

This document contains two letters.

- 1) Letter from Mr. Beryl Gamse, McDowell Owens Engineering, Inc. to the U.S. Consumer Product Safety Commission (CPSC) regarding CPSC's document titled, *Final Report on Electric Clothes Dryers and Lint Ignition Characteristics, May 2003*. (dated July 11, 2003)

- 2) Letter from Mr. Arthur Lee, U.S. Consumer Product Safety Commission, responding to Mr. Gamse's letter. (dated June 8, 2004)

July 11, 2003

Via Email Only

Mr. Arthur Lee, Electrical Engineer
Division of Electrical Engineering
Directorate for Engineering Sciences
U.S. Consumer Product Safety Commission

Re: *Final Report on Electric Clothes Dryers and Lint Ignition Characteristics, May 2003*

Dear Mr. Lee:

The above report has been reviewed recently and we have serious reservations about the testing program and the conclusions drawn from the results of the tests. The following comments are a preliminary assessment based on the report text only. The CD-ROM, which includes other information, has been ordered. In order to respond to the report in a timely manner, the comments here will be limited to some of the basic issues. At a later date, a more detailed assessment with supporting documentation may be made.

In the test program, a great deal of effort was put into establishing some of the operating characteristics of several electric clothes dryers and demonstrating certain conditions under which lint, taken from a clothes dryer lint screen, will burn when positioned on or near an energized clothes dryer heating unit that had been removed from a dryer. Very little of the report was devoted to lint accumulation. The report strongly inferred that: 1.) lint collected on the heating unit housing in locations and at densities similar to the samples tested and that large clumps of lint could become located within a few inches of the heater unit entrance along its longitudinal axis and 2.) the burning lint could ignite and create a larger fire downstream of the heater unit, i.e. in the tumbler drum or at the lint screen.

There was nothing in the report that established that lint, similar to that used in the test in density and amount, could become positioned relative to the heater unit as it was in the tests. Statements in the Executive Summary and the Summary and Conclusion sections, to the effect that lint accumulates on the heater are unsubstantiated. In fact, evidence exists that accumulations of lint on the heater in the positions tested do not occur. Dryers that have operated for years without cleaning of the cabinet, show no such accumulations of lint. There are only thin layers of lint on the

horizontal surfaces, mainly at the bottom of the cabinet. Thus, a false impression is given relative to the possibility of dryer fires. Until it is established that lint accumulation patterns such as those tested can actually occur, the lint ignition testing and conclusions relating to it should be deleted from the report.

There are other flaws in the lint ignition testing that invalidate any findings based on it. The configuration of the test chamber is such as to create an airflow field around the heating unit that is different from the conditions in the actual dryer. The heating unit in the test chamber is isolated from the chamber wall, whereas in Design A and B classes of dryers, one vertical (relative to orientation in the dryer) side is essentially in contact with the tumbler support bulkhead. Also, the heating unit is mounted horizontally in the test chamber rather than vertically. The effects of gravity and buoyancy due to air temperature gradients are therefore different, which will affect flow into, through and around the heating unit. It appears that the flow field (i.e. air flow direction, speed, and temperature distributions) was not documented as part of Task 2. Therefore the flow fields that existed in Task 4 cannot be validated. Though not stated in the report, it is assumed that the direction of the air flow external to the heater unit was from the inlet towards the exhaust. Tests have shown that, in an operating Design A type dryer, the flow is downward in the cabinet, i.e. from the exhaust end towards the inlet. The downward flow continues past the heater inlet with only a portion of air being drawn into the heater. The general downward flow prevents any lint that is more than a few inches below the inlet from possibly being drawn into the heater unit. Thus, no lint accumulated on the bottom of the cabinet can be drawn to the heater and the premise of Task 4.4, lint ingestion tests, is problematic, if not invalid. A clump of lint that is placed, somehow, in the updraft at the entrance to the heater unit may be too dense to be drawn into the unit., i.e. the force of gravity may be greater than the aerodynamic drag trying to lift it.

The Task 4 configuration would most probably result in a distribution of temperatures on the heating unit surface that differed from that of an actual operating dryer. An actual temperature distribution could alter the results of the Tasks 4.3.1 and 4.3.2 testing where lint is artificially held against the surfaces of the heater unit. It appears that the temperature distributions on the heating unit surfaces were not documented as part of Task 2. Therefore the temperature distribution incorporated in the Task 4 testing cannot be validated.

