

File IN15149
Project 06CA08042

February 28, 2006

FACT-FINDING REPORT

on

CLOTHES DRYER VENT DUCT LONG RADIUS 90° ELBOW

JB Engineering and Code Consulting, P.C.
Munster, IN

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GENERAL

Section 504.6.1 of the 2003 edition of the International Code Council's International Mechanical Code prescribes the maximum length for a clothes dryer exhaust duct (including fittings). The maximum prescribed length shall not exceed 25 ft. from the clothes dryer location to the outlet terminal. It further prescribes that the maximum length of duct shall be reduced 2 ½ feet for each 45° bend and 5 feet for each 90° bend.

In the process of preparing for the 2004/2005 code development cycle, the Mechanical Code Change Committee received a proposal to revise section 504.6.1 based upon empirical calculations. These calculations showed that the equivalent length of a 90°, smooth bend, 10-inch radius elbow was significantly less than the current value of 5 feet for generic 90° elbows. The Mechanical Code Change Committee had requested laboratory data to substantiate the proposed change prior to taking any action to revise requirements.

For the 2006/2007 IMC code development cycle, JB Engineering intends to submit a proposal to revise Section 504.6.1 and include a new Table 504.6.1 (see Public Proposal Form, Appendix A attached). In this proposal, an additional equivalent length value was proposed for 4-inch diameter, 10-inch long-radius smooth 90° elbows. The substantiation for this proposal referenced a test program that was carried out to measure the volumetric air flowrate through commonly used 4-section adjustable 90° elbows and the aforementioned smooth 90° elbows.

OBJECTIVE

The purpose of this Fact-Finding Investigation is to determine the equivalent length of four-inch diameter rigid straight-section clothes dryer duct, based upon the volumetric flowrate measurements through four-inch diameter, ten-inch radius smooth-section 90° clothes dryer exhaust duct elbow fittings. Details regarding the scope and plan for this work is included in the following tasks.

A copy of proposed Section and Table 504.6.1 is shown below with the new material underlined.

504.6.1 Maximum length. The maximum length of a clothes dryer exhaust duct shall not exceed 25 ft (7620 mm) from the dryer location to the outlet terminal. The maximum length of duct shall be reduced ~~2-1/2 feet for each 45-degree (0.79 rad) bend and 5 feet (1524 mm) for each 90-degree (1.6 rad) bend~~ for each fitting used in accordance with the equivalent pipe lengths shown in Table 504.6.1. The maximum length of the exhaust duct does not include the transition duct.

Table 504.6.1
Equivalent Length for Fittings

<u>Dryer Exhaust Duct Fitting</u>	<u>Equivalent Length</u>	
	<u>feet</u>	<u>mm</u>
<u>45 degree, 5 sectioned bend, 4 inch radius</u>	<u>2-1/2</u>	<u>768</u>
<u>90 degree, 5 sectioned bend, 4 inch radius</u>	<u>5</u>	<u>1524</u>
<u>90 degree, smooth bend, 10 inch radius</u>	<u>1-1/2</u>	<u>456</u>

Exceptions: (No change to exception)

G PROPOSAL *Continued* (Attach additional sheets as necessary)

8) SUPPORTING INFORMATION (State purpose and reason, and provide substantiation to support proposed change):

⋮ SUPPORTING INFORMATION *Continued* (Attach additional sheets as necessary)

INVESTIGATION

Scope of Investigation

This fact-finding investigation intended to investigate the reduced equivalent length value for 4-inch diameter, 90°-smooth-bend, 10-inch radius elbows based upon volumetric air flowrate measurements in accordance with the proposed Table 504.6.1 as shown on page 3. Data to support expanding the existing Section 504.6.1 in the IMC to specifically cover 4-inch diameter, 90°-smooth-bend, 10-inch radius elbows was to be obtained. Only two styles of 90° elbows were tested as being representative of verifying 4-section adjustable angle, short-radius-bend elbows and smooth-bend, long-radius elbows shown in the revised table.

Plan of Investigation

The scope of this project will cover an appropriate number of volumetric air flowrate measurements through various combinations of clothes dryer duct straight sections and 90° elbow fittings. This will provide practical flowrate data utilizing real world components. The baseline tests with the straight duct and 4-section adjustable elbows are based upon the IMC's 25-foot maximum length of exhaust duct. The tests with the smooth elbow will require additional lengths of straight duct in addition to the proposed test combinations, to establish equivalent duct straight and elbow combinations based upon volumetric air flowrate values. Various test duct assembly configuration combinations were included to reduce possible measurement error.

The various combinations of straight duct and elbow fittings are referred to duct sample assemblies. In this Report, the original duct sample assembly experiment is referred to as a test. Various adjustments (addition or removal of fittings) are made to each original duct sample assembly, with volumetric air flowrate measurements made after the adjustments and denoted with the letter "a" or "b". The individual tests are tabulated in the Recorded Data Table located in Appendix C. All of the duct fittings were manufactured from galvanized steel. To provide a basis for validating the various calculated equivalent length for fittings, some tests were conducted for comparison purposes using the 4-section adjustable 90° elbows. These elbows were fixed at a 90° angle with aluminum duct tape.

Test Method

The test method for this fact-finding investigation consisted of constructing various duct sample assemblies of various lengths and fitting combinations. The baseline duct sample assembly consisted of five five-foot sections of straight duct as shown in photograph 1. The volumetric air flowrate meter was positioned at the outlet of the clothes dryer and the sample assembly was attached to the output of the meter as shown in photograph 2. A baseline volumetric air flowrate value was recorded. This baseline duct sample assembly represents the maximum permitted length of dryer exhaust duct per the aforementioned IMC requirements. The current requirements assign an equivalent straight duct length to each elbow fitting, which must be considered when calculating the total length of the dryer exhaust duct.



All duct fitting joints were taped, as were the seams, of the 4-section adjustable 90° elbows and the 10-inch smooth radius 90° elbows. This permitted comparison measurements of the various duct components without incurring flowrate loss from leakage.

