EMTEQUE LLC
A WCD Group Company

November 14, 2012

New York City Office of Environmental Remediation
City Voluntary Cleanup Program
c/o Shaminder Chawla
100 Gold Street, 2nd Floor
New York, NY 10038

Re: 13CVCP093K
60 Water Street (Dock Street)
Remedial Action Work Plan (RAWP) ***Revised*** Stipulation List

Dear Mr. Chawla:

Emteque, LLC hereby submits a Remedial Action Work Plan (RAWP) Stipulation List for the Site to the New York City Office of Environmental Remediation (OER) on behalf of Two Trees Management Co, LLC. This letter serves as an addendum to the RAWP to stipulate additional content, requirements, and procedures that will be followed during the site remediation. The contents of this list are added to the RAWP and will supersede the content in the RAWP where there is a conflict in purpose or intent. The additional requirements/procedures include the following Stipulation List below:

1. The criterion attached in **Appendix 1** will be utilized if additional petroleum containing tank or vessel is identified during the remedial action or subsequent redevelopment excavation activities. All petroleum spills will be reported to the NYSDEC hotline as required by applicable laws and regulations. This contingency plan is designed for heating oil tanks and other small or moderately sized storage vessels. If larger tanks, such as gasoline storage tanks are identified, OER will be notified before this criterion is utilized.

2. A pre-construction meeting is required prior to start of remedial excavation work at the site. A pre-construction meeting will be held at the site and will be attended by OER, the developer or developer representative, the consultant, excavation/general contractor, and if applicable, the soil broker.

3. A pre-approval letter from all disposal facilities will be provided to OER prior to any soil/fill material removal from the site. Documentation specified in the RAWP - Appendix 3 - Section 1.6 “Materials Disposal Off-Site” will be provided to OER. If a different disposal facility for the soil/fill material is selected, OER will be notified immediately.

4. A CD containing the final RAWP including this approved Stipulation List will be placed in the library that constitutes the primary public repository for project documents.

5. Signage for the project will include a sturdy placard mounted in a publically accessible right of way to building and other permits signage will consist of the NYC BCP Information Sheet (attached **Appendix 2**) announcing the remedial action. The Information sheet will be laminated and permanently affixed to the placard.

1350 Broadway, Suite 1901
New York, NY 10018-0891
P: 212 631 9000
F: 212 631 8066

23 Route 31 North, Suite B26
Pennington, NJ 08534-1600
P: 609 730 0007
F: 609 730 0011

6. This NYC BCP project involving the removal and transportation of hazardous waste may be subject to the New York state Department of Environmental Conservation's Special Assessment Tax (ECL 27-0923) and Hazardous Waste Regulatory Fees (ECL 72-00402). See DEC's website for more information: http://www.dec.ny.gov/chemical/9099.html.

7. All hotspot areas will be disposed in accordance with applicable laws and regulations as well as disposal facility requirements. Waste characterization sampling results will be provided to OER.

8. Note that Lots 1, 3, 14, 49, 52 & 53 were merged into Lot 1 of Block 36.

9. Collection and analysis of endpoint samples (Section 4.2) will be conducted to evaluate the performance of the remedy with respect to attainment of Track 1 SCOs. A map indicating post-remedial endpoint sampling locations is provided in **Appendix 3** and include sampling locations in both the area of the building footprint and the area of the unexcavated setback area.

10. Remedy bullet #10 (Section 4.0) of the RAWP indicates that a sub-slab depressurization system (SSDS) will be installed beneath the structure's [grade] in the setback areas along north east property boundary. The Enrollee is continuing to work with the SCA relative to the need for, and requirements of, an SSDS. Information will be provided to OER relative to this item upon resolution of the issue with SCA and upon approval of OER. If required, enrollee shall describe SSDS system in detail and provides PE/RA certified building plans with SSDS installation details (sub-slab matrix, piping configuration, risers, depressurization mechanism, etc.) with respect to the proposed building foundation, footings, slab, and sidewalls. The proposed installation shall satisfy OER and SCA requirements.

11. Section 4.3 of the RAWP describes the vapor barrier system (indicates Figure 9) manufactured by WR Grace that will be installed beneath the structure's slab and along foundation sidewalls. **Appendix 4** provides building plans with vapor barrier system installation details (penetrations, joints, etc.) with respect to the proposed building foundation, footings, slab, and sidewalls. Include elevator details for slab and sidewall installations as well.

12. CHASP is included as **Appendix 5**. Truck route will be forwarded and placed in Appendix 6, once the hauler and the disposal facility has been finalized.

13. Dewatering will be performed in full compliance with applicable laws, rules and regulations.

14. Three (3) additional groundwater monitoring wells will be installed and sampled. **Appendix 6** includes the sampling location map. Groundwater samples will be analyzed for Full List TCL and TAL Metals (both filtered and unfiltered).

15. **Appendix 7** includes comments to the Phase II Work Plan and Remedial Investigation Report from School Construction Authority (SCA) memorandum dated September 17, 2012. The "Response to Comments" to SCA is also included.

16. **Appendix 8** includes Vapor Barrier Pre-Certification from the Vapor Barrier manufacturer stating that the proposed vapor barrier system mitigates against the contaminants of concern at the site.

17. Building storage rooms in the sub-cellar will be properly ventilated. The ventilation issues have been addressed and drawing A200 and A200a, attached as **Appendix 9.**

18. Signed and stamped RAWP certification page is attached in **Appendix 10**.

19. Upon completion of any additionally requested sampling, the results and Amended STIP (if warranted) will be submitted OER in a timely manner for review/approval.

Very Truly Yours,

Eric Telemaque
Principal

cc: B. Gribble, OER

APPENDIX 1

NYC BCP GENERIC PROCEDURES FOR UST MANAGEMENT

Generic Procedures for Management of Underground Storage Tanks
Identified under the NYC BCP

Prior to Tank removal, the following procedures should be followed:

- Remove all fluid to its lowest draw-off point.
- Drain and flush piping into the tank.
- Vacuum out the “tank bottom” consisting of water product and sludge.
- Dig down to the top of the tank and expose the upper half.
- Remove the fill tube and disconnect the fill, gauge, product, vent lines and pumps. Cap and plug open ends of lines.
- Temporarily plug all tank openings, complete the excavation, remove the tank and place it in a secure location.
- Render the tank safe and check the tank atmosphere to ensure that petroleum vapors have been satisfactorily purged from the tank.
- Clean tank or remove to storage yard for cleaning.
- If the tank is to be moved, it must be transported by licensed waste transporter. Plug and cap all holes prior to transport leaving a 1/8 inch vent hole located at the top of the tank during transport.
- After cleaning, the tank must be made acceptable for disposal at a scrap yard, cleaning the tanks interior with a high pressure rinse and cutting the tank in several pieces.

During the tank and pipe line removal, the following field observations should be made and recorded:

- A description and photographic documentation of the tank and pipe line condition (pitting, holes, staining, leak points, evidence of repairs, etc.).
- Examination of the excavation floor and sidewalls for physical evidence of contamination (odor, staining, sheen, etc.).
- Periodic field screening (through bucket return) of the floor and sidewalls of the excavation, with a calibrated photoionization detector (PID).

<u>Impacted Soil Excavation Methods</u>

The excavation of the impacted soil will be performed following the removal of the existing tanks. Soil excavation will be performed in accordance with the procedures described under Section 5.5 of Draft DER-10 as follows:

- A description and photographic documentation of the excavation.
- Examination of the excavation floor and sidewalls for physical evidence of contamination (odor, staining, sheen, etc.).
- Periodic field screening (through bucket return) of the floor and sidewalls of the excavation, with calibrated photoionization detector (PID).

Final excavation depth, length, and width will be determined in the field, and will depend on the horizontal and vertical extent of contaminated soils as indentified through physical examination (PID response, odor, staining, etc.). Collection of verification samples will be performed to evaluate the success of the removal action as specified in this document.

The following procedure will be used for the excavation of impacted soil (as necessary and appropriate):

- Wear appropriate health and safety equipment as outlined in the Health and Safety Plan.
- Prior to excavation, ensure that the area is clear of utility lines or other obstructions. Lay plastic sheeting on the ground next to the area to be excavated.
- Using a rubber-tired backhoe or track mounted excavator, remove overburden soils and stockpile, or dispose of, separate from the impacted soil.
- If additional UST’s are discovered, the NYSDEC will be notified and the best course of action to remove the structure should be determined in the field. This may involve the continued trenching around the perimeter to minimize its disturbance.
- If physically contaminated soil is present (e.g., staining, odors, sheen, PID response, etc.) an attempt will be made to remove it, to the extent not limited by the site boundaries or the bedrock surface. If possible, physically impacted soil will be removed using the backhoe or excavator, segregated from clean soils and overburden, and staged on

separated dedicated plastic sheeting or live loaded into trucks from the disposal facility. Removal of the impacted soils will continue until visibly clean material is encountered and monitoring instruments indicate that no contaminants are present.

- Excavated soils which are temporarily stockpiled on-site will be covered with tarp material while disposal options are determined. Tarp will be checked on a daily basis and replaced, repaired or adjusted as needed to provide full coverage. The sheeting will be shaped and secured in such a manner as to drain runoff and direct it toward the interior of the property.

Once the site representative and regulatory personnel are satisfied with the removal effort, verification of confirmatory samples will be collected from the excavation in accordance with DER-10.

APPENDIX 2

NYC VCP SIGNAGE

NYC Voluntary Cleanup Program

60 Water Street (Dock Street)

Site #: 13CVCP093K

This property is enrolled in the New York City Voluntary Cleanup Program for environmental remediation. This is a voluntary program administered by the NYC Office of Environmental Remediation.

For more information, log on to:

www.nyc.gov/oer

If you have questions or would like more information, please contact:

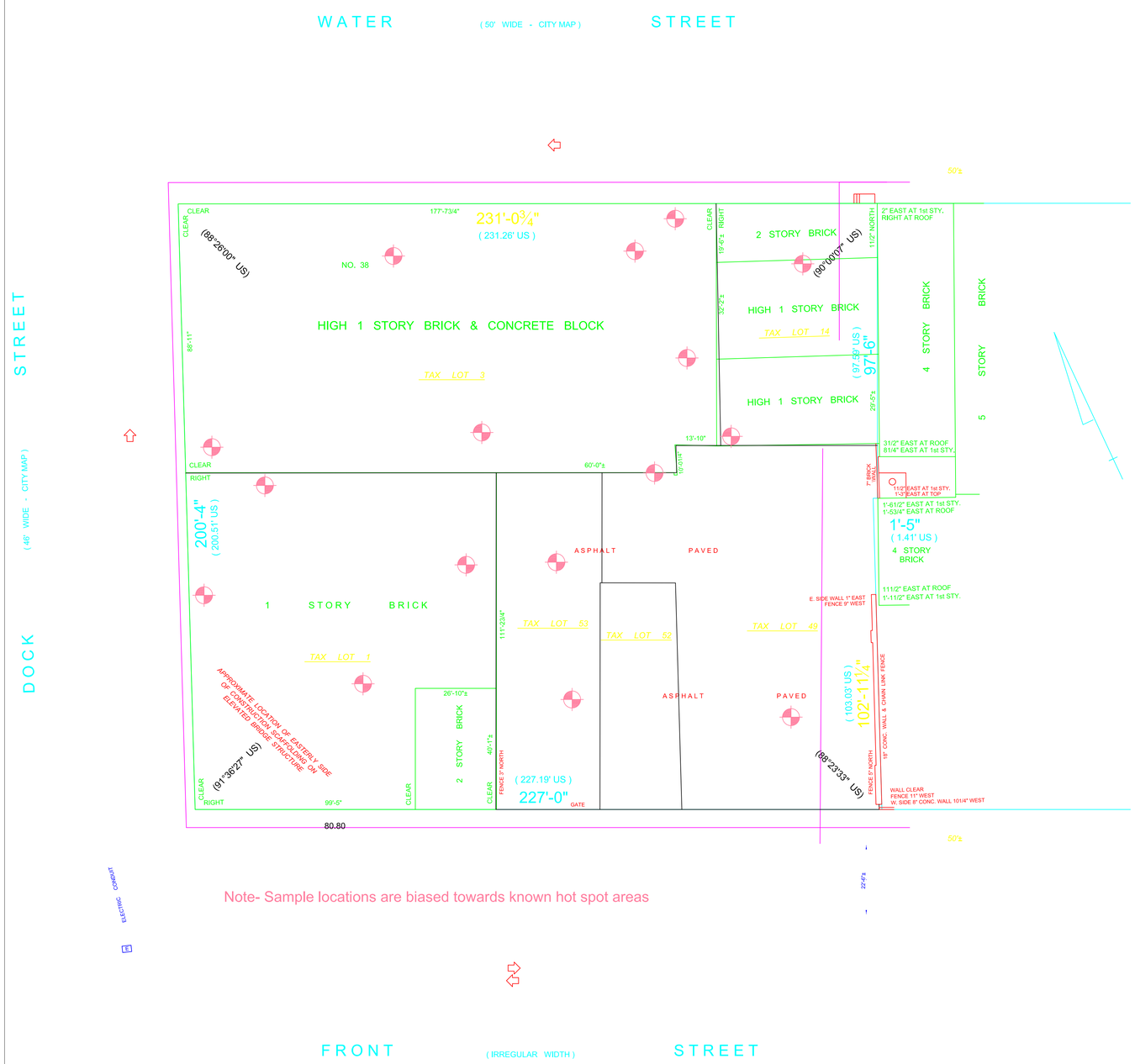
Breanna Gribble at (212) 788-8841

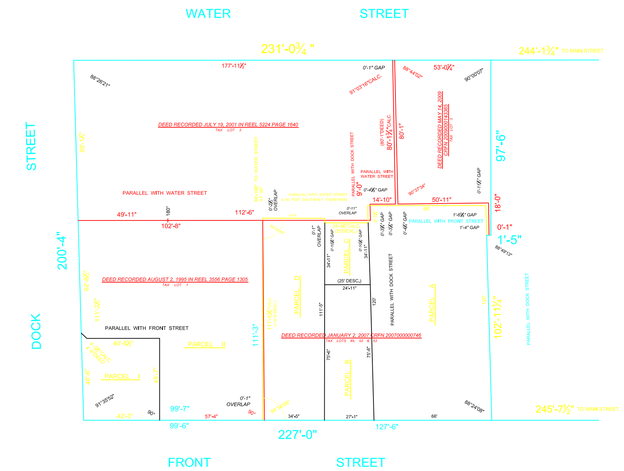
or email us at bgribble@dep.nyc.gov

APPENDIX 3

ENDPOINT SAMPLING PLAN

SURVEY OF PROPERTY
IN THE
BOROUGH OF BROOKLYN, COUNTY OF KINGS
CITY AND STATE OF NEW YORK





EL. 0.00 (BKLYN HWY. DEPT. DATUM)
SURVEY DATUM
2.56'
EL. 0.00 (NGVD 1929)
(FEMA - FIRM DATUM)

Note- Sample locations are biased towards known hot spot areas

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WWW.EMTEQUE.COM
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EMTEQUE LLC
A WCD Group Company

REVISIONS

NO.	DATE	ISSUE OR REVISION	CHECKED BY

CLIENT:
Two Trees Management Co. LLC
45 Main Street, Suite 602
Brooklyn NY 11201

PROJECT SITE:
60 Water Steet (Dock Street)
Brooklyn NY 11201

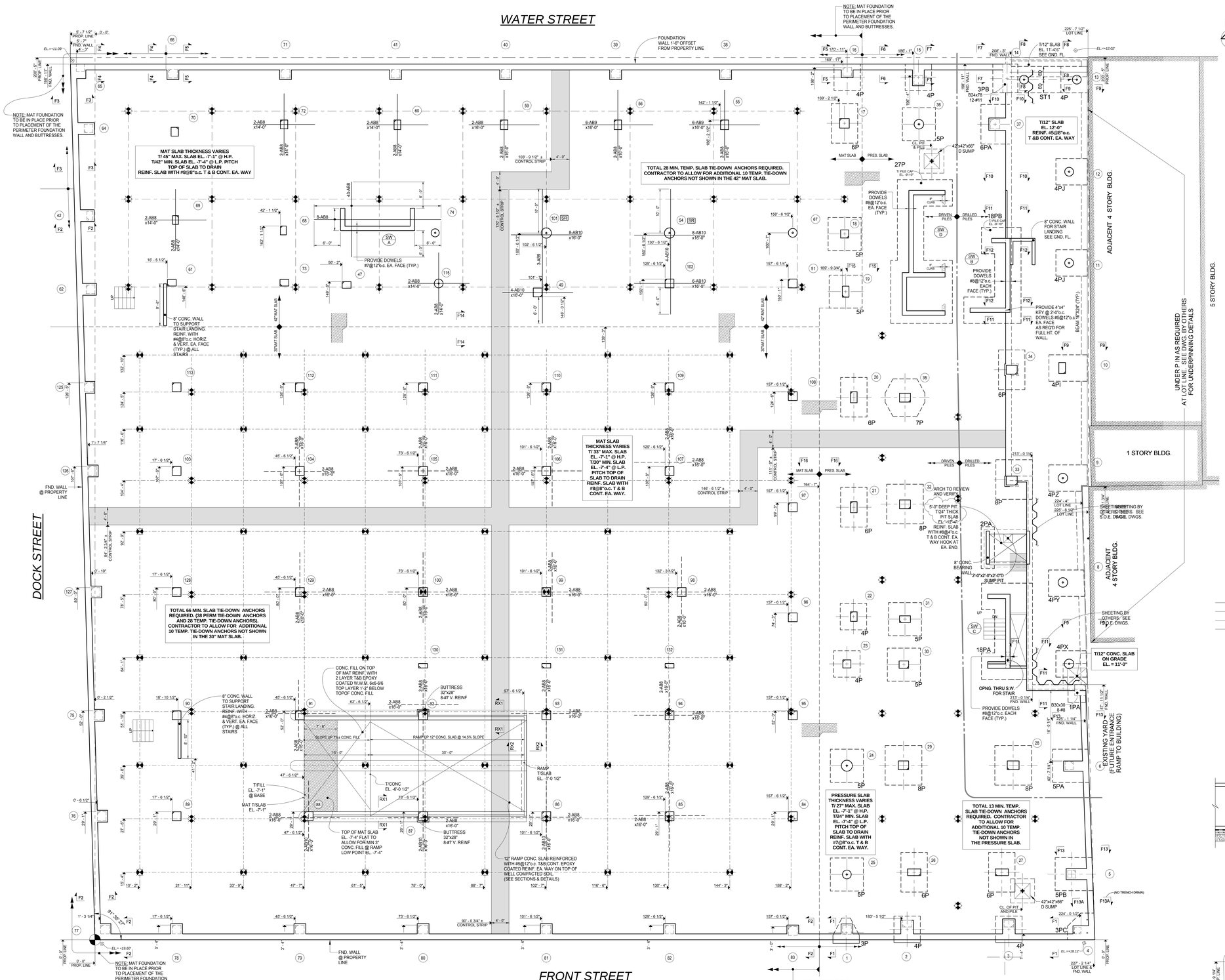
DESIGN TEAM:

DRAWING TITLE:
PROPOSED POST EXCAVATION SAMPLING PLAN

SEAL:	PROJECT # 12-5663	SCALE: N.T.S
CHECKED BY:	DATE: 11/09/12	DRAWING#
	DRAWN BY:	

APPENDIX 4

ARCHITECTURAL DRAWINGS/VAPOR BARRIER DETAILS



FOUNDATION PLAN

SCALE: 1/8"=1'-0"

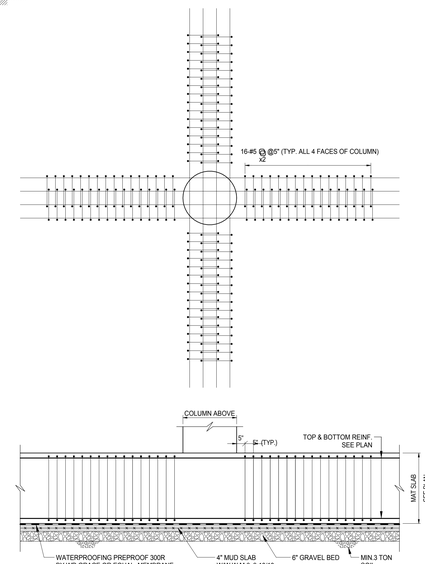
PLAN NOTES:
1. ALL ELEVATIONS ARE REFERENCED TO THE UNITED STATES COAST AND GEODETIC SURVEY MEAN SEA LEVEL DATUM OF 1929 ("NGVD").
2. SEE PLAN FOR SLAB THICKNESSES, ELEVATIONS, & REINFORCING.
3. TOP AND BOTTOM MAT REINFORCING SEE PLAN. (FOR ADDITIONAL GARAGE NOTES SEE THIS DWG.)
4. FOR COLUMN SIZES, SEE DWG. S-031.
5. FOR NOTES, PILE CAP DETAILS, AND TYPICAL DETAILS SEE DWG. FO-020
6. FOR FOUNDATION SECTIONS SEE DWG. FO-030
7. SEE ARCH. DWGS. FOR ALL CURBS SIZE & LOCATIONS. ALL CURBS TO BE REINFORCED AS REQUIRED, SEE DETAILS.
8. PROPOSED ELEVATION AT SIDEWALK SHOWN THUS EL.=XX.XX ON PLAN. FOR ACTUAL ELEVATIONS SEE LATEST BUILDERS PAVING PLAN.
9. SR DENOTES STIRRUPS SHEAR REINFORCMENT WHERE SHOWN, SEE DETAIL.

NOTES FOR GARAGE AREAS:
1. SEE ARCHITECTURAL DRAWINGS FOR EXTENT OF GARAGE.
2. PROVIDE MINIMUM 1-1/2" CONCRETE COVER FOR ALL TOP REINFORCING FROM TOP OF SLAB LOW POINT (4-1/2" FROM SLAB HIGH POINT)
3. ALL SLAB TOP REINFORCING SHALL BE EPOXY COATED. FOR EPOXY COATED REINFORCING, TABULATED VALUES SHOWN IN "REINFORCEMENT ANCHORAGE SCHEDULE ON DRAWING FO-021 SHALL BE INCREASED AS INDICATED IN REINFORCEMENT ANCHORAGE SCHEDULE (NOTE 'B') (SEE NOTE B & E).
4. AT ALL GARAGE SLABS & RAMPS PROVIDE A SURFACE LIQUID MEMBRANE WATERPROOFING TO PROTECT REINFORCING FROM CORROSION APPROVED BY ARCHITECT AND ENGINEER. FUTURE MAINTENANCE SHALL BE PROVIDED BY THE OWNER AND/OR GARAGE OPERATOR.
5. PITCH TOP OF SLAB DOWN TO DRAIN AS REQUIRED. SEE ARCHITECTURAL AND MECHANICAL DRAWINGS FOR H.P. AND L.P. LOCATIONS.
6. PROVIDE FIBER ADDITIVE AND ANTI-HYDRO AS PER NOTES ON DWG. FO-021.

ADDITIONAL FOUNDATION CONTRACTOR NOTES:
1. UNDERPINNING OF ADJACENT PROPERTIES IS THE FOUNDATION CONTRACTOR'S RESPONSIBILITY
2. DURING THE TIME OF DESIGN, THE GROUNDWATER ELEVATION WAS IDENTIFIED IN THE GEOTECHNICAL ENGINEER'S REPORT (DATED MARCH 2012) AS +3' - 3".

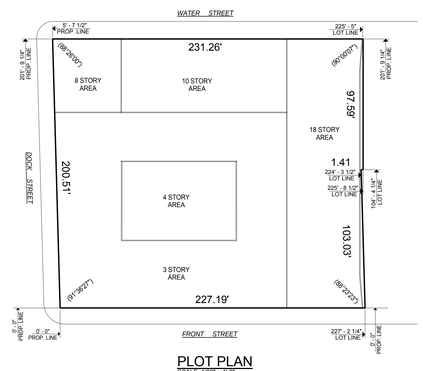
TIE-DOWN NOTES:
1. TIE DOWN ANCHORS ARE DESIGNED BY THE GEOTECHNICAL ENGINEER.
2. FOR TIE-DOWN ANCHOR DETAIL SEE DRAWINGS BY OTHERS.
3. TIE-DOWN DESIGN CAPACITY 300K SERVICE LOAD. TIE DOWN TO BE TESTED FOR 133% OF SERVICE LOAD (399k).
4. THE QUANTITY OF TIE-DOWN ANCHORS WAS DETERMINED USING AN UPLIFT CAPACITY OF 25 TONS PER PILE THAT MUST BE VERIFIED BY UPLIFT TESTS AS SPECIFIED IN THE GEOTECHNICAL ENGINEER'S REPORT.
5. PERMANENT TIE DOWN ANCHORS SHOWN THUS SHALL BE SHOP FABRICATED "DOUBLE CORROSION" PROTECTION.
6. TEMPORARY TIE DOWN ANCHORS SHOWN THUS
7. TEMPORARY TIE DOWN ANCHORS MAY BE OMITED IF DEWATERING IS ACHIEVABLE AND MAINTAINED UNTIL THE 4TH FLOOR SUPERSTURCTURE IS CAST IN PLACE. (SHOULD FLOOD LEVELS BE EXPECTED DEWATERING OPERATIONS MUST REMAIN UNTIL THE 6TH FLOOR SUPERSTRUCTURE IS CAST-IN-PLACE.)

DESIGN NOTES:
1. FOUNDATION WALLS & SLABS HAVE BEEN DESIGNED FOR A FLOOD ELEVATION OF +11'-0" NGVD.
2. MAT SLABS HAVE BEEN DESIGNED USING A SUBGRADE MODULUS OF 200 lb/ft³.



DETAIL OF STIRRUP SHEAR REINFORCEMENT AT COLUMNS 54 AND 101 IN MAT SLAB

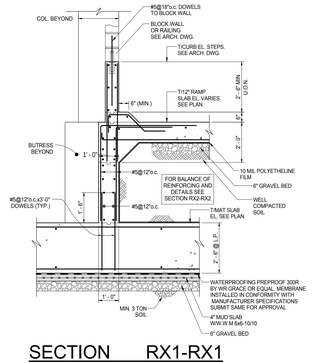
SCALE: 3/8"=1'-0"



PLOT PLAN

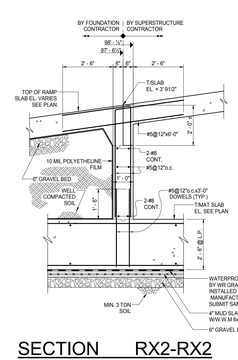
SCALE: 1/32" = 1'-0"

NOTES:
1. FOUNDATION CONTRACTOR RESPONSIBLE FOR REMOVING ALL FOUNDATIONS,TANKS ETC. FOUND DURING EXCAVATION
2. PRELIMINARY ALL INFORMATION GIVEN AND DIMENSIONS ARE TO BE REVIEWED AND VERIFIED BY FOUNDATION CONTRACTOR'S SURVEYOR WITH LATEST SURVEY, PREPARED BY BARTLETT, LUDLAM & DILL ASSOCIATES ORDER NO. 111181, BLOCK NO. 36



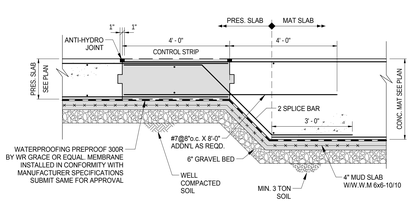
SECTION RX1-RX1

SCALE: 3/8"=1'-0"

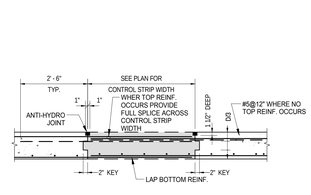


SECTION RX2-RX2

SCALE: 1/2"=1'-0"



MAT & PRESSURE SLAB



AT INTERIOR

TYPICAL CONTROL STRIP DETAILS

CONTROL STRIP NOTES:
1. CONTROL STRIP TO BE PLACED 28 DAYS AFTER ADJACENT SLAB HAS BEEN PORRED.
2. FORMS ADJACENT TO CONTROL STRIP ARE NOT TO BE REMOVED UNTIL CONTROL STRIP IS PLACED AND CURED.
3. FOR LOCATION OF CONTROL STRIP SEE PLAN.

ISMAEL LEYVA ARCHITECTS, P.C.
48 West 37th St. New York, NY 10018
TEL.(212)290-1444 FAX.(212)290-1425

LEESER Architecture PLLC
Design Architects
20 Jay Street M03
Brooklyn, NY 11201
TEL: (718) 643-6656

Rossenwasser/Grossman
Structural Engineers
132 West 36th Street
New York, NY 10018
TEL: (212) 564-2424
FAX: (212) 620-8157

Ettinger & Associates
MEP/FS Engineers
505 8th Avenue, 24th Floor
New York, NY 10018
TEL: (212) 244-2410
FAX: (212) 643-1606

Pillori Associates, P.A.
Geotechnical Consultants
71 Route 35
Laurence Harbor, NJ 08879
TEL: (732) 335-0059
FAX: (732) 335-8515

No	Date:	Rev	Issue:
1	06/22/12		DOB SUBMISSION
2	08/24/12		PROGRESS FOUNDATION SET
3	08/27/12		PROGRESS SET
4	09/05/12		PROGRESS SET

NOTES:
ALL ELEVATIONS ARE MEASURED RELATIVE TO NGVD (1929).
BROOKLYN HIGHWAY DATUM (BHD) IS +2.55'

CLIENT
Two Trees Management
45 Main Street Suite 602
Brooklyn, NY 11201

PROJECT
60 Water Street
Brooklyn, NY

TITLE
FOUNDATION PLAN - PARKING LEVEL 3

SCALE: As indicated
DATE: 6/22/2012
PROJECT No: Project Number

STATE OF NEW YORK · BENJAMIN PINKERTON · 038628 · LICENSED PROFESSIONAL ENGINEER

FO-011.00

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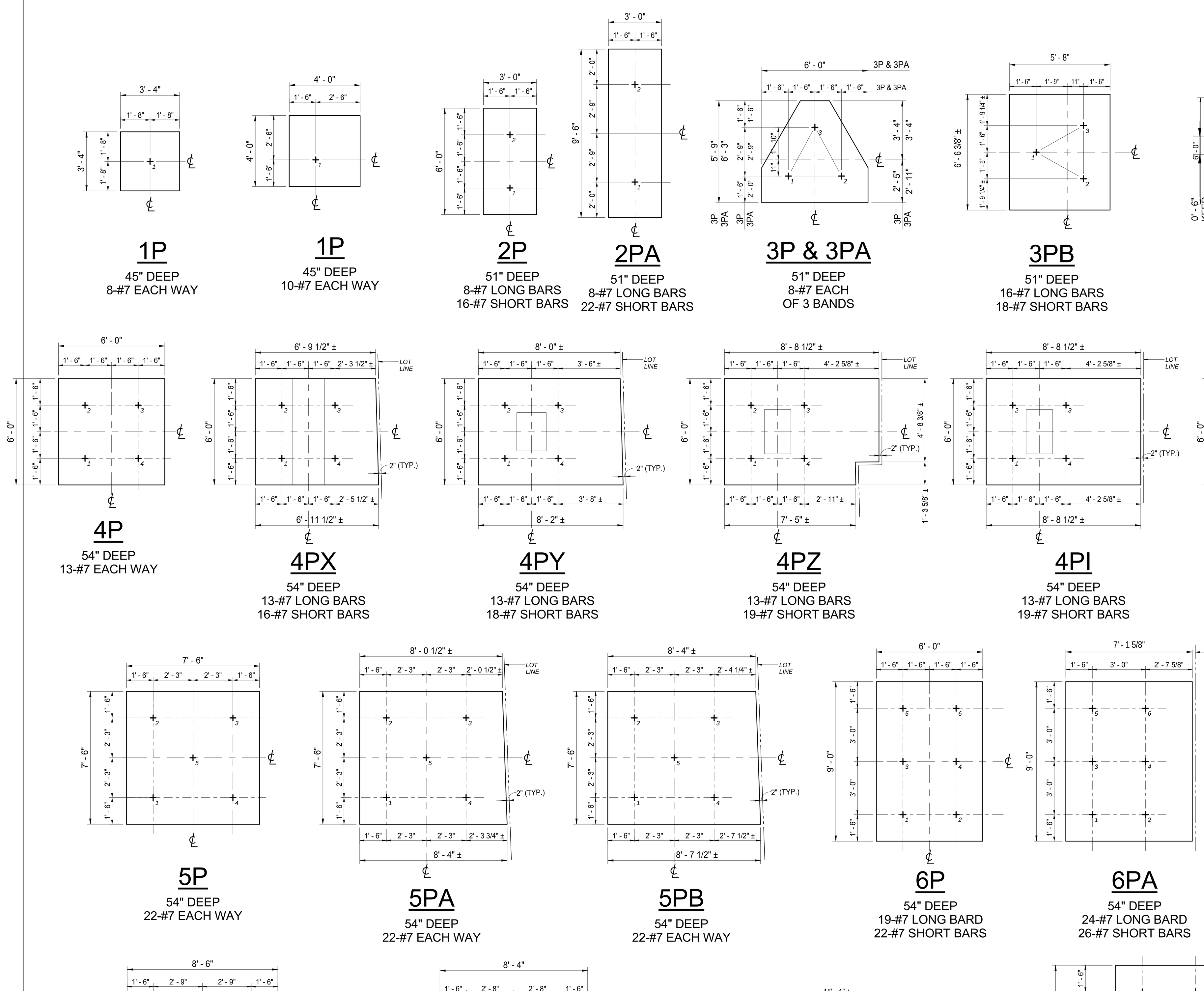
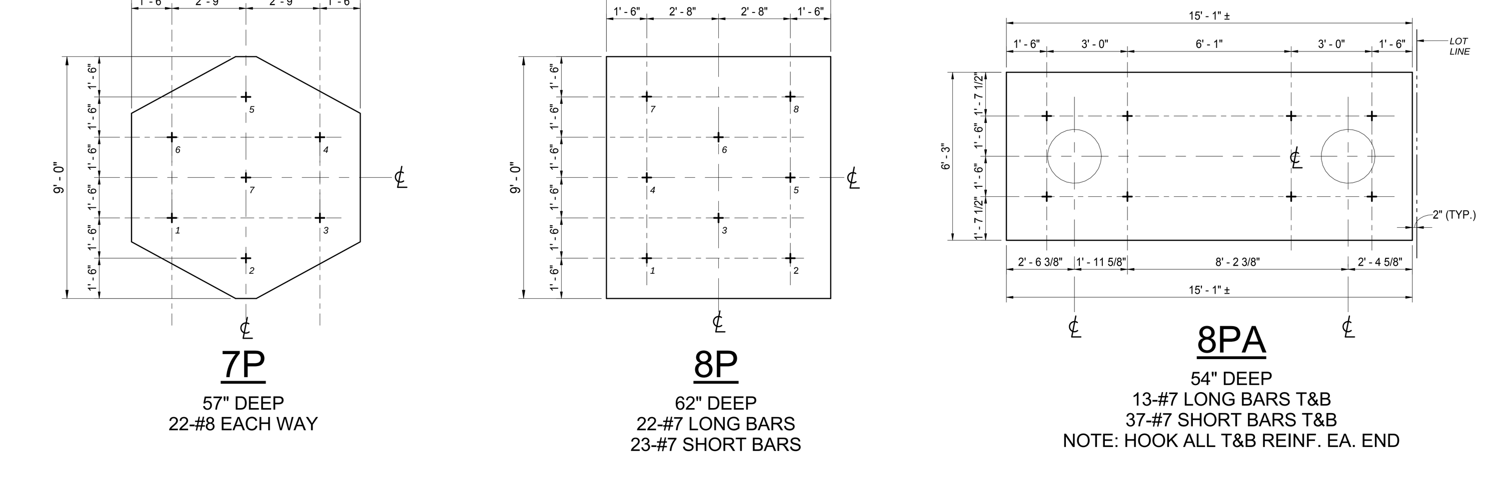
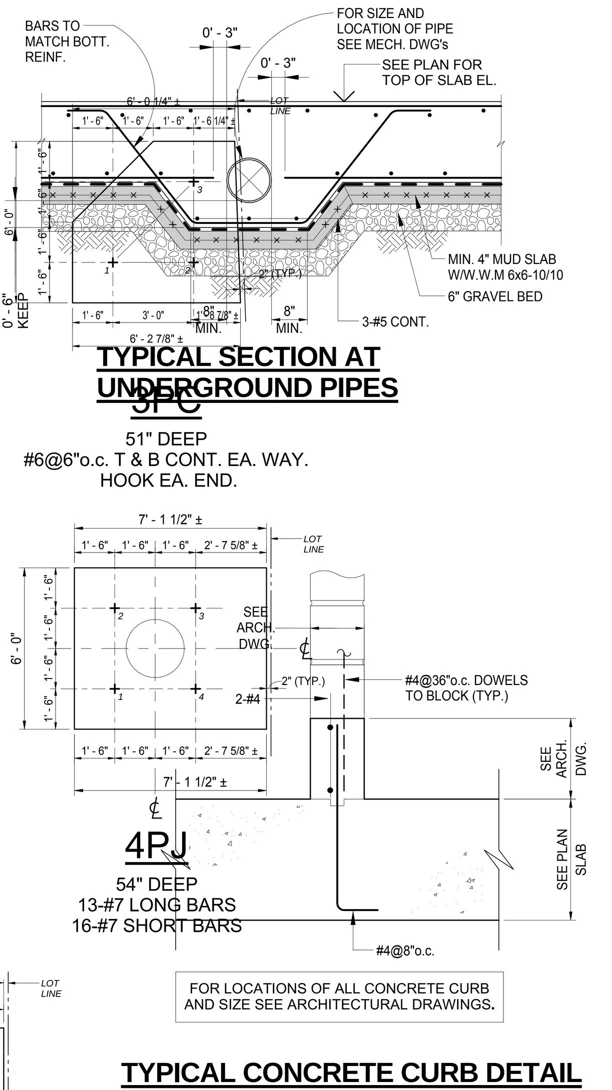
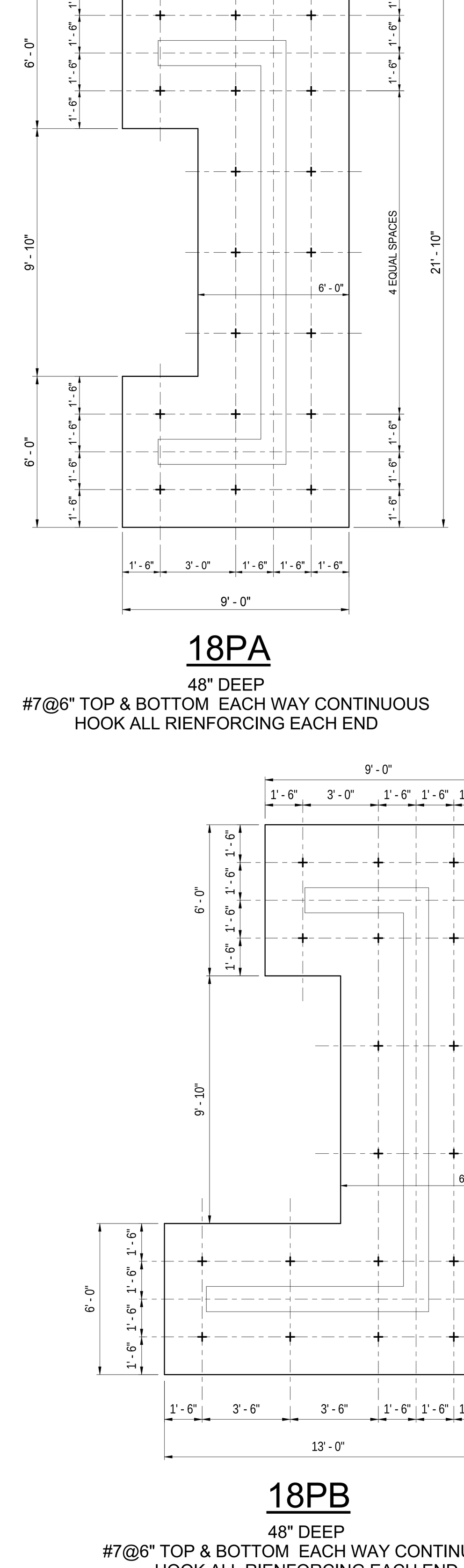
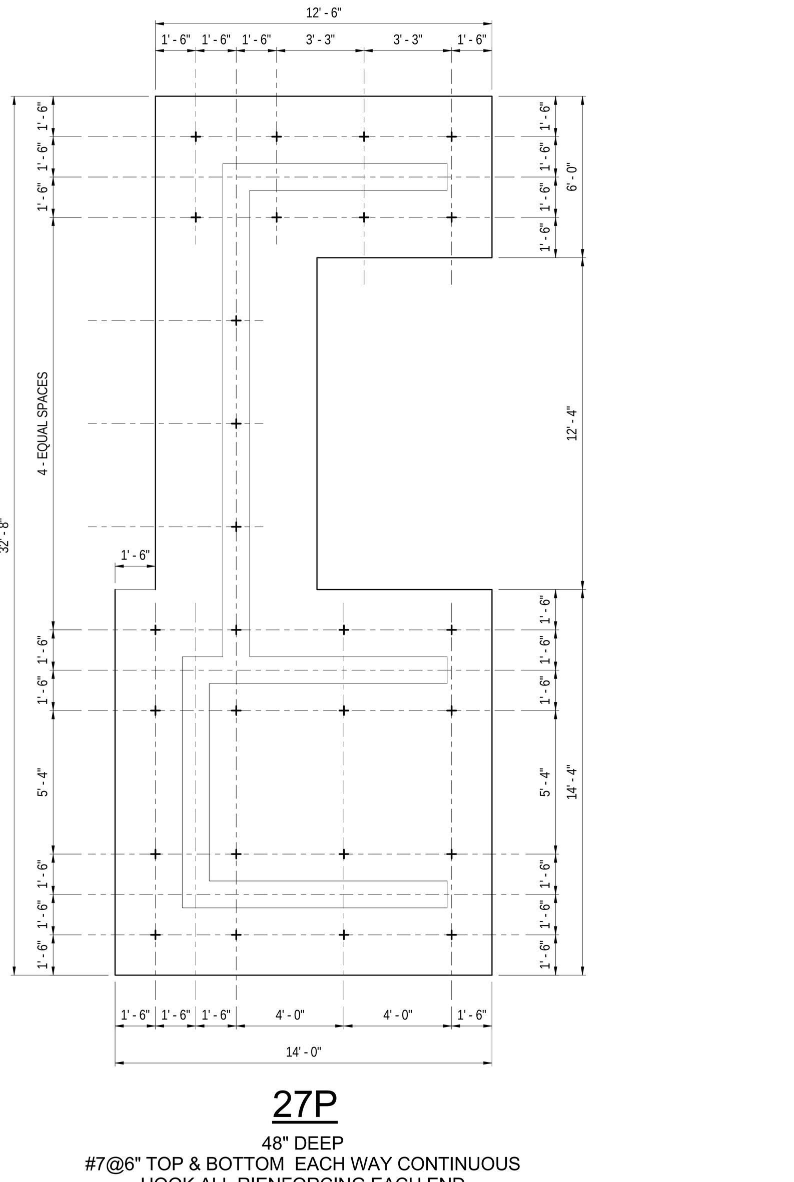




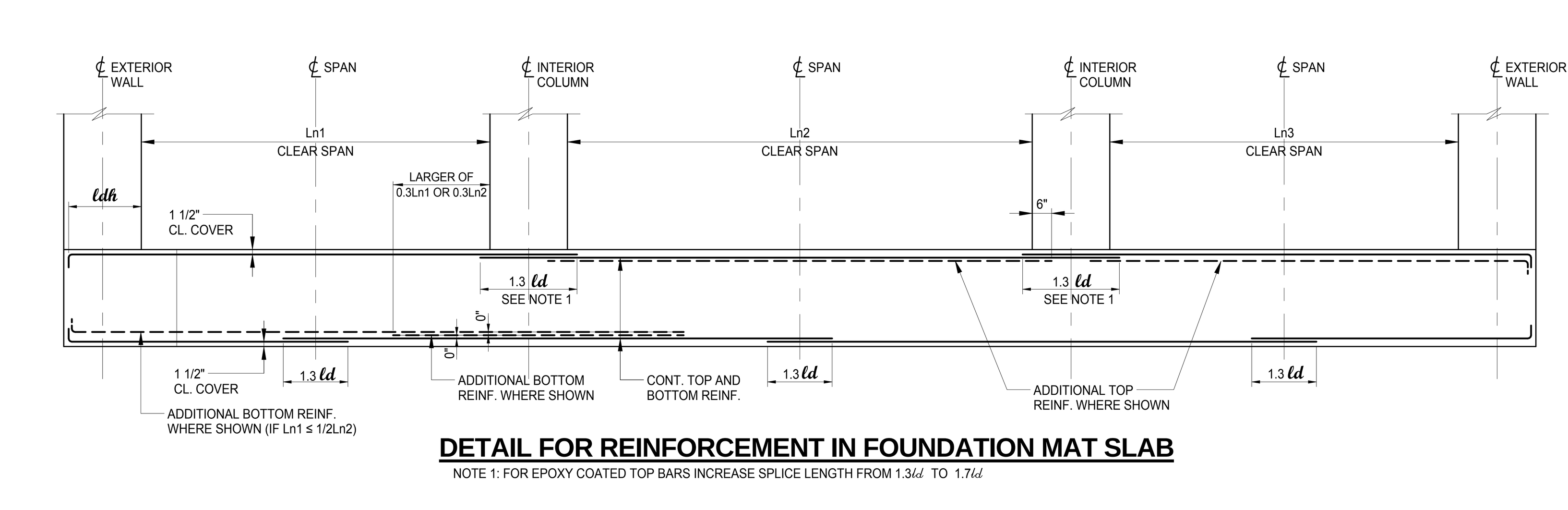


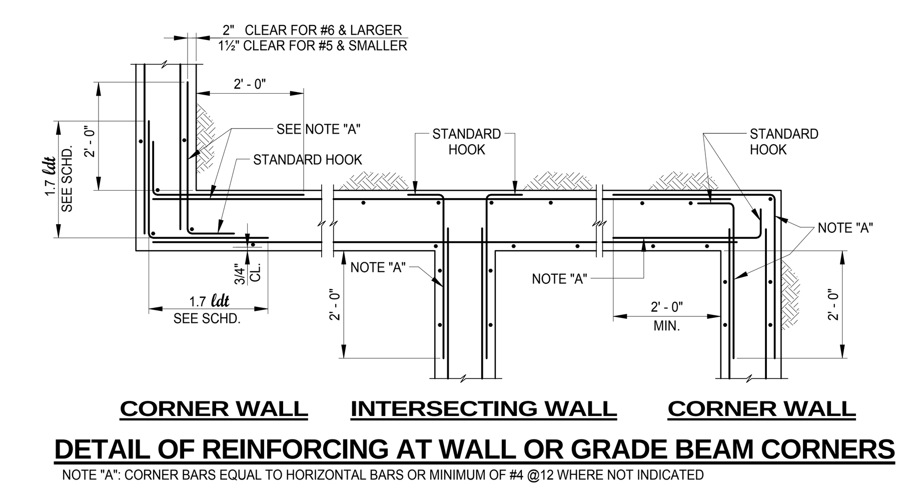


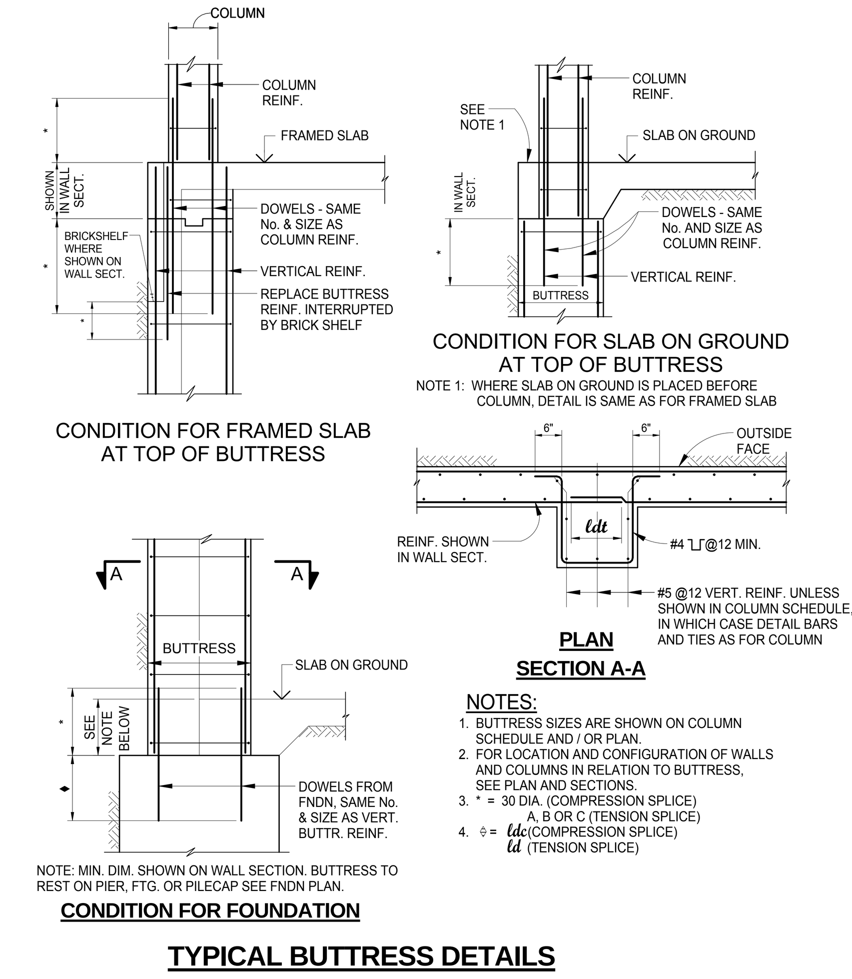


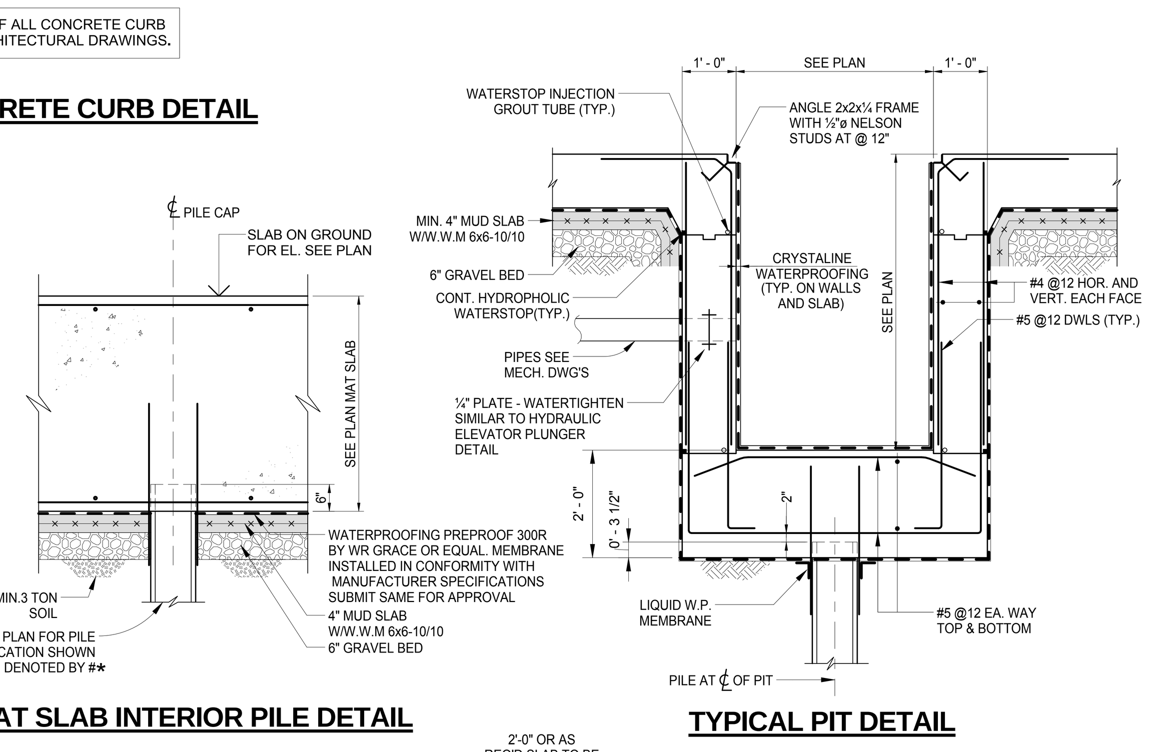
PILE CAP DETAIL NOTES

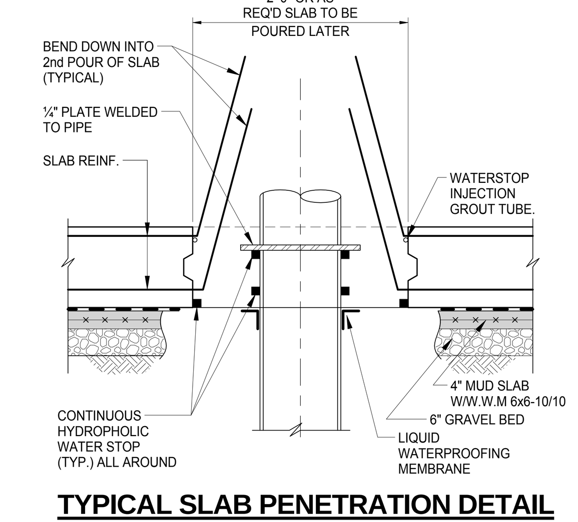
1. FOR LOCATION OF PILE CAPS SEE DWG. FO-011.
2. FOR TYPICAL PILE CAP DETAILS SEE DWG. FO-020
3. ALL REINFORCING IS CONTINUOUS UNLESS OTHERWISE NOTED.
4. ALL PILES TO BE SURVEYED AFTER CUT-OFF. PILE CAP DETAILS MAY BE ADJUSTED BASED ON IN-PLACE DEVIATIONS.

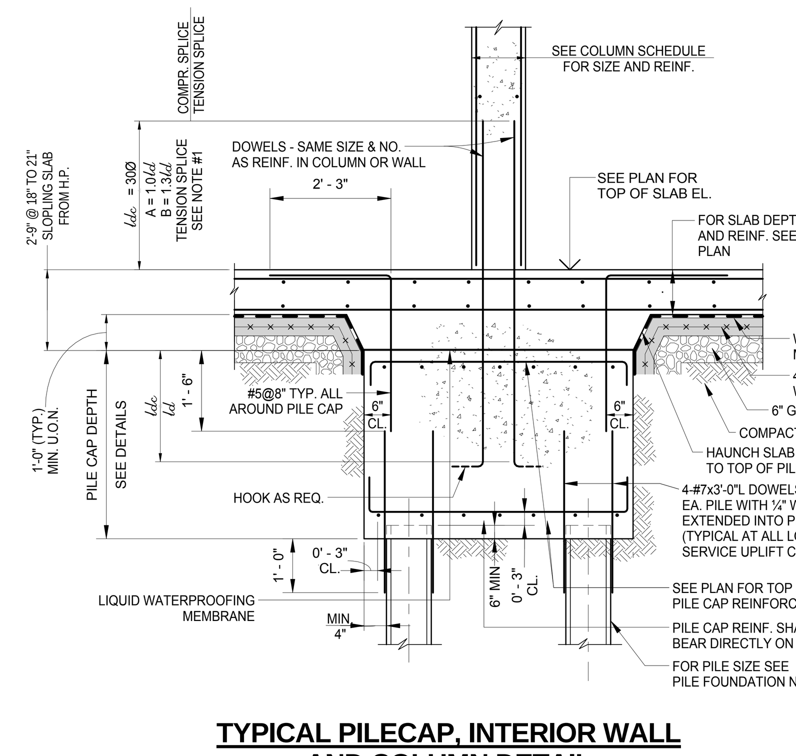








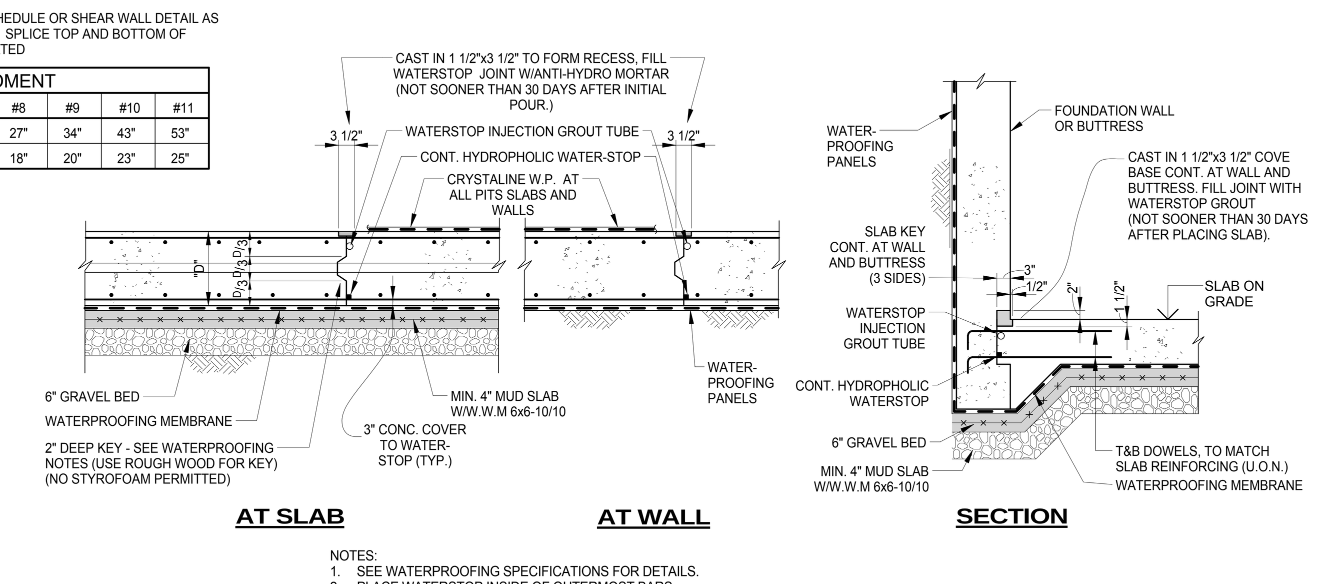




TYPICAL PILECAP, INTERIOR WALL AND COLUMN DETAIL

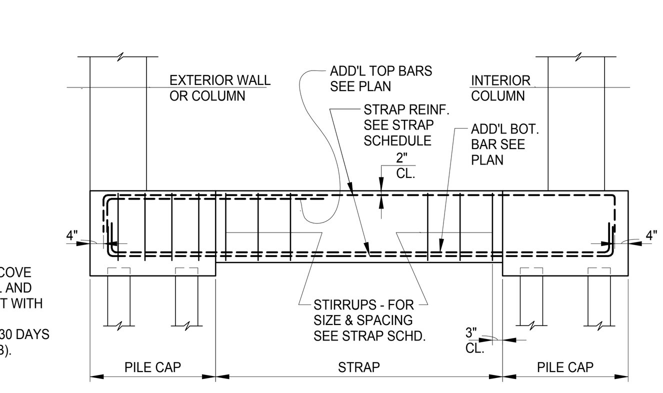
NOTE:
1. TENSION SPLICE IS SHOWN ON SCHEDULE OR SHEAR WALL DETAIL AS "A" OR "B" i.e. 4-#11/B REQUIRES 1.3ld SPLICE TOP AND BOTTOM OF COLUMN AS LEFT OF COLUMN INDICATED

DOWEL EMBEDMENT							
BARS	#5	#6	#7	#8	#9	#10	#11
ld	15"	18"	21"	27"	34"	43"	53"
ldc	11"	14"	16"	18"	20"	23"	25"



NOTES:
1. SEE WATERPROOFING SPECIFICATIONS FOR DETAILS.
2. PLACE WATERSTOP INSIDE OF OUTERMOST BARS.
3. PROVIDE CONTINUOUS 3" KEY, WATER STOP AND COVE BASE AT WALLS AND ALL AROUND BUTTRESS (3 SIDES)

TYPICAL SLAB AND WALL WATERPROOFING DETAIL AT CONSTRUCTION JOINT



TYPICAL STRAP DETAIL

STRAP SCHEDULE							
MARK	SIZE		BOTTOM BARS	TOP BARS	STIRRUPS		REMARKS
	WIDTH	DEPTH			SIZE	SPACING EA. END	
ST1	72"	48"	12-#11	12-#9	#5 (x5)	@6"o.c.	SEE PLAN FOR ADD'L BARS

FOUNDATION NOTES

THIS BUILDING WAS DESIGNED IN ACCORDANCE WITH STRENGTH DESIGN REQUIREMENTS AS PER BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE (ACI 318-2002) AS MODIFIED BY THE NEW YORK CITY BUILDING CODE 2008 (THE NYCBC). ALL STANDARDS FOR THE AMERICAN SOCIETY FOR TESTING (ASTM) LISTED BELOW ARE REFERENCED TO LATEST EDITION APPROVED BY THE NYC BC.

