

A Closed-Loop Approach to Turbomachinery Asset Management

Flexware Inc. brings together remote performance monitoring, root cause engineering, precision manufacturing, and field services under one roof—giving operators a true end-to-end partner for the life of their rotating equipment.

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For operators of centrifugal and axial compressors, gas turbines, steam turbines, and pumps, the frustration of managing multiple service vendors across a single equipment problem is a familiar one. A vibration anomaly triggers a call to one firm for analysis, another for replacement parts, another for installation—and still another, perhaps, for ongoing monitoring once the machine is back online. Grapeville, Pennsylvania-based Flexware, Inc. is built to eliminate that fragmentation.

"If a client has a problem, we can complete the root cause analysis, redesign the affected parts, manufacture and install them for a longer trouble-free life, then monitor the machine remotely to confirm it's running clean—and if necessary, plan future maintenance according to what the monitoring forecast tells us. That full loop, handled by one team, is what sets us apart," says Ted Gresh, President & CEO, Flexware, Inc.

FCAM: THE CLOUD-CONNECTED EYE ON YOUR ASSET

At the center of Flexware's service offering is the Flexware Cloud Asset Monitor (FCAM; **Figure 1**), the company's cloud-based platform for continuous performance and vibration monitoring. FCAM collects operating data in real time—flow, pressure, temperature, efficiency, vibration, seal leakage and other process variables—transmits it securely to the cloud, and presents it through a unified dashboard accessible to both the operator and Flexware's engineering team.

The platform is built around four core functions: trending and forecasting, diagnosis, analysis, and problem resolution. Trending and forecasting capabilities allow

Flexware engineers to identify gradual performance deterioration—efficiency erosion, increased seal leakage, changes in vibration—well before those trends manifest as an unplanned outage. This predictive posture converts reactive maintenance into a managed, scheduled activity, with direct consequences for operating cost and plant availability.

Diagnosis goes deeper. When an anomaly appears, FCAM's data record gives Flexware's turbomachinery engineers the raw material for a true root cause investigation—not a guess based on a single field measurement, but a time-stamped history of how the machine arrived at its current state (**Figure 2**). That diagnostic foundation is precisely what enables the next step in the Flexware model: engineering-led problem resolution.

FROM MONITORING TO ENGINEERING ACTION

Where many monitoring services end with a report and a recommendation, Flexware's model extends into execution. The company's engineering staff, with decades of hands-on experience in turbomachinery design and failure analysis, translates FCAM findings into corrective action.

Root cause failure analysis is available for a broad range of mechanical failure modes, including gas face seals, oil seals, bearings, impeller failures, and vibration and rotor dynamics problems. When a failure mode is identified, Flexware's aerodynamic and mechanical engineering capabilities allow the team to redesign the affected components—not simply replace them with the same part that failed.

Gas path modeling supports rerates and upgrades for both compressors and turbines, enabling Flexware to optimize a

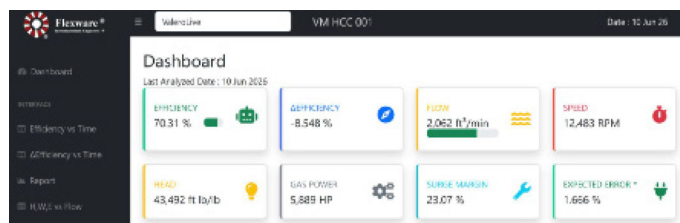


Figure 1: Flexware Cloud Asset Monitor dashboard. Credit: Flexware Inc.

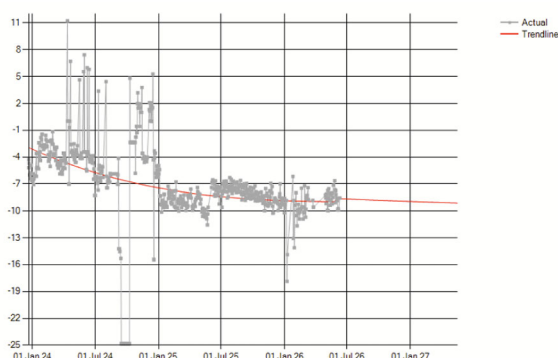


Figure 2: % Delta efficiency vs time. Credit: Flexware, Inc.