Eight sets of tests were conducted as shown in the Test Set Description Table.

Test Set Description Table

Test Set Number	Test Set Description	Test Numbers
1	4-section elbow / straight duct combination (5 pieces)	0,1,2,3,4,5
2	Smooth elbow / straight duct combination (5 pieces)	6,7,8,9,10
3	Smooth elbow / straight duct combination ‡	6a,7a,8a,9a,10a
4	Straight duct	11,12,13,14,15,16,17,18,19,20
5	Smooth Elbows	21,22,23,24,25,26
6	4-Section Elbows	27,28,29,30,31,32,33,34,35,36,37,38
7	Mixed, 40 feet	39,40,41,42,42b,43,44,44b,45
8	Mixed, 50 feet	41a,42a,43a,44a,45a
‡	Additional lengths of straight duct used	

The Recorded Data Table in Appendix C shows the data collected during each of the individual tests conducted. The following is a basic description of each of the eight sets of tests. The first set of tests utilized a combination of straight ducts and 4-section adjustable 90° elbows and was based on the maximum duct length permitted by the current IMC requirements. The second set of tests utilized a combination of straight ducts and smooth radius 90° elbows also based on the maximum duct length permitted by the current IMC requirements. The third set of tests utilized the sample assemblies

from the second set of tests (using smooth elbows) with additional lengths of straight duct. The fourth set of tests utilized from one to ten five-foot straight duct sections. The fifth set of tests utilized from one to six smooth radius 90° elbows. The sixth set of tests utilized from one to six 4-section adjustable 90° elbows. The seventh set of tests utilized a four-foot section of flexible aluminum duct in addition to forty feet of straight duct with the addition of 0-2 4-section adjustable 90° elbows or 0-2 smooth radius 90° elbows. The eighth set of tests is similar to the seventh set, except fifty feet of straight duct is used. The following paragraphs further describe each of the eight test sets shown in the Test Set Description table.

Each of the first two sets consisted of four types of basic five piece test duct configurations. The first basic test duct configuration consisted of 1 elbow and 4 five-foot sections of straight duct. The second basic test duct configuration consisted of 2 elbows and 3 five-foot sections of straight duct. The third basic test duct configuration consisted of 3 elbows and 2 five-foot sections of straight duct. The fourth basic test duct configuration consisted of 4 elbows and 1 five-foot section of straight duct.

The first set used 4-section adjustable 90° elbows in conjunction with five-foot sections of straight duct. The current IMC duct length requirements were used, specifying a maximum total duct length of 25 feet with each 4-section adjustable 90° elbow replacing the same number of five-foot sections of straight duct. Volumetric air flowrate (CFM) measurements were made for each test configuration. The Duct Orientation photographs showing the actual orientation of each duct fitting relative to the entire duct sample assemblies is shown in Appendix D.

The second set of tests duplicated the first set of tests with the following exception: 10-inch smooth radius 90° elbows were substituted for the previous 4-section adjustable 90° elbows. The Duct Orientation photographs showing the actual orientation of each duct fitting relative to the entire duct sample assemblies is shown in Appendix D.

The third set of tests duplicated the second set of tests (using smooth radius 90° elbows) with the following exception: additional straight duct (of various lengths) were added until the measured volumetric air flowrate (CFM) was equal to that measured during the baseline test consisting of five five-foot sections (25 feet) of straight duct. The length of the additional section of straight duct was recorded. This was for comparison purposes.



Each of the fourth, fifth, and sixth set of tests utilized duct fittings of the same type. None of these sets utilized combinations of duct fitting types.

The fourth set of tests utilizes 5-foot lengths of straight ducts. A total of ten five-foot straight ducts were connected in the same manner as shown in photograph 3 for this set of tests. Volumetric airflow measurements were made for modified duct assemblies, where a single

five-foot section of straight duct was removed after each test. Measurements were recorded for duct sample assemblies consisting of ten sections, nine sections, eight sections, seven sections, six sections (not conducted), five sections, four sections, three sections, two sections, and one section.

The fifth set of tests utilizes smooth radius 90° elbows. A total of six smooth elbows were connected as shown in photograph 4 for this set of tests. Volumetric airflow measurements were made for modified duct assemblies, where a single elbow was removed after each test. Measurements were recorded for duct sample assemblies consisting of six elbows, five elbows, four elbows, three elbows, two elbows, and one elbow.



The sixth set of tests utilized 4-section adjustable 90° elbows. A total of six 4-section adjustable 90° elbows were connected as shown in photograph 5 for this set of tests. Volumetric air flowrate measurements were made for modified duct assemblies, where a single elbow was removed after each test. Measurements were recorded for duct sample assemblies consisting of six elbows, five elbows, four elbows, three elbows, two elbows, and one elbow.



Measurements had shown that duct sample assembly orientation affected the volumetric air flowrate of the various duct sample assemblies, including the modified assemblies. Photograph 6 shows an example of one such configuration. It appears as though the physical construction of the four-section adjustable 90° elbows affects the volumetric flowrate through various physical orientations of each elbow.



Explanation of Recorded Data and General Observations

A number was assigned to each test and the duct fitting and location within the duct sample assembly was identified and recorded as shown in the Recorded Data Table in Appendix B. Volumetric air flowrate, measured from outlet of the dryer, prior to the inlet of the duct sample assembly, was recorded. The following includes a discussion of this data and some of the conditions noted during the tests.

Duct Fitting Samples

The actual length of the each straight duct fitting was measured and identified as shown in the following Duct Fittings Table.

Duct Fittings Table

Quantity	Code	Sample #	Description	Actual Length (ft.)
10	D	1-10	Straight Duct (D = Duct)	4.920
6	SE	1-6	5 Section Elbow (SE = Sectioned Elbow)	
6	LE	1-6	Smooth Elbow (LE = Long Radius Elbow)	
3	a	1-3	0.5' section of straight exhaust duct	0.375
3	b	1-3	1.0' section of straight exhaust duct	0.875
3	c	1-3	1.5' section of straight exhaust duct	1.417
3	d	1-3	2.0' section of straight exhaust duct	1.875
3	e	1-3	2.5' section of straight exhaust duct	2.375
1	f	1	4.0' section of flexible aluminum duct	4.000
1	f	2	4.0' section of flexible aluminum duct w/ 90°	4.000

Duct Fitting Sample Assemblies

For each test, the duct fitting sample identification number and physical position within the duct sample assembly were recorded. The Exhaust Duct Fitting Position Number table (shown in Appendix B) shows the position of each fitting within the duct sample assembly.