1. THIS BUILDING WAS DESIGNED TO BEAR ON PILES. SEE PILE NOTES, THIS DRAWING.
2. THE SPECIAL INSPECTIONS OF CONCRETE (STRUCTURAL CONCRETE) SHALL BE IN ACCORDANCE WITH CHAPTER 17 OF THE NYC BC SEE STRUCTURAL CONCRETE NOTES AND NOTE FOR FIBER ADDITIVE ON THIS DRAWING.
   CONCRETE FOR WALLS, BUTTRESSES, PIERS, PILE CAPS, & STRAPS SHALL DEVELOP A MINIMUM COMPRESSIVE STRENGTH OF **5000** P.S.I. AT 28 DAYS UNLESS OTHERWISE SHOWN.
3. ALL SLABS ON GROUND SHALL BE **5000** P.S.I. STONE CONCRETE AT 28 DAYS UNLESS OTHERWISE NOTED. SEE PLAN NOTES FOR DEPTH AND REINFORCING. SEE TYPICAL WATERPROOFING PANEL DETAIL.
   AT ALL SLABS ON GRADE PROVIDE CONTINUOUS WATER CURING, NOT LESS THAN FOUR DAYS AFTER POUR. PUMPING OF UNDERGROUND WATER SHALL KEEP AREAS FOR SLABS ON GRADE DRY FOR THE DURATION OF THE POUR AND 48 HOURS AFTERWARDS. FOUNDATION CONTRACTOR TO REPAIR ALL CRACKS IN CONCRETE SLABS.
4. ALL REINFORCING BARS SHALL BE DEFORMED BARS OF NEW BILLET STEEL CONFORMING TO ASTM A-615 GRADE 60 (SEE REINFORCING NOTES ON THIS DRAWING).
5. FOUNDATION WALLS:
   A. PROVIDE POCKETS AND DOWELS FOR ALL BEAMS FRAMING INTO FOUNDATION WALLS
   B. PROVIDE 2-#5 BARS ALL AROUND OPENINGS IN FOUNDATION WALLS, UNLESS OTHERWISE SHOWN ON PLANS. BARS TO EXTEND 2'-0" BEYOND OPENINGS.
   C. NO HORIZONTAL CONSTRUCTION JOINTS ARE PERMITTED IN FOUNDATION WALLS WITHOUT THE EXPRESS CONSENT OF THE ENGINEER.
   D. NO BACK FILL SHALL BE PLACED AGAINST FOUNDATION WALLS, UNLESS SUPPORTING SLABS ARE IN PLACE AND SET OR THE WALLS HAVE BEEN ADEQUATELY BRACED.
   E. CONSTRUCTION EQUIPMENT SHALL NOT BE PERMITTED CLOSER THAN 8'-0" FROM WALL, UNLESS ADEQUATE BRACING IS PROVIDED OR PERMISSION FROM THE ENGINEER OF RECORD HAS BEEN GRANTED.
   F. ALL HORIZONTAL REINFORCING IN WALLS & GRADE BEAMS TO BE SPLICED & LAPPED @ CORNERS UNLESS OTHERWISE SHOWN IN DETAILS.
   G. FOUNDATION CONTRACTOR TO REPAIR ALL CRACKS IN CONCRETE WALLS.
6. REINFORCING DETAIL DRAWINGS SHALL BE SUBMITTED TO THE ENGINEER FOR REVIEW BEFORE WORK MAY PROCEED.
7. THE FOUNDATION CONTRACTOR SHALL PREPARE DRAWINGS SHOWING ANY NECESSARY UNDERPINNING, BRACING AND SHEETING OR OTHER CONSTRUCTION REQUIRED FOR THE SUPPORT OF ADJACENT PROPERTIES OR BUILDINGS. NO WORK SHALL BEGIN UNTIL SUCH DRAWINGS HAVE BEEN SUBMITTED TO THE ENGINEER AND REVIEWED BY HIM.
8. THE CONTRACTOR SHALL VERIFY DIMENSIONS AND LOCATIONS OF ALL OPENINGS, PIPE SLEEVES, ANCHOR BOLTS, ETC., AS REQUIRED BY ALL TRADES BEFORE CONCRETE IS POURED.

NOTE FOR FIBER ADDITIVE:
1. ALL CONCRETE FOR SLAB ON GROUND AND FOUNDATION WALLS SHALL HAVE FIBER MESH FIBERS ADDED TO THE CONCRETE MIX. ONE AND HALF POUNDS OF FIBER MESH FIBERS SHALL BE ADDED FOR EVERY CUBIC YARD OF CONCRETE AS PER MANUFACTURER'S RECOMMENDATIONS. FIBER MESH SHALL BE POLYPROPYLENE FIBRILLATED FIBERS 11/2" LONG, SUPER-NET, MANUFACTURED BY FORTA OR EQUAL.
2. DO NOT INCREASE QUANTITY OF WATER IN EXCESS OF THAT ESTABLISHED BY DESIGN MIX. IF LOSS OF SLUMP OCCURS BECAUSE OF THE USE OF FIBER MESH, ADD SUPERPLASTICIZER IN ACCORDANCE WITH TESTING LABORATORIES INSTRUCTIONS.

ANTI-HYDRO ADDITIVE:
1. CONCRETE FOR SLABS ON GROUND & FOUNDATION WALLS SHALL CONTAIN 1½ GALLONS ANTI-HYDRO NC TYPE PER CUBIC YARD OF CONCRETE.

STRUCTURAL CONCRETE NOTES:
1. CONCRETE MIXES SHALL CONFORM TO THE N.Y.C. BUILDING CODE SECTION BC 1905, EITHER CONCRETE PROPORTIONING ON THE BASIS OF FIELD EXPERIENCE OR TRIAL MIXTURES MAY BE USED.
2. NO CONCRETE SHALL BE PLACED UNTIL A PROFESSIONAL ENGINEER RETAINED BY THE OWNER AND APPROVED BY THE ENGINEER OF RECORD HAS FILED AN AMENDMENT WITH THE BUILDING DEPARTMENT CERTIFYING THAT THIS PROFESSIONAL ENGINEER ASSUMES THE RESPONSIBILITY FOR THE INSPECTION OF CONCRETE WORK IN ACCORDANCE WITH SECTION BC 1704.4 OF THE NEW YORK CITY BUILDING CODE
3. COMPRESSION TEST SAMPLES SHALL BE TAKEN FROM THE MIXER IN ACCORDANCE WITH ASTM C172, CURED IN ACCORDANCE WITH ASTM C-31 AND TESTED AT THE AGE NOTED BELOW IN ACCORDANCE WITH ASTM C-39, REQUIRED NUMBER OF "STRENGTH TESTS" (SEE BELOW) SHALL BE MOLDED FOR EACH 50 CUBIC YARDS OR FRACTION THEREOF OF EACH CLASS OF CONCRETE PLACED IN ANY ONE DAY.
   FOR CONCRETE WITH A REQUIRED STRENGTH LESS THAN 6000 P.S.I., EACH "STRENGTH TEST" SHALL CONSIST OF 5 CYLINDERS. 2 SHALL BE TESTED AT 7 DAYS AND 3 SHALL BE TESTED AT 28 DAYS.
   ADDITIONAL CYLINDERS SHALL BE TAKEN FROM BUCKETS, HOPPERS OR FORMS AS DIRECTED BY THE INSPECTING ENGINEER WHEN CONCRETE IS PLACED FROM AN INTERMEDIATE CONVEYOR (BUCKET, HOPPER, ETC.) THE CYLINDERS TO BE TAKEN FROM THE SAME BATCH AND CURED AND TESTED IN THE SAME MANNER AS THE SAMPLES TAKEN FROM THE MIXER. THESE ADDITIONAL CYLINDERS SHALL BE THREE FOR EACH 150 CUBIC YARDS OR FRACTION THEREOF OF EACH CLASS OF CONCRETE MIXED IN ANY ONE DAY'S CONCRETING.
   EACH CYLINDER SHALL BE SUITABLY IDENTIFIED BY A MARK AND THE AREA WHERE THE CONCRETE IS PLACED SHALL BE RECORDED.
   ADDITIONAL FIELD TESTS TO BE TAKEN AS REQUESTED BY SUPERINTENDENT. ALL TESTS SHALL BE MADE BY A CERTIFIED LABORATORY IN ACCORDANCE WITH SECTION BC 1905.6 OF THE NEW YORK CITY BUILDING CODE. TEST RESULTS SHALL BE SUBMITTED PROMPTLY TO THE ENGINEER OF RECORD.
4. CONCRETE SHALL (EXCEPT AS STATED ABOVE AND AS MODIFIED BY CHAPTER 19 OF THE NEW YORK CITY BUILDING CODE) CONFORM TO ACI 318-02 CHAPTER 4 FOR DURABILITY AND CHAPTER 5 FOR CONCRETE QUALITY, MIXING AND PLACING.

MASS CONCRETE NOTES:
1. CONCRETE POURS HAVING A MINIMUM DIMENSION OF 36 IN SHALL BE CONSIDERED AS MASS CONCRETE.
2. THE CONTRACTOR SHALL SUBMIT THE THERMAL CONTROL PLAN TO THE ENGINEER OF RECORD FOR APPROVAL A MINIMUM OF THIRTY (30) WORKING DAYS PRIOR TO CONCRETE PLACEMENT. MASS CONCRETE PLACEMENT SHALL NOT BEGIN UNTIL THE ENGINEER HAS APPROVED THE THERMAL CONTROL PLAN.
3. AS A MINIMUM, THE THERMAL CONTROL PLAN SHALL INCLUDE THE FOLLOWING:
   A. MIX DESIGN. IF THE MIX WILL BE COLLED, THE CONTRATOR SHALL DEFINE THE METHODOLOGY AND NECESSARY EQUIPMENT TO ACHIEVE THESE MIX TEMPERATURES
   B. DURATION AND METHOD OF CURING
   C. METHODS OF CONTROLLING TEMPERATURE DIFFERNTIAL, INCLUSIVE OF ACTIVE COOLANT SYSTEMS NOT PREVIOUSLY DEFINED WITHIN THE ENGINEERING DRAWINGS.
   D. AN ANALYSIS OF THE ANTICIPATED THERMAL DEVELOPMENTS IN THE MASS CONCRETE ELEMENTS FOR ALL EXPECTED PROJECT TEMPERATURE RANGES USING THE PROPOSED MIX DESIGN, CASTING PROCEDURES, AND MATERIALS. IT SHALL SHOW COMPLETE DETAILS AND DETERMINE THE MAXIMUM TEMPERATURE DIFFERENTIALS WITHIN THE CONCRETE MASS.
   E. TEMPERATURE SENSOR TYPES AND LOCATIONS INCLUDING INSTALLATION DETAILS
   F. TEMPERATURE MONITORING SYSTEM INCLUDING SYSTEM DESCRIPTION, OPERATION PLAN, RECORDING AND REPORTING PLAN, AND REMEDIAL ACTION PLAN.
   G. FIELD MEASURES AND DOCUMENTATION PROCEDURES TO ENSURE CONFORMANCE WITH THE MAXIMUM CONCRETE TEMPERATURE AND TEMPERATURE DIFFERENTIAL REQUIREMENTS.
   H. FIELD METHODS OF APPLYING IMMEDIATE CORRECTIVE ACTION SHOULD THE TEMPERATURE DIFFERENTIAL APPROACH THE MAXIMUM TEMPERATURE DIFFERENTIAL AND MAXIMUM ALLOWABLE CONCRETE TEMPERATURE.
4. MAXIMUM TEMPERATURE OF MASS SHALL NOT EXCEED 160 deg F
5. MAXIMUM TEMPERATURE DIFFERENTIAL BETWEEN THE CENTER OF MASS AND THE CONCRETE SURFACE SHALL NOT EXCEED 35 deg F.

CONCRETE NOTES FOR MAT SLAB FOUNDATION:

CONCRETE FOR FOUNDATION MAT SHOULD BE DESIGNED, PROPORTIONED, MIXED, PLACED AND CURED AS PER ACI 207. SELECTION OF MATERIALS; INCLUDING CONCRETE AGGREGATES, MINERAL AND CHEMICAL ADMIXTURES SHALL BE AS FOLLOWS:
1. CEMENT C150 TYPE II; AS PER ACI 207.1R CHAPTER 2.2 RECOMMENDATION OR C150 TYPE IV; IF AVAILABLE.
2. AGGREGATES ASTM C-33 WITH THE PROPERTIES AS RECOMMEDED BY ACI 207.1R CHAPTER 2.5.
3. MINERAL ADMIXTURES:
   A. FLY ASH ASTM C-618 CLASS F, FOLLOW RECOMMENDATION OF ACI 207.1R CHAPTER 2.3
   B. GRANULATED BLAST FURNACE SLAB; ASTM C-989, FOLLOW ACI 207.1R CHAPTER 2.3
4. CHEMICAL ADMIXTURE: USE AIR ENTRAINMENT (UP TO 50% TOTAL AIR CONTENT); WATER REDUCERS, RETARDS (WHEN NEEDED) AND HIGH RANGE WATER REDUCER; IN ORDER TO ACHIEVE LOW HEAT OF HYDRATION AND PROVIDE WORKABLE, LOW PERMEABLE AND HIGHLY DURABLE CONCRETE.
5. IN ORDER TO SELECT CONCRETE PROPORTIONS, COMPLY WITH ACI 207, 211, 305, AND 306.
6. THE CONTRACTOR SHALL BE RESPONSIBLE FOR CURING AND PROTECTING CONCRETE IN ORDER TO MINIMIZE ANY EFFECT OF THE HEAT INCREASE; THAT COULD RESULT IN CONCRETE CRACKING.
   THE CONTRACTOR SHALL BE RESPONSIBLE FOR INSTALLING THERMOCOUPLES IN AT LEAST 3-
4 DISTANCE LOCATIONS; SURFACE, CENTER AND BOTTOM OF THE MAT. 3 SETS OF THERMOCOUPLERS SHALL BE INSTALLED IN THE 48" MAT. CONTRACTOR SHALL SUBMIT LOCATIONS TO ENGINEER FOR APPROVAL. THE READINGS SHALL BE TAKEN AT LEAST 15 MIN FOR 48 HOURS, AS DIRECTED BY THE ENGINEER. THE CONTRACTOR WILL PROTECT CONCRETE SURFACE, UNTIL THE ENGINEER DIRECTS THE CONTRACTOR, THAT PROTECTION
IS NO LONGER REQUIRED (FOR EACH CONCRETE PLACEMENT).

REINFORCING:

A. 1. ALL REINFORCING BARS SHALL BE DEFORMED BARS CONFORMING TO "SPECIFICATION FOR DEFORMED BILLET-STEEL BARS FOR CONCRETE REINFORCEMENT" ASTM A615 GRADE 60, UNLESS OTHERWISE INDICATED ON PLANS OR SCHEDULES.
   2. WELDED PLAIN WIRE FABRIC SHALL CONFORM TO "SPECIFICATION FOR STEEL WELDED WIRE REINFORCEMENT, PLAIN, FOR CONCRETE" (ASTM A185) AND HAVE A MINIMUM YIELD STRENGTH OF 60,000 PSI.
   3. WELDED DEFORMED WIRE FABRIC SHALL CONFORM TO "SPECIFICATION FOR STEEL WELDED WIRE FABRIC, DEFORMED, FOR CONCRETE REINFORCEMENT" (ASTM A497) AND HAVE A MINIMUM YIELD STRENGTH OF 60,000 PSI.
   4. THE WELDING OF REINFORCING BARS WHEN SO INDICATED ON PLANS OR PERMITTED BY THE STRUCTURAL ENGINEER SHALL CONFORM WITH RECOMMENDED PRACTICES FOR WELDING REINFORCING STEEL, METAL INSERTS AND CONNECTIONS IN REINFORCED CONCRETE CONSTRUCTION (AWS D1.4) AND SECTION 3.5.2 OF THE ACI 318-02.
   5. THE STEEL SUPPLIER SHALL PROVIDE THE ENGINEER WITH AN AFFIDAVIT OF THE PRODUCER OF STEEL CERTIFYING THAT THE STEEL MEETS THE REQUIREMENTS OF THE AMERICAN SOCIETY OF TESTING AND MATERIALS.

B. ALL CONTINUOUS REINFORCING SHALL BE LAPPED AT SPLICES, BENT AROUND CORNERS AND FULLY EMBEDDED AT NON-CONTINUOUS ENDS. (SEE TYPICAL DETAILS, EMBEDMENT AND SPLICE LENGTH SCHEDULES ON DETAIL DRAWINGS.) THE SPACE BETWEEN SPLICED BARS SHALL NOT EXCEED THE LESSER OF 6" OR 1/5 OF THE REQUIRED LENGTH OF LAP.

C. PROVIDE MINIMUM CONCRETE PROTECTION TO REINFORCING AS SHOWN IN SECTIONS AND DETAILS BUT NOT LESS THAN REQUIRED BY SECTION 7.7 OF THE ACI 318-02.

D. ALL REINFORCING SHALL BE FREE OF LOOSE FLAKY RUST, MUD, OIL OR OTHER COATING THAT WILL DESTROY, REDUCE OR HAMPER FULL BOND CAPACITY. PLACING REINFORCING SHALL CONFORM TO SECTION 7.5 AND SPACING OF BARS TO SECTION 7.6 OF ACI 318-02.

ADDITIONAL NOTES:
1. AT LEAST 24 HOURS WRITTEN NOTICE SHALL BE GIVEN TO THE COMMISSIONER PRIOR TO COMMENCEMENT OF ANY WORK AS PER SECTIONS BC 105.5.1 AND BC 3304.3.1 OF THE NYCBC.
2. TEN DAYS PRIOR WRITTEN NOTICE SHALL BE GIVEN TO THE OWNERS OF ALL ADJOINING LOTS, BUILDING AND SERVICE FACILITIES WHICH MAY BE AFFECTED BY THE FOUNDATION WORK OR EXCAVATION OPERATIONS BEFORE APPLICATION FOR BUILDING DEPARTMENT CONSTRUCTION PERMIT AS PER SECTIONS BC 105.5 AND BC 3304.3.2 OF THE NYCBC.
3. WHEN EXCAVATIONS ARE 5'-0" OR GREATER IN DEPTH FROM THE LEVEL OF ADJACENT GROUND, THE SIDES SHALL BE SHORED AS PER SECTION BC 3304.4.1 OF THE NYCBC.
4. PROVIDE GUARD RAILS OR FENCE AT EXCAVATIONS AS PER SECTION BC 3304.4.4.
5. THE CONTRACTOR SHALL PROVIDE, MAINTAIN AND OPERATE ALL NECESSARY PUMPING AND DEWATERING EQUIPMENT, AND BE RESPONSIBLE FOR THE REMOVAL OF WATER FROM ANY SOURCE OF CAUSE, BY WHATEVER MEANS AND EQUIPMENT NECESSARY, AND AS LONG AS MAY BE REQUIRED TO PROPERLY PERFORM THE FOUNDATION WORK. WATER SHALL BE CONDUCTED AWAY FROM EXCAVATIONS AND ALL NECESSARY PRECAUTIONS SHALL BE TAKEN TO PREVENT SETTLEMENT, EROSION OR ANY OTHER DAMAGE TO ADJOINING STRUCTURES DUE TO LOSS OF GROUND WATER.

PILE FOUNDATION NOTES:
1. PILES AND DRIVING OF PILES SHALL CONFORM TO THE REQUIREMENTS OF CHAPTER 18 AND CHAPTER 33 OF NEW YORK CITY BUILDING CODE.
2. ALL PILES PENETRATING LESS THAN 10 FEET BELOW CUT-OFF OR LESS THAN 10 FEET BELOW GROUND LEVEL SHALL BE BRACED AGAINST LATERAL MOVEMENT.
3. THE CONTRACTOR SHALL VERIFY THE SIZE AND LOCATION OF ALL UNDERGROUND UTILITIES PRIOR TO DRIVING PILES.
4. THE FOLLOWING DOCUMENTS SHALL BE SUBMITTED TO THE ENGINEER OF RECORD:
   A. PILE IDENTIFICATION PLAN.
   B. PILE DRIVING LOGS SIGNED AND SEALED BY A LICENSED SURVEYOR OR A PROFESSIONAL ENGINEER.
   C. PILE DEVIATION PLAN.
   THE CONTRACTOR SHALL NOT POUR ANY PILES CAPS OR STRAPS UNTIL THE ENGINEER OF RECORD AND BUILDING DEPARTMENT HAS APPROVED THE ABOVE DOCUMENTS.
5. PILE CAPS CAN BE LOWERED, NOTCHED, INCREASED IN THICKNESS OR ALTERED IN AN APPROPRIATE MANNER TO ACCOMMODATE MECHANICAL SERVICE LINES, PENDING APPROVAL OF THE STRUCTURAL ENGINEER OF RECORD.
6. DRIVEN PILE CAPACITIES SHALL BE VERIFIED BY LOAD TEST IN ACCORDANCE WITH THE CODE . TWO DRIVEN PILES SHALL HAVE A LATERAL LOAD TEST IN ACCORDANCE WITH THE CODE. TEST SHALL BE TAKEN FROM NEAR FINAL SUBGRADE ELEVATION. PILES SHALL HAVE A LATERAL WORKING CAPACITY OF 5T.
7. ECCENTRICITIES OF "AS-BUILT" PILE GROUPS SHALL BE ADJUSTED BY STRAPS, ADDITIONAL REINFORCING OR BY THE DRIVING OF ADDITIONAL PILES AS INDICATED ON REDESIGN SHEETS AS PREPARED BY THE STRUCTURAL ENGINEER.

8*. ALL DRIVEN PILES SHALL BE **HP12x74** WITH A DRIVING SHOE AND HAVE A DESIGN CAPACITY OF **150T**.

9*. ALL DRILLED PILES SHALL HAVE A DESIGN CAPACITY OF **150T** AND BE 10.75" OD; .5" WALL THICKNESS; 6000psi GROUT; REINFORCE WITH 1-#20 AT CENTER, 75ksi. DRILLED PILE SOCKET TO BE MIN 8.75" DIAMETER, WITH MINIMUM 5'-0" SOCKET IN NYC CLASS 1b ROCK OR BETTER.

10. SPLICE IN THE STEEL PILE, IF REQUIRED, SHALL BE MADE USING A FULL PENETRATION, PRE-QUALIFIED, SINGLE VEE GROOVED BUTT WELD, OR AND APPROVED SPLICE CONNECTER. NO SPLICES SHALL BE PERMITTED IN TOP 15' IN PILES BELOW THE SHEARWALL AND PILE CAPS IMMEDIATELY ADJACENT TO SHEARWALL.

* AS AN ALTERNATIVE TO ABOVE DRIVEN PILES, MONOTUBE PILES MAY BE USED PER THE RECCOMENDATIONS OF THE GEOTECHNICAL REPORT DATED MARCH 2012 PREPARED BY PILLORI ASSOCIATES. AN EQUIVALENT INCREASE IN THE NUMBER OF PILES SHALL BE PROVIDED GIVEN THE LOWER 130T CAPACITY OF THE MONOTUBE PILES. WHERE REQUIRED, PILE CAPS SHALL BE INCREASED TO ACCOMODATE THE LARGER NUMBER OF PILES.

FOUNDATION CONTRACTOR NOTES:

PRIOR TO EXCAVATING AND INSTALLING FOOTINGS OR PILES IN THE PROXIMITY OF LOT LINES, THE FOUNDATION CONTRACTOR SHALL DO THE FOLLOWING:
1. IN ORDER TO REDUCE THE POTENTIAL FOR VIBRATION DAMAGE TO ADJACENT STRUCTURES, THE CONTRACTOR SHALL PRE-AUGER, PRE-CORE, PRE-EXCAVATE OR USE OTHER PROCEDURES TO PENETRATE OR REMOVE ANY OBSTRUCTIONS THAT MAY IMPEDE PILE DRIVING AND CREATE UNACCEPTABLE VIBRATION LEVELS. THE CONTRACTOR SHALL USE A SINGLE ACTING HAMMER. DRIVING WITH VIBRATORY HAMMERS IS NOT PERMITTED.
2. SETTLEMENTS AND VIBRATIONS AT ADJACENT BUILDINGS SHALL BE MONITORED BY AN INDEPENDENT LABORATORY. THE SETTLEMENT MONITORING POINTS SHALL BE ESTABLISHED NOT MORE THAN 10 FEET APART ON THE WALLS OF ALL STRUCTURES ADJACENT TO THE SITE, ABOUT FIVE (5) FEET ABOVE GRADE. ELEVATIONS OF THESE POINTS SHOULD BE MEASURED NEAR THE MIDDLE AND AT THE END OF EACH DAY. THE CONTRACTOR SHOULD BE PREPARED TO MODIFY HIS DRIVING PROCEDURES IF THE CUMULATIVE SETTLEMENT AT ANY POINT EXCEEDS 1/8 INCH.
3. MAGNITUDE OF VIBRATIONS SHALL BE MONITORED AT LEAST TWICE A DAY ON ALL STRUCTURES ADJACENT TO THE SITE, WITH AN IMMEDIATE MEASUREMENT MADE EACH TIME THE PILE DRIVING OPERATION CHANGES LOCATION. THE MAXIMUM ALLOWED LEVEL OF VIBRATION MEASURED AT ANY ADJACENT STRUCTURE SHALL BE A PEAK PARTICLE VELOCITY OF 0.5 INCHES PER SECOND. THE CONTRACTOR SHOULD BE PREPARED TO MODIFY THIS DRIVING PROCEDURES IF THE VIBRATION LEVEL EXCEEDS THAT VALUE.
4. CONTRACTOR'S P.E. SHALL FILE SIGNED AND SEALED REVISED DRAWING WITH THE BUILDING DEPARTMENT, FOR APPROVAL PRIOR TO PROCEEDING WITH CONSTRUCTION, SHOWING NECESSARY MEASURES TO PROTECT THE EXISTING STRUCTURES (SUCH AS GROUTING, UNDERPINNING, AUGURED PILES, ETC.) TO PREVENT ANY DISPLACEMENT OF SUPPORT MATERIALS.

WATERPROOFING NOTES:

WATERPROOFING SHALL CONFORM TO THE REQUIREMENTS OF SECTION BC 1807 OF THE NYC BC.
1. WATERPROOFING SHOWN IS SCHEMATIC. SEE WATERPROOFING DRAWINGS FOR DETAILS.
2. WATERPROOFING PANEL SHALL BE INSTALLED AS PER MANUFACTURER'S SPECIFICATIONS AT ALL FOUNDATION WALLS AND BELOW SLAB ON GRADE.
3. PROVIDE A 1" H.I.T. ON ALL SLABS AND WALLS OF ELEVATOR PITS AND ALL OTHER PITS AS SHOWN ON DETAILS.
4. CONSTRUCTION JOINTS IN WALLS AND SLABS ON GRADE, AND ALL PENETRATIONS FOR PLUMBING AND MECHANICAL SHALL BE DETAILED IN CONFORMITY WITH WATER PROOF PANEL MANUFACTURER'S DETAILS TO MAINTAIN THE INTEGRITY OF THE WATER PROOFING ENVELOPE.
5. CONTRACTOR TO USE APPROVED WATERPROOF FORM TIE DETAIL AT ALL WALL LOCATIONS BELOW EL.=+13'-6".
6. AT ALL NEW TO EXISTING CONSTRUCTION JOINTS, THE EXISTING SURFACE TO BE PAINTED WITH AN APPROVED BONDING SLURRY PRIOR TO PLACING NEW CONCRETE.
7. AT CONDITIONS WHERE WATER STOP IS VERTICALLY ORIENTED (i.e. A HORIZONTAL CONSTRUCTION JOINT), TOP OF WATER STOP TO BE WIRE SUPPORTED FROM REBAR ABOVE.
8. AT CONDITIONS WHERE WATER STOP IS VERTICALLY ORIENTED (i.e. A HORIZONTAL CONSTRUCTION JOINT), THE TOP BARS IN THE BOTTOM HALF OF THE CONSTRUCTION JOINT ARE TO BE LOWERED SO THAT THE WATER STOP CAN BE INSTALLED CONTINUOUSLY WITHOUT HAVING TO CUT AROUND THE BARS.
9. WATER STOPS ARE NOT TO BE CUT TO FACILITATE PLACEMENT OF BARS.
10. BENTONITE ROPES AND OTHER TYPE OF MATERIAL MUST BE KEPT DRY UNTIL CONCRETE IS PLACED ON IT. IF THE BENTONITE BECOMES WET BEFORE CONCRETE PLACEMENT, SUBCONTRACTOR SHALL REPLACE IT.
11. ALL FLOOR DRAINS IN SLAB ON GRADE TO BE WATERPROOF TYPE WITH FLANGE.
12. WHERE AREAS ARE DEWATERED FOR THE PLACING OF PITS, THE DEWATERING WILL CONTINUE FOR A MINIMUM OF 72 HOURS AFTER PLACEMENT OF PIT CONCRETE SO THAT THE CONCRETE HAS TIME TO DEVELOP STRENGTH BEFORE BEING EXPOSED TO THE WATER.
13. SUBCONTRACTOR SHALL PATCH ANY CRACKS WHICH OCCUR IN NEWLY PLACED CONCRETE USING AN APPROVED EPOXY CRACK REPAIR COMPOUND IN ACCORDANCE WITH THE MANUFACTURERS RECOMMENDATIONS. THE DESIGN MIX SHOULD BE DESIGNED TO MINIMIZE SHRINKAGE IN ORDER TO MINIMIZE CRACKING. WHERE CRACKS OCCUR THEY WILL NEED TO BE CHASED AND PATCHED WITH AN EPOXY CRACK FILLER.
14. ALL SLEEVES WHICH ARE TO BE CAST INTO FOUNDATION WALLS SHALL HAVE A MINIMUM OF A THREE INCH FLANGE AT THE CENTER OF THE WALL.
15. SLABS ON GRADE TO BE WATER CURED USING SPRINKLERS AND BURLAP.
16. AT LOCATIONS WHERE CONSTRUCTION JOINTS OCCUR BETWEEN NEW AND EXISTING CONCRETE, CUT A 4"x4" KEY WAY INTO THE EXISTING CONCRETE. GROUT WATER STOP INTO THE KEY WAY BEFORE PLACING THE NEW CONCRETE.
17. AT LOCATIONS WHERE CONSTRUCTION JOINTS OCCUR BETWEEN NEW AND EXISTING CONCRETE, CHOP EXISTING CONCRETE, AND FORM NEW CONCRETE TO FORM A RECESS WHICH CAN BE LATER PACKED WITH WATER PROOF MORTAR. WAIT A MINIMUM OF 30 DAYS AFTER THE INITIAL CONCRETE POUR TO ALLOW FOR SHRINKAGE AND SETTLEMENT, THEN PACK THE RECESS WITH A SAND/CEMENT/ANTI-HYDRO MORTAR.

SPECIAL INSPECTIONS:

THE SPECIAL INSPECTIONS OF CONCRETE (STRUCTURAL CONCRETE) SHALL BE IN ACCORDANCE WITH CHAPTER 17 OF THE NYCBC.
INSPECTION SHALL INCLUDE:
- (A) PRELIMINARY TESTS OF CONCRETE
- (B) BATCH PLANT INSPECTION
- (C) CONCRETE PLACEMENT
- (D) FORM SIZE AND DIMENSIONS
- (E) REINFORCING PLACEMENT
- (F) BORINGS
- (G) INSPECTION OF SURGED FOR FOOTINGS, FOUNDATION PIERS AND FOUNDATION WALLS.
- (H) ON SITE INSPECTION, INCLUDING CYLINDER PREPARATION, SLUMP, AIR CONTENT, WEIGHT AND TEMPERATURE.

ALL UNDERPINNING SHEETING, SHORING OR OTHER CONSTRUCTIONS REQUIRED FOR THE SUPPORT OF ADJACENT PROPERTIES OR BUILDINGS SHALL BE SUBJECT TO SPECIAL INSPECTION AS ESTABLISHED BY NEW YORK CITY BUILDING CODE SECTION BC 1814. THE CONTRACTOR SHALL RETAIN A PROFESSIONAL ENGINEER ACCEPTABLE TO THE ENGINEER OF RECORD TO PROVIDE THE REQUIRED INSPECTIONS. THE PROFESSIONAL ENGINEER SHALL PREPARE THE REQUIRED FORM TR-1 FOR FILING WITH THE BUILDING DEPARTMENT.

REQUIRED SPECIAL INSPECTIONS:
1. STRUCTURAL STEEL - WELDING
2. STRUCTURAL STEEL - ERECTION & BOLTING
3. CONCRETE - CAST-IN-PLACE
4. MASONRY
5. PILE FOUNDATIONS & DRILLED PIER INSTALLATION
6. SPRAYED FIRE-RESISTANT MATERIALS
7. FIRESTOP, DRAFTSTOP, AND FIREBLOCK SYSTEMS
8. CONCRETE TEST CYLINDERS
9. CONCRETE DESIGN MIX

REQUIRED PROGRESS INSPECTIONS:
1. FOOTING AND FOUNDATION
2. FRAME INSPECTION

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No	Date:	Rev	Issue:
1	06/22/12		DOB SUBMISSION
2	08/24/12		PROGRESS FOUNDATION SET
3	08/27/12		PROGRESS SET
4	09/05/12		PROGRESS SET

NOTES:
ALL ELEVATIONS ARE MEASURED RELATIVE TO NGVD (1929).
BROOKLYN HIGHWAY DATUM (BHD) IS +2.55'

CLIENT
Two Trees Management
45 Main Street Suite 602
Brooklyn, NY 11201

PROJECT
60 Water Street
Brooklyn, NY

TITLE
FOUNDATION NOTES AND DETAILS

SCALE: As indicated
DATE: 6/22/2012
PROJECT No: Project Number

STATE OF NEW YORK · BENJAMIN PIMENTEL · 086645 · LICENSED PROFESSIONAL ENGINEER

FO-021.00

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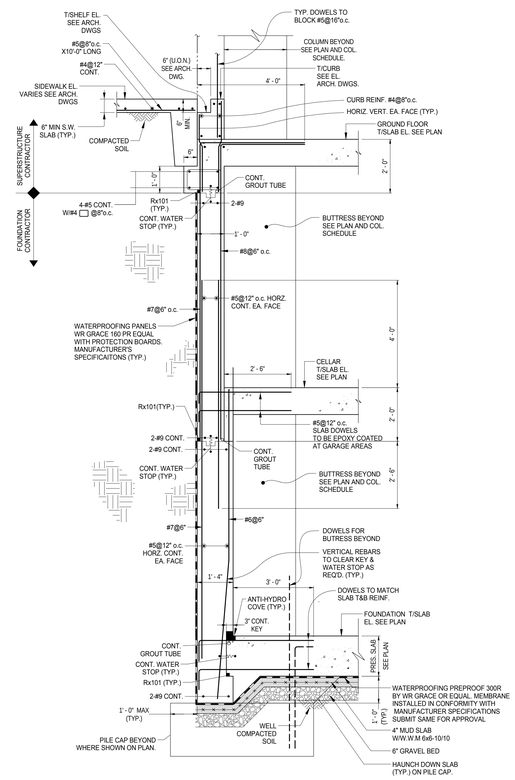
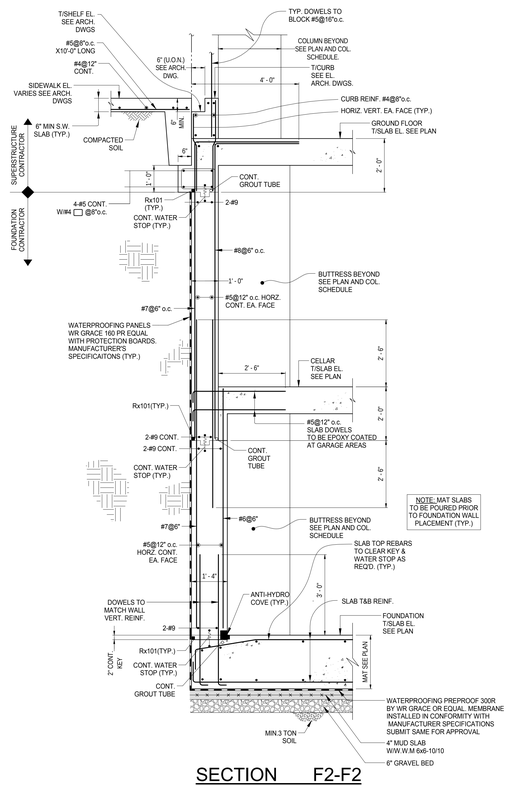


SECTION F1-F1

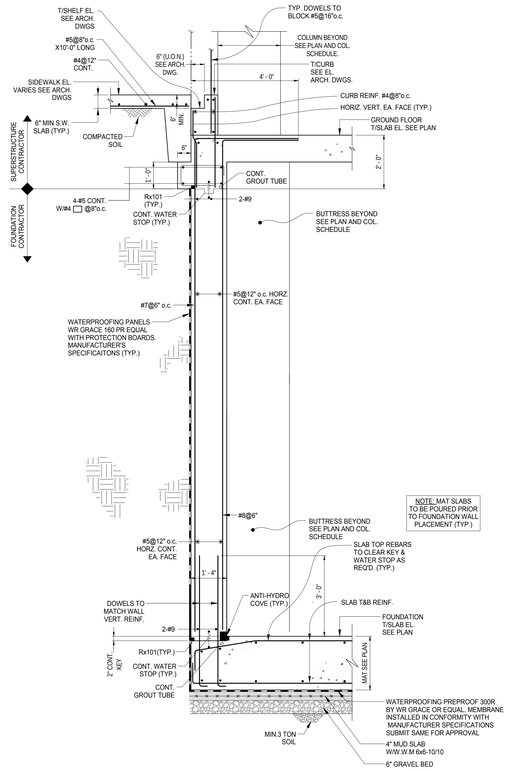
SCALE: 1/2"=1'-0"



NOTE: MAT SLABS TO BE POURED PRIOR TO FOUNDATION WALL PLACEMENT (TYP.)

SECTION F2-F2

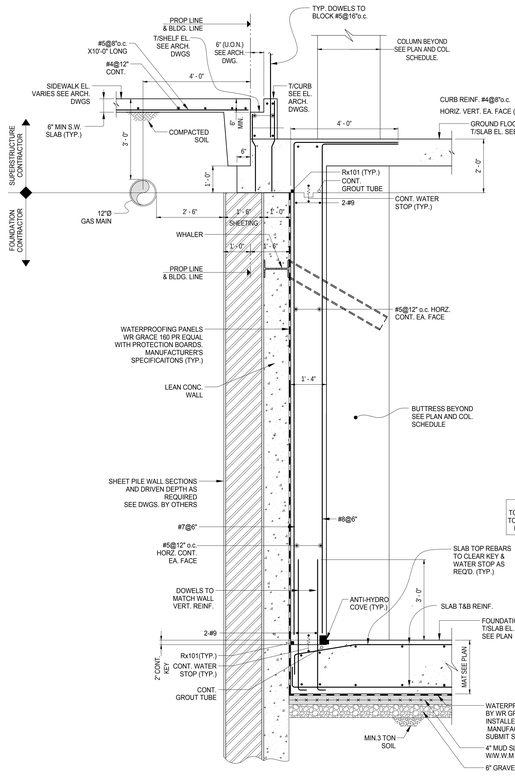
SCALE: 1/2"=1'-0"



NOTE: MAT SLABS TO BE POURED PRIOR TO FOUNDATION WALL PLACEMENT (TYP.)

SECTION F3-F3

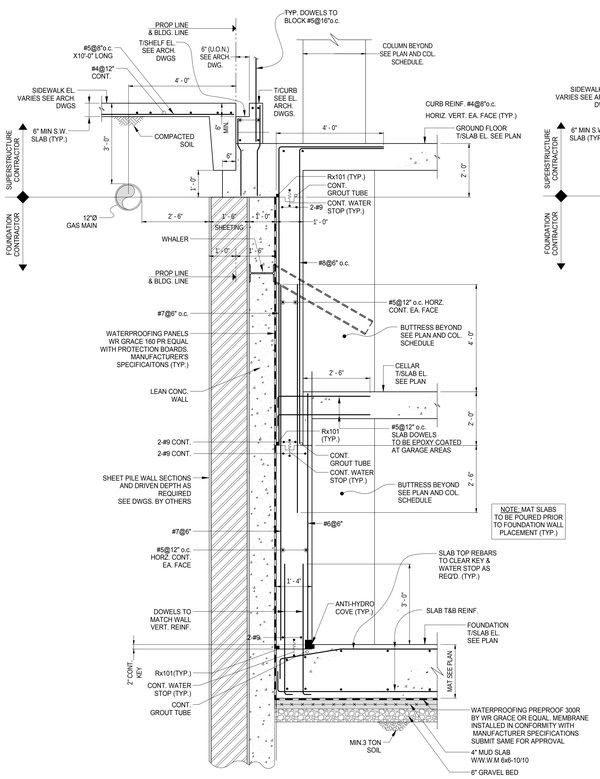
SCALE: 1/2"=1'-0"



NOTE: MAT SLABS TO BE POURED PRIOR TO FOUNDATION WALL PLACEMENT (TYP.)

SECTION F4-F4

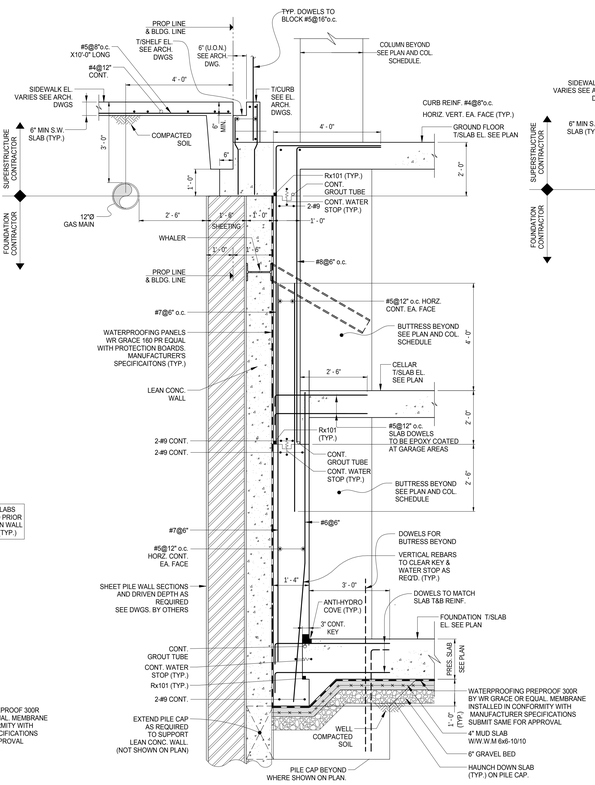
SCALE: 1/2"=1'-0"



NOTE: MAT SLABS TO BE POURED PRIOR TO FOUNDATION WALL PLACEMENT (TYP.)

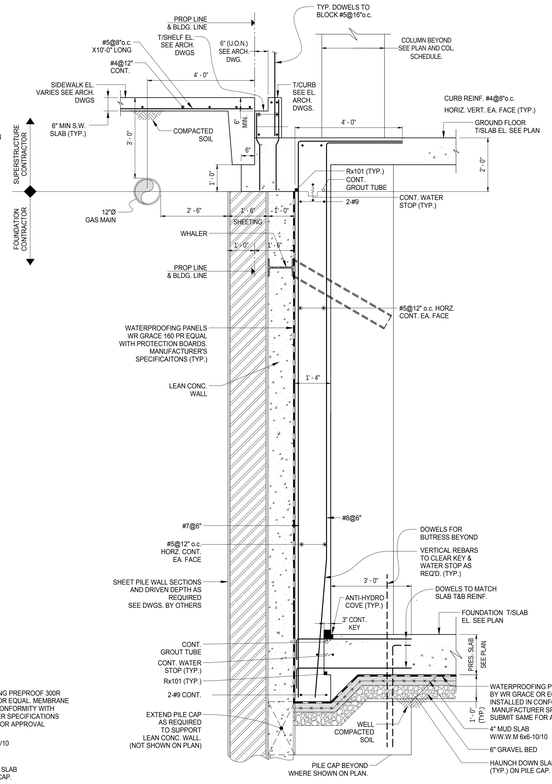
SECTION F5-F5

SCALE: 1/2"=1'-0"



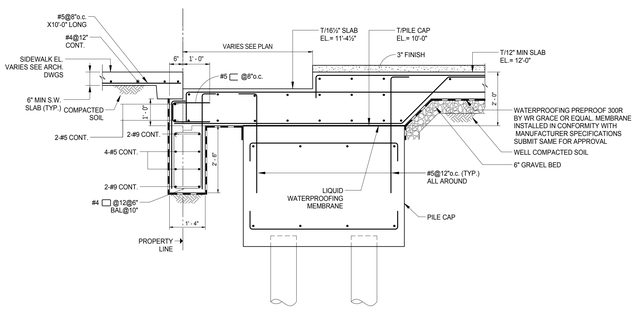
SECTION F6-F6

SCALE: 1/2"=1'-0"



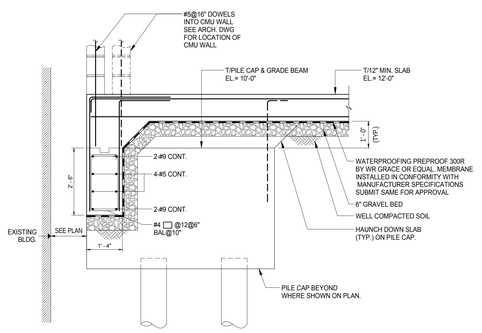
SECTION F7-F7

SCALE: 1/2"=1'-0"



SECTION F8-F8

SCALE: 1/2"=1'-0"



SECTION F9-F9

SCALE: 1/2"=1'-0"

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No	Date:	Rev	Issue:
1	06/22/12		DOB SUBMISSION
2	08/24/12		PROGRESS FOUNDATION SET
3	08/27/12		PROGRESS SET
4	09/05/12		PROGRESS SET

NOTES:
ALL ELEVATIONS ARE MEASURED RELATIVE TO NGVD (1929).
BROOKLYN HIGHWAY DATUM (BHD) IS +2.55'

CLIENT

Two Trees Management
45 Main Street Suite 602
Brooklyn, NY 11201

PROJECT
60 Water Street
Brooklyn, NY

TITLE

FOUNDATION SECTIONS

SCALE: 1/2" = 1'-0"
DATE: 6/22/2012
PROJECT No: Project Number

STATE OF NEW YORK · BENJAMIN PIMENTEL · 086645 · LICENSED PROFESSIONAL ENGINEER

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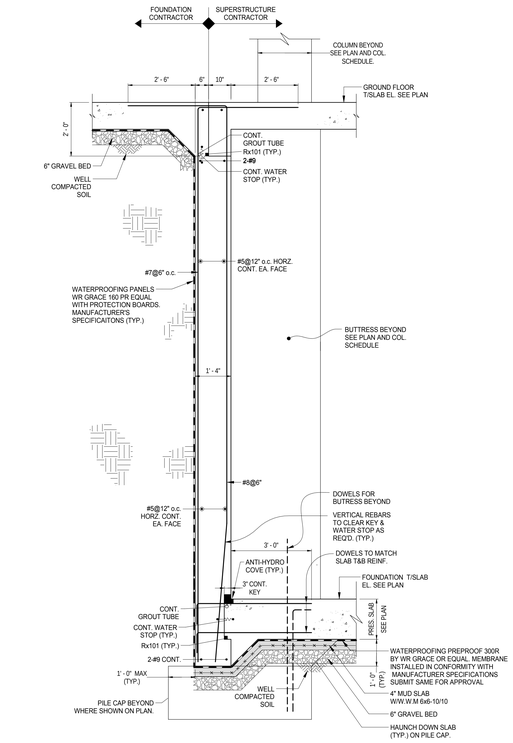
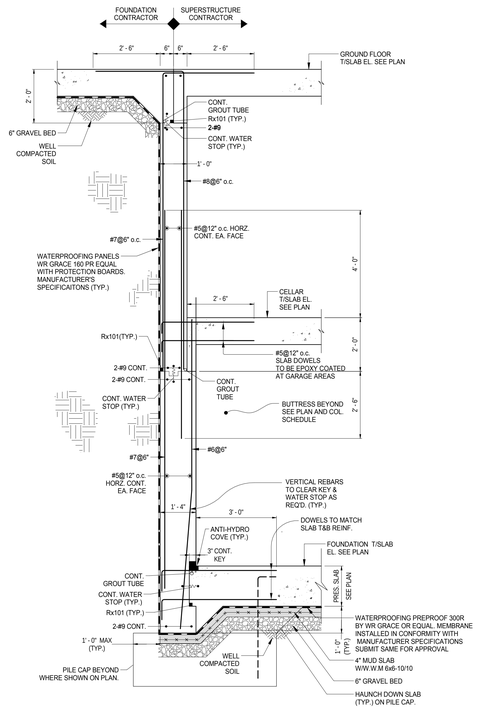


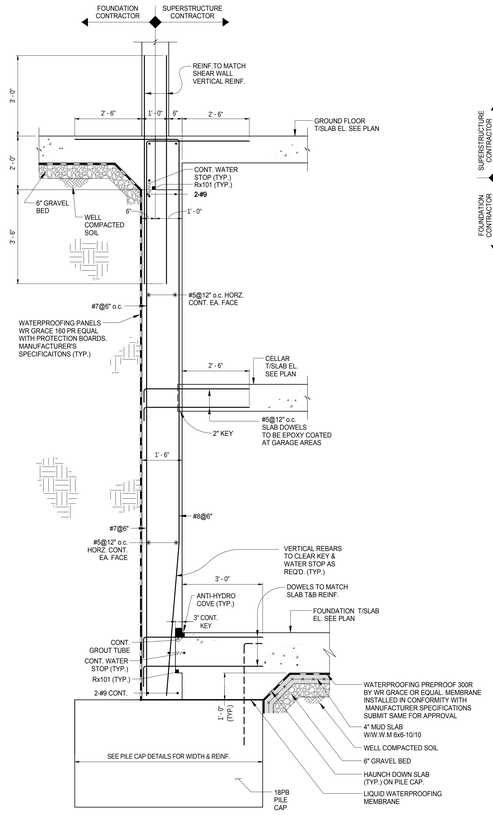
SECTION F10-F10

SCALE: 1/2"=1'-0"



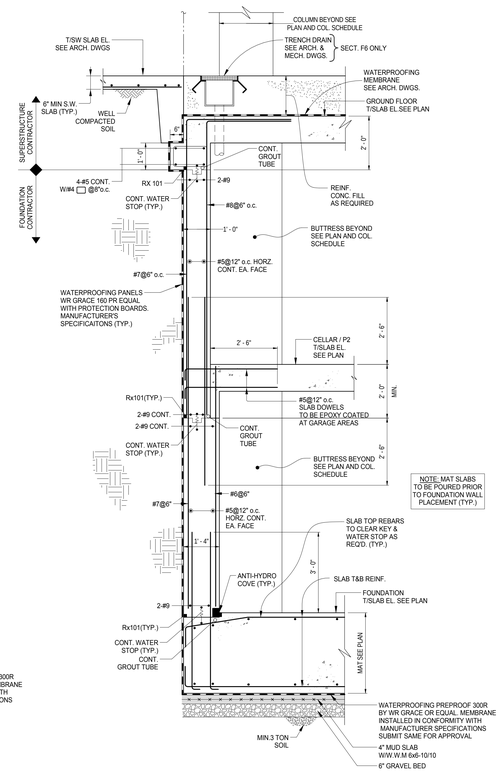
SECTION F11-F11

SCALE: 1/2"=1'-0"



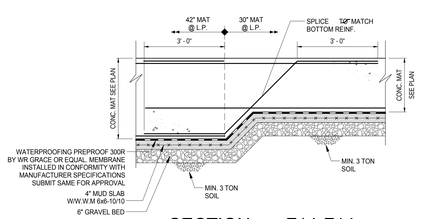
SECTION F12-F12

SCALE: 1/2"=1'-0"



SECTION F13-F13 / F13A-F13A

SCALE: 1/2"=1'-0"



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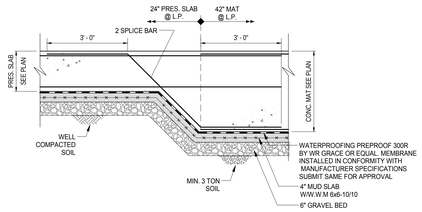
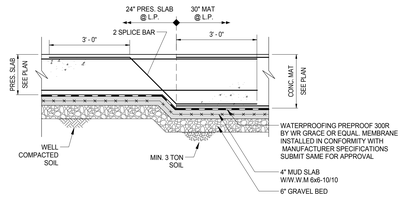
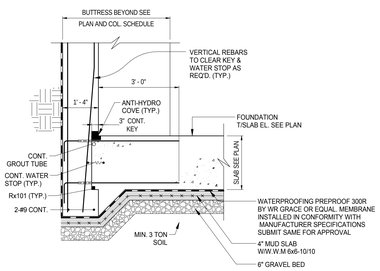


SECTION F15-F15

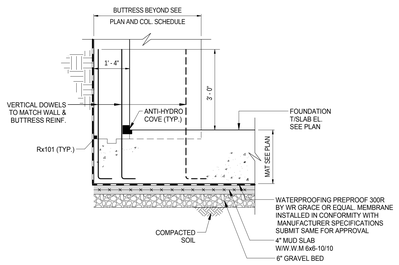


SECTION F16-F16



ALT. AT WALL BASE FOR MECH. ANCHORS

SCALE: 1/2"=1'-0"



ALTERNATE DETAIL AT BASE OF FDN. WALL

SCALE: 1/2"=1'-0"

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NOTES:
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BROOKLYN HIGHWAY DATUM (BHD) IS +2.55'

CLIENT

Two Trees Management
45 Main Street Suite 602
Brooklyn, NY 11201

PROJECT
60 Water Street
Brooklyn, NY

TITLE

FOUNDATION
SECTIONS 2

SCALE: 1/2" = 1'-0"
DATE: 6/22/2012
PROJECT No: Project Number

STATE OF NEW YORK · BENJAMIN PIMENTEL · 086645 · LICENSED PROFESSIONAL ENGINEER

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LOW-RISE COLUMN SCHEDULE

COLUMN No. / FLOOR	SW B	SW C	SW D	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
3rd FLOOR (EL. 37'-6" int.)	SEE DETAIL	SEE DETAIL	SEE DETAIL																																					
2nd FLOOR (12'-0")																18x18 4-#8																								
GROUND FLOOR (SEE PLAN)				24"Ø 6-#7	26x18 6-#9	26x18 6-#9	18x18 4-#7	22x22 4-#9	22x22 4-#10	(SP) 22x72 12-#11	20x26 4-#10	18x30 8-#11	18x30 6-#8	22x22 4-#9	22x22 4-#9	24"Ø 6-#8	24"Ø 6-#8	24"Ø 6-#8	24"Ø 6-#7		(SP) 22x22 8-#10	(SP) 18x30 8-#11												30x24 6-#10	30x24 6-#9			26"Ø 6-#8
CELLAR (SEE PLAN)				"B" 32x44 18-#7	"B" 34x53 20-#7	"B" 34x57 20-#7	"B" 59x38 22-#7	"B" 72x30 22-#7	"B" 68x30 20-#7									"B" 32x59 22-#7	"B" 32x37 16-#7														"B" 38x32 16-#7	"B" 38x32 16-#7			"B" 62x34 24-#7
FOUNDATION (SEE PLAN)				"B" 32x44 18-#7	"B" 34x53 20-#7	"B" 34x57 20-#7	"B" 59x38 22-#7	"B" 72x30 22-#7	"B" 68x30 20-#7									"B" 32x59 22-#7	"B" 32x37 16-#7	26x26 12-#10	22x22 8-#10	18x30 8-#8	18x30 8-#11	18x30 10-#11	18x26 10-#11	22x22 4-#10	30"Ø 12-#10	24"Ø 6-#10	36x18 6-#9	36x18 6-#10	32x24 10-#11	28x24 14-#11	26x20 4-#10	30x18 6-#8	30x24 10-#11	"B" 38x32 16-#7	"B" 38x32 16-#7	30x24 6-#10	26"Ø 4-#10	"B" 62x34 24-#7
LOAD ON FOUNDATION				620	1050	1110	650	1230	1400	1000	1180	1180	1140	970	1160	720	930	1180	1080	1700	1420	1280	1540	1590	1170	1020	1440	1240	1650	1660	2150	2200	1270	1260	2200	2270	1680	1990	1110	1680
FLOOR / COLUMN No.	SW B	SW C	SW D	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

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LOW-RISE COLUMN SCHEDULE

COLUMN No. / FLOOR	SW A	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73
3rd FLOOR (EL. 37'-6" int.)	SEE DETAIL						NOT USED	NOT USED	NOT USED	NOT USED																	12x24 4-#6										
2nd FLOOR (12'-0")						(SP) 16x24 8-#11								24x16 4-#7		30x14 6-#6	18x26 4-#8				18x26 4-#8	18x26 4-#8														
GROUND FLOOR (SEE PLAN)		24"Ø 6-#7	24"Ø 6-#7	24"Ø 6-#7	24"Ø 6-#7	16x24 4-#11						(SP) 24x16 8-#9	(SP) 24x24 8-#11		(SP) 24x24 12-#11			(SP) 28"Ø 8-#11								24x24 4-#8		24x24 4-#7	22x22 4-#7	24x24 4-#7	(SP) 24"Ø 8-#11			24"Ø 6-#7		
CELLAR (SEE PLAN)		"B" 32x42 18-#7	"B" 32x42 18-#7	"B" 32x41 18-#7	"B" 32x38 18-#7	"B" 53x29 20-#7									8-#8											"B" 54x32 20-#7		"B" 60x32 20-#7	"B" 42x48 20-#7	"B" 32x42 18-#7	4-#11				"B" 32x42 16-#7		
FOUNDATION (SEE PLAN)		"B" 32x42 18-#7	"B" 32x42 18-#7	"B" 32x41 18-#7	"B" 32x38 18-#7	"B" 53x29 20-#7					24x18 8-#9	24x16 4-#8	24x24 8-#11		24x24 8-#7			28"Ø 8-#11	22x26 8-#11	20x26 8-#10			20x26 10-#11	18x26 4-#10	24x18 4-#11		"B" 54x32 20-#7		"B" 60x32 20-#7	"B" 42x48 20-#7	"B" 32x42 18-#7	24"Ø 4-#9	16x24 4-#10	16x24 6-#11	18x24 6-#10	"B" 32x42 18-#7	20x24 8-#10	24x18 4-#11
LOAD ON FOUNDATION		1040	980	1000	1010	800					885	1180	1530		990			1475	1475	1475			1475	1180	860	760		840	510	820	1050	1080	1180	1130	885	1180	870
FLOOR / COLUMN No.	SW A	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73

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COLUMN SCHEDULE NOTES:

1. FIRST COLUMN SIZE SHOWN IN SCHEDULE IS IN EAST-WEST DIRECTION.
2. LOADS ARE GIVEN IN KIPS (1 KIP = 1000LB) AND ARE ACTUAL LOADS.
3. NUMBERS SHOWN IN PARENTHESIS ARE VERTICAL REACTIONS DUE TO SEISMIC LOAD AND ARE SHOWN ONLY WHERE THE COMBINATION OF DEAD+LIVE+LATERAL LOAD CONTROLS.
4. INDICATES A CHANGE IN THE FIXED FACE OF THE COLUMN. SEE RESPECTIVE FRAMING PLANS FOR LOCATION.
5. CONCRETE STRENGTHS FOR COLUMNS ARE INDICATED IN SCHEDULE AND GENERAL NOTES, DWG. S-401.
6. "B" DENOTES BUTTRESS DETAIL ON DRAWING FO-020.
7. FOR SHEAR WALL REINFORCING AND TYPICAL COLUMN DETAILS, SEE DWG. S-402. ALL COLUMNS (INCLUDING SHEAR WALLS AND DETAILED COLUMNS) SHALL BE TIED AND CROSS-TIES AS DESCRIBED IN THE SCHEDULE AND COLUMN DETAILS ON DWG. S-402.
8. (SP) SHOWN IN SCHEDULE DENOTES TIES SPACED AT 1/2 SPACING IN THE LIFT OF THE COLUMN. SEE DETAIL ON DWG S-401.

LOW-RISE COLUMN SCHEDULE

COLUMN No. / FLOOR	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	125	126	127	128	129	130	131	132
4th FLOOR																																																
3rd FLOOR (10'-0")																																																
2nd FLOOR (EL. 37'-6" int.) (12'-0")																																																
GROUND FLOOR (SEE PLAN)	(SP) 22"Ø 6-#9	24x24 8-#8	24"Ø 8-#8	24"Ø 8-#8	24"Ø 8-#8	24"Ø 8-#8	24"Ø 8-#8	24"Ø 8-#8	24"Ø 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8																(SP) 28"Ø 8-#11	(SP) 24x24 8-#11																24"Ø 8-#8	24"Ø 8-#8					
CELLAR (SEE PLAN)		6-#7	"B" 43x32 14-#7	"B" 43x32 14-#7	"B" 39x40 16-#7	"B" 39x40 16-#7	"B" 38x40 16-#7	"B" 32x40 14-#7	"B" 32x40 14-#7	"B" 32x40 14-#7	"B" 32x40 14-#7																														"B" 42x32 14-#7	"B" 45x32 14-#7	"B" 45x32 14-#7			24x12 4-#8	24x12 4-#8	24x12 4-#8	
FOUNDATION (SEE PLAN)		22"Ø 6-#7	"B" 43x32 14-#7	"B" 43x32 14-#7	"B" 39x40 16-#7	"B" 39x40 16-#7	"B" 38x40 16-#7	"B" 32x40 14-#7	"B" 32x40 14-#7	"B" 32x40 14-#7	"B" 32x40 14-#7		24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	28"Ø 8-#11	24x24 4-#11	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	24x24 8-#8	"B" 42x32 14-#7	"B" 45x32 14-#7	"B" 45x32 14-#7			24x12 4-#8	24x12 4-#8	24x12 4-#8	
LOAD ON FOUNDATION	740	2255	2255	2140	2020	1580	2380	2625	2595	2685	3200	2755	925	1415	1230	1255	1535	1195	805	1225	2190	1620	2285	2680	1645	1825	430	3045	1245	1550	1305	1135	460	3045	1245	1550	1305		460	1135	1135	460	3045	1245	1550	1305	1135	460
FLOOR / COLUMN No.	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	125	126	127	128	129	130	131	132

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SCALE: 12" = 1'-0"
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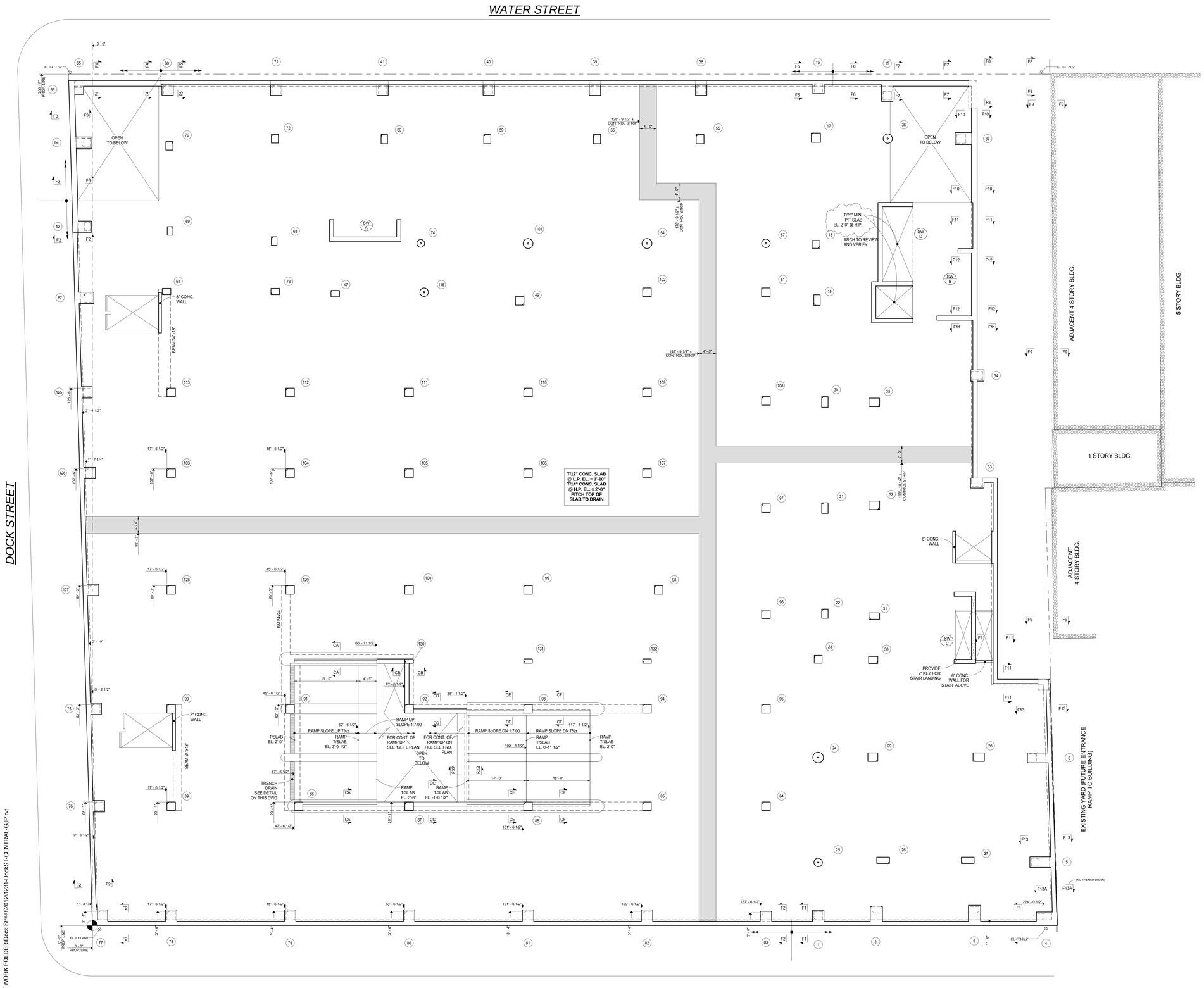


ADDITIONAL NOTES FOR GARAGE AREAS

1. ALL SLAB AND BEAM REINFORCING SHALL BE EPOXY COATED. FOR SPLICE LENGTH INCREASE AND CHAIRS SEE NOTES 2F & 2G ON TYPICAL DETAIL DWG. S-___.
2.
   a. PROVIDE 1½" CONCRETE COVER FOR BOTTOM REINFORCING.
   b. FOR TOP REINFORCING, PROVIDE 1½" CONCRETE COVER @ SLAB LOW POINT. (12" SLAB) AND 3½" CONCRETE COVER @ SLAB HIGH POINT (14" SLAB).
   c. CONTRACTOR SHALL PROVIDE APPROPRIATE CHAIR HEIGHTS TO MAINTAIN PROPER CONCRETE COVER AS INDICATED IN NOTES 2a & 2b ABOVE, TO RESPECT INTEGRITY OF SLAB DESIGN, & MINIMIZE SLAB CRACKS.
2. CONCRETE FOR SLAB AND BEAMS SHALL CONTAIN A MINIMUM 1½ lbs. FIBER MESH PER CUBIC YARD OF MIX.
3. CONCRETE FOR SLAB AND BEAMS SHALL CONTAIN 1½ GALLONS OF ANTI-HYDRO PER CUBIC YARD OF MIX.
4. THE CONTRACTOR SHALL PROVIDE A LIQUID MEMBRANE WATERPROOFING ON TOP OF GARAGE SLABS, AS APPROVED BY THE ARCHITECT. FUTURE WATERPROOFING MAINTENANCE SHALL BE PROVIDED BY THE OWNER OR GARAGE OPERATOR.
5. FOR CONCRETE MIX, SPECIAL EXPOSURE REQUIREMENTS (AIR CONTENT, WATER CEMENT RATIO, ETC.) SEE CONCRETE NOTE 1-E ON DWG. S-___.

