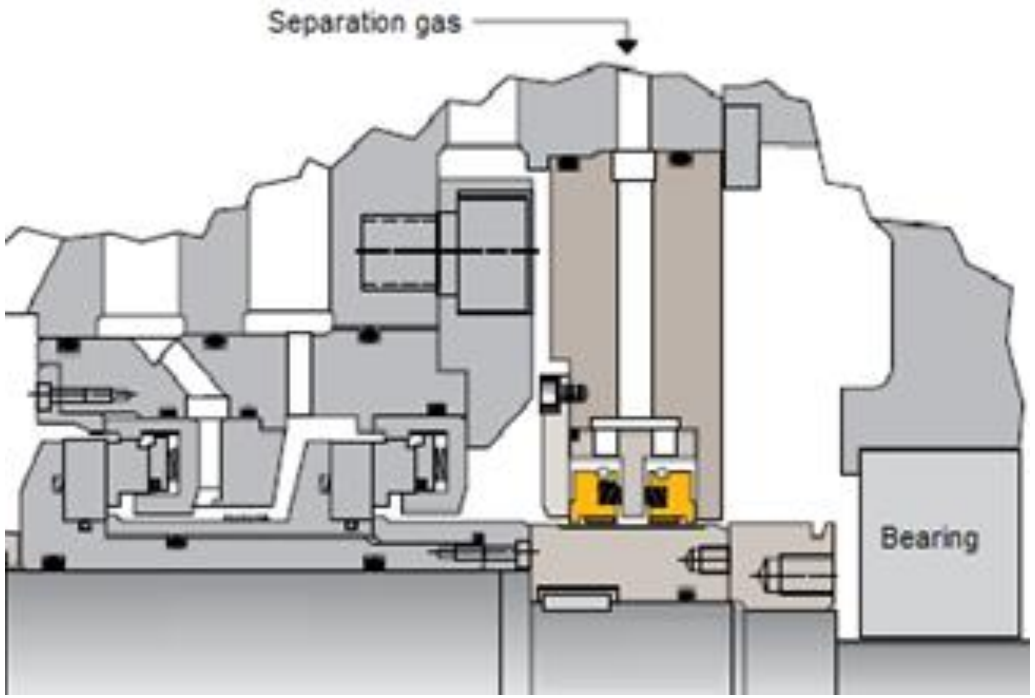
CENTRIFUGAL COMPRESSOR



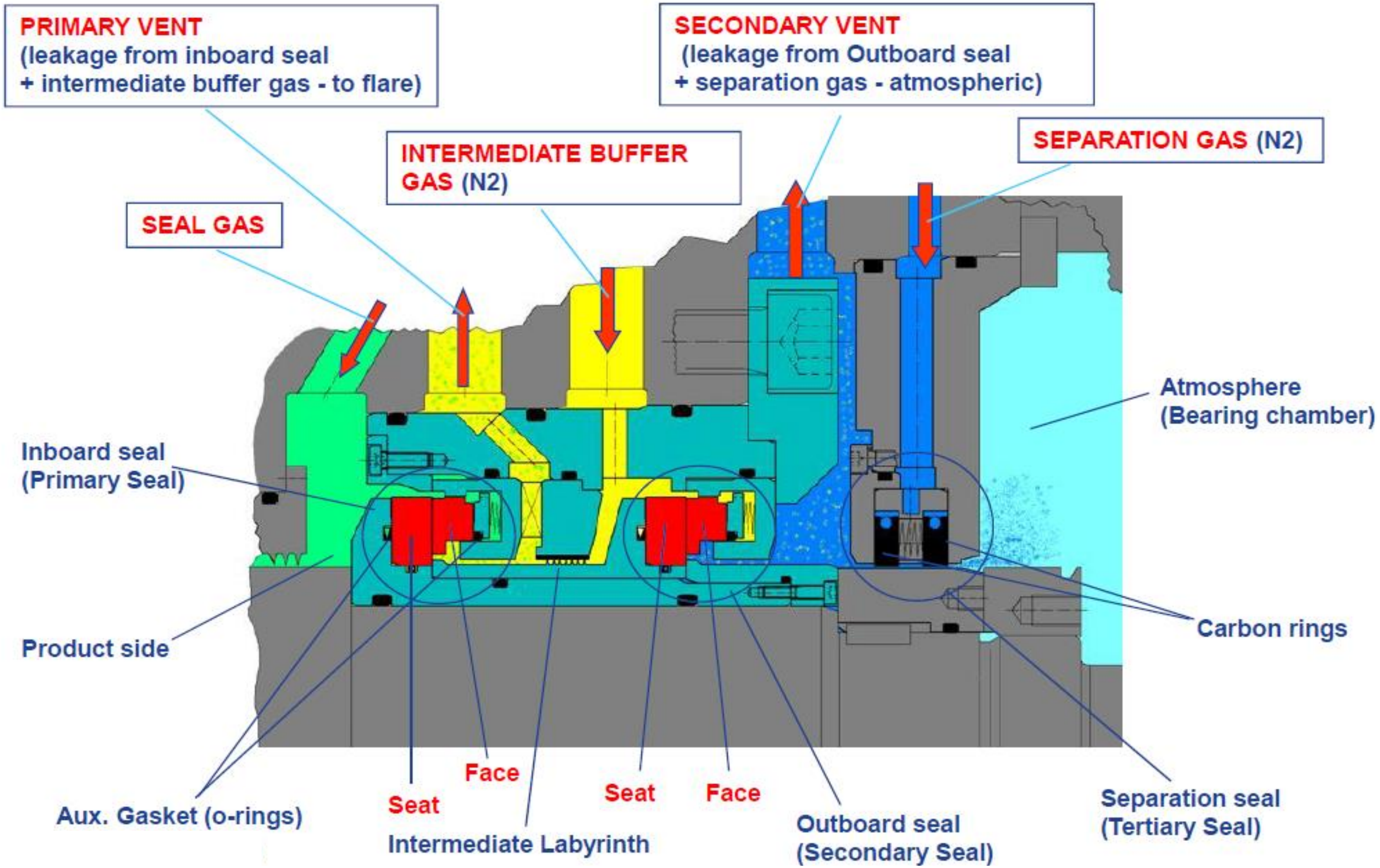
- Barrel type Pipeline Centrifugal Compressor
- 3 stage rotor
- Horizontal nozzles;
- Design Pressure 1200 psi-g;
- Design Temperature 392 °F;
- Direct connection to gas turbine driver (no gearbox is present)

DRY GAS SEALS

- Tandem Dry Gas Seals with intermediate labyrinth
- Uni-directional grooves;
- Non-contact carbon ring tertiary (separation) seal type;



TANDEM DRY GAS SEAL LEAKAGES



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SEAL GAS SOURCE FOR START-UP (1)

- Many different approaches were considered during the design phase
- Three potential solutions have been considered for seal gas at startup:
  - ✓ Provide Nitrogen as seal gas from dedicated bottles;
  - ✓ Provide a Seal Gas Booster system with associated control;
  - ✓ Provide a solution to have compressor suction pressure lower than headers pressure at startup.

