Tab C

I. Executive Summary

Occupants of some homes built with imported (Chinese) drywall have reported adverse health symptoms and corrosion of indoor metals. It has been hypothesized that the drywall emits sulfur-containing gases which are associated with the odor, health, and corrosion complaints, and that elevated levels of humidity and temperature increase the emission. To better assess these issues, the United States (US) Environmental Protection Agency Environmental Response Team (EPA/ERT) and the Florida Department of Health (FDOH) conducted indoor air testing on ten homes in Florida and Louisiana.[1]

This report reviews the air sampling results from a total of 6 Test homes and 4 Control homes[2] in Florida and Louisiana. The data obtained from these tests were evaluated to preliminarily identify if any chemicals are different in Test versus Control homes. It also evaluates whether some of these chemicals might be present at levels that potentially could be of health concern. This evaluation does not address individual health problems, if any, of occupants living or formerly living in the homes tested.

The EPA/ERT and FDOH samplings were also conducted to evaluate potential methods for collecting and identifying a variety of chemical compounds that might be present in the indoor and outdoor air of homes with Chinese drywall (Test homes) different from those found in Control homes. Information from this investigation will be considered to refine the sampling and testing procedures for homes with problems associated with Chinese drywall and may used for future studies. Although not a part of the Technical Team evaluation, Appendix K contains the EPA proposed sampling approach for drywall investigations. It should be noted that the preliminary sampling approach does not reflect upcoming results from other studies by the interagency task force, which may suggest changes in approach once those studies are complete.

While the results of this investigation provide some preliminary information on chemicals that might be linked with the health effects identified by occupants of affected homes, these results should be viewed as suggestive rather than conclusive until more comprehensive testing can be completed. The results presented in this report also should not be used to draw conclusions or make inferences regarding the condition of a specific residence or the impact of measured levels on materials or people within the homes tested or to the universe of homes known to contain Chinese drywall.[3]

A review of the data the technical team resulted in the following conclusions:

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[1]This report is a collaborative effort of staff (the Technical Team) from the federal and state agencies listed above as well as from the U.S. Department of Housing and Urban Development and the Virginia state Department of Health. The Technical Evaluation Team members are listed in Appendix M. Due to the interrelated nature of these investigations, these technical reports are being released in draft until the final results from further studies are available for interpretation. These studies are staff level documents and have not yet been reviewed or approved by the agencies participating in this investigatory effort.

[2]Control homes were selected on the basis that they did not meet the state of Florida's "case definition" of homes described below in the section on investigative design and methodologies.

[3]This technical report does not address nor differentiate between homes with corrosive Chinese drywall and homes containing Chinese drywall but lacking signs of corrosion.

- Based on these limited air sampling results no *obvious* differences between the types and amounts of compounds were found in the indoor air of Test versus Control homes.
- The majority of compounds found in the Test and Control homes are commonly found in U.S. homes. Indoor air monitoring in homes and chamber testing of emissions from building materials and furnishings (EPA 1997, Alevantis 2003, Colombo 1990, Hodgson 2000) have found similar levels of compounds.

- According to the growing number of reports to federal and state agencies as well as private consulting companies and laboratories, it was hypothesized that Chinese drywall emits reduced sulfur compounds, which are suspected to be the cause of metal corrosion, and possibly occupant reported symptoms. The three reduced sulfur compounds of greatest interest, hydrogen sulfide, carbon disulfide and carbonyl sulfide were rarely detected above method detection limits in this limited sampling of 10 homes. The peak hydrogen sulfide level was detected outdoors when a lawn sprinkler system was running outside a Florida home. The use of "reclaimed water" for sprinklers is associated with these hydrogen sulfide levels. The Technical Team recognizes this is a possible contribution to indoor air quality. Ongoing investigations and sampling in a larger number of homes should help to clarify the role that these compounds may play in reported symptoms and corrosion to metal components in homes.

- With few exceptions, the levels of formaldehyde and acetaldehyde were consistent with those found in newly manufactured homes in the U.S. and elsewhere. Formaldehyde levels found in Test and Control homes were not different. The small number of homes tested for formaldehyde limits the ability to generalize the results from these investigations. Levels of formaldehyde were generally below concentrations that typically cause acute respiratory irritation in most people. When the air conditioning systems were not used in hot weather, formaldehyde concentrations rose above levels that have been associated with symptoms of respiratory irritation in sensitive individuals. Formaldehyde and acetaldehyde were found at levels that exceed chronic exposure limits that have been calculated to be protective. However, the lack of clear and relevant public health guidance for residential exposures to formaldehyde prevents the Technical Team from adequately evaluating the health implications of the levels found in this study.

- Although not observed for all compounds detected, operating the air conditioning system was correlated with notable reductions in formaldehyde levels. However, because of the AC coil failures indicative of this problem, it should not be assumed that a home has an operating AC system.

- Indications of the presence of sulfur dioxide were found inside three Test homes and not inside either Control home with one air monitoring instrument. However, another instrument with a lower detection limit did not confirm these results. Great care should be taken not to over interpret these results, especially for health

- Sulfuric acid was not detected using real-time monitoring instruments. Time weighted sampling showed results inside and outside Test and Control homes at levels very near the method detection limit. Because exposure to low levels of sulfuric acid is a health concern and the possibility of its presence as part of a contaminated drywall reaction, the Technical Team recommends sampling for this compound in chamber testing.

- Compounds were detected above odor thresholds. These may result in temporary sensory irritation, discomfort, nuisance, and reduced quality of life for some individuals which resolve when the exposure ends.

- The additive irritant effects of contaminants found may cause mucous membrane irritation (eyes, nose and throat) or trigeminal nerve irritation, resulting in a reduced quality of life for some individuals. Upper airway irritation may also exacerbate pre-existing respiratory health conditions, most notably asthma.

- Characteristics (e.g., air exchange rate, construction) of Test and Control homes were similar, suggesting that these variables were not a major factor for drywall emissions or copper corrosion.

Primary Recommendations are as follows:

- People who feel ill, especially those with persistent symptoms, should see their doctors—regardless if they believe their symptoms are associated with drywall or other indoor air problems. They should tell their doctors about any concerns they might have about environmental exposures.

- Operate air conditioning systems and increase air exchange rates in a way that keeps temperature and humidity low to reduce indoor air contaminant levels.

- Test for sulfur dioxide, sulfuric acid and other acid vapors in chamber studies to determine if these compounds should be further investigated.

Secondary recommendations are as follows:

- Consider exploring the effects of chemical mixtures on occupant symptoms and copper corrosion. Recognizing the significant limitations in evaluating low level chemical mixtures, and the absence of standard or consensus methods of evaluating health effects from chemical mixtures, the Technical Team briefly examined the possible role of chemical mixtures found in Test and Control homes. Further examination of the data is necessary to ascertain if any of the compounds detected in the Test homes were a result of chemical reactions

between corrosive drywall emissions and other building materials, coatings, adhesives, or chemicals in the indoor environment.

- Re-evaluate and revise the FDOH Case Definition for homes meeting the Chinese drywall criteria as new data becomes available.

II. Background:

Drywall from China was imported into the United States to address the shortage of essential construction materials created following record-breaking 2004 and 2005 hurricane seasons and a national demand for new home construction. In 2008 homeowners began reporting upper respiratory irritation and copper corrosion in their recently built homes (2001-2007). In late February 2009, the Louisiana Department of Health and Hospitals (LADHH) became aware of similar concerns from homeowners in that state.

