New recycle valves installed in 1994 on the compressors in the East Brae field in the North Sea corrected the noise and vibration problem that damaged the original valves shortly after commissioning the platform.

The original recycle valves, especially on the second-stage compressors, showed severe damage.

East Brae
To further develop the Brae field, Marathon Oil U.K. Ltd. brought on stream the Fast Brae platform (Fig. 1). First oil was produced in mid-December 1993.

East Brae primarily serves as a facility for recycling gas, exporting natural gas liquids or condensate to the Forties pipeline, reinjecting dry gas into the reservoir, and exporting gas to the SAGE pipeline for processing at the St. Fergus gas terminal.

The platform was designed to handle 125,000 b/d from a single-train separation system comprised of four main separation vessels and to process gas at the rate of 670,000 kg/hr (1,460,000 lb/hr) or 626 MMscfd.

Gas from the separation train was introduced into the first of three gas compressor trains in the early part of 1994.

Each train is driven by a General Electric LM5000 gas turbine. This engine is used as a gas generator to drive a power turbine manufactured by European Gas Turbines Ltd. The power turbine develops about 33 megawatts (mw) that, in turn, drive the three stages of the compressor through a gearbox. Suction gas at about 65 barg (940 psig) comes from the separation train via a glycol water removal system.

Gas discharge from the first compression stage, at about 166 barg (2,400 psig), can be exported to the SAGE pipeline and/or transferred to the next compression stage for injection into the reservoir.

North Brae gas can be imported into the second-stage suction and, along with East Brae gas, is compressed to about 290 barg (4,200 psig). The third and last compression stage raises the gas pressure to about 500 barg (7,250 psig) before entering the manifold for injection into the reservoir.

Each of the compressor trains can move 339,300 kg/hr (730,000 lb/hr) or 321 MMscfd of gas. Hence, two trains are required to handle all of the required capacity.

Each stage of compression is protected against compression surge by a fast-acting control system provided by the Compressor Controls Corp. This system modulates individual stage, recycle-control valves.

The valves were the multi-stage, drill hole-cage type. Problems with these valves during the commissioning stages led to their eventual replacement in the summer of 1994, and the previous problems have ceased.

Recycle system
Essentially, a recycle system functions by maintaining the minimum flow required to avoid surge conditions for the established compressor speed. Regardless of design or application, centrifugal compressors have one common characteristic. That is, at low flow because of high external circuit resistance, orderly gas flow through the compressor is impossible.
because gas velocities are too low to be converted to the required pressure energy level in the discharge line.

When discharge pressure exceeds impeller discharge pressure, backflow occurs until the discharge pressure is less than impeller outlet pressure. At this point, forward flow is reestablished, and the compressor operation is nearing unstable conditions, resulting in vibration and possible damage to the compressor.

This phenomenon is called “stall” and produces a “surge” in the system. As a function of its design, every centrifugal compressor has a “stall/flow” point at any given operating speed. While the gas flow corresponding to this surge point is fixed for a constant-speed compressor, it changes at each operating speed for a variable-speed compressor.

In any event, good industry practice dictates that compressor gas flow should never drop below 5% in excess of the surge point for any operating speed. It is for this purpose that compressor recycle valves are used to appropriately recycle gas flow from compressor discharge to suction to prevent operation below this critical flow.

**Recycle valves**
Compressor recycle valves perform two functions:
1. React quickly during startup and shutdown operations and to emergency situations.
2. Modulate recycle flow during normal operations to avoid compressor operation near or below the critical surge point.

Fig. 2 shows a typical recycle valve control integration into the compressor cycle. Fig. 2A indicates the relationship of the four critical flow points for three typical compressor operating speeds. Fig. 2B indicates safety on response, an operating feature of the control system.

If the line is crossed, the control and recycle trip lines will be moved to the right by X% because their position is assumed to be too close to the surge point. If crossed three times, the compressor will trip.

The main problems generally associated with compressor recycle valves include:
- The potential for high noise levels.
- Vibration.
- Inadequate response times such as the time required to fully open a closed recycle valve on system upset.
- Control instability (hunting) due to improper actuator and controls selection.

High noise levels in excess of 100 dbA can be experienced with conventional recycle valves. Severe vibration is created because of the high mass flow at high pressure drop. This can cause valve and trim fatigue and can also lead to piping failure.

Noise levels at East Brae have been reduced to below 80 dbA with accompanying drastic reduction in damaging vibration levels after fitting DRAG trimmed valves (DRAG is a registered trade mark of Control Component Inc.)

**Operations**
Each of the three compressors on East Brae normally handles 339,500 kg/h (750,000 lb/hr) of natural gas at 500 barg (7,250 psig), and 750 C (1670 F). This very high discharge pressure optimizes gas injection back into the reservoir.

Prior to entering each compressor train, the nature gas is scrubbed of water vapor. Shortly after initial commissioning of the platform, the drilled cage-type recycle valves, especially those serving the second stage compressors, showed signs of severe vibration. These problems involved excessive noise and vibration that led to valve damage.

Several modifications to the original design were tried to alleviate noise and vibration problems. The valve trim was improved to try to produce the effect of multistage velocity control.

In the spring of 1994, one valve failed to the closed position causing its compressor to surge. At this point, Marathon Oil decided to replace the valves with a different design.