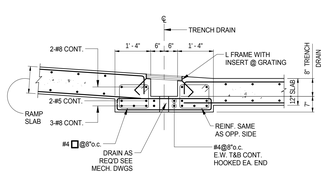
N

CELLAR FRAMING PLAN

SCALE: 1/8" = 1'-0"

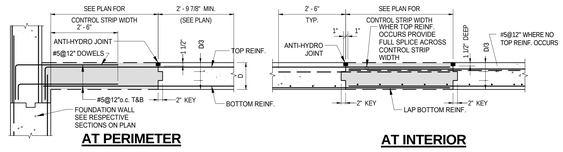
PLAN NOTES

1. TOP OF 14" SLAB EL. = 2'-0" AT HP, 12" SLAB EL. = 1'-10" AT LOW POINT, U.O.N. PITCH TOP OF SLAB TO DRAIN SEE ARCH. AND MECH. DWGS FOR DRAIN LOCATIONS
2. BOTTOM MAT TO BE #5@12"o.c. EACH WAY CONT. U.O.N. TOP AND ADDITIONAL BOTTOM REINFORCING SHOWN ON PLAN
3. SEE ADDITIONAL NOTES FOR GARAGE AREAS ON THIS DRAWING



TYPICAL TRENCH DRAIN DETAIL

SCALE: 1/2"=1'-0"



AT PERIMETER

AT INTERIOR

TYPICAL CONTROL STRIP DETAILS

SCALE: 1/2" = 1'-0"

CONTROL STRIP NOTES:

1. CONTROL STRIP TO BE PLACED 28 DAYS AFTER ADJACENT SLAB HAS BEEN PORRED.
2. FORMS ADJACENT TO CONTROL STRIP ARE NOT TO BE REMOVED UNTIL CONTROL STRIP IS PLACED AND CURED.
3. FOR LOCATION OF CONTROL STRIP SEE PLAN.

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FAX: (732) 335-8515

No	Date:	Rev	Issue:
1	06/22/12		DOB SUBMISSION
2	08/24/12		PROGRESS FOUNDATION SET
3	08/27/12		PROGRESS SET
4	09/05/12		PROGRESS SET

NOTES:
ALL ELEVATIONS ARE MEASURED RELATIVE TO NGVD (1929).
BROOKLYN HIGHWAY DATUM (BHD) IS +2.55'

CLIENT

Two Trees Management
45 Main Street Suite 602
Brooklyn, NY 11201

PROJECT
60 Water Street
Brooklyn, NY

TITLE

CELLAR - PARKING
LEVEL 2

SCALE: As indicated
DATE: 6/22/2012
PROJECT No: Project Number

STATE OF NEW YORK · BENJAMIN PINSKER · 086668 · LICENSED PROFESSIONAL ENGINEER

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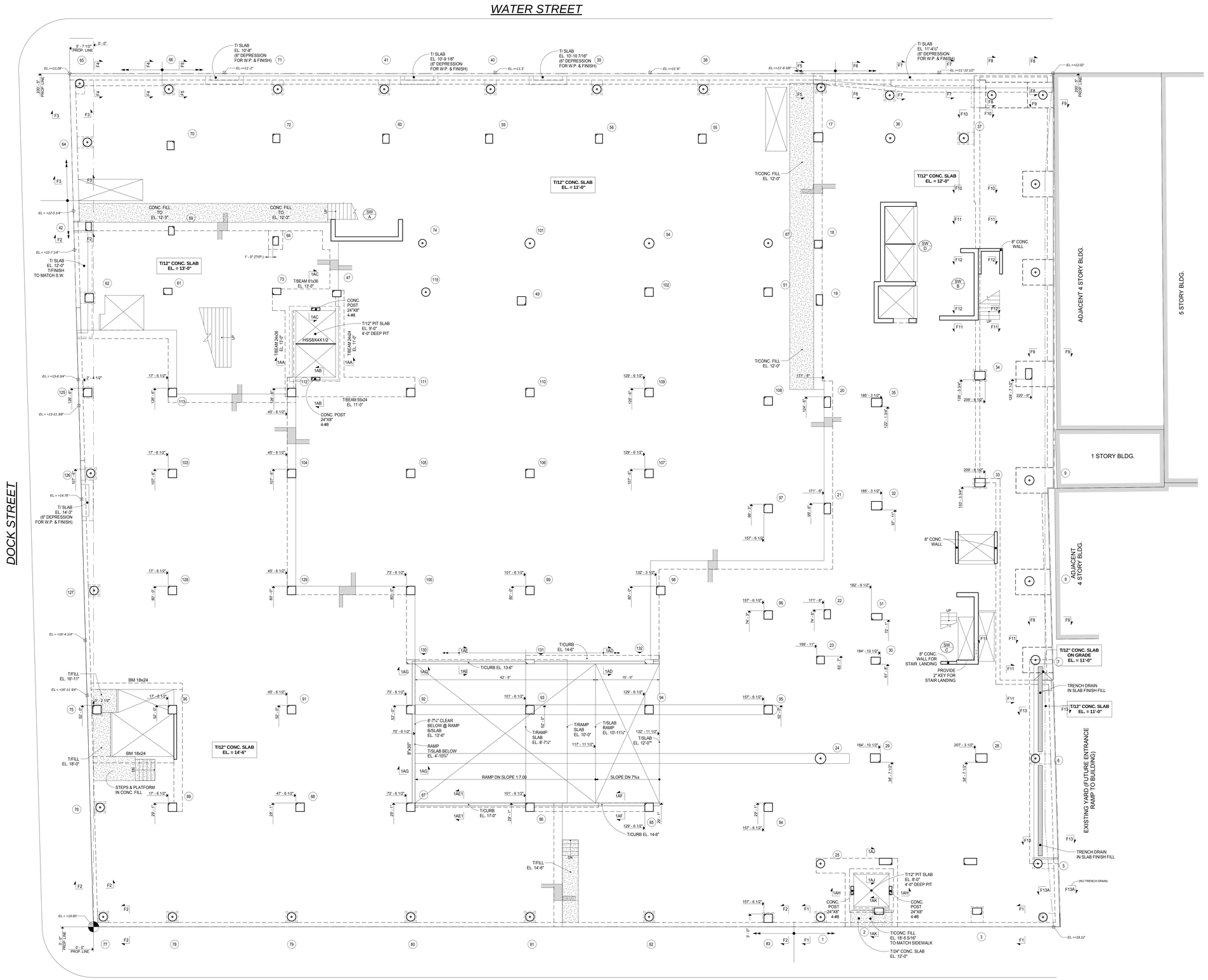

GROUND FLOOR FRAMING PLAN

SCALE: 1/8" = 1'-0"

PLAN NOTES:

1.

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4	09/05/12		PROGRESS SET

NOTES:
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BROOKLYN HIGHWAY DATUM (BHD) IS +2.55'

CLIENT

Two Trees Management
45 Main Street Suite 602
Brooklyn, NY 11201

PROJECT
60 Water Street
Brooklyn, NY

TITLE

GROUND FLOOR FRAMING PLAN

SCALE: 1/8" = 1'-0"
DATE: 6/22/2012
PROJECT No: Project Number

STATE OF NEW YORK · BENJAMIN PIMENTEL · 086868 · LICENSED PROFESSIONAL ENGINEER

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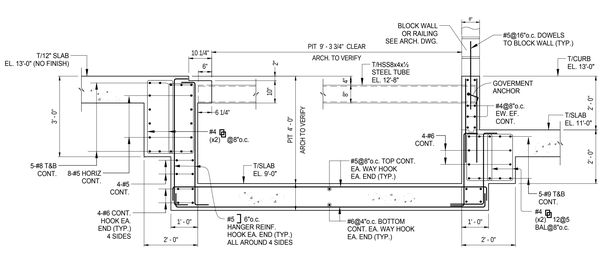
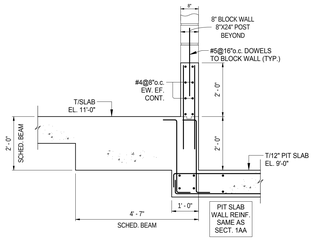


SECTION 1AA-1AA

SCALE: 1/2"=1'-0"



SECTION 1AB-1AB

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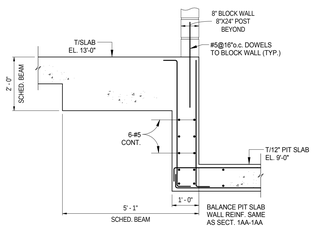

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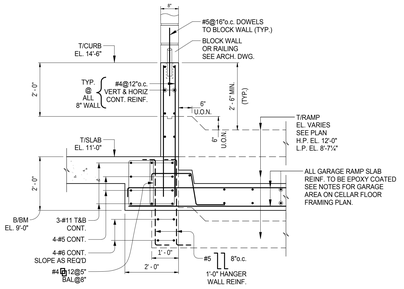

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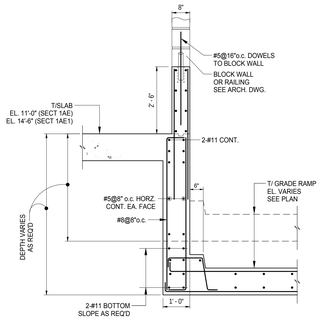
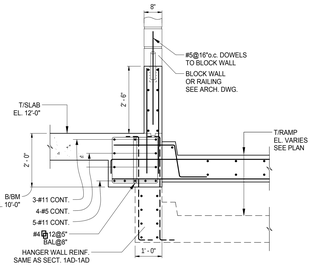


SECTION 1AE-1AE/ 1AE1-1AE1

SCALE: 1/2"=1'-0"



SECTION 1AF-1AF

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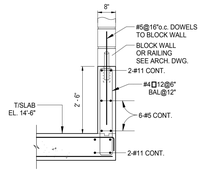

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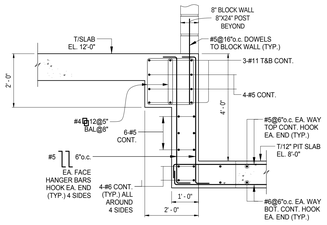

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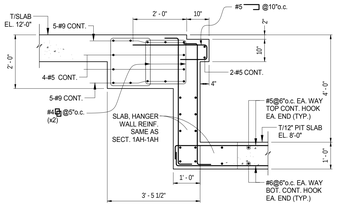

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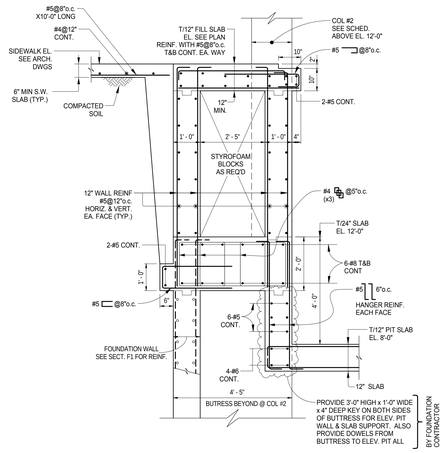

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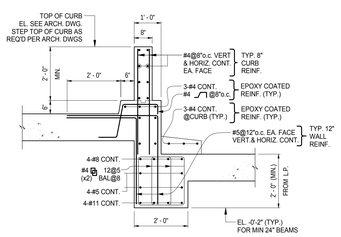

SECTION CA-CA

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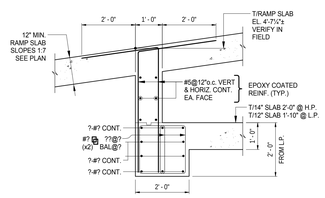

SECTION CB-CB

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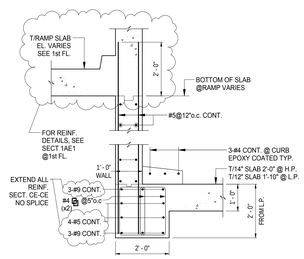

SECTION CC-CC

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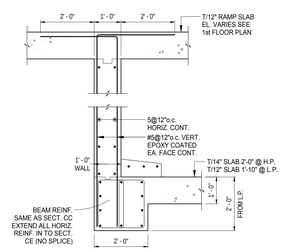

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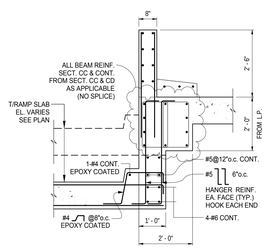

SECTION CE-CE

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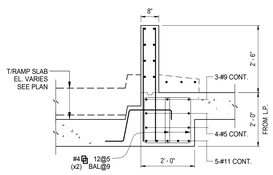

SECTION CF-CF

SCALE: 1/2"=1'-0"

NOTES:
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BROOKLYN HIGHWAY DATUM (BHD) IS +2.55'

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4	09/05/12		PROGRESS SET

CLIENT

Two Trees Management
45 Main Street Suite 602
Brooklyn, NY 11201

PROJECT
60 Water Street
Brooklyn, NY

TITLE

CELLAR AND GROUND
FLOOR SECTIONS

SCALE: 1/2" = 1'-0"
DATE: 6/22/2012
PROJECT No: Project Number

STATE OF NEW YORK · BENJAMIN PIMENTEL · 086645 · LICENSED PROFESSIONAL ENGINEER

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GRACE

PREPRUFE® 300R & 160R

Pre-applied waterproofing membranes that bond integrally to poured concrete for use below slabs or behind basement walls on confined sites

Description

Preprufe® 300R & 160R membranes are unique composite sheets comprising a thick HDPE film, an aggressive pressure sensitive adhesive and a weather resistant protective coating.

Unlike conventional non-adhering membranes, which are vulnerable to water ingress tracking between the unbonded membrane and structure, the unique Preprufe bond to concrete prevents ingress or migration of water around the structure.

The Preprufe R System includes:

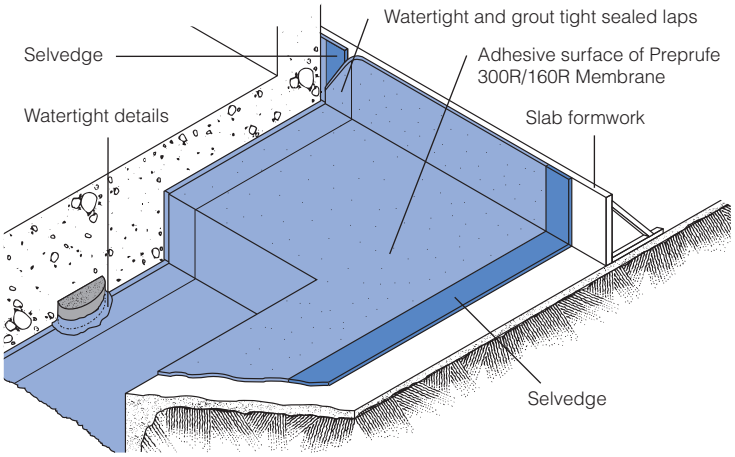
- **Preprufe 300R**—heavy-duty grade for use below slabs and on rafts (i.e. mud slabs). Designed to accept the placing of heavy reinforcement using conventional concrete spacers.
- **Preprufe 160R**—thinner grade for blindside, zero property line applications against soil retention systems.
- **Preprufe Tape LT**—for covering cut edges, roll ends, penetrations and detailing (temperatures between 25°F (-4°C) and 86°F (+30°C)).
- **Preprufe Tape HC**—as above for use in Hot Climates (minimum 50°F (10°C)).
- **Bituthene® Liquid Membrane**—for sealing around penetrations, etc.
- **Adcor™ ES**—waterstop for joints in concrete walls and floors
- **Preprufe Tieback Covers**—preformed cover for soil retention wall tieback heads
- **Preprufe Preformed Corners**—preformed inside and outside corners

Preprufe 300R & 160R membranes are applied either horizontally to smooth prepared concrete, carton forms or well rolled and compacted earth or crushed stone substrate; or vertically to permanent formwork or adjoining structures. Concrete is then cast directly against the adhesive side of the membranes. The specially developed Preprufe adhesive layers work together to form a continuous and integral seal to the structure.

Preprufe can be returned up the inside face of slab formwork but is not recommended for conventional twin-sided formwork on walls, etc. Use Bituthene self-adhesive membrane or Procor® fluid applied membrane to walls after removal of formwork for a fully bonded system to all structural surfaces.

Advantages

- **Forms a unique continuous adhesive bond to concrete poured against it**—prevents water migration and makes it unaffected by ground settlement beneath slabs
- **Fully-adhered watertight laps** and detailing
- **Provides a barrier to water, moisture and gas**—physically isolates the structure from the surrounding ground
- **BBA Certified** for basement Grades 2, 3, & 4 to BS 8102:1990
- **Zero permeance** to moisture
- **Solar reflective**—reduced temperature gain
- **Simple and quick to install**—requiring no priming or fillets
- **Can be applied to permanent formwork**—allows maximum use of confined sites
- **Self protecting**—can be trafficked immediately after application and ready for immediate placing of reinforcement
- **Unaffected by wet conditions**—cannot activate prematurely
- **Inherently waterproof, non-reactive system:**
  - not reliant on confining pressures or hydration
  - unaffected by freeze/thaw, wet/dry cycling
- **Chemical resistant**—effective in most types of soils and waters, protects structure from salt or sulphate attack



Drawings are for illustration purposes only.
Please refer to graceconstruction.com for specific application details.

BBA BRITISH BOARD OF AGREMENT CERTIFICATE No. 97/3325

Installation

The most current application instructions, detail drawings and technical letters can be viewed at graceconstruction.com. For other technical information contact your local Grace representative.

Preprufe 300R & 160R membranes are supplied in rolls 4 ft (1.2 m) wide, with a selvedge on one side to provide self-adhered laps for continuity between rolls. The rolls of Preprufe Membrane and Preprufe Tape are interwound with a disposable plastic release liner which must be removed before placing reinforcement and concrete.

Substrate Preparation

All surfaces—It is essential to create a sound and solid substrate to eliminate movement during the concrete pour. Substrates must be regular and smooth with no gaps or voids greater than 0.5 in. (12 mm). Grout around all penetrations such as utility conduits, etc. for stability (see Figure 1).

Horizontal—The substrate must be free of loose aggregate and sharp protrusions. Avoid curved or rounded substrates. When installing over earth or crushed stone, ensure substrate is well compacted to avoid displacement of substrate due to traffic or concrete pour. The surface does not need to be dry, but standing water must be removed.

Vertical—Use concrete, plywood, insulation or other approved facing to sheet piling to provide support to the membrane. Board systems such as timber lagging must be close butted to provide support and not more than 0.5 in. (12 mm) out of alignment.

Membrane Installation

Preprufe can be applied at temperatures of 25°F (-4°C) or above. When installing Preprufe in cold or marginal weather conditions 55°F (<13°C) the use of Preprufe Tape LT is recommended at all laps and detailing. Preprufe Tape LT should be applied to clean, dry surfaces and the release liner must be removed immediately after application. Alternatively, Preprufe Low Temperature (LT) is available for low temperature condition applications. Refer to Preprufe LT data sheet for more information.

Horizontal substrates—Place the membrane HDPE film side to the substrate with the clear plastic release liner facing towards the concrete pour. End laps should be staggered to avoid a build up of layers. Leave plastic release liner in position until overlap procedure is completed (see Figure 2).

Accurately position succeeding sheets to overlap the previous sheet 3 in. (75 mm) along the marked selvedge. Ensure the underside of the succeeding sheet is clean, dry and free from contamination before attempting to overlap. Peel back the plastic release liner from between the overlaps as the two layers are bonded together. Ensure a continuous bond is achieved without creases and roll firmly with a heavy roller. Completely remove the plastic liner to expose the protective coating. Any initial tack will quickly disappear.

Refer to Grace Tech Letter 15 for information on suitable rebar chairs for Preprufe.

Vertical substrates—Mechanically fasten the membrane vertically using fasteners appropriate to the substrate with the the clear plastic release liner facing towards the concrete pour. The membrane may be installed in any convenient length. Fastening can be made through the selvedge using a small and low profile head fastener so that the membrane lays flat and allows firmly rolled overlaps. Immediately remove the plastic release liner.

Ensure the underside of the succeeding sheet is clean, dry and free from contamination before attempting to overlap. Roll firmly to ensure a watertight seal.

Roll ends and cut edges—Overlap all roll ends and cut edges by a minimum 3 in. (75 mm) and ensure the area is clean and free from contamination, wiping with a damp cloth if necessary. Allow to dry and apply Preprufe Tape LT (or HC in hot climates) centered over the lap edges and roll firmly (see Figure 3). Immediately remove printed plastic release liner from the tape.

Details

Refer to Preprufe Field Application Manual, Section V Application Instructions or visit graceconstruction.com. This manual gives comprehensive guidance and standard details.

Membrane Repair

Inspect the membrane before installation of reinforcement steel, formwork and final placement of concrete. The membrane can be easily cleaned by power washing if required. Repair damage by wiping the area with a damp cloth to ensure the area is clean and free from dust, and allow to dry. Repair small punctures (0.5 in. (12 mm) or less) and slices by applying Preprufe Tape centered over the damaged area and roll firmly. Remove the release liner from the tape. Repair holes and large punctures by applying a patch of Preprufe membrane, which extends 6 in. (150 mm) beyond the damaged area. Seal all edges of the patch with Preprufe Tape, remove the release liner from the tape and roll firmly. Any areas of damaged adhesive should be covered with Preprufe Tape. Remove printed plastic release liner from tape. Where exposed selvedge has lost adhesion or laps have not been sealed, ensure the area is clean and dry and cover with fresh Preprufe Tape, rolling firmly. Alternatively, use a hot air gun or similar to activate adhesive and firmly roll lap to achieve continuity.

Pouring of Concrete

Ensure the plastic release liner is removed from all areas of Preprufe membrane and tape.

It is recommended that concrete be poured within 56 days (42 days in hot climates) of application of the membrane. Following proper ACI guidelines, concrete must be placed carefully and consolidated properly to avoid damage to the membrane. Never use a sharp object to consolidate the concrete.

Removal of Formwork

Preprufe membranes can be applied to removable formwork, such as slab perimeters, elevator and lift pits, etc. Once the concrete is poured the formwork must remain in place until the concrete has gained sufficient compressive strength to develop the surface bond. Preprufe membranes are not recommended for conventional twin-sided wall forming systems.

A minimum concrete compressive strength of 1500 psi (10 N/mm^2) is recommended prior to stripping formwork supporting Preprufe membranes. Premature stripping may result in displacement of the membrane and/or spalling of the concrete.

Refer to Grace Tech Letter 17 for information on removal of formwork for Preprufe.

Figure 1

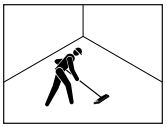


Figure 2

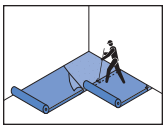
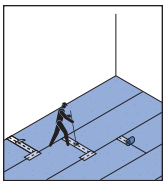
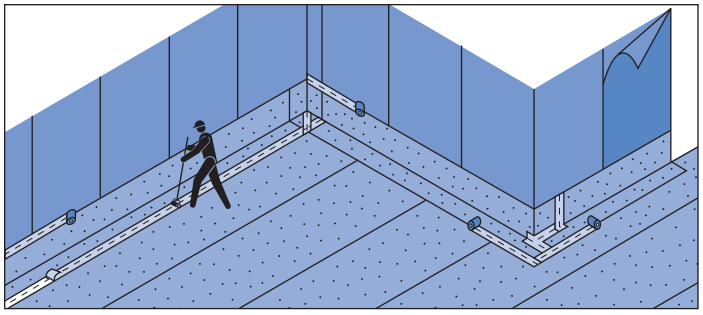


Figure 3

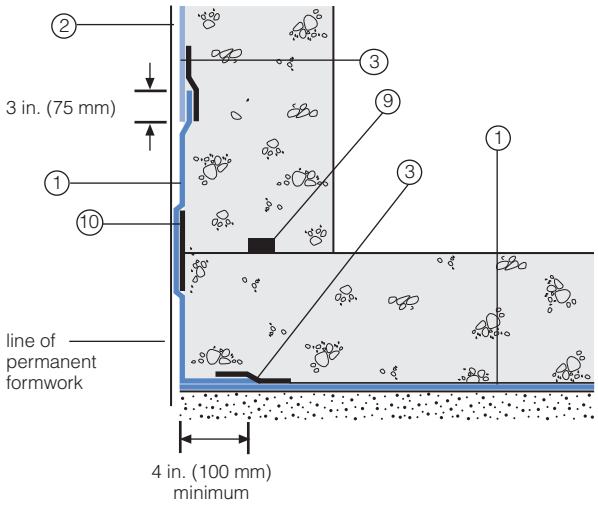




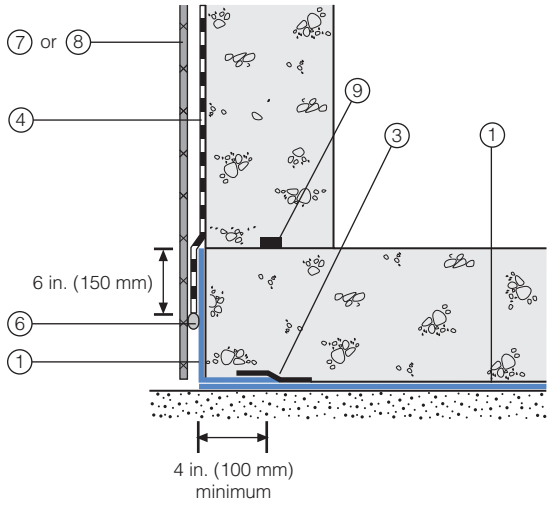
Detail Drawings

Details shown are typical illustrations and not working details. For a list of the most current details, visit us at graceconstruction.com. For technical assistance with detailing and problem solving please call toll free at 866-333-3SBM (3726).

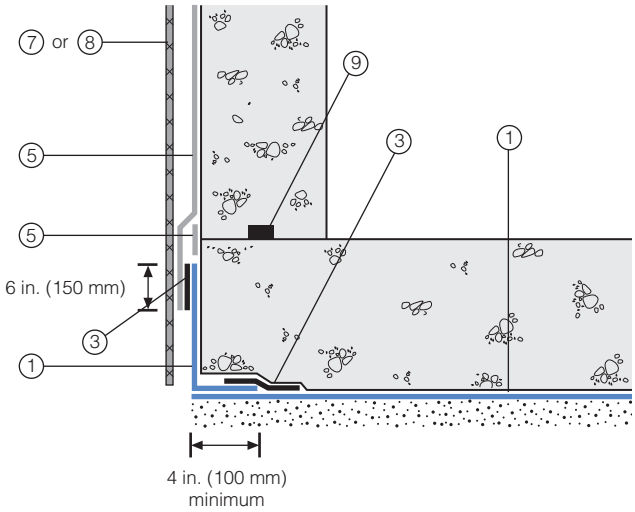
Wall base detail against permanent shutter



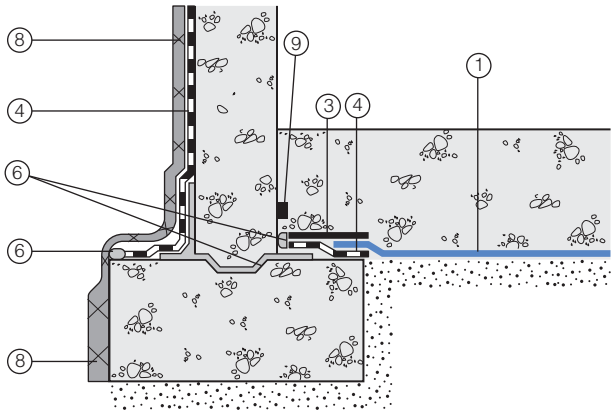
Bituthene wall base detail (Option 1)



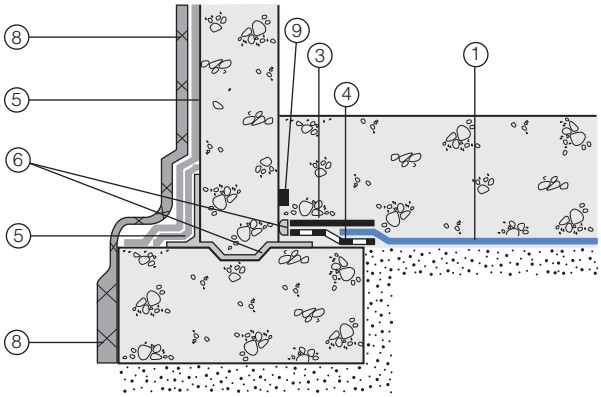
Procor wall base detail (Option 1)



Bituthene wall base detail (Option 2)



Procor wall base detail (Option 2)



1 Preprufe 300R
2 Preprufe 160R
3 Preprufe Tape
4 Bituthene
5 Procor
6 Bituthene Liquid Membrane
7 Protection
8 Hydroduct®
9 Adcor ES
10 Preprufe CJ Tape

Supply

Dimensions (Nominal)	Preprufe 300R Membrane	Preprufe 160R Membrane	Preprufe Tape (LT or HC*)
Thickness	0.046 in. (1.2 mm)	0.032 in. (0.8 mm)	
Roll size	4 ft x 98 ft (1.2 m x 30 m)	4 ft x 115 ft (1.2 m x 35 m)	4 in. x 49 ft (100 mm x 15 m)
Roll area	392 ft^2 (36 m^2)	460 ft^2 (42 m^2)	
Roll weight	108 lbs (50 kg)	92 lbs (42 kg)	4.3 lbs (2 kg)
Minimum side/end laps	3 in. (75 mm)	3 in. (75 mm)	3 in. (75 mm)
* LT denotes Low Temperature (between 25°F (-4°C) and 86°F (+30°C)) HC denotes Hot Climate (50°F (>+10°C))			
Ancillary Products			
Bituthene Liquid Membrane—1.5 US gal (5.7 liter) or 4 US gal (15.1 liter)			

Physical Properties

Property	Typical Value 300R	Typical Value 160R	Test Method
Color	white	white	
Thickness	0.046 in. (1.2 mm)	0.032 in. (0.8 mm)	ASTM D3767
Lateral Water Migration Resistance	Pass at 231 ft (71 m) of hydrostatic head pressure	Pass at 231 ft (71 m) of hydrostatic head pressure	ASTM D5385, modified[1]
Low temperature flexibility	Unaffected at -20°F (-29°C)	Unaffected at -20°F (-29°C)	ASTM D1970
Resistance to hydrostatic head	231 ft (71 m)	231 ft (71 m)	ASTM D5385, modified[2]
Elongation	500%	500%	ASTM D412, modified[3]
Tensile strength, film	4000 psi (27.6 MPa)	4000 psi (27.6 MPa)	ASTM D412
Crack cycling at -9.4°F (-23°C), 100 cycles	Unaffected, Pass	Unaffected, Pass	ASTM C836
Puncture resistance	221 lbs (990 N)	100 lbs (445 N)	ASTM E154
Peel adhesion to concrete	5 lbs/in. (880 N/m)	5 lbs/in. (880 N/m)	ASTM D903, modified[4]
Lap peel adhesion	5 lbs/in. (880 N/m)	5 lbs/in. (880 N/m)	ASTM D1876, modified[5]
Permeance to water vapor transmission	0.01 perms (0.6 ng/(Pa x s x m^2))	0.01 perms (0.6 ng/(Pa x s x m^2))	ASTM E96, method B
Water absorption	0.5%	0.5%	ASTM D570

Footnotes:

1. Lateral water migration resistance is tested by casting concrete against membrane with a hole and subjecting the membrane to hydrostatic head pressure with water. The test measures the resistance of lateral water migration between the concrete and the membrane.
2. Hydrostatic head tests of Preprufe Membranes are performed by casting concrete against the membrane with a lap. Before the concrete cures, a 0.125 in. (3 mm) spacer is inserted perpendicular to the membrane to create a gap. The cured block is placed in a chamber where water is introduced to the membrane surface up to the head indicated.
3. Elongation of membrane is run at a rate of 2 in. (50 mm) per minute.
4. Concrete is cast against the protective coating surface of the membrane and allowed to properly dry (7 days minimum). Peel adhesion of membrane to concrete is measured at a rate of 2 in. (50 mm) per minute at room temperature.
5. The test is conducted 15 minutes after the lap is formed (per Grace published recommendations) and run at a rate of 2 in. (50 mm) per minute.

Specification Clauses

Preprufe 300R or 160R shall be applied with its adhesive face presented to receive fresh concrete to which it will integrally bond. Only Grace Construction Products approved membranes shall be bonded to Preprufe 300R/160R. All Preprufe 300R/160R system materials shall be supplied by Grace Construction Products, and applied strictly in accordance with their instructions. Specimen performance and formatted clauses are also available.

NOTE: Use Preprufe Tape to tie-in Procor with Preprufe.

Health and Safety

Refer to relevant Material Safety data sheet. Complete rolls should be handled by a minimum of two persons.

www.graceconstruction.com

For technical assistance call toll free at 866-333-3SBM (3726)

Adcor is a trademark and Preprufe, Bituthene and Hydroduct are registered trademarks of W. R. Grace & Co.–Conn.
Procor is a U.S. registered trademark of W. R. Grace & Co.–Conn., and is used in Canada under license from PROCOR LIMITED.

We hope the information here will be helpful. It is based on data and knowledge considered to be true and accurate and is offered for the users' consideration, investigation and verification, but we do not warrant the results to be obtained. Please read all statements, recommendations or suggestions in conjunction with our conditions of sale, which apply to all goods supplied by us. No statement, recommendation or suggestion is intended for any use which would infringe any patent or copyright. W. R. Grace & Co.–Conn., 62 Whittemore Avenue, Cambridge, MA 02140.
In Canada, Grace Canada, Inc., 294 Clements Road, West, Ajax, Ontario, Canada L1S 3C6.

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PF-111H Printed in U.S.A. 07/12 FA/PDF

GRACE

From:	Eric Telemaque
To:	Lynelle Cardone
Subject:	FW: Dock Street
Date:	Wednesday, November 14, 2012 10:37:23 AM
Attachments:	WR_GRACE_PP300R.pdf WATER_ST_DOCK_ST_09-05-2012 PROGRESS SET.pdf

---

From: Everets, Hale [mailto:heverets@TwoTrees-Dumbo.com]
Sent: Thursday, November 08, 2012 2:48 PM
To: Eric Telemaque
Cc: Campbell, Bonnie; Blair, Anne
Subject: Dock Street

Hello Eric,

Please see the following attached,

- Grace PP300R & 160R waterproofing specification
- Foundation drawings with detailed sections at all slabs, walls and pits. See sheets FO-021 thru FO-023

Note for clarification that the 300R product is used for all horizontal surfaces below the slab (including the underside of all pits). It is a 1.2 mm product that is laid on top of a 3" mud slab and poured directly on top off. The 160R product is used for the vertical wall surfaces. It is a .8 mm membrane that is applied from within a 3' zone between the steel sheeting and the foundation wall. Because of the difficult conditions it is installed from, a lighter weight/easier material to work with is required. It is also less susceptible to punctures during construction (i.e. rebar). Prior to backfilling around the perimeter, the 160R is protected with a drainage board. Please let me know if you feel additional clarification is warranted.

Thank you,

Hale Everets

Two Trees
45 Main Street, Suite 602
Brooklyn, NY 11201
T 718.222.2500

APPENDIX 5

CONSTRUCTION HEALTH AND SAFETY PLAN (CHASP)

CONSTRUCTION HEALTH AND SAFETY PLAN

PROJECT:

Dock Street Development

Surface Parking - 31-45 Front Street, Block 36; Lots 53, 52, 49
(comprised of 31 Front Street, aka 31-33 Front Street; 35 Front Street, aka 35-37 Front Street; 39 Front Street, aka 39-45 Front Street)

Conducted For:
Two Trees Management Co., LLC
45 Main Street, Suite 602
Brooklyn, NY 11201
www.twotreesny.com

Conducted by:
Emteque LLC
505 Eighth Avenue, Suite 900
New York, NY 10018
www.emteque.com

EMTEQUE LLC
A WSP Group Company

Project No. 12-5663

May 2012

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APPENDICES

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Executive Summary

As a result of the New York City Department of Buildings/NYC Office of Environmental Remediation's designation of this site as a "little e" site, a subsurface investigation has been planned for the site which is currently in use as a surface parking lot. Emteque LLC proposes to provide for the collection of five (5) soil samples via Geoprobe ® technology and the installation of three (3) temporary groundwater wells to sample those media for the presence of semi-volatile organic compounds, volatile organic compounds and metals. This Health and Safety Plan will be implemented during drilling activities at the site.

1.0 PURPOSE

The purpose of this Construction Health and Safety Plan (CHASP) is to assign responsibilities, establish personnel protection standards and mandatory safety practices and procedures, and provide for contingencies that may arise during excavation for construction of a new building at the property which occupies 31-45 Front Street, Brooklyn NY, herein referred to as the "subject property". This plan applies to the parking area of the above referenced site. The CHASP is intended to minimize health and safety risks resulting from the known and potential presence of hazardous materials on the site.

This plan is not designed to address potential geotechnical, mechanical or structural safety concerns, nor to supersede or replace any OSHA regulation and/or local and state construction codes or regulations.

2.0 APPLICABILITY

Work subject to this CHASP and SMP shall be all activities that disturb the existing soil on-site. The contractors and their subcontractors involved in the construction project shall provide a copy of this CHASP and SMP for their employees whose work involves any potential exposure to the on-site chemical hazards in the soils, and shall complete all work in accordance with this CHASP. The present time the majority of the site work involving soils has been performed. Limited soils disturbance is anticipated during the completion of the foundation work and the foundation work waterproofing.

3.0 SITE DESCRIPTION

3.1 General Information

The subject property is identified as Block 36, Lots 49, 52 and 53, consisting of parking facilities. The general site will be developed by Two Trees and the development is identified as Dock Street.

Dock Street is a mixed use project located at the base of the Brooklyn Bridge in the Dumbo neighborhood of Brooklyn. The lot is approximately 46,000 sf on which we will build a combination of Parking, Retail, School and Residential. There will be a total of +/- 333 units in a 222,000 GSF tower with a double loaded corridor that steps up from 7 stories to 17 stories at its highest. The residential units rest on top of a podium the full dimension of the lot. On the 2nd floor of the podium will be a school of approximately 47,000 GSF with approximately 10,000 GSF of retail at the ground floor. Combined at grade will be the residential lobby, the school lobby and the entry to the parking level that will occupy 3 levels extending to 1 level below Water Street.

3.2 Hazard Potential

Hazards are not known at this time. It is expected that we will encounter historic fill during drilling operations and historic fill in NYC typically contains, semi-volatile organic compounds and metals.

3.3 Hazard Evaluation

The most likely routes of exposure are breathing of volatile and semi-volatile compounds and metals or particulate-laden air released during soil disturbing activities and dermal contact. Appendix A includes specific health effects from the known on-site chemicals. The remaining sections of this CHASP address procedures (including training, air monitoring, work practices and emergency response) to reduce the potential for unnecessary and unacceptable exposure to these contaminants. The potential adverse health effects from these detected contaminants are diverse. Many of these compounds are known or suspected to result in chronic illness from long-term exposures. However, due to the limited nature of the proposed construction, acute effects are a potential concern.

This Construction Health and Safety Plan addresses potential environmental hazards from the presence of hazardous materials. It is not intended to address the normal hazards of construction work, which are separately covered by 051-IA regulations and/or local and state construction codes and regulations.

4.0 HEALTH AND SAFETY OFFICER

Emteque LLC has appointed one of its on-site personnel as the Health and Safety Officer (HSO), Robert Imbriale. Mr. Imbriale is a competent person responsible for the implementation of this plan. He has completed a 40-hour training course training (up-dated by an annual refresher) that meets OSHA requirements of 29 CFR Part 1910, Occupational Safety and Health Standards. Mr. Imbriale has stop-work authorization, which he will execute on his determination of an imminent safety hazard, emergency situation, or other potentially dangerous situation. If Mr. Imbriale must be absent from the site, he will designate a suitably qualified replacement who is familiar with the health and safety plan.

4.1 Training

All those who enter the work area while intrusive activities are being performed must recognize and understand the potential hazards to health and safety. All construction personnel upon entering the site must attend a brief training meeting, its purpose being to:

- Make workers aware of the potential hazards they may encounter;
- Provide the knowledge and skills necessary for them to perform the work with minimal risk to health and safety;
- Make workers aware of the purpose and limitations of safety equipment; and
- Ensure that they can safely avoid or escape from emergencies.

Each member of the construction crew will be instructed in these objectives before he/she goes onto the site. The HSO or other suitably trained individuals will be responsible for conducting the training program. Others who enter the site must be accompanied by a suitably trained construction worker.

5.0 SOIL MANAGEMENT PLAN

The purpose of the Soil Management Plan is to present measures for managing known or potentially contaminated soils in accordance with the NYC Department of Environmental Protection's (DEP's) and potentially New York State Department of Environmental Conservation (NYSDEC) requirements.

This plan is not designed to address potential geotechnical, mechanical or structural safety concerns, nor to supersede or replace any OSHA regulation and/or local and state construction codes or regulations.

5.1 Introduction

The spoils from the drilling activities will be replaced in the hole or left on site.

5.2 Dust Control

To prevent the potential off-site transport of dust that may contain above-background levels of contaminants, the following dust control measures will be implemented during all

- Water will be available (and used) on-site for sprinkling/wetting to suppress dust in dry weather or as necessary

All work that involves soil disturbance or otherwise generates dust will be performed utilizing methods to minimize dust generation to the extent practicable. In addition to the particulate air monitoring requirements under the Hazardous Materials Contingencies section of this Plan, water will be available on site at all times to be used for dust suppression.

5.3 Erosion Control/Stormwater Management

Normally, for a site larger than one acre, a Stormwater Pollution Prevention Plan (SPPP) is required for any land disturbance activities (i.e., excavation, regarding, etc.). However, since the subject site discharges to a combined sewer (i.e., not separate storm sewers), no NYSDEC SPDES General

Stormwater Permit for Construction Activity (GP-02-01) is required.

5.4 Soil Stockpiling

N/A

5.5 Soil Testing

N/A

5.6 Transportation and Disposal

N/A

6.0 HAZARDOUS MATERIALS CONTINGENCIES

6.1 Hazardous Materials Contingency Response

In the event that previously unidentified hazardous materials are discovered during excavation, the following contingency procedures will be followed. All excavation will be continuously monitored for the presence of buried tanks, drums or other containers, sludges, or soil which shows evidence of potential contamination, such as discoloration, staining, or odors. If any of these are detected, excavation in the area will be halted, and the HSO will notify the following:

Company	Name	Phone	Cell
Two Trees	Hale Everets	718.222.2500	
Emteque LLC	Eric Telemaque	212.631.9000	646.529.6526
Emteque LLC	Chris Spicer, CIH, CHMM	212.631.9000 609.730.0007	609.792.5754
Emteque LLC	Jim Capritti, CHMM	609.730.0007	609.751.1952
Emteque LLC	Jim Blaney, CHMM	609.730.0007	609.613.2004
Emteque LLC	Rob Imbriale	212.631.9000	347.439.8239
NYC DEP (Project Manager)	TBD		

The affected area will be cordoned off and no further work will be performed at that location until the appropriate contingency response plan described in Section 6.2 is implemented. All contingency response actions will be carried out in accordance with the contingency Health and Safety procedures specified in Section 6.5.

6.2 Soil Contamination Plan

Contaminated soils which may be discovered during any subsequent foundation and waterproofing work will be treated as follows:

1. Soils will be excavated and stockpiled on-site, either in a container or in a stockpile placed on plastic sheeting and securely covered by plastic sheeting. Composite samples of the soil will be collected and analyzed for disposal. The excavated soil will then be disposed of in accordance with all applicable regulations.

2. In the event that contaminated soils are noted, post excavation samples will he collected from the sides and bottom of the excavated area. All soil samples will be properly containerized, labeled, sealed, and placed in a chilled cooler for shipment to the laboratory. A chain-of-custody will be maintained throughout the field sampling, transport of samples to the laboratory, and during lab analysis. Analytical parameters for post excavation soil samples will be determined based on the original analysis of the contaminated soil. If post-excavation samples exceed action levels, then additional excavation will be performed.

6.3 Contingency Health and Safety Procedures

6.3.1 Site Work Zones for Contaminated Areas

During any activities involving disturbance of contaminated areas, the work area must be divided into various zones to prevent the spread of contamination, ensure that proper protective equipment is dunned, and provide an area for decontamination. The Exclusion Zone is defined as the area where potentially contaminated materials are located. The Contamination Reduction Zone (CR2) is the area where decontamination procedures take place and is located next to the Exclusion Zone. The Support Zone is the zone area where support facilities, such as vehicles, a field phone, fire extinguisher, and first aid supplies are located. The emergency staging area (part of the Support Zone) is the area where all workers on-site would assemble in the event of an emergency. These zones shall be designated daily, depending on that day's activities. All field personnel will be informed of the location of these zones before work begins.

Control measures such as "Caution" tape and traffic cones will be placed around the perimeter of the work area when work is being done in the areas of concern to prevent entrance onto the area with exposed soil.

6.3.2 Air Monitoring in Contaminated Areas

An Organic Vapor Meter (OVM), a type of photo ionization detector (PID), will be used to perform air monitoring during sampling and excavation work at areas where volatile organic compounds have been detected. A Dustrak® dust monitor or equivalent will be used to measure concentration of total particulate matter during the excavation in contaminated areas. Results of the air monitoring will be used to determine the appropriate response action, if needed.

Real time air monitoring for volatile organic compounds will be done with the OVM/PTD whenever soil removal or sampling is performed in areas contaminated with VOCs. Measurements will be taken prior to commencement of work and for at least 1 minute every 60 minutes during the work. The OVM will be calibrated with isobutylene in accordance with the manufacturer's recommendations. These measurements will be made as close to the workers as practicable and at the breathing height of the workers. The HSO shall set up the equipment and confirm that it is working properly. His/her designee may oversee the air measurements during the day. The initial measurement for the day will be performed before the start of work and will establish the background level for that day. The final measurement for the day will be performed after the end of work. The action levels and required responses are listed in Table 1 below.

Table 1 – Action Levels and Required Responses

Instrument	Action Level (Note 1)	Response Action
OVM	<10 ppm in breathing zone.	Level D or D-Modified (Requires coveralls and steel toe boots). (As applicable: chemical resistant gloves, chemical resistant boot covers, hard hat, safety glasses, face shield or escape mask).
	10 - 20 ppm	Level C (Requires full face or half face respirator, hooded chemical resistant two piece Tyvek suit or overalls, chemical resistant inner and outer gloves, chemical resistant boot covers, steel toe and shank boots) (As applicable: hardhat, face shield or escape mask)
	>20 ppm	Stop work. Resume work when source of vapors is abated and readings are less than 20 ppm above background
Particulate monitor	<5 mg/m^3	Level D
	5 - 125 mg/m^3	Level C Apply dust suppression measures. If less than 2.5 mg/rn^3, resume work using Level D. Otherwise, upgrade, Level C.
	>125 mg/m^3	Stop work. Apply additional dust suppression measures. Resume work when less than 125 mg/rn^3 and maintain Level C.

7.0 EMERGENCY RESPONSE

The construction crew will be equipped with emergency equipment, such as a first aid kit and disposable eye washes, In the case of a medical emergency, the HSO will determine the nature of the emergency and he/she will have someone call for an ambulance, if needed. If the nature of the injury is not serious i.e., the person can be moved without expert emergency medical personnel he/she should be driven to a, hospital by on-site personnel. There will be an on-site field phone. In the event of an on site emergency, Emteque's on site representative shall contact Emteque's main office and we will in turn notify the client. The on site supervisor shall make all arrangements to evacuate injured personnel from the site.

The location of the nearest hospital (see Appendix E), is New York Downtown Hospital at 170 William Street, New York, NY.

PERTINENT CHASP INFORMATION:

New York Downtown Hospital 212.312.5000

Ambulance, Fire and Police Departments 911

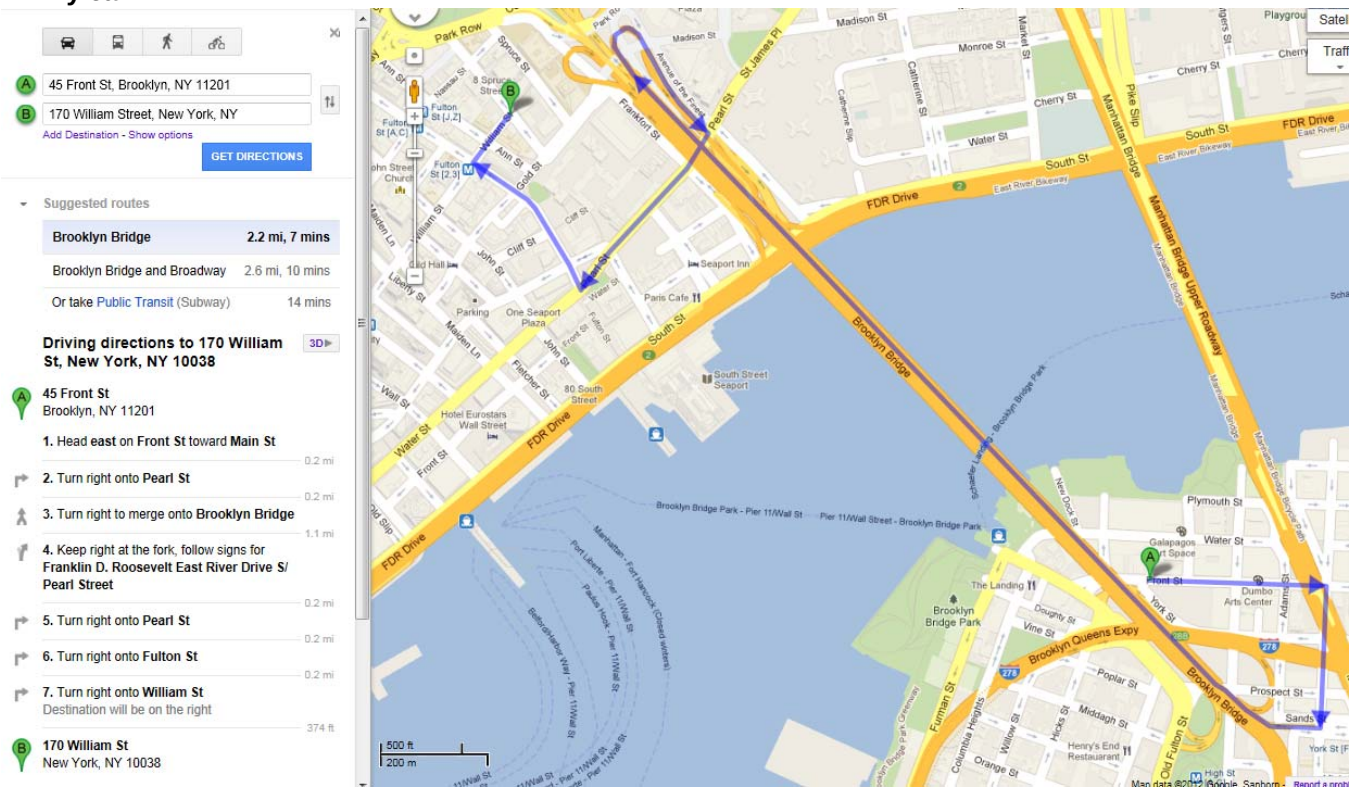
Local Poison Control 212.447.8224
1.800.222.1222
Call 311, ask for Poison Control Center

NYSDEC Spill Hotline 800.457.7362

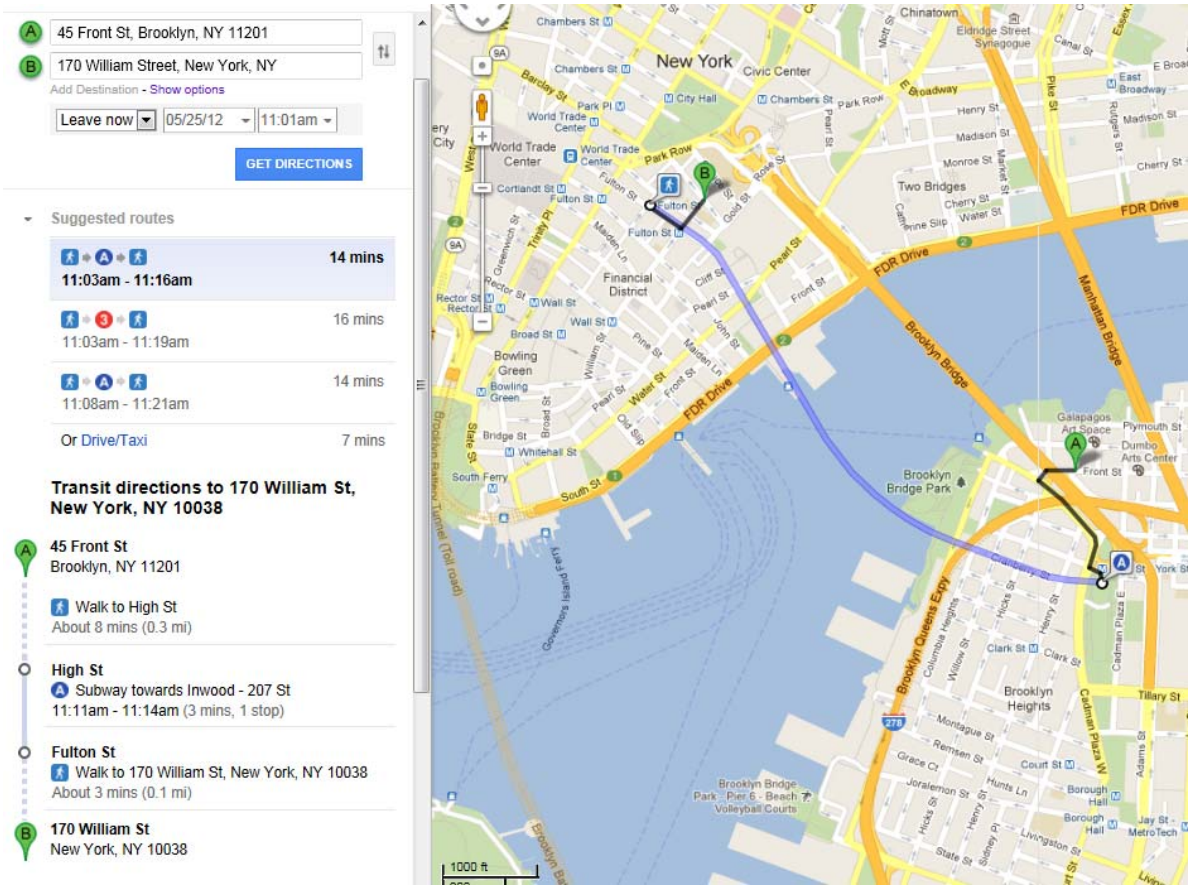
NYCDEP Hotline 718.DEP.HELP

DIRECTIONS TO NEW YORK DOWNTOWN HOSPITAL

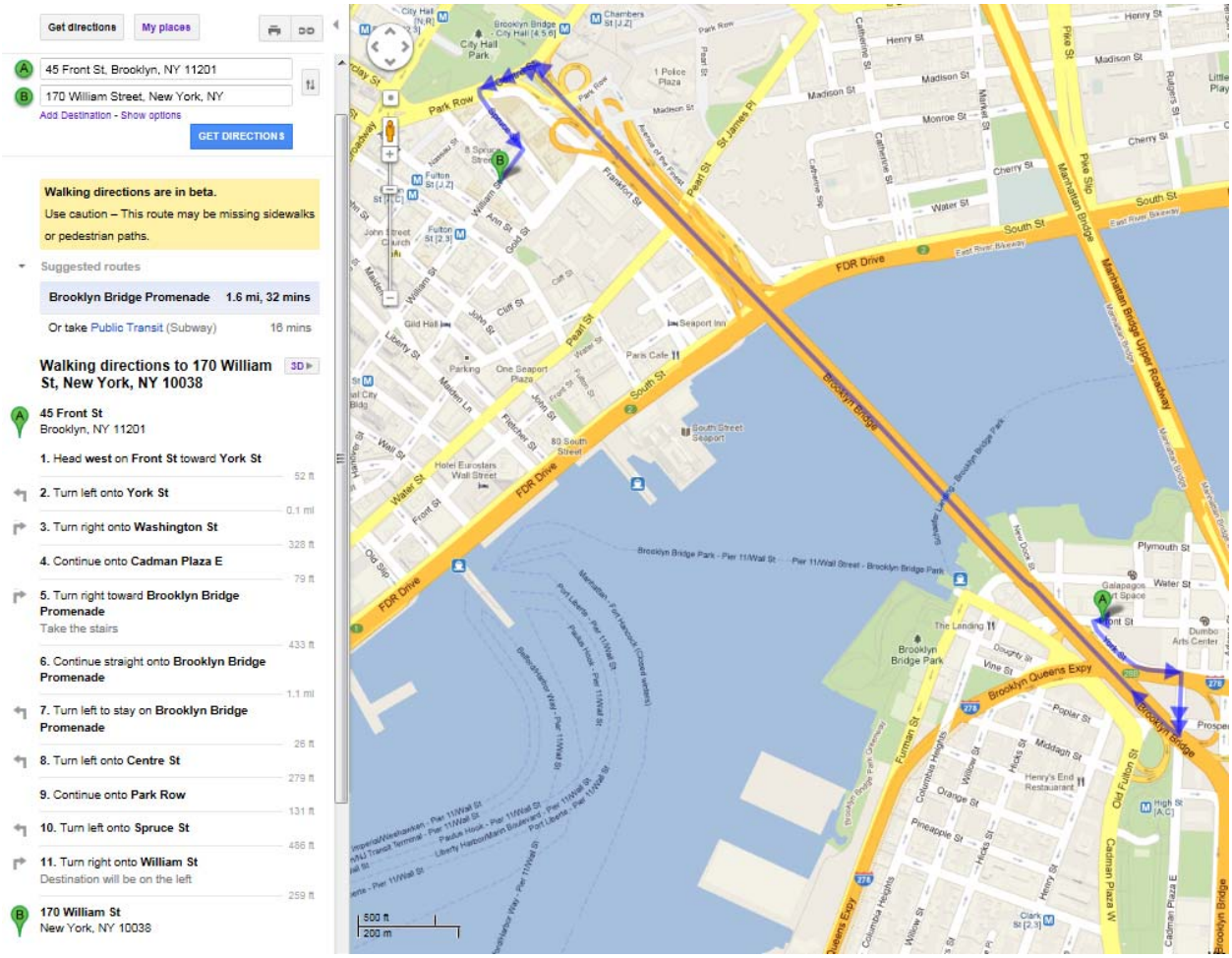
By car



By Public Transportation



By Foot


Get directions
My places
45 Front St, Brooklyn, NY 11201
170 William Street, New York, NY
Add Destination - Show options
GET DIRECTIONS
Walking directions are in beta.
Use caution – This route may be missing sidewalks or pedestrian paths.
Suggested routes
Brooklyn Bridge Promenade 1.6 mi, 32 mins
Or take Public Transit (Subway) 16 mins
Walking directions to 170 William St, New York, NY 10038
3D
45 Front St
Brooklyn, NY 11201
1. Head west on Front St toward York St
52 ft
2. Turn left onto York St
0.1 mi
3. Turn right onto Washington St
328 ft
4. Continue onto Cadman Plaza E
79 ft
5. Turn right toward Brooklyn Bridge Promenade
Take the stairs
433 ft
6. Continue straight onto Brooklyn Bridge Promenade
1.1 mi
7. Turn left to stay on Brooklyn Bridge Promenade
26 ft
8. Turn left onto Centre St
279 ft
9. Continue onto Park Row
131 ft
10. Turn left onto Spruce St
486 ft
11. Turn right onto William St
Destination will be on the left
259 ft
170 William St
New York, NY 10038
Park Row
FDR Drive
Brooklyn Bridge
Manhattan Bridge
South St
Pearl St
Water St
Brooklyn Queens Expy
500 ft
200 m

8.0 ACKNOWLEDGEMENT OF THE CHASP

Below is an affidavit that must be signed by all workers who enter the site. A copy of the CHASP must be on-site at all times and will be kept by the HSO.