In January 2009, the Florida Department of Health (FDOH) initiated a preliminary investigation into the use of Chinese drywall in newly constructed homes.

Residents reported premature failures of central air conditioning system evaporator coils located indoors in the air handling unit and intermittent failure of appliances and/or electronic devices. Consumer Product Safety Commission (CSPC) staff inspections have noted corrosion of bare copper electrical wiring and the presence of sooty material on electrical wires (CPSC, 2009). Tarnishing and pitting of other metallic surfaces have also been observed in the affected homes in Florida and Louisiana by state and federal investigators.

Consumers in affected homes have reported various health-related symptoms including persistent coughs, bloody and runny noses, headaches, difficulty in breathing and irritated itchy eyes and skin. The most common symptoms reported among children (< 18 years of age) were respiratory infection, headache, dry cough, nosebleeds and eye irritation/redness. For both adults and children the most common "other" symptom reported was allergies/sinus/congestion. Many of these residents reported that the symptoms lessen or go away entirely when they leave their homes and return when they re-enter their homes (CPSC, 2009). In an informal survey of more than 400 callers to LADHH, the most common complaint reported was the presence of sulfur-like or other unusual odors.

Several federal agencies, the EPA, the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (ATSDR), and CPSC, joined discussions with Florida, Louisiana, and Virginia state officials in early 2009 as the number of homeowner complaints began to increase. A collaborative effort among state and federal officials was formed to begin assessing the nature and scope of the problem.

According to the growing number of reports from federal and state agencies as well as

private consulting companies and laboratories, it was hypothesized that Chinese drywall emits reduced sulfur compounds, which are suspected to be the basis for the complaints.

Despite previous materials analysis data and test results received from private consultants on drywall, a number of data gaps prevented the FDOH from conducting an assessment of potential health hazards for occupants of affected homes. To begin to address these data gaps, the FDOH and EPA's Environmental Response Team (EPA/ERT) initiated an investigation to measure chemical concentrations present in the indoor and outdoor air of six test homes in Florida and Louisiana that met the FDOH case definition (Appendix A) and four control homes in those same states (3 in FL, 1 in LA). It was hoped that the results from this testing would provide the scientific basis for developing a standardized testing protocol for homes reported as adversely impacted by imported drywall (preliminary approaches are given in Appendices D and K) and would begin to provide a scientific basis for assessing the possible corrosive drywall-related health hazards for those living in these homes.

The FDOH and EPA/ERT investigation was not designed to determine the cause of metal corrosion or determine the source of the chemicals measured in the indoor air of these ten homes. However, the investigation was developed to help determine whether an association might exist between homes with imported drywall and the chemicals detected in the indoor air of affected homes. If data clearly demonstrated that outdoor sources were responsible for indoor concentrations of chemicals, this would also be reported.

The focus of the EPA/ERT and FDOH investigation[4] was limited to the following objectives:

1. Determine if building characteristics for affected homes differed from unaffected homes.
2. Measure the in-home concentrations of potentially corrosive gases, irritants and other volatile organic compounds.
3. Determine if the contaminants in the air of homes with Chinese drywall are different than homes with no apparent problems.
4. Evaluate the influence that chemicals in the outside air and environmental conditions had on the indoor air chemical concentrations.

III. Investigation Design and Methodologies:

As the FDOH began to investigate homeowner complaints of sulfur-type odors, corrosion of copper in homes and health-related concerns, they developed criteria for selecting homes to be included in this investigation (Appendix A). The FDOH "case definition" for homes that exhibit the key signs of corrosion associated with imported drywall was used as the initial screening for home selection in this investigation.

[4]An additional objective for the FDOH study was to evaluate the reliability and repeatability of available sample collection and analysis methods.

A. Home selection: In May 2009, preliminary site visits of 7 possible test homes in Florida and 5 in Louisiana were conducted to familiarize technical experts from EPA and ATSDR with the conditions present in homes experiencing premature copper corrosion believed to be associated with the presence of imported Chinese drywall. The test homes were selected by each state based on homeowner reports to them and from health department personnel visiting the homes to confirm that they met Florida's case definition (Appendix A). Homes selected for testing had extensive copper corrosion, severe odors, and a history of repeated AC coil failures. Control homes were selected based on the absence of signs indicating drywall associated corrosion, proximity to Test homes and comparability to Test home construction dates.

The following criteria were used to select homes for testing:

Test Homes:

1. Met FDOH Case Definition (Appendix A)
2. Had severe odor, copper corrosion, frequency of A/C coil replacement, and occupant symptoms
3. No cigarette or other tobacco smoking in the home prior to testing
4. Occupants agreed to vacate the premises for several days during testing
5. Investigators had access to the home around the clock during the testing period

Control Homes:

1. Met Test Home criteria 3,4 and 5
2. Located near one of the Test homes and constructed or renovated close to the time of the Test home construction
3. No apparent drywall-related problems

EPA/ERT staff, in consultation with FDOH, LADHH and EPA Headquarters, selected six homes in Louisiana and the west coast of Florida for monitoring /sampling. The EPA/ERT sampled two Test homes and one Control home in each state. Additionally, the FDOH conducted air sampling in four homes, two on the east coast (one Test and one Control), and two on the west coast of Florida (one Test and one Control) (see Table 1 below).

Table1. Summary Information on Test and Control Homes

Home Identifier #	Resident State	Tested by	Test or Control
80	Florida	FDOH	Test
81	Florida	FDOH	Control
90	Florida	FDOH	Test
91	Florida	FDOH	Control
100	Florida	EPA/ERT	Test
101	Florida	EPA/ERT	Control
102	Florida	EPA/ERT	Test
200	Louisiana	EPA/ERT	Test
201	Louisiana	EPA/ERT	Control
202	Louisiana	EPA/ERT	Test

B. Home Characterization and Air Change Rates:

All Test and Control homes were constructed or renovated in 2006-2007. The year each home was constructed was determined from interviews with homeowners and verified by examining local tax assessor records and/or by the date of the Certificate of Occupancy as described by builder. The construction style (i.e. construction techniques) was determined by walk-through inspection and interviews with either the homeowner or builder.

To evaluate how the air leakage rate of selected homes possibly influenced the resulting concentrations of chemicals in the indoor air, the air change rate (ACR) was measured in each home by the FDOH and LADHH. The test method was adapted from the *Manual for Ventilation Assessment in Mechanically Ventilated Commercial Buildings*, NISTIR 5329, National Institute of Standards and Technology, Jan 1994. For a complete description, see Appendix B.

C. Air Sampling Approach and Methods

Table 2 summarizes the approaches used by EPA/ERT and FDOH to sample the indoor and outdoor air in the Test and Control homes. The air was tested for a number of chemical compounds of interest, including sulfur-containing compounds, volatile organic compounds (VOCs), acids, and aldehydes (e.g. formaldehyde). EPA/ERT tested six homes in June-July, 2009. The FDOH tested four homes at two different times (#80 and #81, in May, 2009, and #90 and #91 in June, 2009). Detailed information about the test protocols and analytical methods is provided in Appendices B and C, for FDOH and EPA/ERT respectively.

