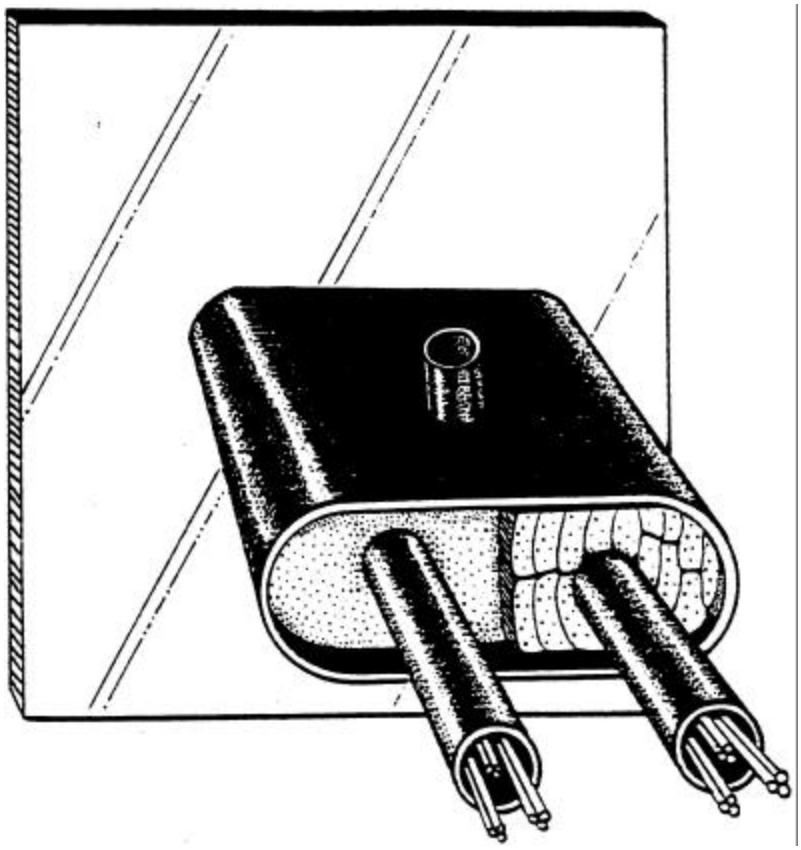
2. Flammadur® Geaquello® System for Fire Sealing Cables Penetrating through Bulkheads and Decks

A. Flammadur® E950 (an Improved E750)
B. Special Swell Strips (for Easy Installation).



2.1 The Geaquello® System Product Description

The Geaquello® System consists of :

1. Flammadur® E950, the inorganic cement-like powder which is mixed with water and placed where desired with help of damming material. Upon drying it sets like cement to form a firestop seal.

2. Geaquello® R312 and R380, which are like strips of dry sponge. They are used for forming a damming barrier by inserting appropriate length pieces in between cables. When impregnated with Flammadur® E824 (see Item 3 below), the strips expand rapidly to fill all the void space between cables to form a water-tight damming barrier. This damming barrier is used for holding E950/water mixture in place for setting upon drying.

3. Flammadur® E824 is fire-retardant liquid for impregnating R312 and R380 strips above to make them rapidly expand as described in (2) above.

2.2 Advantages of the Flammadur® Geaquello® System

SAFE

- Mostly *inorganic* materials are mixed solely with water.
- *No asbestos, lead or halogen* content.
- *No toxic or flammable gases* are produced during storage, mixing, or curing.
- *No hazardous combustion by-products* are produced at temperatures as high as 1000^{E}C (1982^{E}F). Main gases released are H_2O vapor and CO_2.

EFFECTIVE

- In case of fire, special *inorganic heat-sink materials absorb heat* thereby *cooling penetrating pipes, conduits and cables* as well as surrounding bulkheads and decks.

- Temperature increases on the off-fire side (adjacent to the compartment on fire) are strongly retarded, thereby qualifying fire seals for *approval under the standards of the International SOLAS Convention.*

- *No derating for the ampacities* for the embedded cables, i.e., they can carry their full, air-suspended electric current without the necessity for increasing the cable cross-sections.

- *No material decomposition* for temperatures up to at least 1100EC (2012EF.)

- Stops flame propagation, stops smoke penetration.

