Long-Term Stability of Superabsorbent Gel for Cable Water-Blocking Performance

presented by

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Overview

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- Issues
- SAP 101
- Key Questions
- Testing
- Discussion
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Background

Background

- Today's cable constructions are robust
- Sheath of a cable can be cut without disturbing fibers or conductors inside
- If transmission satisfactory, cut can go undetected, water still present
- Concern is water travels to sensitive electronics

Background: Dry Water-Blocking

- Current method used for fiber-optic and power cables
- Superabsorbent polymer incorporated via
  - Direct powder application
  - Tapes
  - Coated yarns
  - Other coated components

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Background: Dry Water-Blocking

- Main function to stop axial penetration of liquid along cable
- Ingress from damaged outer jacket or splice
- Creates a blockage (hydrated gel) to prevent further water migration

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Background: Benefits

- Manufacturing and installation cost savings
- Volume in a cable is fraction of what it replaces
- Cable weights and diameters reduced
- Safety
- Easier pulls into conduits
- Handling and splices simplified – no cleaning with solvents required

Background: Current Testing

Testing varies by cable type and application:

Outdoor Fiber Optic Cables

- Telecordia GR-20 and FOTP-82
- Maximum axial penetration of one meter when exposing cross section to one meter pressure head of water

Energy cables

- One meter of cable axially exposed to 3-5 psi of water

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Background: Current Standards

Measure ability of superabsorbent to perform from a dry state only (virgin or aged)

Only considers whether superabsorbent will provide immediate block of water

Issue

Issue

- If transmission is satisfactory, leaks can go undetected
- Cable interior can be exposed to water for years
- Will superabsorbent maintain blockage over time in such a situation?

Remember …

Product specifications include dry state only

Issue: Performance Variations

Some superabsorbents

- are quite stable in a dry state aged at 80°C
- can meet water penetration requirements after dry prolonged heat exposure

Other superabsorbents

- degrade after aging
- suffer reduction of swell height and capacity to absorb water

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Issue: Industry Convention

Superabsorbents that:

- absorb at a faster rate and
- have very high swell capacities

are pereceived better for cable construction…

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Issue: **Tests**

Tests Show

Penetration distance in a cable does not depend solely on SAP swelling speed or capacity

Other characteristics of the polymer (and its carrier) are important:

- ability to swell against pressure
- morphology of superabsorbent particles
- polymer stability and longevity
- etc.

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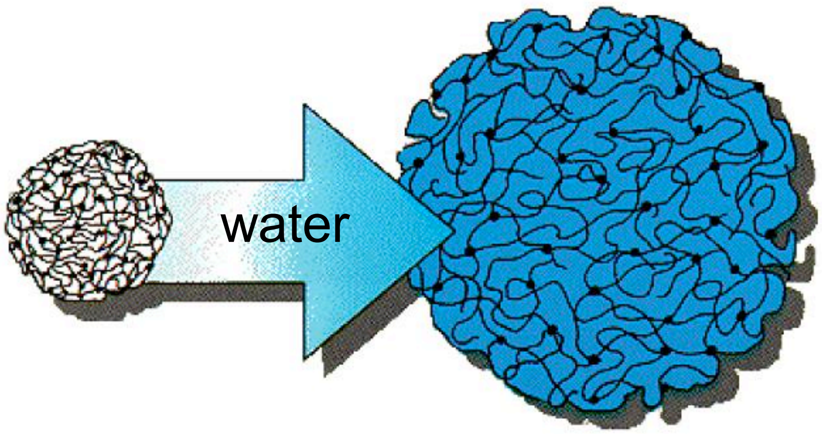
SAP 101

SAP 101: Definition

Typically crosslinked acrylates,
superabsorbent polymers absorb and retain
at least 15x their own weight