Table 2. EPA/ERT and FDOH Air Sampling and Monitoring Approach

		EPA/ERT FL homes	EPA/ERT LA homes	FDOH FL homes
# test/control homes		2/1	2/1	2/2
# indoor sample locations per home		3-4	3-4	2
# outdoor sample locations per home		1	1	1
# Sampling days/home		2(48-hr)	2(48-hr)	1 (24-hr)
# Sampling events/home		4+	4+	80 and 81: 2 90 and 91: 12(reduced sulfur) 6 (VOCs)
Sampling time of day		2 day, 2 night	24 hours	
Real-time Air monitoring:	Hydrogen sulfide	continuous	continuous	every 2 hours
	Sulfur dioxide	continuous	continuous	N/A
	Sulfuric acid	continuous	continuous	N/A
	VOCs	continuous	continuous	N/A
	Particulate matter	N/A	continuous	N/A
Time-weighted Air Sampling:	Sulfur compounds	grab	grab	grab
	VOCs	8-hr/sample	8-hr/sample	4 hr/sample
	Aliphatic amines	8-hr/sample	8-hr/sample	N/A
	Aromatic amines	8-hr/sample	8-hr/sample	N/A
	Formaldehyde	8-hr/sample	8-hr/sample	N/A
	Inorganic acids	8-hr/sample	8-hr/sample	N/A
	Acetic, formic acid	N/A	8-hr/sample	N/A
	Pesticides/PCBs	N/A	48 hr/sample	N/A
	PAHs	10 hr/sample	10 hr/sample	N/A

+ Except for home 102 in FL and 202 in LA, 1 day and 1 night sampling event was conducted with the air conditioning system running at each home; the other day and night event was conducted with no HVAC system running. The HVAC system in FL home 102 was not functioning, so all 4 sampling events occurred with no air conditioning. The LA 202 home was also sampled with no air conditioning in order to compare to FL home 102. Particulate matter was only measured in home 202. Real-time air monitoring is a continuous instrument measurement for the duration of sampling; it is not analyzed by a laboratory. A grab sample is a one-time measurement, a snapshot in a given place and time. N/A – not measured. Time-weighted sampling refers to a sample collected over time and analyzed by a laboratory. Its results reflect the average concentration of the contaminant detected over the sampling period.

D. FDOH Air Sampling and Monitoring (Appendix B)

FDOH tested four homes, two on Florida's east coast and two on its west coast. In May 2009, FDOH tested homes #80 (Test) and #81 (Control)[5]. Two VOC and two reduced sulfur compound indoor and outdoor sampling events occurred over one 24 hour period at these homes, with 5 simultaneous samples collected during each sampling event for each test method. In June 2009, FDOH tested home #90 (Test home) and #91 (Control home). Six VOC and 12 reduced sulfur compound indoor and outdoor sampling events occurred over one 24 hour period at these homes. Grab samples for reduced sulfur compounds were collected every 2 hours. VOC samples were collected every 4 hours. For both sets of homes, continuous measurements of indoor and outdoor environmental parameters were made using direct reading instruments. Measurement of temperature, relative humidity, and carbon dioxide provides useful information on how environmental

[5] Phase I, homes 80 and 81, was a scoping investigation to generate data on the variability and reliability of available test methods to measure concentrations of sulfur-containing gasses and volatile organic compounds (VOCs). As a secondary goal, this phase of testing was anticipated to generate data on the types of chemical compounds found in affected and unaffected homes and their respective concentrations. Two sampling events were conducted to evaluate possible diurnal effects on indoor air concentrations. The investigation protocol for Phase II activities (Units 90 and 91) were evaluated and refined based on observations and experiences in Phase I.

conditions may impact indoor air concentrations of chemicals. Simultaneous measurement of indoor and outdoor conditions also makes it possible to evaluate the building's communication with the outside and its ability to control indoor humidity. Indoor and outdoor continuous real-time monitoring was collected for pressure differentials, CO, CO_2, temperature, and relative humidity. Outdoor air quality and weather conditions were continuously recorded.

Equipment, methodology specification and sensitivities, materials, supplies, software, and laboratories used to measure or sample the environment are described in the Appendix B.

E. EPA/ERT Air Sampling and Monitoring (Appendix C)

EPA/ERT performed a total of six air sampling events at each house (two events per day over the course of three days). Except for two of the homes where testing was done without operating air conditioning systems (homes 102 and 202), half of the air sampling events occurred with the air conditioning [AC] off and the other half with the AC on. Ambient (outdoor) air samples were collected concurrent with each indoor air testing event. Real-time continuous monitoring was performed at two locations in the home (living room and bedroom) and one outside of the home, for total volatile organic compounds (VOCs), hydrogen sulfide (H_2S), sulfur dioxide (SO_2), carbon monoxide (CO), carbon dioxide (CO_2), temperature and relative humidity. Air grab samples utilizing Tedlar bags (Zefon International) were collected from the living room, bedroom, a wall cavity, and outdoor air for reduced sulfur gases. SUMMA® canisters were utilized to collect grab samples in each home. Time weighted air sampling was conducted for VOCs, aliphatic and aromatic amines, formaldehyde, inorganic acids, and poly-cyclic aromatic hydrocarbons (PAHs). Real-time monitoring for particulate matter was added to the Louisiana (LA) sampling scheme (for Test home 202). Time-weighted air sampling for acetic and formic acids, and pesticides/polychlorinated biphenyl (PCBs) were also added for LA sites only. Details for the instruments and methods EPA/ERT used for real-time air monitoring and time-weighted air samplings are found in Appendix C.

F. Quality Assurance/Quality Control (Appendices B, D, E)

For detailed information regarding EPA/ERT QA/QC handling of sampling and data refer to the EPA/ERT Quality Assurance Project Plans (QAPP) located in Appendices D and E. EPA/ERT aldehyde samples results from LA homes (home 202) exhibited contaminant breakthrough. Therefore, these results should be treated as conservative estimated values and may underestimate the actual concentrations. Evaluation of FDOH data focused on addressing the three primary objectives set forth at the beginning of this report. All measurement results were subjected to a data evaluation process to ensure they accurately reflected the measurement that was collected. Data collected was verified for completeness and correctness, to the extent possible, by Salazar Consulting Group, a contractor for the FDOH. Quality assurance measures included confirming the data type, significant digits, units, and ranges using methods selected specifically for each data set.

For detailed information regarding FDOH QA/QC handling of sampling and data refer to Appendix B. Some reduced grab samples exceeded method holding times prior to analysis. Therefore, results may be underestimates of the actual concentrations.

G. Evaluation Process for Selecting Chemicals of Interest from the Data

The Technical Team used the following criteria to select chemicals found in the air sampling tests for further evaluation:

- Chemicals found to be emitted from suspected drywall in laboratory tests (some details provided in Appendix L).
- Chemicals only found in Test Home(s) at either
  - A mean concentration above the quantifiable limit, or
  - At a frequency ≥ 50%
- Chemicals found in both Test Homes and Control Homes, but at a higher mean concentration in at least one of the Test Homes (this only applies to measured concentrations above the quantifiable limit of the method).[6]
- Chemicals found in both Test Homes and Control Homes, at a frequency ≥ 50% in at least one of the Test Homes and at a greater frequency than in the Control Home.