The configuration used for Task 4.4.2, the ignition of target materials downstream of the heater, has no relationship to the conditions that would exist in a dryer. The target material, lint or cotton toweling, was placed immediately downstream of the horizontal heater unit in a 4 inch diameter duct. The air flow speed across the target material, which restricted the cross-section of the duct, was not reported, but was probably significantly higher than the 800 sfpm at the heater inlet. This

air flow would fan any smoldering embers into flames. In an actual dryer, the exhaust of the heater unit must pass through a perforated metal wall before reaching toweling type materials, and then must traverse the tumbler plenum and, in some designs, another perforated metal wall to reach lint material on the collection screen. The perforated metal walls would act as spark arresters such as those used on engine exhausts of forestry equipment eliminating most if not all of the lint embers. The directed airflow goes to essentially zero in the plenum chamber of the drum. The only air movement would be due to the tumbling clothes, which in fact would probably beat any surviving embers out of existence. The survival rate for lint embers reaching the lint screen would be negligible. It took 5 to 10 pieces of flaming lint to ignite the target materials under conditions ideal for ignition. No explanation is given as to how so many lumps of lint could make their way into the heater unit. Even if one accepts that somehow clumps of lint are ingested into the heater unit, it must be demonstrated in an actual dryer that embers from it will survive in sufficient size and quantity to cause ignition of material downstream of the heater unit.

An example of general misinterpretation of data is given on page 14 of the report. The decrease in vent exhaust airflow that is shown in Figure 9 is attributed to blockage of the lint screen. Lint screens do not create that much flow resistance after a single load. The centrifugal blower will pump a constant air volume for a fairly wide range of back pressures. What may change is the mass flow rate due to changes in the air density, mainly a function of the air temperature. The hot wire anemometer basically measures mass flow rate. The greater the density, or the lower the temperature, for a given air speed, the higher the indicated air speed on the anemometer. At the beginning of a cycle, the cold air down stream of the heater box produces the “overshoot” after which the temperature sharply increases as the heated air arrives at the vent exhaust. As the load dries and the cooling effect of the water in the load decreases, the exhaust air temperature rises and the mass flow rate decreases. Note that near the end of the cycle, the heater element cycles on and off. As the exhaust temperature spikes downward, the air flow speed spikes upward. The same syndrome is shown on all of the graphs where air flow and duct temperatures are presented together. The misinterpretation of the data gives a false impression of the effects of lint accumulation on the screen.

Two high limit thermostat switches failed. Both, incorporated in the Task 4 horizontal heater unit test apparatus. This may be an indication of the extremely atypical conditions during that test series.

There are several other concerns relating to test parameter selection, analytical methods and interpretation of data. Discussion of those items will be left to a later time.

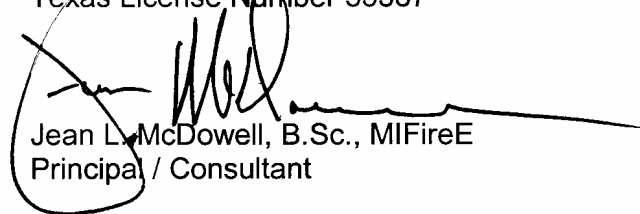
The report covers a large number of tests which is described in great detail; much data are presented which are analyzed and discussed extensively. The extent of the discussion and the rather handsome presentation of the mountains of data divert the readers' attention from the fact that, though what is presented follows the two subjects mentioned in the title of the report, "Electric Clothes Dryers" and "Lint Ignition Characteristics", no valid connection is made between the two. The testing program and report, in our opinion, are examples of bad science.

It is our suggestion that, in its present form, the report should be withdrawn from distribution so that the public is not given a false impression relative to lint fires in electric clothes dryers.

Sincerely,
McDOWELL OWENS ENGINEERING, INC.



Beryl Gamse, Ph.D., P.E.
Consulting Engineer
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Jean L. McDowell, B.Sc., MIFireE
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June 8, 2004

Mr. Beryl Gamse, Ph.D., P.E.
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Dear Mr. Gamse:

On July 14, 2003, the staff of the U.S. Consumer Product Safety Commission (CPSC) received your letter (dated July 11, 2003) regarding the CPSC staff report, *Final Report on Electric Clothes Dryers and Lint Ignition Characteristics, May 2003*. We appreciate your review of the report and regret the delay in responding to your letter. After the report was released to the public, the Association of Home Appliance Manufacturers (AHAM) requested that CPSC retract or substantially revise the report because they believed it did not adhere to CPSC's Information Quality Guidelines. We did not think it appropriate to respond to your letter prior to the resolution of AHAM's challenge, which took several months. AHAM's letter, and the resolution of their request, were posted on the CPSC website since they involved CPSC's Information Quality Guidelines. Your comments were not specifically processed under those guidelines. However, we are posting your letter and this response there as well. More information on these guidelines can be found at <http://www.cpsc.gov/LIBRARY/infoguidelines.html>

The CPSC staff would now like to respond to the comments you provided. Although we believe that the report was explicit in describing how testing was conducted and what the results of those tests were, this letter may help clarify the questions you raised regarding the report. These comments are those of the CPSC staff and have not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.

