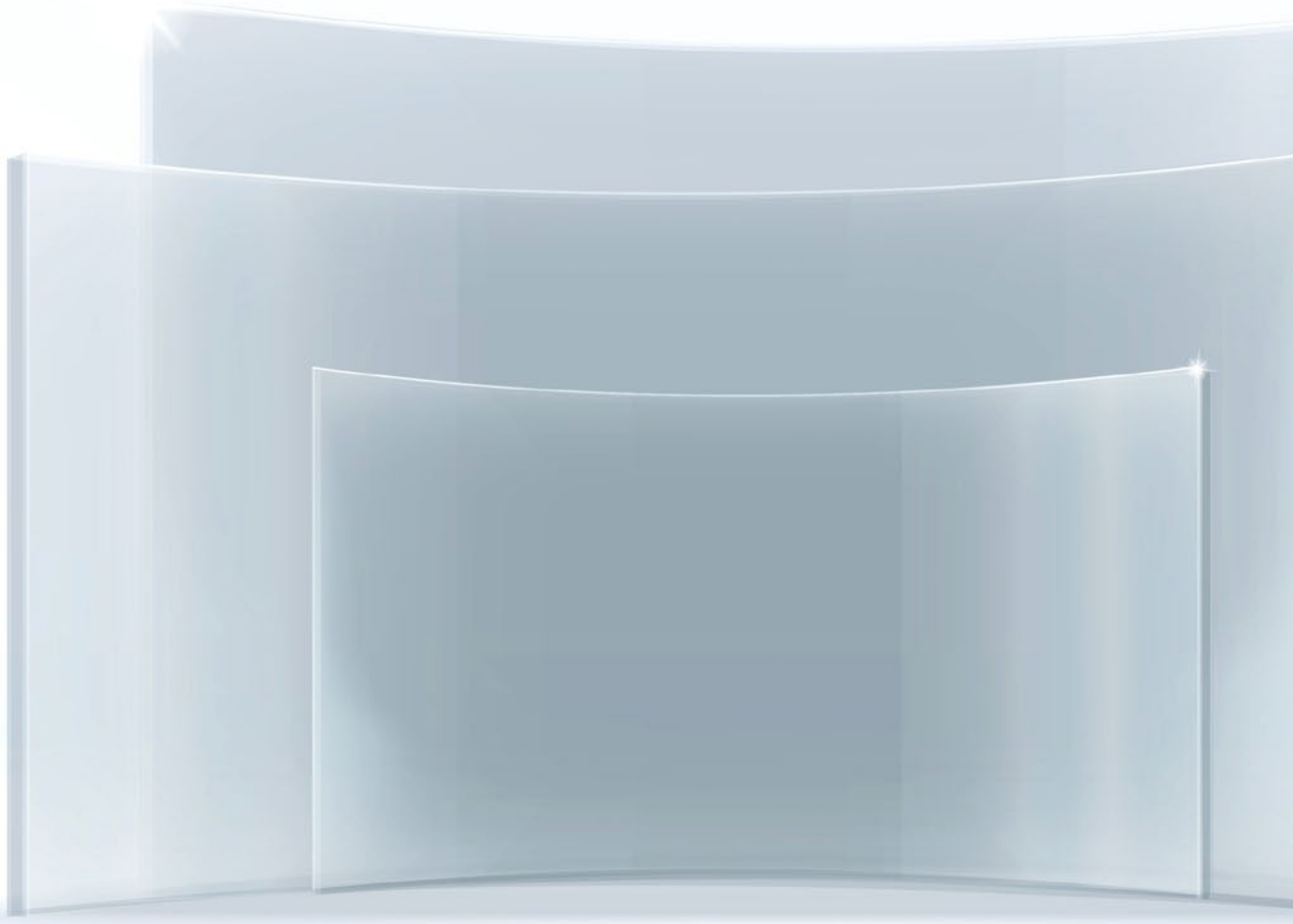




Interleaving Solutions for Next Gen Tempered Glass



The global glass manufacturing sector is currently navigating a period of unprecedented technological advancement. As architects demand larger, more transparent structural elements and the automotive industry shifts toward complex, curved, and sensor-integrated glazing, the pressure on Quality Control (QC) managers is higher than ever. In this high-stakes environment, the integrity of the glass surface is not merely an aesthetic concern but a fundamental requirement for product safety and functional performance. The transition from traditional commodity glass to high-performance, tempered, flexible, ultra-thin and coated “next-generation” products necessitates a corresponding evolution in packaging and protection strategies. This report provides a comprehensive technical exploration into the world of glass interleaving paper, offering a manufacturing master class designed specifically for the professional peer group responsible for maintaining the bottom line through superior surface quality.

THE PARADIGM SHIFT IN GLASS SURFACE PROTECTION

Often, the glass industry relied on relatively simple methods of separation. Interleaving powders, often comprised of adipic or boric acid mixed with polymer beads, served the needs of the flat glass industry effectively. However, as the industry matured, the limitations of powder became apparent. Powder remains a viable solution when glass surfaces are perfectly flat, environments are strictly controlled and operation environments allow for powders to be washed from the glass. In applications involving curved or bent glass, such as automotive windshields or architectural curves, gravity and movement cause powders to migrate, leaving large areas of the glass unprotected and vulnerable to glass-on-glass abrasion. Furthermore, the dust generated by these powders presents a significant cleanliness issue in modern clean-room environments and automated de-stacking lines.

This has led to a paradigm shift toward engineered glass interleaving paper. Unlike powder, which only provides spot contact, a high-quality interleaving tissue provides a continuous, stable barrier that remains in place throughout the rigors of transportation and long-term warehousing. Yet, the adoption of paper is not a universal panacea. QC managers frequently encounter a frustrating array of defects—ranging from “tiger-striping” to chemical etching—that are often misattributed to environmental factors or glass chemistry, when they are, in fact, the result of using inferior or non-specialized paper products.