Utilizing this process enabled the Technical Team to remove from consideration all but 112 airborne compounds identified in either or both of the Test homes tested by the FDOH and to 109 chemicals in homes tested by EPA/ERT. Appendix F displays the chemicals that met one or more of the criteria. The table includes chemicals from EPA/ERT and FDOH sampling results, which are not mutually exclusive. Indoor chemicals not included in the evaluation, which were at values below method reporting limits, are found in Appendix G. These additional compounds were reviewed to ensure there were no obvious trends or warranted health evaluation.

IV. Results:

A. Building Characteristics of Test versus Control Homes

The size of Test homes was more consistent than among Control homes. Test homes averaged 2,480 ft^2, ranging from 1,100 to 3,810 ft^2. Control homes averaged 2,510 ft^2, but ranged from 287 (a small guest house) to 5,704 ft^2. All Test homes were constructed in 2006, with the exception of #202, which was originally constructed approximately 30 years ago, but renovated in 2007. Control homes were constructed or renovated between 2006 and 2007. Test and Control homes in Florida had lower air change rates than homes in Louisiana, averaging 0.19 air change rate per hour (ACH) in Florida and 0.52 ACH in Louisiana homes.

[6]Appendix F data from EPA/ERT sampling are mean values which were significantly different between the Test home(s) and the Control home.

Table 3 below compares the air change rates between Test and Control homes evaluated by FDOH and EPA/ERT.

Table 3: Louisiana and Florida Home Characteristics

Air Change Rates (Test)		Air Change Rates (Controls)	
Average	0.27	Average	0.31
Median	0.25	Median	0.20
Minimum	0.12	Minimum	0.16
Maximum	0.47	Maximum	0.68

Using ASHRAE 62.2P guidance to estimate the minimum whole-house total ventilation for each home, Table 4 demonstrates the comparison of measured air change rate to the recommended minimum for each home.

Table 4: Calculated Minimum Air Change Rates (ACR) for Test and Control Homes

Home ID	Yr	ft^2	Measured ACR*	Recommended Minimum ACR*	Meas./Min. Ratio
80 (FL)	2006	3,240	0.22	0.20	1.1
81 (FL)	2007	287§	0.17	0.49	0.35
90 (FL)	2006	3,810	0.12	0.18	0.67
91 (FL)	2007	5,704	0.16	0.15	1.07
100(FL)	2006	2,460	0.28	0.21	1.33
101 (FL)	2006	1,735	0.24	0.31	0.77
102 (FL)	**2006**	**1,977**	**0.13**	**0.30**	**0.43**
200 (LA)	2006	2,300	0.47	0.24	1.96
201 (LA)	2007	2,313	0.68	0.27	2.52
202 (LA)	**2007**	**1,100**	**0.42**	**0.36**	**1.17**

*Reported in Air Changes per Hour (ACH)
§A small guest house
Bold = No AC system running

Table 5 below, orders the rank of ventilation ratios; the ratio of the measured air change rate to that of the recommended minimum air change rate, ranking them from highest to lowest. A ratio with a value greater than 1.0 means that home exceeds the recommended minimum ACR as per ASHRAE 62.2P. A ratio less than 1.0 means a home does not meet the minimum ACR as per ASHRAE 62.2P.

Table 5: Ranking of Air Change Rate Ventilation Ratios

Home ID	Ratio	Home Description
201	2.52	Control
200	1.96	Test
100	1.33	Test
202	**1.17**	**Test**
80	1.1	Test
91	1.07	Control
101	0.77	Control
90	0.67	Test
102	**0.43**	**Test**
81	0.35	Control

Bold = No AC system running

B. Summary of Results from FDOH Air Sampling and Testing (Appendix B)

Overall, FDOH air sampling results showed the following:

- Reduced sulfur gases were not detected in Test home 80 or Control homes 81 and 91. A single measurement of Hydrogen Sulfide in Unit 90 (Test Home) was quantified at 5.72 ppbv (8 $\mu g/m^3$). This was the only sample above the 5 ppbv (7 $\mu g/m^3$) method reporting limit out of the twelve samples collected in Unit 90. Similarly a single sample was reported to contain 4.14 ppbv (5.6 $\mu g/m^3$) of Carbonyl Sulfide (an estimate with some uncertainty because it was below the laboratory's method reporting limit/quantitation limit, see Appendix B).

- Assessment of diurnal trends was not possible due to the small number of positive detects for reduced sulfur compounds. Examination of VOC data did not reveal any trends in indoor air concentrations that would suggest diurnal variations. All homes effectively controlled temperature and relative humidity, suggesting that uncontrolled environmental conditions within Test homes were not contributing factors to drywall emissions or copper corrosion.

- Low levels of individual volatile organic compounds (VOCs) were detected in Test and Control homes. Outdoor ambient sources of certain VOCs were periodically observed to cause transient elevations indoors. However, the predominant source of most indoor VOCs was attributable to indoor sources.

C. Summary of Results from EPA/ERT Air Sampling and Testing (Appendix H)

Results of the EPA/ERT testing in homes (four Test, two Control) in Florida and Louisiana is summarized in Appendix H.

Overall, EPA/ERT air sampling analytical results demonstrated the following:

- There were no obvious differences in indoor air results between homes meeting the FL case definition versus those that did not.

- Reduced sulfur gases in homes 100, 101, 102, 200, 201, and 202, were below the limit of detection (BLD) with the exception of carbonyl sulfide (BLD-21.6 $\mu g/m^3$) and carbon disulfide (BLD-19.6 $\mu g/m^3$), also in outdoor air carbonyl sulfide (BLD-16.5 $\mu g/m^3$) and carbon disulfide (BLD-9.9 $\mu g/m^3$) which were detected during the second night sampling event in Test home 102.

- Real-time monitoring detected low levels (BLD to 8.0 $\mu g/m^3$) of hydrogen sulfide in homes 100, 101, 102, 200, 201 and 202. Hydrogen sulfide was also detected in the outdoor air (BLD to 25.8 $\mu g/m^3$) of all sampled homes. The maximum hydrogen sulfide level occurred concurrently with peak outdoor levels.

- Low levels of target volatile organic compounds were detected in all houses in FL and LA. The target organic compounds that were detected are typically found in indoor air.

- Several non target volatile organic compounds were detected in indoor air (e.g., pinene, nonanal)

- Low levels of acetic acid and formic acid were detected in both Test and Control homes in LA. Sampling for these compounds was not conducted in FL homes.

- Formaldehyde was detected in all homes at or above ~100 ppb (122.7 $\mu g/m^3$) under AC "OFF" conditions. In Test home 202 formaldehyde was measured at concentrations up to 400ppb (490.8 $\mu g/m^3$).

- The use of air conditioning systems appeared to result in lower levels of formaldehyde in homes 100, 101, 200, and 201.

D. Chemicals of Interest (Appendix F, G, J)

From all the chemicals detected during testing, a subset was selected using the criteria described in the Investigation Design and Methodologies section for a preliminary assessment of possible chemicals that might be associated with the corrosion and health complaints. This information can also be used to focus the scope of future drywall studies on selected chemicals.

