Flame Effect Compliance and Operation Document

LiveSpark FirePixel

Date: September 2018 l Version: 1.6

1.0 Introduction

This document provides information useful in preparing a Flame Effect Plan that satisfies the requirements of NFPA 160-2011 section 5.3, "Content of Flame Effect Plans."

Because FirePixels are components incorporated as part of a system installation, this document does not in itself constitute a complete Flame Effect Plan. Please consult with local fire officials to determine if there are additional requirements at the city or county level that are not covered here.

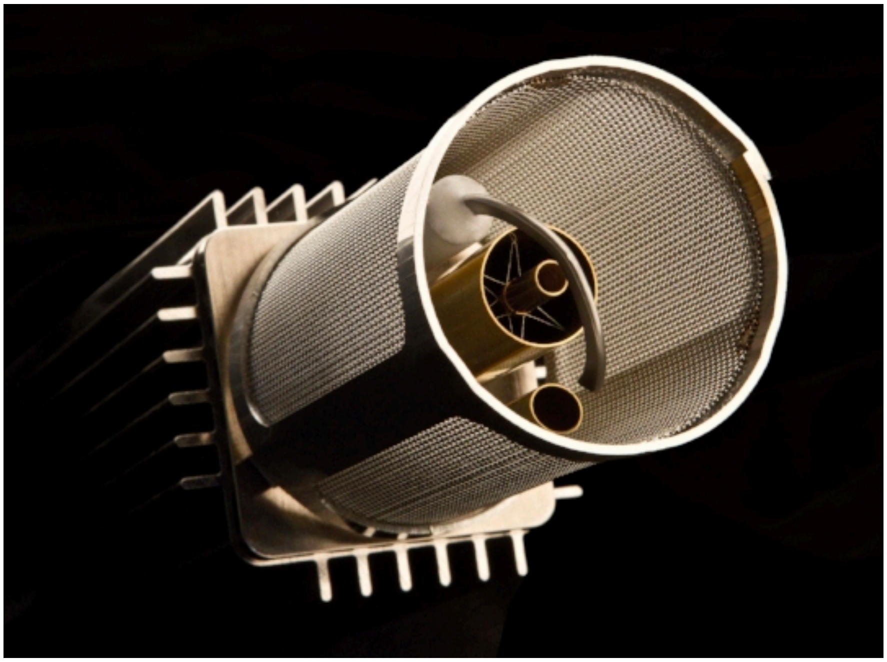


Figure 1.1 FirePixel flame effect

2.0 FirePixel Description

FirePixels are designed to be used as a system and capable of chaining multiple addressable units providing a variety of effects.

The basic components to a FirePixel system include:

FirePixel Flame Effects: Propane-fueled, self-igniting, auto-calibrating flame effects that produce a highly luminous, virtually smoke-free, soot-free and wind resistant flame. The FirePixel’s low latency flame reactivity and variable flame height can deliver a wide range of visual effects.

LiveSpark Controller: FirePixels may be directly controlled by the LiveSpark Controller. The LiveSpark Controller also accept inputs from other industry standard performance control systems such as DMX light boards, midi devices, and network signal generators.

The LiveSpark Controller communicates with and receives status from each FirePixel via a dedicated bi-directional command protocol. To further increase safety, the Controller features three levels of shutoff including nominal operation off button, data key lock and an emergency stop (e-stop) switch.

An ethernet port accepts control commands from any external network broadcaster, such as the Ableton Live FirePixel plugin provided by LiveSpark.

Stage3D Visualizer: A complete visual rendering and monitoring software app that visualizes the expected behavior of a FirePixel installation. The address and real-time status of each FirePixel is displayed in 3D against the backdrop of a user-created stage photo. Nominal performance visualization are represented graphically in 3D block or fire particle system simulation. Any FirePixel error condition that may occur such as “out of fuel” or “failure to ignite” is highlighted graphically and textually on the display as it occurs.

Individual FirePixels are NFPA160 Group VII Flame Effects, so classified because they are components designed to be incorporated into a complete flame effect system, comprising of multiple FirePixels, in any of NFPA 160 Groups I, III, V or VI.