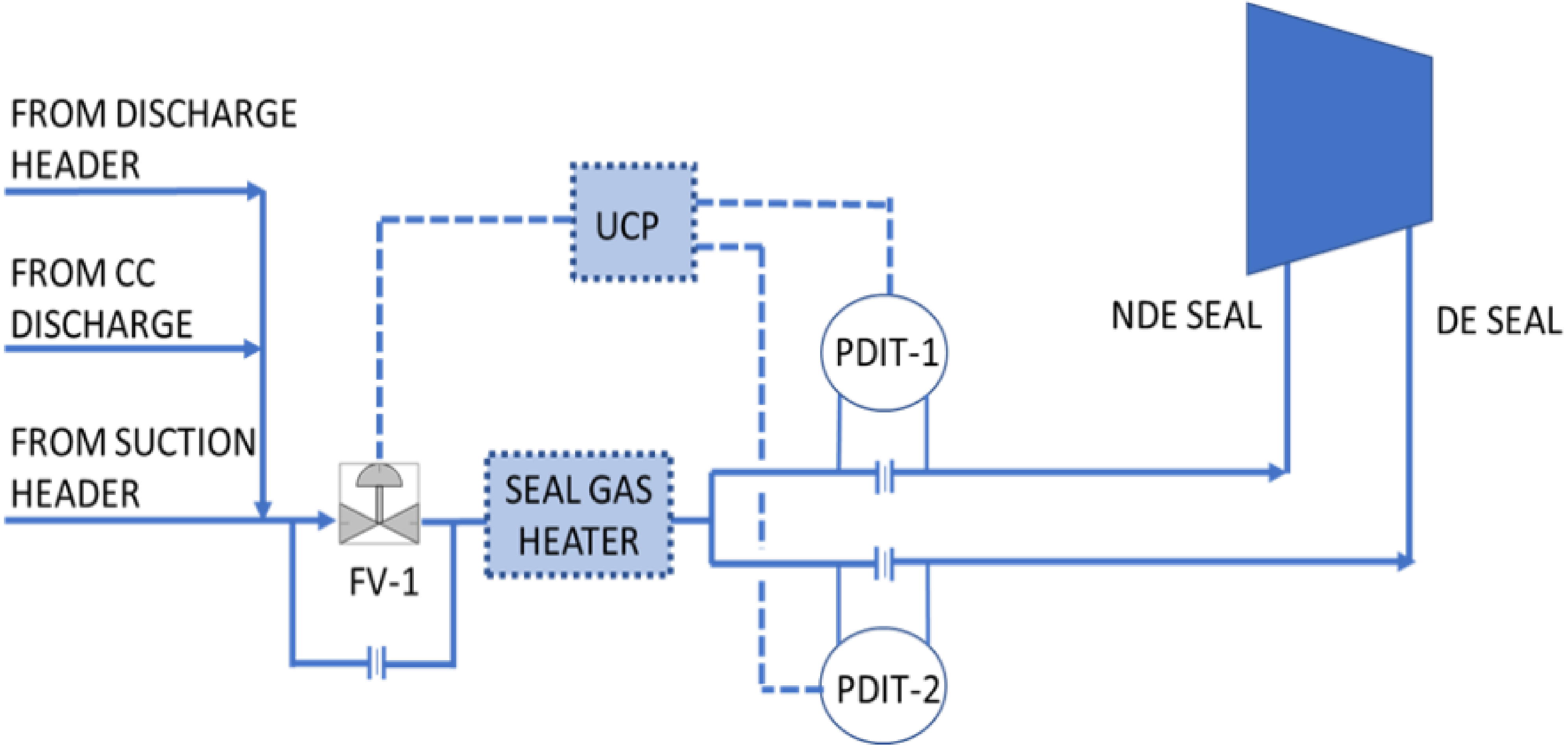
SEAL GAS SOURCE FOR START-UP (2)

- The first solution, related to N2 bottles for seal gas at startup, was discarded due to logistical challenges on N2 availability, supply, system reliability, and additional storage facilities
- The second solution, related to seal gas booster, was discarded due to potential low availability and cost of the systems. This took into account the required number of systems for the station including back ups, system components, and system maintenance

SEAL GAS SOURCE FOR START-UP (3)

- The third solution, related to the reduction of the suction pressure with respect to the discharge pressure, was selected due to low cost, availability and reliability.