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A MANUFACTURING MASTER CLASS: THE ARCHITECTURE OF GLASS INTERLEAVING PAPER

To understand why some papers fail while others protect, one must delve into the molecular and mechanical architecture of the paper itself. Interleaving paper is not a commodity; it is a high-precision technical filter designed to manage the micro-environment between two sheets of glass.

Pulp Purity: The 100% Virgin Cellulose Mandate

High performance glass interleaving begins with a carefully controlled fiber source. These papers are typically produced from 100% virgin fiber because a controlled furnish reduces the risk of adhesives, inks, silicones, fillers, and other contaminants associated with recovered paper.

The term “virgin fiber,” however, may include clean mill broke, such as edge trim, clippings, and off specification paper generated during production and returned to the papermaking process. Mill broke from the same controlled virgin fiber stream does not necessarily present a concern. The greater risk arises when the source, composition, or prior chemical treatment of the returned material is not well controlled. For glass interleaving applications, manufacturers should therefore verify not only that the paper is 100% virgin, but also that any reused material comes from a documented and chemically compatible production stream.

High-performance glass interleaving must be constructed from 100% virgin cellulose fibers. These fibers are harvested from controlled sources and undergo a chemical pulping process—typically the Kraft process—designed to remove lignin and other non-cellulosic components that could otherwise leach out and stain the glass. The use of 100% virgin pulp ensures a baseline of chemical neutrality and physical cleanliness that is impossible to achieve with recycled materials.

Fiber Characteristic	100% Virgin Cellulose	Recycled/ Blended Fiber
Chemical Control	Precise, no carryover chemicals	Uncontrolled, high risk of contamination
Ionic Purity	Ultra-low sulfates/chlorides	High potential for corrosive ions
Physical Debris	Negligible; controlled pulp stream	Presence of dirt, plastic, and metal traces
Consistency	Batch-to-batch uniformity	Significant fluctuations in fiber length/strength
Resin Content	Minimal, specifically washed	High, residual adhesives and wood resins



Mechanical Refinement: The Science of Fiber Filtration

The physical properties of the paper—its smoothness, strength, and porosity—are determined during the refining process. Refining is a mechanical treatment where the pulp is passed between rotating discs. This process subjects the fibers to intense compressive and shear forces, causing them to undergo structural changes known as fibrillation.

