VELAN

# Hardfacing in Power Plant Applications: Challenges and Solutions

Hidden risks that can escalate into major plant events

# F91 HARDFACING DELAMINATION AND CRACKING

Understand the risk. Trust the solution. Protect your plant.

## THE ISSUE

Hardfacing delamination occurs in F91 valves. Separation of the hardfaced layer from the underlying F91 base material.

## WHAT CHANGED

Operating conditions have evolved.

Increased cycling
Frequent startups and shutdowns
High sustained temperatures (>1,000°F / 540°C)

## THE CONSEQUENCE

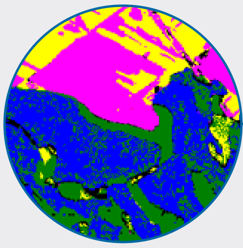
SMALL DEFECT → MAJOR PLANT RISK.

Fragments travel downstream

Potential turbine damage

Forced outages

Extended downtime and repair costs

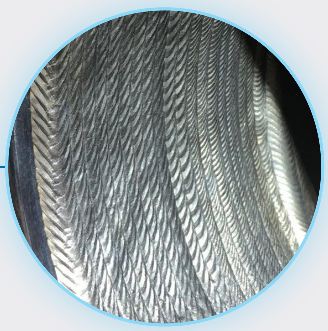


## ROOT CAUSE INSIGHT

Legacy hardfacing systems are vulnerable.

Traditional Stellite™ buffer layers can form hard, brittle phases over time

Increased susceptibility under cycling conditions



## VELAN SOLUTION

Proven design improvement implemented in 2016:

Nickel-based buffer layer
Retention of Stellite™ 6 hardfacing
Optimized welding procedures and dilution control

No reported delamination claims
Stable long-term performance in cycling service

## WHAT TO DO NOW

Assess and act proactively.

Evaluate installed base Identify at-risk valves.

Replace or upgrade with validated solutions.

Protect reliability and avoid costly outages.

# In-Service Failure Modes in Valve Hardfacing

## Industry Experience and Lessons Learned from Power Plant Applications

Cr-Mo ferritic steels are widely used in power generation to achieve higher operating temperatures and improved plant efficiency. Historically, low-alloy ferritic steels such as Grades 11 and 22 were used in applications below 1,000°F (537°C), under relatively stable operating conditions. With increasing efficiency demands, the industry transitioned to higher-temperature materials such as Grade 91 (F91 / 9Cr-1Mo-V) for critical components.

To protect against wear and high contact stresses, Co-Cr based hardfacing (Stellite™ alloys) is applied on functional surfaces of valves operating under severe service conditions.

However, increasing performance requirements continue to push the metallurgical limits of these material combinations. The interaction between F91 and Stellite™ hardfacing systems is therefore a key engineering focus under elevated temperatures and long service durations.

## What Changed?

Hardfacing delamination was historically rare under traditional base-load operations, where thermal and mechanical conditions remained relatively stable. However, as power plant operations have evolved toward more flexible and cycling duty, the issue has become increasingly prevalent across the industry.

In modern combined-cycle power plants, since the early 2000's, operating conditions, frequent thermal cycling, rapid start-ups and shutdowns, and sustained exposure above 1,000°F (540°C), significantly increase thermo-mechanical loading at material interfaces. These conditions accelerate interfacial degradation in the F91–Stellite™ system, increasing the risk of hardfacing delamination in service.

## In-Service Hardfacing Main Failure Modes

Two primary in-service failure modes are observed in valve hardfacing systems:


**Radial (Transverse) Cracking**

Cracks initiate within the hardfacing layer and propagate through the deposited Stellite™ material, driven by excessive thermal and mechanical stresses beyond the interface's capacity to accommodate service conditions.

**Delamination (Disbonding / Interfacial Cracking)**

Delamination occurs when the hardfacing layer separates from the F91 base material, typically initiating at the fusion line or butter layer region. This interfacial failure leads to circumferential cracking and progressive loss of adhesion between the deposited layer and the substrate.

# Delamination and Radial Cracking: A Plant-Wide Operations Risk

## Radial Cracking and Delamination are Two Phenomena with Different Root Causes

These degradation phenomena are primarily observed in:

- Main steam stop valves
- Stop check valves
- Other critical pressure-seal valves in combined-cycle and fossil power plants

These applications are highly critical to maintain active power delivery services; any interruptions can be financial losses.