Each FirePixel has a 2.5" x 2.5" outer enclosure boundary, and a height of 8.215". The lower half of the unit is a metal body that houses its fuel inlet, effect valve and control circuitry; the upper half is the effect burner and windscreen, which contains its igniter and effect head. The fuel supply for a single FirePixel may be a single 1LB cylinder and dedicated regulator or a group of FirePixels may be supplied by a regulated manifold connected to a surge tank or accumulator. FirePixel inlet pressure is specified as 30psi.

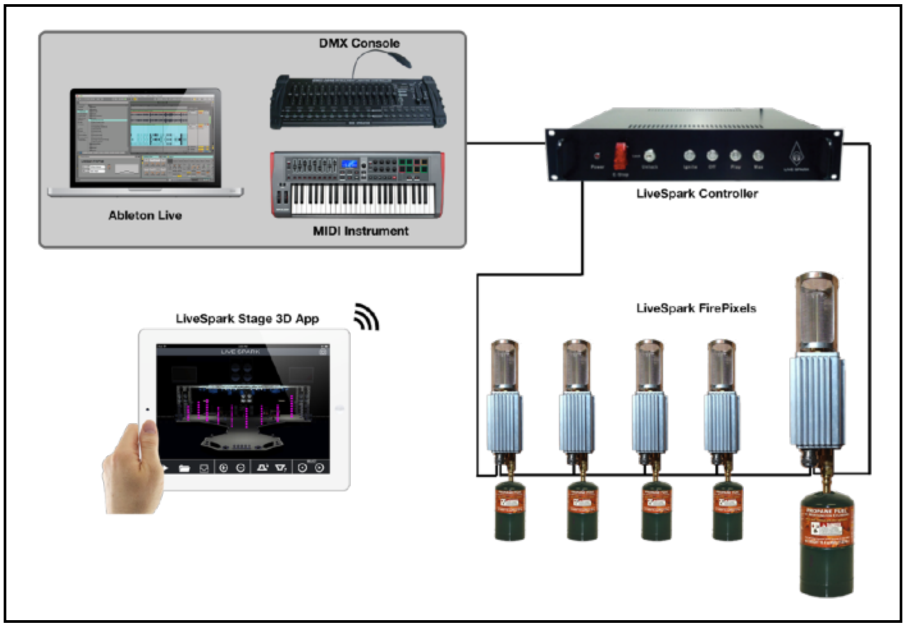


Figure 2.1: Flame System Organization

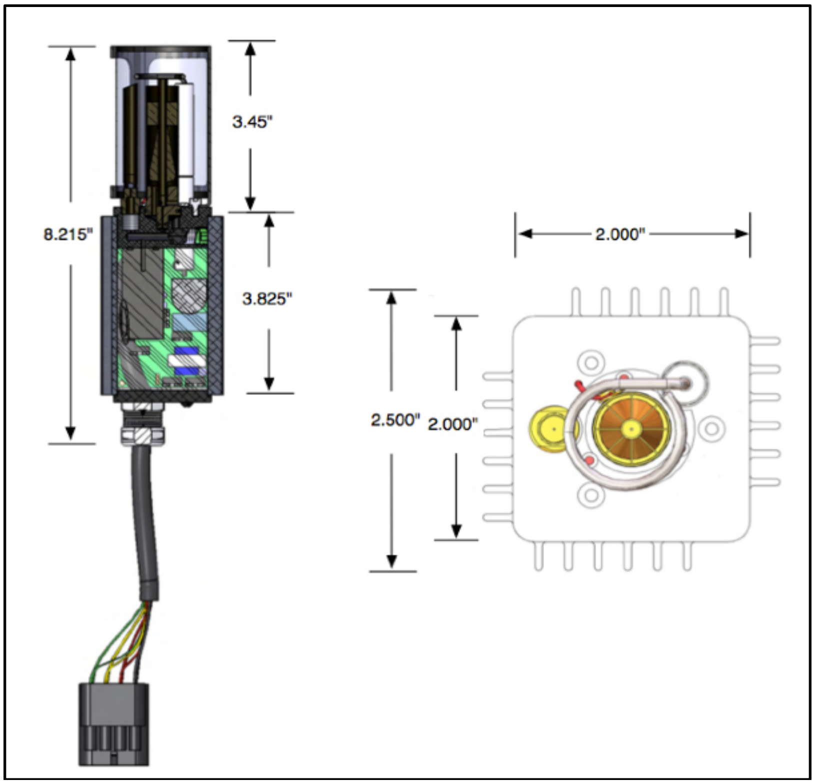


Figure 2.2: FirePixel Dimensions

Groups of FirePixels are controlled via a proprietary LiveSpark bi-directional data protocol, signaled with RS-422 transceivers.

The flame emitted by each FirePixel can be adjusted to any of 256 different levels, up to a maximum height of approximately 4 feet. The flame height can be changed as many as 1200 times per second, depending on data rate.

General Safety Features

- FirePixels communicate via a dedicated bi-directional protocol allowing the LiveSpark Controller to monitor the status of any FirePixel attached to the connected daisy chain.
- The FirePixel thermal conductivity characteristics are such that the body and lower windscreen remain thermally below pain threshold even after prolonged operation, even at maximum flame height.
- A highly efficient flow path allows immediate (< 1S) extinguish of the flame, under either normal or emergency conditions, even while the FirePixel is operating at maximum flame height.
- The FirePixel auto-calibrates continuously when operating and adjusts its flame height to maintain a stable flame despite varying environmental conditions. In transient wind conditions that cause a FirePixel to extinguish, feedback from the flame-proving circuit relights it automatically.