Internal fibrillation involves the delamination of the fiber wall into separate layers or lamellae. This process allows water to penetrate the fiber structure, causing it to swell and become more flexible. Increased fiber flexibility is critical for glass interleaving because it allows the paper to conform to the microscopic topography of the glass, maximizing the contact area and reducing the pressure at any single point. This conformability is a primary defense against micro-abrasions.

External fibrillation refers to the generation of fibrils that extend from the surface of the fiber. These fibrils act as biological “Velcro,” increasing the hydrogen bonding between fibers and significantly enhancing the paper’s tensile strength and surface integrity. However, refining is a delicate balancing act. Excessive refining leads to fiber shortening or “cutting,” which reduces the tear strength of the paper and can create fines—tiny fiber fragments that may migrate onto the glass surface as dust.

Surface Engineering: MG, MF, and the Yankee Dryer Effect

The final physical characteristic of the paper is its finish. For the most demanding glass applications, Machine Glazed (MG) paper is the gold standard. During the MG papermaking process, the wet paper web is pressed against a massive, highly polished steam-heated cylinder known as a Yankee dryer. As the paper dries in contact with this mirror-like surface, the side facing the cylinder becomes extremely smooth and glossy.

This MG finish provides two critical benefits for QC managers:

1. **Reduced Friction:** The low coefficient of friction on the glazed side allows glass sheets to slide against the paper during loading and unloading without the paper “grabbing” or bunching, which is a common cause of edge chips and surface scratches.
2. **Particle Capture:** The smoothness of the MG side means there are fewer protruding fibers that could break off and contaminate the glass surface.

In contrast, Machine Finished (MF) paper is dried on a series of smaller cylinders without the Yankee dryer effect, resulting in a more matte, uniform finish on both sides. While MF paper is suitable for many industrial applications, it often lacks the extreme smoothness required for optical-grade or high-definition display glass.

THE CHEMISTRY OF THE INTERFACE: MANAGING THE MICRO-ENVIRONMENT

While the physical structure of the paper prevents mechanical damage, the chemistry of the paper is what prevents chemical destruction. When two sheets of glass are interleaved and stacked, a semi-sealed micro-environment is created. Within this space, the paper acts as a reservoir for chemistry that can either protect or destroy the glass.

The Mechanism of Soda-Lime-Silicate Corrosion

To effectively select an interleaver, a QC manager must understand the chemistry of glass corrosion. Soda-lime-silicate glass, though seemingly impervious, is susceptible to a two-stage corrosion process when it comes into contact with moisture.

Stage 1: The Ion Exchange

The process begins within minutes of moisture - whether from humidity or residual process water - contacting the glass. Water molecules (H_2O) react with the sodium ions (Na^+) in the glass structure. This is an ion exchange process where hydrogen ions from the water replace sodium ions in the glass network:



This reaction leaches sodium from the surface and, crucially, releases hydroxide ions (OH^-) into the thin film of moisture between the glass and the paper.

Stage 2: The Network Attack

As long as the pH of the moisture remains below 9.0, the damage is largely limited to the surface layer and can often be cleaned. However, as the OH^- concentration builds, the pH rises. Once the pH reaches 9.0 or higher, the hydroxide ions begin to attack the actual silica network of the glass—the very skeleton of the material. The hydroxide ions sever the silicon-oxygen bonds:



This reaction is essentially a slow dissolution of the glass. It results in permanent microscopic pitting, iridescence, and a dense, translucent haze that cannot be washed away.

