Raven 405

DESCRIPTION

Raven® 405 is a solvent-free 100% solids, ultra high build epoxy coating formulated with exceptionally high physical strengths and broad range chemical resistance. 405 exhibits superior bond to concrete, steel, masonry, fiberglass and other surfaces. Designed for operating temperatures up to 200°F, 405's unique ultra high-build ability allows it to be spray applied on vertical and overhead surfaces. The surface tolerance and high physical strengths of 405 allow it to be designed as a structural lining in manholes, pipelines, tanks and other deteriorated structures.

TYPICAL USES

Surfaces where rehabilitation of an existing structure requires enhancement of the structural integrity and where exposure to concentrated acids and caustics may be expected, including:

- Tunnels and pipelines
- Digesters
- Secondary containment
- Wastewater facilities
- Clarifiers
- Tanks
- Manholes
- Floors and walls

COLOR

The Part A Resin is white; the Part B Curing Agent is blue. When mixed the product is light blue. Limited special colors are available on request.

SOLIDS BY VOLUME

100% solids by volume
Volatile Organic Compounds: 0.0 pounds per gallon

FILM THICKNESS

Raven 405 is a 100% solids epoxy with zero shrinkage. Wet film thickness and dry film thickness are the same (i.e. 80mils WFT = 80mils DFT). Depending on substrate type and profile, a maximum of 200 mils per coat is recommended to prevent sagging. Recommended thickness will vary from 40 - 250 mils+ based on service conditions.

COVERAGE

Theoretical coverage is 20 square feet per gallon at 80 mils wet film thickness. Actual surface coverage will depend on substrate porosity and roughness. Good painting practices suggest application of two coats for quality assurance. A wet film thickness gauge may be used to determine actual coating coverage.

APPLICATION

Apply with brush, roller, airless or air-assisted spray or other suitable method. Optimal proportioning and mixing is achieved with the use of a Raven approved plural component airless spray system. For best results, apply this product to concrete when its temperature is stable or falling.

THINNING

Do not thin with solvents. If lower viscosity is needed, heat unmixed material by placing the containers in hot tap water until the desired flow properties are obtained. To heat larger quantities, drum heaters or inline heaters on specialized spray equipment may be used. Unmixed material should not be heated above 150°F.

COMPONENTS AND MIX RATIO

Part A Resin:Part B Curing Agent mix ratio is 3:1 by volume.

POWER MIXING

Individually power mix both Part A and Part B containers prior to measuring out 3 parts of Part A to 1 part of Part B by volume into a clean disposable pail. Completely mix combined A & B for a minimum of one minute before transferring contents to a clean pail. Continue mixing at least another minute, scraping the sides and bottom, to obtain a thorough mix before application. Properly mixed material will be a uniform color without light or dark spots.

CLEAN UP

To clean tools, use acetone, MEK or xylene. To clean skin, wash immediately and thoroughly with soap and water. Refer to the Material Safety Data Sheet for additional information on health and safety.

POT LIFE

The pot life is 20 minutes for one gallon at 72°F. The working life varies depending on the amount and temperature of epoxy mixed and the ambient temperature.

CURE TIME

Thin film set time varies with substrate temperature and application thickness. Generally, the coating will be tack-free in 3 ½ hours at 72°F and dry-hard in about 5 hours.

RECOAT TIME

This product may be recoated as soon as it becomes tacky but does not transfer to the finger. When applying multiple coats, do not allow more than 12 hours at 72°F substrate temperature to pass between coats, higher temperatures will shorten this window. Before recoating; inspect, clean and dry surface thoroughly to remove all contamination, including amine blush or condensation. If the recoat time is missed, clean and abrade surfaces prior to recoating.

SUBSTRATE TEMPERATURE

Minimum recommended substrate temperature: 40°F
Maximum recommended substrate temperature: 120°F

TEMPERATURE RESISTANCE

Maximum recommended dry temperature: 150°F. May be post-cured for service up to 200°F. Wet temperature resistance depends on chemical concentration and exposure time.

SURFACE PREPARATION

Prior to coating, the substrate must be prepared in a manner that provides a uniform, clean, sound, neutralized surface suitable for the specified coating. The substrate must be free of all contaminants, such as oil, grease, rust, scale or deposits. In general, coating performance is proportional to the degree of surface preparation.

STEEL surfaces may require "Solvent Cleaning" (SSPC-SP 1) to remove oil, grease and other soluble contaminants. Chemical contaminants may be removed according to SSPC-SP 12/NACE No. 5. Identification of the contaminants along with their concentrations may be obtained from laboratory and field tests as described in SSPC-TU 4 "Field Methods for Retrieval and Analysis of Soluble Salts on Substrates". Surfaces to be coated should then be prepared according to SSPC-SP 5/NACE No.1 "White Blast Cleaning" for immersion service or SSPC-SP 10/NACE No. 2 "Near White Blast Cleaning" for all other service. In certain situations, an alternate procedure may be to use high (>5,000 psi) or ultrahigh (>10,000 psi) pressure water cleaning or water cleaning with sand injection. The resulting anchor profile shall be 2.5-5.0 mils and be relative to the coating thickness specified.

CONCRETE AND MASONRY surfaces must be sound and contaminant-free with a surface profile equivalent to a CSP2 to CSP5 in accordance with ICRI Technical Guideline No. 03732. This can generally be achieved by abrasive blasting, shot blasting, high pressure water cleaning, water jetting, or a combination of methods.

AVAILABLE PACKAGES

Available in 5 gallon pails (20 gallon kit), 30 gallon drums (120 gallon kit) and 55 gallon drums (220 gallon kit). Kits are supplied in the correct proportions of A & B; these two components must be mixed together before use. Raven 405 is available through Raven Certified Applicators.

SHELF LIFE AND STORAGE

Product shelf life is 1 year from purchase date in sealed, unmixed containers, stored in a sheltered area between 60°F and 80°F (15°C and 27°C).

SAFETY

Consult the Material Safety Data Sheet for this product concerning health and safety information before using. Strictly follow all notices on the Material Safety Data Sheet and container label. If you do not fully understand the notices and procedures provided on the MSDS or if you cannot strictly comply with them, do not use this product. Actual safety measures are dependent on application methods and work environment. Contact Raven Lining Systems to obtain a copy of the Material Safety Data Sheet at 800-324-2810.

TYPICAL PROPERTIES(1)

DESCRIPTION	METHOD	RESULT
Tensile Strength	ASTM D 638	7,600 psi
Tensile Ultimate Elongation	ASTM D 638	1.5%
Compressive Strength	ASTM D 695	18,000 psi
Flexural Strength	ASTM D 790	13,000 psi
Hardness, Shore D	ASTM D 2240	88
Taber Abrasion, CS-17 wheel	ASTM D 4060, 1 kg load/1,000 cycles	<112 mg loss
Adhesion, Concrete	ASTM D 7234	Substrate Failure

(1) Typical properties are to be considered as representative of current production and should not be construed as specifications.

Warranty and Disclaimer: Raven Lining Systems, Inc. ("Raven") warrants its products to be free of manufacturing defects in accord with applicable Raven quality control procedures and that they meet the formulation standards of Raven. To the best of our knowledge the technical data contained herein is true and accurate on the date of publication and is subject to change without prior notice. If, within one year from purchase, any product is proven defective, Raven, at its sole option, will either replace the defective product or refund the purchase price. This warranty is void if the product is used contrary to Raven's written directions.

THE AFORESAID IS THE EXCLUSIVE WARRANTY AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED. THERE IS NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. UNDER NO CIRCUMSTANCES SHALL RLS SOLUTIONS INC. BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES OR FOR LOST PROFITS. NO ACTION AGAINST RAVEN MAY BE COMMENCED MORE THAN ONE YEAR AFTER THE CLAIM ARISES.

MATERIAL SAFETY DATA SHEET

Trade Name: **Raven 405 - Part A**

SECTION I: COMPANY INFORMATION

Company:	RLS 13105 East 61st Street South, Suite A Broken Arrow, OK 74012	**Emergency Telephone #:**	800-424-9300 Chemtrec
Revision Date:	10/10/07	**Information Telephone #:**	918-615-0020 800-324-2810

SECTION II: INGREDIENT INFORMATION

INGREDIENT	CAS NUMBER	PERCENT	PEL	TLV
Epoxy Resin	25085-99-8	> 70%	N/E	N/E
Silica, Amorphous, Fumed, Crystalline-free	67762-90-7	0 - 5%	*6 mg/m^3	*3 mg/m^3

N/E indicates "not established"
SARA Title III, Section 313 ingredients: None All ingredients are TSCA inventory listed.
*Note: The PEL and TLV for this ingredient are the TWA for respirable dust levels only. In this product, it is pre-dispersed and not available as a dust. Therefore, under normal use conditions it is not considered a hazard.

SECTION III: PHYSICAL DATA

Boiling Point: > 200 deg F
Specific Gravity: 1.4
Vapor Pressure: Not determined
Melting Point: Not determined
Vapor Density: Not determined
Evaporation Rate: Not determined
Solubility in Water: Negligible
% Volatile by Volume: <1%
Appearance and Odor: White liquid with heavy paint consistency - mild epoxy odor

SECTION IV: FIRE & EXPLOSION HAZARD DATA

Flash Point: >200 deg F, PMCC Method
OSHA/NFPA Fire Hazard Classification: Class III B
Extinguishing Media: Foam, CO_2, Dry Chemical, Water Spray
LFL: Not determined
UFL: Not determined
Special Fire Fighting Procedures: The use of self-contained breathing apparatus is recommended for firefighters. Water may be helpful in keeping adjacent containers cool. Avoid spreading burning liquids with water used for cooling purposes.
Unusual Fire and Explosion Hazards: Keep work areas free of hot metal surfaces and other source of ignition.
NFPA classification: Health: 2 Flammability: 1 Reactivity: 0

SECTION V: REACTIVITY DATA

Stability: Stable, will react with amines.
Incompatibility: Strong acids and bases, selected amines and oxidizing agents.
Hazardous Decomposition or Byproducts: Thermal decomposition in the presence of air may yield carbon monoxide, carbon dioxide, phenolics, acids, aldehydes and other unidentified toxic and/or irritating compounds.
Hazardous Polymerization: Will not occur.