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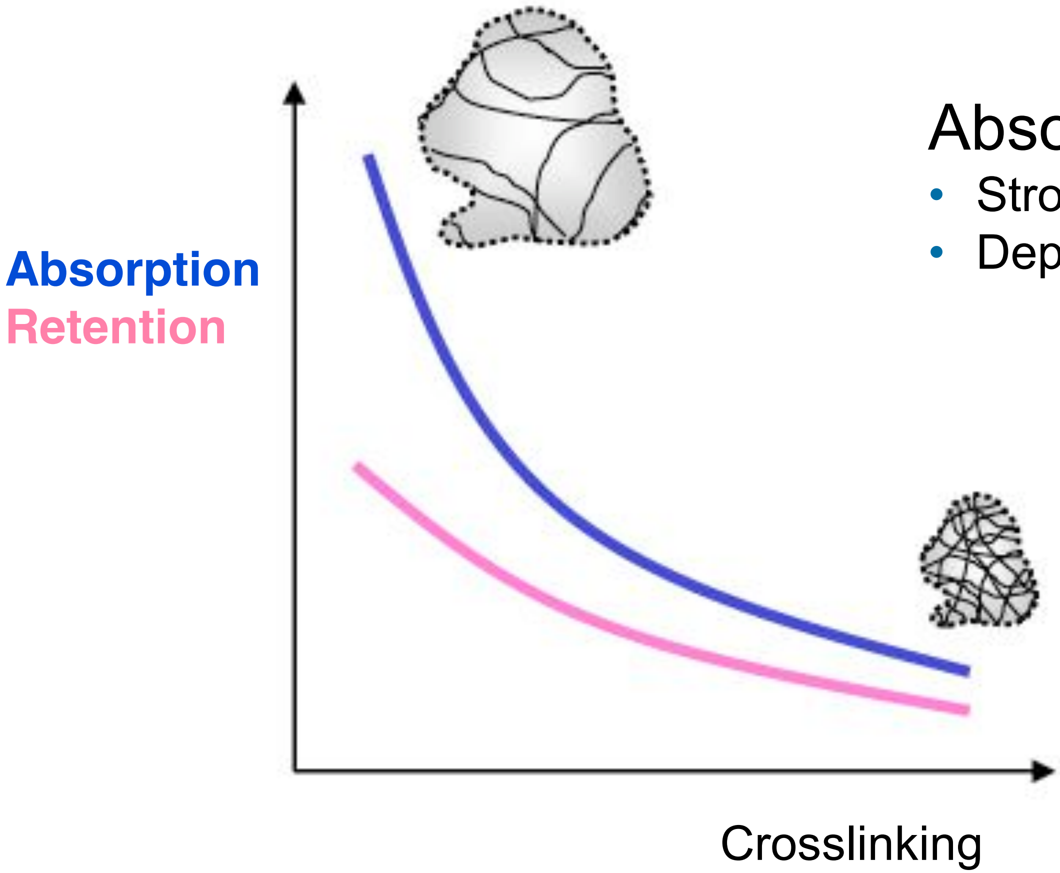
SAP 101: Basic Properties



Absorption and Retention

- Strongly correlated
- Depend on level of crosslinking

SAP 101: Manufacturing

Manufactured by two methods of polymerization:

Solution

- most common – continuous belt production
- particles have fractal crystalline structure

Suspension

- smaller discrete batch sizes
- spheres or agglomerated beads and cauliflower- shaped structures

SAP 101: Unique Features

Various morphologies determine:

- surface area
- porosity of particles
- packing density

Other differences determine performance characteristics:

- absorption capacity
- absorption speed
- ability to swell against pressure
- stability

SAP 101: For Cables

Superabsorbents must:

- swell enough to block the interstitial spaces of the cable core
- have sufficient speed to stop water ingress within one meter

Resulting hydrated gel must:

- be strong enough to hold the head of water
- prevent migration of water over time

Currently, GR-20 only requires preventing migration for 24 hours!

Key Questions

Key Questions

What is the ability of the superabsorbent to maintain water-blocking ability over time once activated?

Are the best performing superabsorbents in dry virgin state the best in the aged hydrated state?

Testing

Testing: Overview

Surveyed a range of commercially available water-blocking superabsorbents for cable

Tested to determine long-term gel stability

- Viscosity measurements
- Flow
- Liquid extrudate
- Water propagation

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Testing: Samples

Sample	Solution/Suspension Polymer	Morphology	Absorption Capacity (g/g) (Deionized H_20)
1	Solution	Crystal	360
2	Solution	Crystal	380
3	Suspension	Sphere	460
4	Solution	Crystal	380
5	Suspension	Cauliflower	420
6	Suspension	Agglomeration	470
7	Solution	Crystal	310
8	Solution	Crystal	330