AFFIDAVIT

I,_____**,** (name), of_____(company name), have read The Construction Health and Safety Plan (CHASP) for 31-45 Front Street, Brooklyn NY. I agree to conduct all on-site work in accordance with the requirements set forth in this CHASP and understand that failure to comply with this CHASP could lead to my injury and/or removal from the site.

Signed:		Company:		Date:	
Signed:		Company:		Date:	
Signed:		Company:		Date:	
Signed:		Company:		Date:	
Signed:		Company:		Date:	
Signed:		Company:		Date:	
Signed:		Company:		Date:	
Signed:		Company:		Date:	

Appendix A

POTENTIAL HEALTH EFFECTS FROM ON-SITE CONTAMINANTS

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ARSENIC

CAS # 7440-38-2

Division of Toxicology and Environmental Medicine ToxFAQs™ August 2007

This fact sheet answers the most frequently asked health questions (FAQs) about arsenic. For more information, call the ATSDR Information Center at 1-800-232-4636. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It is important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Exposure to higher than average levels of arsenic occur mostly in the workplace, near hazardous waste sites, or in areas with high natural levels. At high levels, inorganic arsenic can cause death. Exposure to lower levels for a long time can cause a discoloration of the skin and the appearance of small corns or warts. Arsenic has been found in at least 1,149 of the 1,684 National Priority List sites identified by the Environmental Protection Agency (EPA).

What is arsenic?

Arsenic is a naturally occurring element widely distributed in the earth's crust. In the environment, arsenic is combined with oxygen, chlorine, and sulfur to form inorganic arsenic compounds. Arsenic in animals and plants combines with carbon and hydrogen to form organic arsenic compounds.

Inorganic arsenic compounds are mainly used to preserve wood. Copper chromated arsenate (CCA) is used to make "pressure-treated" lumber. CCA is no longer used in the U.S. for residential uses; it is still used in industrial applications. Organic arsenic compounds are used as pesticides, primarily on cotton fields and orchards.

What happens to arsenic when it enters the environment?

❑ Arsenic occurs naturally in soil and minerals and may enter the air, water, and land from wind-blown dust and may get into water from runoff and leaching.
❑ Arsenic cannot be destroyed in the environment. It can only change its form.
❑ Rain and snow remove arsenic dust particles from the air.
❑ Many common arsenic compounds can dissolve in water. Most of the arsenic in water will ultimately end up in soil or sediment.
❑ Fish and shellfish can accumulate arsenic; most of this arsenic is in an organic form called arsenobetaine that is much less harmful.

How might I be exposed to arsenic?

❑ Ingesting small amounts present in your food and water or breathing air containing arsenic.
❑ Breathing sawdust or burning smoke from wood treated with arsenic.
❑ Living in areas with unusually high natural levels of arsenic in rock.
❑ Working in a job that involves arsenic production or use, such as copper or lead smelting, wood treating, or pesticide application.

How can arsenic affect my health?

Breathing high levels of inorganic arsenic can give you a sore throat or irritated lungs.

Ingesting very high levels of arsenic can result in death. Exposure to lower levels can cause nausea and vomiting, decreased production of red and white blood cells, abnormal heart rhythm, damage to blood vessels, and a sensation of "pins and needles" in hands and feet.

Ingesting or breathing low levels of inorganic arsenic for a long time can cause a darkening of the skin and the appearance of small "corns" or "warts" on the palms, soles, and torso.

Skin contact with inorganic arsenic may cause redness and swelling.

Almost nothing is known regarding health effects of organic arsenic compounds in humans. Studies in animals show that some simple organic arsenic compounds are less toxic than inorganic forms. Ingestion of methyl and dimethyl compounds can cause diarrhea and damage to the kidneys

How likely is arsenic to cause cancer?

Several studies have shown that ingestion of inorganic arsenic can increase the risk of skin cancer and cancer in the liver, bladder, and lungs. Inhalation of inorganic arsenic can cause increased risk of lung cancer. The Department of Health and Human Services (DHHS) and the EPA have determined that inorganic arsenic is a known human carcinogen. The International Agency for Research on Cancer (IARC) has determined that inorganic arsenic is carcinogenic to humans.

How can arsenic affect children?

There is some evidence that long-term exposure to arsenic in children may result in lower IQ scores. There is also some evidence that exposure to arsenic in the womb and early childhood may increase mortality in young adults.

There is some evidence that inhaled or ingested arsenic can injure pregnant women or their unborn babies, although the studies are not definitive. Studies in animals show that large doses of arsenic that cause illness in pregnant females, can also cause low birth weight, fetal malformations, and even fetal death. Arsenic can cross the placenta and has been found in fetal tissues. Arsenic is found at low levels in breast milk.

How can families reduce the risks of exposure to arsenic?

❑ If you use arsenic-treated wood in home projects, you should wear dust masks, gloves, and protective clothing to decrease exposure to sawdust.

❑ If you live in an area with high levels of arsenic in water or soil, you should use cleaner sources of water and limit contact with soil.

❑ If you work in a job that may expose you to arsenic, be aware that you may carry arsenic home on your clothing, skin, hair, or tools. Be sure to shower and change clothes before going home.

Is there a medical test to determine whether I've been exposed to arsenic?

There are tests available to measure arsenic in your blood, urine, hair, and fingernails. The urine test is the most reliable test for arsenic exposure within the last few days. Tests on hair and fingernails can measure exposure to high levels of arsenic over the past 6-12 months. These tests can determine if you have been exposed to above-average levels of arsenic. They cannot predict whether the arsenic levels in your body will affect your health.

Has the federal government made recommendations to protect human health?

The EPA has set limits on the amount of arsenic that industrial sources can release to the environment and has restricted or cancelled many of the uses of arsenic in pesticides. EPA has set a limit of 0.01 parts per million (ppm) for arsenic in drinking water.

The Occupational Safety and Health Administration (OSHA) has set a permissible exposure limit (PEL) of 10 micrograms of arsenic per cubic meter of workplace air (10 $\mu g/m^3$) for 8 hour shifts and 40 hour work weeks.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological Profile for Arsenic (Update). Atlanta, GA: U.S. Department of Public Health and Human Services, Public Health Service.

Where can I get more information? For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology and Environmental Medicine, 1600 Clifton Road NE, Mailstop F-32, Atlanta, GA 30333. Phone: 1-800-232-4636, FAX: 770-488-4178. ToxFAQs Internet address via WWW is http://www.atsdr.cdc.gov/toxfaq.html. ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

BARIUM AND COMPOUNDS

CAS # 7440-39-3

Division of Toxicology and Environmental Medicine ToxFAQs™ August 2007

This fact sheet answers the most frequently asked health questions (FAQs) about barium and barium compounds. For more information, call the ATSDR Information Center at 1-800-232-4636. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It is important you understand this information because these substances may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Exposure to barium occurs mostly in the workplace or from drinking contaminated water. Ingesting drinking water containing levels of barium above the EPA drinking water guidelines for relatively short periods of time can cause gastrointestinal disturbances and muscle weakness. Ingesting high levels for a long time can damage the kidneys. Barium and barium compounds have been found in at least 798 of the 1,684 National Priority List sites identified by the Environmental Protection Agency (EPA).

What is barium?

Barium is a silvery-white metal which exists in nature only in ores containing mixtures of elements. It combines with other chemicals such as sulfur or carbon and oxygen to form barium compounds.

Barium compounds are used by the oil and gas industries to make drilling muds. Drilling muds make it easier to drill through rock by keeping the drill bit lubricated. They are also used to make paint, bricks, ceramics, glass, and rubber.

Barium sulfate is sometimes used by doctors to perform medical tests and to take x-rays of the gastrointestinal tract.

What happens to barium when it enters the environment?

❑ Barium gets into the air during the mining, refining, and production of barium compounds, and from the burning of coal and oil.
❑ The length of time that barium will last in air, land, water, or sediments depends on the form of barium released.
❑ Barium compounds, such as barium sulfate and barium carbonate, which do not dissolve well in water, can last a long time in the environment.
❑ Barium compounds, such as barium chloride, barium nitrate, or barium hydroxide, that dissolve easily in water usually do not last in these forms for a long time in the environment. The barium in these compounds that is dissolved in water quickly combines with sulfate or carbonate that are naturally found in water and become the longer lasting forms (barium sulfate and barium carbonate).
❑ Fish and aquatic organisms can accumulate barium.

How might I be exposed to barium?

❑ Ingesting small amounts present in your food and water or breathing air containing very low levels of barium.
❑ Living in areas with unusually high natural levels of barium in the drinking water.
❑ Working in a job that involves barium production or use.
❑ Living or working near waste sites where barium has been disposed of.

How can barium affect my health?

The health effects of the different barium compounds depend on how well the compound dissolves in water or in the stomach contents. Barium compounds that do not dissolve well, such as barium sulfate, are not generally harmful.

Barium has been found to potentially cause gastrointestinal disturbances and muscular weakness when people are exposed to it at levels above the EPA drinking water standards for relatively short periods of time. Some people who eat or drink amounts of barium above background levels found in food and water for a short period may experience vomiting, abdominal cramps, diarrhea, difficulties in breathing, increased or decreased blood pressure, numbness around the face, and muscle weakness. Eating or drinking very large amounts of barium compounds that easily dissolve can cause changes in heart rhythm or paralysis and possibly death. Animals that drank barium over long periods had damage to the kidneys, decreases in body weight, and some died.

How likely is barium to cause cancer?

The Department of Health and Human Services (DHHS) and the International Agency for Research on Cancer (IARC) have not classified barium as to its carcinogenicity. The EPA has determined that barium is not likely to be carcinogenic to humans following ingestion and that there is insufficient information to determine whether it will be carcinogenic to humans following inhalation exposure.

How can barium affect children?

We do not know whether children will be more or less sensitive than adults to barium toxicity. A study in rats that swallowed barium found a decrease in newborn body weight; we do not know if a similar effect would be seen in humans.

How can families reduce the risks of exposure to barium?

The greatest potential source of barium exposure is through food and drinking water. However, the amount of barium in foods and drinking water are typically too low to be of concern.

Is there a medical test to determine whether I've been exposed to barium?

There is no routine medical test to determine whether you have been exposed to barium. Doctors can measure barium in body tissues and fluids, such as bones, blood, urine, and feces, using very complex instruments. These tests cannot be used to predict the extent of the exposure or potential health effects.

The geometric mean barium level measured in the U.S. general population aged 6 and older is reported by the Centers for Disease Control and Prevention (CDC) as 1.44 μg/g creatinine (measured in urine).

Has the federal government made recommendations to protect human health?

The EPA has set a limit of 2.0 milligrams of barium per liter of drinking water (2.0 mg/L), which is the same as 2 ppm.

The Occupational Safety and Health Administration (OSHA) has set Permissible Exposure Limits (PELs) of 0.5 milligrams of soluble barium compounds per cubic meter of workplace air (0.5 mg/m^3) for 8 hour shifts and 40 hour work weeks. The OSHA limits for barium sulfate dust are 15 mg/m^3 of total dust and 5 mg/m^3 for respirable fraction.

The National Institute for Occupational Safety and Health (NIOSH) has set Recommended Exposure Limits (RELs) of 0.5 mg/m^3 for soluble barium compounds. The NIOSH has set RELs of 10 mg/m^3 (total dust) for barium sulfate and 5 mg/m^3 (respirable fraction).

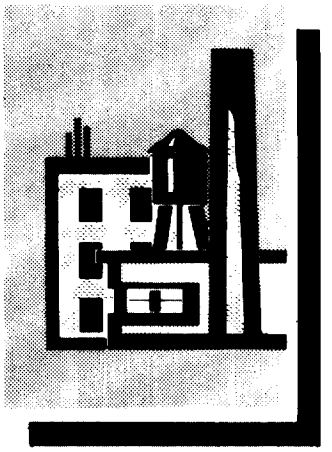
References

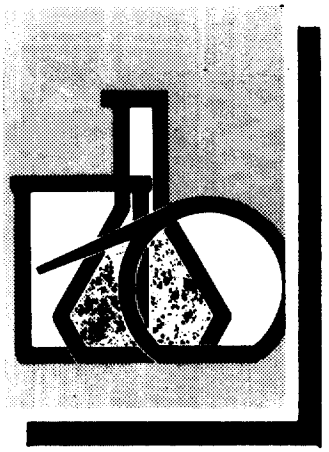
Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological Profile for Barium and Compounds (Update). Atlanta, GA: U.S. Department of Public Health and Human Services, Public Health Service.

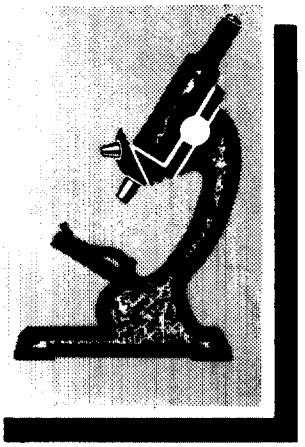
Where can I get more information? For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology and Environmental Medicine, 1600 Clifton Road NE, Mailstop F-32, Atlanta, GA 30333. Phone: 1-800-232-4636, FAX: 770-488-4178. ToxFAQs Internet address via WWW is http://www.atsdr.cdc.gov/toxfaq.html. ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

NIOSH

SPECIAL OCCUPATIONAL HAZARD REVIEW and CONTROL RECOMMENDATIONS







CHRYSENE

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health

SPECIAL OCCUPATIONAL HAZARD REVIEW AND CONTROL RECOMMENDATIONS FOR CHRYSENE

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PREFACE

The Occupational Safety and Health Act of 1970 emphasizes the need for standards to protect the health and safety of workers exposed to an ever-increasing number of potential hazards in their workplace. To fulfill this need, the National Institute for Occupational Safety and Health (NIOSH) has developed a program to assist employers in protecting the health of workers exposed to substances considered to have carcinogenic, mutagenic, or teratogenic potential. This program involves the development of Special Occupational Hazard Reviews which serve to support and complement the other major standards development or hazards documentation activities of the Institute. It is the purpose of a Special Occupational Hazard Review to analyze and document the industrial health and safety problems associated with a given chemical or process, and to recommend the implementation of engineering controls and work practices designed to ameliorate these problems. While Special Occupational Hazard Reviews are not intended to supplant the more comprehensive NIOSH Criteria Documents, nor the brief NIOSH Current Intelligence Bulletins, they are nevertheless prepared in such a way as to be amenable to regulatory application if so desired. Special Occupational Hazard Reviews are made available to the occupational health community, trade associations, labor unions, industries, and the general scientific community for their evaluation and consideration for use in developing and implementing preventive measures and identifying areas for additional research.

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ACKNOWLEDGEMENTS

The Division of Criteria Documentation and Standards Development (DCDSD) had primary responsibility for the development of this Special Occupational Hazard Review on chrysene.

Norbert P. Page, D.V.M., and Murray L. Cohen, M.P.H., shared NIOSH program responsibility for and assisted in the preparation of this document.

The DCDSD review staff for this document consisted of Richard A. Rhoden, Ph.D. (Chairman), Howard L. McMartin, M.D., and Frank L. Mitchell, D.O.

Valuable and constructive comments were also provided by Robert B. O'Connor, M.D., NIOSH consultant in occupational medicine.

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SUMMARY AND CONCLUSIONS

Exposure to chrysene as an isolated chemical presently occurs only in specific occupations, i.e., chrysene synthesis, laboratory experimentation, and possibly in the synthesis of anthraquinone vat dyes. However, chrysene and its derivatives, e.g., certain methylchrysene isomers, along with hundreds of other polycyclic aromatic hydrocarbons (PAH's), are formed during the pyrolysis of organic matter and can occur in any occupational environment where this process takes place. While it has been suggested that 700 C is the optimum pyrolytic temperature for PAH-formation, other factors such as the chemical and physical nature of the pyrolyzed material, the presence or absence of oxygen, and the period of time during which the compound is pyrolyzed also determine the amounts and mixtures of various PAH's formed. Chrysene has been detected in many materials which result from, or are used in, industrial processes. Chrysene also has been detected in the ambient atmosphere and in certain food products.

A number of experimental animal studies have been conducted for the purpose of assessing the carcinogenicity of chrysene, with varying results. When three 100(u)g doses of chrysene were administered by subcutaneous (s.c.) injection to newborn mice, an increased incidence of liver tumors was observed. The increase, however, was not statistically significant. Marginal results were obtained when mice were injected (s.c.) with 1 mg chrysene in arachis oil, once a week, for 10 weeks. This treatment resulted in the development of injection-site tumors in 2 of 20 animals.

Tumors also developed after chrysene (1% solution in acetone) was applied to the shaved backs of mice. Chrysene appears to exert a stronger carcinogenic effect when used as a tumor initiator than when used as a "complete" carcinogen, e.g., when the shaved backs of each of 20 mice were painted with ten doses of 0.1 mg chrysene (each in 0.1 ml acetone), followed by treatment with tetradecanoyl phorbol acetate (TPA), 11 of the 18 surviving mice had tumors (total of 19 tumors) after 20 weeks. Similar results were obtained using chrysene (total dose of 4.4 micromoles) either as an initiator with TPA, or when chrysene (1.0 mg in 0.4 ml acetone) was painted on the shaved backs of mice prior to treatment with croton resin. Chrysene also has produced positive results in mammalian cell transformation tests and in the "Ames" test for mutagenicity.

Certain methylchrysene isomers have also been shown to possess carcinogenic potential: 5-methylchrysene has been reported to be a strong "complete" carcinogen as well as a stronger tumor initiator than chrysene. Epidemiologic evidence for the carcinogenicity of chrysene as an isolated chemical was not located. However, certain industry-related materials which contain many PAH's, including chrysene and its methyl derivatives, have been linked with cancer induction in humans. A historical review of these occurrences can be found in the preamble of International Agency for Research on Cancer (IARC) Monograph, Volume 3 (1973).

While the evidence is not conclusive, the positive results obtained in certain animal studies, coupled with the demonstrated biochemical activity of chrysene and its presence in materials which have been found to be

carcinogenic to humans, indicate that chrysene should be regulated as a potential occupational carcinogen.

Control measures recommended in this report are designed for chrysene work areas, i.e., areas where the isolated chemical is manufactured, used, or stored. These control measures include: primary emphasis on engineering controls, e.g., process enclosure and local exhaust ventilation, where technologically feasible; use of personal protective equipment, e.g., coveralls, rubber gloves, and appropriate respirators; posting of warning signs; provision for medical surveillance; institution of spill-disposal procedures; and recordkeeping.

Chrysene may be generated inadvertently in numerous industrial processes which involve the pyrolysis of organic matter. Further, conditions which are favorable for the formation of chrysene also are likely to be favorable for the formation of methylchrysenes and numerous other PAH's whose carcinogenic potencies range from greater than to less than that of chrysene. While the aforementioned control measures may be applied to the general class of PAH's, NIOSH recognizes that under certain circumstances of PAH-exposure, they will be neither appropriate nor feasible.

While no workplace environmental limit for chrysene is recommended at this time, information on analytical methodology is included in this review. Most methods for the identification and quantitation of chrysene involve various forms of chromatography and spectrometry.

INTRODUCTION

The carcinogenic potential of certain polycyclic aromatic hydrocarbons (PAH's), e.g., benz(a)pyrene and benz(a)anthracene, has been well documented (IARC Monograph, Volume 3, 1973; Dipple, 1976). However, comparatively little information exists upon which to base an evaluation of the carcinogenic potential of chrysene. Further, isolated exposure to chrysene occurs only in specific operations, i.e., chrysene manufacture, laboratory experimentation, and possibly in the synthesis of anthraquinone vat dyes. The number of workers thus exposed is small relative to the number of workers exposed to chrysene ad-mixed with other PAH's in industrial processes which involve the pyrolysis of organic matter. This notwithstanding, sufficient quantities of chrysene may now be in use to elicit concern over any biological effects exerted by this chemical. Thus, an integration and evaluation of all experimental data pertinent to the carcinogenic potential of chrysene appears warranted.

There is now no federal occupational health standard for chrysene, or for any other individual PAH. Nor has the American Conference of Governmental Industrial Hygienists (ACGIH) recommended Threshold Limit Values (TLV's) for individual PAH's. Concern for occupational exposure to PAH's as a class is reflected, however, in the federal occupational exposure limit for Coke Oven Emissions (29 CFR 1910.1029) of 0.15 milligram/cubic meter of air (mg/cu m) measured as the benzene-soluble fraction of total particulate matter (BSFTPM) and as a time weighted

average (TWA). In addition, the ACGIH (1976) has recommended a TLV-TWA of 0.20 mg/cu m (as BSFTPM) for both coal tar pitch volatiles (CTPV) and particulate polycyclic aromatic hydrocarbons (PPAH). Completed NIOSH criteria documents on asphalt fumes, and coal tar products also address PAH exposures, as will future criteria documents on the roofing industry, carbon black, and welding and brazing. It also should be noted that the criteria document on coal tar products contains a recommendation for a permissible exposure limit of 0.1 mg/cu m measured as the cyclohexane-soluble fraction of total particulate matter (CSFTPM).

The Federal coke oven standard, the ACGIH TLV's, and the NIOSH recommended standards, all deal with PAH's from particular sources. Different sources produce various amounts and mixtures of PAH's, and the individual PAH's have considerable ranges of toxicity. Adequate assessment of the hazards from occupational exposure to the general class of PAH's, and development of effective standards for worker protection probably will require their handling on a process basis.

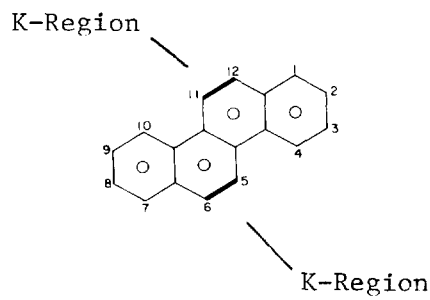
A review of the health hazards associated with chrysene and some of its derivatives, i.e., methylchrysene isomers, follows. General recommendations are included for control of occupational exposure in chrysene work areas, i.e., areas where chrysene is manufactured, used, or stored. Chrysene is merely one of many PAH's (which have wide ranges of toxicity) generated inadvertently in certain occupational environments, and the control recommendations included in this document may be applicable to

many PAH's, regardless of their source or fractional content. However, NIOSH recognizes that this will not necessarily be the case under all circumstances of PAH-exposure. The information and recommendations will aid the U.S. Department of Labor, industrial hygienists, occupational physicians, and employers in providing workers with protection from the hazards of exposure to chrysene. They also will aid workers in recognizing these hazards so that individual protective action may be taken.

I. PROPERTIES AND CHARACTERISTICS OF CHRYSENE

A. Identification

1. Synonyms: 1,2-benzophenanthrene
   1,2-benzphenanthrene
   benz (a) phenanthrene
   1,2,5,6-dibenzonaphthalene
2. CAS number: 000218019
3. Formula: C18H12
4. Molecular weight: 228.28



B. Physical/Chemical

1. Appearance and odor: colorless and odorless platelets, i.e., solid at STP in pure reagent form
2. Boiling point: 448 C (at 760 mm Hg)

3. Melting point: 254 C

4. Specific gravity: 1.274

5. Solubility: insoluble in water; slightly soluble in alcohol, ether, carbon disulfide, glacial acetic acid; soluble in benzene.

II. COMMON OPERATIONS, USE, AND OCCURRENCE

A. Workplace Environment

PAH's are perhaps the most ubiquitous of the carcinogenic agents that have been detected in the atmosphere. Chrysene, along with other PAH's, occurs most frequently as an adsorbate on airborne particulates resulting from the pyrolysis of carbonaceous materials (Filatova et al., 1972). Chrysene is sometimes encountered as a vapor. The yield of chrysene can be affected by the chemical and physical nature of the pyrolyzed compound, the pyrolysis temperature, the presence or absence of adequate oxygen for complete combustion, and the period of time during which the compound is exposed to heat. Experimental determinations have shown the optimal temperature for PAH formation to be around 700 C (Masuda et al., 1967). From an occupational health standpoint it is important to identify the sources of these compounds. Table I lists some of these sources for chrysene.

TABLE I. SOURCES AND CONCENTRATIONS OF CHRYSENE FOUND IN WORKPLACE ENVIRONMENTS

Source	Concentration*	Reference
Particulate matter, catalyst regeneration flue gas of an oil refinery	12,000 ppm	Sawicki et al., 1965
Coal tar pitches from coke oven production	7400 ppm and 10,000 ppm	Wallcave et al., 1971
Particulate matter, effluent of coal furnace	7000 ppm	Sawicki et al., 1965
Coal tar	2130 and 2860 ppm	Lijinsky et al., 1963
Creosote	940 and 1340 ppm	Lijinsky et al., 1963
Asphalt	34.0 ppm	Wallcave et al., 1971
Effluent from tar-fired retorts in a gas-producing plant	12.6 ppm	Cleary, 1963
Carbon black	3.0 ppm	Qazi and Nau, 1975
Soot from brick kiln exhaust	2.5 ppm	Cleary, 1963
Smoke from burning wood	0.58 ppm of sawdust burned	Rhee and Bratzler, 1968

TABLE I. SOURCES AND CONCENTRATIONS OF CHRYSENE FOUND IN WORKPLACE ENVIRONMENTS (continued)

Petrolatums	0.01 and 0.44 ppm	Lijinsky et al., 1963
Certain organic solvents derived from coal tar or petroleum:		Lijinsky and Raha, 1961
hexane-2	0.12 ppm	
benzene AR-1	0.0018 ppm	
iso-octane	0.0009 ppm	
Resinous substances from air in coke and metallurgical plants	----	Filatova et al., 1972
Extracts from bituminous coal prior to pyrolysis	----	Tye et al., 1966
Stack gases from sulfate pulping mill	----	Hendrickson et al., 1963
Extracts of processed rubber stoppers and automobile tires	----	Falk et al., 1951

*Unless otherwise stated, the units (ppm) refer to parts of chrysene per million parts of source material sampled, as a weight/weight ratio.

B. Occupational Areas of Concern

At present, it is believed that exposure to chrysene as an isolated chemical occurs only in specific occupations, i.e., in chrysene manufacture, laboratory experimentation, and perhaps in the synthesis of anthraquinone vat dyes. It was Holbro (1953) who suggested the use of chrysene as a starting material in the synthesis of dyestuffs, particularly of anthraquinone vat dyes, to which the results of his research showed chrysene imparted favorable properties regarding "affinity, shade, and fastness". While the scope of this report is limited primarily to chrysene as an isolated chemical, its occurrence with other PAH's in a wide range of occupational environments cannot be disregarded.

The following list of occupational areas, where worker exposure to chrysene and other PAH's is likely to occur, is separated into stationary-point and non-stationary point source categories; the former refers to inplace operations, i.e., where engineering controls could be expected to substantially reduce employee exposure, and the latter refers to outdoor or mobile operations where the application of engineering controls may be more difficult. In the latter case, however, it would be expected that natural factors (wind, etc.) would contribute to reductions in worker exposure. While this list is based on the occurrence of chrysene as it has been reported in the scientific literature, many other occupational exposure sources undoubtedly exist.

Stationary point sources

Aluminum reduction operations

Boiler-room operations

Carbon black manufacturing operations

Charcoal manufacturing operations

Coffee roasting operations

Coke oven operations (refer to Federal Standar

on Coke Oven Emissions)

Grill cooking operations

Iron foundry operations

"Liquid smoke" production

Municipal incinerator operations

Petroleum cracking operations

Rubber processing operations

Sintering mill operations

Smokehouse operations

Sulphate paper pulping mills

Wood preservative treatment processes

Non-stationary point sources

Acetylene-torch cutting and brazing operations

Airport runway operations

Bus terminal operations (boarding areas)

Diesel trucking operations

Furnace maintenance and repair operations

Gasoline station and automobile repair operations

Heavy equipment operations, e.g., tractors, cranes and earth-movers

Road paving and sealing operations

Roofing operations

Street sweeping operations

Telephone line repair and installation

Traffic control

Traffic tunnel repair

C. General Environment

Chrysene is found in the general environment primarily as a product of the pyrolysis of fossil fuels for energy production and the operation of diesel- and gasoline-fueled internal combustion engines.

Chrysene has been measured in the atmospheres of several major cities. In Sydney, Australia, a 12-month survey of the ambient PAH content of suspended particulate matter showed chrysene at concentrations ranging from 0.0002 to 0.0065 (u)g/cu m of air (Cleary and Sullivan, 1965). Chrysene was found in the atmosphere of Buffalo, New York, at concentrations of 0.082-0.116 (u)g/cu m of air, and in composite samples from the air of urban Cincinnati, Ohio at concentrations of 0.0032 and 0.006 (u)g/cu m of air (Conlee et al., 1967).

Studies have been conducted to determine the contribution of the gasoline engine to atmospheric levels of PAH's. Gasoline engine exhaust

tar was found to contain 175 ppm chrysene (Hoffman and Wynder, 1962). In another investigation, the PAH emissions from diesel- and gasoline-powered vehicles were compared (Sullivan and Cleary, 1964), and chrysene was found in a diesel-trafficked area at a concentration of 0.0032 (u)g/cu m of air; in the gasoline-trafficked area, chrysene was found at a concentration of 0.0034 (u)g/cu m of air.

In addition to the finding of chrysene in ambient air, its presence in soil and water has been substantiated. Although quantitative data are few, chrysene has been identified in soils in rural Massachusetts and Connecticut (Blumer, 1961), and in wells, rivers, lakes, and soils in Germany (Borneff, 1964; Borneff and Kunte, 1965). One investigator suggested that the occurrence of chrysene and other PAH's in rural soil is not due to fallout from polluted air but, rather, is the result of the natural pyrolytic transformation of plant organic matter to peat and lignite; or that alternatively, they occur as metabolites of organisms which reside in the soils (Blumer, 1961).

Chrysene also has been detected in certain food products: roasted coffee (Kuratsune and Hueper, 1960), spinach and tomatoes (Grimmer and Hildebrand, 1965), baker's yeast (Grimmer and Wilhelm, 1969), "liquid smoke" (Lijinsky and Shubik, 1965), smoked ham and barbecued beef (Malanoski et al., 1968), charcoal-broiled steak and chicken (Lijinsky and Ross, 1967), and electric-broiled fish (Masuda et al., 1966).

Of particular importance is the occurrence of chrysene in cigarette-smoke condensate. Chrysene has been found in cigarette-smoke condensate at a concentration of 0.06 (u)g per 100 cigarettes (Van Duuren, 1958). Cigarette smoke may add significantly to the total exposure to chrysene from both the general environment and work environment.

III. BIOLOGICAL EFFECTS OF EXPOSURE

A. Toxic Effects in Animals

Schmid et al. (1967) used mortality and body and organ weight changes in mice as measures of chrysene toxicity. Each of 10 male AKR and 10 male C57BL/6 mice was given a single i.p. injection of 7.5 mg chrysene dissolved in 1 ml of sesame oil. All animals were alive after 20 days of observation at which time they were killed. Autopsies revealed that none of the mice had experienced any significant change in body, spleen, or thymus weight. The investigators concluded that chrysene was not toxic as reflected by the aforementioned parameters and experimental conditions.

Gershbein (1958) tested the effects of chrysene on liver regeneration in partially hepatectomized adult male Sprague-Dawley rats. Single s.c. injections of 12.0 mg chrysene in peanut oil were given daily for the 11-day test period to each rat (320 mg/kg body weight). This treatment caused no significant change in the extent of liver regeneration from that in the corresponding controls.

Bernheim et al. (1953) found that a 0.3% solution of chrysene in benzene, when painted on the skins of white mice, inhibited fatty acid peroxide-induced thiobarbituric acid-color development on the epidermal side, but did not in the subcutaneous fat. The investigators attributed these results to inhibition of fatty acid oxidation. They noted that oxidized fatty acids are more effective inhibitors of certain enzymes and of bacterial growth than are the corresponding unoxidized acids, so that a carcinogen, by inhibiting peroxide formation, might produce conditions favorable for growth. They also suggested that inhibition of fatty acid oxidation may be a necessary, but certainly not a sufficient, condition for tumorigenesis.

B. Carcinogenicity in Animals

A number of experimental animal studies of the carcinogenic potential of chrysene have yielded varying results. Most of these studies have been conducted with mice, and various investigators have described chrysene as a weak carcinogen (Wynder and Hoffman, 1959); a cancer "initiator" (Hoffman et al., 1974); an "incomplete" carcinogen (Horton and Christian, 1974); and as a cancer "inhibitor" (Huggins et al., 1964). The following experimental results illustrate the variability in reported carcinogenic activity of chrysene.

Grover et al. (1975) tested the carcinogenicity of chrysene and chrysene 5,6-oxide (an epoxide), in newborn Swiss mice (Table II.A.), from a specific pathogen-free breeding colony. The mice were each injected

TABLE II. SUMMARY OF SELECTED EXPERIMENTS TO ASSESS THE CARCINOGENICITY OF CHRYSENE

A. MICE, newborn Swiss. Route of exposure: Subcutaneous injection
Grover et al., 1975)

Compound	dose per treatment	no. of treatments	total mice injected (M&F)	no. mice weaned (day 21) total, M,F	no. survivors at week 70	no. mice examined at termination of experiment (70-75 week) with:				
						liver tumors	multiple liver tumors	lung tumors	multiple lung tumors	other tumors
Chrysene	100(u)g	3	104	51, 29, 22	27 M 21 F	13 0	6 0	1 1	1 0	0 0
Chrysene 5,6-oxide	100(u)g	3	107	47, 24, 23	21 M 20 F	8 1	3 0	0 0	0 0	0 0
PEG 400 (controls)	-	3	96	52, 34, 18	30 M 15 F	9 0	1 0	3 1	1 0	0 0

B. MICE, C 57 black. Route of exposure: Subcutaneous injection
(Boyland and Sims, 1967)

Compound	number of injections x dose in mg	number of animals surviving until the appearance of the first tumor	sex	number of animals with tumors	time of first appearance of tumors (in days after first injection)
Chrysene	10 x 1	20	M	2	248 and 262
Chrysene 5,6-oxide	10 x 1	20	M	3	189, 284, and 303
Arachis oil (controls)	10 x 1	20	M	0	-

C. MICE, CD-1. Route of exposure: Skin application
(Scribner, 1973)

Compound	dose in (u) moles	dose of TPA in (u) moles	animals per group	tumor incidence, papillomas/mouse (% mice with tumors) (wk)						survivors 35 wk.
				10	15	20	25	30	35	
Chrysene	4.4	10	30	0.33 (20)	2.03 (60)	3.27 (73)	3.07 (77)	2.83 (67)	2.87 (73)	29
none	-	10	30	0 (0)	0 (0)	0 (0)	0.03 (3)	0 (0)	0 (0)	30

*TPA - tetradecanoyl phorbol acetate, applied, after chrysene, as a "promoter."

TABLE II: SUMMARY OF SELECTED EXPERIMENTS TO ASSESS THE CARCINOGENICITY OF CHRYSENE (continued)

D. MICE, ICR/HA Swiss. Route of exposure: Skin application
(Van Duuren et al., 1966)

primary (single dose)	secondary dose per animal (3 times weekly)	cumulative no. of mice with: papilloma	cancer	days to first: papilloma	cancer	survivors at end of experiment	weeks on test
Chrysene, 1 mg in 0.4 ml acetone	croton resin, 25(u)g in 0.1 ml acetone	16	2	125	411	10/20	63
Chrysene, 1 mg in 0.4 ml acetone	none	0	0	-	-	7/20	63
none	0.1 ml acetone	0	0	-	-	16/20	63
none	croton resin, 25(u)g in 0.1 ml acetone	5	1	237	411	13/20	63
none	none	0	0	-	-	70/100	63

E. MICE, C3H. Route of exposure: Skin application
(Horton and Christian, 1974)

Compound	vehicle	number and volume in (u)l applications per week	original no. mice	no. mice alive at 52 weeks	number of mice with tumors: carcinomas	papillomas	median time of tumor induction (wk)
1:1 (vol) Dodecane:Decalin	none	2 x 60	unknown	13	0	2	74
Chrysene, 0.15%	Decalin	2 x 60	20	12	0	1	76
Chrysene, 0.15%	1:1 (vol) Dodecane:Decalin	2 x 60	20	19	12	5	49

F. MICE, C57 black. Route of exposure: Subcutaneous injection
(Steiner and Falk, 1951) (Steiner and Falk, 1951)

Compound	amount of chemical	no. of mice	no. of mice surviving when first tumor appeared	no. of induced sarcomas	tumor yield (per cent)	minimum induction time (days)	average induction time (days)
Chrysene	5.0 mg in 0.5 cc tricaprylin	50	24	4	16.6	349	401
1,2-benzanthracene	5.0 mg in 0.5 cc tricaprylin	50	44	8	18.2	161	285
Chrysene plus 1,2-benzanthracene	2.5 mg each, in 0.5 cc tricaprylin	50	34	15	44.1	230	346

(s.c.) with 100(u)g of a test chemical, on each of the first 3 days of life. The test compounds were administered as 0.02 ml suspensions using polyethylene glycol (PEG) 400 as the vehicle. Surviving mice were weaned at 21 days of age and observed for 70-75 weeks. Of the 48 survivors at 70 weeks in the chrysene-treated group, liver tumors were observed in 13 (6 of which had multiple tumors) and lung tumors were seen in 2 (one of which had multiple tumors). Of the 45 chrysene 5,6-oxide-treated survivors at the end of 70-75 weeks, 9 had developed liver tumors (3 of which had multiple tumors). With the PEG 400 vehicle controls, of the 45 mice surviving to 70 weeks, 9 had liver tumors (1 of which was multiple) and 4 mice had lung tumors (1 of which was multiple). The investigators concluded that chrysene seemed to be a more active tumorigen than its epoxide, and that it increased the incidence of liver tumors above that in the controls, while the epoxide did not do so, and that neither chrysene nor the epoxide affected the incidence of lung tumors. The liver tumors ranged in appearance from well differentiated liver cell masses that were difficult to distinguish from normal liver tissues to those exhibiting pleomorphism, invasion, and metastasis. The increased incidence of liver tumors after exposure to chrysene, however, was not statistically significant (P=0.05).

Boyland and Sims (1967) conducted a similar experiment with chrysene and chrysene 5,6-oxide (Table II.B.). C57 black mice, 120 days old, were injected s.c. with 1.0 ml suspensions of arachis oil that contained 1.0 mg of either chrysene or chrysene 5,6-oxide, once/week, for 10 weeks. A third group, given only arachis oil, served as the control. After an observation period ranging from 60 to 80 weeks, 2 of the 20 chrysene-treated mice

surviving at the time of observation of the first tumor (initial number of animals treated was not stated) had developed injection-site tumors. A comparable number of animals (3 of 20) developed injection-site tumors from the epoxide but the time-to-tumor was longer by an average of 8.6 days. Because of the longer latency period for the epoxide, the investigators concluded that the parent PAH was a more active tumorigen. None of the control animals had tumors. Of the tumors induced by the active compounds, about 80% were spindle-cell sarcomas, about 12% were pleomorphic sarcomas and about 8% were squamous cell carcinomas.

Wynder and Hoffman (1959) applied a 1% solution of chrysene in acetone to the backs of female Swiss (Millerton) mice, three times weekly until the last animal died (sometime during the 13th month of treatment). Nine of the original 20 animals had developed papillomas and 8 had developed carcinomas, with the first tumor appearing after 8 months of treatment. From the original data it is not possible to determine with exactitude the number of animals with both papillomas and carcinomas. A decrease in lifespan was also noted; no controls were included in the experiment. It is unlikely, however, that such a high incidence of carcinomas would occur spontaneously in this strain of mouse.

Several investigators have shown chrysene to act as a cancer "initiator." Hoffman et al. (1974) tested the tumor-initiating activity of chrysene and of six of its methyl derivatives. The purities of the test substances were greater than 99.9 %. Ten doses of 0.1 ml of acetone each containing 0.1 mg of the test PAH (total dose, 1.0 mg) were applied on

alternate days to the shaved backs of each of 20 female Swiss albino mice (Ha/ICR/Mil). Application of the "promoting" substance, tetradecanoyl phorbol acetate (TPA) was begun 10 days following the last PAH-treatment. TPA, in doses of 2.5 (u)g in 0.1 ml of acetone, was applied three times a week for 20 weeks, for total doses of 0.15 mg. Acetone alone (10 doses of 0.1 ml) served as a control treatment and was reported to have produced negative results in a separate group of mice, although no quantitative data were given. In the chrysene-exposed group, after 20 weeks of TPA applications, 11 of the 18 surviving mice had a total of 19 tumors. The 3-methyl- and especially the 5-methylchrysene were even stronger tumor initiators than was chrysene, with 14 of 20 surviving mice sharing a total of 26 tumors, and 17 of 20 surviving mice sharing a total of 96 tumors, respectively. Each compound was concurrently bioassayed for "complete" carcinogenicity in mice of the same strain and sex. Solutions of 0.1 mg of each material in 0.1 ml acetone were applied under identical conditions to the shaved backs of the animals, three times weekly for the duration of the experiment. After 30 weeks, 5-methylchrysene showed high carcinogenic activity. Each of the 20 mice had tumors (with a total of 99 tumors), including 12 with 37 carcinomas, and 2 with multiple metastases to the lungs and spleen. Chrysene and the other five methylchrysenes showed no significant tumorigenic activity according to the investigators. Quantitative data for chrysene and for the control vehicle were not given.

Hecht et al. (1976) also tested 5-methylchrysene for "complete" carcinogenicity via two routes. Ten s.c. injections of 0.05 mg 5-methylchrysene in trioctanoin (0.1 ml each injection) were given to each of

25 male C-57 black mice at 2-week intervals, after which the animals were observed for 32 weeks. This exposure to 5-methylchrysene resulted in 24 fibrosarcomas in 22 animals, with the first tumor appearing at 25 weeks. Vehicle controls had no tumors. In addition, 5-methylchrysene was compared with benzo(a)pyrene (BaP) for tumor-initiating potential and "complete" carcinogenicity on mouse skin. For the tumor-initiating tests, ten initiator doses of 3 (u)g of 5-methylchrysene dissolved in acetone were applied to the skins of 20 female Swiss mice (Ha/ICR) during the second resting phase of the hair growth cycle. "Promotion" was accomplished by applying 0.1 ml of a 0.0025% solution of TPA in acetone thrice weekly for 20 weeks. Benzo(a)pyrene was tested similarly. The results indicated that 5-methylchrysene was a stronger tumor initiator than BaP; application of the former compound resulted in a total of 45 tumors in 20 mice (including 1 mouse with 1 carcinoma), whereas exposure to the latter resulted in a total of 6 tumors (no carcinomas) in 6 mice. The latency period for both groups was 5 weeks. None of the control mice had tumors. Each chemical was also applied thrice weekly at concentrations of 0.01% and 0.005% in 0.1 ml acetone to the shaved skins of 20 mice. After 55 weeks of exposure to 5-methylchrysene, 15 mice bore 38 tumors, including 10 mice with 12 carcinomas. Comparable results were seen in the BaP-treated mice. The control mice (solvent alone) developed no tumors. The investigators suggested that the demonstrated carcinogenicity of 5-methylchrysene may have resulted from the high electron densities at its 5-6 and 11-12 K-regions due to the electron-releasing effect of the methyl group; the high electron density might facilitate either metabolic activation to an

"ultimate" carcinogen or detoxification. (See additional discussion below.)

Scribner (1973) (Table II.C.), showed chrysene to produce multiple papillomas when used in small doses as an initiator. The backs of 30 female CD-1 mice, 8 weeks old, were shaved and treated 2 days later with chrysene in acetone (total chrysene dose, 4.4 (u) moles). One week later, a twice-weekly treatment with TPA was begun. At the end of 35 weeks, 73% of the 29 survivors had developed papillomas, whereas the control group (TPA only) had developed none.

Similar results had been obtained by Van Duuren et al. (1966) when, in order to test its cancer-initiating potential, they applied chrysene in doses of 1.0 mg (in 0.4 ml of acetone) to the shaved backs of 20 female ICR/HA Swiss strain mice (Table II.D). A known tumor promoter, croton resin, in doses of 25.0 mg (in 0.1 ml of acetone) was applied to the same mice beginning 13-21 days after the chrysene treatment and thrice weekly thereafter. This combined treatment resulted in papillomas in 16 of 20 mice and carcinomas in 2 of 20 mice, with the first observation of the former after 125 days and of the latter after 411 days of the 63-week experiment. Controls receiving only croton resin showed a much lower incidence of tumors (5 benign, 1 malignant). The authors stated that previous experimentation with this substance alone by other investigators had resulted in no malignancies. The investigators concluded that chrysene acts as a "notable" cancer- initiating substance. In the same experiment,

exposure to chrysene alone failed to result in the development of tumors in mice.

Other investigators have found evidence that chrysene may act synergistically with certain susbtances to induce tumorigenesis. Horton and Christian (1974) found that a 0.15% solution of chrysene in decahydronaphthalene (Decalin), a "non-carcinogenic" agent, when painted on the backs of 20 C3H male mice (60 (u)l doses, 2 x week), induced a papilloma in 1 of 12 surviving animals after 76 weeks of treatment (Table II.E.). However, when chrysene was applied in a 0.15% solution with a 50:50 Decalin: n-dodecane mixture (a known co-carcinogenic mixture) to the backs of 20 mice, 12 and 5 out of 19 surviving animals developed papillomas and carcinomas, respectively. The median time for tumor induction was 49 weeks. The effects of n-dodecane alone were not tested for. The authors classified chrysene as an "incomplete" carcinogen, i.e., one lacking the co-carcinogenic activity of a strong "complete" carcinogen.

Steiner and Falk (1951) studied the carcinogenic activity of chrysene in combination with 1,2-benzanthracene (Table II.F.). The actions of chrysene and of 1,2-benzanthracene were first tested separately. Fifty C57 black mice, 3-4 months old and in about equal numbers of males and females, were injected s.c. with 5.0 mg chrysene in 0.5 cc tricaprylin. There was a total of 4 injection-site sarcomas among the 24 surviving mice for a tumor incidence of 16.6 % compared with a 1.3 % incidence of tumors in the tricaprylin controls and a zero incidence in the uninjected controls. The

investigators considered the results to have shown that chrysene has a definite carcinogenic potential. A tumor incidence of 18.2 % was seen after the administration of 1,2-benzanthracene with the average induction time of 285 days. A mixed solution of the two PAH's (2.5 mg each) in tricaprylin was then administered to each of 50 mice in a like manner. The tumor incidence from this dose was 44.1%. Because this incidence was a little greater than the summation of the individual responses at full doses, the investigators concluded that the results were demonstrative of either summation or synergism.

In a follow-up study by Steiner (1955), a mixture of the "strong" carcinogen 1,2,5,6-dibenzanthrene with chrysene, when administered s.c. to approximately fifty C57BL mice, showed no significant additivity of effects, i.e., the incidence of tumors was the same as for either agent alone, and the question was raised by the investigator as to whether there had not been actual inhibition of tumorigenesis.

Huggins et al. (1964) attempted to detect any inhibitory effects of chrysene upon the action of a more potent carcinogen. In these experiments, 2 mg i.v. injections of 7,12-dimethylbenz(a)anthracene (7,12-DMBA) were given to each of 74 rats on days 50, 53, and 56 of their lives. Mammary tumors resulted in all 74 animals (100%). A separate group of animals was given (gastric intubation) single doses of chrysene (40 mg) followed by the same 7,12-DMBA treatment. These animals showed no significant change in the incidence of mammary tumors. However, in another group of test animals, multiple doses of chrysene (15 mg x 16 days) during

a period that overlapped i.v. injections of 7,12-DMBA greatly reduced the incidence of mammary tumors (60% vs 100%).

Riegel et al. (1951), painted a mixture of chrysene (15%) and methylcholanthrene (15%) in acetone on the shaved backs of CF1 mice (0.02 ml of test solution, twice weekly, for 31 weeks) and compared its carcinogenic activity with that of methylcholanthrene (15% in acetone) alone. In the group treated only with methylcholanthrene, 23 of 28 animals (82%) developed tumors after a mean latent period of 14.1 weeks. In the group painted with the chrysene/methylcholanthrene mixture, 17 of 20 animals (85%) developed tumors after a mean latent period of 13.8 weeks. Mean latent periods were calculated from the day that painting with the mixture was begun. From these results, the investigators concluded that chrysene had no significant inhibitory effect on the carcinogenicity of methylcholanthrene. Similar applications of 0.20% chrysene in acetone to 20 mice resulted in one tumor among 16 survivors at 31 weeks.

In addition to the positive animal test results, indirect evidence for the carcinogenicity of chrysene can be derived from results with two different in vitro test systems.

McCann et al. (1975) reported that both chrysene and chrysene-5,6-oxide were mutagenic in the Ames test. This test utilizes the organism, Salmonella typhimurium, to indicate DNA damage, and mammalian liver extracts for metabolic activation of the test chemical. Chrysene was tested on strain TA100 and resulted in 38 revertants per nanomole. The

investigators noted that the relationship between the mutagenic potency of a substance on a particular strain to its overall mutagenic potential on DNA in general, and to carcinogenic potency, remained to be determined.

Huberman et al. (1972) tested the effects of chrysene (15.0 (u)g/ml for 4 hours) on Syrian hamster embryo cells in culture and found definite dose dependent increases in the numbers of "malignant" transformations in exposed cell colonies. Also, it was found that chrysene 5,6-oxide (15.0 (u)g/ml) was even more active in producing transformations. Similar relationships were observed between other PAH's and their epoxides. For this reason, and because such epoxides had been shown to be metabolic intermediates of PAH's, the investigators postulated that the epoxides are possibly the ultimate carcinogenic forms of at least those PAH's that do not contain active methyl groups.

In a follow-up to the 1972 study of Huberman et al., Huberman and Sachs (1976) tested chrysene, in the presence of enzymes required for its metabolic activation, on Chinese hamster cells in culture (2-day treatment at 1(u)g/ml/day). Chrysene showed negligible mutagenic activity (9 mutants for chrysene vs 6 mutants for solvent alone, per 10,000 surviving cells).

Negative results were also obtained by Marquardt et al. (1972) who tested the ability of chrysene and its epoxide (1.0-10.0 (u)g/ml doses for each) to transform cells derived from mouse prostate.

According to other investigators, the primary process in cancer induction (by PAH's) involves binding to a cellular component, e.g., DNA, RNA, or protein, at the K-region of the PAH (Raha et al. 1973). Typically,

the K-region of a PAH is a highly reactive site. Experimentally measured bond lengths, chemical reactivities, and valence-bond and molecular orbital calculations all agree in assigning a higher electron density to the K-region than to any other bond in the PAH molecule (Herndon, 1973).

C. Toxic Effects in Humans

No reports concerning the toxicity of chrysene in humans were located. Considerations for any toxic effects of chrysene in humans would primarily be concerned with inhalation of particulate matter, since chrysene is encountered most frequently as an airborne particulate or as an adsorbate on airborne particulates. The occurrence of any biological effect would be closely related to the physical characteristics of the particle. Particle size predominantly determines the extent to which penetration of (and retention by) the tracheobronchial tree will occur, with maximum retention falling within an aerodynamic particle size range of 0.5 to 2.0 microns (Kotin and Falk, 1964). Ingestion and skin absorption must also be considered potential routes of exposure. Further, it should be noted that small amounts of chrysene-containing particles might be ingested following their inhalation as particles and mucus reflux from the bronchial tree (Hill et al., 1972).

No epidemiologic studies concerning the carcinogenicity of chrysene per se were located in the literature. The carcinogenic potential of chrysene in humans must therefore be estimated on the basis of animal studies or be deduced from experiences with mixed exposure to chrysene and other PAH's.

D. Summary of Carcinogenicity Data

While it is clear that exposure to PAH's is associated with increased risk for both lung and skin cancer in humans, the relative contribution of individual compounds is difficult to determine. Chrysene is a component in virtually all occupational exposures to PAH's. In order to assess the specific carcinogenic potential of chrysene, evidence based mainly on animal experiments, and supported by in vitro test results, must be utilized.

Evidence of chrysene's carcinogenic potential has come primarily from experiments in which the isolated chemical (and certain derivatives) was administered to animals by skin painting or by s.c. injection. Chrysene also has been shown to be active in some mammalian cell culture tests and in microbial assays for mutagenicity.

Certain generalizations can be made regarding the tumorigenic potential of chrysene. For instance, its tumorigenic potential seems to vary in a dose-dependent manner. Large doses and repeated applications, as well as lengthy induction periods, are usually required to obtain significant incidences of tumorigenesis, prompting many investigators to classify chrysene as a "weak" carcinogen. Further, it seems that chrysene may have a greater effect when acting in concert with other, more potent agents, i.e., as a tumor-initiator, a synergist, or an "incomplete" carcinogen, enhancing tumor formation but lacking the capacity for complete carcinogenesis. In one study, chrysene appeared to have inhibited the

activity of a more potent carcinogen, but this case was contradicted by other similar investigations that have produced evidence to the contrary. Thus, no generalization can be made regarding chrysene's possible tumor "inhibiting" properties. Tests on mammalian cells in culture also have produced conflicting results: some investigations have shown chrysene to produce malignant transformations in a dose-dependent fashion, while others have shown it to have a negligible effect. In microbial assays, however, chrysene has been mutagenic.

Chrysene's methyl derivatives and certain of their epoxides have been shown to possess carcinogenic potential. The 5,6 oxide of chrysene (an epoxide) was shown to be less active than chrysene in in vivo tests, but in in vitro tests on mammalian cell cultures and in microbial assays, the converse was seen. Because such epoxides have been shown to react covalently with cellular macromolecules in vitro, they have been postulated to be likely candidates for the role of the ultimate carcinogenic derivatives of PAH's (Huberman et al., 1972). Several possible explanations have been suggested for the lack of epoxide activity in vivo as opposed to in vitro. For instance, because of solubility and other factors the epoxide may be less able to enter the cell (Boyland and Sims, 1967), or possibly the high chemical reactivity of such epoxides could cause them to react nonspecifically in tissues (with extracellular keratin and other molecules) and hence be depleted before reaching and reacting with intracellular target macromolecules (Huberman et al., 1972). The 5-methylchrysene has been shown to be both a strong, "complete" carcinogen and a more active tumor "initiator" than the parent chrysene. One possible

explanation for the carcinogenic potential of this compound may lie in its metabolic activation by the formation of a carbonium ion on the methyl group (Marquardt et al., 1972).

Thus, there exists certain evidence indicating that chrysene and its derivatives have carcinogenic potential. Additional research is needed to elucidate the nature and extent of chrysene's carcinogenic activity and the mechanisms whereby such effects may be exerted. No experimental studies were found in the literature concerning the inhalation of chrysene as an adsorbate on airborne particulate matter, i.e., the mode of entry that represents one of the most probable routes of occupational exposure. Further, and most importantly, it should be noted that early studies which produced negative results for chrysene quite likely used inadequate numbers of animals with insufficient periods of observation (Steiner and Falk, 1951).

IV. CONTROL RECOMMENDATIONS FOR CHRYSENE

A. Engineering Controls

Engineering controls should receive primary emphasis for the reduction of occupational exposure to chrysene. Typically, such engineering controls include process enclosure. In addition, chrysene work areas, i.e., areas where chrysene is manufactured, used, or stored, should be isolated from all other work areas. Chrysene work areas should be maintained under negative pressure with respect to non-chrysene work areas. This may be

accomplished by providing continuous local exhaust ventilation so that air movement is always from non-chyrsene to chrysene work areas. Exhaust air from chrysene work areas, including laboratory gloveboxes, should not be discharged into any work area or into the general environment unless it is first decontaminated. One means to accomplish this is through the use of bag filters in conjunction with the ventilation system. All process equipment, including laboratory gloveboxes, should be inspected for leaks and other malfunctions on a regular basis. In addition, ventilation systems should be tested periodically for their effectiveness, e.g., air velocity, static pressure, and air volume.

B. Respiratory Protection

Use of respirators for protection against exposure to chrysene should be permitted only during the time period necessary to install feasible engineering controls. Two other exceptions would be during nonroutine maintenance and repair activities where engineering controls are not technologically feasible, and during emergencies. A type C supplied-air respirator operated in pressure-demand or other positive pressure modes, or self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure modes would provide appropriate protection. Respirators should be selected from among those approved by the National Institute for Occupational Safety and Health or the Mining Enforcement and Safety Administration under the provisions of 30 CFR 11.

C. Protective Clothing

Employers should provide and ensure that all employees use appropriate protective clothing, e.g., coveralls and rubber or latex gloves, to prevent skin contact with chrysene during cleanup of spills and during those activities described in part B above.

D. Posting of Signs

Entrances to chrysene work areas should be posted with signs indicating:

DANGER

AUTHORIZED PERSONNEL ONLY

CANCER SUSPECT AGENT

E. Work Practices

Procedures for cleanup of spills and disposal of chemical waste should be instituted. Persons involved with cleanup activites should wear appropriate personal protective equipment and clothing as outlined above. Since chrysene crystals can be electrostatic, contaminated surfaces should be wetted with clean or soapy water followed by careful wiping with disposable towels. All materials collected (including disposable towels) should be placed in sealed containers for disposal in a secured sanitary landfill, or disposed of in an appropriate incinerator, i.e., one operating

at high enough temperatures and with sufficiently long contact times for complete combustion. General housekeeping and sanitation practices should also be established and enforced. Before leaving chrysene work areas at the end of each day, employees who have had direct dermal contact with chrysene, e.g., through handling, cleanup of spills, or accidents, should wash exposed skin areas with soap and water and discard contaminated clothing for laundering or disposal. Further, food storage, preparation, and consumption should be prohibited in chrysene work areas.

F. Informing Employees of the Hazard

Persons employed in chrysene work areas should be informed of the potential hazards of chrysene, including the results of animal carcinogenicity and mutagenicity tests.

G. Medical Surveillance

Medical surveillance for workers with potential for exposure to chrysene should consist of preplacement examinations and periodic evaluations on at least an annual basis.

The history and physical examinations should place emphasis on the smoking habits, skin, respiratory tract, and urinary system. Clinical testing should include chest x-rays and urinalysis with such other tests as sputum cytology carried out as considered appropriate by the responsible physician.

H. Recordkeeping and Availability of Records

Employers should keep accurate records of (1) all measurements taken to determine employee exposure to chrysene, (2) measurements demonstrating the effectiveness of mechanical ventilation, and (3) all data obtained from medical examinations which is pertinent to chrysene exposure. Pertinent records from medical examinations should be maintained for at least 30 years after the worker's employment has ended.

V. SAMPLING AND ANALYTICAL METHODS

A workplace environmental limit for chrysene is not recommended at this time. However, in the event that NIOSH should establish such a limit (either for chrysene or for the general class of PAH's) in the future, a validated sampling and analytical procedure would be required.

NIOSH has not validated a sampling method for chrysene. Chrysene is normally encountered as an airborne pollutant (usually adsorbed on airborne particulate matter, but sometimes as a vapor) along with numerous other PAH's and their derivatives. When chrysene is encountered as a solid or is adsorbed on particulate matter, a sampling method similar to the one described in the occupational standard for coke oven emissions (29 CFR 1910.1029) would be appropriate.

NIOSH has not validated a specific analytical procedure for chrysene. The choice of any particular method depends upon the sample source, the

amount collected, time constraints, financial constraints, or personal preferences. The occupational standard for coke oven emissions (29 CFR 1910.1029) utilizes the benzene-soluble fraction of total particulate matter (BSFTPM) as an indicator of worker exposure to PAH's. This procedure, however, does not identify individual PAH's. In order to identify and quantify individual PAH's, they must first be separated from any interfering compounds with which they occur.

Many reviews concerning the state of the art of PAH analysis have appeared in the literature, e.g., Sawicki, 1964; Sawicki et al., 1967; Rutzinger et al., 1973; Zander, 1975. In addition, Appendix A contains a list of some analytical methods which have been used to determine the PAH content of various compounds.