SECTION VI: HEALTH HAZARD DATA

Primary Routes of Entry:

EYES: May cause moderate eye irritation. Corneal injury is possible.
SKIN: May cause allergic skin reaction in susceptible individuals. Prolonged exposure likely to cause skin irritation. Repeated exposure may cause skin irritation. A single prolonged exposure is not likely to result in the material being absorbed through skin in harmful amounts.
INHALATION: Vapors are unlikely due to physical properties.
INGESTION: Moderately toxic, may be harmful if swallowed. No hazards anticipated from ingestion incidental to industrial exposure.
SYSTEMIC and OTHER EFFECTS: Except for skin sensitization, repeated exposures to low molecular weight epoxy resins of this type are not anticipated to cause any significant adverse effects.

Carcinogenicity: Contains no ingredient listed as a potential carcinogen or as a carcinogen per OSHA, ACGIH, NTP or IARC at concentrations equal to or greater than 0.1%.

Emergency and First Aid Procedures:

EYES: Flush with large quantities of water for at least 15 minutes. Consult a physician.
SKIN: Wash thoroughly with soap and flowing water. Remove and wash contaminated clothing before reuse.
INHALATION: Remove to fresh air if effects occur. Consult a physician.
INGESTION: Seek immediate medical attention. Do not induce vomiting unless directed to do so by a physician.

SECTION VII: PRECAUTIONS FOR SAFE HANDLING AND USE

Steps to Be Taken in Case Material is Released or Spilled: Keep sources of ignition and hot metal surfaces isolated from the spill. Material may flow slowly. Scrape into containers for disposal.
Waste Disposal Methods: Dispose of according to all local, state and federal regulations.
Precautions to Be Taken in Handling and Storing: Keep containers closed when not in use. Avoid prolonged or repeated contact with skin. Do not handle or store near flame, heat or strong oxidants. Do not store in direct sunlight. Avoid prolonged storage above 38 deg C (100 deg F).

SECTION VIII: CONTROL MEASURES

RESPIRATORY: Respiratory protection should not be needed. If exposure may or does exceed occupational exposure limits, respiratory irritation is experienced, or during spray application, use a properly fitted MSHA/NIOSH approved respirator fitted with organic vapor cartridges. In addition, spray application may require the use of paint pre-filters. If sanding or grinding on cured material, use above respirator fitted with HEPA filters or a dust mask.
VENTILATION: General mechanical ventilation is sufficient for most conditions. Local exhaust ventilation may be necessary for some operations.
EYES: Use chemical safety glasses, splash-proof eye goggles or goggles with full faceshield.
CLOTHING/GLOVES: Use nitrile or other impermeable chemical resistant gloves to prevent skin irritation. If potential for skin contact is present, wear impervious, long-sleeved, body covering clothing and rubber boots.
OTHER PROTECTIVE EQUIPMENT: The availability of eye washes and safety showers in work areas is recommended.

SECTION IX: TRANSPORT DATA

Proper Shipping Name: Not regulated
Hazard Class: Not regulated by D.O.T. regulations
Identification Number: None
Packing Group: None

SECTION X: DISCLAIMER

RLS MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO ANY INFORMATION PRESENTED HEREIN, ALL OF WHICH IS PROVIDED "AS IS". TO THE MAXIMUM EXTENT PERMITTED BY LAW, RLS EXPRESSLY EXCLUDES ALL WARRANTIES, OBLIGATIONS, REPRESENTATIONS, LIABILITIES, TERMS AND CONDITIONS (WHETHER THEY ARE EXPRESS OR IMPLIED, OR ARISE IN CONTRACT, STATUTE, OR OTHERWISE, AND IRRESPECTIVE OF THE NEGLIGENCE OF RLS, ITS EMPLOYEES OR AGENTS) IN CONNECTION WITH THE INFORMATION PRESENTED HEREIN. RLS MAKES NO REPRESENTATIONS OR WARRANTIES AS TO MERCHANTABILITY, FITNESS FOR PURPOSE, NONINFRINGEMENT OR CONFORMITY WITH DESCRIPTION OR SAMPLE.

MATERIAL SAFETY DATA SHEET

Trade Name: **Raven 405 - Part B**

SECTION I: COMPANY INFORMATION

Company:	RLS 13105 East 61st Street South, Suite A Broken Arrow, OK 74012	**Emergency Telephone #:**	800-424-9300 Chemtrec
Revision Date:	4/29/08	**Information Telephone #:**	918-615-0020 800-324-2810

SECTION II: INGREDIENT INFORMATION

INGREDIENT	CAS NUMBER	PERCENT	PEL	TLV
Aliphatic Amine	1477-55-0	20 - 30%	N/E	0.1 mg/m^3 skin
Alkylphenol	84852-15-3	15 - 20%	N/E	N/E
Polyoxypropylene Diamine	trade secret	7 - 12%	N/E	N/E
Silica, Amorphous, Fumed, Crystalline-free	67762-90-7	7 - 12%	*6 mg/m^3	*3 mg/m^3
Isophorone Diamine	2855-13-2	5 - 10%	N/E	N/E
Diethylenetriamine	111-40-0	5 - 10%	4 mg/m^3	1 ppm TWA
4,4'-Methylenebiscyclohexanamine	1761-71-3	1 - 5%	N/E	N/E
Mixed Cycloaliphatic Amines	trade secret	1 - 5%	N/E	N/E
2,2-bis(4-hydroxyphenyl)propane	80-05-7	0 - 5%	N/E	N/E
Phenol	108-95-2	1 - 3%	5 ppm (skin)	5 ppm (skin)

N/E indicates "not established"
SARA Title III, Section 313 ingredients: 2,2-bis(4-hydroxyphenyl)propane All ingredients are TSCA inventory listed.
*Note: The PEL and TLV for this ingredient are the TWA for respirable dust levels only. In this product, it is pre-dispersed and not available as a dust. Therefore, under normal use conditions it is not considered a hazard.

SECTION III: PHYSICAL DATA

Boiling Point: > 200 deg F
Specific Gravity: 1.1
Vapor Pressure: Not determined
Melting Point: Not determined
Vapor Density: Not determined
Evaporation Rate: Not determined
Solubility in Water: Negligible
% Volatile by Volume: <1%
Appearance and Odor: Gel consistency with characteristic ammonia odor

SECTION IV: FIRE & EXPLOSION HAZARD DATA

Flash Point: >200 deg F, Setaflash Method
OSHA/NFPA Fire Hazard Classification: Class III B
Extinguishing Media: Foam, CO_2, Dry Chemical, Water Spray
LFL: Not determined
UFL: Not determined
Special Fire Fighting Procedures: The use of self-contained breathing apparatus is recommended for firefighters. Water may be helpful in keeping adjacent containers cool.
Unusual Fire and Explosion Hazards: Keep work areas free of hot metal surfaces and other source of ignition. Sudden reaction and fire may result if product is mixed with an oxidizing agent.
NFPA classification: Health: 3 Flammability: 1 Reactivity: 0

SECTION V: REACTIVITY DATA

Stability: Stable
Incompatibility: Strong acids and bases, selected epoxy resins and strong oxidizing agents.
Hazardous Decomposition or Byproducts: Thermal decomposition in the presence of air may yield carbon monoxide, carbon dioxide, ammonia, aldehydes, ketones, nitrogen oxides and other unidentified toxic and/or irritating compounds.
Hazardous Polymerization: Will not occur.

SECTION VI: HEALTH HAZARD DATA

Primary Routes of Entry:

EYES: Severe eye irritant. May cause burns. Vapors may be irritating.
SKIN: Severe skin irritant. May cause injury to skin following prolonged or repeated contact. Repeated exposure may cause sensitization of the individual.
INHALATION: Vapors/mists may be corrosive to the upper respiratory tract. Repeated or prolonged exposure can result in lung damage. May cause respiratory tract sensitization and/or irritation of mucous membranes.
INGESTION: Not expected to be a relevant route of exposure. However, the material is corrosive and may cause permanent damage to the mouth, throat and stomach.
SYSTEMIC and OTHER EFFECTS: Product can be alkaline, corrosive and irritating to skin, ears, eyes and mucous membranes. Aliphatic amines can cause changes in the lungs, liver, kidneys and heart. May cause injury upon prolonged contact and repeated contact.

Carcinogenicity: Contains no ingredient listed as a potential carcinogen or as a carcinogen per OSHA, ACGIH, NTP or IARC at concentrations equal to or greater than 0.1%.

Emergency and First Aid Procedures:

EYES: Flush with large quantities of water for at least 15 minutes. Seek immediate medical attention.
SKIN: Wash immediately with soap and water. If irritation or sensitization occurs, remove individual from further contact with material. Remove and wash contaminated clothing before reuse.
INHALATION: Remove to fresh air if effects occur. Consult a physician.
INGESTION: If this product is swallowed, administer one glass of water. Do not induce vomiting. Seek medical attention immediately.

SECTION VII: PRECAUTIONS FOR SAFE HANDLING AND USE

Steps to Be Taken in Case Material is Released or Spilled: Keep sources of ignition and hot metal surfaces isolated from the spill. Material may flow slowly. Scrape into containers for disposal.
Waste Disposal Methods: Dispose of according to all local, state and federal regulations.
Precautions to Be Taken in Handling and Storing: Keep containers closed when not in use. Avoid breathing vapors and prolonged or repeated contact with skin. Do not handle or store near flame, heat or strong oxidants. Do not store in direct sunlight. Avoid prolonged storage above 38 deg C (100 deg F).