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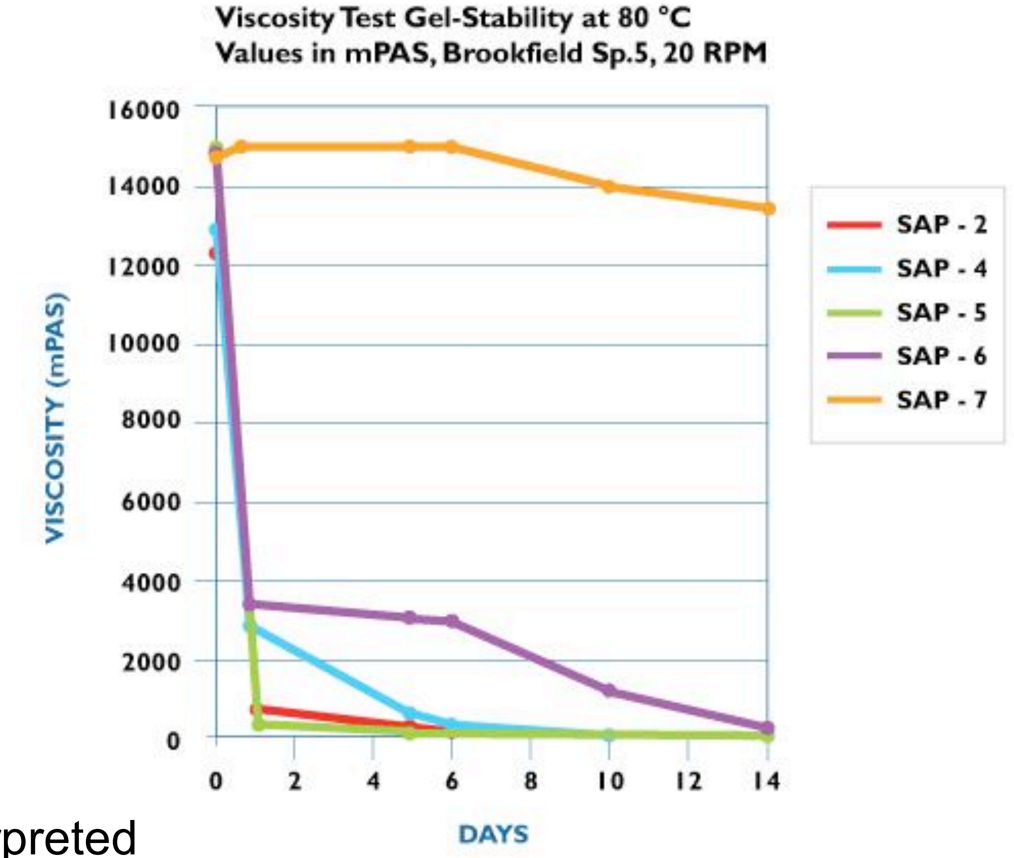
Testing: Aged Gel Viscosity

Results

Sample	Polymer Type	Morphology
2	Solution	Crystal
4	Solution	Crystal
5	Suspension	Cauliflower
6	Suspension	Agglomeration
7	Solution	Crystal
8	Solution	Crystal



Observations:

- All samples exhibited high initial viscosity
- Sample 7 displayed the smallest change
- All other samples degraded rapidly

Dramatic decrease with aging is interpreted as sign of low gel stability

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Testing: Flow

Method

- Hydrated gel poured into polyethylene funnel
- Time to flow out of funnel recorded
- Gel placed into closed container and aged at 80°C
- Samples removed every 24 hours for 4 days
- Cooled to room temperature, test repeated, returned to oven