Predictable Equivalent Length Tests

Four correlation tests were performed for the smooth long radius elbows combined with lengths of straight duct. For this set of tests, a baseline volumetric airflow was obtained through five five-foot sections (25 feet) of straight duct. The duct sample assemblies were constructed using from one to four smooth radius 90° elbows. Each duct sample assembly was adjusted with additional lengths of straight duct, until the volumetric airflow matched that of the baseline 25 feet duct sample assembly.

Test 6a was the baseline configuration. The volumetric air flowrate slightly exceeded the previous test of test 6 (204 CFM vs. 203 CFM) due to an improved seal at the dryer. 204 CFM was used as the baseline measurement for Test Set #3. Test 7a used one smooth radius 90° elbow and required an additional 1.417 feet of straight duct. The graphical data suggested that the equivalent straight duct length should be 2.5 feet. This is a 43% deviation from the predicted value. Test 8a used two smooth radius 90° elbows and required an additional 0.375 feet of straight duct. The graphical data suggested that the equivalent straight duct length should be 5.0 feet. This is a 92% deviation from the predicted value. Test 9a used three smooth radius 90° elbows and required an additional 5.417 feet of straight duct. The graphical data suggested that the equivalent straight duct length should be 7.5 feet. This is a 28% deviation from the predicted value. Test 10a used four smooth radius 90° elbows and required an additional 10 feet of straight duct. The graphical data suggested that the equivalent straight duct length should be 10 feet. This is a 0% deviation from the predicted value.

Atmospheric Conditions

For each project, the temperature and relative humidity were recorded and was 21°C and less than 27% relative humidity for all measurements. The clothes dryer's electric heater was not energized during this project and thus did not heat the airflow.

Instrumentation Used

The volumetric air flow meter used indicated that the dryer flowrate varied by up to approximately 8 CFM. The median value observed during each trial run was recorded for each test. The rotating vane anemometer used was manufactured by Alnor Instruments Co. and is designated as model RVD, number usnbk01741. Last calibrated 08/2005. The volumetric air flowrate range is 0 to 2,604,000 CFM. The actual range is a function of velocity range and duct size. The velocity range is 50 to 6,000 ft/min with an accuracy of $\pm 1\%$ of the reading or ± 3 ft/min which ever is greater.

Comments

All comparison testing was performed with the current IMC total maximum duct length requirements of 25 feet as the primary focus.

Recorded Data

The recorded data is tabulated in the Recorded Data Table shown in Appendix C. This table lists the tests by type and number and the corresponding volumetric air flowrate measurement value, fitting information, temperature and humidity data, and test date. Additionally, the combination numbers of duct fittings used for each duct sample assembly is also noted. The location of each duct fitting sample within the duct sample assembly was also recorded and tabulated in Appendix B. Volumetric air flowrate values (CFM) were manually recorded for each duct sample assembly and associated

duct sample assembly variation (denoted with the letter “a” or “b”). Photographs showing the representative orientation of each duct fitting within each sample test assembly of the first ten tests are shown in Appendix D.

The following summary information regarding each of the eight Test Sets is gathered from the Test Set Description Table (Page 5), Exhaust Duct Fitting Position Number table (Appendix B), Recorded Data Table (Appendix C), and photographs in the Duct Sample Assembly Fitting Orientation (Appendix D).

The first set of tests includes test numbers 0, 1, 2, 3, 4, and 5 and was performed with the 4-section adjustable 90° elbows. Representative photographs are shown in Appendix D.

The second set of tests repeated test numbers 1, 2, 3, 4, and 5 but substituted the smooth radius elbow for the 4-section adjustable 90° elbow, corresponding to test numbers 6, 7, 8, 9, and 10. Representative photographs are shown in Appendix D.

The third set of tests includes test numbers 6a, 7a, 8a, 9a, and 10a, and also used the smooth radius 90° elbow as during test numbers 6, 7, 8, 9, and 10. This set of tests duplicated the second set of tests with the following exception: additional straight duct (of various lengths) were added until the measured volumetric air flowrate (CFM) was equal to that measured during the baseline test consisting of five five-foot sections (25 feet) of straight duct. The length of the additional section of straight duct was recorded. This was for comparison purposes. Representative photographs are shown in Appendix D.

The fourth set of tests includes test numbers 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20 correspond sample assemblies consisting of increasing numbers of 5' straight duct from 1 section to 10 sections as represented in photograph 1. Test number 16 (consisting of 6 sections) was not conducted.

The fifth set of tests includes test numbers 21, 22, 23, 24, 25, and 26 correspond sample assemblies consisting of increasing numbers of smooth elbows from 1 elbow to 6 elbows as shown in photograph 4.

The sixth set of tests includes test numbers 27, 28, 29, 30, 31 and 32 correspond sample assemblies consisting of increasing numbers of 4-section adjustable 90° elbows from 1 elbow to 6 elbows. The physical configuration of the elbows resembles stair steps as shown in photograph 5.

The sixth set of tests also includes test numbers 33, 34, 35, 36, 37, and 38 correspond sample assemblies consisting of increasing numbers of 4-section adjustable 90° elbows from 1 elbow to 6 elbows. The physical configuration of the elbows resembles a series of the letter “U” as shown in photograph 6.