For each chemical compound identified as a candidate "Chemical of Interest" (Appendix F tables), available health-based exposure guidelines (see Appendix I for expanded discussion) were compared with maximum and mean concentrations found in the

homes[7]. When available in the literature, the odor threshold of each chemical of interest was compared to concentrations found in the affected home and a determination was made about whether the chemical was a known irritating substance. Maximum and mean concentrations of these chemicals found during EPA/ERT and FDOH sampling and associated health-based screening guidelines, odor characteristics, odor threshold and common sources are listed in Appendix F. The table in Appendix F provides values with and without the air conditioning system running, which affected the levels of many of the chemicals detected. Classes of chemicals found in this table are sulfur-containing compounds, VOCs, acids, and aldehydes (including formaldehyde).

The following tables, 6 and 7, sum up the mean levels measured for some of the major chemical families. The summation is a basic screening tool to evaluate whether a trend exists between the Test and Control homes in total chemical compounds measured in the home. The total for terpenes is dominated by pinene levels, and for esters it is propanoic acid and its esters. Note, Tables 6 and 7 are preliminary. It is recommended to only draw comparisons for trends within the investigator's table itself (e.g., solely contrasting the EPA/ERT sampled homes).

Table 6: Sum Total of the means of Compounds of Interest in EPA/ERT Sampled Homes (ug/m^3)

Compound Class	Sampled Home 100	101	102	200	201	202
Total Aldehydes	227	213	389	203	143	434
Total Alcohols	106	19	18	67	BLD	43
Total Carboxylic Acids	BLD	0.4	8	BLD	BLD	BLD
Total Esters	18	58	241	201	67	149
Total Ketones	60	52	208	4	BLD	5
Total Hydrocarbons	24	9	39	169	9	15
Total Aromatic HC	5	6	9	57	16	15
Total PAHs	4	3	BLD	BLD	BLD	BLD
Total Terpenes/Terpenoids	60	27	636	1138	587	889
Total Other	68	2	5	3	2	3
Total Acid Compounds	1?	1?	1?	860	3069	3645
Total Sulfur Compounds*	BLD	BLD	BLD	BLD	BLD	BLD

Test Homes: 100,102,200,202
Control Homes: 101, 201
*Reduced sulfur compounds

[7]Appendix F data from EPA/ERT sampling are mean values which were significantly different between the Test home(s) and the Control home.

Table 7: Sum Total of Compounds of Interest in FDOH Sampled Homes (ug/m^3)

Compound Class	Sampled Home 80	81	90	91
Total Aldehydes	37	22	22	17
Total Alcohols	24	10	33	13
Total Carboxylic Acids	5	3	5	0.5
Total Esters	17	11	1	BLD
Total Ketones	17	10	9	2
Total Hydrocarbons	149	18	24	9
Total Aromatic HC	39	8	13	5
Total PAHs	3	1	4	2
Total Terpenes/Terpenoids	200	108	136	132
Total Other	3	1	4	BLD
Total Reduced Sulfur Compounds	4	3	5	2

Test Homes: 80, 90
Control Homes: 81, 91

E. Sulfur-containing Compounds

1. Hydrogen sulfide and other reduced sulfur compounds

H_2S Real-time air monitoring: Readers should interpret real-time monitoring results with a note of caution because concentrations near 2 ppb (2.8 µg/m^3) are very close to the lower detection limit of the instrument. EPA/ERT continuous real-time monitoring found hydrogen sulfide (H_2S) present at very low levels in the indoor and outdoor air of all EPA/ERT Test and Control homes. The maximum indoor and outdoor concentrations were 5.72 ppb[8] (8 µg/m^3, FL home 102) and 18.5 ppb (25.8 µg/m^3, FL home 102), respectively. The two highest outdoor levels were found on the FL control home (101) and Test home (102) properties. This neighborhood used reclaimed water for lawn irrigation. The distinctive odor of hydrogen sulfide was observed by sampling personnel as soon as the irrigation system was turned on.

H_2S was detected at each sampling location (including outdoor air), during each of the 4 test periods in Test home 102, for a total time of 32 hours during the 3-day monitoring period. In Louisiana, H_2S was detected in at least one sample location in each home (for a total of 3.25 hours in Test home 200, 18 hours in Test home 202, and 0.25 hours in Control home 201). It was also detected in each homes' outdoor sample location.

In general, levels inside and outside LA homes were lower than results in and around FL homes. No trend is apparent between maximum concentrations in Test homes versus Control homes. A slight trend is noted with mean values (the mean hydrogen sulfide

[8]This maximum concentration was measured in the wall cavity, not in the living space

concentration over the entire monitoring event). Three of the four Test homes had values slightly above the instrument's lower detection limit. Two of these homes also had mean hydrogen sulfide values near the detection limit. No Control homes had mean hydrogen sulfide concentrations above the detection limit. In general, when higher hydrogen sulfide levels were detected outdoors, the longer it was found indoors for both Test and Control homes. This suggests that the outdoor source may be contributing to hydrogen sulfide levels indoors.

Reduced sulfur compounds--grab sampling: The only reduced sulfur compound detected by EPA/ERT was carbon disulfide at Test home 102 at a concentration of 2.62 ppb (8.2 $\mu g/m^3$). It was found in 91% of the 16 indoor samples from this home when the air conditioning system was off. The maximum level detected, 2.64 ppb (8.2 $\mu g/m^3$) is lower than the specified method reporting limit of 5.00 ppb (15.6 $\mu g/m^3$). These results should be treated as estimated values. Reduced sulfur compounds were not found in outdoor samples. Reduced sulfur compounds were not detected in any of the Louisiana homes.

With few exceptions, FDOH collected samples were below the reporting limit of the method (15.6 $\mu g/m^3$). Only one FLDOH sample out of the twelve samples collected throughout the 24 hour testing period at Test home 90, measured above the reporting limit for H_2S at a concentration of 17.9 $\mu g/m^3$. In the early morning hours on June 9, 2009, H_2S was detected in two outdoor samples. A single sample contained carbonyl sulfide at a concentration of 10.2 $\mu g/m^3$, an estimate with some uncertainty because it was below the laboratory's method reporting limit/quantitation limit (see Appendix B).

2. Sulfur Dioxide

One real-time instrument found sulfur dioxide (SO_2) inside three Test homes and none of the Control homes. An instrument with a lower limit of detection (used in LA), did not confirm this finding. Other than recommending additional investigation, care should be used in drawing general conclusions.

3. Sulfuric acid

EPA/ERT conducted real-time monitoring for sulfuric acid inside and outside of LA homes. It was not detected above one instrument's lower detection limit of 26 ppb. Time-weighted air samples detected low levels up to 0.051 mg/m^3 in outside air of FL home 101, and up to 0.047 mg/m^3 in the outside air of LA homes 200 and 201. Sulfuric acid was detected up to 0.05 mg/m^3 in Control and Test homes (101, 102, 200, and 201). There was no significant difference in outdoor air and indoor air results. The majority of the time, sulfuric acid was not detected in the collected samples. The method detection limit is approximately 0.046 mg/m^3. Therefore, other than recommending additional investigation, care should be used in drawing general conclusions.

F. Other Acids

Formic and Acetic acids

Time-weighted samples detected levels of formic acid (up to 1.1 ppm) inside LA homes 200, 201 and 202, though most levels were non-detectable. Formic acid was detected

outside homes 201 and 202 up to 0.73 ppm. The maximum levels detected inside and outside the home are not significantly different and are close to the method detection limit of 0.55 ppm and therefore should be interpreted with caution. Formic acid was not sampled for in FL homes. Time-weighted samples detected low levels of acetic acid, up to 590 ppb (1450 $\mu g/m^3$) inside LA homes 200, 201 and 202. The method detection limit was 49 ppb (121 $\mu g/m^3$). There was no statistical difference between Test homes and Control homes suggesting that the source of acetic acid was not imported corrosive drywall. No acetic acid was detected outside the homes.