The CPSC staff estimates that there were 14,600 fires associated with clothes dryers in 1999.¹ These estimates are based on information collected by the National Fire Protection Association (NFPA) and the National Fire Incident Reporting System (NFIRS). There is a broad professional community that addresses the causes of such fires, including fire prevention organizations, insurance agencies, product certification organizations, fire and forensics investigators, and consumer safety advocates. Fire investigators have studied evidence from many fires that were determined to have originated in clothes dryers. In its January 2002 report, *U.S. Home Product Report: Appliances and Equipment Involved in Fires*, NFPA reported that "Lack of Maintenance" was the leading cause of clothes dryer fires and that the first material ignited in almost 28 percent of the fires was "dust, lint, and fibers."

¹ 1999 Residential Fire Loss Estimates, U.S. Consumer Product Safety Commission

While a specific point of origin within a clothes dryer is often difficult to establish following a dryer fire, many dryers involved in a fire display excessive accumulations of lint and evidence of an involvement of lint in the fire. A number of fire and consumer safety organizations have developed guidelines for consumers that emphasize the importance of regular dryer maintenance and removing or preventing lint accumulation as a fire prevention measure. CPSC staff believes that consumers should continue such steps, such as cleaning lint accumulation in and around the clothes dryer, to help prevent dryer fires.

The mechanisms by which lint contributes to some clothes dryer fire incidents are not thoroughly understood. The primary objective of the CPSC staff testing was to help quantify the characteristics of lint buildup in clothes dryers during normal operation and the circumstances, normal or abnormal, under which lint ignition may occur. The following are responses to specific concerns, noted in bold font, that you raised in your letter.

“The report strongly inferred that: 1.) lint collected on the heating unit housing in locations and at densities similar to the samples tested and that large clumps of lint could become located within a few inches of the heater unit entrance along its longitudinal axis and 2.) the burning lint could ignite and create a larger fire downstream of the heater unit, i.e. in the tumbler drum or at the lint screen. There was nothing in the report that established that lint, similar to that used in the test in density and amount, could become positioned relative to the heater unit as it was in the tests.”

CPSC staff did not set out to establish a direct cause-and-effect relationship between lint accumulation and clothes dryer fires, but rather relied on a substantial body of evidence that indicates lint can be a contributor to some clothes dryer fires.

In-depth investigations conducted by CPSC staff on clothes dryers involved in fire incidents have shown moderate and heavy accumulations of lint throughout the dryer, depending on the age of the dryer and how it was maintained. Some of this lint accumulation has been on or near areas that produce and transport heat used for drying clothes. CPSC staff set out to investigate whether there were conditions that could lead to the ignition of lint on or near a heat source, given that an accumulation could reasonably be expected in some dryers.

CPSC staff concluded during its testing that lint accumulation begins upon the first use of a clothes dryer, and that lint accumulates in areas throughout the dryer chassis. CPSC staff tests demonstrated that lint accumulates in a dryer even when the dryer is installed according to manufacturer instructions and the lint screen is cleaned between drying cycles. Testing also demonstrated that lint could breach internal seals between the dryer ducting and chassis.

AHAM, in cooperation with member clothes dryer manufacturers, investigated 191 clothes dryer fire incidents in 2002 to provide more detailed information on the causes of clothes dryer fires. An analysis of the data was reported in *AHAM Analysis of Industry Data on Clothes Dryer Fire Incidents, August 2002*. In addition, in response to CPSC staff questions regarding the report, AHAM provided CPSC staff with supplemental information.²

In their report, AHAM concluded that, “In the cases where some evidence of fire was observed, no one cause stands out as a leading contributor to dryer fires.” Of the 191 incidents, three were associated with external fire, and there was no evidence of fire observed for 25 of the samples. For an additional 64 dryers, the precise factor contributing to the fire could not be determined. Of the remaining

² Letter from W. Morris, Association of Home Appliance Manufacturers, to A. Lee, CPSC, October 16, 2002

99 incidents, 11 incidents were associated with “lint flash over only,” and 17 incidents were associated with “lint flashover involving other components.” In the supplemental information provided by AHAM regarding these 28 incidents, accumulation of lint was observed at the clothes dryer base, motor and/or burner. The amount of lint reportedly accumulated in these areas varied from light to heavy.³ The data provided by AHAM shows that, for dryers in their study that were involved in fire incidents associated with lint ignition, lint was reported to have accumulated on and near the heater.