The seventh set of tests includes test numbers 39, 40, 41, 42, 43, 44, and 45 correspond sample assemblies consisting of a four-foot length of flexible aluminum dryer duct with one 0° bend (test 39 – no bend) and one 90° bend (test 40). Test 41 is a four-foot length of flexible aluminum dryer duct with one 90° bend with forty feet of straight duct. Test 42 duplicated Test 41 and inserted a 4-section elbow at 15 feet of straight duct. Test 43 duplicated Test 42 and inserted a 4-section elbow at 30 feet of straight duct. Test 42b duplicated Test 41 and inserted a 4-section elbow at 20 feet of straight duct. Test 44 duplicated Test 41 and inserted a smooth elbow at 15 feet of straight duct. Test 44b duplicated Test 41 and inserted a smooth elbow at 20 feet of straight duct. Test 45 duplicated Test 44 and inserted a smooth elbow at 30 feet of straight duct.

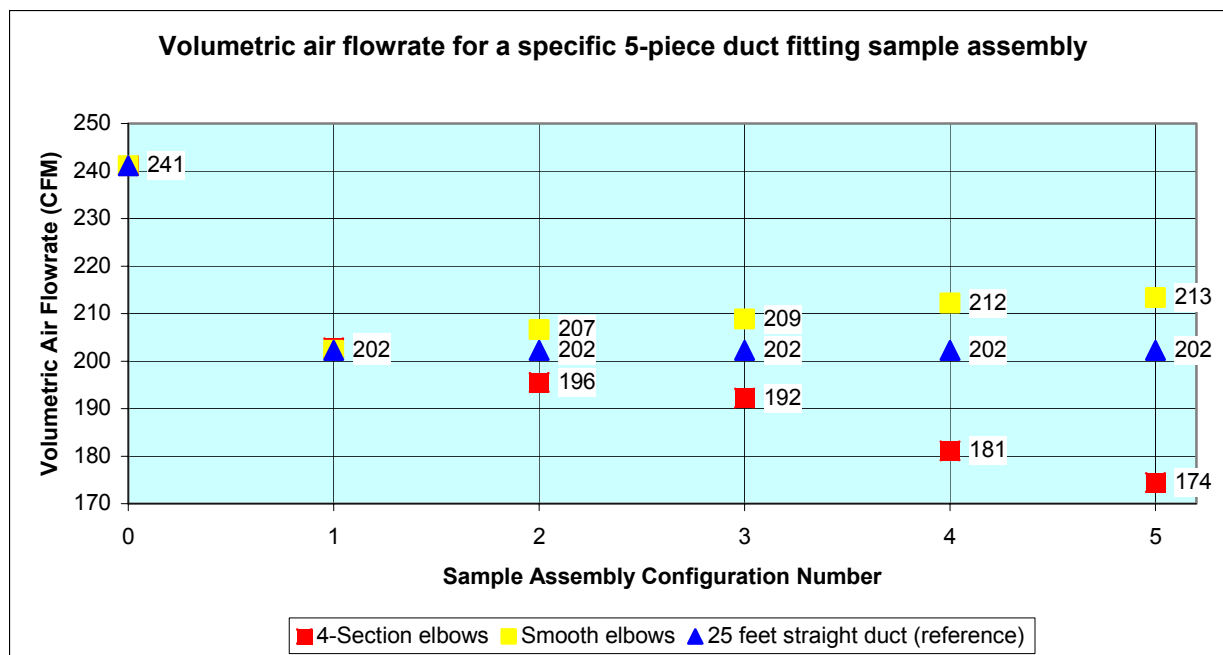
The eighth set of tests includes test numbers 41a, 42a, 43a, 44a, and 45a. Test 41a is a four-foot length of flexible aluminum dryer duct with one 90° bend with fifty feet of straight duct. Test 42a duplicated Test 41a and inserted a 4-section elbow at 20 feet of straight duct. Test 43a duplicated Test 42a and inserted a 4-section elbow at 40 feet of straight duct. Test 44a duplicated Test 41a and inserted a smooth elbow at 20 feet of straight duct. Test 45a duplicated Test 44a and inserted a smooth elbow at 40 feet of straight duct.

SUMMARY

In consideration of the fact-finding character of this investigation, the forgoing Report is to be construed as information only and should not be regarded as conveying any conclusion or recommendations on the part of Underwriters Laboratories Inc. regarding the acceptability of the construction or performance of the product for recognition by any code or standard or for any other purpose.

With the volumetric air flowrate measurement of clothes dryer exhaust duct work, there are many variables that must be considered in addition to the airflow resistance characteristics of the individual duct fittings under test. Some of these variables include the airflow resistance at the joint of each duct fitting from variable crimped ends, the overall length of the ductwork, the actual three dimensional shape of the ductwork, the method of obtaining the volumetric air flowrate, and the specific conditions surrounding the airflow entering the test ductwork. This work used an actual electric clothes dryer for the air source, which provided a turbulent airflow.

The following chart (Volumetric Air flowrate for a specific 5-piece duct fitting sample assembly) plots the volumetric air flowrate values for each of the five sample test assembly configurations from Test Set #1 and #2. For these tests all duct sample assemblies consist of a total of only five discrete duct fittings. This chart's baseline test used 5 five-foot sections of straight duct. The resulting air flowrate value is shown in yellow and included for each of the five Sample Assembly Configurations denoted on the chart. For each subsequent test, every 90° elbow added to the sample assembly resulted in the removal of a single five-foot section of straight duct. The Sample Assembly Configuration Number (1, 2, 3, 4, 5) corresponds to the number of 90° elbows (0, 1, 2, 3, 4 respectively) used during each test represented. This chart is intended to compare the volumetric air flowrate through identical representative duct configurations in accordance with the current IMC maximum duct length requirements, referenced to 25 feet of straight duct. The only difference being the type of elbow used (4-section adjustable 90° elbows or smooth radius 90° elbows) in each representative duct configuration.