G. Aldehydes - Formaldehyde

All the homes tested by EPA/ERT were found to contain formaldehyde[9]. No statistical difference was found between formaldehyde levels measured in the Florida and Louisiana Test and Control homes. No correlation appears to exist between the air exchange rate and measured formaldehyde levels for each home. The highest value measured, with a mean concentration of 398 $\mu g/m^3$, occurred in Louisiana Test home 202 where "AC on" data was not collected.[10] The mean concentration for the remaining Test and Control homes was 131 $\mu g/m^3$ (with a range of 109-151 $\mu g/m^3$). Although the measurements taken with the air conditioning on demonstrate a significant decrease in detected levels and are in the range of what has been reported in published studies, these lower values remain above some of the minimal risk levels found in Appendix I (mean home levels ranged from 52-85 $\mu g/m^3$). Outdoor levels ranged from 2.0-6.5 $\mu g/m^3$.

V. Discussion:

To evaluate the FDOH and EPA sampling data, the federal/state Technical Team formulated the following questions:

- Are chemicals found in the indoor air of homes with signs of imported drywall that met the case definition different than similar homes that do not meet the Florida case definition and are believed to not have imported drywall?
- Were any of the chemicals found indoors attributable to chemicals present in the outdoor air, and therefore not from the imported drywall?
- Are there contaminants present at health relevant levels in the air inside the homes, regardless of their source?

In order to address the above questions, this evaluation includes:

- Examining of Quality Assurance/Quality Control of data
- Comparing building characteristics of Test versus Control homes
- Comparing the chemicals found in Test but not Control homes
- Comparing the chemicals found both in indoor and outdoor air

[9]The FDOH did not originally test for formaldehyde, however when early reports identified formaldehyde at levels above the odor threshold, measurements were taken in October 2009 on homes 80, 81, 90 and 91. Since different test methods were used and the data received late, a consensus decision was made to not include that data into this technical report.

[10]The air conditioning unit was functioning in LA home 202, however to maintain consistency in the sampling with the FL Test home 102, the air conditioning remained off.

- Examining differences in chemical concentrations with the air conditioner on or off
- Developing a Chemicals of Interest list that narrows the field of compounds for assessment as possible health hazards for occupants
- Comparing the chemicals found in the 10 homes with those described in published literature as being generally found in indoor air of homes
- Conducting a preliminary health evaluation for certain chemicals of interest

A. Building Characteristics of Test versus Control Homes

In this 10-home investigation, 60% of the homes exceeded the minimum ventilation rates recommended in ASHRAE 62.2P. Two of the four Control homes and four of the six Test homes exceeded their recommended minimum ventilation rates. No apparent trends were observed in homes that met or failed to meet minimum recommended ventilation rates. Therefore within the population of homes studies, the likelihood of experiencing corrosion associated with imported drywall did not appear to depend upon whether or not the homes provided adequate ventilation to control typical indoor air pollutant concentrations.

Care must be taken to not over interpret these findings. Homes were not chosen based upon their ventilation rates, but rather upon them exhibiting signs of premature copper corrosion associated with the use of imported drywall in recent construction. The measurement of air change rates was intended to ascertain if the homes were similar to other contemporary homes. What can be gained from these observations is that neither excessive nor restrictive air change rates were consistently found in either Test or Control homes. The homes selected for Test and Control homes were found to span the wide range of homes constructed using new materials and techniques.

B. Results of Chemical Sampling and Testing

What can be said about the chemicals found overall in the test versus control homes?

Of the chemicals that were sampled and tested for in this ten home investigation, twelve compounds were detected in homes sampled by both the EPA/ERT and FDOH, using two different sampling/analysis methods. Those 12 chemical compounds are 1-butanol, acetic acid, acetic acid (phenyl methyl ester), acetone, benzaldehyde, formic acid, 2-heptanone, hexanal, naphthalene, octanal, pentanal and propanoic acid. Propanoic acid and its other forms (e.g., esters, anhydride) are considered as one compound for this discussion. It is not unexpected to observe a low frequency of common chemicals among these 10 homes due to the low number of homes sampled. Variability of compounds within a respective home should be large based upon the construction materials used in that particular home and contributions from other items in the home including, but not limited to, the vast selection and diversity of cleaning agents, furnishings and personal care products. Many of the chemicals of interest listed in Appendix F are considered typical indoor air constituents and are associated with daily activities, home construction, and furnishing materials (EPA 1997, Colombo 1990, Alevantis 2003, Hodgson 2000).

Appendix J provides available information on typical indoor levels for compounds of interest.

What can be said about chemicals found indoors versus outdoors?

An influence from chemicals in the outside air and/or environmental conditions was demonstrated on some indoor air chemical concentrations. The peak hydrogen sulfide levels detected in homes only occurred when the lawn sprinkler systems were activated. The levels became non-detectable in outdoor air after the sprinklers were shut off for five minutes.

What can be said about the differences seen with AC on/off?

EPA/ERT conducted sampling with air conditioning (AC) off in all Test and Control homes and sampled with the AC on in Test Homes 100 and 200 as well as Control Homes 101 and 201.[11] For many of the compounds the maximum level listed occurred in the second Test home (102 and 202) and therefore "AC on" data was not available for comparison. Approximately 50% of the homes for which "AC on" data was available, had notable reductions in the measured concentrations, the most noteworthy were the chemical class aldehydes. Changes in chemical concentrations may have been the result of increased air change rates due to supply and return duct leakage, removal of chemicals by contact with the wet coils, reduction in temperature and humidity, or a combination of the these mechanisms.

C. Potential Health Impacts in Test Homes

Health Evaluation

From the list of the chemicals of interest found in Appendix F, the Technical Team evaluated the following chemicals or chemical classes to develop a preliminary health evaluation for residents. Additional details about the health guidelines used by the technical team for this assessment are in Appendix I.

- Reduced sulfur compounds, sulfur dioxide, inorganic gases – Generally concentrations of these chemicals found in the home sampling data were below levels set by EPA, ATSDR and others as health guidelines, with some exceptions. Some measurements SO_2 appeared higher than EPA ambient limits and the ATSDR MRL of 10ppb. However due to discrepancies from the methodologies and lower limits of detection used, further examination of SO_2 is necessary in order to ascertain its presence/absence. Some of the hydrogen sulfide measurements exceeded EPA's RfC of 1.4ppb. Many of these compounds were detected close to method and instrument levels of detection and therefore stated levels must be considered estimated values. No non-occupational health guideline is available for sulfuric acid.

[11] The HVAC fan was off when the AC was off.