CHEAPER

- *Less-expensive* than other comparably-rated systems. The Geaquello® system costs about half of Nelson Frames, not counting the savings in labor costs.

ROBUST

- *Watertight and gastight* seals are achieved by the expansion of the nonporous sealant material of up to 0.5% by volume during curing.

- Fire-stops can withstand water pressures of 58 psi for at least 30 min. and of 145 psi for at least an additional 5 min.

- *High mechanical stability* and *resistance to bending and compression.*

- *Resistant to acids, alkalis, gasoline, etc.*

RELIABLE

- *Proven* with applications throughout the world.

PRACTICAL

- *Long shelf-life.*

- Expected *lifetime of more than 50 years* after installation.

- *Easy to install* without specialized tools and equipment.

- *Spills* readily mopped up with water.

- *Readily retrofitted,* drilled, finished, and painted. The sealant E950 is easy to drill, to remove or to replace new cables and it is easy to seal the hole with new material.

- After a fire, only damaged surface portions need to be removed and replaced with the same material.

APPROVALS

- Geaquello® System has been approved under the International SOLAS (Safety of Life at Sea) Convention 1979/1984, Det Norske Vepitas, Germanic Lloyd, Lloyd's Register of Shipping, U.S. Coast Guard (E795), American Bureau of Shipping (E795), etc., as described in Section 2.8.

2.3 Health Hazards and Care

All materials by Geaquello® system are physiologically harmless and are not subject to any health hazard classifications. All installations can be made without special ventilation requirements. Splashes of E950 sealant liquid and of E824 impregnation liquid on skin and clothes can be simply washed off with water. Eye contact by these substances requires copious rinsing with water only.

All spilled materials can be mopped up with water.

2.4 Properties of Flammadur® E950

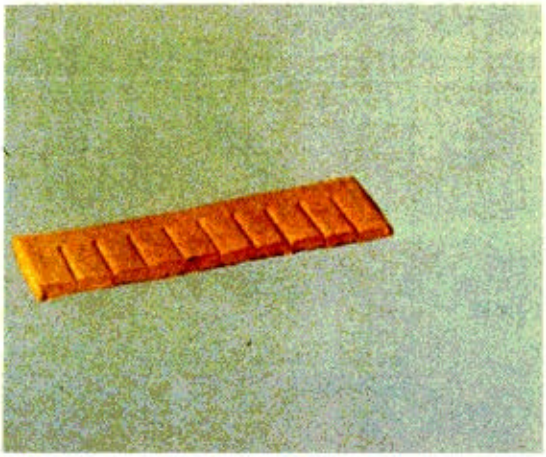
Property	E950
Material composition	Inorganic cementitious mixture
Final color	Beige
Consistency, before mixing	Powder
Shelf life from date of production (frost-free)	3 years
Material needed per unit volume to be filled	62 lbs/ft^3 (1000 kg/m^3)
Required additive (base)	Water
Mixing ratio by weight or by volume	2 parts powder to 1 part water
Pot life–at 68EF	45–75 minutes
Cure time–At 68EF	72 hrs.
Expansion during curing	0.5 percent volume
Final material density: at 68EF (18EC)	Density of water: 62 lbs/ft^3 (1000 kg/m^3)
Cleaning solvent	Water

Note: E950 needs to be mixed with only water. Predecessor to E950, called E795, required mixing two components just before use.

2.5 Typical Static Material Properties of the Heat-Sink Material Flammadur® E950 at 20EC (68EF)

Resistance to water penetration	58 psi for at least 30 min. 145 psi for at least an additional 5 min.
Shore A hardness	>80
Thermal conductivity	0.15 kcal/m–hr–EK (0.10 Btu/ft–hr–ER)
Specific volume heat	150 kcal/m^3–EK (9.4 Btu/ft^3–ER)
Thermal diffusivity	$1.0x10^{-3}m^2$/hr ($1.1x10^{-2}ft^2$/hr)
P_H-value while curing when fully cured	7 7

2.6 Swell Modules and Impregnation Liquid



Dry swell module before soaking with impregnaion liquid E824.

Expanded swell module after soaking with impregnation liquid E824. The volume expands up to ten times the original size.

