

Real-Time Condition Monitoring of Water-Glycol Fire-Resistant Hydraulic Fluids

Inline measurement of water/glycol concentration, viscosity and particle contamination, with an optional pH node, for HFC fluid integrity and fire safety

Water-glycol (HFC) fire-resistant hydraulic fluids are used wherever a hydraulic leak could meet an ignition source: steel mills, foundries, die-casting and mining. Their fire resistance, viscosity and wear protection all depend on keeping water content within a narrow band. Water evaporates in service, so the fluid drifts out of specification between periodic laboratory samples.

Spectrolytic **FluidInspectIR®** combines our novel mid-infrared (MIR) measurement engine with inline viscosity and particle-count sensors to track water/glycol concentration, viscosity and cleanliness continuously, with an optional pH probe node where pH is required.

R² = 0.97 Water content model (MIR, 0–100% water)	~2% Expected RMSE over the 0–50% water range	Multi-sensor Water/glycol · Viscosity Particles · optional pH node
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The Challenge

An ISO VG 46 water-glycol hydraulic fluid typically contains 35–45% water. Water gives the fluid its fire resistance, but it also sets its viscosity: as water evaporates from a hot hydraulic system, viscosity climbs and fire resistance falls. The viscosity window for this fluid is just 39–42 cSt at 40 °C.

Historical laboratory reports for the system illustrate the problem. Between May 2023 and May 2024, viscosity rose from 41.4 cSt to 59.7 cSt, more than 40% above the upper limit, and was only flagged once the laboratory reported atypical results. Particle cleanliness swung between ISO 14/13/10 and 19/17/15 over the same period.

- Water loss goes unseen between laboratory samples, eroding fire resistance
- Viscosity drifts out of the 39–42 cSt window with no early warning
- Particle contamination swings by several ISO codes between samples
- Strong, overlapping water and glycol IR bands make conventional analysis of these fluids difficult
- Make-up and fluid-management decisions are made weeks after the fluid has changed

The Solution

Spectrolytic FluidInspectIR® was evaluated on the water-glycol fluid, combining three inline measurements in one system: water/glycol concentration from our novel MIR engine, temperature-compensated viscosity from an integrated inline viscometer, and particle counting reported as ISO 4406 cleanliness codes.

Water and glycol dominate the mid-infrared spectrum of an HFC fluid, with broad, overlapping O–H, C–H and C–O bands. The MIR engine measures the infrared spectrum, and a chemometric model converts the signal directly into water content. Where pH must be monitored, an **optional inline pH probe node** can be fitted to the same system.

Implementation

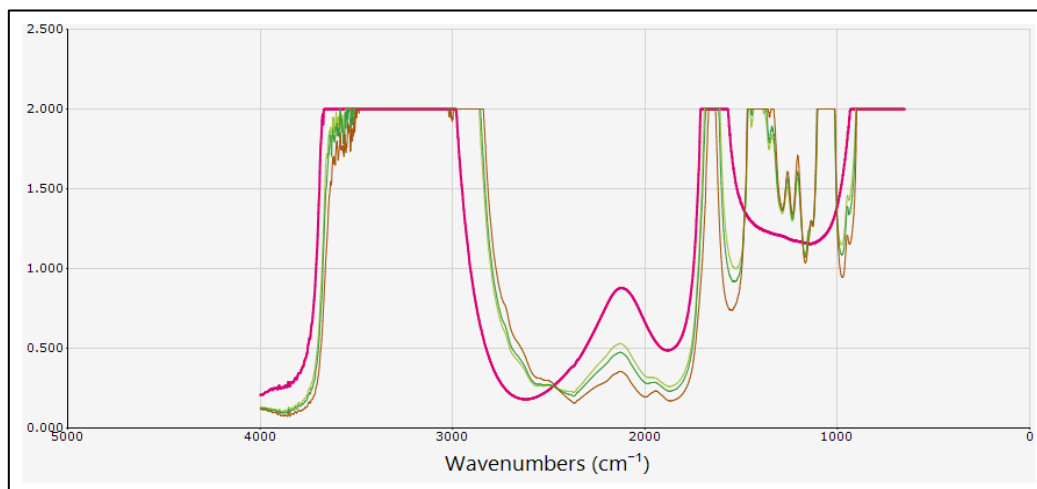
- Reference water/glycol blends from 0 to 100% water, including the 30–50% working range, measured on a laboratory FTIR and natively on the FluidInspectIR® MIR sensor
- Chemometric water-content model built from the MIR sensor data ($R^2 = 0.973$, RMSE = 5.4 across 0–100% water)
- Unseen in-service HFC fluid sample predicted against the model, with no sample preparation
- Inline viscometer characterised from 31 to 65 °C; converts live readings to KV40 for direct comparison with the 39–42 cSt specification
- Inline particle counting reports cleanliness as ISO 4406 codes, the same format as the laboratory reports
- Optional pH probe node available for sites that require pH (specification for this fluid: pH 9–10)