SEALS GAS FEED SCHEMATIC

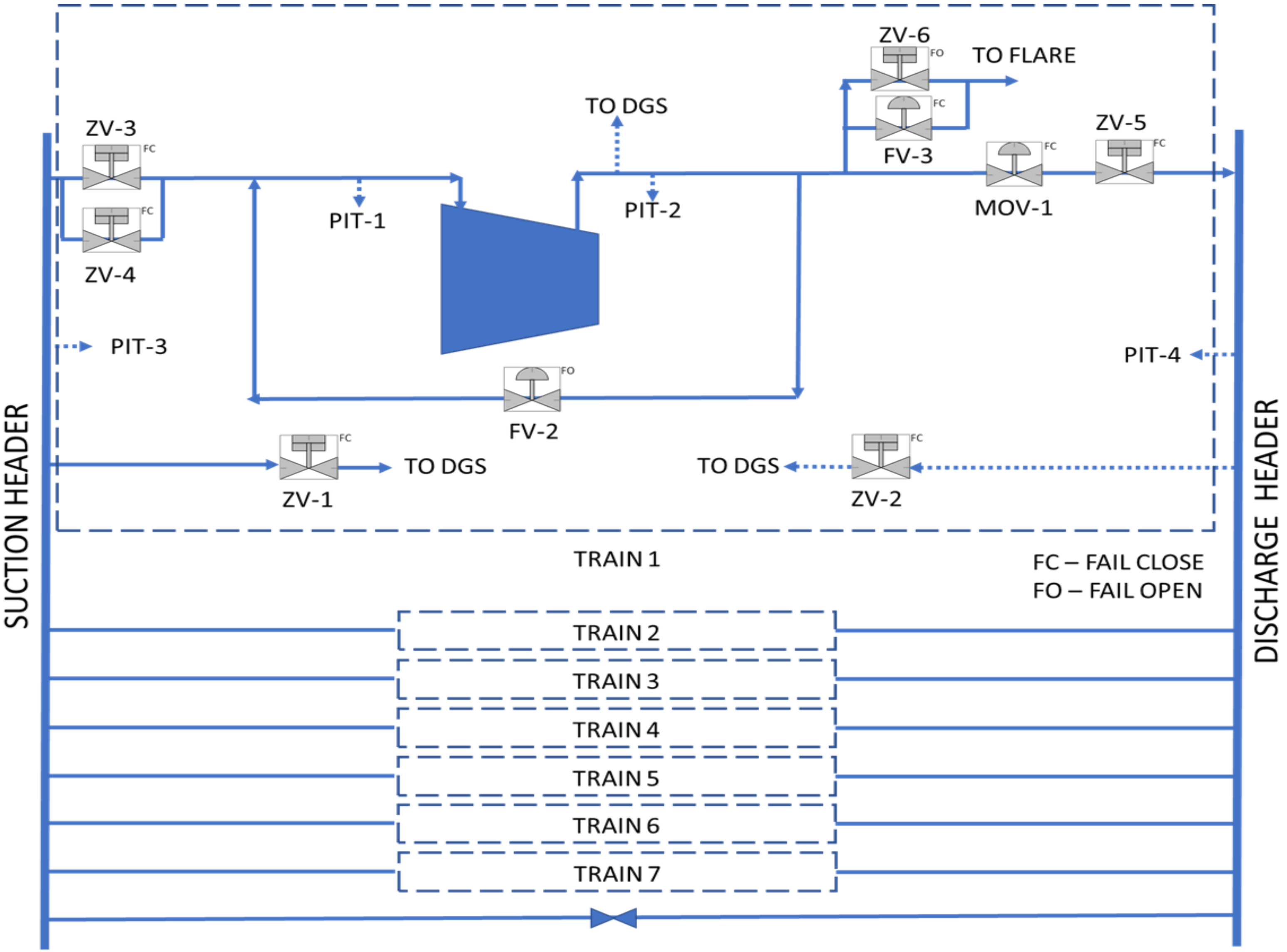


ACTUAL SOURCES OF SEAL GAS FOR EACH STATION

1. From DISCHARGE HEADER (when pressure has been raised to adequate delta P above suction header. Can be used for other trains startup, via valve ZV-2))
2. AUTOBUFFER from Compressor discharge (normal running)
3. From SUCTION HEADER (for transient conditions like black startup, compressor trip, etc., valve ZV-1)