SECTION VIII: CONTROL MEASURES

RESPIRATORY: Respiratory protection should not be needed. If exposure may or does exceed occupational exposure limits, respiratory irritation is experienced, or during spray application, use a properly fitted MSHA/NIOSH approved respirator fitted with ammonia & methylamine cartridges. In addition, spray application may require the use of paint pre-filters. If sanding or grinding on cured material, use above respirator fitted with HEPA filters or a dust mask.
VENTILATION: General mechanical ventilation is sufficient for most conditions. Local exhaust ventilation may be necessary for some operations.
EYES: Use chemical safety glasses, splash-proof eye goggles or goggles with full faceshield.
CLOTHING/GLOVES: Use nitrile or other chemical resistant gloves. Wear clean, long-sleeved, body covering clothing and rubber boots.
OTHER PROTECTIVE EQUIPMENT: The availability of eye washes and safety showers in work areas is recommended.

SECTION IX: TRANSPORT DATA

Proper Shipping Name: Amines, liquid, corrosive, N.O.S. (aliphatic amines)
Hazard Class: Corrosive Material - 8
Identification Number: UN 2735
Packing Group: III

SECTION X: DISCLAIMER

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Raven 405 Third Party Testing, Evaluations and Municipal Approvals

Third Party Physical Property and Chemical Resistance Testing

Attached documentation of physical property and coating performance testing from accredited, independent testing laboratories:
Weldon Laboratories, Imperial, PA, Sherry Laboratories, Tulsa, OK, Charter Coating Service Ltd., Calgary, Alberta, KTA-Tator, Inc., Pittsburgh, PA

Municipal Product Evaluations

County Sanitation Districts of Los Angeles County; Evaluation of Protective Coatings for Concrete a.k.a "The Redner Report", 2004 Final Report (Successful pass as Coating System C-69 at 60 mils)

CIGMAT/UH 98-3 Greater Houston Wastewater Program, City of Houston; Evaluating Raven Lining Systems Product for Coating Wastewater Concrete and Clay Brick Facilities in the City of Houston, May 1993 (Successful pass of application, hydrostatic and chemical exposure testing)

City of Los Angeles; SSPWC Section 210-2.3.3 Chemical Resistance Test a.k.a. "Pickle Jar Test", 2003 (Successful pass of chemical exposure and subsequent physical property testing)

City of Phoenix/Peoria; City of Phoenix/Peoria Supplement to Maricopa Association of Governments Uniform Standard Specifications (MAG SPEC) Product Approval List, 2008

King County, WA; King County Wastewater Treatment Division Qualification Testing, 2006/2009

Municipal Approvals

City of Austin; City of Austin Water and Wastewater Utility Standards Committee Approval, 1992

Baton Rouge, LA; East Baton Rouge Parish Department of Public Works Approved Materials List, 2008

County of Berkeley, SC; Berkeley County Water and Sanitation Approved List of Manhole Liners

City of Dallas; Dallas Water Utilities Standard Technical Specification for Corrosion Protection Epoxy Liners Approval, 2004

Raven 405 Municipal Approvals cont'd.

County of Clark, NV; Clark County Water Reclamation Materials Committee - Approved Materials List, 2009

City of Escondido, CA; Escondido Utilities Approved Materials List – Manhole Lining, 2008

City of Goodyear, AZ; Public Works Department Approved Materials List for Wastewater Collection, 2009

City of Henderson, NV; Department of Utility Services Approved Materials List – Manhole Lining Systems, 2006

City of Houston; Product Approval Committee-Wastewater Subcommittee Approval, 2008

City of Loveland, CO; Water and Wastewater Development Standards Approved Materials List – Manhole Linings, 2007

City of Mesa, AZ; Approved List of Wastewater Manhole Corrosion Protective Coating Systems, 2009

City of Phoenix/Peoria; City of Phoenix/Peoria Supplement to Maricopa Association of Governments Uniform Standard Specifications (MAG SPEC) Product Approval List, 2008

City of San Diego, CA; Metropolitan Wastewater Departments Approved Materials List – Sewer Rehab Products, 2003

City of Virginia Beach; Department of Public Utilities, Engineering Division Product Selection Committee Approval, 2009

Inclusion in Municipal Standard Specifications

Charleston, SC
Charlotte County, FL
Chandler, AZ
Humble, TX
Daphne, AL
Fayetteville, AR
Gainesville, FL
Knoxville, TN
Lafayette, LA
Lake Havasu, CA
Lakehaven, WA
Laredo, TX
Marina Coast, CA
Nashville, TN
Oklahoma City, OK
Pearland, TX
Peoria, AZ
Phoenix, AZ
Pittsboro, NC
Port Orange, FL
Queen Creek, AZ
Rogers, AR
Roswell, NM
San Antonio, TX
Savannah, GA
Scottsdale, AZ
Tampa, FL
Texas DOT, TX
Thorton, CO
Tulsa, OK
Whitehouse, TN
Yolo County, CA
Many others…

SHERRY LABORATORIES

TESTING TODAY, PROTECTING TOMORROW

WWW.SHERRYLABS.COM

Sherry Laboratories
3100 North Hemlock Circle
Broken Arrow, OK 74012-1115

Tel: 918-258-6066
800-982-8378
Fax: 918-258-1154

LABORATORY REPORT

Attn: David Stanley
Raven Lining Systems
13105 East 61st Street South, Suite A
Tulsa, OK 74012

Report No.: 11010341-001-v1
Date Received: 1/4/2011
Date Reported: 1/11/2011
P.O. No.: 316280

Sample Description: P/N: Raven 405
Specification: Tensile testing per ASTM D638

Tensile Strength of Plastics per ASTM D638-10

Specimen Preparation: As-Received
Specimen Type: Type I
Test Rate, in/min.: 0.2
Test Temperature, °F: 76°
Test Humidity, %: 23

Specimen	Thickness, in.	Width, in.	Ultimate Load, lbs.	Tensile Strength, psi	Modulus of Elasticity, psi	Elongation, %
T1	0.098	0.507	431.4	8,680	706,000	1.63
T2	0.097	0.506	427.2	8,710	747,000	1.47
T3	0.101	0.507	409.3	7,990	719,000	2.23
T4	0.098	0.507	393.5	7,920	707,000	1.31
T6	0.098	0.507	426.1	8,580	760,000	1.42
Average	---	---	---	8,380	728,000	1.61

Approved by: Blake M

Blake Minton, Nonmetallics Project Leader
Sherry Laboratories

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LABORATORY REPORT

Attn: David Stanley
Raven Lining Systems
13105 East 61st Street South, Suite A
Tulsa, OK 74012

Report No.: 11010341-002-v1
Date Received: 1/4/2011
Date Reported: 1/11/2011
P.O. No.: 316280

Sample Description: P/N: Raven 405
Specification: Compression testing per ASTM D695

Compression Strength of Plastics per ASTM D695-10

Method of Preparing Specimens: As-Received
Specimen Type: Cylinder
Test Rate, in./min.: 0.05
Test Temperature, °F: 76°
Test Humidity, %: 24

S/N	Height, in.	Diameter, in.	Max. Load, lbs.	Strength at Break, psi	Modulus of Elasticity, psi
C1	0.991	0.604	5128	17,900	311,000
C2	0.989	0.602	5180	18,200	323,000
C3	0.989	0.604	5179	18,100	320,000
C4	0.990	0.603	5155	18,100	320,000
C5	0.992	0.601	5192	18,300	325,000
Average	---	---	---	18,100	320,000

Approved by: Blake Minton, Nonmetallics Project Leader
Sherry Laboratories

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LABORATORY REPORT

Attn: David Stanley
Raven Lining Systems
13105 East 61st Street South, Suite A
Tulsa, OK 74012

Report No.: 11010341-003-v1
Date Received: 1/4/2011
Date Reported: 1/11/2011
P.O. No.: 316280

Sample Description: P/N: Raven 405
Specification: Flexural testing per ASTM D790

Flexural Properties of Plastics per ASTM D790-10, Procedure A

Specimen Preparation: Molded, As-Received
Span to Depth Ratio: 16:1
Test Rate, in./min.: 0.05
Test Temperature, °F: 76°
Test Humidity, %: 23

S/N	Thickness, in.	Width, in.	Load, lbs.	Strength at Break, psi	Modulus of Elasticity, psi
F1	0.108	0.505	29.07	12,800	707,000
F2	0.108	0.506	27.07	11,900	689,000
F3	0.111	0.507	34.17	14,200	664,000
F4	0.109	0.508	34.63	14,900	734,000
F5	0.106	0.506	31.37	14,300	724,000
Average	---	---	---	13,600	704,000

Approved by: Blake M

Blake Minton, Nonmetallics Project Leader
Sherry Laboratories

COUNTY SANITATION DISTRICTS
OF LOS ANGELES COUNTY

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ng Address: P.O. Box 4998, Whittier, CA 90607-4998
hone: (310) 699-7411, FAX: (310) 695-6139

CHARLES W. CARRY
Chief Engineer and General Manager

February 22, 1994

Evaluation of Raven 405 Epoxy Coating for Concrete Protective Characteristics

Raven Chemicals' Raven 405 epoxy coating system was evaluated for its concrete protective characteristics in the Districts Concrete Coating and Liner Testing facilities in Compton for approximately one year of acid service. The coating system was well bonded to the concrete substrate. No indication of corrosion to the liner or the underlying concrete was observed.

As a result of this evaluation, Raven Chemicals' Raven 405 epoxy coating system will be included as an alternative coating product in specifications that we prepare in the future for concrete coating systems. Information contained in this letter is not for publication or advertisement. No endorsement is intended for this coating system. Prior written approval of the Sanitation Districts is required for any advertisement or promotion that involves this agency.

Thank you for your continued cooperation and interest in the Districts' evaluation program for concrete coatings. If you have any questions or need additional information, please contact Edward Esfandi at (310) 638-1161 ext. 222.