The size and density of the lint samples used in CPSC staff tests were chosen to provide better repeatability of the tests. The report stated that the size and density of the material used in the testing was not necessarily related to the amount of lint that collects within a specific clothes dryer, the amount of usage, or the installation configuration.

“The configuration of the test chamber is such as to create an airflow field around the heating unit that is different from the conditions in the actual dryer.”

CPSC staff tests were conducted to determine temperature and airflow characteristics required to ignite lint on or near a clothes dryer heater. The test setup was explicitly chosen to include those components that are typical in clothes dryer designs but in a configuration that does not represent any one dryer design, thus eliminating specific designs from the test variables.

“The configuration used for Task 4.4.2, the ignition of target materials downstream of the heater, has no relationship to the conditions that would exist in a dryer.”

CPSC staff measured temperature and airflow in four sample clothes dryers under controlled conditions that simulated exhaust blockages of 0%, 25%, 50%, 75% and 100%. The test configuration allowed the staff to control conditions to simulate those that were previously measured in actual dryers and that might be anticipated during real world operation. The configuration of the test setup was explicitly chosen so that it did not represent any one dryer design, thus eliminating specific designs from the test variables while accounting for the physics of airflow and temperature near a clothes dryer heater.

“An example of general misinterpretation of data is given on page 14 of the report. The decrease in vent exhaust airflow that is shown in Figure 9 is attributed to blockage of the lint screen. Lint screens do not create that much flow resistance after a single load.”

The blockage of the lint screen does cause the airflow to be reduced in the exhaust duct directly after the dryer. Tests were conducted in which the lint screen was blocked 25%, 50%, 75%, and 100%. When the lint screen was 50% to 100% blocked, airflow was reduced directly after the dryer exhaust, as shown in Figure 1 of Attachment 1.

“The hot wire anemometer basically measures mass flow rate. The greater the density, or the lower the temperature, for a given air speed, the higher the indicated air speed on the anemometer.”

The hot wire anemometer of the type to which you refer appears to be a Constant Power Anemometer (CPA). A CPA provides constant electrical power to a resistance element. A temperature sensor is attached to the heater and is heated by conduction from the heater element. The difference between the temperature of the heated sensor and the ambient fluid temperature sensor is measured. The temperature difference is large at a low velocity and small at a high velocity. The temperature difference

³ Table 5, Location and Degree of Lint When it was a Contributing Factor

signal is conditioned to be linear with the mass velocity. Ambient temperature compensation is usually accomplished with analog signal processing.

The anemometers used in CPSC staff testing were Constant Temperature Anemometers (CTAs). Each anemometer uses two heat wires for measuring the airflow. One sensor is operated by a solid-state feedback control circuit to maintain a constant temperature difference between the heated sensor and the process fluid temperature, which is measured by a second sensor. The amount of electrical power needed to maintain this temperature difference is the measured output variable. As the fluid temperature changes, the CTA control circuit maintains a constant "over-heat" temperature difference between the heated sensor and the ambient fluid temperature. The CTA compensates for density, and the CPA does not.

The airflow measurements presented in the report were in Standard Feet per Minute (SFPM). The measurements are referenced to 23°C and 1 Atmosphere. To convert SFPM to FPM, Equation (1), as shown in Attachment 1, would be used. Equation (1) is derived from the *Ideal Gas Law* and *Conservation of Mass*. In this equation, the actual pressure divided by the standard pressure can be assumed to be 1 because the pressure change in the exhaust duct is insignificant. Figures 2 and 3 in Attachment 1 show that pressure changes very little when the exhaust air temperature changes. The actual exhaust air temperature shows a difference between the SFPM and FPM data as shown in Figures 4 and 5 of Attachment 1. (Since Equation (1) uses degrees Kelvin, the difference between SFPM and FPM is most pronounced at higher temperatures.)

“Two high limit thermostat switches failed. Both, incorporated in the Task 4 horizontal heater unit test apparatus. This may be an indication of the extremely atypical conditions during that test series.”

The cause of failure of the two high limit thermostat switches is still unknown. However, they were applied in the test configuration in a manner consistent with their operation in a clothes dryer. The thermostats were forwarded to Underwriters Laboratories, Inc. for their evaluation; however, a failure analysis report has not been received for review.