STATION SCHEMATIC

Gas from Upstream Piping



Cooled higher pressure Gas to piping

FIRST / BLACK START-UP SEQUENCE

I. Nitrogen purge and depressurization of the compressor;

II. Process gas introduction in the loop by opening discharge line valves (ZV-5 and MOV-1) and the anti-surge valve (FV-2) ;

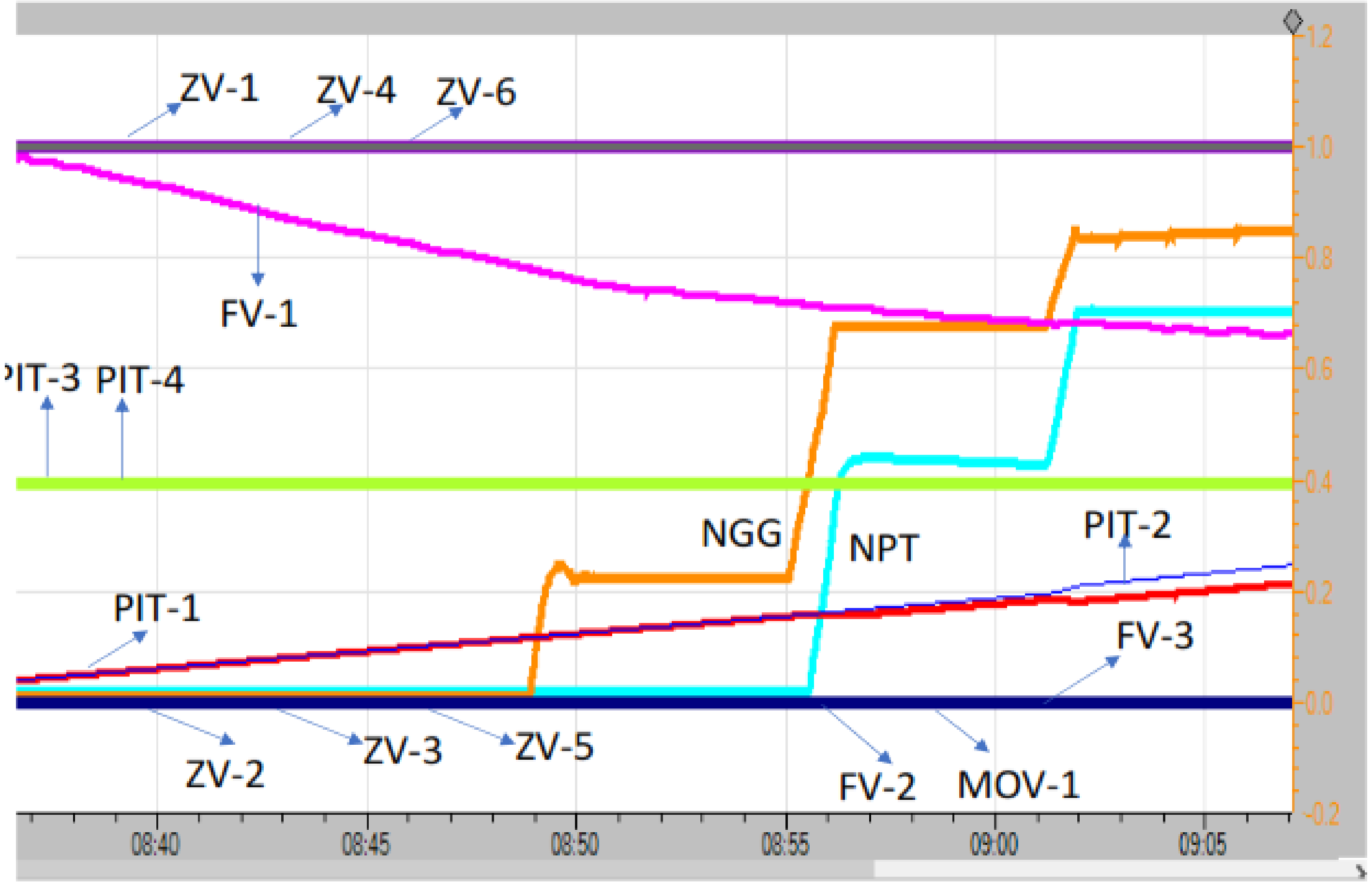
III. The compressor is pressurized until the pressure is at the required delta pressure below the suction header pressure. ZV-5 and MOV-1 are then closed;