Measure

Decrease in flow time indicates gel integrity change

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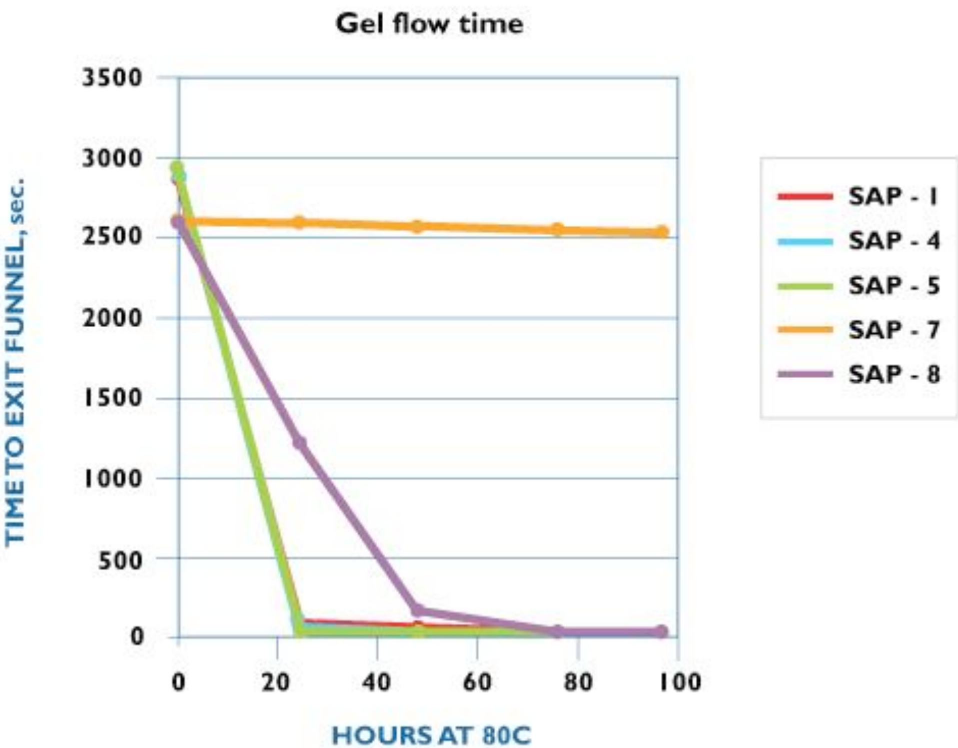
Testing: Flow

Results

Sample	Polymer Type	Morphology
1	Solution	Crystal
4	Solution	Crystal
5	Suspension	Cauliflower
7	Solution	Crystal
8	Solution	Crystal

Observations:

- Initial samples had low propensity to flow and slow to exit funnel
- Sample 7 maintained similar exit times, high resistance to gravity flow after aging
- All other samples flowed freely after 48 hours



High resistance to flow correlates to better blockage in water penetration test.

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Testing: Extrudate

Method

- Samples placed in closed containers and heated to 80°C
- Removed at 24 hour intervals, cooled to room temperature
- Gel poured into 150 mesh conical wire mesh
- Liquid extrudate from gel allowed to drain for three hours
- Liquid weighed, compared to original gel mass

Measure:

Percentage loss of liquid versus original hydrated gel

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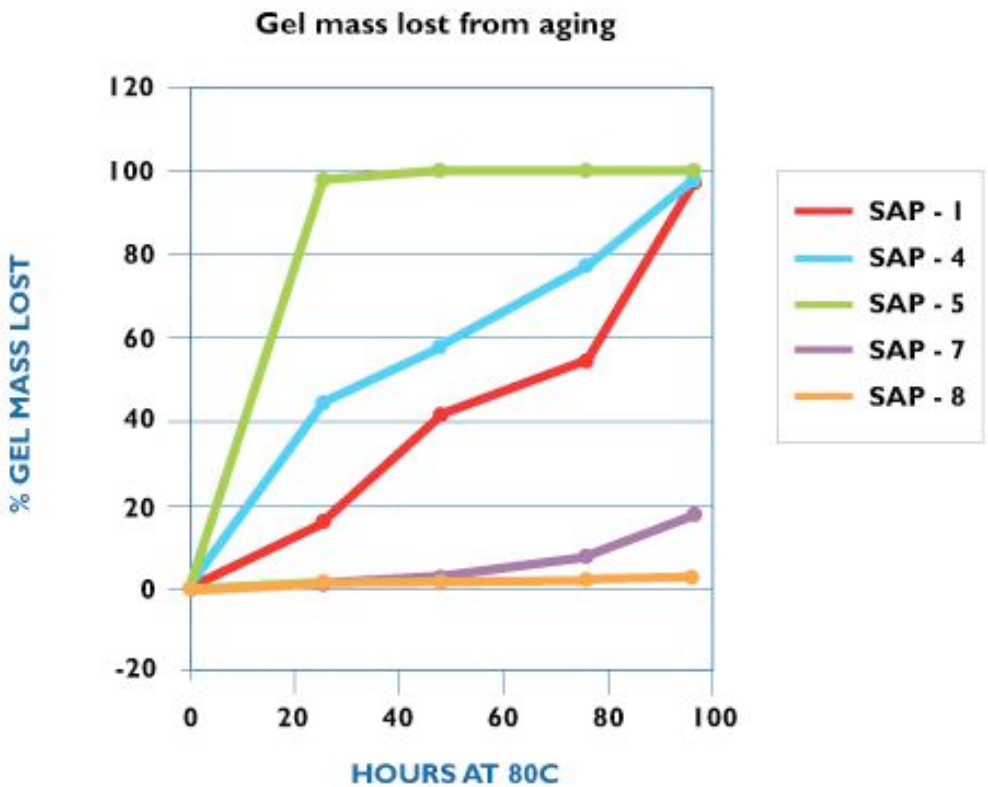
Testing: Extrudate