- Acetic acid and formic acid – Acetic acid is an organic acid, with a distinctive pungent vinegar odor, and is used as a solvent, preservative and in the manufacture of rubber, plastics, acetate fibers, pharmaceuticals, and photographic chemicals. It is emitted from building materials such as plywood. Both EPA/ERT and FDOH testing revealed acetic acid in samples from Test and Control homes. The mean levels of acetic acid detected in the homes tested are almost 20-fold lower than regulatory health guidance values (see Appendix I), but above the published odor threshold. The levels of formic acid measured in the Louisiana homes fell 5-fold below regulatory exposure limits (OSHA and NIOSH); formic acid was not tested for in Florida homes by EPA/ERT. Formic acid levels in the LA homes fell below the published odor threshold. Caution needs to be used in applying the referenced occupational health guidelines since these guidelines typically utilize shorter total time exposures than what may occur in a residence, where time spent in the home can be 24 hours a day, 7 days a week.

- Aldehydes – including formaldehyde – Of all the chemicals identified in this investigation, the maximum concentrations of only three chemical compounds exceeded health-based guideline values described above. Two of these compounds, acetaldehyde and formaldehyde, are known irritants. The third compound, naphthalene, had an estimated maximum concentration and a mean concentration which just exceed the RfC guideline value. However, these are estimated concentrations due to the high method detection limit for naphthalene and therefore must be confirmed by additional studies.

  Formaldehyde can serve as the typical example for the aldehyde chemical class. A number of building products used in the home can be sources of formaldehyde (e.g. pressed wood products, paper products, personal care products and insulation, see CPSC preliminary chamber report 2009). A previous study of new homes found a mean formaldehyde level of 44.2 $\mu g/m^3$ in Eastern and Southeastern U.S. site-built homes (Hodgson 2000) and a mean of 94.9 $\mu g/m^3$ in new Florida homes (Hodgson 2002). The mean value for FL and LA Test homes was 206 $\mu g/m^3$ and for Control homes 113 $\mu g/m^3$ when the air conditioning system was not operating. When the air condition system was on, the mean level for Test homes was 69.5 $\mu g/m^3$ and for Control homes 61.9 $\mu g/m^3$.

  No statistical difference was found between formaldehyde levels measured in the Florida and Louisiana Test and Control homes. No correlation appears to exist between the air exchange rate and measured formaldehyde levels for each home. The highest value measured, with a mean concentration of 398 $\mu g/m^3$, occurred in the second Louisiana Test home where "AC on" data was not collected.[12] The mean concentration for the remaining Test and Control homes was 131 $\mu g/m^3$ (with a range of 109-151 $\mu g/m^3$). Although the measurements taken with the air conditioning on demonstrate a significant decrease in detected levels and are in

[12]The air conditioning unit was functioning in LA home 202, however to maintain consistency in the sampling with the 2nd FL test home, the air conditioning remained off.

the range of what has been reported in published studies, these lower values remain above some of the minimal risk levels found in Appendix I (mean home levels ranged from 52-85 $\mu g/m^3$). Outdoor levels ranged from 2.0-6.5 $\mu g/m^3$. The threshold for development of acute symptoms due to inhaled formaldehyde that is typically reported in the literature is 983 $\mu g/m^3$; however, sensitive individuals have reported symptoms at concentrations $\geq$ 123 $\mu g/m^3$ (HSDB). The indoor guideline values for formaldehyde, recommended with the intention of preventing acute sensory irritation, vary. In general, the reported estimated thresholds are in the range of 625–1250 $\mu g/m^3$ (Salonen 2009, Lang 2008). In order to prevent significant sensory irritation in the general population, the WHO has recommended a guideline value of 100 $\mu g/m^3$ as a 30-minute average (WHO 2001). The broad range of these guideline values results from including various safety factors and whether the health guideline value is addressing shorter or longer exposure (e.g., acute, intermediate or life-time). Although the levels for reported symptoms are generally at formaldehyde concentrations greater than 614 $\mu g/m^3$, it has been reported that long-term exposure to a formaldehyde concentration of 20 $\mu g/m^3$ may be associated with asthma-related and allergy-related health effects; concentrations above 60 $\mu g/m^3$ have been associated with exacerbation of existing asthma or development of asthma (Salonen 2009, NTP 2009, Tang 2009, WHO 2001). Tang 2009 reported that the likelihood of developing allergic asthma increases proportionately with indoor concentrations, especially at concentrations greater than 120 $\mu g/m^3$ (NTP 2009). The lack of clear and relevant public health guidance on residential formaldehyde exposure prevents the Technical Team from adequately evaluating the health implications of the levels found in this investigation. The broader issue of health risks due to formaldehyde exposure in homes is beyond the scope and capacity of this Technical Team and should be considered separately from issues surrounding corrosive drywall.

- Pinene and its isomers – Though pinene was detected in all EPA/ERT sampled homes, the maximum concentration measured for pinene falls just below its odor threshold.

Odors and Sensory Irritation

Upper airway irritation and skin irritation were common complaints from some occupants of affected homes. Many of the chemicals found in Test and Control homes are known respiratory irritants and/or malodorants (having an objectionable odor) when present above certain threshold levels. It is important to note that these compounds were not found at levels high enough to produce irritation normally. While the concentrations of individual chemicals found in the homes may fall below known levels for odor or irritation, it is not clear if there are additive effects that might alter individual sensitivities when occupants are exposed to a combination of chemicals.

Of the chemicals that were selected as chemicals of interest (Appendix F), information on odor characteristics was available for 56 compounds. Maximum concentration values measured during the EPA/ERT and FDOH sampling are also indicated. Odor threshold

values were also available for 82 of the compounds listed in Appendix F. Of these, fifteen chemical compounds exceeded their odor threshold. These chemical compounds are: acetic acid, butanoic acid, formaldehyde, formic acid, furfural, heptanol, hydrogen sulfide, nonanal, octanal, pentanal, 2-methyl propanal, 2-methyl propanoic (aka isobutyric acid), propanoic acid, 2-methyl-propanoic acid anhydride, thiophenes, and TXIB (2,2,4-Trimethyl-1,3-pentanediol diisobutyrate).

The Technical Team found that Test homes had more sulfur-containing and other malodorants at or near their odor thresholds than Control homes. Levels of formaldehyde were found at concentrations above its odor thresholds, but generally below reported limits of respiratory irritation in Test and Control homes, although some homes did have levels above reported levels of respiratory irritation. Formaldehyde has been documented to cause symptoms of respiratory irritation above 100 ppb (123 $\mu g/m^3$), particularly in sensitive individuals. A confounder for the Technical Team when evaluating the possible health hazards present in affected homes was that similar levels of formaldehyde and acetaldehyde were also found in unaffected Control homes in this investigation.

Symptoms resulting from a toxic response to a chemical may be differentiated from temporary sensory irritation by the underlying mechanism causing the response. A toxic response often results in cellular, tissue, or organ damage that persists after exposure to the causative agent ends and requires healing for the person to return to normal. On the other hand temporary sensory irritation is often characterized by upper airway or eye symptoms caused by irritating nerve endings in the nose. Typically these symptoms resolve without treatment after exposure ends. Because the trigeminal nerve, the fifth cranial nerve with exposed nerve endings in the nose, can be aggravated by many different chemical and physical agents, it is possible that a combination of factors can result in symptoms of irritation.

The trigeminal nerve is responsible for sensing the irritation or pungency of a chemical (Shusterman 1992). The trigeminal nerve works together with the olfactory nerve to distinguish and characterize chemicals present in the air we breathe. This combination of sensory nerves forms the common chemical sense known as chemesthesis. The ability of certain chemicals to activate this early warning system depends on their potency, concentration, and duration of exposure. The potency of certain chemicals is based on their water solubility, composition, and functional groups. Many sulfur-containing compounds are potent sensory irritants, reflected by their relatively low odor thresholds. It has been observed that low level volatile organic compounds (VOCs) can be additive and produce sensory irritation at concentrations lower than individual threshold limits (Sullivan 2001). However which chemical combinations and the levels at which they can produce sensory irritation has not be determined.