Chemical Requirements: pH, Ionic Purity, and Reducible Sulfur

The primary role of technical interleaving paper is to interrupt this corrosion cycle. This is achieved through three critical chemical controls:

1. **pH Neutrality/Acidity:** High-performance interleaving papers, such as Flexsheen® Premium paper, are manufactured to maintain a specific pH level—often slightly acidic or neutral—to neutralize the alkali (OH⁻) produced during Stage 1 corrosion. By keeping the interface pH well below 9.0, the paper prevents the transition to Stage 2 network attack.
2. **Ionic Purity (Chlorides and Sulfates):** Soluble ionic contaminants, including chloride and sulfate, may influence the conductivity and chemistry of moisture present at the glass interface. Their significance depends on the glass composition, surface treatment, environmental conditions, and downstream application.
3. **Reducible Sulfur:** Sulfur compounds in paper can react with moisture to form weak acids that tarnish metals or lead to hazing in tempered glass. Technical glass interleaver must be run to “ultra-low” reducible sulfur standards, typically far below the levels found in standard packaging papers.

Process Chemical Carryover and Surface Contamination

Trace process chemicals in interleaving paper can transfer to the glass surface and interfere with downstream operations such as coating, printing, bonding, and laminating. Silicone based process aids, including certain defoamers, are one potential source of this contamination.

Silicone can reduce the surface energy of glass, making it more difficult for coatings and adhesives to wet the surface and form a reliable bond. The resulting defects may include poor coating adhesion, delamination, or fish eyes.

In one customer application involving automotive glass, coating adhesion problems occurred on glass that had been stored with a particular interleaving paper. As part of the investigation, the paper itself was analyzed by an independent laboratory. The laboratory measured organosilicone content of approximately 5 parts per million on an oven dry basis. The combination of the observed field failure and the laboratory result indicated that silicone carryover from the interleaving paper was a likely contributing factor.

This finding should not be interpreted as establishing 5 parts per million as a universal failure threshold. Adhesion performance can vary with the coating system, glass preparation, contact conditions, storage environment, application method, and test procedure. It does demonstrate, however, that relatively low levels of silicone in interleaving paper can be significant in applications that are sensitive to surface contamination.

For applications in which coating or adhesion performance is critical, Flexlink Premium papers are produced in controlled manufacturing streams where silicone based defoamers and other incompatible process chemicals are prohibited. Flexlink also offers more economical grades for applications where downstream surface adhesion is not a primary requirement.

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DIAGNOSTIC GUIDE TO CRITICAL GLASS QUALITY ISSUES

For the QC manager on the factory floor, identifying a defect is the first step; understanding why it happened is the second. The following table provides a diagnostic framework for the four most common paper-related glass defects.

Paper Related Defect Type	Physical Manifestation	Root Cause/ Reason for Failure	Flexlink Interleaving Solution
Tiger-stripping	Linear, wavy bands of haze or discoloration across the glass.	Combination of chemical impurities and poor paper formation.	Flexsheen™ Premium is engineered for uniformity and chemical purity.
Staining	Mottled, cloudy patches or iridescent “oil-slick” patterns.	Stage 1 corrosion; high resin content or ionic impurities in the paper leaching onto the glass.	Flexsheen™ Natural MG Ultra-low resin and ionic content to prevent chemical leaching.
Etching	Dull, frosted appearance that cannot be cleaned; microscopic pitting.	Unrestrained Stage 2 corrosion; paper pH too high or failed to neutralize alkali buildup.	Flexsheen Chemically Controlled Precise pH buffering to keep surface pH below 9.0.
Scratching	Fine, hairline abrasions or “scuffs” on the glass surface.	High resin specks (nibs), paper pattern transfer, or abrasive fines from over-refined pulp.	Flexsheen™ MG Finish: Mirror-smooth surface and high pulp cleanliness to eliminate mechanical friction.

Tiger-striping: Moisture, Paper Expansion, and Surface Haze

Tiger-striping is a hazy, wavelike pattern that can sometimes develop on glass stored with interleaving paper. The precise mechanism is not fully understood and may involve a combination of physical contact, moisture, paper formation, and chemical conditions at the glass surface.

Interleaving paper is typically manufactured at approximately 4% to 5% moisture. When exposed to ambient relative humidity that may range from 50% to nearly 80%, the paper absorbs additional moisture. As the cellulose fibers absorb water, they swell, causing the sheet to expand. Because the paper is restrained between sheets of glass, this expansion can produce waves or raised areas in the paper.