- If a FirePixel fails to ignite (or relight after a blowout), it performs nine (9) additional attempts, occurring automatically at a rate of 1 attempt per second. If these relight attempts fail to ignite and successfully prove a stable flame, the FirePixel extinguishes and disables itself, and then enters a lockout state that can only be reset with manual intervention by the flame effect operator. If the flame effect operator so chooses to re-attempt ignition, an ignition command may be issued and the ignition sequence will begin again with a maximum of nine (9) further attempts.

3.0 Safe Clearance Distances

3.1 Audience Proximity to FirePixels

To comply with NFPA 160 2011, section A.7.1.2, which addresses exposure of audiences to radiant thermal energy, audiences should be located at a minimum distance as specified in the table below.

Table 3.1: Minimum Audience Separation

FirePixel Spacing	Minimum Horizontal Audience Separation
1ft	8ft
2ft	5ft

The above assumes the following conditions:

- The nearest group of FirePixels to the audience is a horizontal row with consistent spacing.
- The audience is approximately at the same height as the flame produced by the nearest row of FirePixels.
- FirePixels are operated at no more than a 30% duty cycle over any 30s period.
- FirePixels do not remain above 50% output for longer than 10 seconds.
- Then next nearest group of FirePixels is at least eight feet further from the audience than the nearest group.

Either independently or in a combination of higher planned duty cycles, longer periods of output, different arrangements of FirePixels, and high ambient temperature may require greater separation than that specified in Table 1. An infrared thermometer may be used to verify compliance in the field.

3.2 Exclusion Zone for Surrounding Flammable Materials

To comply with NFPA 160-2011 section 10.3.3, unprotected combustible materials should not be placed within a particular zone near the FirePixel, shown in the following figure. This exclusion zone is defined by two cylinders with vertical axes, concentric with the burner of each FirePixel. The lower cylinder is 42 inches in diameter and extends 2 inches below and 60 inches above the FirePixel's burner. The second cylinder is 28 inches in diameter and extends to 9 feet above the burner (i.e., an additional 48 inches above the first cylinder).