Sincerely,



Arthur Lee
Project Manager for Clothes Dryers
Division of Electrical Engineering

Attachment

Attachment 1

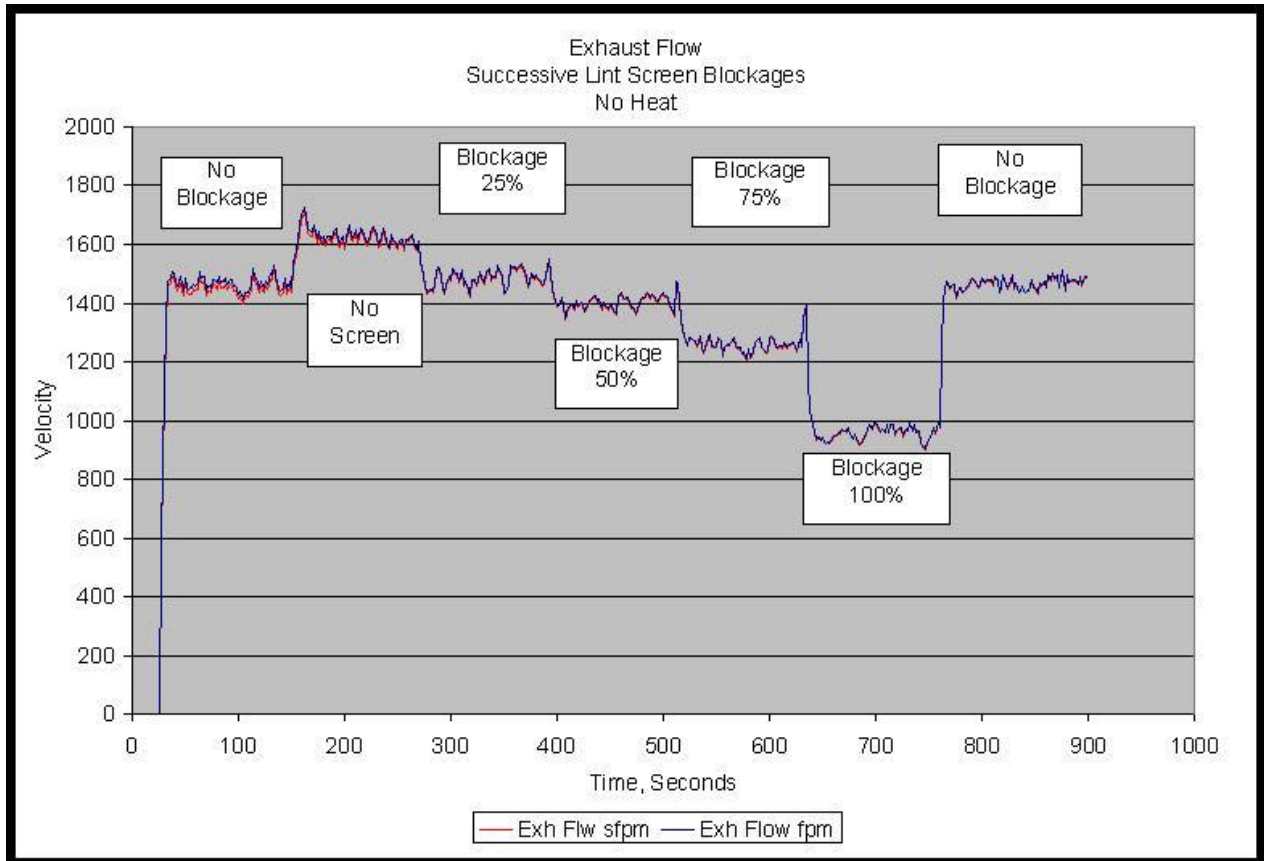


Figure 1. Velocity (FPM) Measured in the Exhaust Duct after Dryer

Ideal Gas Law

$$pV = nRT$$

$$pV$$

$$----- = nR = \text{Constant (low pressures)}$$

$$T$$

- p = pressure
- V = volume
- T = temperature
- n = # moles
- R = gas constant

$$\frac{P_1 \cdot V_1}{T_1} = \frac{P_2 \cdot V_2}{T_2}$$

$$\frac{\rho_1 \cdot D_2}{T_1} = \frac{\rho_2 \cdot D_1}{T_2}$$

$$D_2 = \frac{\rho_2 \cdot D_1 \cdot T_1}{\rho_1 \cdot T_2}$$

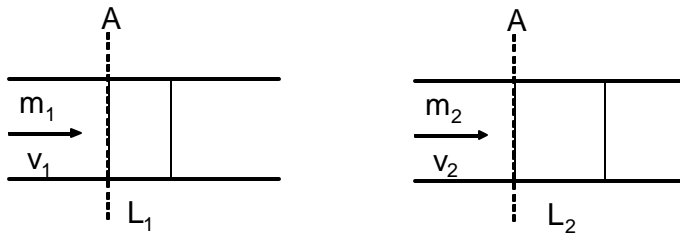
If $\rho_1 = \rho_2$,

Density (D) = mass/volume

$$D_1 = \frac{m}{V_1} \quad D_2 = \frac{m}{V_2}$$

$$D_2 = \frac{D_1 \cdot T_1}{T_2} \quad \text{if } \rho_1 = \rho_2$$

Conservation of Mass



m = mass
 A = area cross section
 t = time
 L = length
 v = velocity

$$m_1 = A \cdot L_1 \cdot D_1$$

$$m_2 = A \cdot L_2 \cdot D_2$$

$$m_1 = \frac{A \cdot L_1 \cdot D_1}{t}$$

$$m_2 = \frac{A \cdot L_2 \cdot D_2}{t}$$

$$m_1 = A \cdot v_1 \cdot D_1$$

$$m_2 = A \cdot v_2 \cdot D_2$$

If $m_1 = m_2$

$$A \cdot v_1 \cdot D_1 = A \cdot v_2 \cdot D_2$$

$$v_1 \cdot D_1 = v_2 \cdot D_2$$

$$v_1 * D_1 = v_2 * D_1 * T_1 \quad v_2 = v_1 * T_2$$
$$\frac{\quad}{T_2} \quad \frac{\quad}{T_1}$$

Equation (1)

$$v_a = v_s * T_a$$
$$\frac{\quad}{T_s}$$

v_a = actual velocity (fpm)
 v_s = standard velocity (sfpm)
 T_a = actual temperature, Kelvin
 T_s - standard temperature, Kelvin