2.6.1 Swell Strips Modules

Approx. Dimensions:

Swell strips R312	: 120 x 25 x 6 mm
Swell strips R380	: 800 x 26 x 6 mm

Max. swelling: : approx. 10 x original size

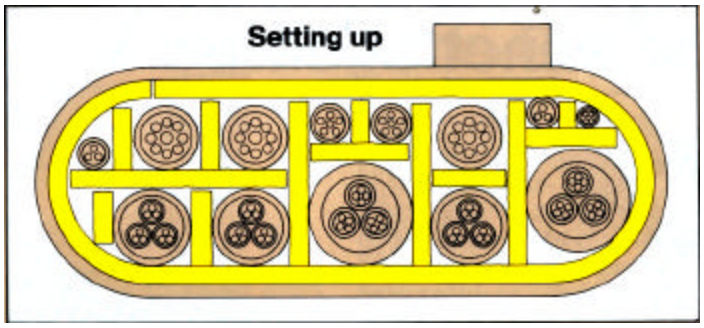
Delivery sizes:

Frontwall package 120	: 120 swell strips R312 4 swell strips R380 4 liters impregnating fluid E824 in 1 liter sprinkling bottles
Systempack 2	: 25 swell strips R380 5 liters impregnating fluid E824 in 1 liter sprinkling bottles
Pack swell strips R380	: 25 pieces
Box swell strips R312	: 360 pieces
Impregnating fluid E824 free of solvents	: 1 liter sprinkling bottle 10 liter canister

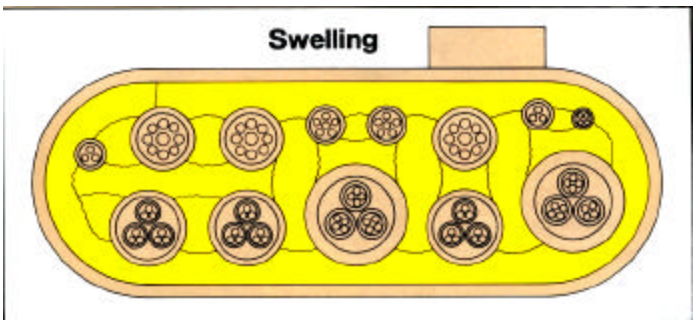
2.7 Installation Summary of the Geaquello® System -- Schematic Representation

Cable penetrations:

- fireproof
- gastight
- watertight
- nontoxic



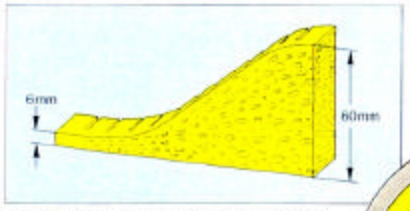
Top: Set up the penetrating cables by insertion of the swell modules at both ends of the penetration



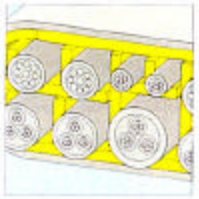
Center: Spray-soak swell modules with impregnation liquid E824 to form a damming barriers. The swollen swell modules automatically provide the proper spacing between the cables and between the cables and the metal penetration ducts and act as damming material at both ends of the penetration.

Bottom: From hole on the top, pour 2-part E950/1-part water cement-like mixture in between the damming barriers filling the voids between the damming modules with the sealing compound E950. A solid fire seal will form upon drying.