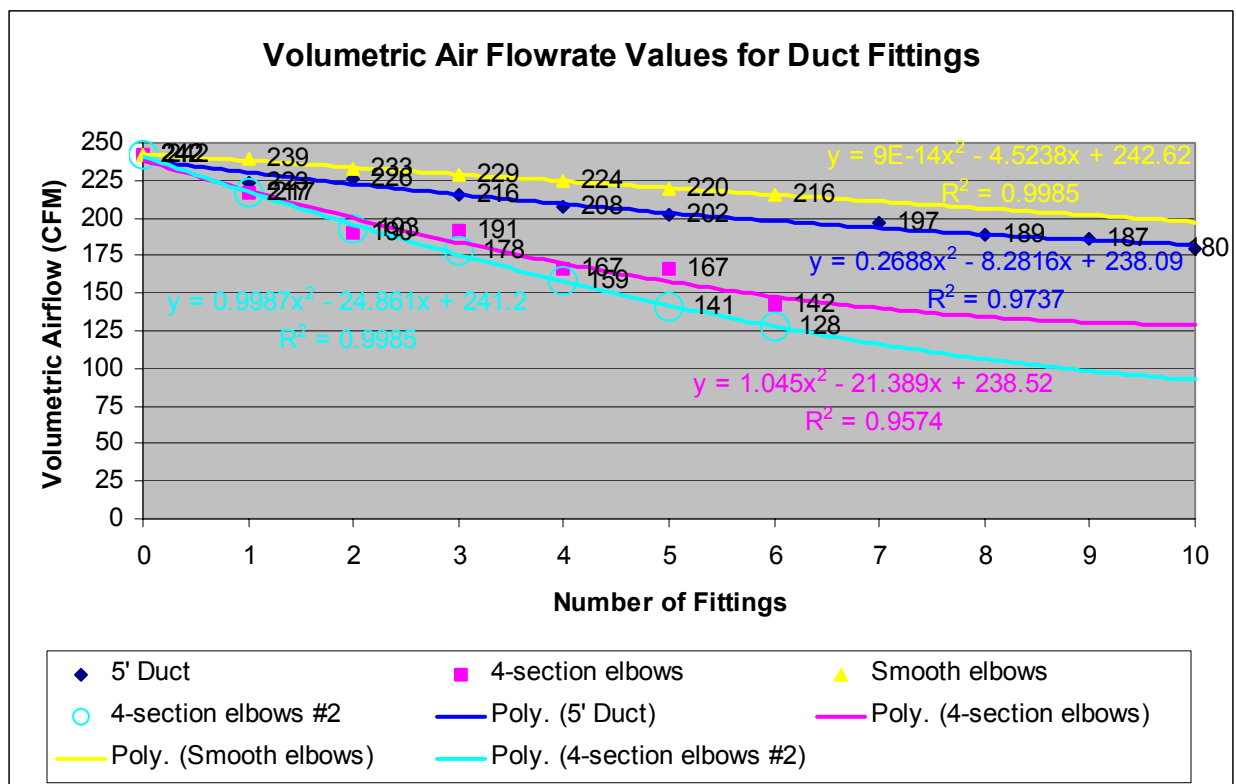
This chart indicates the volumetric air flowrate values directly out of the clothes dryer, which is sample assembly configuration number 0. This corresponds to zero fittings and is the same value for each of the test sets. The blue triangles simply indicate the volumetric air flowrate for a duct sample assembly consisting of five sections of 5-foot long straight ducts. It is included as a reference point for each of the five sample assembly configurations. The large red squares indicate the volumetric air flowrate values for each duct sample assembly test numbers 1 through 5. The small yellow squares indicate the volumetric air flowrate values for each duct sample assembly test numbers 6 through 10. The only difference between each sample assembly configuration is the number of elbows in each duct sample assembly. Refer to the Exhaust Duct Fitting Position Number table in Appendix B for the specific locations each fitting within the duct sample assembly.

The following chart (Volumetric Air Flowrate Values for Duct Fittings) shows the data points collected for the three single type duct fitting tests. The correlation coefficients for the polynomial trend line, corresponding to each data set, shows excellent correlation.

The correlation coefficient improved with the re-orientation (labeled “4-section #2” - see photograph 5) of the 4-section adjustable 90° elbows (tests 27-32). Label “4-section elbows” corresponds to photograph 6 (tests 33-38). This chart also indicates that the volumetric air flowrate through six smooth radius 90° elbows is approximately the same as through three five-foot sections (fifteen feet) of straight duct. Mathematically this is a ratio of two smooth 90° elbows for each five-foot section of straight duct replaced.

This chart indicates that replacing five-foot sections of straight duct with smooth radius 90° elbows improves the volumetric air flowrate of the resultant duct sample assembly over that of a duct sample assembly consisting exclusively of 25 feet of straight duct. This chart also indicates that replacing five-foot sections of straight duct with 4-section adjustable 90° elbows degrades the volumetric air flowrate of the resultant duct sample assembly from that of a duct sample assembly consisting exclusively of 25 feet of straight duct.

The following chart (Volumetric Air flowrate Values for Duct Fittings) plots the volumetric air flowrate values for each of the three types fittings used for this research project, 4-section adjustable 90° elbows, five-foot sections of straight duct, and smooth radius 90° elbows. For these four series of tests (tests 11 – 38) all duct sample assemblies consist of a single type of duct fitting. The first series of tests, shown in dark blue, used increasing numbers of five-foot sections of straight duct. The second series of tests, shown in magenta, used increasing numbers of 4-section adjustable 90° elbows arranged in a “U” shaped orientation. The third series of tests, shown in yellow, used increasing numbers of smooth radius elbows. The fourth series of tests, shown in cyan, used increasing numbers of 4-section adjustable 90° elbows in a stair step orientation. This chart compares the volumetric air flowrate through the three types of duct fittings without mixing fitting types relative to each type.