**New valve design**
Initially, Marathon decided to retrofit the first-stage valves by replacing the existing drilled cages with a true multistage trim design with the existing valve bodies. But this proved impractical because Marathon felt that it could not afford to take the first-stage recycle valves out of service for the time required to transport them ashore and install new multi-
stage trim.

Therefore, only two sets of first-
stage multistage valve trim were
ordered for valve retrofit and one
complete new first-stage valve
was purchased to initiate the to-
tal recycle valve replacement
process.

Because time was short, and a
new cast steel body could not
be procured within the required
accelerated delivery schedule,
the replacement first-stage valve
body was machined out of a
forged steel billet with enlarged
internal gas passages (Fig. 3).

A forged steel billet uses more
material than a cast steel valve
body and is therefore heavier but
has the advantage of absorbing
more vibration. Existing face-face
dimensions were held, and the
new body was machined with
Grayloc fittings to match exist-
ing piping requirements.

Second and third-stage re-
placement valves were procured
again with bodies fabricated from
forged steel billets, incorporat-
ing multistage velocity letdown.
First stage (10 in. x 10 in.) and
second stage (4 in. x 4 in.) gas
recycle valve bodies were de-
signed in accordance with ANSI
1500 and 2500 requirements   re-
spectively, but third stage (4 in. x
4 in.) valve bodies were in accor-
dance with API 10,000.

API design rules allow bolted
end connections as per Mara-
thon specification.

Table I shows the essential
operating parameters of the re-
cycle valves. First-stage recycle
valves in each train were “char-
acterized” (Fig. 4) with four, mul-
tistage disk groups to produce
linearity within the control range
(valve coefficient Cv-vs.-valve
stroke) up to about 62% of maxi-
num stroke.

A velocity-control transition
zone was incorporated from 62
to 75% of stroke. From there to
100% of stroke, no velocity con-
trol was needed. Flow in this
range is required for settle-out
flow, such as the result of a trip
and isolation. Discharge flows
back to suction to settle out at
some intermediate pressure.

Second and third-stage re-
cycle valves were not character-
ized; for example, valve coeffi-
cient Cv-vs.-stroke was linear
from 0 to 100% of stroke.

For the retrofit of the first-stage
valves, replacement trim had to
fit into the existing valve bodies
in all respects without the need
for remachining the existing
valve bodies. This meant that
the multistage, redesigned trim
was confined to a 6-in. stroke.
Subsequently, complete first,
second, and third-stage trim was
also designed with a 6-in, stroke,
allowing all nine replacement
valve actuators to be exact du-
plicates.

Fig. 5 details the basic recycle
valve design now in use at
Marathon’s East Brae platform.
The valve is uniquely suited for
compressor recycle service be-
cause it specifically addresses
and solves the potential prob-
lems in this tough service.

Also, this replacement recycle
valve design provides for gas
flow modulation. Therefore, in
addition to reacting quickly to
protect the compressors during
start-up and emergency situa-
tions, the valves modulate the
flow during normal operations to
avoid compressor operation near
or below the surge point.

Noise and vibration

The new recycle valves incorpo-
rate a tortuous flow path. That
is, pressure energy is dissipated
at a controlled velocity head
through multiple, right-angle
turns in a stack of individual
disks.

At East Brae, the replacement
valve trim disks are electro-dis-
charge machined (Fig. 6). The stack
of disks surround the plug through-
out its stroke in the second and third-stage valves. In the first-stage valves, these characterized disks are in only up to 75% of the stroke. Above this, a drilled cage is used because no velocity control is required.

Velocity head \( (pV^2/2) \) through the disk stack is limited to 0.52 MPa (70 psi) to minimize noise and vibration. In addition, the disk stack incorporates a pressure equalizing ring (PER) on its inside diameter to ensure equal pressure acting radially on the valve plug at all times to eliminate vibration that could occur because of rapid plug radial movement.

This propensity for rapid plug radial movement undoubtedly caused plug guide galling in some valve designs. This tortuous path, velocity control design limits noise levels to below 80 dB.

These recycle valves are designed with an ANSI Class V plug/seat-ring design and materials to assure tight valve closure at shutoff. In this under-the-plug design, gas flow passes through the plug/seat-ring area under full compressor discharge pressure. The gas then enters the energy dissipating disk stack that is designed to accommodate changes in gas density from the expanding gas volume.

For the same reason, where new forged steel valve bodies were provided for Fast Brae, larger body runs in this area were machined-in to achieve minimum velocity head.

**Valve actuators**

In an upset situation to protect the compressors from severe damage, the nine recycle valves on the East Brae platform must rapidly stroke from full closed to full open. A 2-sec stroking, through the 150-mm (6-in.) full valve travel, is achieved with quick exhaust valves on both sides of the pneumatic, double-acting actuator piston.

Fig. 7 applies to all nine identical actuators. The actuator is supplied with 5.5-6.8 barg (80-100 psig) air that is controlled by a 4-20 ma input signal to the positioner. Because a spring acts on the actuator piston, quick opening is assured in the event of either power or air failure.

Because all nine actuators incorporate a 150-mm (6-in.) stroke, the installation has maximum interchangeability should the need arise.

All new replacement and retrofitting compressor recycle valves at Marathon’s East Brae platform have been installed. Marathon’s evaluation of the performance indicates that noise and vibration have been significantly reduced to background levels and, in its opinion, previous problems have been eliminated.

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