REFERENCES

ACGIH: Threshold limit values for chemical substances in workroom air adopted by ACGIH for 1976. American Conference of Governmental Industrial Hygienists, 94 pp, 1976

Bernheim M, Bernheim F, Wilbur K: Carcinogens and oxidized fatty acids in the skin. Nature 172:306-07, 1953

Boden H: The determination of benzo(a)pyrene in coal tar pitch volatiles using HPLC with selective UV detection. J. Chromatogr Sci 14:391-95, 1976

Blumer M: Benzpyrenes in soil. Science 134:474, 1961

Borneff J: (Carcinogenic substances in water and soil. XV.) Arch Hyg 148:1-11, 1964 (Ger)

Borneff J, Kunte H: (Carcinogenic substances in water and soil. XVII.) Arch Hyg 149:226-43, 1965 (Ger)

Boyland E, Sims P: The carcinogenic activities in mice of compounds related to benz(a)anthracene. Int J Cancer 2:500-04, 1967

Cautreels W, Van Cauwenberghe K: Determination of organic compounds in airborne particulate matter by gas chromatography-mass spectrometry. Atmos Environ 10:447-57, 1976

Cleary GJ: Measurement of polycyclic aromatic hydrocarbons in the air of Sydney using very long alumina columns for separation. Int J Air Water Pollut 7:753-67, 1963

Cleary GJ, Sullivan JL: Pollution by aromatic hydrocarbons in the city of Sydney. Med J Aust 1:758-62,1965

Conlee CJ, Kenlin PA, Cummins RL, Konopinski VJ: Motor vehicle exhaust at three selected sites. Arch Environ Health 14:429-46, 1967

Dipple A: Polynuclear aromatic carcinogens, in Chemical Carcinogens, (Searle CE, ed). Wash DC, American Chemical Society, ACS Monograph No 173, 1976, chap 5

Dolanski V, Mostecky J, Popl M: (Polycyclic aromatic hydrocarbons in tars) Sb Vys Sk Chem Technol Praze, Technol Paliv 26:71-90, 1972 (Czech)

Dong M, Locke D, Ferrand E: High pressure liquid chromatographic method for routine analysis of major parent polycyclic aromatic hydrocarbons in suspended particulate matter. Anal Chem 48:368-72, 1976

Dubois L, Zdrojewski A, Monkman J: (An improved method for the determination of benzo(a)pyrene in air samples.) Staub Reinhalt Luft 32:22-4, 1972 (Ger)

Falk HL, Steiner PE, Goldfein S, Breslow A, Hykes R: Carcinogenic hydrocarbons and related compounds in processed rubber. Cancer Res 11:318-24, 1951

Filatova AS, Kapitul'skii VB, Kuz'minykh AI: (The problem of standarization of cancerogens in the air of industrial establishments.) Gig Sanit 37:91-93, 1972 (Rus)

Gershbein LL: Effect of carcinogenic and noncarcinogenic hydrocarbons and hepatocarcinogens on rat liver regeneration. J Natl Cancer Inst 21:295-310, 1958

Greinke R, Lewis I: Development of a gas chromatographic ultraviolet absorption, spectrometric method for monitoring petroleum pitch volatile in the environment. Anal Chem 47:2151-55, 1975

Grimmer G, Bohnke H: (Enrichment and gas chromatographic profile analysis of polycyclic aromatic hydrocarbons in lubricating oils.) 9:30-40, 1976 (GER)

Grimmer G, Hildebrand, H: (Content of polycyclic hydrocarbons in different vegetables--III. Hydrocarbons in the human surroundings.) Dtsch Lebensm Rundsch 61:237-39, 1965 (Ger)

Grimmer G, Wilhelm G: (The polycyclic hydrocarbon content of European yeast.) Dtsch Lebensm Rundsch 65:229-31, 1969 (Ger)

Grover PL, Sims P, Mitchley BCV, Roe FJC: The carcinogenicity of polycyclic hydrocarbon epoxides in newborn mice. Br J Cancer 31:182-88, 1975

Hecht S, Loy M, Maronpot R, Hoffman D: A study of chemical carcinogenesis: Comparative carcinogenicity of 5-methyl-chrysene, benzo(a)pyrene, and modified chrysenes. Cancer Letters 1:147-54, 1976

Hendrickson ER, Walker CG, Chapnerkar VD: Identification of non-sulfur organic compounds in stack gases from pulp mills. Am Ind Hyg Assoc J 24:121-26, 1963

Herndon WC: Theory of carcinogenic activity of aromatic hydrocarbons. Trans N.Y. Acad Sci 36:200-17, 1974

Hill FA, Siedle AR, Perry R: Chemical hazards of a fire-fighting training environment. Am Ind Hyg Assoc J 33:423-30, 1972

Hoffman D, Bondinell WE, Wynder EL: Carcinogenicity of methylchrysenes. Science 183:215-16, 1974

Hoffman D, Wynder EL: A study of air pollution carcinogenesis--II. The isolation and identification of polynuclear aromatic hydrocarbons from gasoline engine exhaust condensate. Cancer 15:93-102, 1962 Holbro F: Polycyclic aromatic hydrocarbons as starting materials for the synthesis of dyestuffs. J Appl Chem 3:1-9, 1953

Horton AW, Christian GM: Cocarcinogenic versus incomplete carcinogenic activity among aromatic hydrocarbons: Contrast between chrysene and benzo(b)triphenylene. J Natl Cancer Inst 53:1017-20, 1974

Huberman E, Kuroki T, Marquardt H, Selkirk JK, Heidelberger C, Grover PL, Sims P: Transformation of hamster embryo cells by epoxides and other derivatives of polycyclic hydrocarbons. Cancer Res 32:1391-96, 1972

Huberman E, Sachs L: Mutability of different genetic loci in mammalian cells by metabolically activated carcinogenic polycyclic hydrocarbons. Proc Natl Acad Sci USA 73:188-92, 1976

Huggins C, Grand L, Fukunishi R: Aromatic influences in the yields of mammary cancers following administration of 7,12-dimethyl-benz(a)anthracene. Proc Natl Acad Sci USA 51:737-42, 1964

IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man, Vol 3, International Agency for Research on Cancer, Lyon, France, pp 159-177, 1973

Janini G, Muschik G, Schroer J, Zielinski W: Gas-liquid chromatographic evaluation and gas-chromatography/mass spectrometric application of new high-temperature liquid crystal stationary phases for polycyclic aromatic hydrocarbon separations. Anal Chem 48:1879-83, 1976

Jewell M, Weber J, Bunger J, Plancher H, Latham D: Ion-exchange, coordination, and adsorption chromatographic separation of heavy-end petroleum distillates. Anal Chem 44:1391-95, 1972

Kotin P, Falk HL: Polluted urban air and related environmental factors in the pathogenesis of pulmonary cancer. Dis Chest 45:236-46, 1964

Kuratsune M, Hueper WC: Polycyclic aromatic hydrocarbons in roasted coffee. J Natl Cancer Inst 24:463-9, 1960

Lane D, Moe H, Katz M: Analysis of polynuclear aromatic hydrocarbons, some heterocyclics, and aliphatics with a single gas chromatographic column. Anal Chem 45:1776-78, 1973

Lao R, Thomas R, Monkman J: Computerized gas chromatographic-mass spectrometric anaysis of polycyclic aromatic hydrocarbons in environmental samples. J Chromatogr 112:681-700, 1975

Lee M, Novotny M, Bartle K: Gas chromatography/mass spectrometric and nuclear magnetic resonance determination of polynuclear aromatic hydrocarbons in airborne particulates. Anal Chem 48:1566-72, 1976

Lijinsky W, Domsky I, Mason G, Ramahi HY, Safavi F: The chromatographic determination of trace amounts of polynuclear hydrocarbons in petroleum, mineral oil, and coal tar. Anal Chem 35:952-56, 1963

Lijinsky W, Raha CR: Polycyclic aromatic hydrocarbons in commercial solvents. Toxicol Appl Pharmacol 3:469-73, 1961

Lijinsky W, Ross AE: Production of carcinogenic polynuclear hydrocarbons in the cooking of food. Food Cosmet Toxicol 5:343-47, 1967

Lijinsky W, Shubik P: The detection of polycyclic aromatic hydrocarbons in liquid smoke and some foods. Toxicol Appl Pharmacol 7:337-43, 1965

Malanoski AJ, Greenfield EL, Barnes CJ, Worthington JM, Joe FL: Survey of polycyclic aromatic hydrocarbons in smoked foods. J Assoc Off Anal Chem 51:114-21, 1968

Marquardt H, Kuroki T, Huberman E, Selkirk JK, Heidelberger C, Grover PL, Sims P: Malignant transformation of cells derived from mouse prostate by epoxides and other derivatives of polycyclic hydrocarbons. Cancer Res 32:716-20, 1972

Masuda Y, Mori K, Kuratsune M: Polycyclic aromatic hydrocarbons formed by pyrolysis of carbohydrates, amino acids and fatty acids. Gann 58:69-74, 1967

Masuda Y, Mori K, Kuratsune M: Polycyclic aromatic hydrocarbons in common Japanese food -- I. Broiled fish, roasted barley, shoyu, and caramel. Gann 57:133-42, 1966

Matsushita H, Arashidani K: Simple and rapid analysis of benzo(a)pyrene in coal tar pitch. Bunseki Kagaku 25:76-80, 1976

McCann J, Choi E, Yamasaki E, Ames BN: Detection of carcinogens as mutagens in the Salmonella/microsome test: Assay of 300 chemicals. Proc Natl Acad Sci USA 72:5135-39, 1975

McKay J, Latham D: Polyaromatic hydrocarbons in high-boiling petroleum distillates. Anal Chem 45:1050-55, 1973

Novotny M, Lee M, Bartl K: The methods for fractionation, analytical separation and identification of polynuclear aromatic hydrocarbons in complex mixtures. J Chromatogr Sci 12:606-12, 1974

Popl M, Stejskal M, Mostecky J: Determination of benzo(a)pyrene in tars and petroleum. Anal Chem 46:1581-82, 1974

Popl M, Stejskal M, Mostecky J: Determination of polycyclic aromatic hydrocarbons in white petroleum products. Anal Chem 47:1947, 1975

Qazi AH, Nau CA: Identification of polycyclic aromatic hydrocarbons in semi-reinforcing furnace carbon black. Am Ind Hyg Assoc J 36:187-92, 1975

Raha CR, Gallagher CH, Shubik P: Chemical reactions producing chrysene as an artifact of some K-region metabolites of benzo (a) pyrene. Proc Soc Exp Biol Med 143(2):531-35, 1973

Rhee KS, Bratzler LJ: Polycyclic hydrocarbon composition of wood smoke. J Food Sci 33:626-32, 1968

Rhys Williams A, Slavin W: Polycyclic aromatic hydrocarbon air pollutants by HPLC and fluorescence detection. Chromatogr Newsl 4(2):3-6, 1976

Riegel B, Wartman WB, Hill WT, Reeb BB, Shubik P, Stanger DW: Delay of methylcholanthrene skin carcinogenesis in mice by 1,2,5,6-dibenzofluorene. Cancer Res 11:301-03, 1951

Rutzinger O, Safe S, Zander M: Polycyclic aromatic hydrocarbons. Analabs, Inc. Research Notes, North Haven, Connecticut, 13:1-13, 1973

Sawicki E: The separation and analysis of polynuclear aromatic hydrocarbons present in the human environment. Chemist Analyst 53:24-26, 28-30, 56-62, 88-91, 1964

Sawicki E, Meeker JE, Morgan MJ: The quantitative composition of air pollution source effluents in terms of azo heterocyclic compounds and polynuclear aromatic hydrocarbons. Int J Air Water Pollut 9:291-98, 1965

Sawicki E, Stanley TW, Elbert WC, Meeker J, McPherson S: Comparison of methods for the determination of benzo(a)pyrene in particulates from urban and other atmospheres. Atmos Environ 1:131-145, 1967

Schmid FA, Demetriades MS, Schabel FM, Tarnowski GS: Toxicity of several cancerigenic polycyclic hydrocarbons and other agents in AKR and C57BL/6 mice. Can. Res 27:563-67, 1967

Scribner JD: Tumor initiation by apparently noncarcinogenic polycyclic aromatic hydrocarbons. J Natl Cancer Inst 50:1717-19, 1973

Steiner PE, Falk HL: Summation and inhibition effects of weak and strong carcinogenic hydrocarbons: 1:2-benzanthracene, chrysene, 1:2:5:6-dibenzanthracene, and 20-methylcholanthrene. Cancer Res 11:56-63, 1951

Steiner PE: Carcinogenicity of multiple chemicals simultaneously administered. Cancer Res 15:532-35, 1955

Stroupe R, Tokousbalides P, Dickinson R, Wehry E, Mamantov G: Low temperature fluorescence spectrometric determination of polycyclic aromatic hydrocarbons by matrix isolation. Anal Chem 49:701-05, 1977

Sullivan JL, Cleary GJ: A comparison of polycyclic aromatic hydrocarbon emissions from diesel- and petrol-powered vehicles in partially segregated traffic lanes. Br J Ind Med 21:117-23, 1964

Tye R, Horton AW, Rapien I: Benzo(a)pyrene and other aromatic hydrocarbons extractable from bituminous coal. Am Ind Hyg Assoc J 27:25-28, 1966

Van Duuren BL: The polynuclear aromatic hydrocarbons in cigarette-smoke condensate--II. J Natl Cancer Inst 21:623-30, 1958

Van Duuren BL, Sivak A, Segal A, Orris L, Langseth L: The tumor-promoting agents of tobacco leaf and tobacco smoke condensate. J Natl Cancer Inst 37:519-26, 1966

Wallcave L, Garcia H, Feldman R, Lijinsky W, Shubik P: Skin tumorigenesis in mice by petroleum asphalts and coal-tar pitches of known polynuclear aromatic hydrocarbon content. Toxicol Appl Pharmacol 18:41-52, 1971

Wynder EL, Hoffman D: A study of tobacco carcinogenesis--VII. The role of higher polycyclic hydrocarbons. Cancer 12:1079-86, 1959

Zander M: Analysis of polycyclic aromatics. Int J Environ Anal Chem 4:109-23, 1975

Holbro T: Polycyclic aromatic hydrocarbons as starting materials for the synthesis of dyestuffs. J Appl Chem 3:1-9, 1953

Appendix A. Analytical Methods for PAH Determination

PAH Source	Method of Separation and/or Analysis	Reference
Airborne particulates (general environment)	Column chromatography; computerized gas chromatography/mass spectrometry	Lao et al., 1975
Airborne particulates (general environment)	Single gas chromatographic column	Lane et al., 1973
Airborne particulates (general environment)	High-resolution liquid chromatography; column gas chromatography; ultraviolet and fluorescence spectroscopy	Novotny et al., 1974
Petroleum pitch volatiles	Gas chromatography; ultraviolet absorption spectroscopy	Greinke and Lewis, 1975
	Gas-liquid chromatography; gas chromatography/mass spectrometry	Janini et al., 1976
Airborne particulates (general environment)	Ultraviolet spectroscopy	Dubois et al., 1972
Tars	Gradient adsorption elution chromatography; ultraviolet spectroscopy	Dolansky et al., 1972
Tars and petroleum	Ion exchange, gel permeation, and thin layer chromatography; fluorescence spectrometry	Popl et al., 1974
Coal tar pitch	Fluorescence spectrometry	Matsushita & Arashidani, 1976
Tobacco and marijuana smoke condensates	Gas chromatography/mass spectrometry; nuclear magnetic resonance spectrometry	Lee et al., 1976
Airborne particulates (general environment)	Thin layer chromatography; high pressure liquid chromatography	Dong and Locke, 1976

Appendix A. Analytical Methods for PAH Determination (Cont'd)

PAH Source	Method of Separation and/or Analysis	Reference
Petroleum distillates	Ion exchange and adsorption chromatography; mass spectrometry	Jewell et al., 1972
Petroleum distillates	Ion exchange, gel permeation and thin layer chromatography; fluorenscence spectroscopy	McKay and Latham, 1973
Airborne particulates (general atmosphere)	Gas chromatography/mass spectrometry with computerized data acquisition	Cautreels and Van Cauwenberghe, 1976
Lubricating oils	Gas chromatography	Grimmer and Bohnke, 1976
White petroleum products	Adsorption, gradient elution, and gel permeation chromatography; fluorescence and phosphorescence spectrometry	Popl et al., 1975
Airborne particulates (general environment)	Reversed-phase high pressure liquid chromatography; fluorescence spectroscopy	Rhys Williams and Slavin, 1976
Coal tar pitch volatiles	High-pressure liquid chromatography; ultraviolet spectrometry	Boden, 1976
Coal liquids	Matrix - isolation fluorometry	Stroupe et al., 1977

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AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

COPPER

CAS # 7440-50-8

Division of Toxicology ToxFAQs™ September 2004

This fact sheet answers the most frequently asked health questions (FAQs) about copper. For more information, call the ATSDR Information Center at 1-888-422-8737. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It is important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Copper is a metal that occurs naturally in the environment, and also in plants and animals. Low levels of copper are essential for maintaining good health. High levels can cause harmful effects such as irritation of the nose, mouth and eyes, vomiting, diarrhea, stomach cramps, nausea, and even death. Copper has been found in at least 906 of the 1,647 National Priority Sites identified by the Environmental Protection Agency (EPA).

What is copper?

Copper is a metal that occurs naturally throughout the environment, in rocks, soil, water, and air. Copper is an essential element in plants and animals (including humans), which means it is necessary for us to live. Therefore, plants and animals must absorb some copper from eating, drinking, and breathing.

Copper is used to make many different kinds of products like wire, plumbing pipes, and sheet metal. U.S. pennies made before 1982 are made of copper, while those made after 1982 are only coated with copper. Copper is also combined with other metals to make brass and bronze pipes and faucets.

Copper compounds are commonly used in agriculture to treat plant diseases like mildew, for water treatment and, as preservatives for wood, leather, and fabrics.

What happens to copper when it enters the environment?

❏ Copper is released into the environment by mining, farming, and manufacturing operations and through waste water releases into rivers and lakes. Copper is also released from natural sources, like volcanoes, windblown dusts, decaying vegetation, and forest fires.
❏ Copper released into the environment usually attaches to particles made of organic matter, clay, soil, or sand.
❏ Copper does not break down in the environment. Copper compounds can break down and release free copper into the air, water, and foods.

How might I be exposed to copper?

❏ You may be exposed to copper from breathing air, drinking water, eating foods, or having skin contact with copper, particulates attached to copper, or copper-containing compounds.
❏ Drinking water may have high levels of copper if your house has copper pipes and acidic water.
❏ Lakes and rivers that have been treated with copper compounds to control algae, or that receive cooling water from power plants, can have high levels of copper. Soils can also contain high levels of copper, especially if they are near copper smelting plants.
❏ You may be exposed to copper by ingesting copper-containing fungicides, or if you live near a copper mine or where copper is processed into bronze or brass.
❏ You may be exposed to copper if you work in copper mines or if you grind metals containing copper.

How can copper affect my health?

Everyone must absorb small amounts of copper every day because copper is essential for good health. High levels of copper can be harmful. Breathing high levels of copper can cause irritation of your nose and throat. Ingesting high levels of copper can cause nausea, vomiting, and diarrhea. Very-high doses of copper can cause damage to your liver and kidneys, and can even cause death.

How likely is copper to cause cancer?

We do not know whether copper can cause cancer in humans. The EPA has determined that copper is not classifiable as to human carcinogenicity.

How can copper affect children?

Exposure to high levels of copper will result in the same type of effects in children and adults. We do not know if these effects would occur at the same dose level in children and adults. Studies in animals suggest that the young children may have more severe effects than adults, but we don't know if this would also be true in humans. There is a very small percentage of infants and children who are unusually sensitive to copper.

We do not know if copper can cause birth defects or other developmental effects in humans. Studies in animals suggest that high levels of copper may cause a decrease in fetal growth.

How can families reduce the risk of exposure to copper?

The most likely place to be exposed to copper is through drinking water, especially if your water is corrosive and you have copper pipes in your house. The best way to lower the level of copper in your drinking water is to let the water run for at least 15 seconds first thing in the morning before drinking or using it. This reduces the levels of copper in tap water dramatically.

If you work with copper, wear the necessary protective clothing and equipment, and always follow safety procedures. Shower and change your clothes before going home each day.

Is there a medical test to show whether I've been exposed to copper?

Copper is found throughout the body; in hair, nails, blood, urine, and other tissues. High levels of copper in these samples can show that you have been exposed to higher-than normal levels of copper. These tests cannot tell whether you will experience harmful effects. Tests to measure copper levels in the body are not usually available at a doctor's office because they require special equipment, but the doctor can send samples to a specialty laboratory.

Has the federal government made recommendations to protect human health?

The EPA requires that levels of copper in drinking water be less than 1.3 mg of copper per one liter of drinking water (1.3 mg/L).

The U.S. Department of Agriculture has set the recommended daily allowance for copper at 900 micrograms of copper per day (µg/day) for people older than eight years old.

The Occupational Safety and Health Administration (OSHA) requires that levels of copper in the air in workplaces not exceed 0.1 mg of copper fumes per cubic meter of air (0.1 mg/m^3) and 1.0 mg/m^3 for copper dusts.

Reference

Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Toxicological Profile for Copper. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Where can I get more information? For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology, 1600 Clifton Road NE, Mailstop F-32, Atlanta, GA 30333. Phone: 1-888-422-8737, FAX: 770-488-4178. ToxFAQs Internet address via WWW is http://www.atsdr.cdc.gov/toxfaq.html. ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

MERCURY
CAS # 7439-97-6

Agency for Toxic Substances and Disease Registry ToxFAQs April 1999

This fact sheet answers the most frequently asked health questions (FAQs) about mercury. For more information, call the ATSDR Information Center at 1-888-422-8737. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It's important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Exposure to mercury occurs from breathing contaminated air, ingesting contaminated water and food, and having dental and medical treatments. Mercury, at high levels, may damage the brain, kidneys, and developing fetus. This chemical has been found in at least 714 of 1,467 National Priorities List sites identified by the Environmental Protection Agency.

What is mercury?
(Pronounced mŭr′kyə-rē)

Mercury is a naturally occurring metal which has several forms. The metallic mercury is a shiny, silver-white, odorless liquid. If heated, it is a colorless, odorless gas.

Mercury combines with other elements, such as chlorine, sulfur, or oxygen, to form inorganic mercury compounds or "salts," which are usually white powders or crystals. Mercury also combines with carbon to make organic mercury compounds. The most common one, methylmercury, is produced mainly by microscopic organisms in the water and soil. More mercury in the environment can increase the amounts of methylmercury that these small organisms make.

Metallic mercury is used to produce chlorine gas and caustic soda, and is also used in thermometers, dental fillings, and batteries. Mercury salts are sometimes used in skin lightening creams and as antiseptic creams and ointments.

What happens to mercury when it enters the environment?

- Inorganic mercury (metallic mercury and inorganic mercury compounds) enters the air from mining ore deposits, burning coal and waste, and from manufacturing plants.
- It enters the water or soil from natural deposits, disposal of wastes, and volcanic activity.
- Methylmercury may be formed in water and soil by small organisms called bacteria.
- Methylmercury builds up in the tissues of fish. Larger and older fish tend to have the highest levels of mercury.

How might I be exposed to mercury?

- Eating fish or shellfish contaminated with methylmercury.
- Breathing vapors in air from spills, incinerators, and industries that burn mercury-containing fuels.
- Release of mercury from dental work and medical treatments.
- Breathing contaminated workplace air or skin contact during use in the workplace (dental, health services, chemical, and other industries that use mercury).
- Practicing rituals that include mercury.

How can mercury affect my health?

The nervous system is very sensitive to all forms of mercury. Methylmercury and metallic mercury vapors are more harmful than other forms, because more mercury in these forms reaches the brain. Exposure to high levels of metallic, inorganic, or organic mercury can permanently damage the brain, kidneys, and developing fetus. Effects on brain functioning may result in irritability, shyness, tremors, changes in vision or hearing, and memory problems.

Short-term exposure to high levels of metallic mercury vapors may cause effects including lung damage, nausea,

vomiting, diarrhea, increases in blood pressure or heart rate, skin rashes, and eye irritation.

How likely is mercury to cause cancer?

There are inadequate human cancer data available for all forms of mercury. Mercuric chloride has caused increases in several types of tumors in rats and mice, and methylmercury has caused kidney tumors in male mice. The EPA has determined that mercuric chloride and methylmercury are possible human carcinogens.

How can mercury affect children?

Very young children are more sensitive to mercury than adults. Mercury in the mother's body passes to the fetus and may accumulate there. It can also can pass to a nursing infant through breast milk. However, the benefits of breast feeding may be greater than the possible adverse effects of mercury in breast milk.

Mercury's harmful effects that may be passed from the mother to the fetus include brain damage, mental retardation, incoordination, blindness, seizures, and inability to speak. Children poisoned by mercury may develop problems of their nervous and digestive systems, and kidney damage.

How can families reduce the risk of exposure to mercury?

Carefully handle and dispose of products that contain mercury, such as thermometers or fluorescent light bulbs. Do not vacuum up spilled mercury, because it will vaporize and increase exposure. If a large amount of mercury has been spilled, contact your health department. Teach children not to play with shiny, silver liquids.

Properly dispose of older medicines that contain mercury. Keep all mercury-containing medicines away from children.

Pregnant women and children should keep away from rooms where liquid mercury has been used.

Learn about wildlife and fish advisories in your area from your public health or natural resources department.

Is there a medical test to show whether I've been exposed to mercury?

Tests are available to measure mercury levels in the body. Blood or urine samples are used to test for exposure to metallic mercury and to inorganic forms of mercury. Mercury in whole blood or in scalp hair is measured to determine exposure to methylmercury. Your doctor can take samples and send them to a testing laboratory.

Has the federal government made recommendations to protect human health?

The EPA has set a limit of 2 parts of mercury per billion parts of drinking water (2 ppb).

The Food and Drug Administration (FDA) has set a maximum permissible level of 1 part of methylmercury in a million parts of seafood (1 ppm).

The Occupational Safety and Health Administration (OSHA) has set limits of 0.1 milligram of organic mercury per cubic meter of workplace air (0.1 mg/m^3) and 0.05 mg/m^3 of metallic mercury vapor for 8-hour shifts and 40-hour work weeks.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological profile for mercury. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Where can I get more information? For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology, 1600 Clifton Road NE, Mailstop F-32, Atlanta, GA 30333. Phone: 1-888-422-8737, FAX: 770-488-4178. ToxFAQs Internet address via WWW is http://www.atsdr.cdc.gov/toxfaq.html ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

METHYLENE CHLORIDE

CAS # 75-09-2

Division of Toxicology ToxFAQs™ February 2001

This fact sheet answers the most frequently asked health questions (FAQs) about methylene chloride. For more information, call the ATSDR Information Center at 1-888-422-8737. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It's important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Exposure to methylene chloride occurs mostly from breathing contaminated air, but may also occur through skin contact or by drinking contaminated water. Breathing in large amounts of methylene chloride can damage the central nervous system. Contact of eyes or skin with methylene chloride can result in burns. Methylene chloride has been found in at least 882 of 1,569 National Priorities List sites identified by the Environmental Protection Agency (EPA).

What is methylene chloride?

Methylene chloride is a colorless liquid with a mild, sweet odor. Another name for it is dichloromethane. Methylene chloride does not occur naturally in the environment.

Methylene chloride is used as an industrial solvent and as a paint stripper. It may also be found in some aerosol and pesticide products and is used in the manufacture of photographic film.

What happens to methylene chloride when it enters the environment?

❑ Methylene chloride is mainly released to the environment in air. About half of the methylene chloride in air disappears in 53 to 127 days.

❑ Methylene chloride does not easily dissolve in water, but small amounts may be found in drinking water.

❑ We do not expect methylene chloride to build up in plants or animals.

How might I be exposed to methylene chloride?

❑ The most likely way to be exposed to methylene chloride is by breathing contaminated air.

❑ Breathing the vapors given off by products containing methylene chloride. Exposure to high levels of methylene chloride is likely if methylene chloride or a product containing it is used in a room with inadequate ventilation.

How can methylene chloride affect my health?

If you breathe in large amounts of methylene chloride you may feel unsteady, dizzy, and have nausea and a tingling or numbness of your finger and toes. A person breathing smaller amounts of methylene chloride may become less attentive and less accurate in tasks requiring hand-eye coordination. Skin contact with methylene chloride causes burning and redness of the skin.

How likely is methylene chloride to cause cancer?

We do not know if methylene chloride can cause cancer in humans. An increased cancer risk was seen in mice

breathing large amounts of methylene chloride for a long time.

The World Health Organization (WHO) has determined that methylene chloride may cause cancer in humans.

The Department of Health and Human Services (DHHS) has determined that methylene chloride can be reasonably anticipated to be a cancer-causing chemical.

The EPA has determined that methylene chloride is a probable cancer-causing agent in humans.

How can methylene chloride affect children?

It is likely that health effects seen in children exposed to high amounts of methylene chloride will be similar to the effects seen in adults. We do not know if methylene chloride can affect the ability of people to have children or if it causes birth defects. Some birth defects have been seen in animals inhaling very high levels of methylene chloride.

How can families reduce the risk of exposure to methylene chloride?

❏ Families may be exposed to methylene chloride while using products such as paint removers. Such products should always be used in well-ventilated areas and skin contact should be avoided.
❏ Children should not be allowed to remain near indoor paint removal activities.

Is there a medical test to show whether I've been exposed to methylene chloride?

❏ Several tests can measure exposure to methylene chloride. These tests are not routinely available in your doctor's office.
❏ Methylene chloride can be detected in the air you breathe out and in your blood. These tests are only useful for detecting exposures that have occurred within a few days.
❏ It is also possible to measure carboxyhemoglobin (a chemical formed in the blood as methylene chloride breaks down in the body) in the blood or formic acid (a breakdown product of methylene chloride) in the urine. These tests are not specific for methylene chloride.

Has the federal government made recommendations to protect human health?

❏ The EPA requires that releases of methylene chloride of 1,000 pounds or more be reported to the federal government.
❏ The EPA recommends that exposure of children to methylene chloride be limited to less than 10 milligrams per liter of drinking water (10 mg/L) for 1 day or 2 mg/L for 10 days.
❏ The Food and Drug Administration (FDA) has established limits on the amounts of methylene chloride that can remain after processing of spices, hops extract, and decaffeinated coffee.
❏ The Occupational Safety and Health Administration (OSHA) has set limits of 25 parts methylene chloride per million parts of workplace air (25 ppm) for 8-hour shifts and 40-hour work weeks.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 2000. Toxicological Profile for methylene chloride. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Where can I get more information? For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology, 1600 Clifton Road NE, Mailstop F-32, Atlanta, GA 30333. Phone: 1-888-422-8737, FAX: 770-488-4178. ToxFAQs™ Internet address is http://www.atsdr.cdc.gov/toxfaq.html . ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR 2-BUTANONE

INTRODUCTION

This guideline summarizes pertinent information about 2-butanone for workers, employers, and occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** C_4H_8O
- **Structure:**

$$CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-CH_2-CH_3$$

- **Synonyms:** Ethyl methyl ketone, MEK, methyl ethyl ketone
- **Identifiers:** CAS 78-93-3; RTECS EL6475000; DOT 1193, label required: "Flammable Liquid"
- **Appearance and odor:** Clear and colorless liquid with an odor like acetone

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 72.12
2. Boiling point (at 760 mmHg): 79.6°C (175°F)
3. Specific gravity (water = 1): 0.806
4. Vapor density (air = 1 at boiling point of 2-butanone): 2.5
5. Melting point: -86.5°C (-123.7°F)
6. Vapor pressure at 20°C (68°F): 70 mmHg; at 25°C (77°F), 100 mmHg
7. Solubility in water, g/100 g water at 20°C (68°F): 25.6
8. Evaporation rate (butyl acetate = 1): 5.7
9. Saturation concentration (approximate) at 20°C (68°F): 10.2% (102,000 ppm); at 25°C (77°F), 13.2% (132,000 ppm)
10. Ionization potential: 9.48 eV

- **Reactivity**

1. Incompatibilities: Strong oxidizing agents
2. Hazardous decomposition products: Toxic vapors and gases (e.g., formaldehyde and carbon monoxide) may be released in a fire involving 2-butanone.

- **Flammability**

1. Flash point: -9°C (16°F) (closed cup)
2. Autoignition temperature: 515.5°C (959°F)
3. Flammable limits in air, % by volume: Lower, 2; upper, 10
4. Extinguishant: Carbon dioxide, dry chemicals, or alcohol foam
5. Class IB Flammable Liquid (29 CFR 1910.106), Flammability Rating 3 (NFPA)

- **Warning properties**

1. Odor threshold: 5 ppm
2. Eye irritation levels: 200-350 ppm
3. Evaluation of warning properties for respirator selection: Because of its odor, 2-butanone can be detected below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL); thus, it is treated as a chemical with adequate warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for 2-butanone is 200 parts of 2-butanone per million parts of air (ppm) [590 milligrams of 2-butanone per cubic meter of air (mg/m³)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The NIOSH REL is 200 ppm (590 mg/m³) as a TWA for up to a 10-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 200 ppm (590 mg/m³) as a TWA for a normal 8-hour workday and a 40-hour workweek; the ACGIH short-term exposure limit (STEL) is 300 ppm (885 mg/m³) (Table 1).

Table 1.—Occupational exposure limits for 2-butanone

	Exposure limits	
	ppm	mg/m³
OSHA PEL TWA	200	590
NIOSH REL TWA	200	590
ACGIH TLV® TWA	200	590
STEL	300	885

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

HEALTH HAZARD INFORMATION

• Routes of exposure

2-Butanone may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• Summary of toxicology

Effects on animals: Acute inhalation of 2-butanone by guinea pigs caused narcosis, corneal opacities, emphysema, congestion of the brain, lungs, liver, and kidneys, and death. Inhalation of 2-butanone by pregnant rats caused an increased incidence of reduced lengths and weights in offspring.

• Signs and symptoms of exposure

1. *Short-term (acute):* Exposure to 2-butanone can cause headache, dizziness, drowsiness, vomiting, and numbness of the extremities. Irritation of the eyes, nose, and throat can also occur.
2. *Long-term (chronic):* Exposure to 2-butanone can cause dryness and irritation of the skin.

RECOMMENDED MEDICAL PRACTICES

• Medical surveillance program

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety and health, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• Preplacement medical evaluation

Prior to placing a worker in a job with a potential for exposure to 2-butanone, the physician should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, liver, kidneys, and nervous and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to 2-butanone at or below the NIOSH REL (especially if exposure occurs in combination with 2-hexanone). The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include concurrent dermatitis, a history of chronic skin disease, or a history and physical findings consistent with peripheral neuropathy.

• Periodic medical screening and/or biologic monitoring

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to 2-butanone. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, liver, kidneys, and nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

• Medical practices recommended at the time of job transfer or termination

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic and laboratory tests which were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared to those expected for a suitable reference population.

• Sentinel health events

Acute SHE's include: Contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• TWA exposure evaluation

Measurements to determine worker exposure to 2-butanone should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to deter-

mine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

- **Method**

Sampling and analysis may be performed by collecting 2-butanone vapors with charcoal tubes followed by desorption with carbon disulfide and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure 2-butanone may also be used if available. A detailed sampling and analytical method for 2-butanone may be found in the *NIOSH Manual of Analytical Methods* (method number 2500).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with 2-butanone.

Workers should be provided with and required to use splash-proof goggles where 2-butanone may come in contact with the eyes.

SANITATION

Clothing which is contaminated with 2-butanone should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of 2-butanone from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of 2-butanone's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with 2-butanone should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle 2-butanone should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to 2-butanone may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for 2-butanone

Operations	Controls
During spray application of vinyl and acrylic coatings; during mixing of dye solutions; during use in laboratories	Local exhaust ventilation, personal protective equipment
During surface spreading and coating of nitrocellulose and vinyl resins; during mixing, batching, and packaging of surface coating preparations; during forced drying of furniture finishes; during dewaxing; during use as a chemical intermediate	Local exhaust ventilation
During use in the application of adhesives for artificial leather	Dilution ventilation, personal protective equipment
During preparatory formulations of lacquers; during sponge or brush application of solvent for cleaning operations; during mixing of waterproofing compounds	Personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

- **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to 2-butanone, an eye-wash fountain should be provided within the immediate work area for emergency use.

If 2-butanone gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

- **Skin exposure**

Where there is any possibility of a worker's body being exposed to 2-butanone, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If 2-butanone gets on the skin, wash it immediately with soap and water. If 2-butanone penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**
If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If 2-butanone is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing 2-butanone, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from 2-butanone vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing 2-butanone may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. 2-Butanone should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing 2-butanone may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

BIBLIOGRAPHY

• American Conference of Governmental Industrial Hygienists: "2-Butanone," *Documentation of the Threshold Limit Values and Biological Exposure Indices* (5th ed.), Cincinnati, 1986.
• American Conference of Governmental Industrial Hygienists: *TLVs® Threshold Limit Values and Biological Exposure Indices for 1987-88*, Cincinnati, 1987.
• American Lung Association of San Diego and Imperial Counties: "Taking the Occupational History," *Annals of Internal Medicine*, 99:641-651, November 1983.
• Amoore, J.E., and Hautala, E.: "Odor as an Aid to Chemical Safety: Odor Thresholds Compared with Threshold Limit Values and Volatilities for 214 Industrial Chemicals in Air and Water Dilution," *Journal of Applied Toxicology*, 3:272-290, 1983.
• Browning, E.: *Toxicity and Metabolism of Industrial Solvents*, Elsevier Publishing Co., New York, 1965.
• Clayton, G.D., and Clayton, F.E. (eds.): *Toxicology*, Vol. IIC of *Patty's Industrial Hygiene and Toxicology* (3rd rev. ed.), John Wiley & Sons, Inc., New York, 1982.
• *Code of Federal Regulations*, U.S. Department of Labor, Occupational Safety and Health Administration, 29 CFR 1910.106, 1910.134, 1910.1000, OSHA 2206, revised July 1, 1986.
• Goldman, R.H., and Peters, J.M.: "The Occupational and Environmental Health History," *Journal of the American Medical Association*, 246:2831-2836, 1981.
• Grant, W.M.: *Toxicology of the Eye* (2nd ed.), Charles C. Thomas, Springfield, Illinios, 1974.
• Halperin, W.E., Ratcliffe, J., Frazier, T.M., Wilson, L., Becker, S.P., and Shulte, P.A.: "Medical Screening in the Workplace: Proposed Principles," *Journal of Occupational Medicine*, 28(8):547-552, 1986.
• Hankinson, J.L.: "Pulmonary Function Testing in the Screening of Workers: Guidelines for Instrumentation, Performance, and Interpretation," *Journal of Occupational Medicine*, 28(10):1081-1092, 1986.
• Leidel, N.A., Busch, K.A., and Lynch, J.R.: *Occupational Exposure Sampling Strategy Manual*, U.S. Department of

Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 77-173, Cincinnati, 1977.
• Levy, B.S., and Wegman, D.H. (eds.): *Occupational Health: Recognizing and Preventing Work-Related Disease*, Little, Brown and Company, Boston, 1983.
• National Fire Protection Association: *Fire Protection Guide on Hazardous Materials* (7th ed. 6th printing), Quincy, Massachusetts, 1978.
• National Institute for Occupational Safety and Health, U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control: *Criteria for a Recommended Standard. . . .Occupational Exposure to Ketones*, DHEW (NIOSH) Publication No. 78-173, Cincinnati, 1978.
• National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control: *NIOSH Manual of Analytical Methods* (3rd ed., Vol. 1), Eller, P.M. (ed.), DHHS (NIOSH) Publication No. 84-100, Cincinnati, 1984.
• National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control: *Registry of Toxic Effects of Chemical Substances* (Microfiche Edition), Sweet, D.V., and Lewis, R.J. (eds.), Cincinnati, April 1985.
• Proctor, N.H., and Hughes, J.P.: *Chemical Hazards of the Workplace*, J.B. Lippincott Company, Philadelphia, 1978.
• Rom, W.N. (ed.): *Environmental and Occupational Medicine*, Little, Brown and Company, Boston, 1983.
• Rothstein, M.A.: *Medical Screening of Workers*, Bureau of National Affairs, Washington, DC, 1984.
• Rutstein, D.D., Mullan, R.J., Frazier, T.M., Halperin, W.E., Melius, J.M., and Sestito, J.P.: "Sentinel Health Events (Occupational): A Basis for Physician Recognition and Public Health Surveillance," *American Journal of Public Health*, 73:1054-1062, 1983.
• Scientific Assembly on Environmental and Occupational Health: "Evaluation of Impairment/Disability Secondary to Respiratory Disease," *American Review of Respiratory Diseases*, 126:945-951, 1982.
• Scientific Assembly on Environmental and Occupational Health: "Surveillance for Respiratory Hazards in the Occupational Setting," *American Review of Respiratory Diseases*, 126:952-956, 1982.

Table 3.—Respiratory protection for 2-butanone

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 1,000 ppm	Any powered air-purifying respirator with organic vapor cartridge(s) (substance causes eye irritation or damage—eye protection needed)
	Any chemical cartridge respirator with a full facepiece and organic vapor cartridge(s)
Less than or equal to 3,000 ppm	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any supplied-air respirator operated in a continuous flow mode (substance causes eye irritation or damage—eye protection needed)
	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
Planned or emergency entry into environments containing unknown concentrations or levels above 3,000 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
†The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 200 ppm (590 mg/m^3) (TWA).

METHYLENE CHLORIDE 1005

CH_2Cl_2 MW: 84.94 CAS: 75-09-2 RTECS: PA8050000

METHOD: 1005, Issue 3 **EVALUATION:** FULL **Issue 1: 15 August 1984**
Issue 3: 15 January 1998

OSHA : 25 ppm; STEL 125 ppm
NIOSH: lowest feasible; carcinogen
ACGIH: 50 ppm; suspect carcinogen
(1 ppm = 3.47 mg/m³)

PROPERTIES: liquids, d 1.323 g/mL @ 20 °C; BP 40 °C; MP -95 °C; VP 47 kPa (349 mm Hg) @ 25 °C, nonflammable

SYNONYMS: dichloromethane, methylene dichloride

SAMPLING

SAMPLER: SOLID SORBENT
(2 coconut shell charcoal tubes, 100/50 mg)

FLOW RATE: 0.01 to 0.2 L/min

VOL-MIN: 0.5 L @ 500 ppm
-MAX: 2.5 L

SHIPMENT: separate front and back tubes

SAMPLE STABILITY: ca. 30 days @ 5 °C [1]

BLANKS: 2 to 10 field blanks per set

ACCURACY

RANGE STUDIED: 1700 to 7097 mg/m³ [2]

BIAS: - 4.1%

OVERALL PRECISION ($\hat{S}_{rT}$): 0.076 [1, 2]

ACCURACY: ±15.8%

MEASUREMENT

TECHNIQUE: GAS CHROMATOGRAPHY, FID

ANALYTE: methylene chloride

DESORPTION: 1 mL CS_2

INJECTION VOLUME: 1 µL

TEMPERATURE-INJECTION: 250 °C
-DETECTOR: 300 °C
-COLUMN: 80 to150 °C at 10 °C/min

CARRIER GAS: Helium, 2.4 mL/min

COLUMN: capillary, 30 m x 0.32-mm ID, 0.25-µm film polyethylene glycol, Stabilwax, or equivalent

CALIBRATION: solutions of methylene chloride in CS_2

RANGE: 1.4 to 2600 µg per sample [1]

ESTIMATED LOD: 0.4 µg per sample [1]

PRECISION ($\bar{S}_r$): 0.026 [1]

APPLICABILITY: The working range for GC-FID analysis is 0.4 to 749 ppm (1.4 to 2600 mg/m³) for a 1-L air sample [1]. An electron capture detector (ECD) also may be used to obtain lowest feasible level of detection and quantitation [3]. Conditions for using an ECD are listed in the APPENDIX.

INTERFERENCES: No specific interferences were identified. However, any compound with a similar retention time may interfere. Alternate chromatographic columns are Carbowax-PEG and DB-1 fused silica capillary columns. The capacity of the charcoal is greatly reduced when sampling in high humidity [4].

OTHER METHODS: This revises NMAM 1005 (dated 8/15/94) [5]. If sampling in an atmosphere with high relative humidity (≥80%), a tube with larger bed of charcoal is recommended. OSHA Method 59 uses a sampler with three sorbent sections, each containing 350 mg of charcoal, and has been evaluated for a 10-L air sample at 1 ppm of methylene chloride with 80% relative humidity [4]. OSHA Method 80 uses a carbon molecular sieve sampler and GC-FID analysis, and has been evaluated at 10 ppm and 500 ppm [6].

REAGENTS:

1. Methylene chloride, chromatographic grade.*
2. Carbon disulfide, chromatographic grade. *
3. Helium, purified.
4. Hydrogen, prepurified.
5. Air, filtered.

* See SPECIAL PRECAUTIONS

EQUIPMENT:

1. Sampler: glass tube, 7 cm long, 6-mm OD, 4-mm ID, flame-sealed ends with plastic caps, containing two sections of activated (600 °C coconut shell charcoal (front = 100 mg, back = 50 mg) separated by a 2-mm urethane foam plug. A silylated glass wool plug precedes the front section and a 3-mm urethane plug follows the back section. Tubes are commercially available (SKC #226-01, Supelco ORBO-32s, or equivalent).
2. Personal sampling pump, 0.01 to 0.2 L/min, with flexible connecting tubing.
3. Gas chromatograph, flame ionization detector, integrator, and column (page 1005-1).
4. Vials, autosampler, with PTFE-lined caps.
5. Microliter syringes, 10-µL and other sizes as needed, readable to 0.1 µL.
6. Flasks, volumetric, various sizes.
7. Pipets, various sizes.

SPECIAL PRECAUTIONS: Carbon disulfide is toxic and a serious fire and explosion hazard (flash point = -30 °C). Methylene chloride is a suspected carcinogen. Wear appropriate protective clothing and work with these compounds in a well ventilated hood.

SAMPLING:

1. Calibrate each personal sampling pump with a representative sampler in line.
2. Break ends of sampling tubes immediately before sampling. Attach sampler train to personal sampling pump with flexible tubing.
3. Sample at an accurately known flow rate between 0.01 and 0.2 L/min for a total sample size of 0.5 to 2.5 L.
4. Separate the front and backup tubes to prevent migration of methylene chloride between tubes. Cap the samplers and pack securely for shipment.

SAMPLE PREPARATION:

5. Place front (along with first glass wool plug) and back sorbent sections of each tube in separate vials. Discard the foam plugs.
6. Add 1 mL of desorption solvent, CS_2, to each vial and attach crimp caps.
   NOTE: Significant heat is generated when the desorbing solution is added to the charcoal. To minimize sample loss, chill the desorbing solution before adding to the charcoal [4].
7. Allow to stand 30 min with occasional agitation to aid desorption.

CALIBRATION AND QUALITY CONTROL:

8. Calibrate daily with at least six working standards over the range of interest. Three standards (in duplicate) should cover the range from the LOD to LOQ.
   a. Add known amounts of methylene chloride to CS_2 in 10-mL volumetric flasks and dilute to the mark.
      NOTE: An internal standard such as 2-butanol or hexane can be added to the CS_2

   b. Analyze together with samples and blanks (steps 11 and 12).
   c. Prepare calibration graph (peak area or height vs. µg methylene chloride).
9. Determine desorption efficiency (DE) at least once for each lot of charcoal tubes used for sampling in the calibration range (step 8). Prepare three samplers at each of 6 levels plus three media blanks.
   a. Remove and discard back sorbent sections of sampler and media blanks.
   b. Inject a known amount of methylene chloride directly onto the front sorbent bed of each charcoal tube.
   c. Allow the tubes to air equilibrate for several minutes, then cap the ends of the tubes and allow to stand overnight.
   d. Desorb the samples (steps 5 through 7) and analyze together with standards and blanks (steps 11 and 12).
   e. Prepare a graph of DE vs. µg methylene chloride recovered.
10. Analyze three quality control blind spikes and three analyst spikes to ensure that the calibration graph and DE graphs are in control.

MEASUREMENT:

11. Set gas chromatograph according to manufacturer's recommendations and to conditions given on page 1005-1. Inject a 1-µL sample aliquot manually using solvent flush technique or with an autosampler.
    NOTE: If peak area is above the linear range of the working standards, dilute with appropriate solvent, reanalyze and apply the appropriate dilution factor in the calculations.
12. Measure peak areas.

CALCULATIONS:

13. Determine the mass, µg (corrected for DE), for methylene chloride found in the sample front (W_f) and back (W_b) sorbent sections, and in the average media blank front (B_f) and back (B_b) sorbent sections.
    NOTE: If $W_b > W_f/10$, report breakthrough and possible sample loss.
14. Calculate concentration, C, of methylene chloride in the air volume sampled, V (L):

$$C = \frac{(W_f + W_b - B_f - B_b)}{V}, \text{ mg/m}^3$$

NOTE: µg/mL ≡ mg/m³

EVALUATION OF METHOD:

The method was originally evaluated for methylene chloride (Method S329) and validated over the range 1700 to 7100 mg/m³ at 25 °C and 763 mm Hg using a 1-L sample [2, 7]. Overall precision ($\hat{S}_{rT}$) using flame ionization detection was 0.073 with a recovery of 95.3% (non-significant bias). The concentration of methylene chloride was independently verified by calibrated syringe pump. Desorption efficiency was 0.97 over the range of 1.3 mg to 5.3 mg methylene chloride per sample. Breakthrough (5% on backup section) occurred at 18.5 min when sampling an atmosphere containing 6726 mg/m³ methylene chloride at 0.187 L/min at 0% RH. The stability of methylene chloride on charcoal was not determined in the original method development.

Method 1005 was evaluated for methylene chloride using electron capture detection (ECD) [3]. Toluene was determined to be the best desorption solvent for use with ECD. Desorption efficiency was determined to be 75% at a 230 ng spiking level. After 30 days storage at 5 °C, the stability of 320 ng methylene chloride samples was determined to be 87.3% [3]. The NIOSH storage stability criterion of 90% recovery was within the 95% confidence interval of 80.9 to 93.7%.

REFERENCES:

[1] Pendergrass SM [1997]. Backup Data Report for Methylene Chloride by ECD. Cincinnati, OH: National Institute for Occupational and Health, DPSE (NIOSH)(unpublished report).
[2] NIOSH [1977]. Documentation of the NIOSH Validation Tests. S329. Cincinnati, OH: National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 77-185.
[3] NIOSH [1997]. Analytical Report for Methylene Chloride, Data Chem, NIOSH Sequence #8799-L (unpublished report).
[4] OSHA [1986]. Methylene Chloride: Method 59. OSHA Analytical Methods Manual. Salt Lake City, Utah: DOL, Occupational Safety and Health Administration.
[5] NIOSH [1994]. Methylene Chloride: Method 1005. In: Eller PM, Cassinelli ME, eds. NIOSH Manual of Analytical Methods, 4th ed. Cincinnati, OH: National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94-113.
[6] OSHA [1990]. Methylene Chloride: Method 80. OSHA Analytical Methods Manual. Salt Lake City, Utah: DOL, Occupational Safety and Health Administration.
[7] NIOSH [1977]. Method S329: Methylene Chloride. In: Taylor DG, ed. NIOSH Manual of Analytical Methods, 2nd ed., V3. Cincinnati, OH: National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 77-157-A.

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APPENDIX. MEASUREMENT CONDITIONS FOR METHYLENE CHLORIDE BY GC-ECD.

Desorption: 1 mL toluene, 30 min with agitation
Calibration: Solutions of methylene chloride in toluene
Range: 0.23 to 1.0 µg per sample (instrumental) [1]
Estimated LOD: 0.002 µg per sample [1]
Precision ($\bar{S}_r$): 0.050 at 320 µg

Analytical column, GC temperature program, and injection volume are the same as on page 1005-1.

ORGANIC AND INORGANIC GASES BY EXTRACTIVE FTIR SPECTROMETRY

3800

FORMULA: Table 1 | MW: Table 1 | CAS: Table 1 | RTECS: Table 1

METHOD: 3800, Issue 1 | **EVALUATION: FULL** | **Issue 1: 15 March 2003**

OSHA : Table 1
NIOSH: Table 1
ACGIH: Table 1

PROPERTIES: Table 1

SYNONYMS: See example compounds in Table 1

SAMPLING	
SAMPLER:	Portable direct-reading instrument (filter, if required)
FLOW RATE:	~0.1 to ~20 L/min (system-dependent)
VOL-MIN:	Instrument dependent
-MAX:	None
PRESSURE:	Extracted gases between 725 and 795 mm Hg absolute
TEMPERATURE:	Extracted gases between 10 and 30 °C
BLANKS:	Nitrogen gas, or zero air

ACCURACY	
RANGE STUDIED:	See Table 1
BIAS:	See Appendix E
OVERALL PRECISION ($\hat{S}_{r_T}$):	See Appendix E
ACCURACY:	See Appendix E

MEASUREMENT	
TECHNIQUE:	EXTRACTIVE FOURIER TRANSFORM INFRARED (FTIR) SPECTROMETRY
ANALYTE:	See Table 1 (Additional compounds may be identified/quantified according to data quality objectives and QA/QC requirements)
ANALYTICAL FREQUENCIES:	See Table 2 for example compounds
CALIBRATION:	Calibration gas standards
IDENTIFICATION:	Infrared spectra interpretation and computerized reference library searches
RANGE:	See Table 2 (dependent on compound and absorption pathlength)
ESTIMATED LOD:	See Table 2 for example values at 10-meter absorption pathlength
PRECISION ($\bar{S}_r$):	See Appendix E, 2B and 2C

APPLICABILITY: The usefulness of FTIR techniques has been demonstrated in ambient air and combustion gas mixtures [7,8]. With the participation of an experienced analyst (see Appendix A), the method can be used for the characterization of workspace air containing mixtures of volatile organic and inorganic compounds. See Table 1 for examples.

INTERFERENCES: Overlap of infrared absorption features may affect the quantification of each compound. By appropriate use of multivariable least squares analyses, the analyst may be able to obtain accurate compound concentrations for overlapping compounds.

OTHER METHODS: This method is based on portions of EPA Method 320 [1] and its addendum [2] which describe the determination of gaseous compound concentrations by extractive FTIR spectrometry. Several compatible ASTM standards describing infrared techniques and terminology are also available [3-6].

REAGENTS:

1. Nitrogen gas (N_2) or zero air, HP or better.
2. Calibration Transfer Standard (CTS) Gas, 2% accuracy or better. The proper concentration depends on both the compound used and the system absorption pathlength. For ethylene in nitrogen, a standard concentration leading to a concentration - absorption pathlength product of 100 to 400 ppm-m is recommended. (For example, a standard of 10 ppm to 40 ppm ethylene in nitrogen is recommended for a 10 meter absorption cell).
3. Liquid nitrogen* (LN_2) for cooling the infrared detector, if required.

* See SPECIAL PRECAUTIONS

EQUIPMENT:

1. FTIR spectrometer system (source, interferometer, sample absorption cell, and detector) configured with absorption. A minimum instrumental linewidth (MIL) 2 cm^{-1} or lower is recommended.
   NOTE:A lower or higher MIL may be required or suitable for specific gas matrices. Choose internal absorption cell materials to minimize surface/analyte interactions.
2. Computer system with hardware, software, and required reference spectra for acquisition, storage, and analysis of sample spectra. (A data backup system is recommended.)
3. Sampling pump, 0.1 to 10 L/min, with appropriate particulate filters.
4. Non-reactive gas regulators and sample tubing.
5. Rotameters or other devices, 20% accuracy, for measuring flow rates of sample and calibration gases.
6. Temperature measurement and/or control equipment for all sampling system elements and IR absorption cell.
   NOTE:Temperature control equipment required if ambient temp. <10 °C or >30 °C.
7. Pressure gauge for measuring absolute gas pressure in absorption cell, 5% accuracy at one atmosphere (760 mm Hg) absolute pressure.
8. For system tests (but not for normal operation): Vacuum pump and gauge capable of 100 mm Hg abs. pressure; mid-infrared attenuating filters (50% and 25%); impinger.

SPECIAL PRECAUTIONS: This method requires the use of compressed gases and/or cryogenic liquids and/or toxic chemicals. These materials are dangerous and should be handled only by experienced personnel and according to relevant safety standards. This method does not address all of the safety concerns associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to determine the applicability of regulatory limitations.

NOTE: Please refer to the Appendices for explanations of the terminology used in this document (Appendix A) and several FTIR system tests which must be completed before any testing is performed (Appendix B). Appendices C, D, and E provide (respectively) a general description of FTIR spectrometry, considerations for preparing reference libraries, and examples of calculations required for performance of this method.

PRE-TEST PROCEDURES:

The following procedures (Steps 1 and 2) may be performed only by an experienced "analyst" (see Appendix A).

1. Verify that the FTIR system has been tested for wavenumber reproducibility, minimum instrumental linewidth (MIL), absorption pathlength, system response time, residual squared area (RSA), and detector linearity as described in Appendix B. If the system is new and/or has been recently assembled and/or has been recently serviced, perform and document results of the tests described in Appendix B before proceeding.
2. Prepare a test plan. The plan must include the following:
   a. The proposed system configuration, including the absorption pathlength and integration time for sample spectra.
   b. The data quality objectives, analytical regions, and expected Limit of Detection (LOD) values for each analyte. See Table 2 and Appendix E for example values and calculations.
   c. The names of all "operators" and "analysts" to be involved in the test. Analysts must be experienced in all aspects of the test procedures listed below, and may perform any or all of the test procedures. Operators must be experienced in the performance of Steps 3 through 13 listed below, and may perform *only* those portions of the test procedures.
   d. Verification that the system configuration, existing RSA values, and related LOD values are consistent with the test's data quality objectives. (See Appendix E, Section 3.)

The following procedures (Steps 3 through 13) may be performed by an experienced operator or analyst.

3. Activate the FTIR system according to the manufacturer's instructions. Allow sufficient time for the infrared source, the infrared detector, and (if required) the temperature control systems to stabilize.
4. Verify that the computer system is programmed to store interferograms; if the available data storage capacity is insufficient for storage of all interferograms, store single beam spectra instead. Verify adequacy and performance of the (recommended) data backup system.
5. Bypassing the sampling system, flow N_2 or zero air directly into the infrared absorption cell until a stable infrared response and moisture levels are reached. Record a background spectrum using an integration time equal to or greater than that planned for subsequent sample spectra.
6. Use the entire FTIR system (including all sampling components) to record an absorbance spectrum of a sample stream of N_2 or zero air. Use the integration time planned for subsequent sample spectra. Verify that the sample flow rate meets or exceeds that specified in the system response time documentation. Examine the resulting "system zero" (SZ) spectrum and verify the absence of contaminants in the sampling system and infrared absorption cell. If contaminants are detected, clean or replace the appropriate sampling system components and/or infrared absorption cell and record a new SZ spectrum. If contaminants cannot be eliminated, the test results and LOD values may require revision during the quality control procedures (see Steps 14 through 17).

CALIBRATION:

7. Using the entire sampling system, acquire two or more pre-test CTS spectra and use them to calculate the system absorption pathlength L_S (see Appendix B, Section 1). Use the integration time planned for subsequent sample spectra. Verify that L_S is within 5% of the value quoted in the test plan. Verify that the sample temperature and pressure are within 10 to 30 °C and 725 to 795 mm Hg, respectively.
8. When possible, perform the following system checks before sampling. If necessary, they may be delayed until performance of the (post-testing) quality control procedures (see Steps 14 through 17). If performed after sampling, the results of these procedures may require revision of the test results and LODs.
   a. LOD Check. Using one of the SZ spectra, calculate the RSA values (see Appendix B, Section 2) and LOD values (see Appendix E, Section 2) in the analytical regions pertaining to the test analytes. Verify that the system pathlength, current RSA values, and current LODs are consistent with the test's data quality objectives (see Appendix E, Section 3).

b. Wavenumber Reproducibility Check. Record a preliminary workspace air sample spectrum and perform the calculations described in Appendix B, Section 3.

SAMPLING:

9. Using the integration time specified in the test plan, obtain samples and record infrared spectra of the desired ambient gases using the entire sampling system. The sampling location may be changed as desired. For tests of duration greater than 2 hours, or if the FTIR system is moved during sampling, monitor the system's single-beam response level. If changes greater than 5% in non-absorbing regions of the single beam spectrum occur, suspend sampling and record a new background spectrum (see Step 5). Sample spectra must be acquired at each sampling location for a time period no less than the system response time (see the system test documentation).
10. Repeat Step 6; acquire at least one post-test SZ spectrum of N_2 or zero air; confirm the absence of sampling system contaminates.
11. Record at least one post-test CTS spectrum (see Step 7); confirm that the system configuration and the system absorption pathlength (to within 5%) match those of the test plan.
12. (Optional) Acquire a post-test background spectrum (see Step 5).

SAMPLE ANALYSIS:

13. Using the analytical regions specified in the test plan, employ an appropriate mathematical analysis (see Appendix E) to determine preliminary analyte concentrations and their 3σ uncertainties from the sample spectra, reference spectra, absorption pathlength, and gas pressure.
    NOTE: Reference spectra for all analytes must meet or exceed the QA/QC requirements of Appendix D. The reference library must include at least one wavenumber standard spectrum and at least one calibration transfer standard (CTS) spectrum. The sample absorption due to any analyte may not exceed the maximum concentration-pathlength product represented in the reference library for that compound.

QUALITY CONTROL:

The following procedures (Steps 14 through 18) may be performed only by an experienced analyst.

14. Using one of the SZ spectra, calculate the RSA and LOD values (see Appendix E) in the analytical regions pertaining to the test analytes. Verify that the system pathlength, current RSA values, and current LODs are consistent with the test's data quality objectives. Using a suitable workspace air spectrum, perform the Wavenumber Reproducibility and Resolution tests described in Appendix B, Sections 3 and 4. If either the Wavenumber Reproducibility or Resolution results fail to meet the specifications, corrective actions are necessary (see Step 17).
15. Perform qualitative and/or quantitative analyses of the pre- and post-test SZ spectra and confirm the absence of sampling system contaminants. If contaminants are found which possess significant absorbance in any analytical region, corrective actions may be necessary (see Step 17). Perform qualitative and/or quantitative analyses of the pre- and post-test CTS spectra and confirm that the system absorption pathlength is within 5% of the value quoted in the test plan.
16. Verify that the reference spectra and results meet the data quality objectives of the test plan (see Appendix D). If they do not, corrective actions may be necessary (see Step 17). Examine the results of the quantitative sample analysis (Step 13) and verify some subset of them (including those with relatively high and relatively low concentrations) manually to ensure proper operation of analytical program. (Techniques for generating spectra representing the analytes at the concentration indicated by the analysis - "scaled spectra," as defined in Appendix A—are described in Appendix E. The analyst should generate such spectra and compare them, either visually or mathematically, to the indicated sample spectra.)
17. Corrective actions: If the results of Steps 14 through 16 indicate that the data quality objectives of the test plan have not been achieved, the analyst may perform one or more of the following actions:
    - Averaging of sequential sample spectra to reduce the residual noise area (RSA).
    - Inclusion of contaminant reference spectra in the mathematical analysis.

- Development of more accurate analyte or interferant reference spectra.
- Inclusion of reference spectra for additional compounds in the mathematical analysis.
- Exclusion from the mathematical analysis of analyte and/or interferant compounds which are clearly absent in the samples.
- De-resolution or wavenumber adjustment of the reference spectral library to match that of the sample spectra (or vice versa).
- Revision of the original data quality objectives (those included in the test plan) to levels supported by the test data.

NOTE: After performing any such corrective actions, the analyst must repeat Steps 13 through 16 and re-evaluate the LOD value for each analyte compound.

REPORTING:

18. Reporting requirements include the analyte and interferant concentrations, the concentration uncertainties, the FTIR spectrometer configuration, the sampling locations and conditions, the source(s) of the reference spectra, the CTS spectral analysis results, the results of QA/QC procedures, and certificates of analysis for all standard gases. Any variations of the test procedures and original data quality objectives from those included in the test plan should also be documented and reported. (Several of the terms used here are defined in Appendix A and described in the following Appendices. In particular, see Table D1 for a description of the FTIR spectrometer configuration parameters.)

EVALUATION OF METHOD:

Field evaluations of extractive FTIR methods have been performed for many compounds (see, for example, References 7 and 8) according to EPA Method 301 (Reference 9).