Nasal exposure to sensory irritants at sufficient concentrations can promote symptoms that include a burning and painful sensation in the nasal passages, head, and cornea by stimulation of the trigeminal nerve endings. This stimulation of the trigeminal nerve can induce a neurogenic inflammatory response. The signs and symptoms of neurogenic inflammation include sneezing, nasal stuffiness, rhinorrhea, eye irritation, headache,

sinus congestion, cough, throat irritation, and wheezing. Vasodilation and increased vascular permeability in the nose can also result from prolonged irritation of the trigeminal nerve (Sullivan 2001). It has been shown that the presence of objectionable odors increases the sensitivity of trigeminal nerve endings (DeSesa 2008, Schiffman 2000).

The lack of findings that demonstrate indoor chemical concentrations likely to produce a toxic response suggests that alternative explanations of reported symptoms should be examined. Many of the symptoms described by occupants of affected homes coincide with those of trigeminal nerve sensory irritation. Far from conclusive evidence of a cause, this coincidence of symptoms may suggest a possible mechanism that might be further examined as more data becomes available.

D. Data Limitations

- The data evaluated for this report reflect only a 1 to 3 day sampling period at several locations inside and one location outside for a very limited number of homes. While the homes selected for testing were considered "severely affected" they may not represent the entire body of affected homes. The results should not be used to determine "worst case" exposures, the frequency of worst-case exposures, or representative or "typical" contaminant concentrations. Likewise, the contaminants and their concentrations found in the 10 homes are not necessarily reflective of what is present in other homes.

- Some reduced sulfur compound samples (this applies only to homes 80 and 81; all of the sulfur compound samples from homes 80 and 81 were below reporting and detection limits) were not analyzed within the required 24-hour period, and therefore, the reported values may be an under-estimation of the actual collected levels.

- Reduce sulfur compounds were detected in some FDOH blank samples; this was not considered a problem since the same compounds were not detected in any of the indoor or outdoor air samples.

- EPA/ERT formaldehyde and aldehyde sample results from LA homes (Test home 202) exhibited contaminant breakthrough[13]. Therefore, these results should be treated as conservative estimated values and may underestimate the actual concentrations.

- The inclusion criteria used for the list of compounds of interest could be viewed as either conservative or not conservative. A cut-off demarcation was used by the Technical team to include those compounds which had at least 50% detects in at least one Test home. The purpose of these inclusion criteria was to screen out

[13]For future sampling events an ozone scrubber in-line with the cartridge along with lowering sample volume may reduce collection column breakthrough.

chemicals that were not likely to be relevant in this assessment or were found at levels below reliable reporting limits. Contaminants not included in the evaluation were at values near or below method detection or reporting limits. However, they were reviewed to ensure they did not show obvious trends or warranted health evaluation.

- Many of the compounds in the list of chemicals of interest are tentatively identified compounds (TICs). Investigators identified these compounds by comparing spectra to established chemical libraries and not from internal references. TICs are the best estimate based on what these compounds may be and should be treated as such. If any of these TIC compounds are considered of health concern, the identification should be confirmed by additional testing and analysis with appropriate standards.

VI. Conclusions:

- Based on this limited sampling and analysis, air sampling results revealed no *obvious* differences between types and amounts of compounds found in indoor air in Test versus Control homes.

- The majority of chemical compounds detected are considered common constituents of U.S. homes. Indoor air monitoring in homes and chamber testing of emissions from building materials and furnishings (EPA 1997, Alevantis 2003, Hodgson 2000, Colombo 1990) have found similar levels of compounds such as toluene, benzene, acetone, acetic acid, ethylbenzene, xylene, alkanes (e.g. hexane, pentane), methylene chloride, naphthalene, limonene, tetrachloroethene, trichloroethane, octanal, propanal, pinene, pentanal, formaldehyde and acetaldehyde.

- The formaldehyde levels found in air conditioned homes were consistent with new construction (the primary sources of formaldehyde in homes are believed to be pressed wood products and laminates). Formaldehyde levels appeared to be reduced when air conditioning was operating in the homes. The maximum concentrations of acetaldehyde and formaldehyde were at levels that could exacerbate conditions such as asthma in sensitive populations (Salonen 2009, NTP 2009, Tang 2009, WHO 2001), especially in homes where air conditioning was not operating. The lack of clear and relevant public health guidance on residential formaldehyde exposure prevents the Technical Team from adequately evaluating the health implications of the levels found in this investigation. The broader issue of health risks due to formaldehyde exposure in homes is beyond the scope and capacity of this Technical Team and should be considered separately from issues surrounding corrosive drywall.

- The three reduced sulfur compounds of greatest interest, hydrogen sulfide, carbon disulfide and carbonyl sulfide were rarely detected in this limited sampling of 10 homes. The peak hydrogen sulfide level was detected outdoors when a lawn

sprinkler system was running outside a Florida home. The use of "reclaimed water" for sprinklers is associated with these hydrogen sulfide levels. The Technical Team recognizes this is a possible contribution to indoor air quality. However, the possible role that these compounds play in reported symptoms and corrosion to metal components in affected homes should not be discounted.

- Multiple compounds were detected above odor thresholds. Test homes had more sulfur-containing and other malodorants at or near their odor thresholds than Control homes. These may result in temporary sensory irritation of the nose, discomfort, nuisance, and reduced quality of life for some individuals.

- Sulfuric acid and sulfur dioxide were found at levels very close to the monitoring or sampling detection limits. Further testing will allow evaluation of possible health implications.

- With the exception of imported drywall in Test homes, construction styles, materials, and the ages of Test and Control homes were typical of modern homes and comparable with each other. Four Test homes exceeded the American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE) minimum air change rate while two were less; two Control homes exceeded the recommended amounts, and two were less. All homes effectively controlled temperature and relative humidity, suggesting that uncontrolled environmental conditions within Test homes were not a major factor to drywall emissions or copper corrosion.

Recommendations:

- People who feel ill, especially those with persistent symptoms, should see their doctors—regardless if they believe their symptoms are associated with drywall or other indoor air problems. They should tell their doctors about any concerns they might have about environmental exposures.

- Operate air conditioning systems and increase air exchange rates in a way that keeps temperature and humidity low to reduce indoor air contaminant levels.

- Test for sulfur dioxide, sulfuric acid and other acid gases in chamber studies to determine if these compounds should be further investigated.

- Consider exploring the effects of chemical mixtures. Recognizing the significant limitations in evaluating low level chemical mixtures, and the absence of standard or consensus methods of evaluating health effects from chemical mixtures, the Technical Evaluation Team briefly examined the possible role of chemical mixtures found in Test and Control homes. Further examination of the data is necessary to ascertain if any of the compounds detected in the Test homes were a result of chemical reactions between corrosive drywall emissions and other building materials, coatings, adhesives, or chemicals in the indoor environment.

- Re-evaluate and revise the FDOH Case Definition for homes meeting the Chinese drywall criteria as new data becomes available.

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