When considering volumetric flow rate values, this chart seems to indicate that three five-foot sections of straight duct can be replaced with six smooth radius 90° elbows with no loss of volumetric airflow. No data was obtained for comparisons of

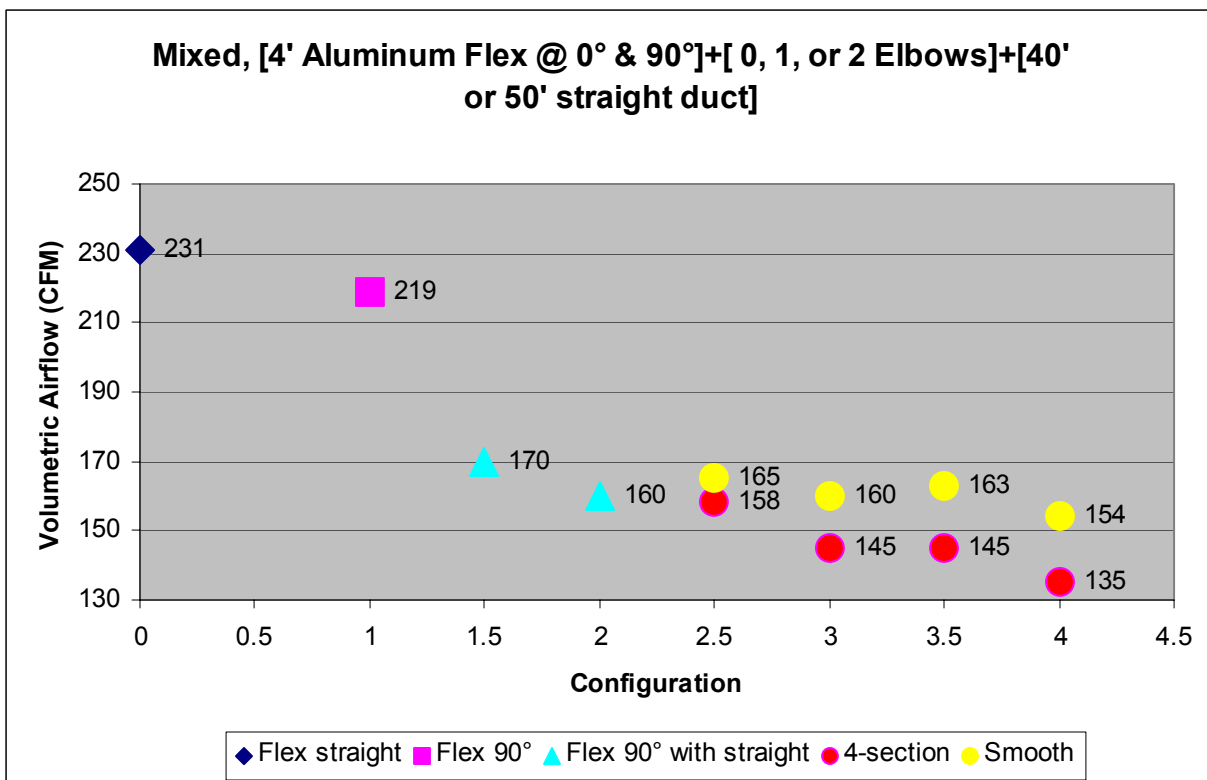
sample assemblies consisting of more than six smooth radius 90° elbow fittings. Mathematically, this suggests that two smooth radius 90° elbows are the equivalent of one five-foot section of straight duct. Therefore, one smooth radius 90° elbow would be the equivalent of a 2.5-foot section of straight duct.

This chart also indicates that one 4-section adjustable 90° elbow is approximately equivalent to fifteen feet of straight duct. In addition, it shows that two 4-section adjustable 90° elbows are the roughly equivalent of eight five-foot sections (or forty feet) of straight duct.

The data plotted in the chart labeled “Mixed, [4' Aluminum Flex @ 0° & 90°]+[0, 1, or 2 Elbows]+[40' or 50' straight duct]”, in conjunction with straight duct data previously measured during this project, indicates that a four-foot section of flexible aluminum duct with one 90° bend at the center (at approximately two feet) is approximately equivalent to fifteen feet of straight duct.

“Flex straight” represents the measurement for fitting f1. “Flex 90°” represents the measurement for fitting f2. “Flex 90° with straight” at x-axis position 1.5 represents the measurement for fitting f2 with forty feet of straight duct. “Flex 90° with straight” at x-axis position 2 represents the measurement for fitting f2 with fifty feet of straight duct.

X-axis labels 2.5 and 3.5 represent tests using forty feet of straight duct with one elbow and two elbows respectively. X-axis labels 3 and 4 represent tests using fifty feet of straight duct with one elbow and two elbows respectively.



Another variable that must be considered when judging volumetric airflow through a series of duct fittings is the amount of air leakage at the duct joints and fitting seams. No attempt was made to categorize the effect of un-taped duct fitting seams or joints.

In consideration of the fact-finding character of the investigation, this Report is rendered without recommendations or conclusions on the part of Underwriters Laboratories Inc.

Report By:



D. G. Dubiel
Associate Research Engineer
ATS

Reviewed By:



Kent Whitfield
Manager ATS
ATS

Appendix A



Date Rec'd.:	Log No.:	Proposal No.:
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PUBLIC PROPOSAL FORM

**FOR PUBLIC PROPOSALS ON THE INTERNATIONAL CODES
2006/2007 CODE DEVELOPMENT CYCLE**

INSTRUCTIONS PLEASE SEE REVERSE FOR INSTRUCTIONS ON SUBMITTING PUBLIC PROPOSALS. PROPOSALS MUST COMPLY WITH THESE

CLOSING DATE: All Proposals Must Be Received by March 20, 2006.

- 1) Indicate the format in which you would like to receive your Public Proposals Monograph (PPM), Report of the Hearing (ROH) and Final Action Agenda (FAA):
 : Paper G *CD G *Download from ICC Website

(*Note: A paper copy will not be sent to you if you have chosen the CD or Download format.)

- 2) PLEASE TYPE OR PRINT CLEARLY: FORMS WILL BE RETURNED if they contain unreadable information.

Name:	Julius Ballanco, P.E.			Date:	January 31, 2006
Jurisdiction/Company:	JB Engineering and Code Consulting, P.C.				
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- 4) **Cost Impact:** Indicate if this Proposal: G will : will not increase the cost of construction.