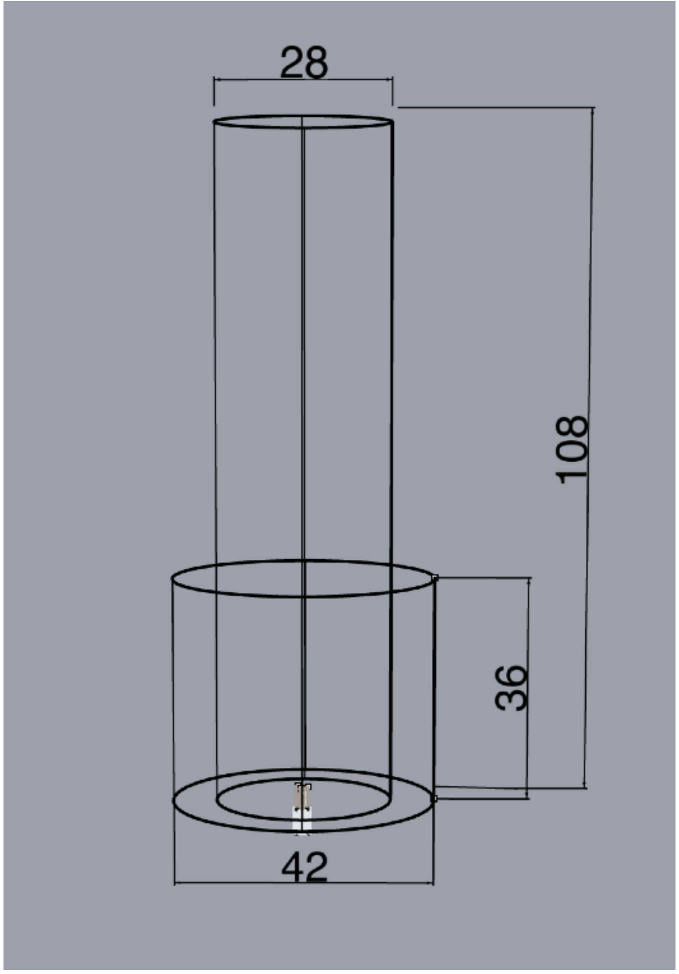


Figure 3.2: Exclusion zone for unprotected combustible materials

4.0 Environmental Considerations

The FirePixel includes a flame proving circuit that utilizes fail-safe rectification sensing and dynamic circuitry to detect the presence of a flame, automatically preventing the release of any significant quantity of unburned gas, even in adverse environments.

High levels of wind, moisture or particulates may interrupt normal operation. It is not recommended to operate FirePixels in wet environments or in winds exceeding 25mph.

5.0 Fire Retardance of Materials

FirePixels have a metal body and are manufactured entirely of non-combustible materials.

6.0 Fuel Types and Consumption

Propane
Propane may contain some portion of butane and up to 5% propylene, per the ASTM's and GPA's HD-5 standard. The maximum sustained flow-rate of propane vapor through a single FirePixel at its maximum flame height setting, at the recommended 30psi inlet pressure is 77 L/min (161.7 SCFH) at 20°C. This results in a maximum consumption of 4.44 gallons (16.8 liters) of liquid propane per hour. However, in a *typical* application with variable use, a FirePixel can be expected to perform for two to six hours on a single 16.4oz propane cylinder.

The exact fuel consumption rate and fuel-supply size will depend on the particulars of the application and should be determined either by actual measurement or calculation using the above figures as starting points.

Natural Gas
A natural gas fuel option is planned for a future revision of FirePixel hardware. Flow rate requirements may very slightly but 30psi inlet pressure will remain the same. FirePixel models configured for use with propane are not compatible with natural gas or other fuels due to internal orifice sizing and burner configuration that are particular to each fuel type.

Other Fuels
No other fuels besides the recommended fuels accompanying the supplied FirePixel model should be used. Please refer to your FirePixel's Installation and Operation Guide

7.0 Propane Supply Plumbing

FirePixels may be supplied with fuel either by individual regulated propane supply cylinders, or by a network of supply hose fed from a surge tank, accumulator, vaporizer or other suitable fuel depot.