Very truly yours

Charles W. Carry

E. J. Esfandi

Edward J. Esfandi
Senior Engineer

EE:lg

EVALUATION OF PROTECTIVE COATINGS FOR CONCRETE

December, 2004 Final Report

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County Sanitation Districts of Los Angeles County, Whittier, California

SCOPE

This report summarizes the results of a testing program to evaluate protective coatings for concrete conducted by the County Sanitation Districts of Los Angeles County (Districts). The testing was conducted at the Districts' Compton Field Office in the City of Compton. The program started in 1983 and ended in 2004. Results for 96 protective coating and lining system tests are reported.

INTRODUCTION

Concrete is the most widely used construction material in wastewater collection and treatment systems. Unfortunately, significant corrosion can occur to unprotected concrete when sulfide generation in wastewater is not controlled. Sources of sulfide in wastewater include degradation of sulfur containing organic matter, the microbiological reduction of sulfate or other oxidized forms of sulfur, and unregulated and/or uncontrolled industrial discharges. The construction of regional collection and treatment systems has increased wastewater travel time in collection systems, culminating in anaerobic wastewater and consequently increased sulfide generation. Odors from manholes or wastewater treatment facilities create significant nuisance problems for most agencies. A major cause of odors is hydrogen sulfide, a gas detectable at extremely low concentrations. Hydrogen sulfide is notorious for its toxicity, as well as its ability to corrode a number of materials used in construction of sewers and treatment plants, including concrete. Concrete corrosion is caused by the aerobic microbial oxidation of hydrogen sulfide to sulfuric acid and the subsequent chemical reaction of the acid with the cement binder in the concrete. Most agencies are particularly sensitive to the nuisances created by the odor releases. Many agencies are often unaware of the significant corrosion occurring to their concrete facilities.

The Districts have utilized different types of protective systems in its history to minimize concrete corrosion. In the mid 1920's the use of vitrified clay liner plates in the construction of large poured-in-place concrete sewers and inlet facilities proved unsuccessful. By the mid 1960's many epoxy coating systems were being tried. Inspections documented coating failure wherever exposure to significant sulfuric acid attack occurred, often within just a few years. This same experience was reported in the 1969 Manual of Practice No. 17, Paints and Protective Coatings for Wastewater Treatment Facilities, "... few, if any, coatings have been effective in preventing the corrosion of concrete under highly corrosive conditions... "[1]. A considerable amount of marketing has occurred for high solids, fast cure coating systems. First hand experiences with these coating systems have resulted in widely different opinions from different agencies. One agency reports nothing but success, while another reports nothing but failure. Figures 1A and 1B illustrate the failure that occurred, after only two years of service, to a urethane coating applied to a drop manhole in 1980.

TABLE 1
Description of Protective Coating Systems Evaluated

CODE NUMBER (Yr tested)	GENERIC TYPE	COATING DESIGNATION	MANUFACTURER
C-67	Epoxy Mortar	Sauereisen-210	Refer to C-34 (Sauereisen)
C-68 (1992)	Polyurea	Structural Seal Polyurea (formerly Sprayseal)	Structural Seal Polyurea Manholes 2652-D North Southport Avenue Chicago, IL 60614
C-69 (1992)	Epoxy Mortar	Raven 405	Refer to C-25 (Raven Lining Systems)
C-70 (1993)	PVC-Liner + Urethane Foam	Linabond Structural Polymer System	Refer to C-35 (Linabond, Inc.)
C-71 (1993)	Urethane	Endura-flex EF1988	Global Eco Technologies P.O. Box 767 Pittsburgh, CA 94565-0767
C-72 (1994)	PVC Liner	Danby PVC Liner	Refer to C-63 (Danby of North America, Inc.)
C-73 (1994)	Fiberglass and PVC Liner	Poly-Triplex Liner	Poly-Triplex Technologies, Inc. 1701 Wynkoop, Suite 250 Denver, CO 80202
C-74 (1994)	Epoxy Mortar	AquataPoxy A-6	Refer to C25 (formerly from American Chemical Corp.)
C-75 (1994)	Polyurea	ThoRoc IC-2480 and Sonneborn TF30 (formerly Polyquick P300)	Refer to C-2 (Degussa Building Systems, formerly from Willamette Valley Company)
C-76 (1995)	Polymer Concrete	Meyer Polycrete	Meyer Rohr + Schacht GmbH http://www.meyer-polycrete.com/en/
C-77 (1996)	Polymer Concrete	iNTERpipe (formerly ICOM)	Polymer Pipe Technology, LLC 500 E. Locust, 5th Floor Des Moines, IA 50309
C-78 (1997)	PVC Liner	PVC 500	Roundeau Phelps Ventures 6603 San Leandro Street Oakland, CA 94621
C-79 (1998)	Polyethylene-coated CMP	SRP (Steel Ribbed Polyethylene Pipe)	Pacific Corrugated Pipe Co. P.O. Box 2450 Newport Beach, CA 92658-8972
C-80 (1998)	PVC Liner	Arrow-Lock	Refer to C-56 (Ameron Protective Coatings)
C-81 (1998)	HDPE Liner	Agru Sure Grip	Agru www.agru.at
C-82 (1999)	HDPE Liner	GSE StudLiner	GSE Lining Technology, Inc. 19103 Gundle Road Houston, TX 77073
C-83 (2000)	GRP Liner	Channeline GRP Liner	Channeline Sewer Systems (N.A.) Inc. 125 Half Mile Road, Suite 200 Red Bank, NJ 07701
C-85 (1999)	Fiberglass and PVC Liner	Multiplexx Liner System	Terre Hill Composites 485 Weaverland Valley Road Terre Hill, PA 17581

TABLE 2
Application Data - Protective Coating Systems Evaluated

Code No.	Surface Preparation [1]	Surface Repair	Primer	Application Method	Coating Thickness Tank Walls mm (mils)	Coating Thickness Tank Base mm (mils)
C-42	WB	No	Yes	Spray	3.2 (125)	9.6 (375)
C-43	WB	No	No	Spray	3.8 (150)	3.8 (150)
C-44	SB	No	Yes	Spray	3.2 (125)	3.2 (125)
C-45	SB	No	Yes	Trowel	6.4 (250)	9.6 (375)
C-46	CH, WRB	No	Yes	Form	85 (3350)	85 (3350)
C-47	WB	Yes [2]	[8]	Spray	3.8 (150)	3.8 (150)
C-48	SB	No	Yes	Spray	2.3 (90)	2.3 (90)
C-49	SB	No	Yes	Trowel/Brush	3.2 (125)	9.6 (375)
C-50	SB	No	Yes	Trowel	3.2 (125)	9.6 (375)
C-51	SB	No	Yes	Trowel/Brush	1.6 (60)	1.6 (60)
C-52	SB	No	Yes	Spray	3.3 (130)	3.3 (130)
C-53	SB	No	Yes	Trowel	-	-
C-54	SB	Yes	[9]	Spray	1.0 (40)	1.0 (40)
C-55	SB	No	No	Spray	1.6 (60)	1.6 (60)
C-56	WB	No	Yes	Trowel	3.8 (150)	15.9 (625)
C-57	SB	No	Yes	Brush/Roll	1.0 (40)	1.0 (40)
C-58	SB	No	Yes	Shot	12 (480)	25 (1000)
C-59	SB	No	Yes	Form	60 (2400)	60 (2400)
C-60	SB	No	Yes	Spray	2.0 (80)	2.0 (80)
C-61	WB	No	No	Trowel	3.3 (130)	4.0 (160)
C-62	-	No	No	Manufactured liner	2.0 (80)	2.0 (80)
C-63	WB	No	No	Interlocking PVC liner	1.5 (60)	1.5 (60)
C-64	WB	No	Yes	Spray foam and hand lay up of liner	20 (800) Foam 0.8 (30) PVC	20 (800) Foam 0.8 (30) PVC
C-65	-	No	No	Manufactured pipe	-	-
C-66	WB	No	No	Brush	1.5 (60)	1.5 (60)
C-67	WB	No	No	Trowel	2 (80)	3 (120)
C-68	WB	No	No	Spray	1.5 (60)	1.5 (60)
C-69	WB	No	No	Spray	1.5 (60)	1.5 (60)
C-70	SB	No	No	Spray foam and hand lay up of liner	3.2 (125) Foam 0.8 (30) PVC	3.2 (125) Foam 0.8 (30) PVC
C-71	SB	No	No	Spray	10 (400)	10 (400)
C-72	WB	No	No	Interlocking PVC liner	1.5 (60)	1.5 (60)
C-73	WB	No	No	Cured in place	1.5 (60)	2 (80)
C-74	WB	Yes [10]	No	Spray	1.5 (60)	1.5 (60)
C-75	WB	No	No	Spray	2.5 (100)	2.5 (100)
C-76	-	-	-	Manufactured pipe	-	-
C-77	-	-	-	[11]	-	-
C-78	WB	No	No	Interlocking PVC liner	1.5 (60)	1.5 (60)
C-79	-	-	-	Manufactured pipe	-	-
C-80	SB	No	Yes	Trowel epoxy gel, hot air weld liner	12.7 (500) gel 1.6 (62) PVC	12.7 (500) gel 1.6 (62) PVC

As stated earlier, the objective of the test is to evaluate the coating's application requirements, concrete bonding characteristics, and acid resistance for one full year of acid service. For each coating system evaluated, data was obtained for the exposure time to failure or completion of the test, and in categories dealing with the relative ease or difficulties of application, the acid resistance, and bonding characteristics demonstrated. The following numerical score (rating system) is used to classify the results for ease and speed in interpretation:

1. No application problems; excellent resistance to acid; and good bond to concrete.

2. Some application problems that are attributed to the applicator and not a reflection of a coating material problem; some reaction with the acid, such as a color change or surface sheen change, but no coating failure; and an adequate, but not necessarily tenacious, bond to the concrete substrate. None of these problems are judged to be significant during the evaluation.