Where these raised areas press more firmly against the glass, moisture and chemical compounds may become concentrated at localized contact points. Under certain storage conditions, these areas can develop a hazy pattern that follows the waves in the paper after it absorbs moisture.

Good paper formation helps reduce this risk by providing a more uniform distribution of fibers and contact pressure across the sheet. However, formation alone cannot prevent fiber swelling or paper expansion. The interleaving paper must also have an appropriately controlled pH and low levels of potentially reactive chemical compounds. These controls help reduce the likelihood that localized moisture and pressure will lead to staining or other reactions on the glass surface.

Flexlink addresses tiger-striping risk through a combination of uniform paper formation, controlled pH, chemical purity, and application specific testing. While no interleaving paper can eliminate the effects of humidity, properly engineered paper can reduce the likelihood that normal moisture absorption will result in visible surface haze.

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Staining and Hazing: The Predominant Stage 1 Failure

Staining is frequently caused by the very thing meant to protect the glass: the paper's chemical content. Commodity papers often contain high levels of wood resins (pitch) that were not sufficiently washed out during the pulping stage. In the presence of heat—especially if the glass is interleaved while still warm from the tempering furnace—these resins can “gas out” or migrate directly onto the glass surface.

Furthermore, “fogging” and “hazing” are often the result of volatile compounds within the paper responding to ambient heat and humidity. Flexlink addresses this by employing a rigorous pulp-washing protocol that creates the lowest possible resin content, combined with a 100% virgin fiber mandate that prevents the introduction of unknown chemical stains from recycled sources.



Etching and Iridescence: Advanced Chemical Surface Degradation

As noted earlier, etching and iridescence can occur when the moisture remains in contact with the glass long enough for the local surface chemistry to become alkaline. As alkali is leached from soda lime silicate glass, the pH of the thin moisture layer may rise and eventually begin attacking the silica network. At this stage, the glass may develop permanent haze, microscopic pitting, or iridescent surface patterns that cannot be removed through normal cleaning. Along with temperature and humidity, interleaving paper can greatly influence this process if manufacturers reduce costs by using standard kraft or newsprint paper with no defined chemical specifications.

Standard papers are often slightly alkaline to begin with, which actually accelerates the glass corrosion process rather than inhibiting it. For high-value tempered glass, the best solution is a paper that is run to ultra-low reducible sulfur and precise pH levels. Flexlink's ability to custom-manufacture paper to these tight tolerances allows glass to be stored longer and shipped through harsher environments without the risk of permanent network attack.

Mechanical Abrasion and Scratching: Friction and Particle Generation

Mechanical damage can occur when glass surfaces move against interleaving paper or when particles become trapped at the interface. The risk is influenced by paper surface uniformity, pulp cleanliness, particle generation, stack pressure, vibration, and handling conditions.

Paper defects such as shives, knots, fiber bundles, pitch deposits, or other contaminants can create localized high points within the sheet. Under the pressure of a glass stack, these irregularities may concentrate contact pressure against the glass surface. If the glass or paper then shifts during handling or transportation, localized scuffing, marking, or scratching may occur.

Particle generation is another important consideration. Papers with inadequate fiber bonding or excessive loose fines may shed material during converting, stacking, or transportation. Although cellulose particles alone may not be sufficiently hard to scratch glass, they can contribute to surface marking or trap harder contaminants between adjacent surfaces.

Glass interleaving paper should therefore be manufactured with a clean pulp furnish, uniform formation, controlled surface roughness, and sufficient internal strength to minimize linting and loose particles. Flexlink MG interleaving papers are designed to provide a smooth contact surface and low particle generation for applications in which glass surface quality is critical.

ACCELERATED COMPARATIVE TESTING: THE FLEXLINK PROTOCOL

One challenge in evaluating glass interleaving paper is that surface defects may not appear immediately. Glass can leave the manufacturing facility without visible damage and later develop haze, staining, or other surface changes following exposure to heat, humidity, transportation, and storage.