- 5) Indicate appropriate International Code(s) associated with this Public Proposal – Please use Acronym:
 (See back of this form or the instructions for list of names and acronyms for the International Codes):

- 6) **Revision to:** : Section 504.6.1 G Table _____ Figure G _____

- 7) **PROPOSAL** Please check appropriate box:
 : Revise as follows: G Add new text as follows G Delete and substitute as follows G Delete without Substitution(s):

Show the proposed NEW, REVISED or DELETED TEXT in legislative format: ~~Line through text to be deleted.~~
Underline text to be added.

Modify section to read as follows:

504.6.1 Maximum length. The maximum length of a clothes dryer exhaust duct shall not exceed 25 ft (7620 mm) from the dryer location to the outlet terminal. The maximum length of duct shall be reduced ~~2-1/2 feet for each 45-degree (0.79 rad) bend and 5 feet~~

(1524 mm) for each 90-degree (1.6 rad) bend for each fitting used in accordance with the equivalent pipe lengths shown in Table 504.6.1. The maximum length of the exhaust duct does not include the transition duct.

Table 504.6.1
Equivalent Length for Fittings

<u>Dryer Exhaust Duct Fitting</u>	<u>Equivalent Length</u>	
	<u>feet</u>	<u>mm</u>
<u>45 degree, 5 sectioned bend, 4 inch radius</u>	<u>2-1/2</u>	<u>768</u>
<u>90 degree, 5 sectioned bend, 4 inch radius</u>	<u>5</u>	<u>1524</u>
<u>90 degree, smooth bend, 10 inch radius</u>	<u>1-1/2</u>	<u>456</u>

Exceptions: (No change to exception)

G PROPOSAL *Continued* (Attach additional sheets as necessary)

8) SUPPORTING INFORMATION (State purpose and reason, and provide substantiation to support proposed change):

⋮ SUPPORTING INFORMATION *Continued* (Attach additional sheets as necessary)

Test #	Appendix B Exhaust Duct Fitting Position Number												
	1	2	3	4	5	6	7	8	9	10	11	12	13
0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1	D-1	D-2	D-3	D-4	D-5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2	SE-1	D-2	D-3	D-4	D-5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
3	SE-1	SE-2	D-3	D-4	D-5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4	SE-1	SE-2	SE-3	D-4	D-5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5	SE-1	SE-2	SE-3	SE-4	D-5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6	D-1	D-2	D-3	D-4	D-5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7	LE-1	D-1	D-2	D-3	D-4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7a	LE-1	D-1	D-2	D-3	D-4	c1	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8	LE-1	D-1	D-2	LE-4	D-5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8a	LE-1	D-1	D-2	LE-4	D-5	a1	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9	LE-1	D-1	LE-2	LE-3	D-9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9a	LE-1	D-1	LE-2	LE-3	D-9	D-7	c1	n/a	n/a	n/a	n/a	n/a	n/a
10	LE-1	LE-4	LE-2	LE-3	D-9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
10a	LE-1	LE-4	LE-2	LE-3	D-9	D-3	D-4	n/a	n/a	n/a	n/a	n/a	n/a
11	D-1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
12	D-1	D-2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
13	D-1	D-2	D-6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
14	D-1	D-2	D-6	D-10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
15	D-1	D-2	D-6	D-10	D-8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
16	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
17	D-1	D-2	D-6	D-10	D-8	D-5	D-7	n/a	n/a	n/a	n/a	n/a	n/a
18	D-1	D-2	D-6	D-10	D-8	D-5	D-7	D-9	n/a	n/a	n/a	n/a	n/a
19	D-1	D-2	D-6	D-10	D-8	D-5	D-7	D-9	D-3	n/a	n/a	n/a	n/a
20	D-1	D-2	D-6	D-10	D-8	D-5	D-7	D-9	D-3	D-4	n/a	n/a	n/a
21	LE-1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
22	LE-1	LE-4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
23	LE-1	LE-4	LE-2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
24	LE-1	LE-4	LE-2	LE-3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
25	LE-1	LE-4	LE-2	LE-3	LE-5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
26	LE-1	LE-4	LE-2	LE-3	LE-5	LE-6	n/a	n/a	n/a	n/a	n/a	n/a	n/a
27	SE-3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
28	SE-3	SE-2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
29	SE-3	SE-2	SE-4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
30	SE-3	SE-2	SE-4	SE-1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
31	SE-3	SE-2	SE-4	SE-1	SE-5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
32	SE-3	SE-2	SE-4	SE-1	SE-5	SE-6	n/a	n/a	n/a	n/a	n/a	n/a	n/a
33	SE-3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
34	SE-3	SE-2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
35	SE-3	SE-2	SE-4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
36	SE-3	SE-2	SE-4	SE-1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
37	SE-3	SE-2	SE-4	SE-1	SE-5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
38	SE-3	SE-2	SE-4	SE-1	SE-5	SE-6	n/a	n/a	n/a	n/a	n/a	n/a	n/a
39	f1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
40	f2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
41	f2	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	n/a	n/a	n/a	n/a
41a	f2	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	n/a	n/a
42	f2	D-1	D-2	D-3	SE-1	D-4	D-5	D-6	D-7	D-8	n/a	n/a	n/a
42b	f2	D-1	D-2	D-3	D-4	SE-1	D-5	D-6	D-7	D-8	n/a	n/a	n/a
42a	f2	D-1	D-2	D-3	D-4	SE-1	D-5	D-6	D-7	D-8	D-9	D-10	n/a
43	f2	D-1	D-2	D-3	SE-1	D-4	D-5	D-6	SE-2	D-7	D-8	n/a	n/a
43a	f2	D-1	D-2	D-3	SE-1	D-4	D-5	D-6	D-7	D-8	SE-2	D-9	D-10
44	f2	D-1	D-2	D-3	LE-1	D-4	D-5	D-6	D-7	D-8	n/a	n/a	n/a
44b	f2	D-1	D-2	D-3	D-4	LE-1	D-5	D-6	D-7	D-8	n/a	n/a	n/a
44a	f2	D-1	D-2	D-3	D-4	LE-1	D-5	D-6	D-7	D-8	D-9	D-10	n/a
45	f2	D-1	D-2	D-3	LE-1	D-4	D-5	D-6	LE-2	D-7	D-8	n/a	n/a
45a	f2	D-1	D-2	D-3	LE-1	D-4	D-5	D-6	D-7	D-8	LE-2	D-9	D-10