3. Significant problems developed during the application or during the evaluation phase; the material did not bond adequately to the concrete, indicating that the coating could not reliably protect the concrete.

4. A failure in the coating system as a result of serious application problems; a reaction of the acid with the coating; or failure of the coating to protect the concrete during the evaluation period.

Two additional abbreviations are also used:

N/E: Not evaluated due to early failure in other categories.

N/A: This category is not applicable to the particular product being tested.

Table 3 contains the evaluation results. Data include: the coating or lining system's code number; the exposure time in days; the assigned numerical score for relative ease of application, acid resistance (concrete protection), and concrete bond; and the total score for each coating system that progressed well into or completed the one year evaluation period. Comments are also included in Table 3 in an effort to pinpoint specific problems and to describe the coating's ability to protect concrete from sulfuric acid attack.

The total score is simply the sum of the category scores. The lower the "application" score, the easier the system is to apply. The lower the "acid resistance" score, the more acid resistant the system is. The lower the "concrete bond" score, the stronger the system bonds to the concrete substrate. The lowest assigned score for each component is one; therefore, the lowest possible total score for a coating system that is assigned a score in all categories is 3, unless one or more of the scores are not applicable to a coating system. For instance, if a liner is applied in the manufacturers' facilities and is subsequently transferred to the Districts' testing facilities, we are unable to score this system for ease of application. Consequently, such a system is not assigned a score for the ease of application category. This may lead to a total score of less than 3. A total score of "Failed" is assigned to those products that either received a total score of 6 or greater, and/or received a score of 3 or 4 in any of the categories.

TABLE 3
Test Results for Protective Coating Systems Evaluated

Code No.	Exposure Time (Days)	Application	Acid Resistance	Concrete Bond	Total Score	Comments
C-58	539	2	2	3	Failed	Bonding problems in uncorroded surfaces of the test tank.
C-59	539	1	2	3	Failed	Blistering of the coating; coating separated from concrete; bonding problems; pinholes.
C-60	106	4	N/E	33	Failed	Corroded concrete found underneath coating in bottom half of tank; pinholes; separation of coating from concrete.
C-61	393	2	3	1	Failed	Acid penetration.
C-62	369	N/A	1	N/A	1	No problems observed.
C-63	371	2	1	N/A	3	No problems observed.
C-64	414	3	4	2	Failed	Reaction with acid.
C-65	2223	N/A	1	N/A	1	No problems observed.
C-66	375	2	1	2	5	No problems observed.
C-67	369	2	1	1	4	No problems observed.
C-68	385	1	1	2	4	No problems observed.
C-69	375	2	1	1	4	No problems observed.
C-70	365	2	1	1	4	No problems observed.
C-71	365	2	1	1	4	No problems observed.
C-72	394	1	1	N/A	2	No problems observed.
C-73	410	2	2	1	5	Acid penetrated the outer layer of fiberglass. Middle PVC layer prevented acid penetration to concrete.
C-74	463	2	1	2	5	Poor adhesion of the coating to the bottom of the tank. No acid penetration.
C-75	404	1	1	1	3	No problems observed.
C-76	445	N/A	1	N/A	1	No problems observed.
C-77	503	N/A	1	N/A	1	Coupons are acid resistant. Pipe product currently available.
C-78	127	4	N/A	N/A	Failed	Acid penetrated joints above grout level due to faulty installation.
C-79	373	N/A	1	N/A	1	Pipe is corrosion resistant.
C-80	363	1	1	1	3	No problems observed.
C-81	349	1	1	N/A	2	No problems observed.
C-82	369	3	1	2	Failed	Acid penetrated welded joint.
C-83	364	1	1	1	3	No problems observed.
C-85	390	1	4	2	Failed	Acid penetrated liner at seam.
C-86	390	1	4	2	Failed	Acid penetrated liner at seam.
C-87	383	2	1	1	4	Liner not embedded at bottom.
C-88	365	2	2	1	5	Slight discoloration, pinholes but no acid penetration.
C-89	365	1	2	1	4	Slight discoloration.

TABLE 3
Test Results for Protective Coating Systems Evaluated

Code No.	Exposure Time (Days)	Application	Acid Resistance	Concrete Bond	Total Score	Comments
C-91	365	2	2	1	5	Poor surface prep at bottom. Liner slightly discolored & sticky.
C-92	370	1	2	2	5	Variable bond. Shallow pinholes, but no acid penetration.
C-93	180	1	4	1	Failed	Corrosion at pinhole. Odorous brown liquid emitted by coating.
C-94	99	2	N/E	3	Failed	20% disbonded in large bubbles.
C-95	430	1	2	1	4	No problems observed except surface discoloration.
C-96	365	3	4	2	Failed	Coating delaminated. Coating over aggregate broke at several locations and allowed concrete corrosion.
C-97	365	1	1	1	3	No problems observed.
C-98	366	1	2	1	4	No problems observed except slight surface discoloration.

Explanation of Rating System:

1. No application problems; excellent resistance to acid; and good bond to concrete
2. Some application problems that are attributed to the applicator and not a reflection of a coating material problem; some reaction with the acid, such as a color change or surface sheen change, but no coating failure; and an adequate, but not necessarily tenacious, bond to the concrete substrate. None of these problems are judged to be significant during the evaluation.
3. Significant problems developed during the application or during the evaluation phase; the material did not bond adequately to the concrete, indicating that the coating could not reliably protect the concrete.
4. A failure in the coating system as a result of serious application problems; a reaction of the acid with the coating; or failure of the coating to protect the concrete during the evaluation period.

N/E: Not evaluated due to early failure in other categories.

N/A: This category is not applicable to the particular product being tested.

Failed: A total score of "Failed" is assigned to those products that either received a total score of 6 or greater, and/or received a score of 3 or 4 in any of the categories.

Figure 7 illustrates the coating failure that occurred after only a short time period to one epoxy coating (C-7). Preliminary tests with ingots of one system (C-23) looked promising, but the manufacturer decided to use a non-epoxy coating system in the evaluation. Lack of sufficient acid resistance and inability to protect the concrete from corrosion plagued the other systems (C-14, C-19, and C-21).

Figure 7. Epoxy coating failure.

Epoxy Mortar

For the epoxy mortars only 9 of the 16 systems (C-25, C-45, C-49, C-50, C-53, C-67, C-69, C-74, and C-95) survived the test. Most of these successful systems involve the application of a thick, inert material filled version of the coating as an intermediate step prior to application of finish coat with the neat epoxy. Minimum thickness of the intermediate coat is 2.2-3.2 mm (90-125 mils). However, C-95 was installed with two thick coats of the epoxy mortar without the filler due to weather concerns. Other epoxy mortar systems (C-15, C-22, C-41, C-42, C-51, C-56, and C-61) failed mostly due to pinholes and application problems. C-67 was applied by a manufacturer's representative after the same system (C-61) failed after being applied by an inexperienced applicator. C-74 is a later version of C-25. Both C-25 and C-74 made extensive use of a gel or filler version of its coating for surface repair and for plugging bug/pinholes in between applications. C-25 was brush applied while C-74 was spray applied. C-25 had almost no problems while C-74 had poor adhesion to the bottom of the tank with no acid penetration.

CONCLUSIONS

Most coating manufacturers will point, and in many cases with justification, to application problems as being the cause of coating failure. It is certainly true that surface preparation and conditions under which the coating is applied are extremely critical. It is difficult to determine the reasons why so many coating systems, advertised to provide protection in wastewater industry, have failed in the test facility, but it really is of little consequence. The purpose of the evaluation facility was to provide a non-laboratory environment to evaluate the coatings. To survive the test, a coating system not only had to be acid proof and able to bond to the concrete substrate, but it also had to be applicator friendly. Ideal conditions for applying a protective coating probably never exist in wastewater collection and treatment facilities. Therefore, a successful coating system has to be one that can be applied under less than ideal conditions.

The predominant reason for failure of so many coating systems was the formation of pinholes or blowholes. In general, the mortar or filler extended coating systems had dramatic improvements in their survival rates versus their parent neat systems. The predominant reason for failure of the lining systems were poor bonding of the liner at the seams. The predominant reason for failure of the specialty concretes was insufficient acid resistance.

The purpose of this evaluation program was to develop a list of suitable coatings and specifications for application of the coatings. The program has fulfilled that purpose to some extent. Table 4 is a list of 39 coating systems that have successfully completed this test. Only successful coating systems that were assigned a score equal to or less than 5 are listed in Table 4. The successful coating systems include: one coal tar mortar (C-37); five epoxies (C-28, C-66, C-88, C-89, and C-97); nine epoxy mortars (C-25, C-45, C-49, C-50, C-53, C-67, C-69, C-74, and C-95); thirteen liners (C-40, C-62, C-63, C-70, C-72, C-73, C-79, C-80, C-81, C-83, C-87, C-91, and C-98); two polyester mortars (C-17 and C-44); two polyureas (C-68 and C-75); three specialty concretes (C-65, C-76 and C-77); three urethanes (C-10, C-71, and C-92); and one vinyl ester mortar (C-38).

The information developed should be of some assistance, but as previously indicated, does not address gas permeability and subsurface microbial acid generation[3]. When attempting to select a coating, don't be satisfied to deal with the manufacturer's sales representative alone. Contact the manufacturer directly and be sure to explain fully the conditions under which the coating will be applied and the environment it has to withstand. Don't hesitate to ask for a list of applications and consult with the owners, as well as the applicators. If application projects are inspected, try to categorize the applications by the exposure level to hydrogen sulfide. Never assume that a coating system that has performed well has been exposed to corrosive conditions unless you can substantiate it. It is recommended that only coatings with total scores of 5 or less be considered for corrosive environments (see Table 3 and 4).