REFERENCES:

[1] U.S. EPA (proposed); Method 320 - Measurement of vapor phase organic and inorganic emissions by extractive FTIR spectroscopy; Federal Register V63 No.56, pp.14219-14228 (March 24 1998); also available (on May 19 1999) at http://www.epa.gov/ttn/oarpg/t3/fr_notices/, file frprop.pdf.
[2] U.S. EPA (proposed); Addendum to Method 320 - Protocol for the use of FTIR spectrometry for the analysis of gaseous emissions from stationary sources; Federal Register V63 No.56, pp.14229-14237 (March 24 1998); also available (on May 19 1999) at http://www.epa.gov/ttn/oarpg/t3/fr_notices/, file frprop.pdf.
[3] ASTM Designation D 6348. Standard test method for determination of gaseous compounds by extractive direct interface fourier transform infrared (FTIR) spectroscopy.
[4] ASTM Designation D 1356. Standard terminology related to sampling and analysis of atmospheres.
[5] ASTM Designation E 168. Practice for general techniques of infrared quantitative analysis.
[6] ASTM Designation E 1252. Practice for general techniques for obtaining infrared spectra for qualitative analysis.
[7] EPA – Fourier Transform Infrared (FTIR) method validation at a coal-fired boiler, available (on May 19 1999) at http://www.epa.gov/ttnemc01/ftir/reports, file r03.html.
[8] W.K. Reagen et al., Environmental Science and Technology 33, pp. 1752-1759 (1999).
[9] EPA – Validation Protocol, Method 301, available (on May 19, 1999) through links provided in the document http://www.epa.gov/ttn/emc/promgate.html.
[10] EPA FTIR Library of Hazardous Air Pollutants, available (on May 19 1999) at http://www.epa.gov/ttnemc01/ftir/data/entropy/. This library contains multiple quantitative spectra for approximately 100 compounds with 0.25 cm-1 resolution (boxcar apodization). The user must calculate spectra for the desired MIL and apodization from the interferometric data provided at the site http://www.epa.gov/ttnemc01/ftir/data/igram/ (see Reference 2, Appendix K). Some of these spectra were recorded at elevated gas temperatures and may not be suitable for quantitative workspace air analyses.

11] NIST Standard Reference Database #79. This library may be purchased through links provided at the website http://www.gases.nist.gov/spectral.htm; it contains quantitative spectra of 24 different compounds for several MILs and several apodization functions.
[12] NIOSH Pocket Guide to Chemical Hazards, US Department of Health and Human Services – Centers and Prevention for Disease Control, June 1997.
[13] 1998 TLV's and BEI's Threshold Limit Values for Chemical Substances and Physical Agents, American Conference of Governmental Industrial Hygienists.
[14] CRC Handbook of Chemistry and Physics 75th Edition, CRC Press, 1994.
[15] Griffiths PR and de Haseth JA, Fourier transform infrared spectroscopy, John Wiley and Sons (New York), 1986.
[16] Hamilton WC, Statistics in physical science, Ronald Press Company, New York, 1964, Chapter 4.
[17] "Traceability protocol for establishing true concentrations of gases used for calibration and audits of continuous emissions monitors (Protocol Number 1)," June 1978, Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III, Stationary Source Specific Methods, EPA-600/4-77-027b, August 1977.
[18] Plummer GM and Reagen WK, "An examination of a least squares fit FTIR spectral analysis method," Annual Meeting of the Air and Waste Management Association, Nashville, Tennessee, June 1996; Paper No. 96.WA65.03.

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TABLE 1. REPRESENTATIVE VOLATILE COMPOUNDS AND CHEMICAL DATA

Compound /Synonyms	CAS# RTECS	Empirical or Molecular Formula	MW[a]	BP[b] (°C)	VP[c] @ 25°C (mmHg)	Exposure Limits (ppm) [d,e,f] (ACGIH[g] / NIOSH[h] / OSHA)
Aromatic Hydrocarbons						
Benzene /benzol	71-43-2 CY1400000	C_6H_6	78.11	80.1	95.2	0.5-C / Ca[e]/10, 25-C
o-xylene	95-47-6 ZE2450000	$C_6H_4(CH_3)_2$	106.7	144.4	6.7	100 / 100/ 100
m-xylene	108-38-3 ZE2275000	$C_6H_4(CH_3)_2$	106.7	139.1	8.4	100 / 100/ 100
p-xylene	106-42-3 ZE2625000	$C_6H_4(CH_3)_2$	106.7	138.4	8.8	100 / 100/ 100
Styrene	100-42-5 WL3675000	$C_6H_5CH{=}CH_2$	104.2	145	5	20 / 50 /100, 200-C
Toluene /toluol	108-88-3 XS5250000	$C_6H_5CH_3$	92.1	110.6	28.4	50 / 100/ 200, 300-C
Aliphatic Hydrocarbons						
n-Hexane /hexyl-hydride	110-54-3 MN9275000	C_6H_{14}	86.18	68.7	151.3	50 / 50
Ketones						
Acetone /2-propanone	67-64-1 AL3150000	C_3H_6O	58.08	58	232	500 / 250
2-Butanone /methyl ethyl ketone	78-93-3 EL6475000	C_4H_8O	72.11	79.6	95	200 / 200
Alcohols						
Methanol /methyl alcohol	67-56-1 PC1400000	CH_3OH	32.04	64.5	95	200 / 200
Halogenated Hydrocarbons						
Methylene chloride /dichloromethane	75-09-2 PA8050000	CH_2Cl_2	84.94	40	349	50 / Ca[e]
Vinylidene Fluoride /1,1 difluoroethene	75-38-7 KW0560000	$F_2C{=}CH_2$	64	-85	498.9	NA[f] / 1
Trichloroethylene /TCE	79-01-6 KX4550000	$ClCH{=}CCl_2$	131.4	87	73.5	50 / Ca[e]

Compound /Synonyms	CAS# RTECS	Empirical or Molecular Formula	MW[a]	BP[b] (°C)	VP[c] @ 25°C (mmHg)	Exposure Limits (ppm) [d,e,f] (ACGIH[g] / NIOSH[h] / OSHA)
Tetrafluoroethylene /TFE	116-14-3	$F_2C=CF_2$	100	-76	>2000	5 [i]
Aldehydes						
Formaldehyde	50-00-0 LP8925000	H_2CO	30	-21	gas	0.3 - Ceiling / Ca[e]
Epoxides						
Ethylene Oxide	75-21-8 KX2450000	C_2H_4O	44	10.5	gas	1 / 5 - Ceiling
Ethers						
Tetrahydrofuran	109-99-9 LU5950000	C_4H_8O	72.1	66	165	200 / 200/200
Inorganic Compounds						
Nitrous Oxide	10024-97-2 QX1350000	N_2O	44	-53	>2000	50 / 25
Carbon Disulfide	75-15-0 FF6650000	CS_2	76.1	116	297	10/1/20
Sulfur Dioxide	7446-09-5	SO_2	64.1	-10	gas	2/2/2
Ammonia	7664-41-7 BO0875000	NH_3	17.0	-28	gas	25/25/50
Inorganic Acids						
Hydrogen Fluoride	7664-39-3 MW7875000	HF	20.0	20	783	3/3/3

[a] Molecular Weight (Obtained from References 12 - 14)
[b] Boiling Point (Obtained from References 12 - 14)
[c] Vapor Pressure (Obtained from References 12 - 14)
[d] Exposure limit as an 8-hour TWA (Time Weighted Average) in ppm (parts per million), by volume. Ceiling values denoted as "Ceiling" following limit.
[e] Ca – NIOSH listed carcinogen (See Appendix A of Reference 12)
[f] NA – TLV for this chemical not published (See Reference 13)
[g] Published 1998 ACGIH TLV (See Reference 13)
[h] Published NIOSH REL – (See Reference 13)
[I] Manufacturer's Recommended Exposure Limit

TABLE 2. REPRESENTATIVE INFRARED DATA FOR THE COMPOUNDS OF TABLE 1

NOTE: The Limit of Detection (LOD) may vary from laboratory to laboratory, analyst to analyst, instrument to instrument, and day to day. Therefore, any determination of this value should be performed under the same conditions used for sample analysis and reported only with those analyses. It is stressed that the values below are only conservative estimates of the expected performance of this method.

Compound	Analytical Region (cm^{-1})	Reference Spectrum Filename[a]	LOD at 10m[b] (ppm)	Max. conc. at 10m[c] (ppm)	Max. RSA[d] ($abs\text{-}cm^{-1}$)	Reference Spectrum Source
Aromatic Hydrocarbons						
Benzene	3000 - 3150	015mav01.spc	0.32	149	.0360	EPA[e]
o-xylene	709 - 781	171mav01.spc	0.65	150	.0444	EPA[e]
m-xylene	782 - 805	172mav01.spc	1.36	146	.0377	EPA[e]
p-xylene	749 - 840	173mav01.spc	1.17	151	.0561	EPA[e]
Styrene	738 - 944	147mav01.spc	1.84	150	.0363	EPA[e]
Toluene	701 - 768	tolmav01.spc	1.16	463	.0499	EPA[e]
Aliphatic Hydrocarbons						
n-Hexane	2778 - 3051	095mav01.spc	0.10	150	.0639	EPA[e]
Ketones						
Acetone	1163 - 1265	192mav01.spc	0.95	148	.0211	EPA[e]
2-Butanone	1127 - 1235	mekmav01.spc	0.27	463	.0233	3M[f]
Alcohols						
Methanol	941 - 1100	104mav01.spc	0.28	151	.0447	EPA[e]
Halogenated Hydrocarbons						
Methylene Chloride	701 – 789	117mav01.spc	0.31	150	.0620	EPA[e]
Vinylidene Fluoride	1080 – 1215	dfemav05.spc	0.21	25.7	.0930	3M[f]
Trichloroethylene	762 – 966	tcemav01.spc	0.43	464	.1071	3M[f]
Tetrafluoroethylene	1080 – 1215	tfemav05.spc	0.17	25.7	.0930	3M[f]

Aldehydes						
Formaldehyde[g]	2727 – 2844	087bb.spt	0.40	1125	.0267	EPA[e,g]
Epoxides						
Ethylene Oxide	3059– 3070	084mav01.spc	0.11	138	.0025	EPA[e]
Ethers						
Tetrahydrofuran	2750 - 3085	thf405.spc	0.18	41	.0782	3M[f]
Inorganic Compounds						
Nitrous Oxide	1226- 1333	n2omav01.spc	0.36	904	.0301	3M[f]
Carbon Disulfide	2109 - 2200	028mav01.spc	0.13	151	.0123	EPA[e]
Sulfur Dioxide[h]	1290 - 1410	so2.spc	0.35	~200[g]	.1394	NIST[h]
Ammonia	998 - 1131	nh3mav01.spc	0.77	470	.0363	3M[f]
Inorganic Acids						
Hydrogen Fluoride	4034 - 4206	21hfrav	0.93	15.8	0.15	3M[f]

[a] Used in LOD calculations; averaged spectra from the quoted libraries; data available from the authors.

[b] Approximate Limit of Detection (LOD) for a 10 meter absorption pathlength. Typical values of the RSA, the quoted Analytical Regions, and the quoted reference spectral data were used to calculate the LOD as described in Appendix E, Equation E1.

[c] The maximum ppm-m value available for the compound in the quoted reference spectrum source.

[d] Maximum Squared Residual Area (RSA) in the specified Analytical Regions consistent with the quoted LOD values. See Appendix E, Section 1.

[e] See Reference 10. Average absorbance and accepted standard concentration values for the low-concentration pairs of spectra were used. Interferograms were truncated to 0.5 cm^{-1} resolution and triangular apodization was employed.

[f] Data available from the authors.

[g] From EPA reference spectra recorded at 100° C (Reference 10).

[h] NIST Standard Reference Database #79 (Reference 9). The quoted maximum concentration for SO_2 is based on linearity studies of 0.5 cm^{-1} resolution spectra with triangular apodization. Non-linear absorbance leads to errors of less than 10% at 1000 ppm-m.

APPENDIX A. Terminology.

absorption cell — a structure which contains a fluid sample, but allows light to pass through a sample at known temperature, pressure, and absorption pathlength.

absorption band — a contiguous wavenumber region of a spectrum (equivalently, a contiguous set of absorbance spectrum data points) in which the absorbance passes through a maximum or a series of maxima.

absorption pathlength — the distance, measured in the direction of propagation of the beam of radiant energy, between the surface of the specimen on which the radiant energy is incident and the surface of the specimen from which it is emergent.

absorbance (units: abs) — in terms of the incident and transmitted intensities I_0 and I, the absorbance A is given by $A = -\log(I/I_0)$. From a pair of FTIR single beam spectra A (the background spectrum) and B (the sample spectrum), the sample absorbance for each wavenumber value (with index i) in the spectra is approximated by $A_i = -\log(B_i/A_i)$.

absorbance linearity — a characteristic of (ideal) absorbance spectrum; for such a spectrum, the measured absorbance is described by Beer's Law (Equation C1).

absorptivity — a measure of the fraction of the incident infrared radiation that is absorbed by a particular compound per molecule and per absorption pathlength; see equation C1.

analytical region — a contiguous wavenumber region (equivalently, a contiguous set of absorbance spectrum data points) used in the quantitative analysis for one or more analytes. Note: The quantitative result for a single analyte may be based on data from more than one analytical region.

analyst — a person familiar with and experienced in performance of all aspects of this FTIR-based method. Analysts may perform any portion(s) of the method, and must perform certain portions of the method (see also "operator").

analyte — a compound whose concentrations in a sample is of interest and must be accurately quantified (see also "interferant").

aperture — an optical device which physically restricts the diameter of the optical beam.

apodization — modification of the interferogram through its multiplication by a weighing function whose magnitude varies with the position of the interferometer's moving element.

background spectrum — the single beam spectrum obtained with all system components and without sample present (or in the presence of a non-absorbing gas replacing the sample).

baseline — any line (or smooth function of wavenumber) drawn on an absorption spectrum to establish a reference point that represents a function of the radiant power incident on a sample at a given wavelength.

Beer's Law — the direct proportionality of the absorbance of a compound in a homogeneous sample to its concentration. See Equation C1, which also describes the more general case of gas mixtures.

calibration transfer standard (CTS) gas — a gas standard of a compound used to measure the sample absorption pathlength; see Step 7, Step 11, Appendix B (Section 1), and Appendix D, (Section 5).

cm^{-1} — see wavenumber

compound — a substance possessing a distinct, unique molecular structure.

concentration — the quantity of a compound contained in a unit quantity of sample. The unit "ppm" (number, or mole, basis) is recommended, and is equivalent to the volume basis for ideal gases.

concentration-pathlength product (CCP) — the mathematical product of concentration of the species and the

absorption pathlength. For reference spectra, this is a known quantity; for sample spectra, it is the quantity directly determined from Beer's Law. The units "ppm-meters" (ppm-m) are recommended.

data quality objectives — parameters pertaining to a certain application of this method, including the estimated LOD values for each compound.

de-resolve — to form spectra of lower resolution (higher FWHM) from spectra of higher resolution (lower FWHM); see Reference 2 (Appendix K) and Reference 11 for de-resolution procedures and programs.

detector linearity — a characteristic of an (ideal) IR detector; for such a detector, the measured detector output voltage, when plotted against the total IR in a broad-band IR signal incident on the detector, would form a straight line.

double beam spectrum — a transmittance or absorbance spectrum derived by dividing the sample single beam spectrum by the background spectrum.

> Note: The term "double-beam" is used elsewhere to denote a spectrum in which the sample and background interferograms are collected simultaneously along physically distinct absorption paths. Here, the term denotes a spectrum in which the sample and background interferograms are collected at different times along the same absorption path.

extractive — the type of spectroscopy which includes extracting and transporting a sample stream from gases at a certain location to an absorption cell, and isolating the sample in the absorption cell for analysis. Other types of spectroscopy in which the sample is not isolated in an absorption cell include “remote”, “open path”, and “local open path” techniques.

filter — (1) A device made of inert materials which physically removes solid and liquid phase particles from a gas stream. (2) An optical device which transmits some fraction of the radiation incident on it; “neutral density” and “mesh” filters transmit an approximately constant fraction of the incident radiation at all wavelengths over a specified wavelength range.

FFT (Fast Fourier transform) — a discrete (digital) approximation to an FT (Fourier transform; see below) involving the factoring of the original data into sparse matrices containing mostly zeros.

FT (Fourier transform) — the mathematical process for converting an analytical (non-discrete) amplitude-time function to an amplitude-frequency function, or vice versa.

FTIR (Fourier transform infrared) spectrometer — an analytical system that employs a source of mid-infrared radiation, an interferometer, an enclosed sample cell of known absorption pathlength, an infrared detector, optical elements that transfer infrared radiation between components, and a computer system. The time-domain detector response (interferogram) is processed by a Fourier transform to yield a representation of the infrared power vs. infrared frequency. See Figures C1 and C2.

FTIR spectrometry — use of an FTIR system to perform quantitative measurements.

FTIR system — the combination of an FTIR spectrometer and a sample interface.

FTIR system configuration — the set of parameters required to reproduce, as closely as possible, results from a particular FTIR system at a later time. This set includes (at least) the nominal MIL, the absorption pathlength, the apodization function, the gas temperature, the gas pressure, the zero filling factor, the measured wavenumbers of specific water absorption bands, the sources of the reference library spectra, the integration time, the detector type and serial number, the detector gain (including hardware and software settings).

FTIR system response time — the minimum time required for the output of an FTIR system to accurately reflect a sudden change in the sample gas composition; see Appendix B, Section 5.

frequency, ν — the number of cycles per unit time; for light, $\nu = s/\lambda$, where s is the speed of light and λ is the light’s wavelength. Unlike the speed and wavelength, which are medium-dependent, the frequency of light is independent of the medium through which the light travels. The term “frequency” is often used to

denote the wavenumber (**w**, cm^{-1}) in FTIR spectroscopy because (in a given medium) the wavenumber is proportional to the frequency ν . (See Appendix C, Section 4, and "wavenumber" in this Appendix.)

full-width-half-maximum (FWHM) — for a single, symmetric absorption band, the full width of the band (in cm-1) between its 50% relative maximum absorption levels.

impinger — a device constructed of inert materials which passes a gas stream through a liquid phase.

infrared source — a device which emits a pattern, stable in intensity and wavelength profile, of infrared radiation over a wide range of infrared wavelengths. High temperature filaments or ceramic elements, in conjunction with appropriate focusing optics, are often employed.

infrared detector — a device which (ideally) produces a voltage proportional to the total infrared power incident on it. Examples are 1) the mercury-cadmium-telluride (MCT) detector, which requires cooling (and is often cooled to liquid nitrogen temperature), and 2) the deuterated triglycine sulfate (DTGS) detector, often operated at ambient temperature.

interferogram — record of the IR detector's response to the modulated component of the interference signal measured as a function of retardation.

interferometer — device that divides a beam of radiant energy into two or more paths, generates an optical path difference between the beams, and recombines them in order to produce repetitive interference maxima and minima as the optical retardation is varied.

integration time — the total time over which the interferometric results of single scans are averaged to produce an interferogram (and its subsequent single- and double-beam spectra). Most software packages allow selection of the number of scans rather than the integration time. The integration time is approximately equal to (but is always less than) the time interval over which the selected number of scans is actually executed.

interferant — a compound whose presence in a sample spectrum must be taken into account to accurately determine one or more analyte concentrations, but whose concentration need not be accurately determined.

least squares fitting (LSF) algorithm — a calculation whereby one or more compound concentrations are estimated from a sample spectrum by minimizing the squared error in Beer's Law within a defined analytical region (see Equations C1 through C6).

limit of detection (LOD, ppm) — for a defined FTIR system configuration and sample matrix, an estimate of the lowest detectable concentration of a specific analyte based on the FTIR system's RSA and the analyte's integrated absorbance for a selected analytical region.

line — see absorption band

linewidth — see full-width-half-maximum (FWHM) and minimum instrumental linewidth (MIL).

metering valve — a gas valve allowing reproducible adjustments of a gas stream flow rate on the order of 2% of the valves full flow rate.

mid-infrared (MIR) — the region of the electromagnetic spectrum from approximately 400 to 5000 cm-1.

minimum instrumental linewidth (MIL) — for a given FTIR spectrometer and FTIR system configuration, the minimum measured FWHM for any absorption band. In wavenumbers, the MIL is often estimated as the reciprocal of the retardation expressed in centimeters. The MIL depends on the choice of apodization function, and is often larger than the MIL estimated from the retardation.

multi-pass cell — an absorption cell which uses mirrors to pass the infrared radiation through the gas sample more than once; this leads to an absorption pathlength larger than the physical length of the cell (see also "White cell").

mm Hg — a measure of pressure difference which results in the vertical displacement of a column of liquid

mercury by one millimeter. A pressure difference of one atmosphere (atm) is equal to 760 mm Hg, to 1.01 x 10^5 Pascals (Pa), and to 14.7 pounds per square inch (psi).

operator — a person familiar with and experienced in performance of only some aspects of this FTIR-based method. Operators may perform many portions of this method, but specific portions of the method (see above) must be performed by an “analyst”.

peak — see absorption band

qualitative analysis — examination of sample spectra to determine the presence or absence of particular compounds in a sample.

quantitative analysis — estimation of the actual concentrations of a specific set of compounds using a specific set of analytical regions.

reference spectra — absorption spectra of gases with known chemical compositions, recorded at a known absorption pathlength, which are used in the quantitative analysis of gas samples.

relative wavenumber accuracy (RWA, %) — the percent difference in wavenumber values measured by an FTIR spectrometer relative to a reference library standard. The RWA is estimated through spectral comparisons of the wavenumbers of two isolated water vapor absorption. See Appendix B, Section 3.

residual squared area (RSA) — a measure of the noise (random and systematic) and/or spectral artifacts for an absorbance spectrum in some analytical region; see Appendix B, Section 2 for a mathematical definition. The RSA can be used to estimate the LOD for a given compound measured with a given FTIR system configuration.

retardation — optical path difference between two beams in an interferometer; also known as "optical path difference" or "optical retardation." In the case of a standard Michelson interferometer, the retardation is simply twice the distance moved by a mirror in the interferometer during a scan.

rotameter — a device indicating the volumetric flow rate of a gas by the vertical displacement of an object suspended by the gas stream.

sampling location — the point in space at which sample gases enter the sample interface.

sample interface — that part of the FTIR system which comes in contact with the sample and/or calibration gases. It includes the sample probe, sample filter, sample line, sample pump, gas valves, internal surfaces of the absorption cell, pressure gauge, sample rotameter, the vent lines, and the calibration components (gas cylinders, regulators, and rotameters).

scaling — application of a multiplicative factor to the absorbance values in a spectrum.

scan — digital representation of the detector output obtained during one complete motion of the interferometer's moving assembly or assemblies.

single beam spectrum — Fourier-transformed interferogram, representing the relative detector response vs. wavenumber.

> Note: The term "single-beam" is used elsewhere to denote any spectrum in which the sample and background interferograms are recorded on the same physical absorption path; such usage differentiates such spectra from those generated using interferograms recorded along two physically distinct absorption paths (see "double-beam spectrum" above). Here, the term applies (for example) to the two spectra used directly in the calculation of transmittance and absorbance spectra of a sample.

system zero (SZ) spectrum — the absorbance spectrum of a non-absorbing gas (nitrogen or zero air) acquired using those portions of the sampling interface used to acquire actual sample gases.

transmittance, T — the ratio of radiant power transmitted by the sample to the radiant power incident on the

sample. Estimated in FTIR spectroscopy by forming the ratio of the single-beam sample and background spectra; often presented in %T (100 x T) in spectral representations.

uncertainty — a mathematical quantity determined in a least-squares fitting procedure, used to estimate the likely error in the determination of the sample concentration in a procedure; see Equations C1-C6.

wavelength λ, — the physical distance between successive maxima in the electromagnetic waves which comprise light. The wavelength and speed of light depend on the medium through which the light travels.

wavenumber, **w** — the reciprocal of the wavelength, also the number of wavelengths of light per unit length, usually expressed in the units cm^{-1}. As is true of both the speed and wavelength of light, the wavenumber is dependent on the medium through which the light travels. (See Appendix C, Section 4, and "frequency" in this Appendix.)

wavenumber adjustment — reassignment of the cm^{-1} values associated with single- and/or double beam spectra. Adjustments may be made locally by shifting or stretching the wavenumber scale, or globally stretched by changing the laser wavenumber during the FFT.

White cell — alternate name for a "multi-pass" absorption cell (see above) indicating its inventor.

zero filling — the addition of zero-valued points to the end of a measured interferogram. In most computer programs, specification of a zero filling "factor" of N results in an interferogram with N times as many points as the original interferogram.

APPENDIX B. System Tests.

These procedures must be conducted at least once on new or significantly altered (by replacement of components, dis- and reassembly, etc.) systems. The tests described in Sections B2 and B4 must also be repeated during either the pre-test preparations or quality assurance procedures. In all cases, activate the FTIR system and allow sufficient time for the infrared source, the infrared detector, and (if required) the temperature control systems to stabilize before proceeding.

B1 Absorption pathlength

Obtain one or more absorbance spectra of a calibration transfer standard (CTS) gas (ethylene at 200 to 300 ppm-meters is recommended) at the gas temperature and pressure of a reference CTS spectrum of the same compound. For each spectrum, calculate the indicated absorption pathlength according as

$$L_S = \frac{L_R P_R A_S}{P_S A_R} \qquad \text{Equation B1}$$

where

L_S = pathlength indicated by the sample CTS spectrum (meters).
L_R = pathlength of the reference CTS spectrum (meters).
A_S = area of the reference CTS spectrum (abs cm^{-1}).
A_R = area of the reference CTS spectrum (abs cm^{-1}).
P_S = pressure of the sample CTS spectrum (mm Hg).
P_R = pressure of the reference CTS spectrum (mm Hg).

When multiple CTS spectra are available, assign to L_S the mean of the single-spectrum L_S results. The reference CTS spectrum pathlength and concentration used must be based on multiple, high-quality gas standards and physical length measurements (see Appendix D, Section 5). The analyst must document criteria for the selection of the analytical region and any baseline correction procedures employed.

B2 Residual Squared Area

Note: If the following calculations are performed during testing or as part of the QC procedures (steps 14 through 17), perform them using a workspace air spectrum instead of the "water vapor (absorbance) spectrum" described in the two paragraphs below.

Use the integration time selected for field testing in recording the spectra described below. Record a background spectrum of dry N_2 gas or zero air. Using a suitable impinger, humidify the N_2 or zero air stream and record a single-beam spectrum at an absolute pressure between 725 and 795 mm Hg. Form the absorbance spectrum of this water vapor sample from the single beam spectra. Assign the spectrum a unique filename and save it for the calculations described below.

From this water vapor spectrum, subtract a scaled spectrum (see Appendix A) formed from the water vapor reference spectrum to be used in subsequent quantitative analyses. The scaling factor may be varied to minimize the absorbance in the resulting difference spectrum in the various analytical regions to be used in the analyses. Subtract a constant offset, a linear function, or a quadratic function from the difference spectrum in each analytical region to form a residual spectrum R for each region. For each residual spectrum R with discrete absorbance value R_i for i = p to q, in the wavenumber range w_p to w_q, the residual squared area (RSA) is defined as:

$$RSA = \frac{[w_p - w_q]}{q - p + 1}\sqrt{\sum_{i=p}^{i=q}\frac{(R_i)^2}{q-p}}$$ Equation B2

The RSA has the dimensions (abs cm^{-1}), and serves as a measure of the integrated absorbance of spectral noise and water subtraction artifacts over the analytical region. The RSA is compared to the total absorbance of a compound in the same region to estimate the LOD for the compound in that region (see Appendix D, Section 9 and Appendix E, Section 1).

The calculation described above assumes that water is the only significant infrared absorber in the samples besides the analytes, and that only one analyte absorbs in any analytical region. If other analytes or interferants are present, a more conservative RSA may be estimated by adding the absorbance of the additional compounds to the difference spectrum using a set of suitable reference spectra, then subtracting their absorbance using a *different* set of reference spectra.

B3 Minimum Instrumental Linewidth (MIL)

Evacuate the absorption cell to a pressure below 100 mm Hg and record a background spectrum. Obtain a workspace air sample at an absolute pressure of approximately 300 mm Hg. Record the absorbance spectrum of this low-pressure sample. Measure at the FWHM (full width at half maximum) linewidth, in absorbance, of at least two isolated water vapor lines (for example, the lines near 1918 cm^{-1} and 2779 cm^{-1}). The MIL is the mean of these FWHM measurements.

B4 Wavenumber Reproducibility

Note: If this calculation is performed during testing or as part of the QC procedures (see Steps 6 and 10), perform these determinations using a workspace air spectrum instead of the water vapor absorbance spectrum described in Section B2.

Using a water vapor spectrum recorded as described in Section B2, determine the center wavenumber values w_{S1} and w_{S2} of two isolated water vapor absorption features; the peaks near 1918 cm^{-1} and 2779 cm^{-1} are suggested, though any other pair of isolated lines separated by 500 cm^{-1} or more is suitable. Compare these results to those center wavenumber values w_{R1} and w_{R2} and for the same absorbance features in the water vapor wavenumber standard associated with the reference library to be used in quantitative analyses as follows: Calculate the relative wavenumber accuracy (RWA) in percent for each of the two absorption bands according to

$$RWA = ABS(w_{Ri} - w_{Si})$$ for i = 1, 2. Equation B3

Compare the maximum of these two values to the MIL for the FTIR system (see Section B3). If the ratio ***RWA/MIL*** exceeds 2%, adjustment of the wavenumber scale for the sample spectra may be required.

Mathematical wavenumber adjustments may be made locally by shifting or stretching the wavenumber scale, or globally stretched by changing the laser wavenumber during the FFT. However, large shifts (on the order of 5% or more of the MIL) indicate that the system requires physical adjustments, such as re-alignment of the laser system responsible for control of the interferometer's moving element. In addition, mathematical wavenumber adjustments require some sort of interpolation procedure in conjunction with the quantitative spectral analysis, and those procedures may result in spectral mismatches whose effects on the accuracy of the analysis are not easily quantified.

The necessity of such wavenumber adjustments depends, in part, on the widths of the absorption peaks of the compounds involved in the spectral analysis. Because many of the absorption bands of water — a nearly ubiquitous interferant in workspace air IR analysis — are very narrow, an accurate analysis usually requires the relatively stringent limits placed above on the RWA to MIL ratio. However, it is possible to obtain accurate results when this ratio exceeds the recommended limit, especially when only broad absorbance features are actually employed. The analyst may choose

to approve analytical results obtained when this ratio exceeds the recommended limit.

B5 System Response Time

Direct N_2 or zero air through the entire sample interface and record spectra at approximately 30 second intervals. Abruptly replace the N_2 or zero air gas flow with CTS gas and continue to record spectra. The system response time is the subsequent time required for the FTIR system to generate an absorbance spectrum in which the CTS compound's calculated concentration reaches 95% of the final (stable) concentration value indicated in later spectra.

B6 Detector Linearity

For the chosen optical configuration, attenuate the power incident on the detector by either 1) modifying the aperture setting or 2) placing filters (neutral density or mesh) in the infrared beam path (see Figure A1). At approximately 100%, 50% and 25% of the system full IR power level, collect pairs of background and CTS spectra. Compare the areas of the CTS bands for the three spectra and verify that they are equal to within 5% of their mean value. If they are not, apply software linearization corrections to the interferometric data according to the manufacturer's instructions. If this option is unavailable, it is necessary to either 1) characterize the system non-linearity and/or apply appropriate concentration corrections or 2) operate the system with attenuation sufficient to ensure linear detector response.

APPENDIX C. General Description of FTIR Spectrometry.

C1. FTIR Spectrometer Components

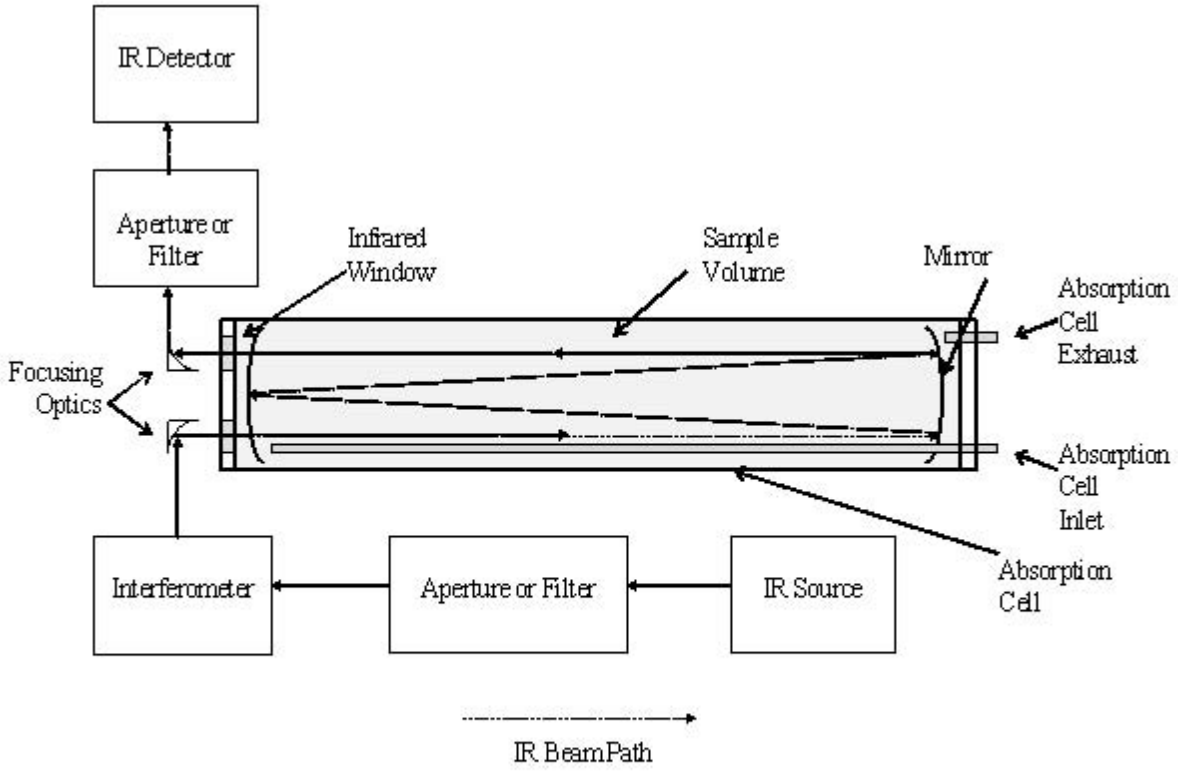


Figure C1. FTIR Spectrometer Components and Beam Path

Figure C1 illustrates the basic FTIR spectrometer configuration required for gas phase analyses. The infrared radiation emitted by the infrared (IR) source contains energy at all wavelengths between 2.0 and 20 microns; this is the portion of the electromagnetic spectrum usually referred to as the "mid-infrared" (MIR). In the units typically employed in FTIR spectroscopy (wavenumbers, or cm^{-1}), this is the wavenumber range 5000 to 500 cm^{-1}. The IR radiation passes through an interferometer, where the motion of an optical element - usually a mirror - optically modulates the infrared beam. The modulated IR beam then enters an absorption cell through a window (typically made of KBr or ZnSe) and interacts with the gases of interest. The physical length over which this interaction takes place is the "absorption pathlength." In "multi-pass" (or "White") absorption cells, mirrors within the cell direct the IR beam through the sample gas many times; in such cells, the absorption pathlength can be from 4 to 50 (or more) times the cell's physical length. (A larger absorption pathlength generally leads to greater sensitivity.) The IR beam then exits the sample cell via a second window and is re-focused onto an IR detector. Because this extractive technique requires the transport of gas samples through the FTIR absorption cell, the design and integrity of the sampling system is of great importance. It is also important that the sampling system allow the operator to perform all the necessary calibration and sampling procedures without compromising the speed and flexibility of the analytical system. Figure C2 illustrates a sampling system configuration that meets these requirements, though other configurations are possible. A computer controls the actions of the interferometer and records the voltage output of the IR detector throughout the motion of the interferometer's optical element. Ideally, the detector voltage is proportional to the total power in the IR beam. The computer must accurately record the detector voltage as a function of the position of the moving element in the interferometer, so a secondary, laser-based optical system is usually used to measure the moving element's position very precisely. In most circumstances, the motion of the mirror or other optical element is repeated many times, and the resulting individual "scans" are

"co-added" (averaged) to reduce the system's residual noise area (RSA). A plot of the resulting IR power-vs.-position signal, referred to as an interferogram, is shown in Figure C3. This interferogram is the co-added result of 64 scans with only nitrogen gas (and some low level of water vapor) present in the absorption cell. Nitrogen is one of the few compounds which does not interact with infrared radiation, so this interferogram very closely represents the fundamental FTIR system response in the absence of a sample. Note that the signal is relatively large near the beginning of the interferogram, where the "zero phase difference (ZPD) burst" is located. The ZPD is often used to rapidly obtain an estimate of the IR signal strength during alignment of the optical system.

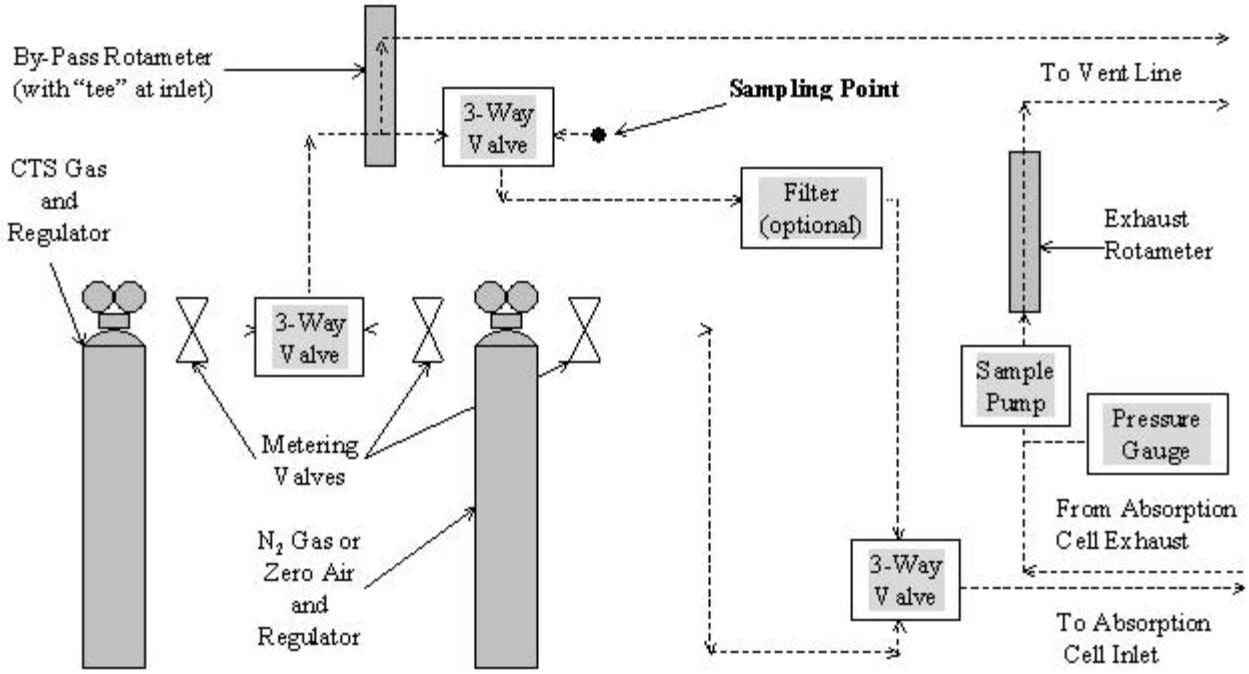


Figure C2. Sampling Components and Sample Paths

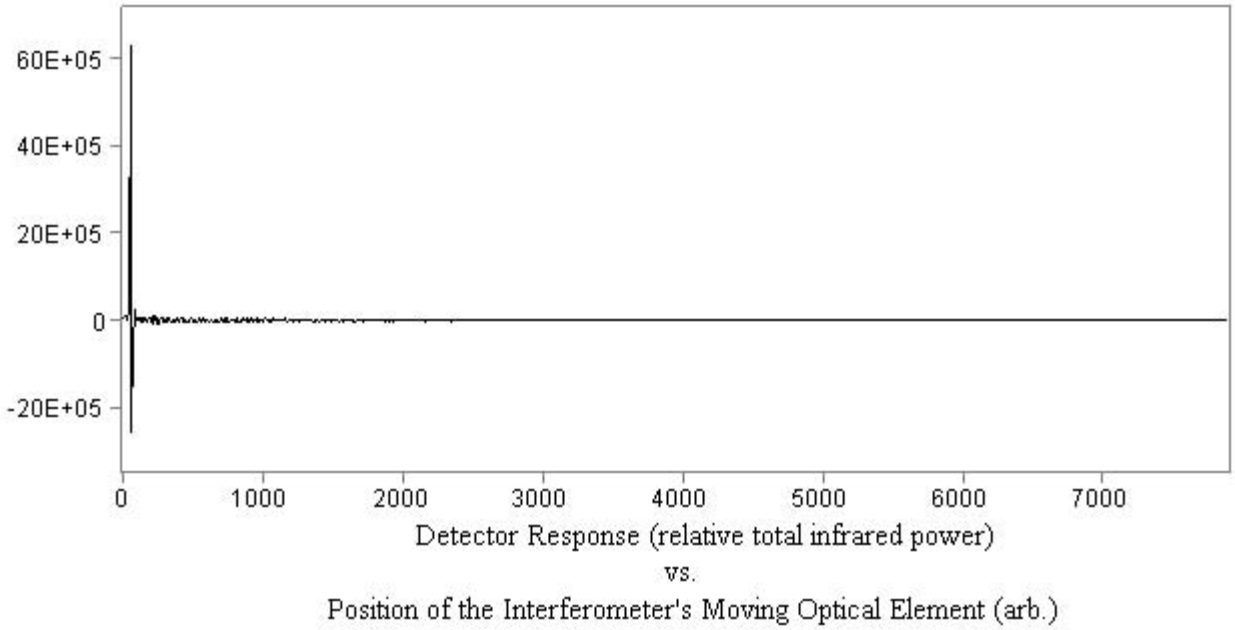


Figure C3. Mid-Infrared Interferogram

C2. The Fast Fourier Transform (FFT)

Every data point in the interferogram contains intensity information about every infrared wavelength transmitted from the source to the detector. It is possible to recover the intensity information as a function of wavelength through application of a Fast Fourier Transform (FFT), from which the FTIR technique's name is derived. This digital transformation of the interferogram can be thought of as the mathematical inverse of the optical modulation applied to the infrared beam as it passes through the interferometer. Its function is similar to that of the human brain and ear, which provide intensity information (loudness) versus wavelength (pitch) for complex signals (sound waves) incident on the eardrum. (Note that, as for an interferogram, each point in a complex sound wave contains intensity information about every pitch contained in the wave. Yet the ear and brain allow a symphony audience to immediately perceive, for instance, that the piccolo is playing very loudly while the tuba is playing very quietly.) Reference 15 (Chapter 3) provides a complete mathematical description of the FFT.

C3. Instrument Resolution, Apodization Function, and Minimum Instrumental Linewidth (MIL)

Most software packages supplied with FTIR systems provide several options associated with the collection of data and application of the FFT. These typically include - at least - the nominal "instrument resolution" (specified in cm^{-1}) and the "apodization function" (e.g., "Boxcar" and "Triangular"). These parameters are very important in quantitative spectroscopy, and are addressed in turn below.

The instrument resolution is the most fundamental and important instrument parameter. It specifies the nominal minimum full-width-at-half-maximum (FWHM, in cm^{-1}) of any spectral "peak" (or "line") in the final instrument output. Every FTIR instrument has a minimum FWHM determined by the maximum distance traversed by the interferometer's moving element during a single scan. (For the basic Michelson interferometer, the FWHM in cm^{-1} is equal to $(2d)^{-1}$, where d is the distance in cm traversed by a moving mirror during a scan.) Clearly, instruments with low FWHM provide more spectral information than instruments with higher FWHM capability. However, this additional information comes at high costs associated with the design, construction, size, mechanical stability, portability, speed, and residual noise area (RSA) of the instruments.

It is important to recognize the two uses of the word “resolution” in the nomenclature used to describe FTIR spectrometers: Instruments of high resolving power, or “*high* resolution,” provide spectral features of *low* FWHM; when the nominal resolution is specified in units of cm^{-1}, a *lower* cm^{-1} specification corresponds to *higher* resolving power, or “higher resolution”. Most commercially available FTIR spectrometers suitable for field use provide FWHM values greater than or equal to 0.5 cm^{-1} -— that is, they are systems whose nominal spectral resolution is specified as a number higher than 0.5 cm^{-1}. Most of the instruments capable of higher resolution (lower FWHM) are suitable for use only in very stable laboratory environments.

Standard FTIR operating software always provides options for recording spectra with FWHM values higher than the instrument's actual lower FWHM limit. These options simply move the mirror (or other optical element) through only some fraction of its maximum possible travel. Operating the instrument in this manner results in larger FWHM values ("lower" resolution, and shorter interferograms) than the instrument is mechanically capable of providing. Spectra of lower resolution (higher FWHM) provide less information, but can be generated more quickly and, in most cases, with lower RSA than spectra of higher resolution.

The instrument operator can also choose the apodization function to be used in the generation of FTIR spectra. Apodization is a mathematical alteration of the interferogram that can be performed before application of the FFT. Several standard alteration functions have been devised, and each affects the final absorption spectrum of the sample gas in a different way. As with the selection of instrument resolution, each choice has its advantages and drawbacks. The simplest choice, known as the "boxcar apodization" function, results in the lowest FWHM but also in relatively low S/N ratio. (Spectra generated with the boxcar function are often referred to as “unapodized” spectra.) Other choices (triangular, Norton-Beer, and several other apodization functions) provide higher S/N ratio at the cost of higher FWHM values and other tradeoffs in quantitative spectroscopy. Reference 15 provides a more thorough description of the characteristics of various apodization functions.

For a given instrument configuration — which includes the nominal spectral resolution and the choice of apodization function — every FTIR system is capable of generating absorption bands with a minimum instrumental linewidth (MIL). Unlike the actual spectral resolution (which has several accepted physical

definitions — see Reference 15, Chapter 1, Section IV) and nominal spectral resolution parameters, the MIL is a parameter which is readily measured to the accuracy required for practical applications of FTIR spectrometry. It can be measured using the water absorption bands present in low-pressure workspace air samples (see Appendix B, Section 3).

C4. Single Beam Spectra

The mathematical result of the FFT (applied to an apodized IR interferogram) is a called a single beam spectrum. Single beam spectra represent the infrared power transmitted through the FTIR spectrometer as a function of the infrared "wavenumber" **w**, which is usually expressed in the units of reciprocal centimeters (cm^{-1}). The wavenumber is actually a measure of the frequency, rather than the wavelength, of the infrared radiation. In a vacuum, the wavelength and frequency are related through the equation $\nu = s/\lambda$, where λ is the wavelength (cm), ν is the frequency (sec^{-1}, or Hz), and s(cm/sec) is the speed of light, equal to $2.99792954 \times 10^{10}$ in a vacuum. In these units, the wavenumber in cm^{-1} is given by the equation $\mathbf{w} = 1/\lambda = \nu / s$. Figure C4 presents the single beam spectra for two samples consisting mainly of nitrogen gas ($\geq$99%) but with different concentrations ($\leq$ 1%) of water vapor. The vertical scales of the two spectra are nearly identical, but they have been offset for clarity. The detected infrared power in certain wavenumber regions is clearly lower in the high moisture sample, indicating both the qualitative nature and strength of water's absorption of infrared radiation.

C5. Double-Beam Spectra - Transmittance and Absorbance

Combinations of pairs of single beam, such as the pair of spectra S and B shown in Figure C4, are referred to as double beam spectra; they provide the quantitative basis for FTIR spectroscopy. One type of double

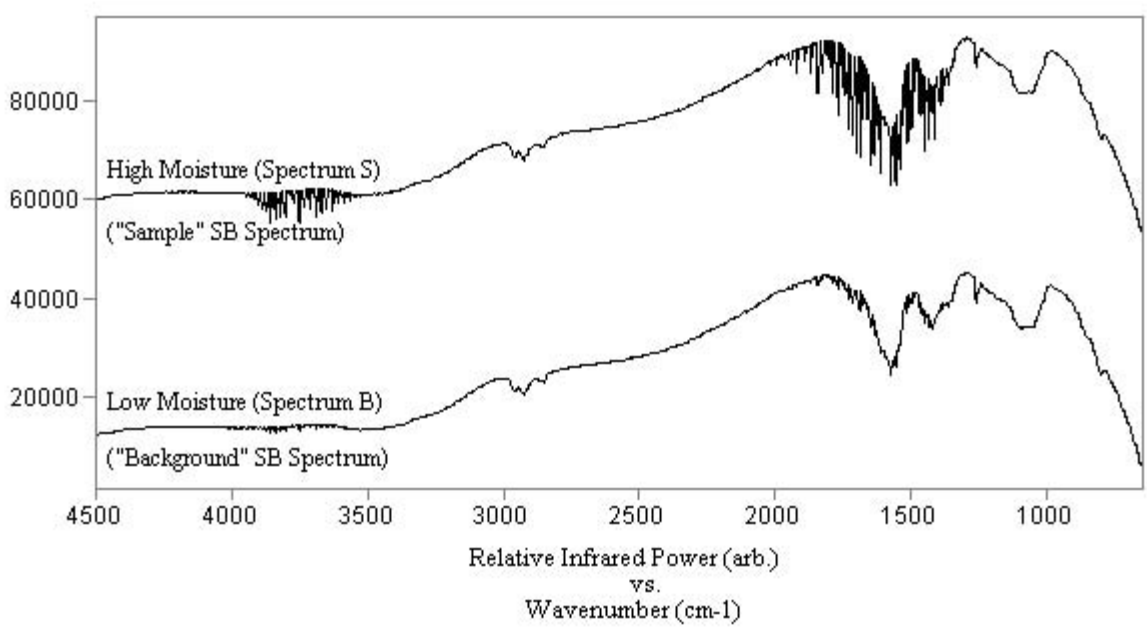


Figure C4. Single Beam Spectra of N2 at Different Moisture Levels

beam spectrum is the transmittance. The percent transmittance of a sample gas possessing the single-beam spectrum S — with respect to the background single-beam spectrum B — is defined as T(%) = 100 * S/B ; a transmittance value is defined for each wavenumber value of the two spectra. If the background spectrum B closely represents the response of the FTIR system to a transparent sample, then the percent transmittance T closely approximates the percentage of the infrared radiation transmitted by the sample (represented by the spectrum S). Because water is the only absorbing compound present in the single-beam spectrum B, the spectrum T (shown in Figure C5) closely approximates the percent transmittance spectrum of water.

The same pair of spectra define the (double beam) absorbance A of the sample through the equation $A = -\log_{10}(S/B)$. The absorbance spectrum of water, as approximated by the two single-beam spectra S and B, is shown in Figure C6. The absorbance is the desired quantity because it appears in the general linear absorption model known as Beer's Law (see below).

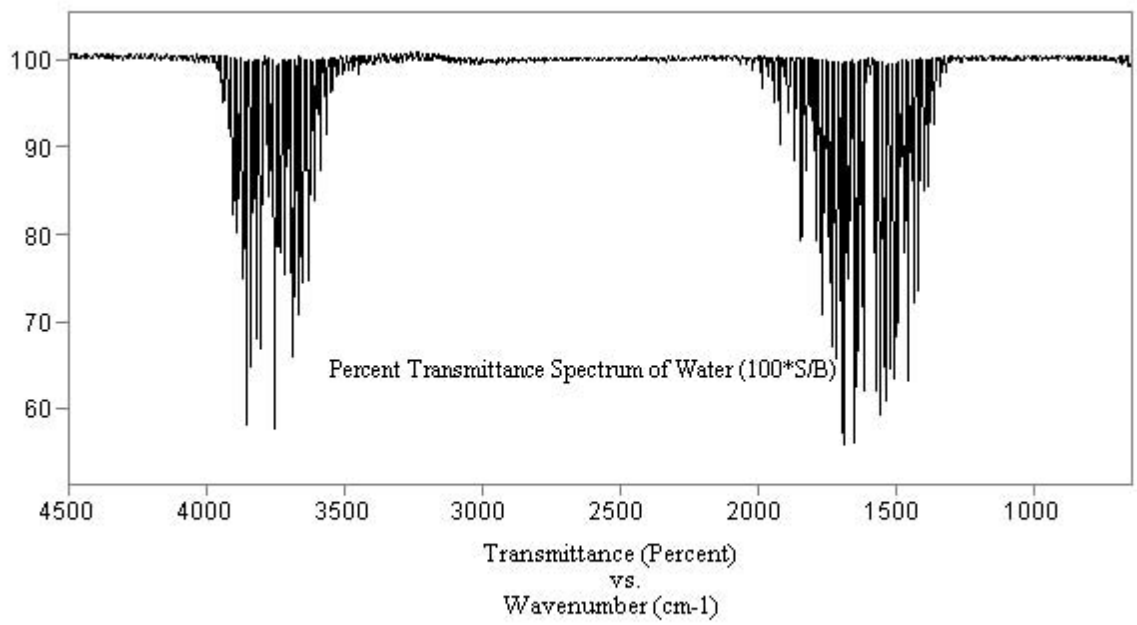


Figure C5. Double Beam Transmittance Spectrum of Water

C6. Beer's Law

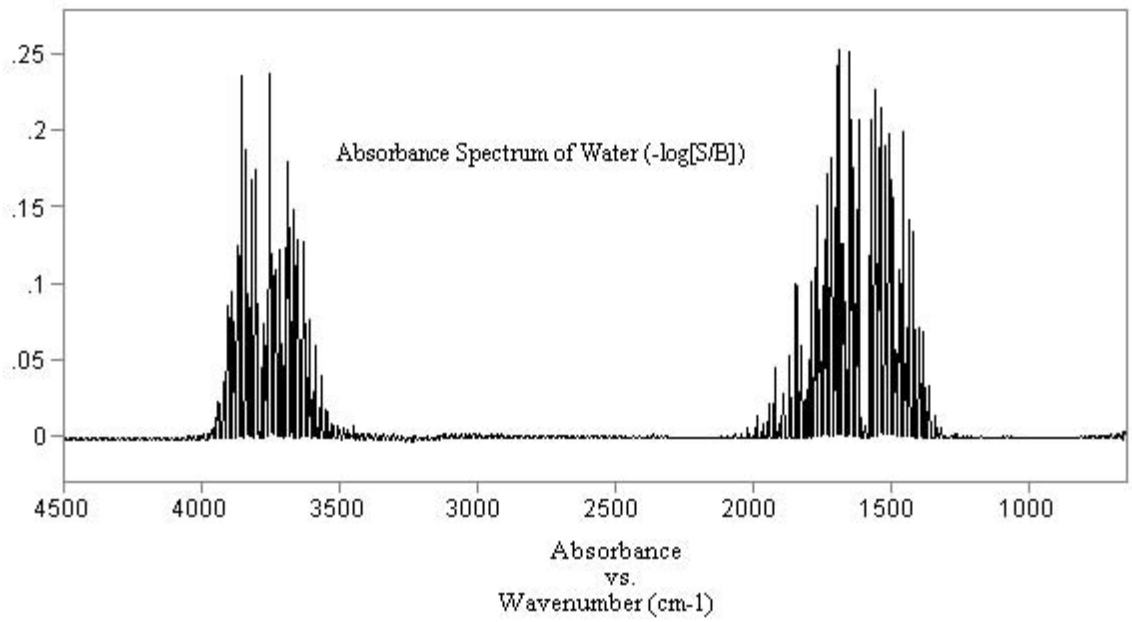


Figure C6. Double Beam Absorbance Spectrum of Water

The absorbance spectrum of a sample gas is determined from single beam spectra of an infrared-transparent gas (the background spectrum) and the sample gas (see Section 5). The fundamental relationship connecting the absorbance spectrum of a sample gas to the concentrations of the compounds comprising the sample is referred to as Beer's Law. This relationship can be written as

$$A_i = \sum_{j=1}^{M} L_S a_{ij} C_j \qquad \text{(Equation C1)}$$

where

i	=	an index labeling the frequencies of the observed absorbance values in the sample's absorbance spectrum.
A_i	=	the observed absorbance of a sample at the ith wavenumber (abs).
L_S	=	the sample absorption pathlength (meters).
j	=	an index labeling the absorbing compounds comprising the sample.
a_{ij}	=	the absorptivity of the jth compound at the ith wavenumber (abs/ppm/meter).
C_j	=	the volumetric concentration of the jth compound (ppm).
M	=	the number of absorbing compounds in the sample.

The procedures described in this method are all related to the parameters which comprise Beer's Law. The following list describes these procedures and relationships in a general context:

1) Record a reference absorbance spectrum for each interesting compound of a nitrogen-diluted sample of the pure compound, at a known concentration and pathlength, then divide the absorbance at each point in that spectrum by the product of the concentration and pathlength. This process yields the absorptivity spectrum (a_{ij}), or reference spectrum, for each compound.

2) Measure the absorbance A_i for the mixture of compounds (see Steps 5 and 9 above).
3) Determine the pathlength L_S for the current measurement of A_i (see Steps 5 and 7 above).
4) Select the analytical region — that is a set of frequencies, corresponding to the possible values of the index i — which are to be used to determine the concentration of each compound, and then mathematically invert Equation C1 to determine the desired concentrations C_j. (Appendix E addresses the topic of spectral analysis in detail.)

NOTE: The true absorptivity for a single gaseous compound is a characteristic only of the compound's structure. However, details of the FTIR system performance and operation affect the observed absorptivity and its accuracy. Similarly, FTIR measurements provide only an approximation of the true absorbance spectrum of a mixture of gaseous compounds, though it is, under many circumstances, a sufficiently accurate approximation. It is the responsibility of the analyst to verify and ensure that the reference and sample spectra provide a sufficiently accurate quantitative analysis according to Beer's Law. The following sections of this Appendix describe the mathematics of such an analysis. Appendix D addresses the topics of developing and using reference spectral libraries. Appendix E provides an illustrative example of the design and evaluation of the quantitative analytical process.

C7. Determining Concentrations with Least Squares Fitting Algorithms.

When a sample gas contains only one absorbing compound, Equation C1 simplifies to

$$A_i = L_S a_{ij} C_j \qquad \text{(Equation C2)}$$

This means that in any analytical region where only one gas absorbs, any one (of the usually many) absorbance spectrum values A_i can be used to yield the concentration C_j.
The absorbance area A_s for single-component spectrum in an analytical region (from i = p to i = q) can be written as

$$A_S = \sum_{i=p}^{i=q} A_i = \sum_{i=p}^{i=q} L_S a_{ij} C_j = L_S C_j \sum_{i=p}^{i=q} a_{ij} = L_S C_j A_R \qquad \text{(Equation C3)}$$

where A_R is the area in the reference spectrum for that compound in the same analytical region. (This is the basis of the absorption pathlength L_S calculation described in Step 7 and Appendix B, Section 1.) Because calculation of the absorbance area involves many points in the sample spectrum, Equation C3 leads to much more accurate results than the single-point calculation represented by Equation C2.

However, when many absorbing compounds are present in a sample, the absorption patterns of the various compounds often overlap. In this case, there is usually not an isolated analytical region for each compound in which only that compound absorbs infrared radiation; no single absorbance point and no simple absorbance area is suitable for determining any of the component concentrations. In this case, the simplest method for determining concentrations is to use a least squares fitting (LSF) algorithm.

LSF algorithms use the fact that there is some set of estimated concentrations D_j which minimizes the "squared error" in Beer's Law for any given analytical region, for any set of compounds. The only requirement on the chosen analytical region is that it must contain a sufficient number of data points; since each FTIR spectrum contains many thousands of absorbance values, this requirement is nearly always fulfilled.

If we use the estimated concentrations D_j (rather that the true concentrations C_j) in Beer's law, they will lead to some estimated error e_i at each value of i (that is , at each point in the analytical region we choose). Equation C1 becomes:

$$A_i = e_i + \sum_{j=1}^{M} L_S a_{ij} D_j \qquad \text{(Equation C4)}$$

The estimated squared error (or "variance") in Beer's Law using the estimated concentrations is:

$$E^2 = \sum_{i=1}^{N} (e_i)^2 = \sum_{i=1}^{N} [\sum_{j=1}^{M} (L_S a_{ij} D_j) - A_i]^2 \qquad \text{(Equation C5)}$$

where N represents the number of absorbance values in the analytical region. Reference 16 demonstrates that 1) for N >M there is a unique set of estimated concentrations D_j which minimizes the estimated squared error; 2) this set of values is calculable from the known quantities in Equations C1 through C5; and 3) estimates σ_j of the uncertainties in the quantities D_j are also calculable from the same quantities. The value $3\sigma_j$ is generally accepted as a conservative estimate of the statistical uncertainty in the related estimated LSF concentration (see Reference 3).

The estimated LSF error at each point in the analytical region,

$$e_i = A_i - \sum_{j=1}^{M} L_S a_{ij} D_j \qquad \text{(Equation C6)}$$

is usually stored following the analysis as a "residual spectrum," which can provide an estimate of the LODs for other compounds. In addition, the residual spectrum and the concentration uncertainties can allow the analyst to detect and identify compounds which are actually present in the sample gas but which were not included in the mathematical analysis. Appendix E provides an example illustrative of these procedures.

The above description illustrates a simple and easily-interpreted LSF analysis. More sophisticated LSF analytical techniques, possibly more accurate for particular types of samples, are described in the literature (see, for example, Reference 18 and references therein).

C8 Calibration Transfer and Reference Libraries

Equations C1 through C6 demonstrate the importance of quantities L_S (the absorption pathlength) and a_{ij} (the absorptivity) in FTIR spectrometry. Accurate determinations of these quantities allow the use of reference libraries for quantitiative analyses without the necessity of compound-specific field calibrations. The system tests described in the procedures and in Appendix B are intended to ensure suitability of the system configuration for such calibration transfers, as are the requirements of obtaining CTS spectra in field. Appendix D describes procedures for recording and processing reference library spectra.

C9 Corrections to Deviations from Beer's Law Exhibited by FTIR Spectra

Beer's Law is based on fundamental, well-established physical principles. It holds absolutely for gas samples which are at thermal equilibrium and dominated by induced (rather than spontaneous) emission and absorption processes. (See Note A1 below). However, *this is **not** to say that the absorbance, as measured by an FTIR spectrometer, follows Beer's Law under all conditions*. Deviations from Beer's Law in FTIR spectra are often observed; however, they indicate inaccuracies in the FTIR spectra, not "violations" of Beer's Law. For example, deviation from Beer's Law is commonly exhibited by sets of single-component reference spectra recorded over a range of absorbance levels. At large enough values of the absorbance, the points A_i of stronger absorption bands of such spectra no longer increase linearly with the concentration-pathlength product $L_R C_j$; this is why Table 2 specifies a maximum ppm-m value for the listed reference spectra. If the assumption of detector linearity does not hold (see Appendix B), similar effects are often present in reference and sample spectra; this is the basis for the system test described in Appendix B, Section 6.