Setting up the Penetration



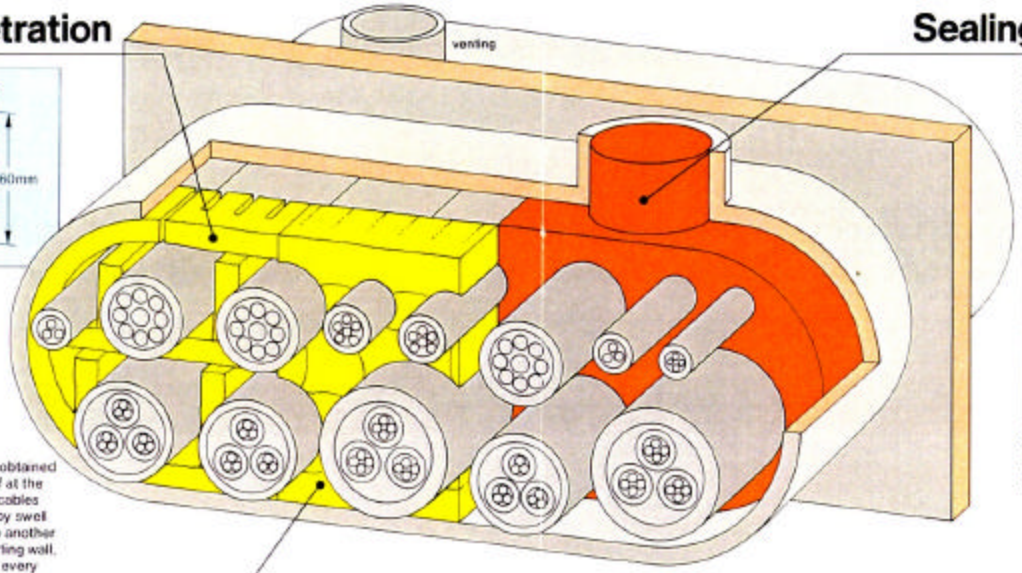
The swell strip is absorbent and can swell up to ten times its original volume.



Cellular buildup around the cables

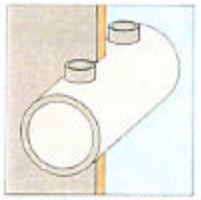
The penetration section is built up by rough fitting of the swell strips around the cables in cellular formation.

Short pieces can be obtained simply by tearing off at the preformed cuts. All cables must be separated by swell strips both from one another and from the supporting wall, so that after sealing every cable is hermetically enclosed.

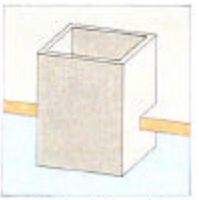


Sealing the Cable Penetration

Penetrations are properly sealed when the filling and venting openings are completely full and the sealing compound no longer sinks. All cables are then hermetically enclosed with sealing compound. The compound jellifies after a pot life of approx. 60 minutes and hardens in approx. 3–4 hours at room temperature. Chemical hardening is completed in a period of 72 hours and requires frost-free conditions.



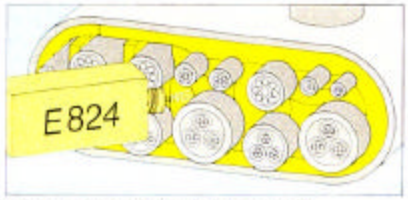
The stability of the swell strips permits sealing of penetrations of every shape and type, i.e.



horizontal, vertical, round, oval or rectangular.

Sealing the Penetration

When sprinkled with impregnation fluid E 824, the strips swell up. This creates a stable and sealing-compound-proof wall in a matter of minutes.
After proper sprinkling and swelling, the penetration section is flame-resistant, fire-retardant, self-extinguishing and free of halogen.



Sprinkling swell strips with impregnation fluid E 824

Mixing the Sealing Compound E 950

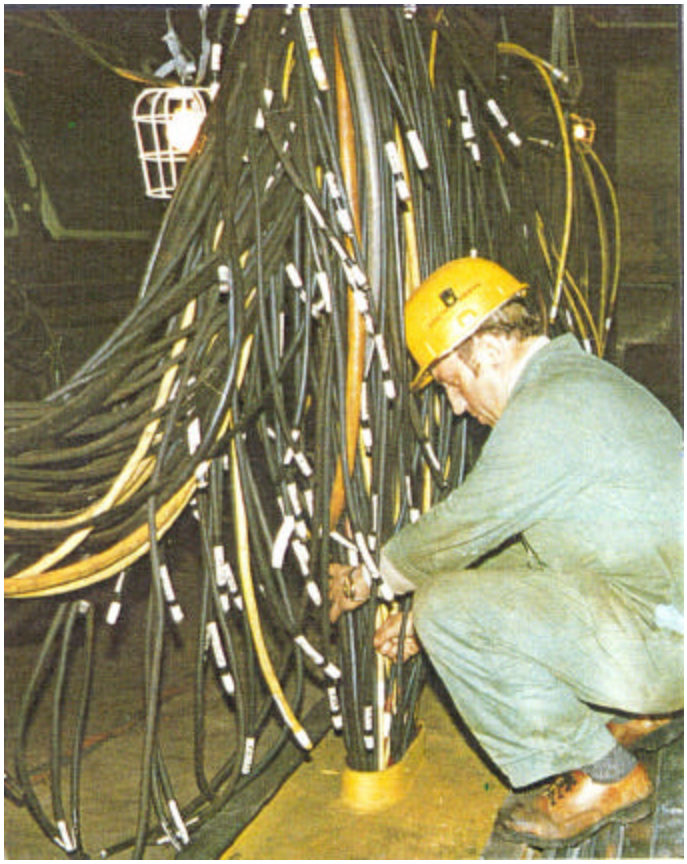
The powder of the sealing compound E 950 is mixed with water (approximately drinking water standard) on site, in the ratio 50 parts of water to 100 parts of powder. If correctly mixed, the sealing compound runs from the mixing stick in a thin stream without drop formation, free of lumps, from a height of approx. 0.3 metre (1 foot).