It is suggested that coating manufacturers, recognized testing agencies, or technical organizations consider the development and use of an accelerated evaluation technique to screen coatings for application in the wastewater field. With such a technique, the advances in coating technology can be evaluated by the end user. A testing chamber and procedure was developed by Tnemec Company, Inc. that includes evaluation of permeability properties[3].

TABLE 4
Successful Protective Coating Systems

CODE NUMBER	COATING DESIGNATION	TOTAL SCORE	MANUFACTURER
C-67	Sauereisen-210	4	Sauereisen 160 Gamma Drive Pittsburgh, PA 15238 (412) 963-0303
C-69	Raven 405	4	Raven Lining Systems 1024 N. Lansing Avenue Tulsa, OK 74106 (800) 324-2810
C-74	A-6 AquataPoxy	5	Raven Lining Systems 1024 N. Lansing Avenue Tulsa, OK 74106 (800) 324-2810
C-95	Tnemec Series 434 Chembloc	4	Tnemec Company inc. 6800 Corporate Drive Kansas City, MO 64120-1372 (800) TNEMEC1
Generic Type – Liner Systems			
C-40	Linabond Mastic System (PVC)	4	Linabond, Inc 12960 Bradley Avenue Sylmar, CA 91342 (818) 362-7373
C-62	Con-plast Plastic Liner System	1[2]	Southwest Concrete Products 519 S. Benson Avenue Ontario, CA 91762-4002 (909) 983-9789
C-63	Danby PVC Liner	3[1]	Danby of North America, Inc. P.O. Box 5127 Cary, NC 27512-5127 (919) 467-7799
C-70	Linabond Structural Polymer System (PVC and polymer)	4	Linabond, Inc 12960 Bradley Avenue Sylmar, CA 91342 (818) 362-7373
C-72	Danby PVC Liner	2[1]	Danby of North America, Inc. P.O. Box 5127 Cary, NC 27512-5127 (919) 467-7799
C-73	Poly-Triplex Liner (PVC and fiberglass)	5	Poly-Triplex Technologies, Inc. 1701 Wynkoop, Suite 250 Denver, CO 80202 (303) 893-3100
C-79	SRP (Polyethylene-coated CMP)	1[2]	Pacific Corrugated Pipe Co. P.O. Box 2450 Newport Beach, CA 92658-8972 (949) 650-4555

Acknowledgments and Credits:

This paper was presented at the Water Environment Federations National Conferences in Los Angeles (1986) and Philadelphia (1987), at the California Water Pollution Control Association Annual Conference in Sacramento (1987), at the National Conference and Exposition of the Steel Structures Painting Council in Baltimore (1988) and in Long Beach (1991). Credit is given to all the coating manufacturers who not only agreed to submit their coatings for evaluation, but arranged for the installation of the coating system.

Authors

John A. Redner was the Sewerage Departmental Engineer, Randolph P. Hsi was an Associate Engineer, Edward J. Esfandi was a Senior Engineer, Roger Sydney was a Civil Engineer, Robin M. Jones was an Associate Engineer, Donna Won is a Senior Engineer, and James Andraska is a Supervising Civil Engineer of the County Sanitation Districts of Los Angeles County. Correspondence may be addressed to Mr. Andraska at 24501 S. Figueroa Street, Carson, CA 90745, or by email at jandraska@lacsd.org.

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WELDON
LABORATORIES, INC.

Ms. Joanne Hughes
Raven Linings
13105 East 61st St., Suite A
Broken Arrow, OK 74012

April 26, 2007
Project J06137

Fax 918-615-0140

Subject – Immersion Testing of Raven 405

Dear Ms. Hughes,

In accordance with your request, Weldon Laboratories, Inc. has performed immersion testing of several samples of concrete which were coated with Raven 405. The coated samples were rectangular and measured approximately 1 ¾" x 1 ¾" x 5 ¾". They were received on August 28, 2006.

The testing involved weighing the samples, and subsequently immersing them halfway in the following reagents:

Deionized water
10% sulfuric acid
30% sulfuric acid
Grease (Crisco shortening)
10% detergent (Tide)
Gasoline

The specimen placed in gasoline was exposed for 7 days, with visual inspections on weekdays. The other specimens were exposed for 6 months, with visual inspections every month. At the end of the testing, the samples were weighed again, and also tested for adhesion (ASTM D 4541) using a Defelsko Positester.

Initially, problems were encountered with glue failures on some samples during the adhesion testing, and in the course of the testing it was found that glue failures could be eliminated if scoring was performed around the dollies. Therefore, some of the adhesion testing was repeated, after first scoring around the dollies. As the data in the following tables show, in every case the failures occurred in the concrete, but those dollies which were scored tended to exhibit substantially lower values than those which were not scored.

The test results are shown in the attached tables.

If you have any questions or comments, please do not hesitate to contact this office.

Sincerely,
Dwight. G. Weldon, President

Dwight G. Weldon

Table #1 – 6 Month Testing of Raven 405

Property	DI Water	10% H_2SO_4	30% H_2SO_4	Grease	10% detergent	Unexposed control
Initial weight	627.7g	645.8g	642.5g	627.6g	651.0g	n/a
Final (6 month) weight	627.9g	646.2g	642.8	627.5g	651.2g	n/a
1 month	No visual effect	No visual effect	No visual effect	No visual effect	No visual effect	n/a
2 months	No visual effect	No visual effect	No visual effect	No visual effect	No visual effect	n/a
3 months	No visual effect	No visual effect	No visual effect	No visual effect	No visual effect	n/a
4 months	No visual effect	No visual effect	No visual effect	No visual effect	No visual effect	n/a
5 months	No visual effect	No visual effect	No visual effect	No visual effect	No visual effect	n/a
6 months	No visual effect	Very faint discoloration	Very faint discoloration	No visual effect	No visual effect	n/a
Adhesion, immersion	1590psi, failure in concrete	1510psi, failure in concrete	1600psi, failure in concrete	1280psi, failure in concrete	800psi, failure in concrete	1050psi, failure in concrete
Adhesion, vapor phase	1470psi, failure in concrete	900psi, failure in concrete	1060psi, failure in concrete	1800psi, failure in concrete	640psi, failure in concrete	1140psi, failure in concrete

Table #2 – 1 Week Testing of Raven 405 in Gasoline

Property	Result
Initial weight	589.4g
1 day	No visual effect
2 days	No visual effect
3 days	No visual effect
5 days	No visual effect
6 days	No visual effect
One week, plus final weight	No visual effect, final wt. = 589.4g
Adhesion, immersion	1260 psi, failure in concrete
Adhesion, vapor phase	900 psi, failure in concrete

CITY OF LOS ANGELES
CALIFORNIA

JAMES K. HAHN
MAYOR

DEPARTMENT OF
PUBLIC WORKS

BUREAU OF
ENGINEERING

VITALY B. TROYAN, P.E.
CITY ENGINEER

650 SOUTH SPRING ST., SUITE 200
LOS ANGELES, CA 90014-1911

April 30, 2003

Joanne Hughes, Vice President
Raven Lining Systems
1024 North Lansing
Tulsa, Oklahoma 74106

Dear Ms. Hughes:

Re: CHEMICAL RESISTANCE TESTING OF RAVEN 405 EPOXY LINING

Attached is Lab No. 2003-514-91, dated April 10, 2003, showing the results of chemical resistance testing for the above maintenance hole product. The lining system responded to chemical exposure as follows:

Weight change: ***Excellent***
Hardness change: ***Excellent***
Tensile strength change: ***Excellent***
Elongation: ***Satisfactory****, with reactions to sulfuric acid, nitric acid, ferric chloride, detergent, biological and bleach exposures and a notable reaction to sodium hydroxide and ammonium hydroxide exposures.*

The lining system is identified as follows:

Trade Name:	*Raven 405*
Approved Use:	*Sanitary Sewer Maintenance Rehabilitation*
Installation:	*SSPWC Section 500-2 as modified by City of Los Angeles Brownbook*
Resin:	*Blue-colored solid epoxy*

The overall summary is that this material **passed** SSPWC Section 210-2.3 Chemical Resistance Test. To complete the evaluation process, a trail demonstration must be arranged where we may observe and verify an installation of the system. If you have any questions, please call me at (213)847-8776.

Sincerely,

Hugh S. Lee, Group Manager
Design Standards and Investigations Group
650 S. Spring Street, Suite 400
Los Angeles, California 90014-1913

HSL:hl/raven4.wpd

Attachment (Lab No. 2003-514-91)

Chemical Resistance Test of
Raven Lining Systems
Raven 405 Blue
Epoxy Resin

Project Title: Maintenance Shaft & Sewer Rehabilitation
Project Number: BD001748
Engineer: Hugh Lee
Source: Raven Lining Systems
Date Received: 10/16/2002
Specification: SSPWC 210-2.3.3, 1997
Description: Raven 405 Blue Epoxy Resin

SOLUTION	RESULTS CONDITIONED WEIGHT CHANGE % maximum				REQUIREMENTS CONDITIONED WEIGHT CHANGE %
	Days Immersion				
	28	56	84	112	
Sulfuric Acid, 20%	0.2239	0.3685	0.6617	0.6543	All Solutions and Periods ± 1.5% max
Sodium Hydroxide, 5%	-0.0435	0.0532	0.1263	0.1700	
Ammonium Hydroxide, 5%	0.0231	0.1234	0.2410	0.2754	
Nitric Acid, 1%	0.0706	0.1708	0.3070	0.3531	
Ferric Chloride, 1%	0.0382	0.1305	0.2120	0.2824	
Soap, 0.1%	0.0351	0.1289	0.2087	0.2865	
Detergent, 0.1%	0.0222	0.1260	0.2322	0.2694	
BOD, ≥ 700ppm	0.0230	0.1314	0.2179	0.2889	
Bleach, 1%	-0.0580	-0.0988	-0.3358	0.2835	
Sodium Hydroxide Buffer to PH 10	0.0203	0.1313	0.2182	0.2703	