Mathematical correction of the concentration estimates D_j derived from Beer's Law can often reduce the error in sample analyses when either type of non-linear effect occurs. Figure C7 provides an example of such a correction. The actual and calculated ppm-m values for a set of reference spectra are plotted against each other; a "piece-wise linear" approximation to the pattern is shown by the solid line, and the dashed line indicates the ideal linear behavior based on the spectrum of lowest absorbance. At any ppm-m value indicated in a Beer's Law sample analysis (that is, for any y-axis value up to approximately 900 ppm-m in the example), reasonably accurate values are available from the corresponding x-axis position of the solid line. If the analyst

employs such corrections, he or she should also calculate the residual (Equation C6) using the reference spectrum which minimizes the squared error (Equation C5). FTIR analysts and manufacturers have devised other correction procedures to improve the sample analysis accuracy in such circumstances, and these are included in some commercially available software packages.

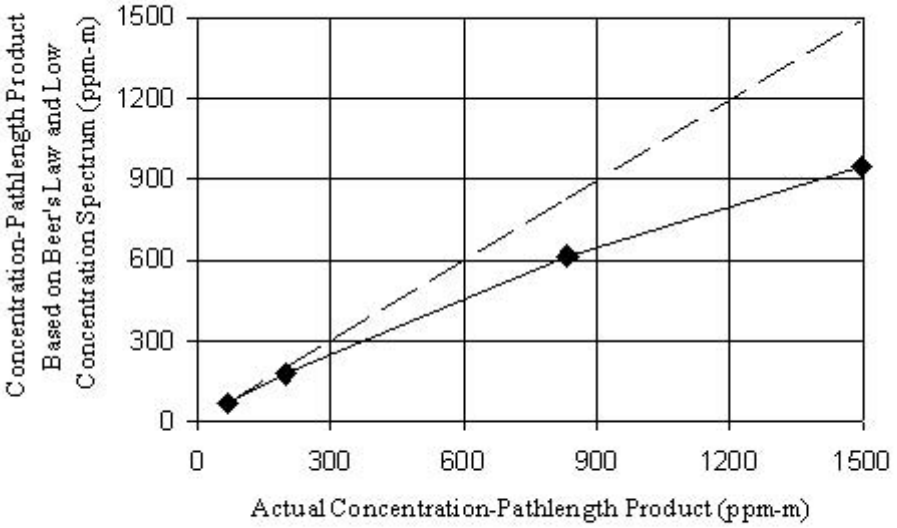


Figure C7. Example Absorbance Non-Linearity for a Set of Single-Component Reference Spectra

Note: Intense infrared radiation, such as that produced by some lasers, can induce non-equilibrium populations of a molecule's rotation-vibration energy states. However, the thermal infrared sources used in commercially available FTIR spectrometers are much weaker than such lasers. In gases at atmospheric pressure, the commercially available thermal sources induce transition rates between quantum energy states which are small compared to those of the competing collisional relaxation processes, and cannot induce non-equilibrium energy state populations. In addition, the induced transition rates related to absorption and emission at mid-infrared frequencies are much larger than the corresponding spontaneous (natural) emission rate. As a result, all *accurate* FTIR measurements at mid-infrared frequencies obey Beer's Law to within the uncertainty related *only* to the S/N ratio of the measured spectra.

APPENDIX D. Purposes, Preparation, and Use of Reference Spectral Libraries.

D1. Purposes of Reference Spectral Libraries

FTIR analyses rely on the availability of libraries of spectral information on the compounds of interest. For gases, the measured absorbance of a single component is often completely independent of the concentrations of other gases comprising the sample, and single-component reference spectra are usually employed. (For condensed phases, there are often strong interactions between components, and reference spectral libraries of mixtures are usually required.) Reference libraries may be used for quantitative measurements of analyte concentrations, for the mathematical removal of spectral features of interferants in a mixture, or simply for the identification of compounds in a mixture. Clearly, the required level of quantitative accuracy of the library is different for these three tasks; the highest quality is required for analyte concentration determinations, while no quantitative information is required for interferant removal and compound identification.

A useful characteristic of extractive FTIR spectrometry is that it provides accurate field measurements for many compounds, but requires field calibration procedures involving only two compounds. The water vapor available in every ambient air sample serves to calibrate the wavenumber (x) axes of FTIR absorbance spectra; a single calibration transfer standard (CTS) gas serves to calibrate their concentration-related (y) axes. When these two field calibrations are combined with an appropriate reference spectral library describing additional compounds, the measurement capability of the technique is practically limited only by the quality and scope of the reference library. If the reference library is carefully prepared and properly employed, this characteristic can lead to greatly lowered field test costs, since the calibration materials need be handled only once, and only in the laboratory.

D2. Reference and Field FTIR System Configurations

In the ideal case, the reference library can be prepared on the field instrument, but this is often impractical; the reference library is usually prepared on specific laboratory systems and employed in measurements made with many field systems. Reference libraries recorded on a specific instrument provide accurate quantitative analyses for spectra recorded on other instruments only when the configurations of the various systems are compatible. The following table lists compatibility considerations for the reference system configuration parameters.

Table D1. Reference and Field System Configuration Parameters.

Parameter	Requirements for Reference and Field Systems
minimum instrumental linewidth	Reference MIL must be less than or equal to field MIL. See Appendix B, Section 3 for MIL measurement technique.
gas temperature	Reference temperature within 20°C of field temperature. Density corrections based on ideal gas law are accurate over only this narrow temperature range, and their exact accuracy is compound-dependent.
gas pressure	Reference pressure within 20% of absolute field pressure. Pressure corrections based on ideal gas law are accurate over at least this range, but their accuracy is compound-dependent. Atmospheric pressure is recommended for all measurements.
apodization function	Reference and field apodization functions must be the same. A single set of reference interferograms (background and sample) can be used to generate a multiple sets of absorbance spectra using different apodization functions.
zero filling factor	Reference and field zero filling factors must be the same. A single set of reference interferograms (background and sample) recorded with no zero filling can be used to generate a multiple set of absorbance spectra using different zero filling factors .
wavenumber accuracy	Characterized by the position of water absorption bands in a wavenumber standard spectrum (see below); if additions to an existing library are being made, care must be taken to match the x-axes of all spectra as closely as possible.

integration time	Reference integration times (for both background and sample interferograms) should be greater than or equal to expected field integration times. For reference libraries, the longest practical integration time is recommended.
detector type and serial number	If an MCT or other potentially non-linear detector is employed in the reference system, IR attenuation may be required to ensure linearity; see Appendix B, Section 6; because each detector may exhibit linearity to a specific degree, the serial number of the detector should be included in any specification of the system configuration.

D3. Wavenumber Standard Spectra

Except in extremely dry conditions, the IR absorption by water vapor in workspace air is detectable at even very short absorption pathlengths. The wavenumber positions of water vapor indicated by the reference system allow the analyst to confirm the wavenumber accuracy of sample spectra recorded on a different FTIR system in the field. Reference spectra used for this purpose are referred to here as the wavenumber standard spectra.

Every spectrum in a reference library should be associated with a wavenumber standard spectrum collected under the identical system configuration; even when the reference FTIR system is in a stable environment, it is recommended that a wavenumber standard spectrum be recorded daily with the system.

Before recording reference spectra, the analyst should check the most recent wavenumber standard spectrum against previous wavenumber standard spectra in the library; see Appendix B, Section 4 for recommended calculations. If the wavenumber reproducibility of the system is poor, the resulting reference spectra may not be suitable for quantitative use on other field systems.

D4. Obtaining and Preparing Standard Reference Gases

The accuracy of any FTIR quantitative analysis is limited by the accuracy of the concentrations of the gas standards used in preparing the reference library. It is therefore important to use gas standards of the highest available quality. NIST-traceable gravimetric standards are available from many commercial sources, and are quoted to 2% accuracy in many circumstances; EPA has also published guidance on the preparation of “Protocol 1" gases (see Reference 17), though these are available for only a limited number of compounds. Users should obtain documentation from the gas vendors regarding the analytical techniques applied and the stability limits (concentration and time) of the compounds in the cylinders. When possible, an alternative analytical method should be used to verify the quoted cylinder concentrations, especially for compounds which are reactive, corrosive, or have relatively high boiling points.

If cylinder standards are not available for a compound, the analyst may prepare reference gases based on gravimetric, barometric, or dynamic methods. In any case, the related mass, pressure, and flow measurements should be made with NIST-traceable equipment whenever possible. In general, methods which provide a stream of standard gas (dynamic methods) provide more reliable results than static methods, since the concentrations of static gases are more prone to change when reactions between the standards and the sampling system or absorption cell surface can occur.

D5. Determining the Reference Absorption Pathlength

The accuracy of any FTIR quantitative analysis is limited by the accuracy to which the pathlength of the absorption cell used in preparing the reference library is known. For single-pass absorption cells through which a collimated IR beam is passed, the pathlength can be physically measured to high accuracy. For multi-pass cells, the nominal pathlength can be estimated from the base pathlength and the number of passes. However, because focused beams and curved mirrors are required in multi-pass cells, the pathlength estimated in this fashion can differ significantly from the actual pathlength. Because of this, combinations of physical and spectroscopic measurements with multiple CTS gas standards (see below) and single-pass absorption cells should be employed to determine the actual pathlength of multi-pass absorption cells.

D6. Recording CTS Spectra

The CTS (calibration transfer standard) gas is used to characterize the absorption pathlengths of the reference and field FTIR systems. Ethylene in nitrogen, at concentrations leading to between 100 and 300 ppm-meter concentration-pathlength values for the systems, is recommended; for ethylene, spectra with ppm-m values greater than 300 begin to exhibit non-linear absorbance, and must be carefully analyzed (see Sections D8 and D9 below). Standards of this gas with 2% accuracy are readily available, and both the EPA and NIST libraries contain ethylene spectra which can be used to link those libraries to measurements performed with field instruments. However, almost any other stable compound with appropriate IR absorption characteristics can be used in developing an independent reference library and for accurate field measurements.

In the field, CTS spectra must be recorded both before and after sample spectra are acquired using the same system configuration employed in recording the sample spectra (see Steps 7 and 11 above).

When developing reference spectra, the analyst must record CTS spectra at least daily; each reference spectrum should be associated with at least one CTS spectrum. The analyst must use the same system configuration employed in recording the reference spectra, with one exception: The integration time used for the CTS spectra may be less than that used for the reference spectra, if the quality of the resulting CTS spectra is still sufficient for an accurate determination of the absorption pathlength. It is highly recommended that the analyst store all the interferograms from which the CTS absorbance spectra are generated, including all background interferograms. The interferometric data provide the most direct method of verifying the FFT calculations and/or adding reference absorbance spectra for other apodization function choices.

D7. Recording Reference Spectra

Before recording reference spectra, verify that the requirements specified for system checks, system configuration parameters, gas standards, absorbance pathlength determinations, and CTS spectra described in the pertinent sections of this Appendix and Appendix B have been met. Additional checks of the sample gas pressure and temperature should also be made periodically as the spectra are recorded.

It is highly recommended that the analyst store all the interferograms from which the reference absorbance spectra are generated, including all background interferograms. The interferometric data provide the most direct method of verifying the FFT calculations and/or adding reference absorbance spectra for other apodization function choices.

Beer's Law (Equation C1) describes the fundamental linearity of the infrared absorbance versus concentration. However, the resolution (and other) limitations of instruments typically used to generate field FTIR spectra often lead to non-linear behavior for many compounds, even at low absorbance levels. The expected accuracy of FTIR-based measurements results for a particular compound can be achieved only when 1) the reference absorbance is characterized at a sufficient number of concentration-pathlength values, up to some maximum value, and 2) the sample absorbance associated with any compound represents a value lower than that of the maximum concentration-pathlength value represented in the reference library for that compound.

For each analyte, the analyst should record two reference spectra at each of two concentration values (that is, at least four spectra) at a single absorption pathlength; the two concentrations should be separated by no more than a factor of ten, and a maximum factor of five is recommended. After recording these spectra, the analyst must 1) permanently record the system parameters and the maximum measured concentration-pathlength product and 2) characterize the linearity of the absorbance across the measured concentration-pathlength range (see Section D8). It may be necessary to record additional reference spectra for the analyte if either the absorbance linearity or maximum concentration-pathlength value proves unsuitable for later field measurements.

D8. Linearity Checks

The performance of linearity checks on a set of reference spectra is an important aspect of FTIR spectrometry, and is best illustrated by a practical example. The following example is based on a series of reference measurements performed in the 3M Environmental Laboratory on the compound tetrafluoroethylene, hereafter referred to as TFE.

Five absorbance spectra for TFE are shown in Figure D1. These spectra were recorded over the entire mid-IR wavenumber range, but only that portion of the spectra showing the most intense TFE absorption bands is included in the Figure. Each of the spectra was calculated by mathematically averaging a number of TFE absorbance spectra recorded with the system configuration parameters given in Table D2, and a linear baseline correction was applied to each of these spectra over the range illustrated in Figure D1.

The reference gas samples were generated by diluting with N_2 the output of a single standard gas cylinder of TFE. The TFE concentration of the standard cylinder was determined (by the gas vendor) according to NIST-traceable gravimetric measurements, and the flow rates of the cylinder gas were measured with a NIST-traceable volumetric device.

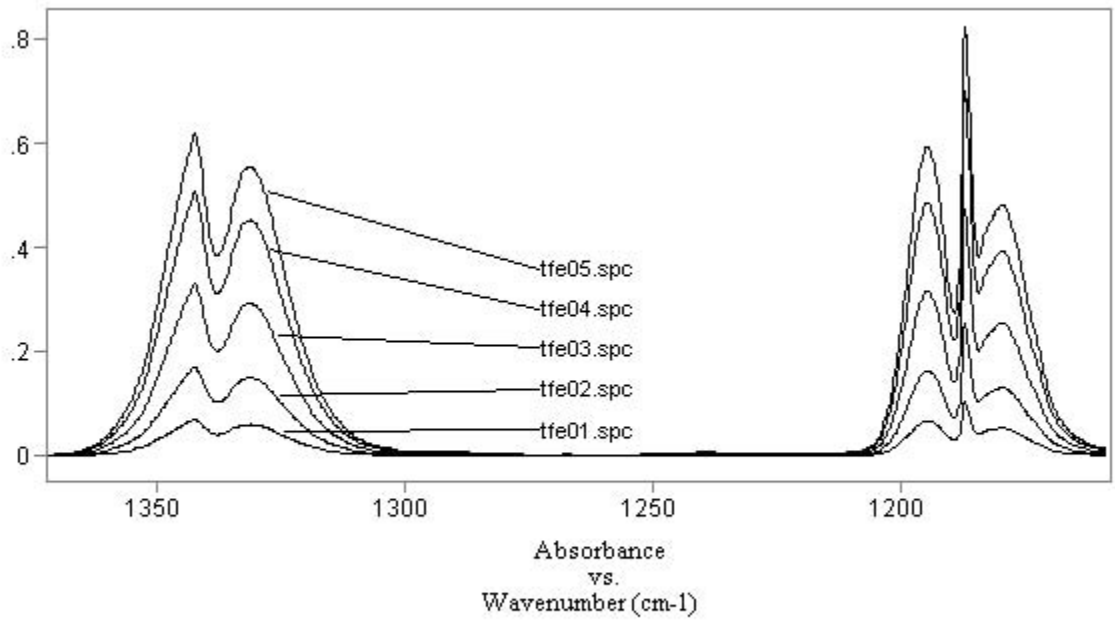


Figure D1. Reference Absorbance Spectra of TFE (x-axis truncated)

One technique to check for the linearity of this set is to form a normalized average of these five spectra and then use it in a linear analysis of the five original spectra. The normalization consists of dividing each spectrum by its concentration-pathlength product; these values, based on the CTS-derived pathlength of 10.23 meters, are given with the actual gas concentrations and new spectral filenames in Table D3. Figure D2 illustrates the normalized spectra, all of which represent spectra of concentration-product values 1.00 ppm-meters. These spectra are nearly equal to one another, as predicted by Beer's Law. Only the spectrum tfe01n.spc, based on the original 25.53 ppm spectrum, is easily discernable from the other spectra in the Figure.

Table D2. System Configuration Parameters for TFE Reference Spectra
(see Figure D1).

System Configuration Parameters	Values/Notes
MIL (cm^{-1})	0.5
integration time (sec)	1080 (120 sec/spectrum × 9 spectra)
absorption pathlength (m)	10.23
gas temperature (C)	15
gas pressure (mm Hg)	760 (±10)
apodization function	Triangular
zero filling factor	zero
detector type	MCT
detector gain (hardware)	jumpers BCD
detector gain (software)	1
reference CTS spectra	j2kety.spc
wavenumber standard spectrum	j2kety.spc

Table D3. Normalization Factors TFE Spectra

Original Spectrum	Concentration (ppm)	Concentration-Pathlength Product (ppm-meter)	Normalized Spectrum
tfe01.spc	2.50	25.5	tfe01n.spc
tfe02.spc	6.63	67.8	tfe02n.spc
tfe03.spc	13.3	133	tfe03n.spc
tfe04.spc	20.4	208	tfe04n.spc
tfe05.spc	25.1	257	tfe05n.spc

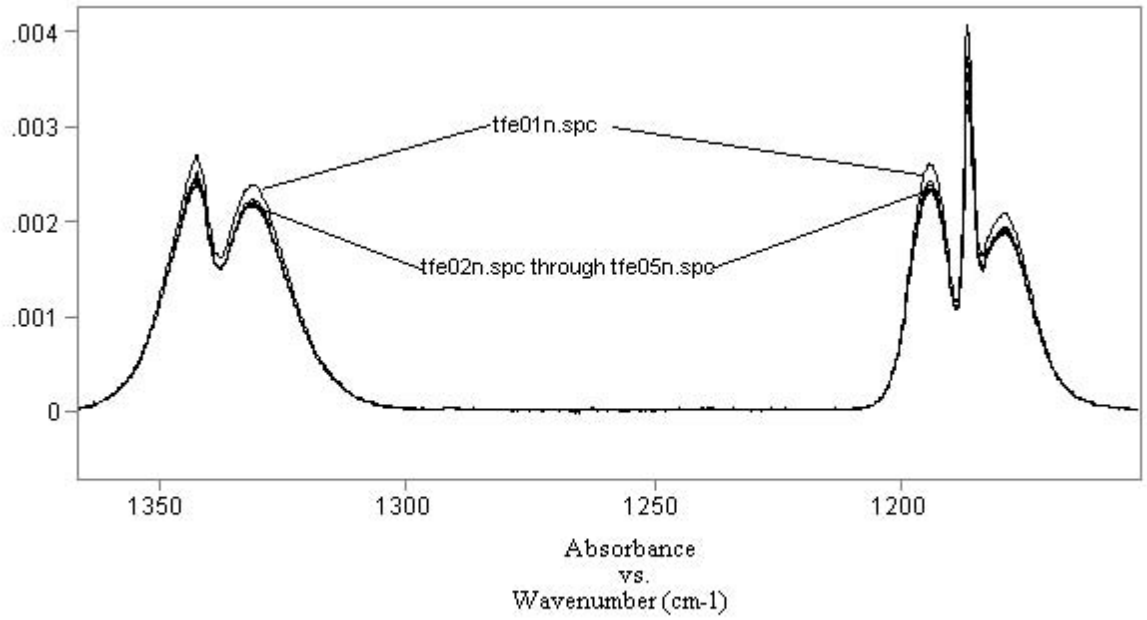


Figure D2. Normalized Reference Absorbance Spectra of TFE

Table D4 shows the results of a linear least-squares analysis using the *average* normalized spectrum as a single reference spectrum (with concentration-pathlength product 1.00 ppm-meters) over the analytical range 1050 to 1400 cm^{-1}. The bias in the linear method is clearly evident in the fourth column of the Table, which indicates that the analysis yields concentrations which are slightly too high at the lowest concentration and slightly too low at the highest concentration. The average of the last column in the table, which represents the absolute percent difference between the actual and calculated concentrations, the "fractional calibration uncertainty" (FCU; see Reference 2), is 3.2%. This value represents the average error over the concentration range for these reference spectra to be expected from the linear analysis up to the maximum concentration-pathlength value used in the analysis (257 ppm-meter). If additional accuracy is required, non-linear analyses or corrections such as those discussed above (Appendix B, Section 9) can be employed.

Table D4. Results of Linear Least Squares Analysis for TFE Reference Spectra.

TFE Reference Spectrum	Calculated Concentration (ppm)	Actual Concentration (ppm)	Actual - Calculated Concentration (ppm)	Absolute Percent Difference
tfe01.spc	2.69	2.50	0.19	7.7
tfe02.spc	6.64	6.63	0.01	0.2
tfe03.spc	12.8	13.0	- 0.2	1.4
tfe04.spc	19.8	20.4	- 0.6	2.9
tfe05.spc	24.2	25.1	- 0.9	3.7

D9. Calculating the Limit of Detection (LOD)

The estimated LODs are the concentrations — for the given system configuration, reference spectra, and analytical region - at which each compound's absorbance area is equal to the RSA. For a specified system configuration and analytical region, an estimate of the LOD for a compound can be made from the absorbance area of a reference spectrum in that region (A_R ,absorbance-cm^{-1}), the reference spectrum concentration-pathlength product (CPP, ppm-m), the sample absorption pathlength (L, meters), and the RSA values (absorbance-cm^{-1}) as

$$LOD = \frac{(CCP)(RSA)}{LA_R} \qquad \text{Equation D1}$$

A simple trapezoidal approximation of $\boldsymbol{A}_R$ over the analytical region of interest, including baseline corrections when necessary, is suitable for the LOD estimate. The RSA is formed from the product of the FTIR system's typical root-mean-square noise level in absorbance and the width of the analytical region in cm^{-1} (see Appendix B, Section 2); the RSA estimate should reflect the error incurred in subtracting known spectral interferences. Appendix E, Section 1 presents detailed examples of RSA and LOD calculations.

D10. Using Existing Reference Libraries

The analyst may use any of the publicly available reference libraries for quantitative analyses, but it is strongly recommended that quantitative results for analytes be based only on spectra from libraries which meet the requirements discussed in this Appendix. If the reference library consists of spectra recorded at a spectral resolution different from that of the field system, the analyst must 1) de-resolve the spectra mathematically to that of the field data and 2) ensure that the library data are suitably linear over the desired measurement range *at the spectral resolution of the field system*.

APPENDIX E. Example Calculations.

This Appendix uses an analysis of tetrafluoroethylene (TFE) and 1,1-difluroethylene (DFE) in workplace air to illustrate the calculations of residual squared area (RSA) and limits of detection (LODs). The topics of designing, applying and verifying, and correcting a spectral analysis are also addressed below.

The FTIR system configuration assumed for this set of calculations is given below. These parameters are consistent with the LOD values presented in Table 2.

MIL:	0.5 cm^{-1}
absorption pathlength:	10 meters
apodization function:	triangular
gas temperature:	293 K
gas pressure:	760 Torr
zero filling factor:	none
wavenumbers of water bands:	1918 cm^{-1} and 2779 cm^{-1}
reference library sources:	3M Environmental Laboratory
integration time:	70 seconds (64 scans)
detector type:	MCT
detector gain - hardware:	Gain jumpers A, D, and H
detector gain - software:	1.0

E1. Residual Squared Area (RSA), Analysis Design, and Limits of Detection (LODs)

The analysis is to be carried out in workspace air, so the only potential spectral interferences are due to water and carbon dioxide. Figure E1 illustrates example reference spectra of TFE, DFE, and water. (The water spectrum shown is typical of workspace air samples; carbon dioxide does not absorb in any of the spectrum. As a result, the limited spectral region shown in Figure E2 is actually of the greatest interest for an analysis of DFE and TFE in workspace air.

Shown in greater detail in Figure E2 are the three reference spectra and two possible analytical regions. Analytical region 1, from 1370 to 1295 cm^{-1}, includes water bands which interfere with the TFE absorbance in the sample spectra. Analytical Region 2 (1215 to 1100 cm^{-1}) may be the best choice for analyzing samples for both TFE and DFE (though the weaker features near 3000 cm^{-1} remain an option for DFE); it avoids the TFE interference with water, but necessarily includes some spectral overlap between the two analytes. Until the relative TFE, DFE, and water concentrations in the samples are known, it is unclear which of the two regions will provide better concentration estimates for TFE, so calculations for both regions are described below.

Estimation of the LODs for TFE and DFE requires a calculation of the residual square area (RSA) in the actual sample spectra over the selected analytical regions. The RSA represents an estimate, based on the assumed sample matrix and available reference spectra, of the residual absorbance (see Equation A6) which will be used to calculate the concentration uncertainties from the actual sample spectra.

The reader should note that the RSA and derived LOD are only estimates. If the actual sample matrix differs substantially from that of the sample matrix assumed in the performance of these estimates, the actual concentration uncertainties and LODs may differ substantially from the RSA and LOD values obtained in the calculations described below. For workplace air samples, water is the only interfering compound which is certain to appear in any of the analytical regions considered below. A realistic

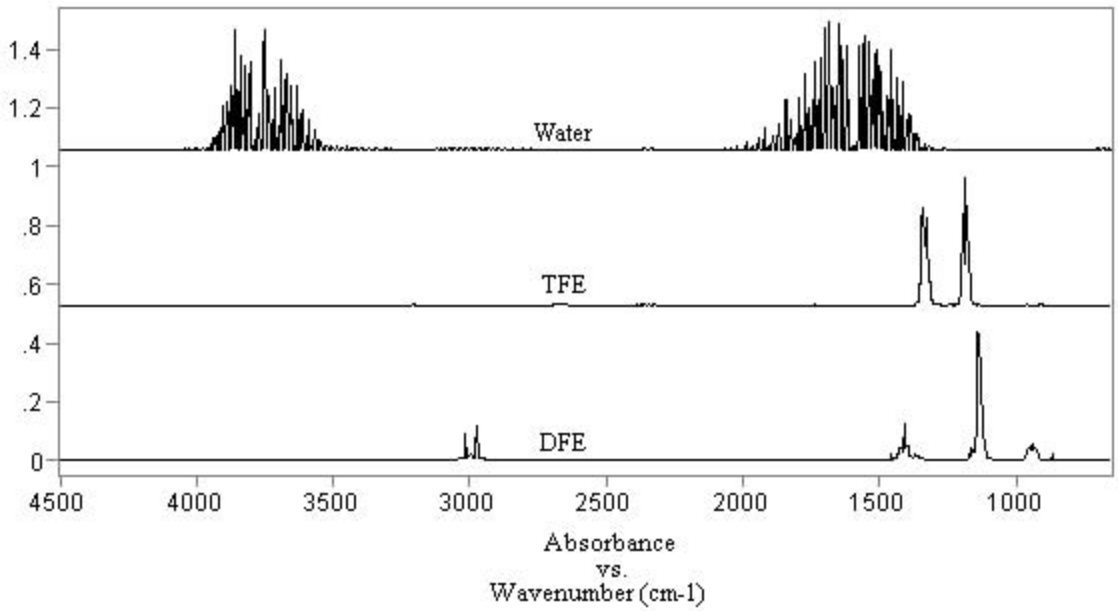


Figure E1. Absorbance Reference Spectra of TFE, DFE, and Water

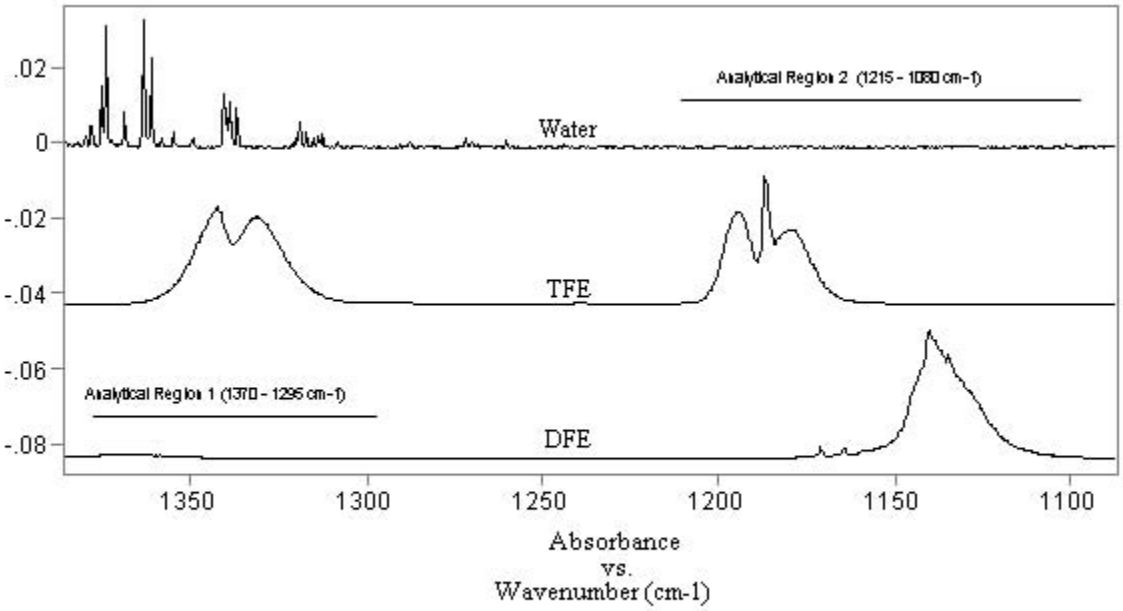


Figure E2. Possible Analytical Regions

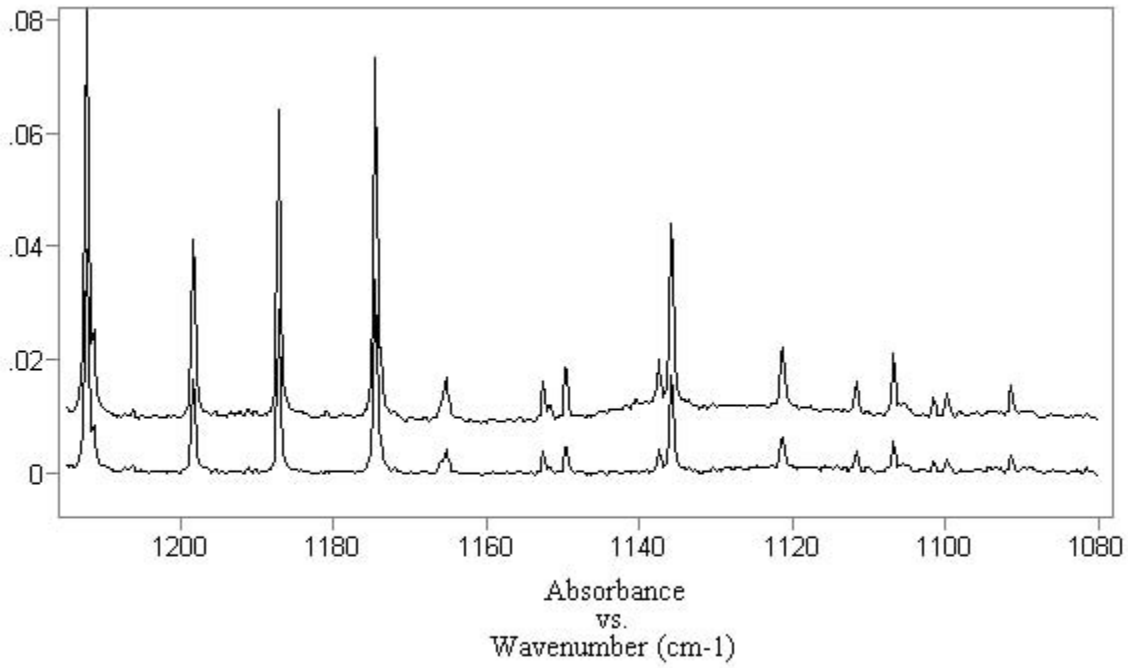


Figure E3. Water Spectra 1295 to 1080 cm-1

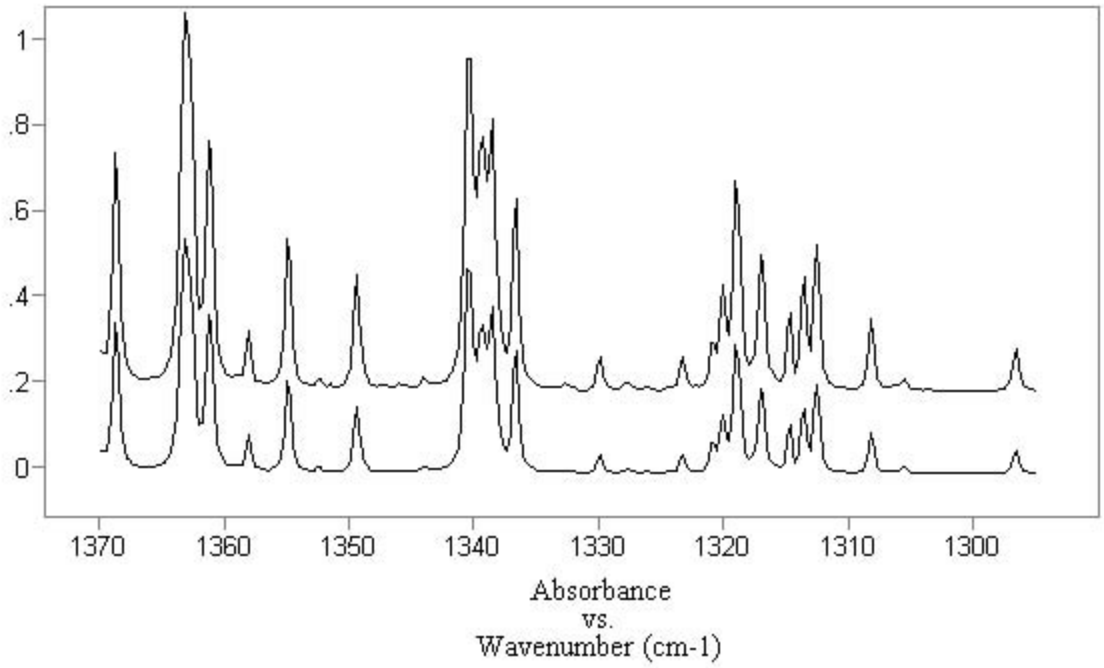


Figure E4. Water Spectra 1370 to 1295 cm-1

estimate of the RSA is therefore available by forming the mathematical difference of two water spectra — of substantially different water concentrations — recorded using the same FTIR system configuration. For each analyte, this estimate assumes that only water and that analyte will absorb substantially in the actual sample spectra. Later analyses based on the actual sample matrix could lead to either lower or higher concentration uncertainty and LOD estimates; examples of such analyses are detailed below.

Figures E3 and E4 illustrate two absorbance spectra recorded using the system configuration described above. They represent spectra of workspace air at approximately 20% and 40% relative humidity. The upper trace in each Figure is slightly offset for clarity.

Figure E5 shows two residual spectra formed by subtracting scaled versions of the lower-absorbance spectrum from the higher-absorbance spectrum. The scaling factors were determined in independent LSF analyses over the two analytical regions. Linear baseline corrections (offset and slope) were also determined during the analyses, so the mean value of each residual spectrum is zero. (These calculations were performed by using the ANOVA data analysis tool in Microsoft Excel 97). The residual squared area (RSA) values for the residual spectra are defined in Equation C2, and the related calculations are presented in Table E1. (The calculations also were performed in the program Excel by applying the function STDEV to the regression residuals.)

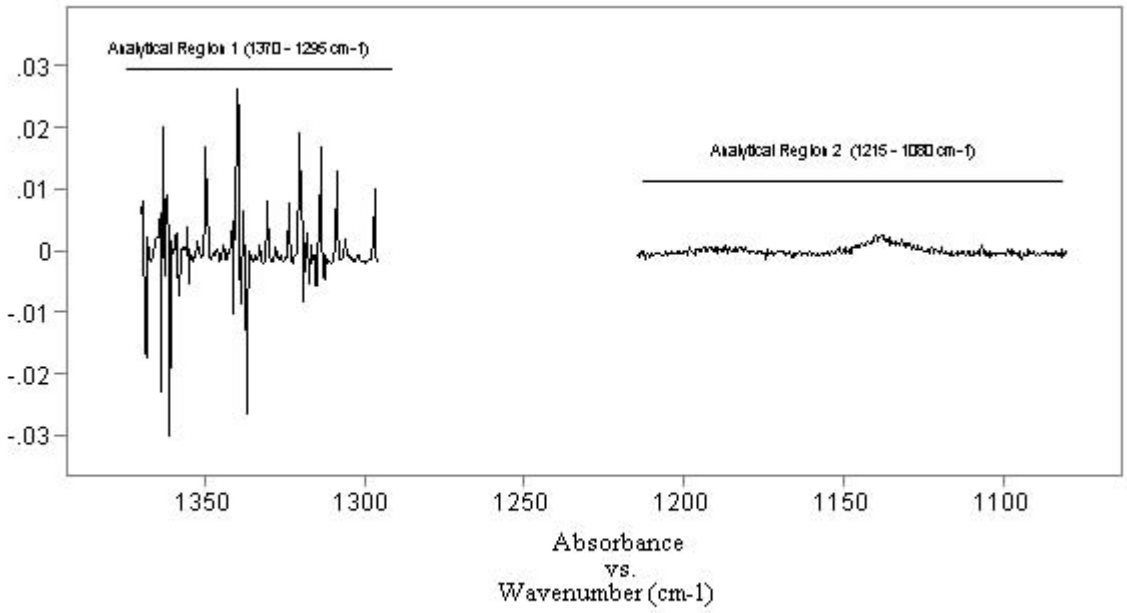


Figure E5. Water Residual Spectra

Table E1. Results of RSA Analysis from Water Reference Spectra.

Analytical Region (cm^{-1})	Calculated Scaling Factor	Scaling Factor Uncertainty (1 σ)	Residual RMS Standard Deviation (absorbance)	RSA (absorbance -cm^{-1}; Eq. B2)
1370-1295	1.636	0.003	0.00575	0.431
1215-1080	1.870	0.008	0.00069	0.093

An estimate of the LODs (ppm) for the two compounds — for the specified system configuration — can be made from the absorbance areas of the reference spectra over these analytical ranges (A_R,absorbance-cm^{-1}), the reference spectra concentration-pathlength products (CPP, ppm-m), the sample absorption pathlength L (meters), and the RSA values (absorbance-cm^{-1}) derived above.

The absorbance areas were determined using a standard trapezoidal approximation without baseline correction. (For these spectra, baseline corrections lead to values which differ from those quoted by less than 3%, and have been neglected below.) Figure E6 shows the spectral features of TFE and DFE used to calculate the A_r for the reference spectra tfeav05.spc (CCP = 256.7 ppm-m) and dfeav05.spc (CCP = 197.8 ppm-m).

The estimated LODs are the concentrations — for the given system configuration, reference spectra, and analytical region - at which each compound's absorbance area is equal to the RSA. Mathematically, the LOD estimates are given by

$$LOD = \frac{(CCP)(RSA)}{LA_R} \qquad \text{Equation E1}$$

Table E2 lists the pertinent quantities and resulting LODs for DFE and TFE in the two analytical regions considered. The results indicate that the analytical region from 1215 to 1080 cm^{-1} is likely to provide the most reliable TFE concentrations.

Table E2. LODs for TFE and DFE from RSA Analysis of Water Reference Spectra.

Analytical Region (cm^{-1})	Compound	Reference Spectra			System Configuration		
		File Name	CCP (ppm-m)	Absorbance Area (abs-cm^{-1})	RSA (abs-cm^{-1})	L (m)	Estimated LOD (ppm)
1370-1295	TFE	tfe05.spc	256.7	16.03	0.431	10.0	0.69
1215-1080	TFE	tfe05.spc	256.7	13.97	0.093	10.0	0.17
1215-1080	DFE	dfe05.spc	197.8	8.72	0.093	10.0	0.21

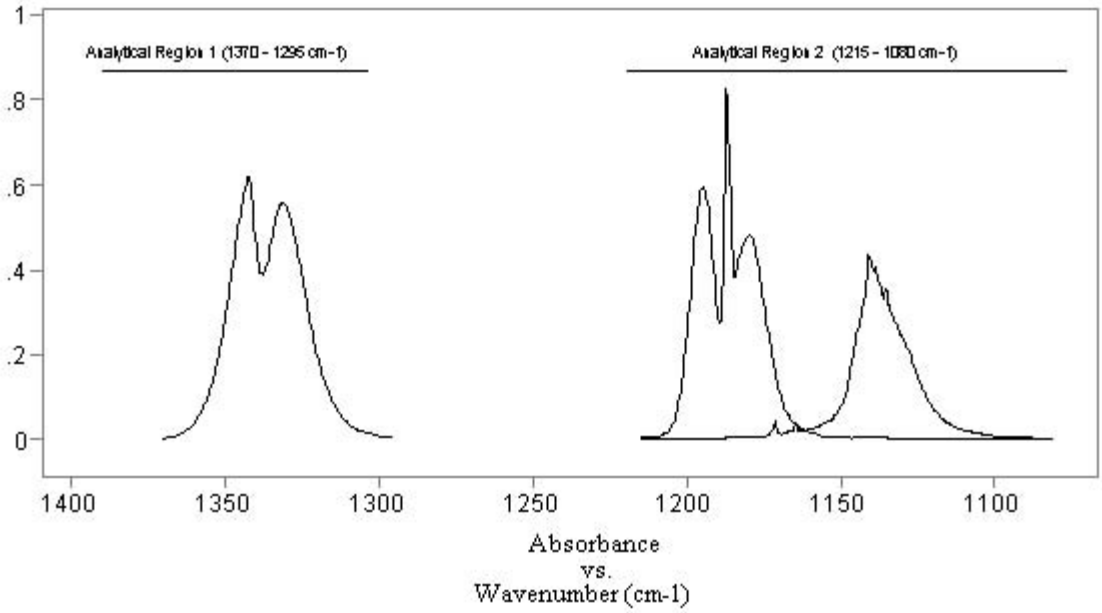


Figure E6. TFE and DFE Spectra for Asorbance Area Calculations

E2. LSF Determinations of TFE and DFE Concentrations

Presented in this section is a description of a least squares fit (LSF) analysis for the two compounds TFE and DFE in ambient air samples. As is always the case before actual measurements are taken, no actual sample data for mixtures of the compounds in the assumed matrix (ambient air) were available as these analyses were performed. Accordingly, the following description is based on synthetic spectra generated from available reference spectra for TFE, DFE, and water.

In order to *not* overestimate the effectiveness of the FTIR technique, the noise levels in the synthetic sample spectra were artificially raised, and the reference spectra used are not those most likely to provide an optimal analysis. This is the most prudent course available to an analyst attempting to predict the performance of the FTIR method under essentially unknown conditions, and it is the course recommended by the authors to analysts who find themselves in this common situation.

Estimates of the LOD for this sample matrix (see Appendix E, Section 1) indicate that the analytical region from 1215 to 1080 cm^{-1} will likely provide the most reliable TFE and DFE concentrations. The system configuration parameters used in those estimates are assumed to hold in the following description.

E2A. Generation and Analysis of Synthetic Sample Spectra of TFE and DFE

Table E3 describes the mathematical generation of synthetic samples for the following LSF analysis description. Each sample spectrum consists of the sum of scaled reference spectra for TFE (tfe4.spc, CCP = 208.3 ppm-m), DFE (dfeav05.spc, CCP = 197.8 ppm-m) and water (wat02bl.spc). The scaling factors indicated in Table E3 were used to generate synthetic sample spectra at the listed concentrations and the assumed absorption pathlength of 10.0 meters.

Table E3. Parameters Used to Generate Synthetic Sample Spectra Containing TFE, DFE, and Water.

TFE Scaling Factor	TFE Synthetic Conc. (ppm)	DFE Scaling Factor	DFE Synthetic Conc. (ppm)	H2O Scaling Factor	Synthetic Sample Spectrum File Name
0	0	0	0	0.6	S001.spc
0	0	0	0	1.2	S002.spc
1.200	25.0	1.264	25.0	0.6	S551.spc
1.200	25.0	0.253	5.00	0.6	S511.spc
0.240	5.00	1.264	25.0	0.6	S151.spc
1.200	25.0	1.264	25.0	1.2	S552.spc
1.200	25.0	0.253	5.00	1.2	S512.spc
0.240	5.00	1.264	25.0	1.2	S152.spc

.

A spectrum representing random absorbance noise was added to each synthetic spectrum. The noise spectrum was generated using the function RANDOM within the program GRAMS/32 V4.11 (Galactic, Inc.; see the Array Basic User's Guide, V4.1, page 316); similar functions are also available in Microsoft Excel. For the noise spectrum, the root mean square absorbance noise $\boldsymbol{N}_{RMS}$ (see also equation C2, which defines the RSA), calculated over the appropriate analytical region(s) according to

$$N_{RMS} = \sqrt{\sum_{i=p}^{i=q} \frac{(R_i)^2}{q-p}} \qquad \text{Equation E2}$$

was 0.00034 in the region 1438 to 1282 cm^{-1}; this is very close to the value obtained from actual absorbance spectra (provided by MIDAC Corporation) recorded with the quoted system configuration in the region 1005 to 932 cm^{-1}.

The synthetic spectra represent four different mixtures of TFE and DFE (including one "mixture" which contains neither compound), each at two different moisture levels.

Table E4 lists the results of a LSF analysis (program 4FTIMD V15, Rho Squared; see Reference 18) for TFE, DFE, and water in the analytical region 1215 to 1080 cm^{-1} using the reference spectral files TFE3.spc (CCP = 133.2 ppm-m) and dfeav04.spc (CCP = 133.3 ppm-m), and wat01bl.spc. Note that these are not the same reference spectra which were used in the generation of the synthetic sample spectra, and that the results for water are in arbitrary units. The analysis included the determination of two baseline correction parameters along with the compound concentrations.

Table E4. Original LSF Results for Original Synthetic Sample Spectra Containing TFE, DFE, and Water.

Synthetic Sample Spectrum File Name	TFE Synth. Conc. (ppm)	TFE LSF Result (ppm)	TFE LSF 3σ Uncert. (%)	DFE Synth. Conc. (ppm)	DFE LSF Result (ppm)	DFE LSF 3σ Uncert. (%)	H_2O LSF Result (arb)	H_2O LSF 3σ Uncert. (%)
S001.spc	0	0.02	52.5	0	0.07	13.7	1.12	1.23
S002.spc	0	0.03	32.2	0	0.14	8.95	2.24	0.80
S551.spc	25.0	**24.41**	**0.26**	25.0	**24.30**	**0.29**	0.87	**11.8**
S511.spc	25.0	**24.43**	**0.25**	5.00	**4.88**	**1.43**	0.87	**11.5**
S151.spc	5.00	**4.88**	**0.41**	25.0	**24.33**	**0.09**	1.07	**3.04**
S552.spc	25.0	**24.43**	**0.26**	25.0	**24.35**	**0.29**	1.99	**5.20**
S512.spc	25.0	**24.45**	**0.26**	5.00	**4.95**	**1.43**	1.99	**5.11**
S152.spc	5.00	**4.90**	**0.43**	25.0	**24.39**	**0.10**	2.19	**1.56**
Average Abs. % Concentration Difference*		**2.24**			**2.34**			
Average Abs. % Concentration Uncertainty*			**0.31**			**0.61**		**6.38**

*The averages exclude the spectra (S001 and S002) with zero synthetic TFE and DFE concentrations.

The LSF results for the non-zero TFE and DFE spectra are consistently good, being different from the synthetic concentrations less than 3% in every case. Listed in the Table for TFE and DFE are the average percent differences between the synthetic concentrations and those derived from the LSF analysis, which are 2.24% and 2.34%, respectively.

The concentration uncertainties listed in Table E4 are the statistically determined 3σ values from the LSF analyses. Included in the last row of the Table are the average percent concentration 3σ uncertainties for the non-zero TFE and DFE spectra. These percent uncertainty parameters and the visual appearance of the LSF residual spectra are important indicators of the quality of the least squares analysis, and are discussed further in the following section.

Though they are not included in the averages presented in the last two rows of Table 3, the TFE and DFE results for the two synthetic spectra which contain no absorption features of TFE and DFE (S001 and S002) are of interest and importance. The LSF concentration results are small. (Their maximum is 0.14 ppm). They are smaller in each case than the LOD estimates of Table E2, and their corresponding 3σ uncertainties from this LSF analysis are smaller still. Unfortunately, no consensus exists on the exact mathematical relationship between the LODs calculated as described in this document and the 3σ concentration uncertainties. This statement is supported by the contents of Section A2 in Reference 3 — a consensus document — which prescribes three different methods for calculating LODs (or, in the terminology of Reference 3, "minimum detectable concentrations"). These three prescriptions include one similar to the LOD method prescribed in this document, and one which is based on the concentration uncertainties derived from spectra similar to S001 and S002. In this limited example, two of the three prescriptions included in Reference 3 provide very different results, and they indicate that the LOD calculation described in this document provides the most conservative estimate — that is, the highest estimate — of the three LOD prescriptions of Reference 3.

E2B. Analyses of Synthetic Sample Spectra with an Interfering Compound

Every compound-specific quantitative analytical technique, including FTIR spectrometry, can fail to provide accurate results when interfering compounds appear in a sample. However, the results of a mathematical FTIR spectral analysis designed for a particular set of compounds provides clues to its failure in the presence of interferants. An experienced analyst can often adjust the analysis to accommodate the interferants and provide accurate results.

To illustrate this important aspect of FTIR spectrometry, a synthetic interference was introduced to the spectra described in Table E3. Scaled versions of a reference spectrum (hfpav06.spc, 256.6 ppm-m) of the compound hexafluoropropylene (HFP), representing the compound at two concentrations (5.00 and 10.0 ppm), were added to the original synthetic spectra. The resulting final synthetic sample spectra are described in Table E5 below. The least squares analysis described above for TFE and DFE only, when applied to these spectra containing spectral features of HFP, gives the results shown in Table E6 below.

Table E5. Parameters Used to Generate Synthetic Sample Spectra Containing TFE, DFE, Water, and HFP.

Original Synthetic Sample Spectrum File Name	HFP Scaling Factor	HFP Synthetic Conc. (ppm)	Final Synthetic Sample Spectrum File Name
S001.spc	0.195	5.00	S0011.spc
S002.spc	0.390	10.0	S0022.spc
S551.spc	0.195	5.00	S5511.spc
S151.spc	0.195	5.00	S1511.spc
S512.spc	0.195	5.00	S5121.spc
S511.spc	0.390	10.0	S5112.spc
S552.spc	0.390	10.0	S5522.spc
S152.spc	0.390	10.0	S1522.spc

Table E6. Original LSF Results for Final Synthetic Sample Spectra Containing TFE, DFE, Water, and HFP

Synthetic Sample Spectrum File Name	TFE Synth. Conc. (ppm)	TFE LSF Result (ppm)	TFE LSF 3σ Uncert. (%)	DFE Synth. Conc. (ppm)	DFE LSF Result (ppm)	DFE LSF 3σ Uncert. (%)	H_2O LSF Result (arb)	H_2O LSF 3σ Uncert. (%)
S0011.spc	0	1.00	39.6	0	-1.58	26.5	1.65	0.89
S0022.spc	0	2.01	39.5	0	-3.16	26.4	3.29	1.78
S5511.spc	25.0	**25.06**	**1.51**	25.0	**22.65**	**1.89**	1.43	**43.3**
S5112.spc	25.0	**25.73**	**2.90**	5.00	**1.57**	**53.8**	1.99	**61.4**
S1511.spc	5.00	**5.53**	**6.64**	25.0	**22.67**	**1.84**	1.63	**37.0**
S5522.spc	25.0	**25.73**	**2.90**	25.0	**21.05**	**4.01**	3.10	**39.2**
S5121.spc	25.0	**25.09**	**1.52**	5.00	**3.29**	**13.1**	2.55	**24.4**
S1522.spc	5.00	**6.20**	**11.87**	25.0	**21.09**	**3.96**	3.30	**36.4**
Average Abs. % Concentration Uncertainty*			**4.56**			**13.1**		**40.3**

*The average excludes the spectra (S0011 and S0022) with zero synthetic TFE and DFE concentrations.

The results shown in the last rows of Table E4 (those of the original LSF analysis *without* HFP interference) and Table E6 (those of the original LSF analysis *with* HFP interference) are clearly quite different. Averaged over the six synthetic spectra containing TFE and DFE in each case, the (absolute) percent concentration uncertainties for TFE, DFE, and H_2O are greater for the spectra with HFP interference. For TFE and DFE, the average percent uncertainties of Table E6 are over ten times greater than those of Table E4.

This exercise shows that:

- For sample spectra containing substantial TFE and DFE concentrations, the HFP interference causes large increases in the TFE and DFE relative absolute concentration uncertainties.

- For sample spectra containing low or zero concentrations TFE and DFE, the relative absolute uncertainties are NOT a reliable indicator of the HFP interference. However, for such spectra, the concentration results themselves are often clearly unreliable; note that the DFE concentration results are negative *and* large compared to the LOD estimate for this compound. (Note also that negative concentration results which are *small* compared to the LOD are statistically valid, and do not necessarily indicate a failure of the analysis.)

If the concentration results show anomalies such as those noted above, the residual spectra from the analyses will also exhibit anomalous behavior. This is illustrated in Figure E7, which shows the residual spectra for four analyses. Compared to the residual spectra resulting from analyses of spectra without the HFP interference, those with HFP interference show large absorbance features which cannot be modeled by the three reference spectra employed. The analyst needs to identify the interfering compound before proceeding. This can often be done by visually comparing the suspect residual spectra to reference spectra of a number of likely interferants, as illustrated in Figure E8.

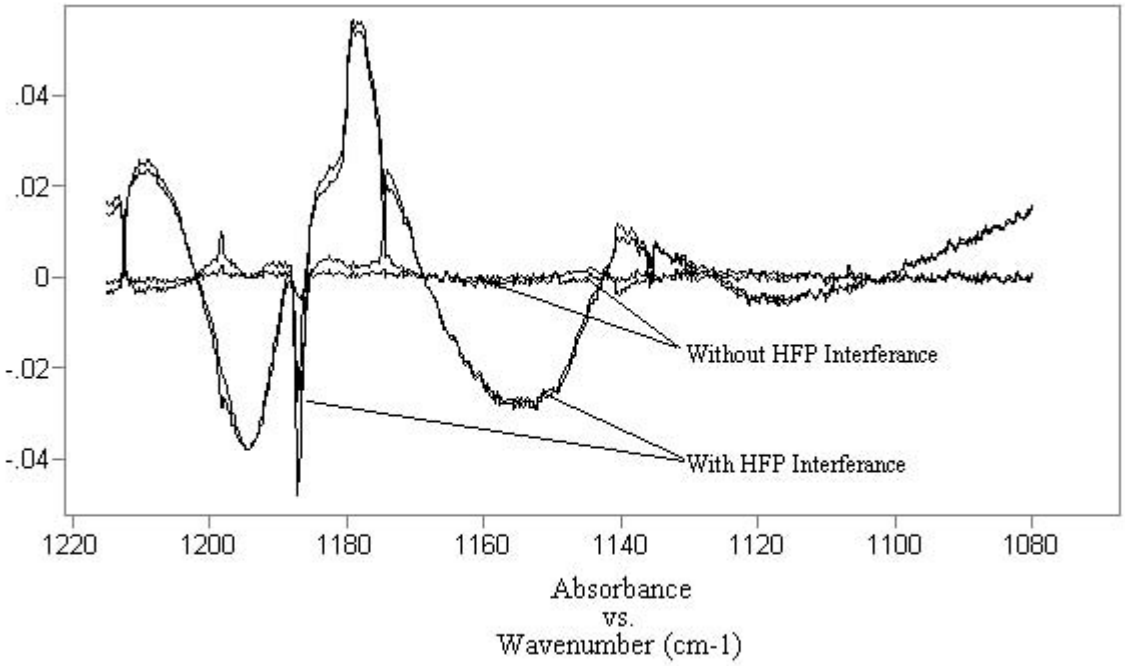


Figure E7. Residual Spectra With and Without HFP Interferance

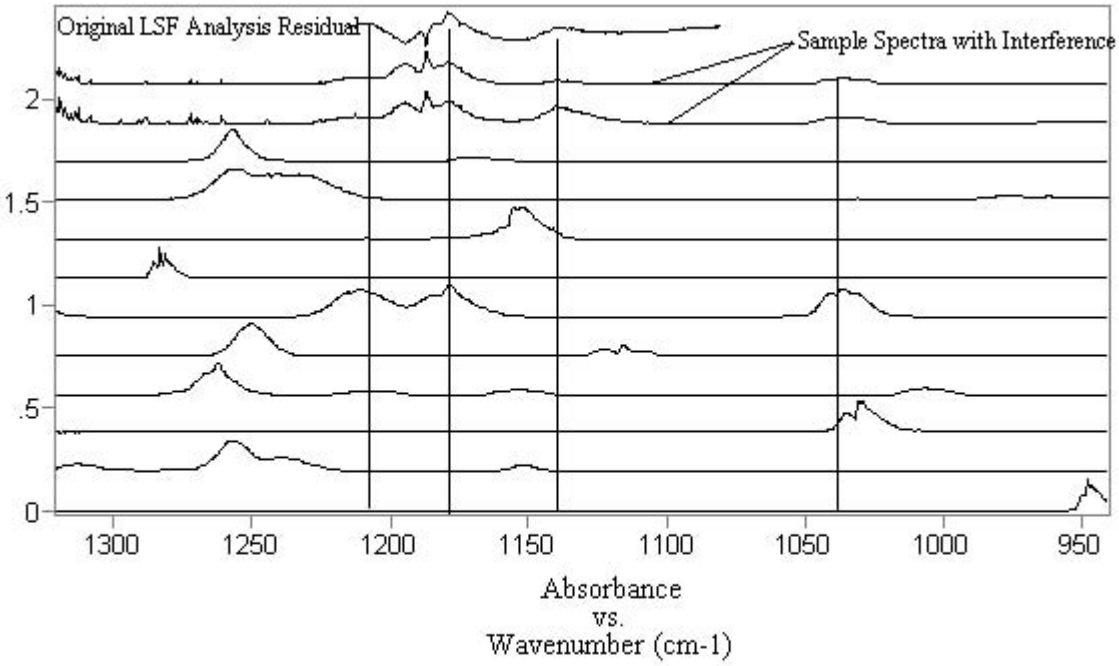


Figure E8. Comparisons of Residual, Sample, and Reference Spectra

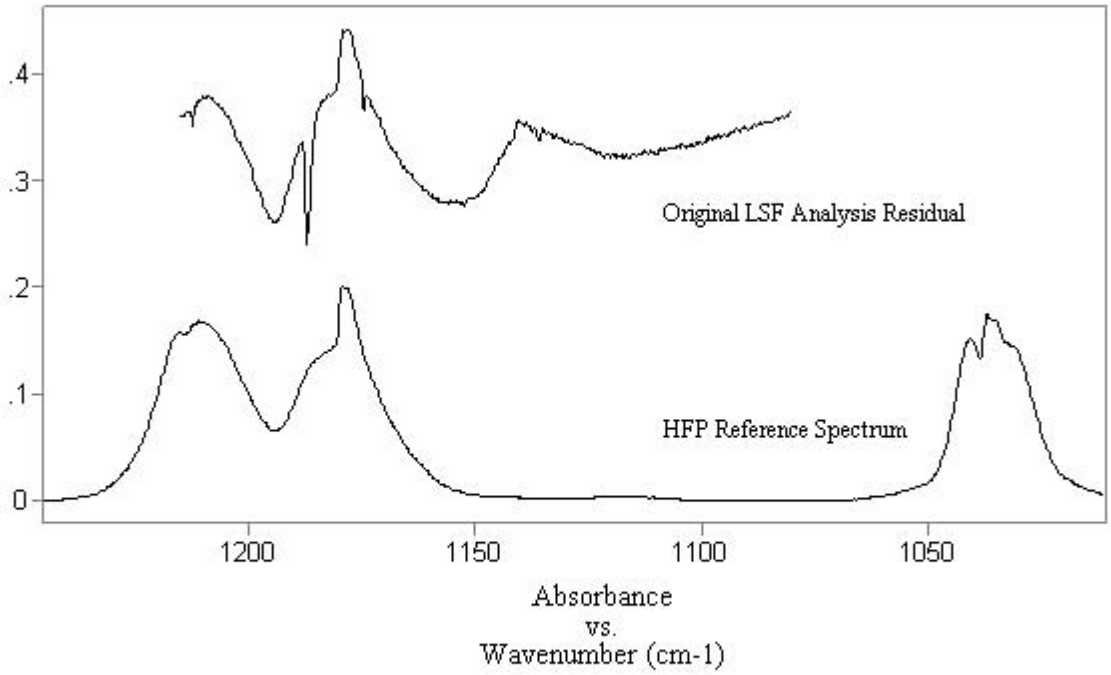


Figure E9. Original LSF Residual and HFP Reference Spectra

Figure E8 shows that the positions of three major relative maxima in the residual spectrum (top trace) correspond well to only one of the nine candidate reference spectra in the lower traces of the Figure. (The nine spectra shown are all of light, partially or fully fluorinated hydrocarbons.) An additional absorbance band from this single reference spectrum also corresponds to a large peak in both of the sample spectra (second and third traces from top of the Figure).

A closer examination of this reference spectrum — that of HFP, of course — is illustrated in Figure E10. It clearly shows a close relationship between the shape of the residual spectrum and the absorption features of HFP. The relationship is not exact because the sample spectrum has had incorrect amounts of the compounds TFE and DFE subtracted, and this distorts the residual spectrum.

Though this identification is tentative, it can be tested by including HFP in the LSF analysis. Table E7 shows the TFE, DFE and water concentrations resulting from an analysis identical to those described above except for the addition of HFP as a fourth compound. (As usual, an HFP reference spectrum different from the one used to add the synthetic interference was employed in the analysis.) To facilitate comparisons with the preceding tables, the HFP results have been excluded from Table E7; they were in all cases similar in quality to those obtained for the other compounds.

The results show that inclusion of HFP in the analysis yields results of the original (high) quality shown in Table E3 for TFE, DFE, and water. The percent relative uncertainties are slightly higher in the final analysis than in the original analysis; this is to be expected because the same amount of spectral information is being used to determine an additional parameter in the final analysis. The quality of the analysis could probably be further improved by extending the analytical region to include the entire HFP absorbance band shown in Figure E9.