Appendix C

Recorded Data Table									
Test Set #	Test Type	Test #	Volumetric Airflow (CFM)	Number of fittings Straight Ducts 5' sections	Elbows	Straight Ducts Add'l feet (ft.)	Temp (°C)	Humidity (%rh)	Date
	Dryer output	0	242	0	0	0	21	14	01/26/06
1	4-section combination	1	203	5	0	0	21	14	01/26/06
1	4-section combination	2	196	4	1	0	21	14	01/26/06
1	4-section combination	3	192	3	2	0	21	14	01/26/06
1	4-section combination	4	181	2	3	0	21	14	01/26/06
1	4-section combination	5	174	1	4	0	21	14	01/26/06
2	Smooth combination	6	203	5	0	0	21	23	02/01/06
3	Smooth combination ‡	6a	204	5	0	0	21	23	02/01/06
2	Smooth combination	7	208	4	1	0	21	23	02/01/06
3	Smooth combination ‡	7a	204	4	1	1.417	21	23	02/01/06
2	Smooth combination	8	206	3	2	0	21	23	02/01/06
3	Smooth combination ‡	8a	204	3	2	0.375	21	23	02/01/06
2	Smooth combination	9	212	2	3	0	21	23	02/01/06
3	Smooth combination ‡	9a	204	2	3	3.292	21	23	02/01/06
2	Smooth combination	10	217	1	4	0	21	23	02/01/06
3	Smooth combination ‡	10a	204	1	4	3.750	21	23	02/01/06
4	Straight duct	11	223	1	0	0	21	24	02/01/06
4	Straight duct	12	226	2	0	0	21	24	02/01/06
4	Straight duct	13	216	3	0	0	21	24	02/01/06
4	Straight duct	14	208	4	0	0	21	24	02/01/06
4	Straight duct	15	202	5	0	0	21	24	02/01/06
4	Straight duct	16	no data	6	0	0	n/a	n/a	n/a
4	Straight duct	17	197	7	0	0	21	24	02/01/06
4	Straight duct	18	189	8	0	0	21	24	02/01/06
4	Straight duct	19	187	9	0	0	21	24	02/01/06
4	Straight duct	20	180	10	0	0	21	24	02/01/06
5	Smooth Elbows	21	239	0	1	0	21	24	02/01/06
5	Smooth Elbows	22	233	0	2	0	21	24	02/01/06
5	Smooth Elbows	23	229	0	3	0	21	24	02/01/06
5	Smooth Elbows	24	224	0	4	0	21	24	02/01/06
5	Smooth Elbows	25	220	0	5	0	21	24	02/01/06
5	Smooth Elbows	26	216	0	6	0	21	24	02/01/06
6	4-Section Elbows	27	217	0	1	0	21	24	02/01/06
6	4-Section Elbows	28	193	0	2	0	21	24	02/01/06
6	4-Section Elbows	29	178	0	3	0	21	24	02/01/06
6	4-Section Elbows	30	159	0	4	0	21	24	02/01/06
6	4-Section Elbows	31	141	0	5	0	21	24	02/01/06
6	4-Section Elbows	32	128	0	6	0	21	24	02/01/06
6	4-Section Elbows †	33	217	0	1	0	21	27	02/03/06
6	4-Section Elbows †	34	190	0	2	0	21	27	02/03/06
6	4-Section Elbows †	35	191	0	3	0	21	27	02/03/06
6	4-Section Elbows †	36	167	0	4	0	21	27	02/03/06
6	4-Section Elbows †	37	167	0	5	0	21	27	02/03/06
6	4-Section Elbows †	38	142	0	6	0	21	27	02/03/06
7	Mixed	39	231	8	0	0	21	9	02/17/06
7	Mixed	40	219	8	0	0	21	9	02/17/06
7	Mixed	41	170	8	0	0	21	9	02/17/06
8	Mixed	41a	160	10	0	0	21	9	02/17/06
7	Mixed	42	158	8	1	0	21	9	02/17/06
7	Mixed	42b	156	8	1	0	21	9	02/17/06
8	Mixed	42a	145	10	1	0	21	9	02/17/06
7	Mixed	43	145	8	2	0	21	9	02/17/06
8	Mixed	43a	135	10	2	0	21	9	02/17/06
7	Mixed	44	165	8	1	0	21	9	02/17/06
7	Mixed	44b	168	8	1	0	21	9	02/17/06
8	Mixed	44a	160	10	1	0	21	9	02/17/06
7	Mixed	45	163	8	2	0	21	9	02/17/06
8	Mixed	45a	154	10	2	0	21	9	02/17/06

† Duct fitting orientation changed to a series of "U" shapes

‡ Additional lengths of straight duct were used to achieve measured CFM of 25' of baseline straight duct test
the baseline 25' straight duct test was repeated immediately prior to test sets #2 & #3 to obtain the benchmark of 204 CFM

Appendix D

Duct Sample Assembly Fitting Orientation

Appendix D contains Photographs of the airflow meter duct assembly and the duct sample assembly fitting orientation. These photographs represent the layout and orientation of the various duct fittings used.



Airflow meter duct fitting



Airflow meter position within the duct fitting



Interior dryer duct prior to airflow meter duct fitting position



Photograph 10



Photograph 11

Representative fitting location and orientation of tests #2 and #7 with 1 elbow



Photograph 12

Representative fitting location and orientation of tests #3 and #8 with 2 elbows



Photograph 13

Representative fitting location and orientation of tests #4 and #9 with 3 elbows



Photograph 14

Representative fitting location and orientation of tests #5 and #10 with 4 elbows



Photograph 15



Photograph 16



Photograph 17

Representative fitting location and orientation of tests # 39 through 45a



Clothes dryer used for testing