Chemical Resistance Test of
Raven Lining Systems
Raven 405 Blue
Epoxy Resin

Project Title: Maintenance Shaft & Sewer Rehabilitation
Project Number: BD001748
Engineer: Hugh Lee
Source: Raven Lining Systems
Date Received: 10/16/2002
Specification: SSPWC 210-2.3.3, 1997
Description: Raven 405 Blue Epoxy Resin

SOLUTION	RESULTS CONDITIONED HARDNESS CHANGE maximum 112 Days Immersion	REQUIREMENTS
Sulfuric Acid, 20%	1	For Information Only
Sodium Hydroxide, 5%	1	
Ammonium Hydroxide, 5%	2	
Nitric Acid, 1%	2	
Ferric Chloride, 1%	1	
Soap, 0.1%	-1	
Detergent, 0.1%	-3	
BOD, ≥ 700ppm	2	
Bleach, 1%	-1	
Sodium Hydroxide Buffer to PH 10	-1	
PHYSICAL PROPERTY	*INITIAL RESULTS*	
Hardness, Shore "D" ASTM D2240	85	For Information Only

Chemical Resistance Test of Raven Lining Systems Raven 405 Blue Epoxy Resin

Project Title: Maintenance Shaft & Sewer Rehabilitation
Project Number: BD001748
Engineer: Hugh Lee
Source: Raven Lining Systems
Date Received: 10/16/2002
Specification: SSPWC 210-2.3.3, 1997
Description: Raven 405 Blue Epoxy Resin

SOLUTION	RESULTS		REQUIREMENTS
	Tensile Strength, psi	Elongation %	
	112 Days Immersion		
Sulfuric Acid, 20%, Type I	8,974	1.7	For Information Only
Sodium Hydroxide, 5%, Type I	8,752	2.1	
Ammonium Hydroxide, 5%, Type I	8,428	1.8	
Nitric Acid, 1%, Type I	8,698	1.7	
Ferric Chloride, 1%, Type I	8,907	1.8	
Soap, 0.1%, Type I	8,615	1.6	
Detergent, 0.1%, Type I	8,568	1.7	
BOD, ≥ 700ppm, Type I	8,668	1.7	
Bleach, 1%, Type I	8,395	1.7	
Sodium Hydroxide Buffer to PH 10, Type I	8,540	1.7	
PHYSICAL PROPERTIES	*INITIAL RESULTS*		
Initial Tensile Strength, psi	9,034		For Information Only
Initial Elongation, %	1.5		

Chemical Resistance

Raven 405 coating has been immersion tested for a minimum of six (6) months according to ASTM D543 (modified) Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents. The results indicate classification of Raven 405 as being suitable for constant immersion duty in the following reagents:

- Water
- Nitric Acid, 5%
- Phosphoric Acid, 10%
- Sulfuric Acid, 20%
- Sodium Hydroxide, 10%
- Unleaded Gasoline
- Vegetable Oil
- Detergent Solution, 0.1%
- Soap Solution, 0.1%

During the course of testing, none of the specimens exhibited weight loss, spalling, cracking or blistering. Immersion samples are “free” coatings without concrete or brick substrates, immersing over twice the area that would normally see service. Color change was a very slight orange surface coloration for the sample immersed in Nitric Acid and a slight darkening of the sample immersed in the Sulfuric Acid. No degradation was experienced.

For additional chemical resistance performance of Raven 405, see the Raven Chemical Resistance Chart or contact Raven with project details at 800-324-2810.

WELDON
LABORATORIES, INC.

Ms. Joanne Hughes
Raven Linings
13105 East 61st St., Suite A
Broken Arrow, OK 74012

April 26, 2007
Project J06137

Fax 918-615-0140

Subject – Immersion Testing of Raven 405

Dear Ms. Hughes,

In accordance with your request, Weldon Laboratories, Inc. has performed immersion testing of several samples of concrete which were coated with Raven 405. The coated samples were rectangular and measured approximately 1 ¾" x 1 ¾" x 5 ¾". They were received on August 28, 2006.

The testing involved weighing the samples, and subsequently immersing them halfway in the following reagents:

Deionized water
10% sulfuric acid
30% sulfuric acid
Grease (Crisco shortening)
10% detergent (Tide)
Gasoline

The specimen placed in gasoline was exposed for 7 days, with visual inspections on weekdays. The other specimens were exposed for 6 months, with visual inspections every month. At the end of the testing, the samples were weighed again, and also tested for adhesion (ASTM D 4541) using a Defelsko Positester.

Initially, problems were encountered with glue failures on some samples during the adhesion testing, and in the course of the testing it was found that glue failures could be eliminated if scoring was performed around the dollies. Therefore, some of the adhesion testing was repeated, after first scoring around the dollies. As the data in the following tables show, in every case the failures occurred in the concrete, but those dollies which were scored tended to exhibit substantially lower values than those which were not scored.

The test results are shown in the attached tables.

If you have any questions or comments, please do not hesitate to contact this office.

Sincerely,
Dwight. G. Weldon, President

Dwight G. Weldon

1188 Rt 30 • P.O. Box 40 • Imperial, PA 15126 • 724-695-2212 • 724-695-2218 FAX

Flexural Strength Enhancement of Concrete Substrate

The additional flexural strength imparted to a concrete substrate via the application of an adhered high performance 100% solids epoxy is demonstrated by testing standard concrete with varying thickness of coating applied. As a baseline an uncoated sample was also tested. The results show that Raven 405 High Build Epoxy coating at 80 mils imparts a load capacity equal to three times that of bare concrete. The lateral deflection of the failure plane exhibits how adhesion of the coating distributes load thus enhancing the performance of the composite system. The total deflection at point of failure was also increased an average of 288%. At typical application thickness, Raven 405 can dramatically reinforce new or deteriorated substrates while also providing high levels of chemical resistance.

120 Lb Load

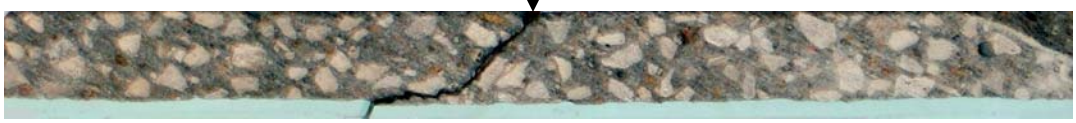
Uncoated Concrete
Failure at 120 Lbs
Deflection of 0.013”

366 Lb Load

Concrete w/80 mils
Failure at 366 Lbs
Deflection of 0.051”

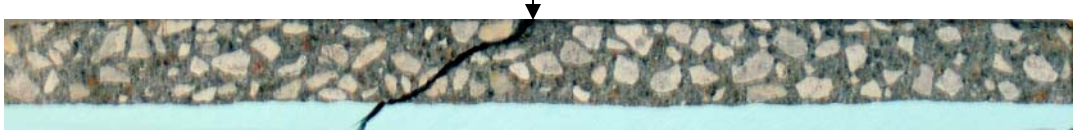
427 Lb Load

Concrete w/125 mils
Failure at 427 Lbs
Deflection of 0.051”



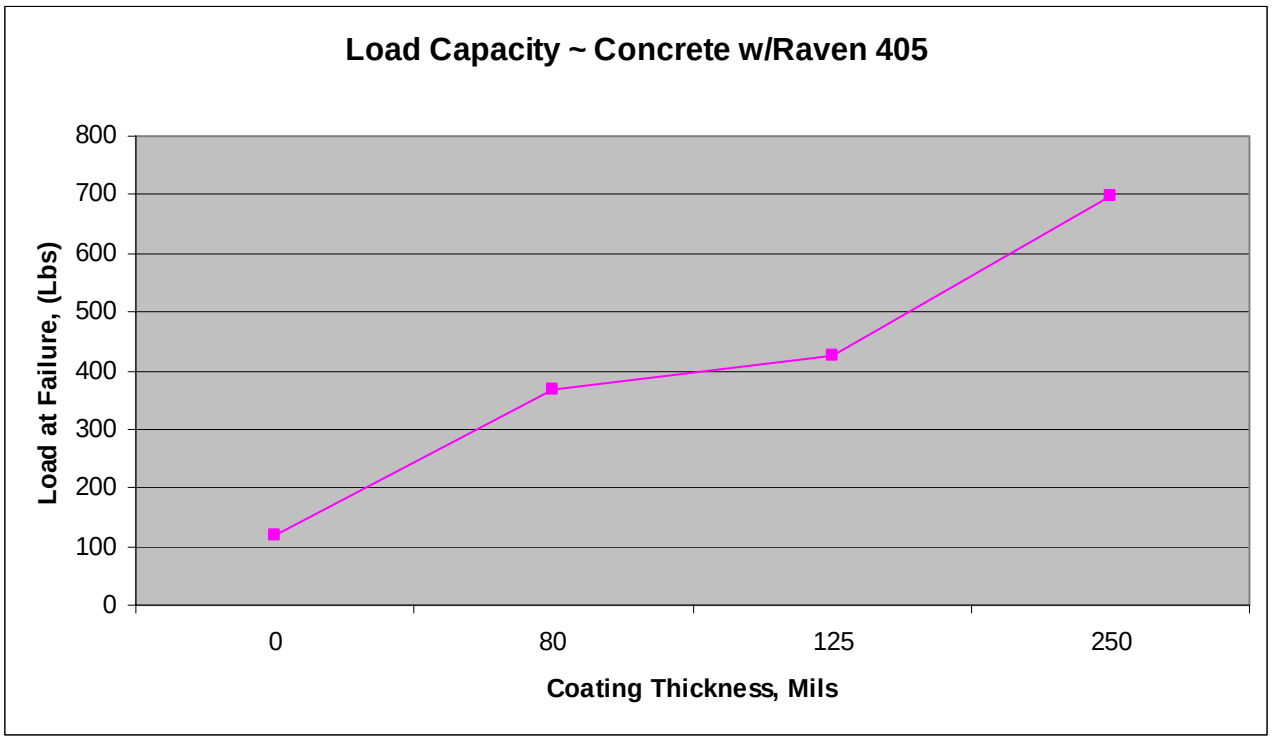
699 Lb Load

Concrete w/250 mils
Failure at 699 Lbs
Deflection of 0.048”



Flexural Strength Enhancement of Concrete Substrate

Coating Thickness, mils (.001")	Average Load at Failure, Lbs	% Increase Load Capacity	Average Deflection, Inches	% Increase Deflection
0	120	-	0.013	-
80	366	205%	0.051	295%
125	427	256%	0.051	294%
250	699	483%	0.048	274%



Testing performed according to ASTM test method by an independent testing laboratory.
Concrete samples cast in approximate 1" x 1" x 10" samples.
Coating spray applied via airless spray. Certified test results available upon request.