**FirePixel Plumbing System -
Fuel depot supply configuration**

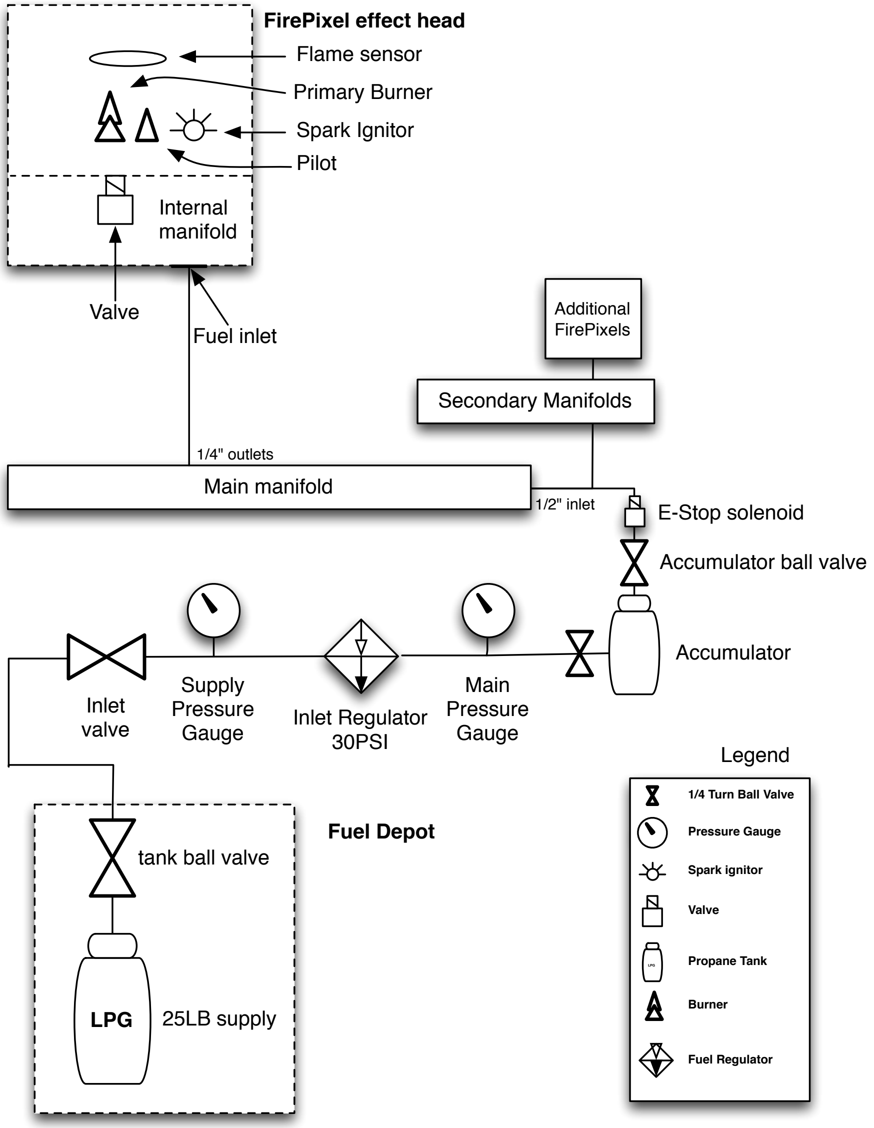


Figure 7.1 Typical plumbing arrangements for a FirePixel system

8.0 Electrical, Data Wiring and Controls

FirePixels operate at 24VDC and consume approximately 415mA, or about 10 watts at full power (maximum flame height). A 24VDC/15A power supply can support up to 35 FirePixels if appropriate gauge wire and connectors are supplied.

FirePixels use 4-conductor combined power and data connectors in a daisy chain sequence, forming a bi-directional, full-duplex RS-422 data network. Each FirePixel has both a female and male connector: the female connector accepts the incoming data and the male connection provides outgoing data.

FirePixel control circuitry is designed to comply with section 30A of the “UL Standard for Safety for Primary Safety Controls for Gas- and Oil-Fired Appliances, UL 372.” No sequence of electrical faults specified in UL372 Table 30A.1 will result in a failed-open condition.

The LiveSpark Controller accepts both DMX and MIDI commands directly with no additional computer or software required. An ethernet port allows for UDP network command input using a wide range of third-party software solutions.