Results

Sample	Polymer Type	Morphology
1	Solution	Crystal
4	Solution	Crystal
6	Suspension	Agglomeration
7	Solution	Crystal
8	Solution	Crystal



Observations:

- Most samples lost up to 40% of absorbed water in first day
- After 4 days, three samples displayed little gel structure
- Sample 7 exhibited consistent extrudate weight, only 3-4% loss during test period

Superasorbent with higher stability retains more absorbed liquid under aging, preventing further water propagation

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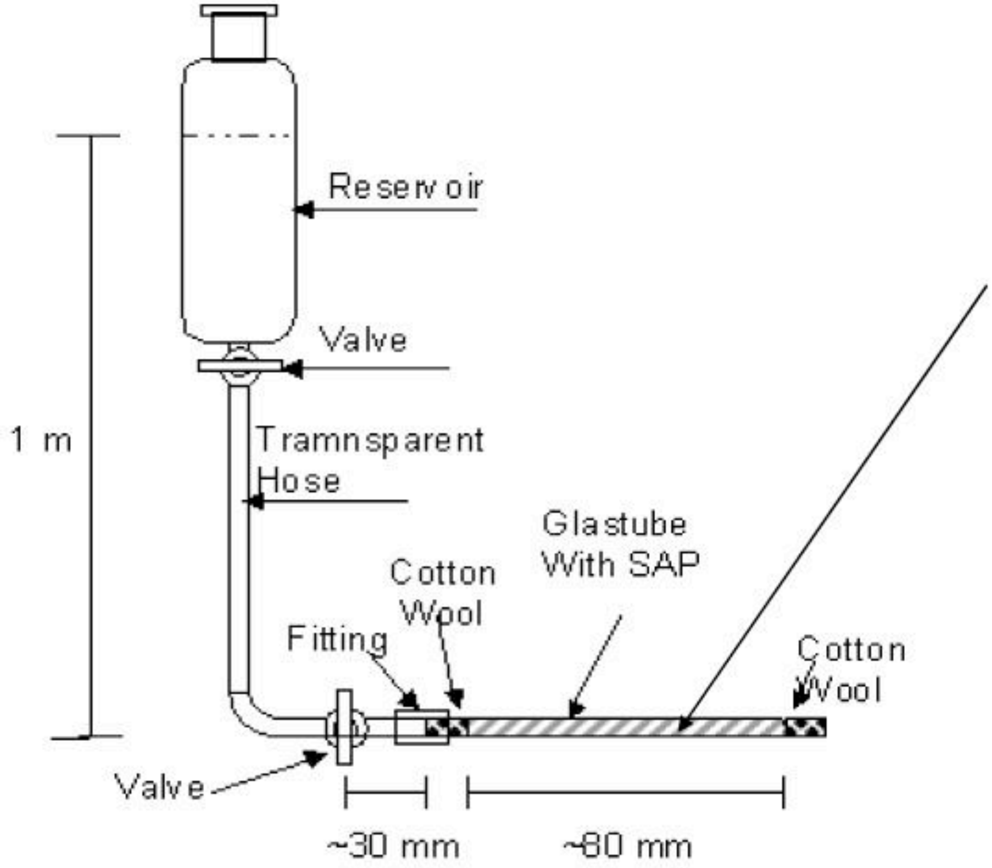
Testing: Long Term SAP Penetration