IV. The compressor is started up and MOV-1, which has inching capability, maintains the discharge pressure to provide proper auto buffering of seal gas with ZV-5 open;

V. If start up is delayed, if required FV-3 maintains the required delta pressure below the suction pressure. In this unlikely scenario, gas to the flare is minimal if any since small leakages across system valves can raise the loop pressure requiring a depressurising;

VI. Once the discharge pressure at PIT-2 reaches the required delta pressure with respect to suction pressure, suction header seal gas valve (ZV-1) is closed, and the system goes to autobuffer from compressor discharge

STATION BLACK START-UP

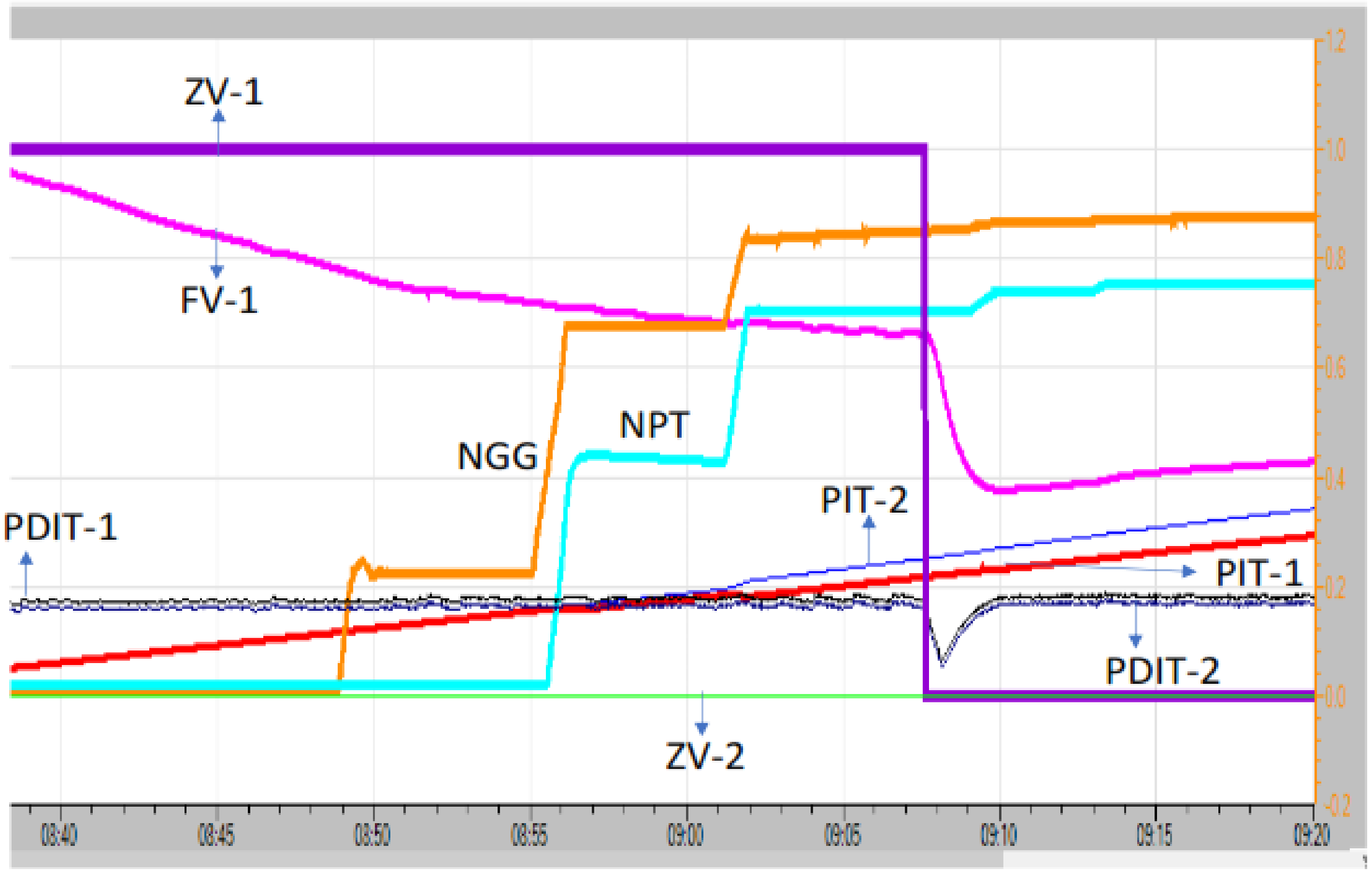


- NGG – Gas Generator Speed
- NPT – Power Turbine Speed
- PIT-1 – Compressor Suct. press
- PIT-2 – Compressor Disch. Press