An optional remote Operator Presence Control (“Deadman switch”) can be attached to the back of the LiveSpark controller.

The LiveSpark controller accepts 110V or 220V AC via an IEC 320 power cable.

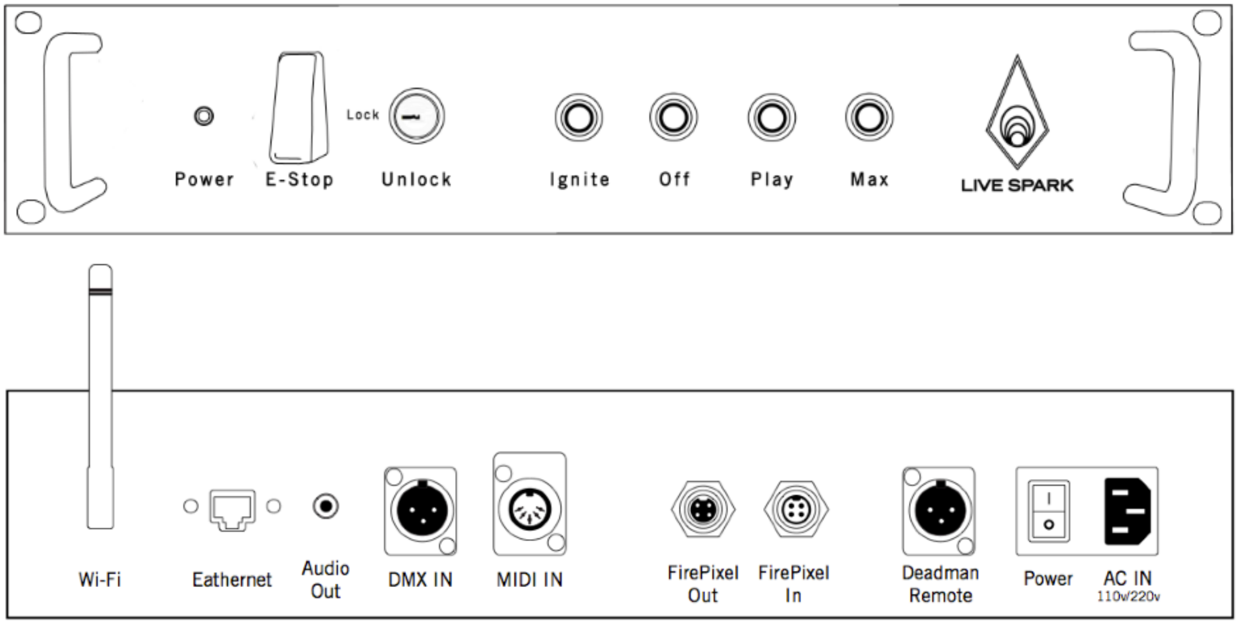


Figure 8.1: LiveSpark Controller Front (top) and Back (bottom)

8.4 LiveSpark Stage3D

LiveSpark Stage3D provides a visual rendering and monitoring solution that works in connection with the LiveSpark Controller. The address and status of each FirePixel is transmitted via Wi-Fi to an external network-enabled display device such as a computer, tablet or smartphone. LiveSpark Stage3D displays the number of connected FirePixels and graphically shows FirePixel status individually in real time.