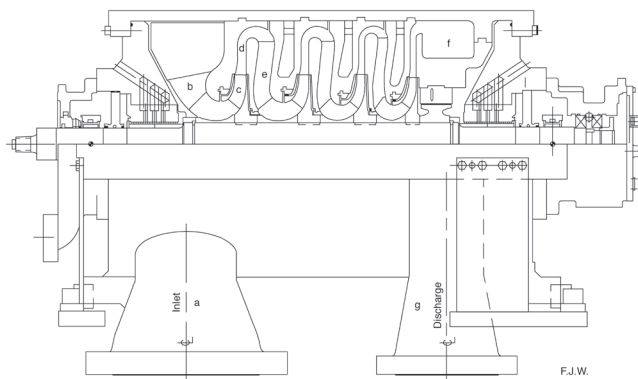


Figure 4: The major elements of the centrifugal compressor consist of (a) the inlet nozzle, (b) inlet guide vanes, (c) impeller, (d) radial diffuser, (e) return channel, (f) collector volute, and (g) discharge nozzle. Credit: Flexware, Inc.

machine's performance characteristics rather than simply restore them to original specification (**Figure 3**). The company's software tools—including CompAero for compressor aerodynamic design and TurbAero for turbine design—underpin this work, and have been used by turbomachinery engineers and OEMs for years. Flex Live, Flexware's performance

monitoring software, completes the software portfolio with real-time performance tracking capabilities that integrate naturally with FCAM data streams.

Finite element analysis using ANSYS is available for frequency, thermal, transient, and steady-state problems. Rotordynamics analysis—covering critical speeds, stability



Figure 3: Flexware service personnel reassembling a Rolls Royce RF2BB-36 Compressor in Cempoala, Mexico following a reate to improve gas delivery service. Credit: Flexware Inc.

analysis, and damper bearing and seal design—rounds out the analytical toolkit, giving Flexware the depth to address even complex, multi-discipline failure scenarios.

MANUFACTURING, PARTS, AND EFFICIENCY ENHANCEMENTS

Engineering solutions require physical execution, and Flexware supports its analysis work with the ability to supply redesigned and replacement parts. Turbomachinery spare parts—including bearings, seals, impellers, and diaphragms—are available through the company, along with Cartridge Sleeve Seals developed using Flexware's proprietary repair technology.

Efficiency enhancement programs address specific loss mechanisms within the gas path. Rub-tolerant labyrinth seals reduce leakage flows without the risk of seal-induced instability. Aerodynamic coatings improve surface finish and reduce profile losses. Impeller staging redesign can recover efficiency points lost to original design compromises or years of operational wear. These targeted interventions, applied after a proper performance analysis, deliver measurable improvement in flow capacity and compression efficiency—outcomes that translate directly into operating cost reduction for the end user.

For operators considering new equipment or modifications to existing trains, Flexware provides design and specification review, inspection and test witness services, and commissioning and startup support, ensuring that new assets enter service with a thorough independent engineering check behind them.



Figure 5: Routine field inspection of a Cooper MSG fuel gas compressor for Electrocentrale Bucuresti, Bucharest, Romania.

OVERHAULS AND FIELD SERVICES

Flexware's field service capability extends to full overhauls of compressors, pumps, gas turbines, and steam turbines. Disassembly, inspection, repair, and reassembly are performed by the same engineering team responsible for root cause analysis and redesign—a structural advantage over arrangements where field mechanics and design engineers operate independently (**Figure 5**).

Inspection services are available as a standalone offering for operators who want an independent assessment of equipment condition between scheduled overhauls, or following an operating event such as a surge, trip, or process upset.

The practical effect of this integrated model is a closed-loop lifecycle: FCAM identifies a developing problem, Flexware engineers perform root cause analysis, redesigned parts are manufactured and installed, and the machine goes back online under FCAM surveillance—with a forecasting model now informed by the actual repair history of that specific asset.

TRAINING AND KNOWLEDGE TRANSFER

Flexware also supports the broader development of operator and engineering competency through training seminars covering Flexware software tools, compressor performance principles, and general turbomachinery mechanical and aerodynamic design and operation. For organizations building internal capability, these programs complement the monitoring and engineering services by raising the technical baseline of the people working alongside Flexware engineers day to day.

LOOKING AHEAD

The increasing push toward maximizing asset utilization and deferring capital expenditure on new equipment makes Flexware's model particularly relevant. For many operators, the most cost-effective path to improved performance is not a new machine—it is a thorough understanding of what the existing machine is doing, why, and what a well-targeted

intervention can accomplish. FCAM provides that understanding continuously. Flexware's engineering and field service capabilities provide the response.

"Contact us today about your turbomachinery questions and challenges. We will be glad to share our experiences with you." — Collin Pillay, Director, Flexware, Inc. ■

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