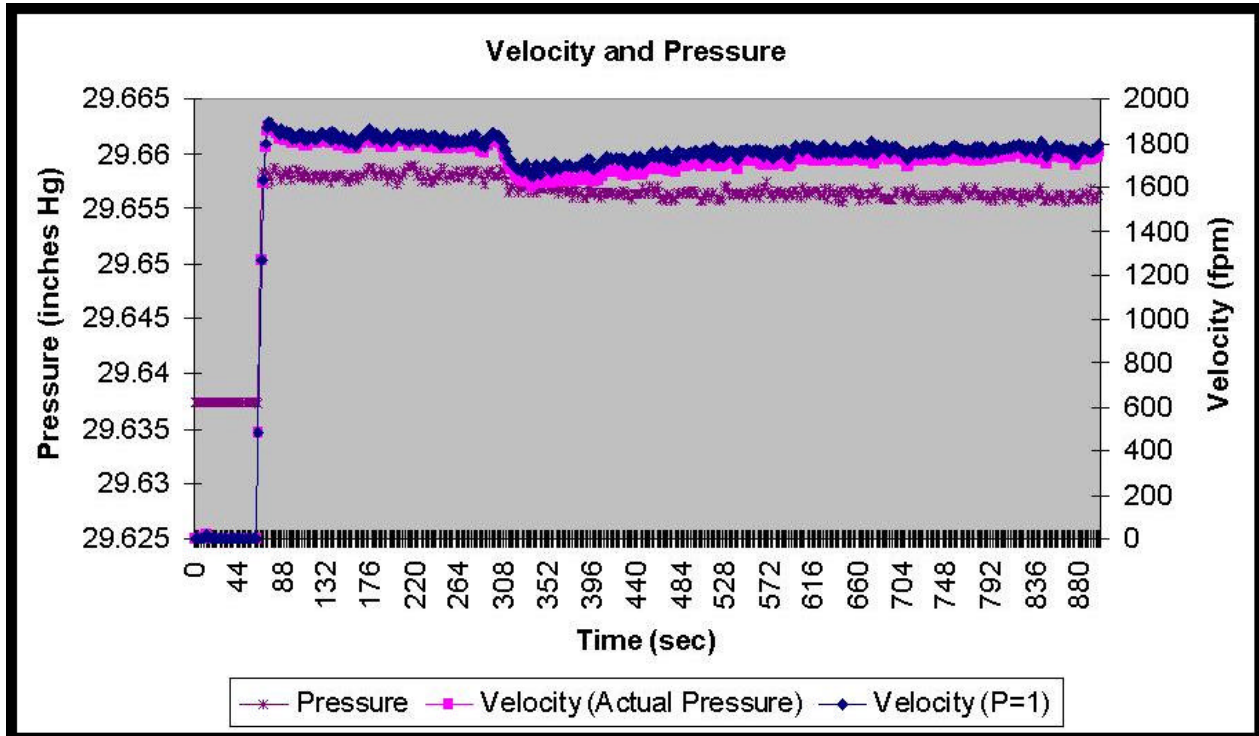


Figure 2. FPM with P=1 and Actual Pressure in the Exhaust Duct after Dryer

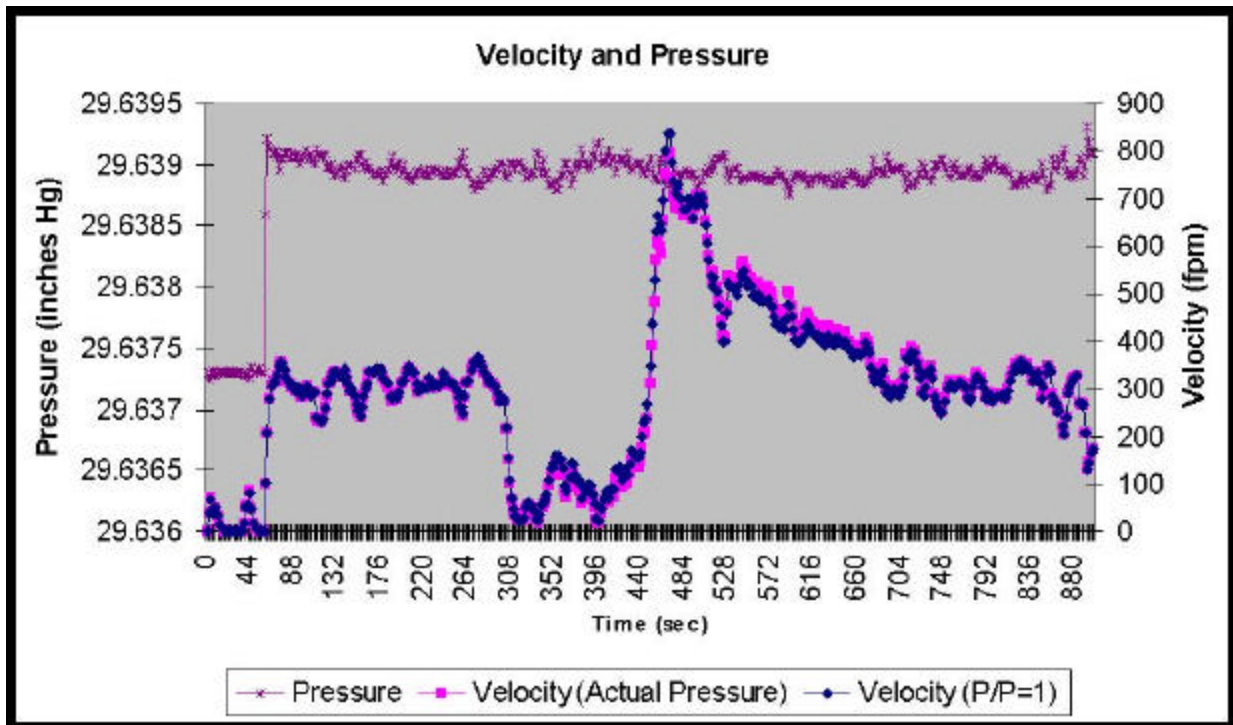