The sealing compound E 950 is pumpable, so that even hard-to-reach penetrations can be sealed without difficulty. The pumps must be cleaned with water after use. If the correct mixing ratio is used this always gives a sealing compound which is easy to pour and to pump.

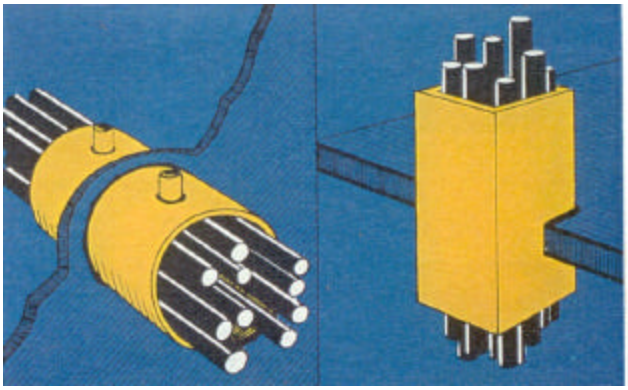
Mixture check

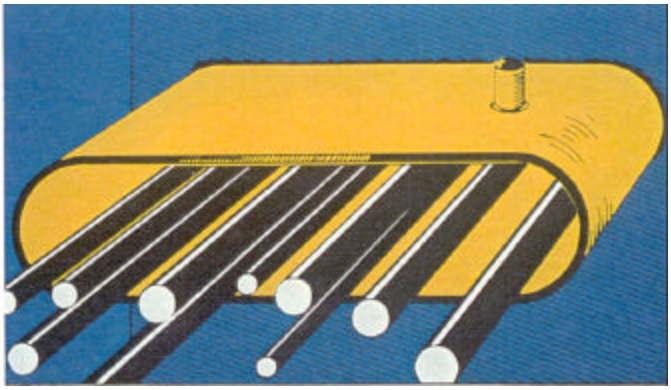
GEAQUELLO® System – Simple, Safe and Speedy.

- Sealing by the absorbtive capacity of the swell strips
- Fire-resistance of swell strips
- Simplicity of installation, thus saving man-hours
- 1-component, only water is added
- Low density
- Removable for re-laying of cables
- Easy to maintain
- Physiologically safe, no danger source



Firestop for Cables Penetrating through Deck





Examples of various configurations for bulkhead and deck penetration fire-stops. The steel sleeves (9/32 - 13/32 in. thick) with filling and venting ports (5/32 - 7/32 in. thick) have to be designed and installed by the shipyard first. Vertical penetrations do not require filling and venting ports and need only one swell-module damming wall at the bottom.

2.8 Approvals

Geaquello® System has been approved under the International Safety of Life at Sea (SOLAS) Convention 1979/1984, Det Norske Vepitas, Germanic Lloyd, Lloyd's Register of Shipping, U.S. Coast Guard (E795), American Bureau of Shipping (E795), and many other approvals as listed below.

The certificates/letters of approval are reproduced in the Appendix. Description of the test according to SOLAS is provided in Section 2.8.2.