Experimental Setup



2 mm diameter tubing is used to mimic capillary action exerted by the cable type

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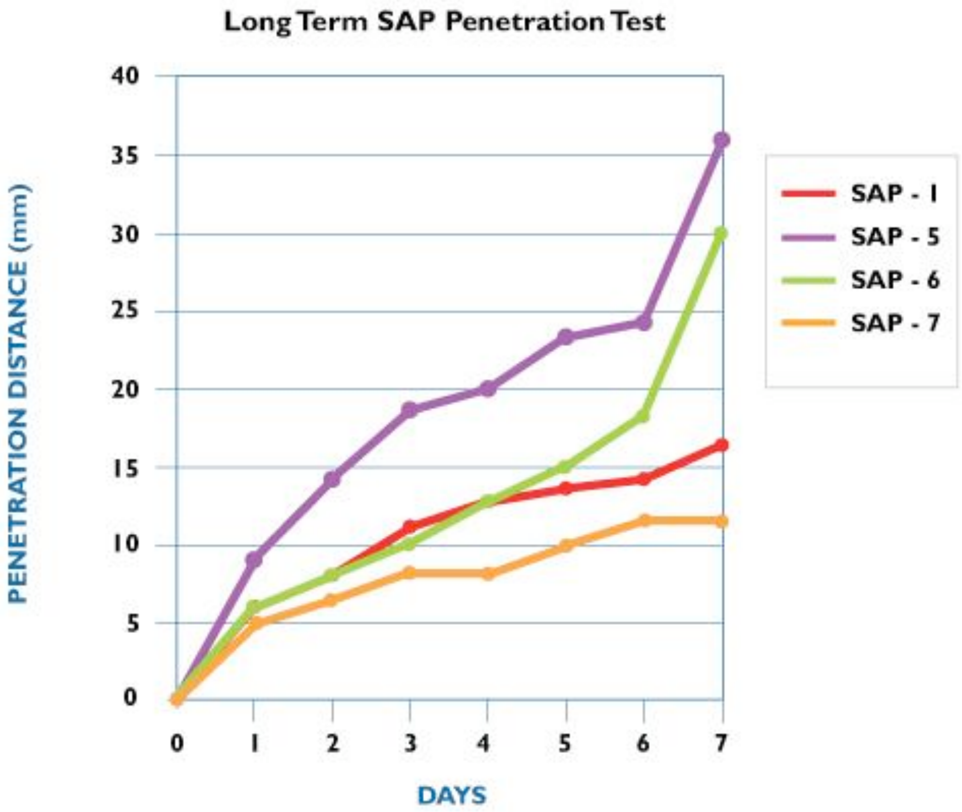
Testing: Long Term SAP Penetration

Results

Sample	Solution/Suspension Polymer	Morphology
1	Solution	Crystal
5	Suspension	Cauliflower
6	Suspension	Agglomeration
7	Solution	Crystal



Observations:

- All show excellent initial performance
- Samples 5 and 6 show significant propagation after 7 days
- Sample 7 exhibited best blockage results

Even at room temperature, weaker superabsorbents cannot maintain blockage over short time periods

Discussion

Discussion: Crosslink Density

Hypothesis

Highest degree of crosslinking would display more stability

Findings

- Heat degrades polymers
- Higher number of initial links in the network need more time to revert to linear form
- Sample 7, most reticulated polymer, displayed the least deviation over time in all tests

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Discussion: Crosslinker

Hypothesis

Type used in superior performing superabsorbents are more resistant to hydrated aging, holding polymer network together

Findings

- Most superabsorbent produced for diaper/hygiene market
- Short service life, hydrolytic stability not a major concern
- Superabsorbent tailored for hydrated stability would use appropriate crosslinker

Discussion: Shape

Hypothesis:

Shape of the expanded superabsorbent has impact on water-blocking performance

Findings

- Jagged edges of crystalline particles lodge to each other more than spheres or cauliflower
- Result is better viscosity and flow numbers
- With age, this increased resistance to movement helps produce superior test results and water-blockage

Summary

Summary

Test results were consistent in ranking integrity of aged superabsorbent gel

Summary: Worst Performer

- Fast swelling / high capacity suspension polymer
- Currently popular in water-blocking tapes
- Low crosslinking density
- High surface area
- Very sensitive to hydrated aging conditions
- Rapidly lost gel integrity, typically within 24 hours

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Summary: Best Performer

- Crystalline-shaped solution polymer
- Highest degree of crosslinking density (determined by absorption capacity)
- Reticulated polymer displayed stable performance through aging study
- Hydrolytic insensitive crosslinker
- Little change in gel mass for test period

Conclusions

Conclusions

Current dry cable water-blocking market is driven by superabsorbents with speed.

Disadvantage is that gel collapses quickly once hydrated.

This can result in undetected water propagation over time down the length of a cable

Conclusions

HOWEVER

use of a sufficiently fast superabsorbent in a dry state

when combined with stable hydrated gel stability performance

RESULTS IN

the best possible candidate to maintain a secure block for the life of the cable

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Initiative

The industry needs to ensure:

- adequate water-blocking over the lifetime of a cable
- security of system performance

by addressing:

superabsorbent hydrated gel stability in GR-20 requirements

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Questions

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