Figure 3. FPM with P=1 and Actual Pressure in the Exhaust Duct after Dryer

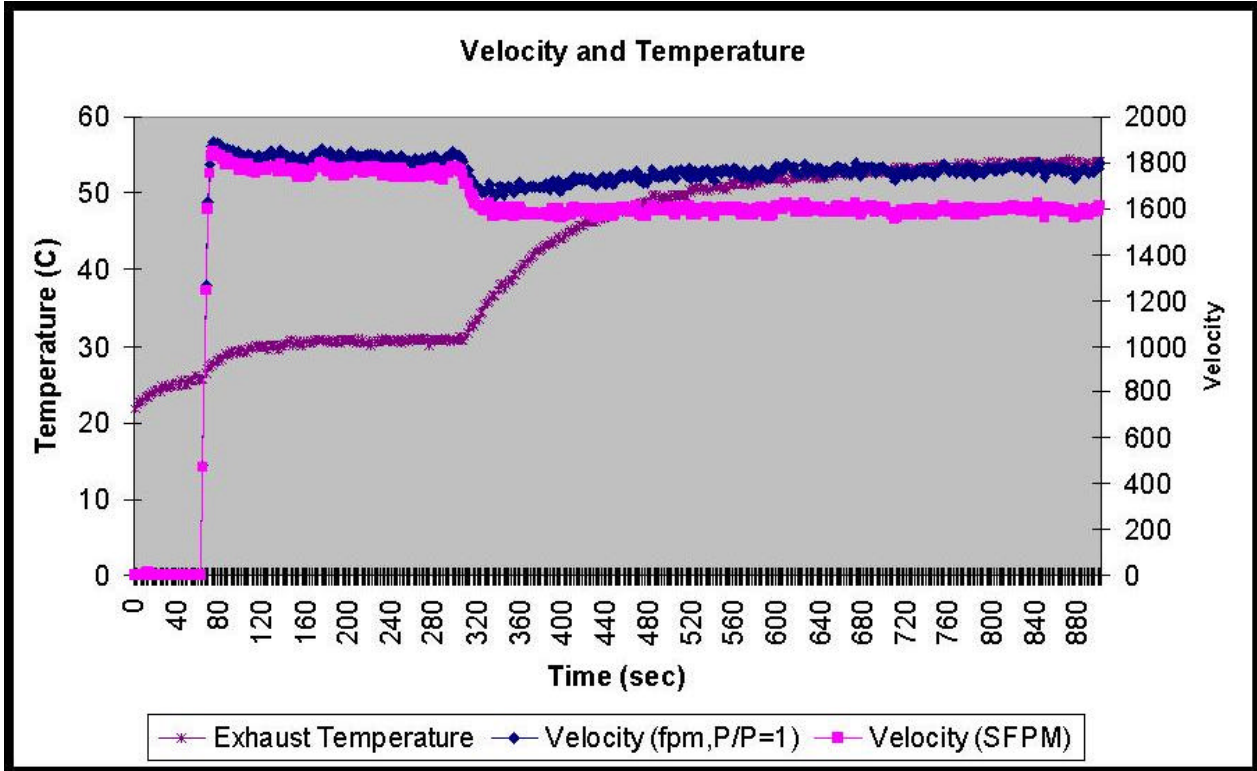