2.8.1 List of Countries which Tested and/or Accepted the Geaquello® System

USA:

- American Bureau of Shipping, July 13, 1984, September 4, 1997
- U.S. Navy, in preparation
- U.S. Coast Guard

Denmark: Government Ships Inspection Service, December 11, 1984

France: Bureau Veritas, June 6, 1984

Great Britain:

- Lloyd's Register of Shipping, August 7, 1986
- Lloyd's Register of Shipping, February 3, 1986
- Marine Surveyors of the Department of Transport, June 19, 1985

Japan: Nippon Kaiji Kyokai, April 28, 1986

West Germany:

- Authority for Economics, Traffic and Agriculture, River and Harbor Construction, January 1, 1984
- Seaman's Union, February 17, 1984
- Lloyd's Register of Shipping, February 3, 1986
- Germanic Lloyd, March 7, 1985
- Germanic Lloyd, February 7, 1985
- Germanic Lloyd, March 7, 1984

USSR: Registry of Shipping, November 7, 1985

The Netherlands: Ministry of Traffic and Waterways, August 29, 1985

Sweden: Administration of Shipping and Navigation, March 13, 1985

Norway: Norske Veritas, August 6, 1984

Belgium: Ministry of Traffic, April 15, 1986

2.8.2 Approval of Geaquello® System Under the International Convention on Safety of Life at Sea (SOLAS)

Fire tests for the Geaquello® System with sealing compound E950 were performed[1] according to the International SOLAS Convention of 1974, Chapter II-2, Part A, Regulation 3b in consideration of "IMO" Document A163 (ES IV) of 28.11.1986 and A215 (VII) for type A-60 bulkheads and type A-60 deck penetrations.

One side of each of these penetration firestops was subjected to *a rapid temperature rise* in a furnace and held at a temperature of up to 1700EF for 1 hr. The temperature rise as a function of time on the off-fire side of the type A-60 bulkhead did not reach an average value of more than 92ºF (51ºC) for five measurement points and did not exceed a maximum value of 122ºF (68ºC) after 1 hr. The respective temperature on the off-fire side of the type A-60 deck penetration firestop rose to an average of not more than 95ºF (53ºC) for 11 measurement points and did not exceed a maximum value of 148ºF (82ºC). These measured temperature increases are well below the permissible average value of 250ºF (139ºC) and the allowed maximum value of 324ºF (180ºC) specified by the SOLAS 1974 requirements. SOLAS certification of the temperature-rise tests was granted on January 24, 1984.

Additional *water pressure tests* required under the SOLAS 1974 convention for the nonfired sealing compound E950 have been certified on August 7, 1986. According to these tests, the sealant E950 of the Geaquello® penetration *firestop system remained watertight for 30 min. For a water overpressure of 58 psi* corresponding to a 133.8 ft-high water column. *This pressure exceeds the SOLAS 1974 requirement by a factor of two.* Subsequent additional pressurization to 145 psi overpressure corresponding to a 334.6 ft-high water column did not show any leakage for at least an additional 5 min.

[1]The tests were conducted, certified and approved under the International SOLAS Convention at the Authority for Economics, Traffic and Agriculture, Division for River and Harbor Construction at Hamburg, West Germany on January 24, 1984 under Test No. 184.84.1.

2.8.3 U.S. Navy Requirements for Multiple Cable Penetrations (MCP) and Comparison with SOLAS

After reviewing the presently applicable U.S. Navy firestop requirements for multiple cable penetrations through bulkheads and decks[2] and comparing them with the present internationally valid SOLAS regulations[3] for merchant ships, we come to the conclusions that the U.S. Navy requirements are much less severe than those for the merchant fleets of all countries in the following two aspects:

1. Whereas the U.S. Navy requires only no flame penetration during their 1-hour fire test, the SOLAS Regulations for class A-60 division[4] for bulkheads and decks require that there shall be
   (a) no flame and no smoke penetration,
   (b) an average temperature increase on the off-fire side of not more than 250ºF (139ºC) and
   (c) a maximum temperature increase at any point on the off-fire side of not more than 324ºF (180ºC) during and after their standardized 1-hour fire test.

The SOLAS limitation on smoke penetration is meant to prevent the loss of human lives in compartments which are adjacent to the fire-stricken compartment. The restriction on allowable temperature increases on the off-fire side of divisions are meant to prevent the ignition of combustible materials in compartments which are adjacent to the fire-stricken compartment.

Note: The Geaquello® System with the sealant compound E950 exhibited in fire tests on the off-fire side of bulkheads an average temperature rise of only 92ºF (51ºC) and a maximum rise of only 122ºF (68ºC) and of decks an average of 95ºF (53ºC) and a maximum rise of only 148ºF (82ºC).