Results

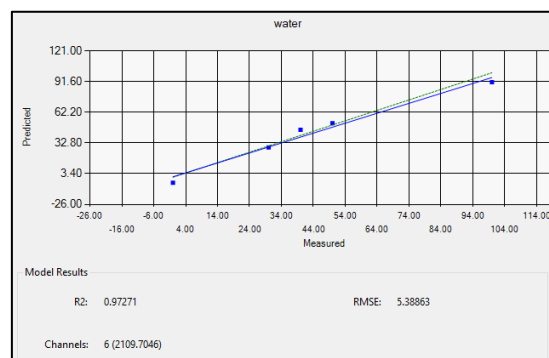
The feasibility study demonstrated the following:

- Water content of the unseen HFC sample predicted at **46.4%** directly from the MIR spectrum
- Water-content model $R^2 = 0.97$ across the full 0–100% range, with error expected to fall to around 2% when the model is focused on the 0–50% operating range
- All absorbance features in the fluid's spectrum attributed to water and glycol, confirming the MIR engine measures the fluid's two key constituents
- Viscosity–temperature behaviour captured by a single power-law relationship, enabling continuous KV40 reporting inline
- Water/glycol concentration, viscosity and particle counting combined in one inline system, with pH available as an add-on node

USE CASE: WATER-GLYCOL HFC FLUIDS — WATER CONTENT, VISCOSITY & CLEANLINESS



Mid-infrared absorbance spectra of pure water (pink) and 30–50% water/glycol blends (green and brown).



MIR water-content model, predicted vs measured ($R^2 = 0.973$, RMSE = 5.4, 0–100% water).

Operational Impact

- Continuous visibility of water content, the parameter that governs both fire resistance and viscosity
- Early warning of water loss, so make-up water can be added before viscosity leaves the 39–42 cSt window
- Inline particle counting flags contamination events and filter issues as they happen, not weeks later
- Fewer laboratory samples and less manual sampling of hot hydraulic systems
- Trend data provides traceability for fire-safety audits and maintenance planning
- Optional pH node completes the picture of fluid condition from a single installation

Key Insight

Water-glycol fluids are among the hardest fluids to analyse by infrared: water and glycol absorb so strongly that most of the spectrum is saturated. By targeting a water band in a clear spectral window, the FluidInspectIR® MIR engine turns that challenge into a direct, inline measurement of water/glycol concentration. Paired with inline viscosity and particle counting, it gives operators the three numbers that matter most for HFC fluids, continuously.

Financial Benefits

Protected fire safety + extended fluid life + fewer unplanned stops:

Strong ROI case

Comprising: optimised make-up water and fluid top-ups, extended fluid and component life, reduced laboratory testing, and avoided downtime from out-of-specification fluid

Conclusion

Spectrolytic FluidInspectIR® brings real-time, inline monitoring to water-glycol fire-resistant hydraulic fluids, measuring water/glycol concentration with our novel MIR engine alongside viscosity and particle counting in a single system.

With a water-content model achieving **R² = 0.97** and the option to add a **pH probe node**, FluidInspectIR® gives operators continuous control of the parameters that define HFC fluid performance and fire safety.

Organisations that deploy FluidInspectIR® can move from reactive, sample-based checks to predictive fluid management, keeping HFC fluids in specification, protecting equipment and maintaining fire resistance.

Interested in understanding how this can be applied within your operations?

Patrick Taylor | patrick.taylor@spectrolytic.com | +44 7795 260490
Carsten Giebeler | carsten.giebeler@spectrolytic.com | +44 7515 697010

spectrolytic.com