Figure 4. SFPM and FPM in the Exhaust Duct after Dryer

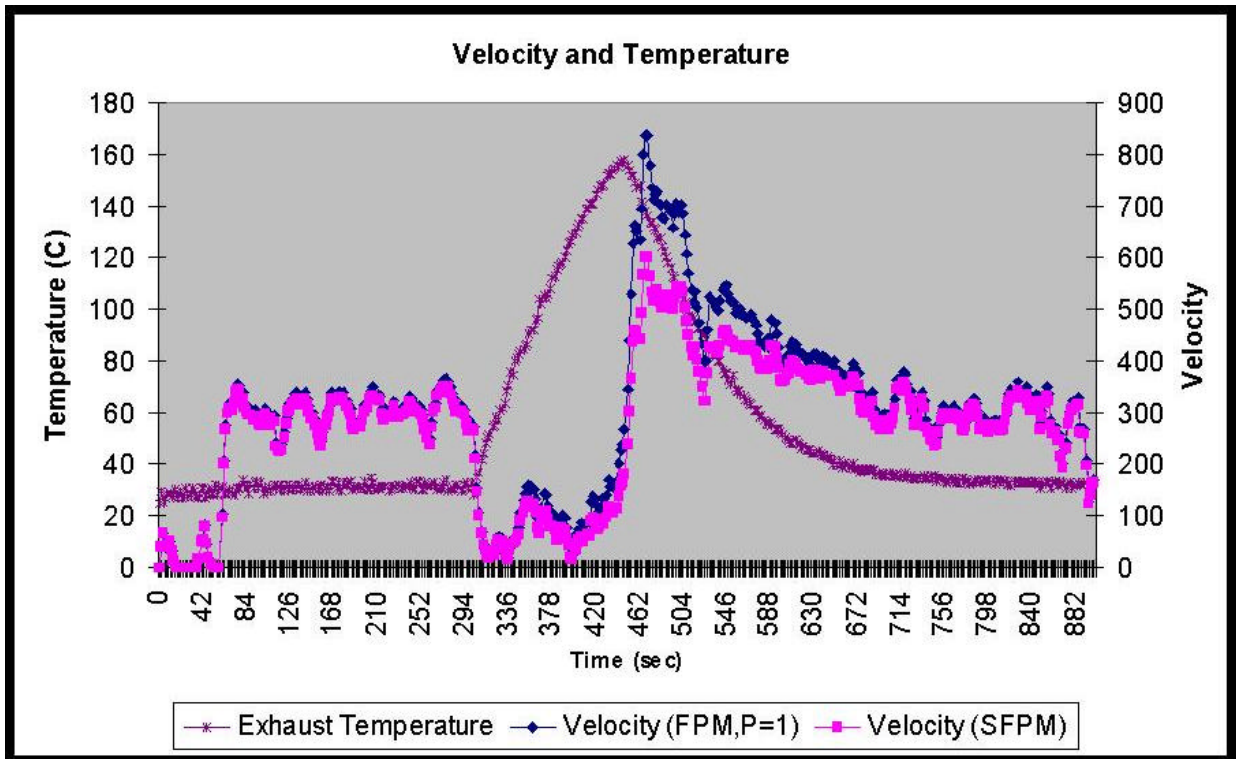


Figure 5. SFPM and FPM in the Exhaust Duct after Dryer