2. Whereas the U.S. Navy requires only that the firestops withstand static water pressure of 25 psi (~58 ft water column) for 30 min, the Geaquello® System is able to withstand a static water pressure of at least 58 psi (134 ft water column for 30 min. The SOLAS Convention requires that watertight bulkheads and decks are strong enough to support, with a proper margin of safety, at least the pressure due to a head of water up to the margin line [2 in.

[2] Technical Meeting on Multiple Cable Penetrations and Firestop Materials, NAVSEA 56Z34, Washington, D.C., March 3-4, 1986.

[3] International Convention for the Safety of Life at Sea (SOLAS) 1974; Amendments of November 1981, Chapter 11-2, Part A Regs. 2.1, 2.2, 3.1, 3.2, 3.3 and 18.1.1.

[4] Class A-60 divisions are bulkheads and decks constructed of steel or other equivalent materials which are capable of preventing the passage of flames and smoke to the end of a 1-hr standard fire test conducted at furnance temperatures according to the temperature-time curve of the ISO (International Organization for Standardization Standard 834).

below the upper-most continuous (main) deck], and the pressure of the maximum head of water which they might have to sustain in the event of damage to the ship. Penetrations through these bulkheads and decks have to be strong enough to ensure the required water tight integrity of these divisions.

Note: The Geaquello® System with the sealant compound E950 has been tested[5] to withstand a static water pressure for 58 psi for 30 min. subsequently, the water pressure was further increased over a time-span of 20 min. to a final pressure of 145 psi (~335 ft water column) and held constant for 5 min. without showing leaks.

2.8.4 SOLAS and U.S. Navy Requirements for Firestops and Test Results For the Flammadur® (Geaquello®) System.

REQUIREMENT	SOLAS	U.S. NAVY	GEAQUELLO® SYSTEM
Stop flame penetration	60 minutes	60 minutes	60 minutes
Stop smoke penetration	60 minutes	not required	60 minutes
Temperature increase on off-fire side	Allowed increase 250ºF (139ºC) avg. for 60 min, 324ºF (180ºC) max. for 60 min.	not required not required	Measured increase 95ºF (53ºC) avg. for 60 min, only 148ºF (82ºC) max. for 60 min.
Static water pressure resistance	Variable for 30 min.	25 psi* for 30 min.	Tested for 58 psi† for 30 min. and up to 145 psi‡ for an additional 5 min.

* Corresponding to a water column of 58 ft (18 m).
† Corresponding to a water column of 134 ft (41 m).
‡ Corresponding to a water column of 335 ft (102 m).

[5] These additional water-pressure tests were conducted at the AIK laboratories at Kassel, West Germany and witnessed and testified for approval under the International SOLAS Convention by the Surveyor of the Lloyd's Register of Shipping on August 8, 1986, Certified No. HNO 600547.

2.9 Partial List of Foreign Vessels Equipped with the Geaquello® System

Vessel Type	Shipbuilding
"EUROPA" Cruise Ship	Bremer Vulkan
Frigate F 122, West Germany	HDW-Kiel
Frigate F 122, West Germany	Blohm & Voss
Frigate F 122, West Germany	Blohm & Voss
Frigate F 122, West Germany	Bremer Vulkan
Frigate F 122, West Germany	AG Weser
Frigate F 122, West Germany	Thyssen-Nordseewerke
Frigate, Argentina	Blohm & Voss
Frigate, Argentina	Blohm & Voss
Frigate, Argentina	Blohm & Voss
Frigate, Argentina	Blohm & Voss
Container Ship	Thyssen-Nordseewerke
Container Ship	Thyssen-Nordseewerke
Container Ship	Thyssen-Nordseewerke
Container Ship	AG Weser
Container Ship	AG Weser
Container Ship	Flender Werft
Container Ship	Flender Werft
Research Vessel, USSR	Werft Nobiskrug
Research Vessel, India	Schlichting Werft
Container Ship	Seebeckwerft
Container Ship	Seebeckwerft
Container Ship	Schichau Unterweser AG
Container Ship	Schichau Unterweser AG
2 Offshore Supply Ships	Sürken Werft
10 Units; Container Ships	Sietas Werft