## Why Radial Cracking and Delamination is More Than a Valve Problem

When hardfacing delaminates, liberated metal fragments can be entrained in high-energy steam flow and transported downstream. In severe cases, these particles may:

- Enter the steam path
- Impact turbine throttle components
- Damage throttle baskets and internal hardware
- Result in significant turbine damage

The consequences can escalate rapidly, including:

- Forced plant outages
- Extended downtime lasting months
- Repair and replacement costs reaching tens of millions of dollars

Hardfacing delamination is therefore not merely a maintenance concern, but a **critical plant reliability and risk management issue.**

**Stellite™ hardfacing delamination of a seat ring***

**Stellite™ debris***

** Photo credits: Kim Bezzant, "Inspect steam valves for Stellite™ delamination", Combined Cycle Journal, 2013 (www.ccj-online.com/steam-valves)*

# Ahead of the Industry: Velan's Proven Delamination Solution

## Early Technical Understanding

Velan initiated investigations into F91 hardfacing delamination well before it was widely recognized across the power generation industry, including work conducted prior to formal EPRI engagement.

This technical foundation was built through a holistic, multi-disciplinary approach combining materials science, failure analysis, and service experience, including:

- Independent metallurgical research, including accelerated aging studies simulating long-term service conditions and advanced microstructural analysis of hardfacing behavior
- Participation in the EPRI P87 program investigating cracking and disbonding of hardfacing, contributing to industry-level understanding of degradation mechanisms in hardfaced alloys
- Failure analysis of in-service components, providing direct insight into crack initiation, interfacial degradation, and delamination mechanisms under operating conditions
- Field trial evaluations under representative cycling service conditions, supporting validation of material performance in real operating environments

Through this integrated body of work, Velan developed a comprehensive understanding of the interaction between base materials and hardfacing under cyclic thermal and mechanical loading, including time-dependent microstructural evolution at the interface. This work was supported by unique experimental data generated by Velan, combining metallurgical testing, failure analysis of in-service components, and field-based validation.
The results further showed that traditional Stellite™ 21 buffer layers can undergo progressive microstructural changes, leading to increased hardness and reduced toughness over extended exposure, thereby increasing susceptibility to interfacial degradation and delamination under demanding operating conditions.

It also enabled the validation of the stability and performance of the alternative nickel-based buffer layer, demonstrating improved resistance to metallurgical degradation under long-term cyclic service conditions.

# Ahead of the Industry:
# Velan's Proven Delamination Solution

## Implementation of the Proven Solution

Based on these findings, Velan implemented a qualified improvement directly addressing the root cause of interfacial degradation:

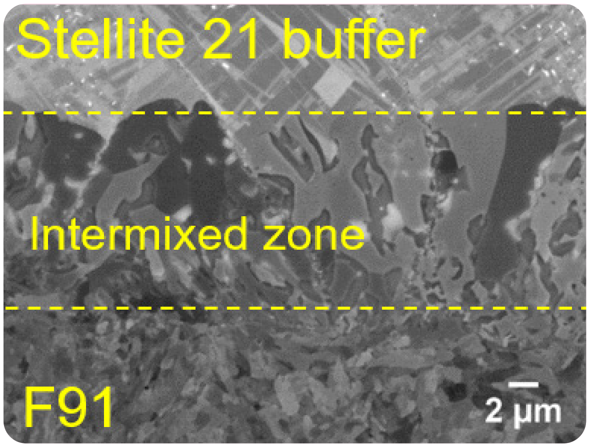
- Replacement of the Stellite™ 21 buffer layer with a nickel-based alloy buffer system to improve metallurgical stability under cyclic service conditions
- Retention of Stellite™ 6 hardfacing as the wear-resistant surface layer
- Optimization of welding procedures and dilution control to ensure consistent interface integrity and stable metallurgical behavior

## Field Performance

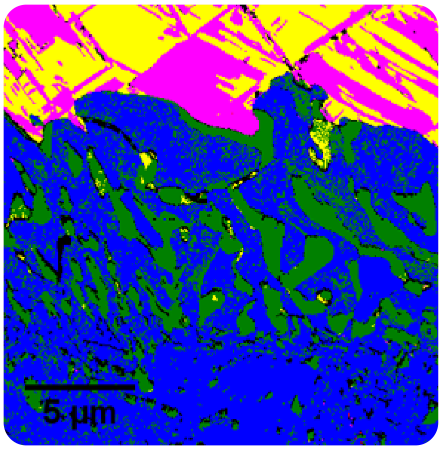
Since implementation in 2016, field experience has demonstrated:

- No reported delamination-related service claims across installed units
- Stable long-term performance of seats and discs under cyclic operating regimes
- Proven reliability in high-temperature, load-following and cycling service conditions

### Traditional Stellite™ 21 Buffer Layer

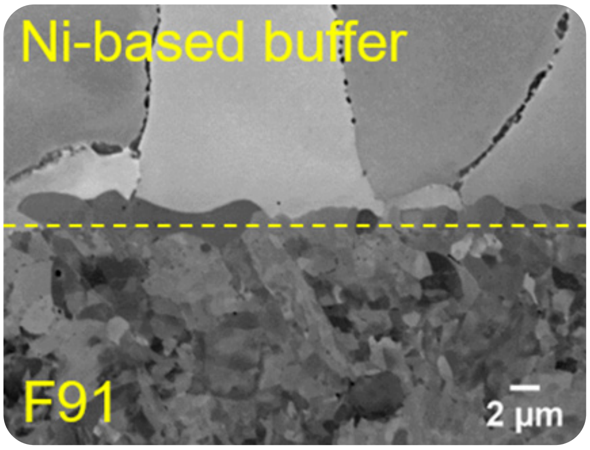



Aged microstructure showing interfacial degradation mechanisms




Advanced analysis of the hardfacing interface identifying the metallurgical changes associated with delamination

### Nickel-Based Buffer Layer




Aged microstructure demonstrating improved long-term stability

# Managing the Risk:
# Velan Aftermarket Services

## Why Velan Aftermarket?

Velan Aftermarket brings the OEM knowledge, technical experience, and service capabilities needed to support F91 Type 2 forged valves throughout their operating life.

Our team combines decades of metallurgical and field experience with proven hardfacing solutions that have been in service since 2016.

As both an OEM and aftermarket provider, Velan offers new valves and full lifecycle support from assessment through repair or replacement, while extending service life, minimizing unplanned outages, and enabling safe operation in cycling conditions.

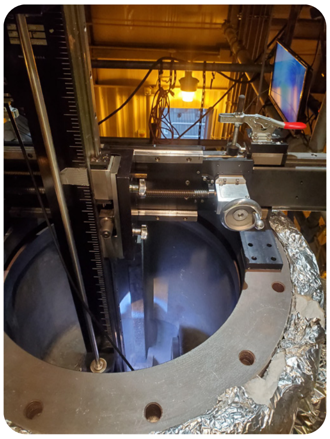
## How Velan Aftermarket Helps You Manage the Risk

**Many plants are still operating valves manufactured before these improvements were introduced. Velan Aftermarket helps operators determine whether those valves remain at risk.**

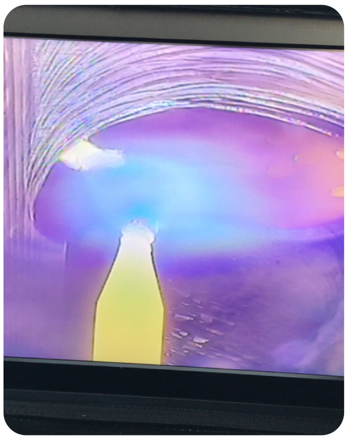
Our Evaluation Approach:

- On site plant visits
- Review of valve service history and past repairs
- Identification of valves 10+ years in service
- Assessment of symptoms such as:
  - Excessive leak by
  - Sticking or restricted stroke (often at 50–60%)
- Recommendations for borescope inspections, where appropriate

This process helps determine whether past repairs were temporary fixes or permanent solutions.



**Robotic welding machine with visual screen system**



**Live welding on visual screen**

## Permanent Solutions — Not Temporary Fixes

Based on the assessment, Velan Aftermarket can support:

- On site seat replacement using delamination resistant materials
- Complete valve replacement, when required
- OEM replacement parts manufactured in North America
- Repairs aligned with Velan's validated hardfacing specifications

**Be proactive. Address delamination risk before it becomes a failure.**

**Talk to us today about assessing your F91 installed base.**

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