Product References

RAVEN LINING SYSTEMS
For a lifetime of protection

City of Fresno
Saeid Vaziry
Chief of Technical Services
5607 West Jensen Avenue
Fresno, CA 93706
W# 559-621-5290
Headworks (25,000 sf) - 2004

Charleston City Public Works
Larry Drolet
Construction Manager
P.O. Box B
Charleston, SC 29402
W# 843-727-6875
Water Filter Basins and 140’ deep x 35’ diameter Lift Station – 2002

Product References

Trinity River Authority
Richard Postma, P.E.
5300 South Collins
Arlington, TX 76018
W# 817-493-5147
M# 817-366-6420
Clarifiers, Effluent Troughs, Manholes,
Lift Stations and Junction Boxes – Since 2001

Trinity River Authority
Jake Burwell
TRA Inspector
5300 South Collins
Arlington, TX 76018
W# 817-493-5151
M# 817-366-4319
35,000 sf on Lift Stations (new & rehab)
since 2002



Trinity River Authority
Winston Silvia
NACE Inspector
5300 South Collins
Arlington, TX 76004
W# 817-671-3158
Numerous WWTP structures – Since 2001




Product References

Little Falls Water Treatment Plant
Tom Zimmerman
800 Union Blvd.
Totowa, NJ 07512
W# 973-837-1402
High performance coating of Ozonization Plant (183,304 sf) – 2003



Albertson Water District
Dvirka & Bartilucci Engineers
William D. Merklin, P.C.
184 Shepard Lane
Roslyn Heights, NY 11577
W# 516-364-9890
Clear Well for Air Stripping
Treatment Facility – Well #5

Town of Arlington, MA
Conti Environment & Infrastructure Inc.
Jim Henebury
W# 978-318-9095
Subcontractor: Insituform Technology
Brick Manholes and various concrete
structures – Raven 405 – 2003

Massachusetts Water Resource Assn.
Dufresne-Henry, Inc./Jacobs Civil, Inc.
JBD'Allessandro Corporation
Jon D' Allessandro
W# 508-559-6400
East Boston Branch Sewer Rehabilitation
Manholes – Raven 405 – 2004

City of Malden, MA
T. Ford Company Inc.
Jack Enos, VP
W# 978-352-5606
Manholes and Drain Outfall at NSTRR
facility, Medford, MA

Product References

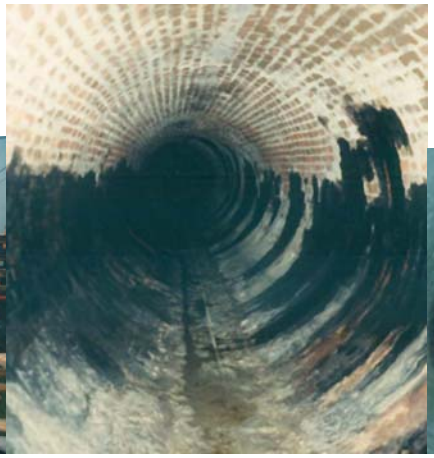
RAVEN LINING SYSTEMS
For a lifetime of protection

City of New York
Department of Environmental Protection
Charles Coniaris
9605 Horace Harding Expressway
Corona, NY 11368
W# 718-595-5117
Sewage Treatment Plant Digester Rehabilitation (15,800 sf) – 2004

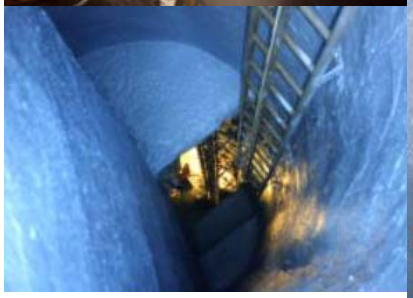
Product References

RAVEN LINING SYSTEMS
For a lifetime of protection

Baltimore Gas & Electric
Tim Long or Dan Norden
P.O. Box 1535
Baltimore, MD 21203
W# 410-291-4531
Rehabilitate interior of 60” brick storm drain with oil infiltration (13,039 sf) – 2001


Pierce County
Fred Hammond, P.E.
Tacoma, WA
W# 253-798-3044
90’ deep x 10’ diameter drop structure and 84” sewer pipeline coated in live flow conditions – 1996



Product References

Boston Water & Sewer Commission
Patrick Toomey
W# 617-989-7000
60” diameter 100+ year-old brick Dorchester Sewer Interceptor Rehabilitation – Raven 405 – 2003

Earth Tech
Patrick Murray, P.E.
1020 North Broadway, Suite G-12
Milwaukee, WI 53202
W# 414-270-4208
Sewers and Tunnels – Raven 405 – 2000

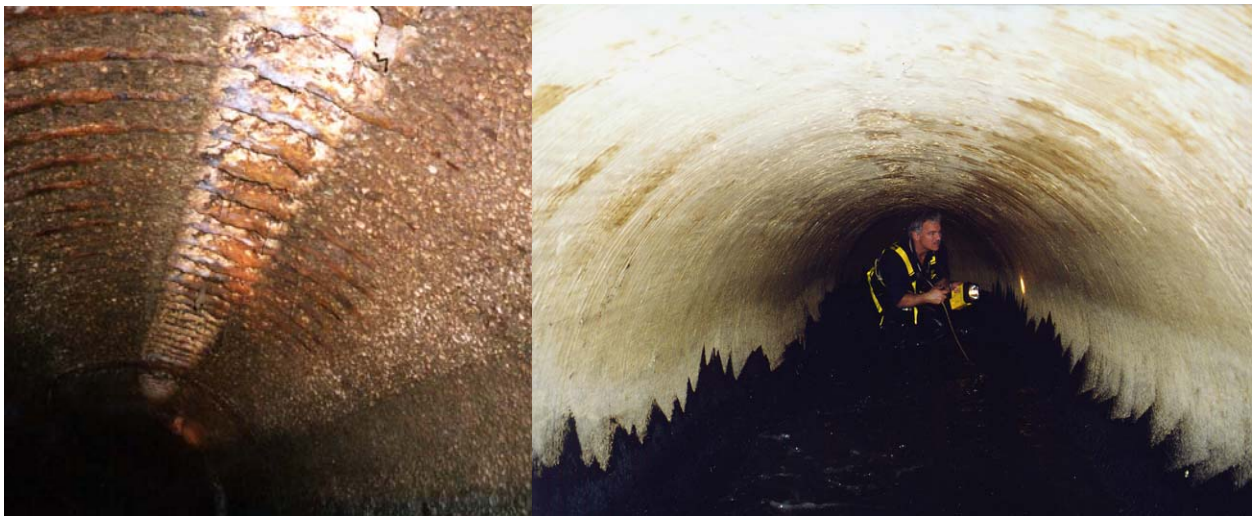
Mar 05

Product References

RAVEN LINING SYSTEMS
For a lifetime of protection

Metropolitan District of Southern California
Roger M. Hickson
700 Moreno Avenue
LaVerne, CA 91750
W# 909-392-5389
Large diameter water conduit/pipe

Miami Dade Water & Sewer Department
David Lee or Rod Lovett
20820 SW 117 Avenue
Miami, FL 33177
W# 305-232-0148
Sewers and Tunnels – AquataPoxy A-6 – 1997



Mar 05

Product References

RAVEN LINING SYSTEMS
For a lifetime of protection

Consolidated Edison of New York
Frank Ciminiello
General Manager
Manhattan Gas Operations
708 First Avenue
New York, NY 10017
W# 212-460-6443
Gas Utility Vaults and Steam Tunnels – since 1997



City of Austin
David Rinn
Engineering Associate
Austin, TX
W# 512-972-0265
M# 512-563-3129
Thousands of collection system structures, since 1994

GSWW & Associates
Leigh Cerda, P.E. (formerly City of Austin)
Austin, TX
W# 512-306-9266
Manholes (new and rehab), lift stations, since 1994
See article attached.






Product References

RAVEN LINING SYSTEMS
For a lifetime of protection

Earth Tech
Mark Cunningham, P.E.
655 Winding Brook Dr. #402
Glastonbury, CT 06033
W# 860-657-1200
Sedimentation Basins at Wastewater Treatment Plant



Alaska Road Boring
Bob Simpson
9024 Vanguard Drive, Suite 102
Anchorage, AK 99507
W# 907-344-6895
Concrete Water Tank in Tundra


Product References

RAVEN LINING SYSTEMS
For a lifetime of protection

City of Orlando
Alan Oyler, P.E.
5100 L B McLeod Road
Orlando, FL 32811
W# 407-246-3623
Various Treatment Plant Structures – since 2000

City of Tulsa
Matt Vaughn, P.E.
Tulsa, OK
Various Collection System and Treatment Plant Structures since 1986

Product References

RAVEN LINING SYSTEMS
For a lifetime of protection

Las Tejas Estate
Jim Forsha
Montecito, CA
W# 805-688-6020
Concrete Water Tank Rehab – AquataPoxy A-6

City of Vancouver
Vancouver, WA
See article attached
W# 360-696-8020