Flexlink operates a dedicated accelerated aging facility where glass and interleaving paper combinations can be evaluated under controlled elevated temperature and humidity conditions. These accelerated exposure conditions allow performance differences to become visible more quickly than they might under normal ambient storage.

The testing is used to compare how characteristics such as paper formation, pH, chemical purity, moisture response, and surface finish may affect glass performance. A common application is paper benchmarking, in which Flexsheen grades and competitive alternatives are tested under the same conditions and evaluated for the timing and severity of visible surface changes.

Accelerated testing does not reproduce every condition encountered during transportation or storage, nor does it establish an exact field shelf life. Actual performance may also be influenced by glass composition, glass cleanliness, paper moisture, stack pressure, condensation, temperature cycling, storage duration, and handling practices. The results are therefore used as a comparative tool to support paper selection, failure investigation, and customer specific validation.

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EVALUATING TOTAL COST: PAPER PRICE, YIELD, AND PROCESS RISK

Interleaving paper generally represents a small portion of the total value of packaged glass. Its chemical and physical properties, however, can influence surface quality during storage, handling, and transportation. For this reason, paper selection should consider not only unit price, but also the potential costs associated with surface defects and process disruption.

Even a small change in reject rate can outweigh the savings achieved by purchasing a lower cost paper. For example, if a shipment contains \$500,000 of glass, a 1% reject rate represents \$5,000 in direct product value. This calculation does not include the additional costs of inspection, sorting, cleaning, rework, replacement production, expedited freight, technical investigation, or customer claims.

Surface defects can also consume valuable labor and production capacity. Glass suspected of staining or contamination may require additional inspection, cleaning, polishing, or reprocessing. More advanced chemical damage, including permanent haze or etching, may require the affected glass to be scrapped.

When defects are discovered after shipment, the financial impact may extend beyond the value of the glass itself. Replacement production, freight, customer investigations, and increased supplier oversight can add substantial cost. Repeated quality problems may also reduce customer confidence and affect future business.

An interleaving paper that performs consistently under validated conditions may provide additional operational flexibility, including longer storage periods, more challenging transportation routes, or changes in process conditions. These benefits should be confirmed through application specific testing and field validation.

Flexlink evaluates interleaving paper using a total cost approach that considers paper price, glass value, process conditions, surface quality requirements, and the consequences of a failure. Flexlink papers are manufactured to controlled chemical and physical specifications, with grades available for applications ranging from general glass separation to demanding automotive, coated, and adhesion sensitive glass.

CONCLUSION: INTERLEAVING PAPER AS PART OF THE GLASS QUALITY SYSTEM

The manufacture and delivery of high value tempered, coated, and automotive glass require careful control beyond the forming and tempering processes. Surface quality can be affected during cooling, packing, storage, and transportation, and interleaving paper is an important part of the overall protection system.

As discussed in this paper, interleaving performance depends on a combination of fiber source, paper formation, surface finish, pH, ionic cleanliness, extractables, process chemical controls, and moisture response. No single paper property can prevent every surface defect. Paper selection should therefore be considered alongside glass composition, surface cleanliness, packing pressure, temperature, humidity, condensation, storage duration, and handling practices.

For demanding applications, interleaving paper should be manufactured to defined chemical and physical specifications and validated under conditions representative of its intended use. Flexlink's Flexsheen® family includes grades designed for different performance requirements, ranging from general glass separation to automotive, coated, and adhesion sensitive applications. Flexlink also uses accelerated comparative testing to help customers evaluate paper alternatives, investigate surface quality concerns, and support application specific validation.

Evaluating interleaving paper on total performance rather than unit price alone can reduce process variability and help lower the risk of staining, abrasion, contamination, rework, and scrap. The paper between the glass is not simply a separator. It is one component of a broader quality system intended to protect the glass from the manufacturing facility through final delivery.



Please [contact us](#) to discuss how Flexsheen® Glass interleaving paper may help resolve your QC problem.