- PIT-3 – Plant header Suct. Press
- PIT-4 – Plant header Disch. press
- FV-1 – Seal Gas Control Valve Cmd (In REG)
- FV-2 – Anti-Surge Valve Cmd (Ini.St - OP Fin.St – OP)
- FV-3 – Blow off Ctrl Valve Cmd (Ini.St - CL Fin.St – CL)
- ZV-1 – Ext.Seal Gas Suct. Side Cmd (Ini.St - OP Fin.St – OP)
- ZV-2 – Ext Seal Gas Disch. Side Cmd (Ini.St - CL Fin.St – CL)
- ZV-3 – Suction Main Valve Cmd (Ini.St - CL Fin.St – CL)
- ZV-4 – Suction loading. Valve Cmd (Ini.St - OP Fin.St – OP)
- ZV-5 – Discharge Main. Valve Cmd (Ini.St - CL Fin.St – CL)
- ZV-6 – Blow off Valve Cmd (Ini.St - CL Fin.St – CL)
- MOV-1 – Motoz. Inching Val.Cmd (Ini.St - CL Fin.St – CL)

REG – REGULATION, CL – CLOSE, OP -OPEN

- Compressor Discharge Pressure starts rising
- NOT enough delta pressure to achieve AUTOBUFFER
- Seal Gas from Suction Header