Table E7. Final LSF Results for Final Synthetic Sample Spectra Containing TFE, DFE, Water, and HFP

Synthetic Sample Spectrum File Name	TFE Synth. Conc. (ppm)	TFE LSF Result (ppm)	TFE LSF 3σ Uncert. (%)	DFE Synth. Conc. (ppm)	DFE LSF Result (ppm)	DFE LSF 3σ Uncert. (%)	H_2O LSF Result (arb)	H_2O LSF 3σ Uncert. (%)
S0011.spc	0	1.00	39.6	0	-1.58	26.5	1.65	0.89
S0022.spc	0	2.01	39.5	0	-3.16	26.4	3.29	1.78
S5511.spc	25.0	**24.43**	**0.27**	25.0	**24.27**	**0.33**	0.87	**12.1**
S5112.spc	25.0	**24.45**	**0.27**	5.00	**4.81**	**1.72**	0.88	**12.34**
S1511.spc	5.00	**4.91**	**0.44**	25.0	**24.27**	**0.11**	1.08	**3.23**
S5522.spc	25.0	**24.46**	**0.28**	25.0	**24.27**	**0.35**	1.99	**5.51**
S5121.spc	25.0	**24.45**	**0.27**	5.00	**4.92**	**1.63**	1.99	**5.25**
S1522.spc	5.00	**4.94**	**0.57**	25.0	**24.29**	**0.14**	2.20	**2.05**
Average Abs. % Concentration Uncertainty*			**0.35**			**0.71**		**6.74**

*The average excludes the spectra (S0011 and S0022) with zero synthetic TFE and DFE concentrations.

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

NICKEL

CAS # 7440-02-0

Division of Toxicology ToxFAQs™ August 2005

This fact sheet answers the most frequently asked health questions (FAQs) about nickel. For more information, call the ATSDR Information Center at 1-888-422-8737. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It is important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Nickel is a naturally occurring element. Pure nickel is a hard, silvery-white metal used to make stainless steel and other metal alloys. Skin effects are the most common effects in people who are sensitive to nickel. Workers who breathed very large amounts of nickel compounds developed chronic bronchitis and lung and nasal sinus cancers. Nickel has been found in at least 882 of the 1,662 National Priority List sites identified by the Environmental Protection Agency (EPA).

What is nickel?

Nickel is a very abundant natural element. Pure nickel is a hard, silvery-white metal. Nickel can be combined with other metals, such as iron, copper, chromium, and zinc, to form alloys. These alloys are used to make coins, jewelry, and items such as valves and heat exchangers. Most nickel is used to make stainless steel.

Nickel can combine with other elements such as chlorine, sulfur, and oxygen to form nickel compounds. Many nickel compounds dissolve fairly easy in water and have a green color. Nickel compounds are used for nickel plating, to color ceramics, to make some batteries, and as substances known as catalysts that increase the rate of chemical reactions. Nickel is found in all soil and is emitted from volcanoes. Nickel is also found in meteorites and on the ocean floor. Nickel and its compounds have no characteristic odor or taste.

What happens to nickel when it enters the environment?

❏ Nickel is released into the atmosphere by industries that make or use nickel, nickel alloys, or nickel compounds. It is also released into the atmosphere by oil-burning power plants, coal-burning power plants, and trash incinerators.

❏ In the air, it attaches to small particles of dust that settle to the ground or are taken out of the air in rain or snow; this usually takes many days.

❏ Nickel released in industrial waste water ends up in soil or sediment where it strongly attaches to particles containing iron or manganese.

❏ Nickel does not appear to accumulate in fish or in other animals used as food.

How might I be exposed to nickel?

❏ By eating food containing nickel, which is the major source of exposure for most people.

❏ By skin contact with soil, bath or shower water, or metals containing nickel, as well as by handling coins or touching jewelry containing nickel.

❏ By drinking water that contains small amounts of nickel.

❏ By breathing air or smoking tobacco containing nickel.

❏ Higher exposure may occur if you work in industries that process or use nickel.

How can nickel affect my health?

The most common harmful health effect of nickel in humans is an allergic reaction. Approximately 10-20% of the population is sensitive to nickel. People can become sensitive to nickel when jewelry or other things containing it are in direct contact with the skin for a long time. Once a person is sensitized to nickel, further contact with the metal may produce a reaction. The most common reaction is a skin rash at the site of contact. The skin rash may also

occur at a site away from the site of contact. Less frequently, some people who are sensitive to nickel have asthma attacks following exposure to nickel. Some sensitized people react when they consume food or water containing nickel or breathe dust containing it.

People working in nickel refineries or nickel-processing plants have experienced chronic bronchitis and reduced lung function. These persons breathed amounts of nickel much higher than levels found normally in the environment.

Workers who drank water containing high amounts of nickel had stomach ache and suffered adverse effects to their blood and kidneys.

Damage to the lung and nasal cavity has been observed in rats and mice breathing nickel compounds. Eating or drinking large amounts of nickel has caused lung disease in dogs and rats and has affected the stomach, blood, liver, kidneys, and immune system in rats and mice, as well as their reproduction and development.

How likely is nickel to cause cancer?

Cancers of the lung and nasal sinus have resulted when workers breathed dust containing high levels of nickel compounds while working in nickel refineries or nickel processing plants. The Department of Health and Human Services (DHHS) has determined that nickel metal may reasonably be anticipated to be a carcinogen and that nickel compounds are known human carcinogens. The International Agency for Research on Cancer (IARC) has determined that some nickel compounds are carcinogenic to humans and that metallic nickel may possibly be carcinogenic to humans. The EPA has determined that nickel refinery dust and nickel subsulfide are human carcinogens.

How can nickel affect children?

It is likely that the health effects seen in children exposed to nickel will be similar to those seen in adults. We do not know whether children differ from adults in their susceptibility to nickel. Human studies that examined whether nickel can harm the fetus are inconclusive. Animal studies have found increases in newborn deaths and decreased newborn weight after ingesting very high amounts of nickel. Nickel can be transferred from the mother to an infant in breast milk and can cross the placenta.

How can families reduce the risks of exposure to nickel?

❑ Avoiding jewelry containing nickel will eliminate risks of exposure to this source of the metal.

❑ Exposures of the general population from other sources, such as foods and drinking water, are almost always too low to be of concern.

Is there a medical test to determine whether I've been exposed to nickel?

There are tests available to measure nickel in your blood, feces, and urine. More nickel was measured in the urine of workers who were exposed to nickel compounds that dissolve easily in water than in the urine of workers exposed to nickel compounds that are hard to dissolve. This means that it is easier to tell if you have been exposed to soluble nickel compounds than less-soluble compounds. The nickel measurements do not accurately predict potential health effects from exposure to nickel.

Has the federal government made recommendations to protect human health?

The EPA recommends that drinking water should contain no more than 0.1 milligrams of nickel per liter of water (0.1 mg/L). To protect workers, the Occupational Safety and Health Administration (OSHA) has set a limit of 1 mg of nickel per cubic meter of air (1 mg/m^3) for metallic nickel and nickel compounds in workplace air during an 8-hour workday, 40-hour workweek.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 2005. Toxicological Profile for Nickel (Update). Atlanta, GA: U.S. Department of Public Health and Human Services, Public Health Service.

Where can I get more information? For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology, 1600 Clifton Road NE, Mailstop F-32, Atlanta, GA 30333. Phone: 1-888-422-8737, FAX: 770-488-4178. ToxFAQs Internet address via WWW is http://www.atsdr.cdc.gov/toxfaq.html. ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

Agency for Toxic Substances and Disease Registry ToxFAQs September 1996

This fact sheet answers the most frequently asked health questions (FAQs) about polycyclic aromatic hydrocarbons (PAHs). For more information, call the ATSDR Information Center at 1-888-422-8737. This fact sheet is one in a series of summaries about hazardous substances and their health effects. This information is important because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

SUMMARY: Exposure to polycyclic aromatic hydrocarbons usually occurs by breathing air contaminated by wild fires or coal tar, or by eating foods that have been grilled. PAHs have been found in at least 600 of the 1,430 National Priorities List sites identified by the Environmental Protection Agency (EPA).

What are polycyclic aromatic hydrocarbons?

(Pronounced pŏl′ĭ-sī′klĭk ăr′ə-măt′ĭk hī′drə-kar′bənz)

Polycyclic aromatic hydrocarbons (PAHs) are a group of over 100 different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances like tobacco or charbroiled meat. PAHs are usually found as a mixture containing two or more of these compounds, such as soot.

Some PAHs are manufactured. These pure PAHs usually exist as colorless, white, or pale yellow-green solids. PAHs are found in coal tar, crude oil, creosote, and roofing tar, but a few are used in medicines or to make dyes, plastics, and pesticides.

What happens to PAHs when they enter the environment?

- PAHs enter the air mostly as releases from volcanoes, forest fires, burning coal, and automobile exhaust.
- PAHs can occur in air attached to dust particles.
- Some PAH particles can readily evaporate into the air from soil or surface waters.
- PAHs can break down by reacting with sunlight and other chemicals in the air, over a period of days to weeks.
- PAHs enter water through discharges from industrial and wastewater treatment plants.
- Most PAHs do not dissolve easily in water. They stick to solid particles and settle to the bottoms of lakes or rivers.
- Microorganisms can break down PAHs in soil or water after a period of weeks to months.
- In soils, PAHs are most likely to stick tightly to particles; certain PAHs move through soil to contaminate underground water.
- PAH contents of plants and animals may be much higher than PAH contents of soil or water in which they live.

How might I be exposed to PAHs?

- Breathing air containing PAHs in the workplace of coking, coal-tar, and asphalt production plants; smokehouses; and municipal trash incineration facilities.
- Breathing air containing PAHs from cigarette smoke, wood smoke, vehicle exhausts, asphalt roads, or agricultural burn smoke.
- Coming in contact with air, water, or soil near hazardous waste sites.
- Eating grilled or charred meats; contaminated cereals, flour, bread, vegetables, fruits, meats; and processed or pickled foods.
- Drinking contaminated water or cow's milk.

- Nursing infants of mothers living near hazardous waste sites may be exposed to PAHs through their mother's milk.

How can PAHs affect my health?

Mice that were fed high levels of one PAH during pregnancy had difficulty reproducing and so did their offspring. These offspring also had higher rates of birth defects and lower body weights. It is not known whether these effects occur in people.

Animal studies have also shown that PAHs can cause harmful effects on the skin, body fluids, and ability to fight disease after both short- and long-term exposure. But these effects have not been seen in people.

How likely are PAHs to cause cancer?

The Department of Health and Human Services (DHHS) has determined that some PAHs may reasonably be expected to be carcinogens.

Some people who have breathed or touched mixtures of PAHs and other chemicals for long periods of time have developed cancer. Some PAHs have caused cancer in laboratory animals when they breathed air containing them (lung cancer), ingested them in food (stomach cancer), or had them applied to their skin (skin cancer).

Is there a medical test to show whether I've been exposed to PAHs?

In the body, PAHs are changed into chemicals that can attach to substances within the body. There are special tests that can detect PAHs attached to these substances in body tissues or blood. However, these tests cannot tell whether any health effects will occur or find out the extent or source of your exposure to the PAHs. The tests aren't usually available in your doctor's office because special equipment is needed to conduct them.

Has the federal government made recommendations to protect human health?

The Occupational Safety and Health Administration (OSHA) has set a limit of 0.2 milligrams of PAHs per cubic meter of air (0.2 mg/m^3). The OSHA Permissible Exposure Limit (PEL) for mineral oil mist that contains PAHs is 5 mg/m^3 averaged over an 8-hour exposure period.

The National Institute for Occupational Safety and Health (NIOSH) recommends that the average workplace air levels for coal tar products not exceed 0.1 mg/m^3 for a 10-hour workday, within a 40-hour workweek. There are other limits for workplace exposure for things that contain PAHs, such as coal, coal tar, and mineral oil.

Glossary

Carcinogen: A substance that can cause cancer.

Ingest: Take food or drink into your body.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 1995. Toxicological profile for polycyclic aromatic hydrocarbons. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Where can I get more information? For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology, 1600 Clifton Road NE, Mailstop F-32, Atlanta, GA 30333. Phone: 1-888-422-8737, FAX: 770-488-4178. ToxFAQs Internet address via WWW is http://www.atsdr.cdc.gov/toxfaq.html ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

Appendix B

WEST NILE VIRUS/ST. LOUIS ENCEPHALITIS PREVENTION

WEST NILE VIRUS/ST. LOUIS ENCEPHALITIS PREVENTION

The following section is based upon information provided by the CDC Division of Vector-Borne Infectious Diseases; Symptoms of West Nile Virus include fever, headache, and body aches, occasionally with skin rash and swollen lymph glands, with most infections being mild. More severe infection may be marked by headache, high fever, neck stiffness, stupor, disorientation, coma, tremors, convulsions, muscle weakness, paralysis, and, rarely, death. Most infections of St. Louis encephalitis ate mild without apparent symptoms other than fever with headache. More severe infection is marked by headache, high fever, neck stiffness, stupor, disorientation, coma, tremors, occasional convulsions (especially infants) and spastic (but rarely flaccid) paralysis. The only way to avoid infection of West Nile Virus and St. Louis encephalitis is to avoid mosquito bites. To reduce the chance of mosquito contact:

- Stay indoors at dawn, dusk, and in the early evening.
- Wear long-sleeved shirts and long pants whenever you are outdoors,
- Spray clothing with repellents containing permethrin or DEET (N, N-diethyl-meta-toluamide), since mosquitoes may bite through thin clothing.
- Apply insect repellent sparingly to exposed skin. An effective repellent will contain 35% DEET. DEET in high concentrations (greater than 35%) provides no additional protection.
- Repellents may irritate the eyes and mouth.
- Whenever you use an insecticide or insect repellent, be sure to read and follow the manufacturer’s directions for use, as printed on the product.

Appendix C

INCIDENT REPORT

WEEKLY SAFETY REPORT FORM

Week Ending: _____ Project Name/Number: _____

Report Date: _____ Project Manager Name: _____

Summary of any violations of procedures occurring that week:

_____

_____

_____

Summary of any job related injuries, illnesses, or near misses that week:

_____

_____

_____

Summary of air monitoring data that week (include sample analyses, action levels exceeded, and actions taken):

_____

_____

_____

Comments:

_____

_____

_____

Name: _____ Company: _____

Signature: _____ Title: _____

INCIDENT REPORT FORM

Date of Report: _____

Injured: _____

Employer: _____

Site: _____ Site Location: _____

Report Prepared By: _____ _____
Signature Title

ACCIDENT/INCIDENT CATEGORY (Check all that applies)

___Injury	___Illness	___Near Miss
___Property Damage	___Fire	___Chemical Exposure
___On-Site Equipment	___Motor Vehicle	___Electrical
___Mechanical	___Spill	___Other

DATE AND TIME OF ACCIDENT/INCIDENT: Narrative report of Accident/Incident: Identify: 1) actions leading to or contributing to the accident/incident; 2) the accident/incident occurrence; and 3) actions following the accident/incident.

_____

_____

_____

_____

_____

_____

WITNESS TO ACCIDENT/INCIDENT:

Name: _____ Company: _____

Address: _____ Phone No.: _____

Name: _____ Company: _____

Address: _____ Phone No.: _____

INJURED – ILL:

Name: _____ SSN:_____ Age: _____

Address: _____

Length of Service: _____ Time on Present Job: _____

Time/Classification: _____

SEVERITY OF INJURY OR ILLNESS:

____Disabling ____Non-Disabling ____ Fatality

____Medical Treatment ____First Air Only

ESTIMATED NUMBER OF DAYS AWAY FROM JOB: _____

NATURE OF INJUREY OR ILLNESS:

_____

_____

_____

_____

CLASSIFICATION OF INJURY:

____Abrasions ____Dislocations ____Punctures

____Bites ____Faint/Dizziness ____Radiation Burns

____Blisters ____Fractures ____Respiratory Allergy

____Bruises ____Frostbite ____Sprains

____Chemical Burns ____Heat Burns ____Toxic Resp. Exposure

____Cold Exposure ____Heat Exhaustion ____Toxic Ingestion

____Concussion ____Heat Stroke ____Dermal Allergy

____Lacerations

Part of Body Affected: _____

Degree of Disability: _____

Date Medical Care was Received:_____

Where Medical Care was Received: _____

Address (if off-site): _____

(If two or more injuries, record on separate sheets)

PROPERTY DAMAGE:

Description of Damage: _____

_____

Cost of Damage: $ _____

ACCIDENT/INCIDENT LOCATION: _____

ACCIDENT/INCIDENT ANALYSIS: Causative agent most directly related to accident/incident (Object, substance, material, machinery, equipment, conditions)

_____

_____

_____

_____

Was weather a factor? _____

Unsafe mechanical/physical/environmental condition at time of accident/incident (Be specific):

_____

_____

_____

Personal factors (Attitude, knowledge or skill, reaction time, fatigue):

_____

_____

_____

ON-SITE ACCIDENTS/INCIDENTS:

Level of personal protection equipment required in Site Safety Plan:

_____

_____

_____

Modifications:

_____

Was injured using required equipment?:

_____

_____

_____

If not, how did actual equipment use differ from plan?:

_____

_____

_____

ACTION TAKEN TO PREVENT RECURRENCE**:** (Be specific. What has or will be done? When will it be done? Who is the responsible party to insure that the correction is made?

_____

_____

_____

_____

ACCIDENT/INCIDENT REPORT REVIEWED BY:

SSO Name Printed	SSO Signature

OTHERS PARTICIPATING IN INVESTIGATION:

Signature	Title
Signature	Title
Signature	Title

ACCIDENT/INCIDENT FOLLOW-UP:

Date: _____

Outcome of accident/incident

_____

_____

_____

_____

Physician's recommendations: _____

_____

_____

_____

_____

Date injured returned to work: _____

Follow-up performed by:

_____ _____

Signature Title

ATTACH ANY ADDITIONAL INFORMATION TO THIS FORM

Appendix D

EMERGENCY HAND SIGNALS

EMERGENCY SIGNALS

In most cases, field personnel will carry portable radios for communication. If this is the case, a transmission that indicates an emergency will take priority over all other transmissions. All other site radios will yield the frequency to the emergency transmissions.

Where radio communications is not available, the following air-horn and/or hand signals will be used:

EMERGENCY HAND SIGNALS

OUT OF AIR, CAN'T BREATHE	**Hand Gripping Throat**
LEAVE AREA IMMEDIATELY, NO DEBATE!	**(No Picture) Grip partner's Wrist or place both hands around waist**
NEED ASSISTANCE!	**Hands on top of head**
OKAY! - I'M ALL RIGHT! - I UNDERSTAND!	**Thumbs up**
NO! – NEGATIVE	**Thumbs down**

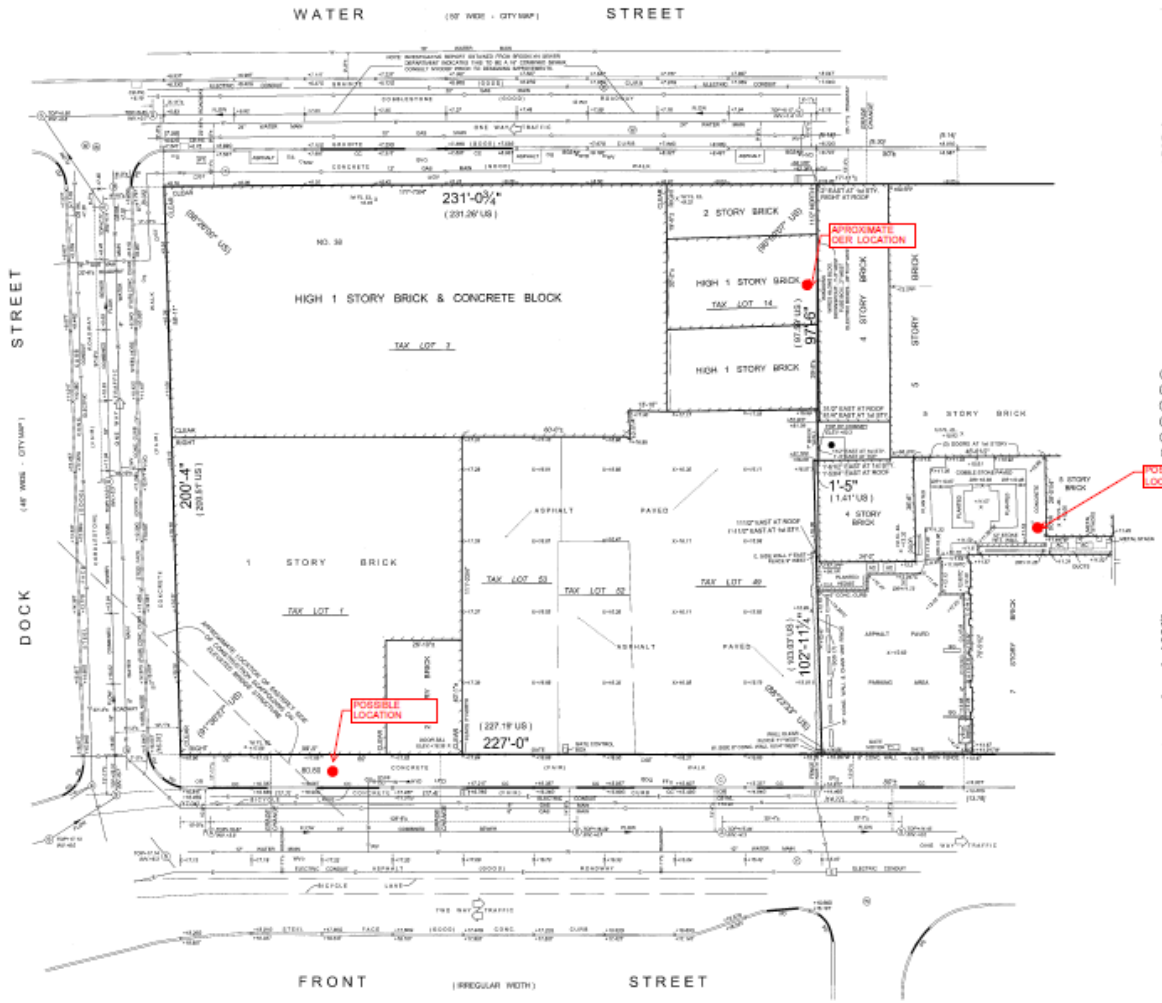
APPENDIX 6

GROUNDWATER SAMPLING LOCATION PLAN

SURVEY OF PROPERTY

IN THE

BOROUGH OF BROOKLYN, COUNTY OF KINGS
CITY AND STATE OF NEW YORK



LEGEND:

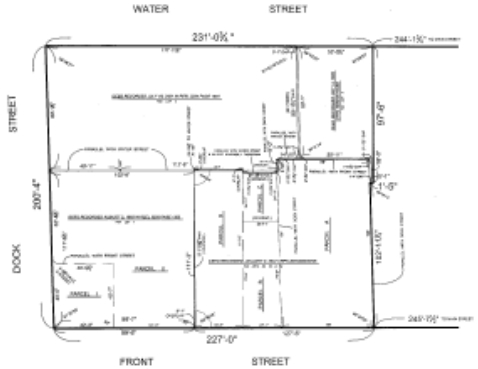
BG	BUMPER GUARD
CC	CURB CUT
FF	FUEL FILL
GD	GAS DRIP
GT	GAS TEST
GV	GAS VALVE
HYD	HYDRANT
LP	LIGHT POLE
MW	MONITORING WELL
PD	PEDESTRIAN DROP
PT	PUBLIC TELEPHONE
S	SIGN
AC	AIR CONDITIONER UNITS
V	VALVE (TYPE UNKNOWN)
WV	WATER VALVE
(5.18)	INDICATES ESTABLISHED GRADE
+5.23	INDICATES ACTUAL ELEVATION
+5.41T	INDICATES ELEVATION AT TOP OF CURB
+4.91B	INDICATES ELEVATION AT BOTTOM OF CURB
+57.79P	INDICATES TOP OF PARAPET ELEVATION
+56.1R	INDICATES ROOF ELEVATION
CB (N) +4.82	INDICATES CATCH BASIN INLET ELEVATION
(SR+11.17)	INDICATES SPAIN INLET ELEVATION
TOP+12.05	INDICATES SEWER MANHOLE RIM ELEVATION
INV+16.4	INDICATES SEWER MANHOLE INVERT ELEVATION
+7.42TW	INDICATES ELEVATION AT TOP OF WALL
+7.66TC	INDICATES ELEVATION AT TOP OF CURB
CO	CLEANOUT MANHOLE
E	ELECTRIC MANHOLE
F	FIRE MANHOLE
S	SEWER MANHOLE
T	TELEPHONE MANHOLE
W	WATER MANHOLE

FEMA FLOOD DESIGNATION:
NATIONAL FLOOD INSURANCE PROGRAM, FLOOD INSURANCE RATE MAP, MAP NO. 3604970005F, REVISED SEPTEMBER 5, 2007 INDICATES PARCEL SURVEYED LIES IN:

- ZONE A - AREAS DETERMINED TO BE OUTSIDE THE 0.2% ANNUAL CHANCE FLOODPLAIN.
- ZONE X - AREAS OF 0.2% ANNUAL CHANCE FLOOD; AREAS OF 1% ANNUAL CHANCE FLOOD WITH AVERAGE DEPTHS OF LESS THAN 1 FOOT OR WITH DRAINAGE AREAS LESS THAN 1 SQUARE MILE; AND AREAS PROTECTED BY LEVEES FROM 1% ANNUAL CHANCE FLOOD.
- ZONE AE (EL 10) BASE FLOOD ELEVATION DETERMINED.

EL. 9.00 (BKLYN HWY. DEPT. DATUM)
SURVEY DATUM
EL. 8.00 (NGVD 1929)
(FEMA - FIRM DATUM)

PARCEL COMPRISED OF TAX LOTS 1, 3, 14, 49, 52, 53
IN BLOCK 36
AREA = 45,821 SQ. FT. OR 1.0191 ACRE



PARCEL DIAGRAM NOT TO SCALE
DIMENSIONS IN LOCAL STANDARD OF MEASUREMENT

NOTE:
THIS SURVEY HAS BEEN PREPARED WITHOUT THE BENEFIT OF A FULL ABSTRACT OF TITLE. EASEMENTS, COVENANTS, EASEMENTS AND RESTRICTIONS, AFFECTING AND/OR BENEFITING PARCEL SURVEYED NOT INDICATED HEREON. BE SURE ANY QUESTIONS PERTAINING TO TITLE ARE SETTLED BEFORE DESIGNING IMPROVEMENTS ON BUILDING.

NOTES:

1. LOT DIMENSIONS SHOWN HEREON ARE IN LOCAL STANDARD OF MEASUREMENT UNLESS NOTED THUS (180' US), WHICH INDICATES UNITED STATES STANDARD OF MEASUREMENT.
2. ELEVATIONS AND ESTABLISHED GRADES SHOWN HEREON REFER TO THE BOROUGH OF BROOKLYN HIGHWAY DEPARTMENT DATUM WHICH IS 2.56 FEET ABOVE MEAN SEA LEVEL DATUM (U.S.C. & G.S.) AT SANDY HOOK, NEW JERSEY AS ESTABLISHED IN 1929.
3. ESTABLISHED GRADES SHOWN HEREON REFER TO TOP OF CURB. SHOULD ESTABLISHED GRADES VARY SIGNIFICANTLY WITH EXISTING ELEVATIONS CONSULT THE BROOKLYN TOPOGRAPHICAL BUREAU PRIOR TO DESIGNING IMPROVEMENTS.
4. ANTENNES AND/OR STREETS SHOWN HEREON ARE AS ON PRESENT CITY MAP UNLESS OTHERWISE NOTED.
5. SIZES AND LOCATIONS OF WATER MAINS SHOWN HEREON AS PER N.Y.C. DEPARTMENT OF ENVIRONMENTAL PROTECTION RECORDS.
6. SIZE AND TYPE OF SEWER SHOWN HEREON AS PER N.Y.C. DEPARTMENT OF ENVIRONMENTAL PROTECTION RECORDS. LOCATIONS OF SEWER MANHOLES AND RIM AND INVERT ELEVATIONS ARE AS FOUND BY FIELD MEASUREMENTS.
7. INFORMATION PERTAINING TO SIDEWALKS, ELECTRIC CONDUIT, SHOWN HEREON, AS OBTAINED FROM CONSOLIDATED EDISON COMPANY OF NEW YORK.
8. INFORMATION PERTAINING TO GAS MAINS, SHOWN HEREON AS OBTAINED FROM KEYSPAN ENERGY.
9. INFORMATION PERTAINING TO ELECTRIC, GAS, SEWER AND WATER SHOWN HEREON IS NOT GUARANTEED AS TO ACCURACY OR COMPLETENESS. NO SUBSURFACE UTILITY INFORMATION OTHER THAN ELECTRIC, GAS, SEWER AND WATER SHOWN HEREON. CONSULT THE APPROPRIATE AGENCY OR UTILITY COMPANY PRIOR TO DESIGNING IMPROVEMENTS.
10. SUBSURFACE ENCROACHMENTS, IF ANY, NOT LOCATED AND NOT INDICATED HEREON.
11. NEW YORK STATE'S LAW, OSHA RULE 53 REQUIRES CONTRACTORS TO GIVE AT LEAST TWO DAYS, BUT NOT MORE THAN TEN DAYS NOTICE BEFORE DIGGING, DRILLING OR BLASTING.
12. THIS IS TO CERTIFY THAT THERE ARE NO STRUCTURES NOR NATURAL WATER COURSES PRESENTLY ON THE PROPERTY AS SHOWN ON THIS SURVEY.
13. ARCHITECT, CONTRACTOR, CLIENT AND/OR HIS REPRESENTATIVES SHALL REPORT ANY DISCREPANCIES TO THE LAND SURVEYOR IMMEDIATELY. IT IS STRONGLY SUGGESTED THAT THE PROPERTY LINES BE PHYSICALLY MARKED BY A LICENSED LAND SURVEYOR PRIOR TO COMMENCING CONSTRUCTION.
14. "UNAUTHORIZED ALTERATION OR ADDITION TO A SURVEY MAP BEARING A LICENSED LAND SURVEYOR'S SEAL IS A VIOLATION OF SECTION 7209, SUBDIVISION 2, OF THE NEW YORK STATE EDUCATION LAW. ONLY COPIES FROM THE ORIGINAL OF THIS SURVEY MARKED WITH AN ORIGINAL OF THE LAND SURVEYOR'S INK SEAL SHALL BE CONSIDERED TO BE VALID TRUE COPIES. CERTIFICATIONS SHALL SIGN ONLY TO THE PERSON FOR WHOM THE SURVEY IS PREPARED, AND ON HIS BEHALF TO THE TITLE COMPANY, GOVERNMENTAL AGENCY AND LENDING INSTITUTION LISTED HEREON, AND TO THE ASSIGNEES OF THE LENDING INSTITUTION. CERTIFICATIONS ARE NOT TRANSFERABLE TO ADDITIONAL INSTITUTIONS OR SUBSEQUENT OWNERS"

BARTLETT, LUDLAM & DILL ASSOCIATES
LAND AND CITY SURVEYORS SINCE 1929
72-41 COOPER AVENUE GLENDALE, NY 11385
PHONE: 718-366-4832 FAX: 718-366-6835

DATE: APRIL 9, 2012 SCALE: 1" = 20'

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ORDER NO.: 111181

BLOCK NO.: 36

APPENDIX 7

SCA COMMENTS TO PHASE II AND RIR
EMTEQUE RESPONSE TO COMMENTS

TRC Engineers, Inc.
1430 Broadway, 10th Floor
New York, NY 10018

Main 212.221.7822
Fax 212.221.7840

Memorandum

To: Ms. Lee Guterman
Deputy Director, IEH Division
New York City School Construction Authority

From: Michael Sherwood
Senior Project Manager
TRC Engineers, Inc.

Subject: Review of Phase II Work Plan and
Remedial Investigation Report
Two Trees Dock Street Development
Brooklyn, New York
Block 36, Lots 1, 3, 14, 49, 52, & 53
SCA LLW# 052791, Job# 29085

Date: September 17, 2012

cc: Srinivas Kanaparthi, NYCSCA

At the request of the New York City School Construction Authority (NYCSCA), TRC Engineers, Inc. (TRC) reviewed the Phase II Work Plan (Work Plan) and the Remedial Investigation Report (RIR) prepared by Emteque, LLC (Emteque) on behalf of Two Trees Management Co., LLC (Developer) for the properties known as the Two Trees Dock Street Development (the "Site"). The Site consists of four properties: St. Ann's Warehouse located at 38 Water Street (Block 36, Lot 3); the Carousel Building located at 56 Water Street (Block 36, Lot 14); a Parking Garage located at 21 Front Street (Block 36, Lot 1); and a Surface Parking located at 35-39 Front Street (Block 36, Lots 49, 52, 53). The Work Plan, dated August 20, 2012, and the RIR, dated August 2012, were prepared for submission to the New York City Mayor's Office of Environmental Remediation (OER) for the purpose of addressing the Hazardous Materials (E-132) E-Designation assigned to the Surface Parking portion of the Site by the New York City Department of City Planning (DCP). The RIR was also completed to assess subsurface environmental conditions at the other properties that comprise the Site.

TRC understands that Site demolition activities have begun for the construction of a new development consisting of a parking garage, retail stores, a school, and residential units. The NYCSCA is considering a lease of the second floor and a ground floor lobby of the building proposed to be developed at the Site.

The findings of TRC's review of the Work Plan and RIR are presented below.

Approved By Jim
9-20-2012
ARG

Phase II Work Plan

1. The Work Plan is dated August 20, 2012. Considering that the environmental investigation proposed in the Work Plan has already been completed and the findings presented in the RIR, the Work Plan date appears inconsistent.

2. The Work Plan provided to the NYCSCA did not contain figures or appendices. At a minimum, the NYCSCA should be provided with a copy of the Proposed Sample Location Figure (i.e., Figure 3) and the Geophysical Survey presented in Appendix A.

3. The geographic directions provided in Section 1.1 do not appear to be accurate. For instance, the Work Plan indicates that Dock Street is South of the Site, but Dock Street appears to be West of the Site.

4. The Phase I Environmental Site Assessment (Phase I ESA) Summary presented in Section 2.3 does not include the NYCSCA recommendations presented in the August 6, 2008 Fleming-Lee Shue, Inc. (FLS) Memorandum. The Work Plan references a Phase I ESA date of November 2007, indicating that the report may not have been revised.

5. In Section 3.2, the methodology for selecting soil samples for laboratory analysis is unclear.

6. In previous project correspondence from 2008 and 2009, the NYCSCA asked to review the Work Plan prior implementation. The NYCSCA was not given this opportunity and the environmental investigation has already been completed.

Remedial Investigation Report

1. The RIR indicates that the Site has been enrolled in the New York City Voluntary Cleanup Program (VCP). TRC is aware of The New York City Brownfield Cleanup Program (NYC BCP) operated by OER. Emteque should confirm that the Site was enrolled in the NYC BCP.

2. The geographic directions provided in Section 1.1 do not appear to be accurate. For instance, the RIR indicates that Dock Street is South of the Site, but Dock Street appears to be West of the Site.

3. The RIR subsections on Pages 18 through 23 do not agree with the Table of Contents and appear to be out of order.

4. Section 4.3 refers to sampling soils just above the "smear zone" when selecting soil samples for laboratory analysis from each boring. TRC is not aware of free product detected at the Site and it appears that Emteque was referring to sampling soils just above the groundwater interface, but this assumption should be confirmed.

5. In Section 4.3, on Pages 15 and 16, the methodology that was used for selecting soil samples for laboratory analysis is unclear, particularly for the deeper soil sample in each boring. The text indicates that the deeper sample was always collected just above the "smear zone" (see Comment 4 above). However, the text also indicates that soil samples "which exhibited the highest PID readings or other indicators of contamination were selected for laboratory analysis of VOCs". The soil sample names do not contain the sample interval and the boring logs provided in Appendix D are unclear with regard to soil samples selected for laboratory analysis.

6. Throughout the RIR, Emteque references a "Little e" designation associated with the Surface Parking portion of the Site. Emteque should explain/define this term in the RIR.

7. Throughout the RIR, references to the number of groundwater samples collected vary between five and six. Based on review of the analytical, it appears that five groundwater samples were collected and one field blank was collected for QA/QC purposes. This should be clarified in the report.

8. The RIR references the collection of "ambient basement level and outside level air samples", but the data tables and laboratory reports do not present this information. Emteque should provide the laboratory report for the above-referenced samples and explain in the RIR where the samples were collected.

9. The Work Plan indicated that both filtered and unfiltered groundwater samples would be collected for analysis, but it appears that only unfiltered samples were analyzed.

10. No borings or vapor samples were collected at the Carousel Building property because the Geoprobe® drilling equipment on site could not access the basement of the building. TRC considers this to be a data gap since the Carousel Building was once an iron foundry, metal smelter, soap factory, and spice processing plant, as indicated in the Phase I ESA. In addition, one of the borings completed nearest to the Carousel Building, SS #11, displayed PID readings of 250 part per million (ppm) in a saturated soil sample.

11. Based on review of the documents provided, TRC does not agree with Emteque's statement that the benzene, naphthalene, and tetrahydrofuran (THF) detected in groundwater at the existing monitoring well called "MW Dock & Water" is necessarily from an offsite source and is not impacting the Site. Specifically, TRC notes that this statement would need to be substantiated by the following:

    a. Collection of environmental samples below the Carousel Building.

    b. Determination of groundwater elevation and flow direction by a survey of the monitoring wells at the Site.

c. Researching the nature and extent of groundwater contamination emanating from the 11 Front Street property, and other presumed upgradient contaminated sites, via Freedom of Information Law (FOIL) requests to the New York State Department of Environmental Conservation (NYSDEC).

12. TRC also notes that methyl tert-butyl ether (MTBE) was detected in the sample collected from monitoring well "MW Dock & Water" at a concentration of 140 micrograms per liter (μg/L) which may indicate a commercial gasoline source.

13. In Section 5.3, the text references "deeper" groundwater samples collected at the monitoring wells labeled "MW Dock & Water/16-W" and "PMW-1/B-5W". It is not clear if there are nested (i.e., multiple wells with varying screen depths) monitoring wells located at these sampling locations or if the wells are just screened deeper relative to the other temporary wells installed during the investigation. This should be clarified in the report.

14. TRC agrees that semi-volatile organic compounds (SVOCs) and metals detected in shallow soils appear to be consistent with historic fill material. The geotechnical report confirms the presence of fill material ranging in thickness from 8feet to 18 feet across the Site. Based on the Site development drawings, it appears that the majority of this fill material will be removed during the excavation for the new building foundation.

15. Throughout the RIR, tetrachloroethene detections are referenced a "TCE". The abbreviation for tetrachloroethene is PCE.

16. TRC does not agree that the sub slab vapor concentrations are consistent with "typical levels noted in commercial properties", as indicated on Page 8. The PCE concentration in soil vapor probe SV-1 of 2,930 micrograms per cubic meter ($\mu g/m^3$) is significantly elevated and suggests the possibility of a nearby source of subsurface PCE contamination. In addition, the trichloroethene (TCE) concentration in soil vapor prove SV-1 of 95.6 $\mu g/m^3$ is well above typical background concentrations. Groundwater samples collected across the Site document that there is some dissolved-phase PCE contamination under the Site buildings with concentrations ranging from 1.2 μg/L in MW #4 to 19 μg/L in PMW #1.

17. TRC does not agree with Emteque's interpretation of the decision matrices provided in the New York State Department of Health (NYSDOH) "Guidance for Evaluating Vapor Intrusion in the State of New York" indicating "no further action to continued monitoring of vapor gases" based on the laboratory results. The NYSDOH decision matrices are designed to evaluate co-located sub slab and indoor air quality (IAQ) samples that were collected simultaneously. As indicated in a previous comment, IAQ sampling results were not presented in the RIR even though the report suggests that these samples were collected. Furthermore, Matrix 2 indicates that a sub slab PCE concentration of 2,930 $\mu g/m^3$ would require mitigation regardless of concurrent IAQ sampling results. Matrix 1 indicates that a sub slab TCE

concentration of 95.6 $\mu g/m^3$ would require either additional monitoring or mitigation, depending on the IAQ concentration.

18. TRC does not agree with Emteque's statement on Page 23, Section 5.4, indicating that vapor mitigation "might include the use of a vapor barrier". Based on the soil vapor concentrations and dissolved-phase groundwater concentrations detected during the RIR, at a minimum the NYCSCA will require both a vapor barrier and an active sub slab depressurization system (SSDS) in order to occupy the building. Based on the NYCSCA's experience, OER and the NYSDOH will require the same vapor mitigation engineering controls.

19. Subsection 3.3.1.1 on Page 23 is titled, "Volatile Organic Compounds (VOCs) and Semi-Volatile Organic Compounds (SVOCs) in Sub-slab Soil Vapor Samples". It does not appear that vapor samples were analyzed for SVOCs, so the title of this subsection should be revised.

20. In Section 5.5, TRC agrees with the recommendation to develop a soils management plan prior to the start of excavation activities to ensure proper characterization and disposal of excavated materials. TRC notes the possibility for hazardous soil handling requirements considering the elevated lead concentrations reported in samples collected from SS-5A and SS-6, and elevated mercury concentrations in samples collected from SS-6A and SS-8. The NYCSCA would like the opportunity to review and comment on the soil management plan once developed.

21. The Site survey provided as Figure 1 indicates that portions of the Site are in the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) Zones AE and X. Zone AE is within the base flood plain and is considered a high risk area.

22. Review of Figure 3 (Drawing A400.00) suggests that the proposed sub-cellar parking garage for the new building will be constructed approximately 7 to 8 feet below groundwater. As a result, dewatering will be required which, if not designed and implemented properly, could draw groundwater contamination on to the Site from neighboring properties. In addition, the vapor barrier and SSDS design will be complicated by the fact that the building slab and portions of the foundation walls will be subject to a hydrostatic condition. The vapor mitigation and dewatering design documents should be provided to the NYCSCA for review and comment.

23. The RIR text indicates that a geophysical survey report is presented in Appendix C, but Appendix C only contains the geotechnical report. It is unclear whether a geophysical survey was completed to attempt to identify the location of underground storage tanks at the Parking Garage property located at 21 Front Street.

24. Laboratory documentation provided in Appendix E indicates that some soil samples submitted for analysis of pesticides and polychlorinated biphenyls (PCBs) exceeded analytical method holding times.

25. In Appendix G, several vapor samples were crossed out on the chain of custody. The location of these samples and rationale for not analyzing them should be presented in the report.

TRC's Recommendations

1. The Remedial Investigation Report should be edited for content and clarity prior to submission to OER.

2. A supplemental environmental investigation should be conducted to assess subsurface conditions at the Carousel Building including soil, groundwater, and vapor analyses, and to evaluate potential for hazardous concentrations of metals for soil management and disposal.

3. A review of the NYSDEC's records pertaining to the spill at 11 Front Street should be completed.

4. The source of dissolved phase chlorinated solvents in groundwater should be further investigated.

5. Monitoring wells at the Site and in the adjacent sidewalk should be surveyed and depth to water measurements collected in order to determine/confirm groundwater flow direction.

6. The proposed soil management plan should be presented to the NYCSCA for review and comment.

7. Details regarding dewatering during Site excavation activities should be presented to the NYCSCA for review and comment.

8. The new building design must include vapor mitigation engineering controls, including an active SSDS. The vapor mitigation design should include partitioning of the garage from the occupied spaces with exhaust locations positioned to be protective of the school/building occupants. The NYCSCA should review and comment on the vapor mitigation plans throughout the design of these systems.

Lynelle Cardone

From: Eric Telemaque
Sent: Tuesday, October 23, 2012 11:00 AM
To: Lynelle Cardone
Subject: FW: 60 Water Street
Attachments: Dock Streeet RIR Review Memo - 9-17-12.pdf

TRC document and our response.

Eric

From: Everets, Hale [mailto:heverets@TwoTrees-Dumbo.com]
Sent: Wednesday, October 03, 2012 9:23 PM
To: BGribble@dep.nyc.gov
Cc: SGOLDBERG@nycsca.org; Eric Telemaque; Wetzel, David; 'Sherwood, Michael (NYC,NY-US)'; MALHOTRA, PRATIMA; ZHANG, MI
Subject: 60 Water Street

Hello Breanna,

We received SCA comments and reviewed with members of the TRC/SCA team today. Attached you will find a copy of their memo, along with a summary of our discussion below regarding the TRC recommendations. Please let me know if you have any questions.

1. OER comments on the RIR are being incorporated for resubmission this week.

2. Additional investigative work will be performed in the area of the former Carousel Building and will be delineated in the Stipulation List related to the RAWP with OER. Our modification of the original probe at this location was communicated to OER during the initial investigation.

3. A request will be made to the NYSDEC to review the records for the spill at 11 Front Street.

4. Permanent wells will be installed and surveyed for groundwater flow direction, then we will further evaluate based on this information. This work will be delineated in the Stipulation List related to the RAWP with OER.

5. Refer to above.

6. A The RAWP addresses this in part. Additionally, the soils management plan will be provided for the excavation work.

7. Water was encountered on site at elevation +/- 6'-0". Therefore dewatering throughout construction is required. Green Star Builders, the GC, has entered into an agreement with Moretrench to provide dewatering services. The dewatering system will consist of a series of well points along the inside of the sheeting line tied to a header. The soil and water will be held back with steel sheeting. The steel sheeting is designed to achieve 15' of toe beneath the bottom of slab. By using interlocking sheets water will be contained with minimum influence to the surrounding water table.
   Well points will be drilled at approximately 4' centers around the interior side of the perimeter sheeting and connecting to a header. The header will distribute water to a settling tank prior to discharge. All fines are filtered at the well point. From the tank water will be distributed to combined sewers along Front and Dock

Street for discharge. A permit with DEC has already been secured. The dewatering system, will be monitored 24/7 and a backup generator and pumps will be maintained on site.

8. OER has reviewed and commented on the latest version of the RAWP. OER is inclined to allow a vapor barrier as part of the foundation installation as a means to control vapors, however, it is still reviewing and may request a passive system over residual contaminated soils. We are having further discussion with OER as it relates to a small section of slab on grade at the northeast corner. As for the larger, two cellar foundation Emteque and Two Trees believe that the proposed vapor barrier combined with the 3 floor buffer, including 2 fully ventilated parking floors is sufficient. This remains under review by SCA and their team

Hale Everets

Two Trees
45 Main Street, Suite 602
Brooklyn, NY 11201
T 718.222.2500

APPENDIX 8

VAPOR BARRIER PRE-CERTIFICATION

Mark A. Franciosi
Technical Service Engineer - Americas

T 617-498-4303

mark.a.franciosi@grace.com

W. R. Grace & Co.-Conn.
62 Whittemore Avenue
Cambridge, MA 02140

October 18th, 2012

Lynelle Cardone
Emteque LLC
1350 Broadway, Suite 1901 NYC 10018

Project: 60 Water Street NYC

Lynelle,

I have reviewed the following documents for the above referenced project:

- Table 1 - Soil Sample Results, pages 1-3 with a collection date of 7/6/2012
- Table 2 - Groundwater Sample Results, pages 1-2 with a collection date of 7/12/2012
- Table 3 - Soil Vapor Sample Results, pages 1-1 with a collection date of 7/12/2012

The identified contaminants at the levels reported will not have an adverse effect on the waterproofing or vapor barrier properties of Preprufe® 300R or Preprufe 160R® systems, provided these additional measures are taken:

- All Preprufe 300R and Preprufe 160R side laps are taped with Preprufe Tape
- All Preprufe 300R and Preprufe 160R end laps are taped with Preprufe CJ Tape.
- Standard design and application procedures are followed

Standard installation instructions and details can be found on our website at www.graceconstruction.com.

If you have any questions, please feel free to call me at the number above.

Sincerely,

Mark Franciosi

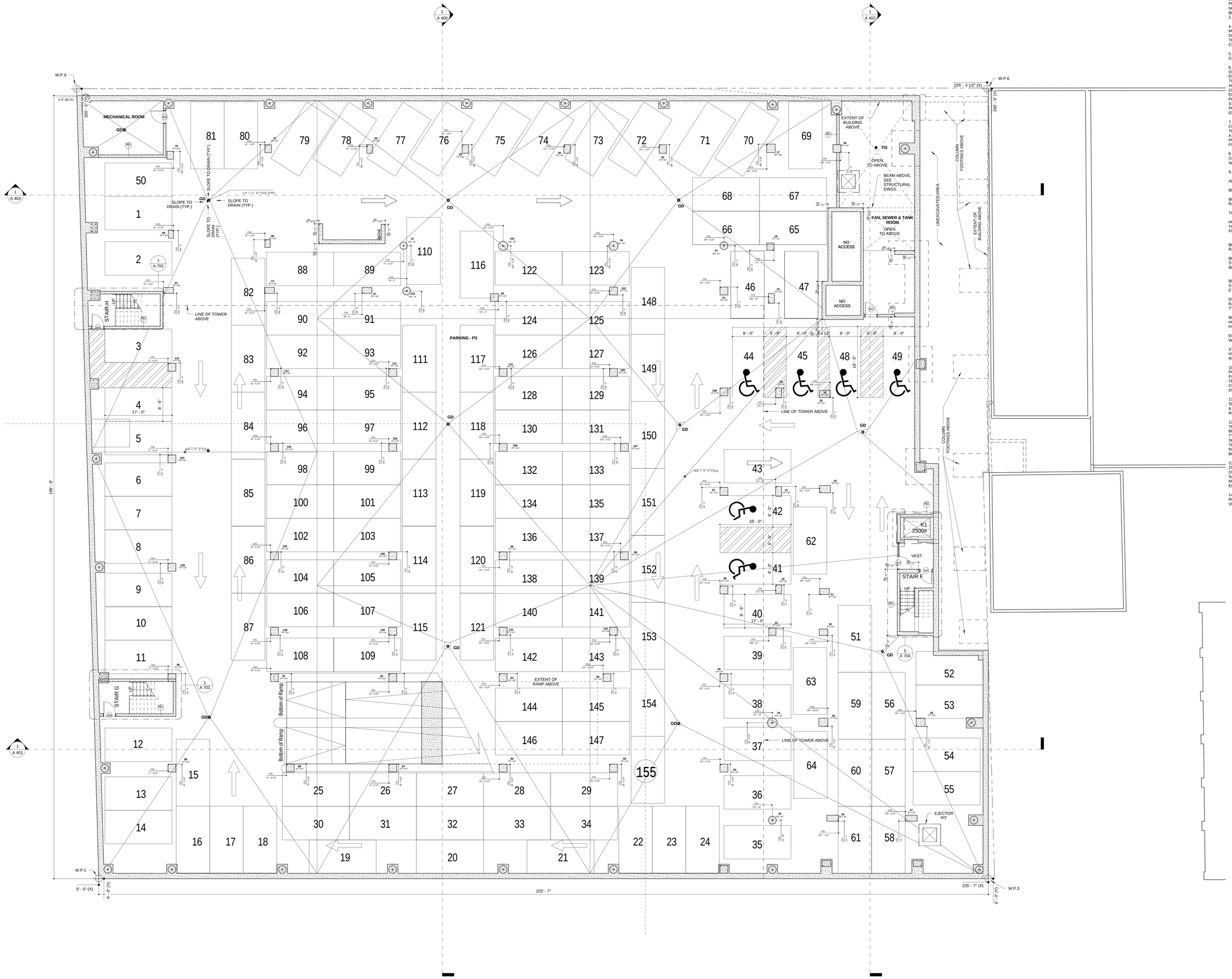
Mark Franciosi

Technical Services Engineer

cc: J. Ridgeway

APPENDIX 9

DRAWINGS A200 AND A200a



FLOOR PLAN GENERAL NOTES
(FLOORS SC - 2):

1. FOR DOOR TYPES AND DETAILS SEE DRAWING A 017A.

2. FOR INTERIOR PARTITION TYPES SEE DRAWING A 012 & A 013.

3. ALL ELEVATIONS SHOWN ON THESE PLANS ARE MEASURED RELATIVE TO NGVD (1929). FOR REFERENCE, BROOKLYN HIGHWAY DATUM (BHD) IS + 2.55'

4. U.O.N., INTERIOR DIMENSIONS ARE MEASURED TO THE CENTERLINE OF DRYWALL PARTITIONS & THE FACE OF THE OUTERMOST GWB AT FURRING, CHASE & SHAFT WALLS.

5. FOR STAIR DETAILS SEE VERTICAL CIRCULATION DRAWINGS A 700 SERIES.

6. IN ALL RESIDENTIAL STAIRS, DOORS OPENING INTO AN INTERIOR STAIR ENCLOSURE SHALL BE LOCKED FROM THE STAIR SIDE AND PROVIDED WITH AN AUTOMATIC FAIL SAFE SYSTEM FOR OPENING IN THE EVENT OF AN EMERGENCY. SIGNS SHALL BE PROVIDED THROUGHOUGHT THE STAIRWAY INDICATED THAT REENTRY IS PROVIDED ONLY DURING FIRE EMERGENCIES.

7. TELEPHONES OR OTHER TWO-WAY COMMUNICATION SYSTEMS, CONNECTED TO AN APPROVED CONSTANTLY ATTENDED STATION, SHALL BE PROVIDED AT NOT LESS THAN EVERY FIFTH FLOOR IN ALL RESIDENTIAL STAIRS.

8. EXIT STAIR ENCLOSURES SHALL BE CONSTRUCTED OF IMPACT RESISTANT WALLS.

9. TYPICAL INTERIOR PARTITION NOTES:
A. DRYWALL PARTITIONS WITHIN APARTMENTS TO BE TYPE D0RR U.O.N.
B. CHASE WALL PARTITIONS TO BE TYPE C0RR U.O.N.
C. DRYWALL PARTITIONS BETWEEN APARTMENTS TO BE MIN. 1 HR RATED TYPE D1/FF U.O.N.
D. FURRING AROUND COLUMNS TO BE TYPE F0/R- U.O.N.
E. FURRING AT ELEVATOR HOISTWAY AGAINST HABITABLE ROOMS TO BE TYPE F0/R-(b) U.O.N.
F. NOT USED
G. CHASE WALL PARTITIONS BETWEEN APARTMENTS TO BE MIN. 1 HR. RATED TYPE C1/FF U.O.N.
H. DRYWALL PARTITIONS BETWEEN APARTMENTS & CORRIDORS, STAIRS, ELECTRICAL CLOSETS, ETC. TO BE 2 HR. RATED TYPE D2/FF U.O.N.
I. NOT USED
J. CHASE WALL PARTITIONS BETWEEN APARTMENTS & CORRIDORS, STAIRWELLS, ELECTRICAL CLOSETS ETC. TO BE 2 HR RATED TYPE C2/FF.
K. ALL EXHAUST AND SUPPLY DUCT RISERS TO BE ENCLOSED IN 2 HR. RATED SOLID SHAFT WALL ASSEMBLIES TYPE H2/LF.
L. SHAFT WALL PARTITIONS BETWEEN CORRIDOR AND ELEVATOR HOISTWAY TO BE 2 HR RATED TYPE H2/LF.
M. TRASH CHUTE TO BE ENCLOSED IN CONTINUOUS 3 HR RATED WALL TYPE H3/LF.
N. PARTITIONS BETWEEN STAIRWELLS AND CORRIDORS TO BE 2 HR RATED ASSEMBLIES WITH IMPACT RESISTANT GWB TYPE D2/FF.

10. PROVIDE 3/4" THICK FIRE RETARDENT PLYWOOD FASTENED TO FINISHED PARTITION FOR ATTACHMENT OF TELECOM PANELS AND EQUIPMENT. COORDINATE LOCATION WITH TELECOM DWGS.

11. FOR LOCATIOSN OF SPRINKLERS, SMOKE/CO DETECTORS, LIGHT FIXTURES & OTHER CEILING FIXTURES, REFER TO RCP'S A 600 SERIES.

12. FINISH LEVEL AT ALL EXTERIOR TERRACES ADJOINING APARTMENTS TO BE 8" ABOVE TOP OF SLAB ELEVATION TYPICAL. OWNER OR BUILDING MANAGER SHALL PROVIDE HANDICAP ACCESS TO TERRACES FROM APARTMENT VIA RAMP INSTALLED IN COMPLIANCE WITH BUILDING CODE.

13. REFER TO SLAB PLANS (SERIES A 250) FOR SLAB EDGE LOCATIONS, OPENING SIZES AND COORDINATES. SEE SAME FOR COORDINATES OF MECHANICAL DUCTS, STAIR AND ELEVATOR SHAFT OPENINGS, ETC.

14. ALL MECHANICAL AND STORAGE ROOMS SHALL BE PROPERLY VENTILATED.

ISMAEL LEYVA ARCHITECTS, P.C.
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Structural Engineers
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FAX: (212) 620-8157

Ettinger & Associates
MEP/FS Engineers
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FAX: (201) 374-1795

No	Date:	Rev	Issue:
1	06/22/12		DOB SUBMISSION
2	10/09/12		DD SUBMISSION
3	10/19/12		DOB SUBMISSION

NOTES:
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BROOKLYN HIGHWAY DATUM (BHD) IS +2.55'

ALL ENCLOSED SPACES BELOW THE DESIGN FLOOD ELEVATION OF +11' - 0" (NGVD) SHALL COMPLY WITH APPENDIX G SECTION G304.1.2 FOR DRY FLOOD PROOFING AS SUCH AREAS ARE TO BE USED FOR PARKING & STORAGE

CLIENT

Two Trees Management
45 Main Street Suite 602
Brooklyn, NY 11201

PROJECT
60 Water Street
Brooklyn, NY

TITLE

SUB-CELLAR FLOOR PLAN

SCALE: 1/8" = 1'-0"
DATE: 06/22/2012
PROJECT No: 12.107

A 200 .00

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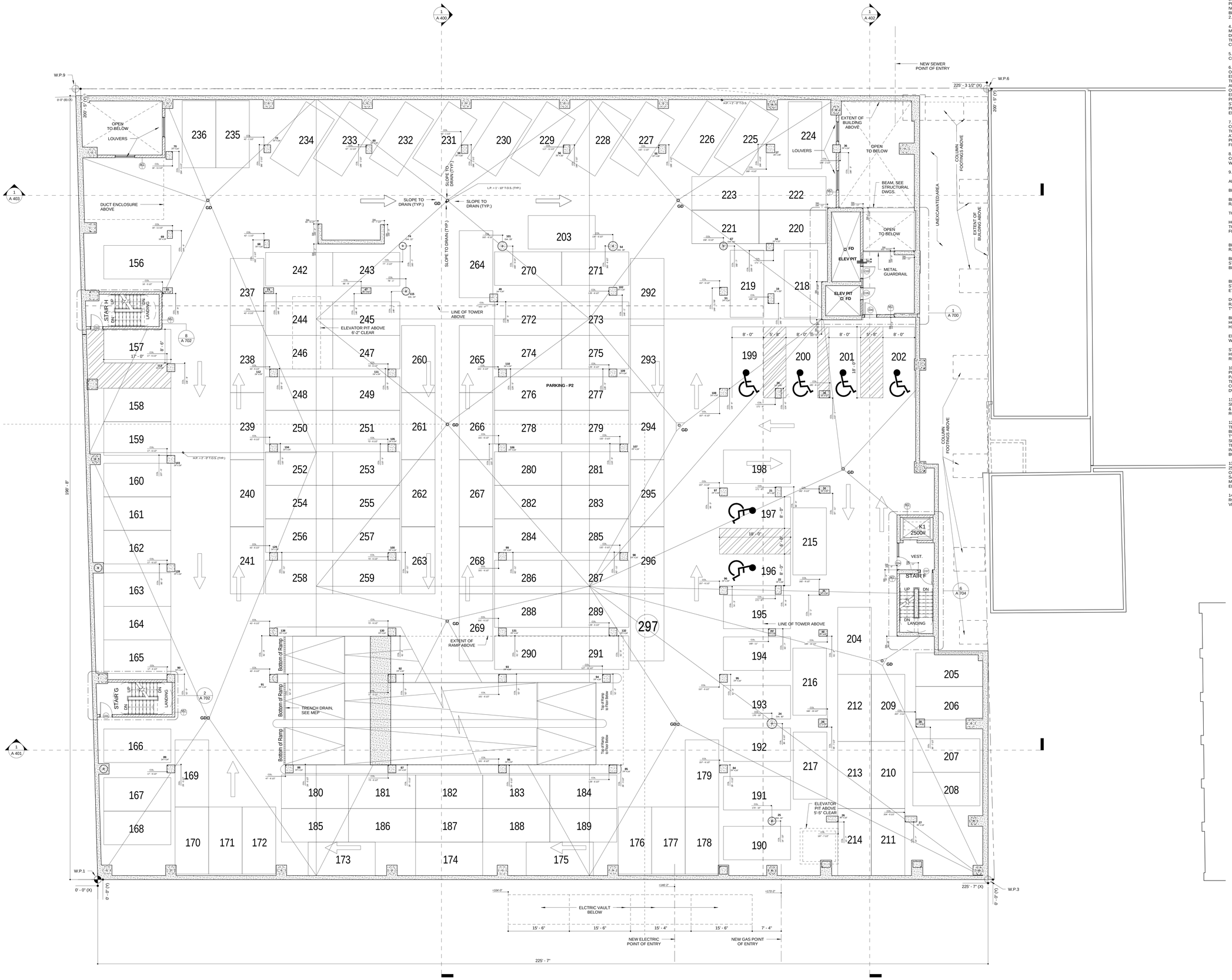

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No	Date:	Rev	Issue:
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Two Trees Management
45 Main Street Suite 602
Brooklyn, NY 11201

PROJECT
60 Water Street
Brooklyn, NY

TITLE
CELLAR FLOOR PLAN

SCALE: 1/8" = 1'-0"
DATE: 06/22/2012
PROJECT No: 12.107

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APPENDIX 9

SIGNED AND STAMPED RAWP CERTIFICATION PAGE

CERTIFICATION

I, Fuad Adib, am a Professional Engineer licensed in the State of New York. I have primary direct responsibility for implementation of the remedial action for the 60 Water Street (Dock Street) Site, E-Designation number E132.

I, James Blaney am a Qualified Environmental Professional as defined in §43-140. I have primary direct responsibility for implementation of the remedial action for the 60 Water Street (Dock Street) Site Number 13CVCP093K.

I certify that this Remedial Action Work Plan (RAWP) has a plan for handling, transport and disposal of soil, fill, fluids and other materials removed from the property in accordance with applicable City, State and Federal laws and regulations. Importation of all soil, fill and other material from off-Site will be in accordance with all applicable City, State and Federal laws and requirements. This RAWP has provisions to control nuisances during the remediation and all invasive work, including dust and odor suppression.

Fuad Adib, P.E.
Name

078921
NYS PE License Number

Fuad F Adib
Signature

October 24, 2012
Date

James Blaney
QEP Name

QEP Signature

October 24, 2012
Date