TRANSITION TO AUTOBUFFER

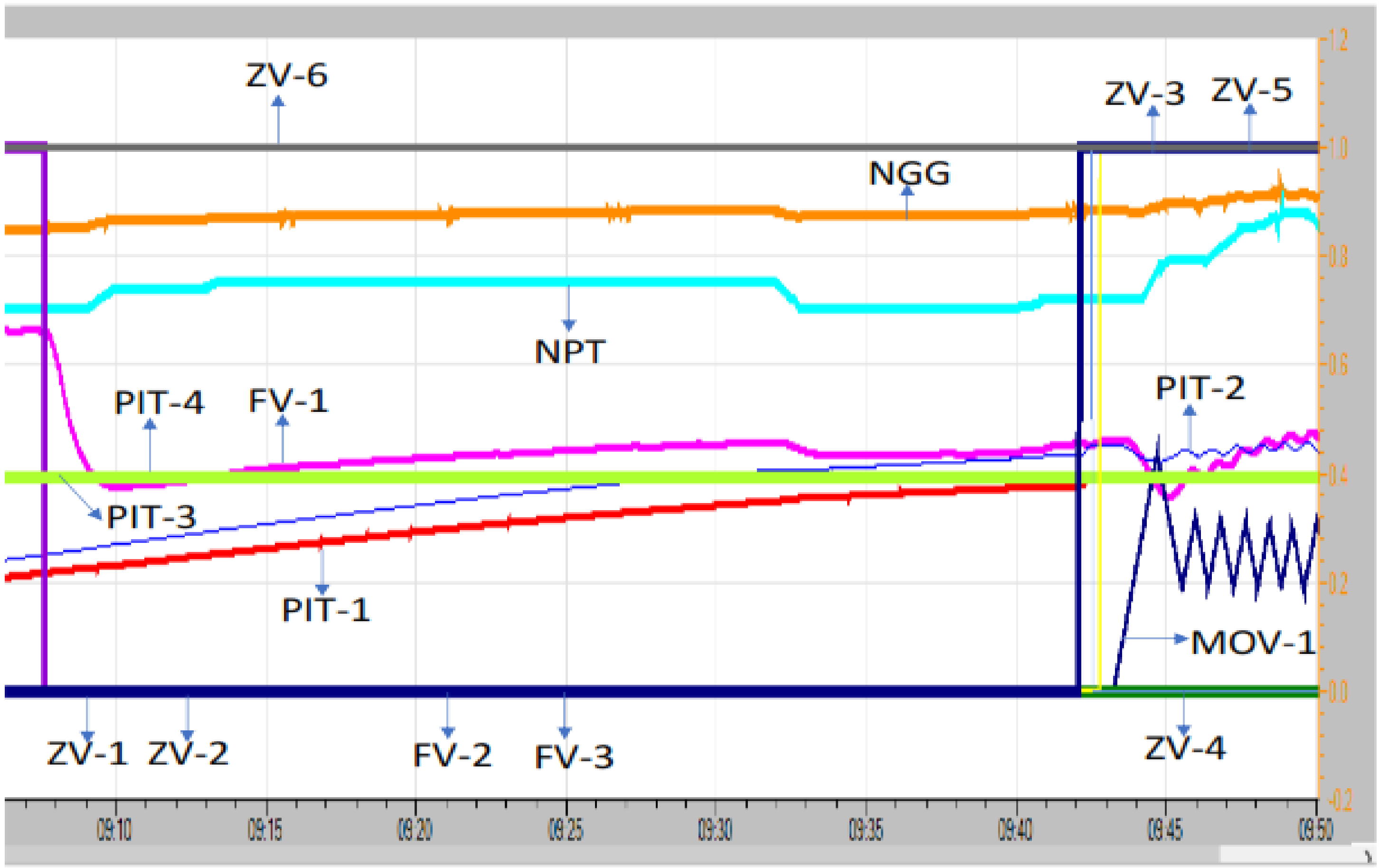


- NGG – Gas Generator Speed
- NPT – Power Turbine Speed
- PDIT-1 – NDE Seal Gas DP
- PDIT-2 – DE Seal Gas DP
- PIT-1 – Compressor Suct. press
- PIT-2 – Compressor Disch. Press
- FV-1 – Seal Gas Control Valve Cmd (In REG)
- ZV-1 – Ext Seal Gas Suct. Side Cmd (Ini.St - OP Fin.St – CL)
- ZV-2 – Ext Seal Gas Disch. Side Cmd (Ini.St - CL Fin.St – CL)

REG – REGULATION, CL – CLOSE, OP -OPEN

- Compressor achieved enough Seal Gas for AUTOBUFFER
- Suction Header connection is closed
- AUTOBUFFER starts to feed DRY GAS SEALS

START-UP SEQUENCE COMPLETED



- NGG – Gas Generator Speed
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- MOV-1 – Motoz. Inching Val.Cmd (Ini.St - CL Fin.St – REG)

REG – REGULATION, CL – CLOSE, OP -OPEN

- STATION under NORMAL RUNNING
- DRY GAS SEALS are fed by AUTOBUFFER

CONCLUSIONS

- ✓ The solution implemented in this case study of the initial startup of the compressor train allows gas from the suction header to be used as seal gas, by reducing the pressure inside the compressor below the minimum required for seal gas buffering;
- ✓ The seal gas system has been developed with different seal gas sources, which are available depending on the running condition (normal running, normal startup, black startup, compressor trip, etc.).

- ✓ The system control philosophy has been developed with the possibility to switch from one seal gas source to another, depending on the compressor actual running condition and its suction and discharge pressure levels

THANK-YOU!

QUESTIONS?