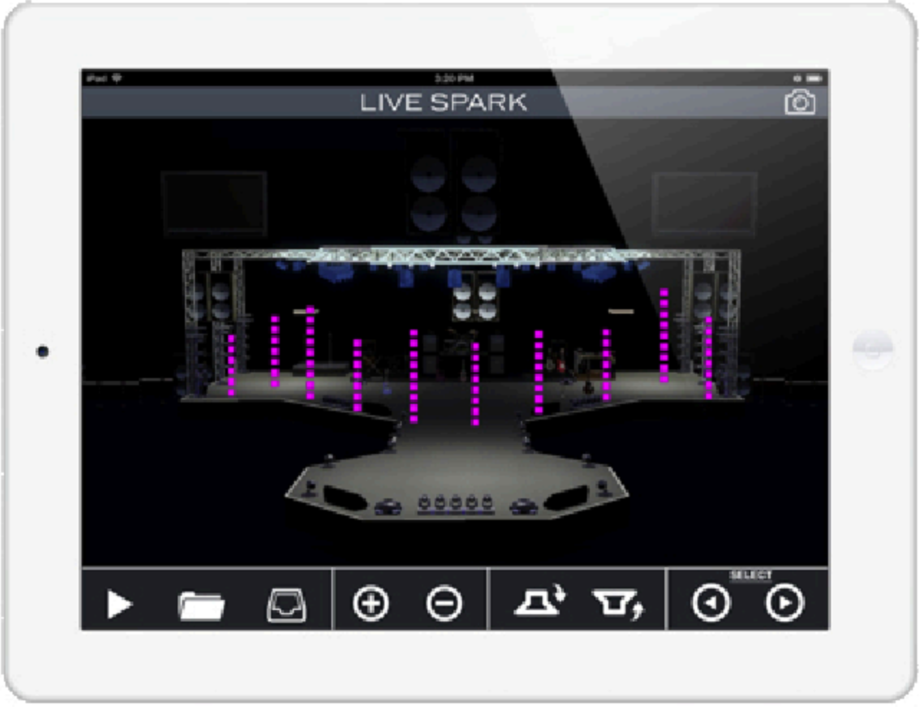


Figure 8.2 LiveSpark Stage3D iPad Display

9.0 Certifications

FirePixels are not certified from any standards agency, primarily due to their operating pressure which does not conform to ANSI standards (0.5 PSI). FirePixels have undergone extensive internal and third-party testing and have been demonstrated to perform reliably and safely under a variety of conditions.

10.0 Manufacturing and Testing

FirePixels are manufactured in California by LiveSpark. Each FirePixel is put through thorough a battery of tests and performance validation in compliance with NFPA 160 “Flame Effects Before a General Audience” as well as dust tightness, wash-down and water immersion testing per IP67 is performed on each unit.

11.0 Setup

11.1 FirePixel Setup Instructions

Required Parts:

- LiveSpark FirePixels
- Fuel Regulators
- Fuel Hose
- Propane Fuel Cylinders
- One (1) Pressure gauge

Step 1: Attach a regular to a propane fuel cylinder
Step 2: Use the quick disconnect fitting to attach the pressure gauge
Step 3: Check the pressure and adjust the pressure to 30psi*
Step 4: Once the pressure is at 30psi, detach the pressure gauge
Step 5: Attach the regulator's quick disconnect fitting to hose then the FirePixel's fuel inlet
Step 6: Attach the FirePixel's clamp to 1.5" or greater diameter tube or truss to support the FirePixel.

11.2 LiveSpark Controller & Cabling Setup Instructions

Required Parts:

- One (1) LiveSpark Controller
- One (1) Operator Presence Control switch (or OPC Bypass)

Step 1: Insert the power cord into the LiveSpark Controller and plug it into a 110-volt outlet
Step 2: Connect an operator presence control ("deadman switch") or OPC Bypass if this feature is not required, into the XLR port located near the power switch on the rear of the LiveSpark Controller.
Step 3: Insert the key into the key lock on the front panel of the LiveSpark Controller.
Step 4: Power on the LiveSpark Controller by flipping the switch on the rear into the ON position. The POWER light will illuminate immediately and may take up to an additional minute for the IGNITE button to illuminate.
Step 5: Attach two FirePixel Adapter cables to the rear ports on the controller
Step 6: Connect the Male connector from the LiveSpark Controller Cable into the Female connector of the first FirePixel in the daisy chain

***NOTE:** The male connection on each cable is the output

Step 7: From first FirePixel to the last, connect additional FirePixels in daisy chain fashion.
Step 8: To complete the network of FirePixels, connect the last FirePixel's male connector to the Female Connector of the LiveSpark Controller input

12.0 FirePixel Operating Procedures

12.1 Ignition

Step 1: Flip up the Emergency Stop switch cover and toggle the switch to the ON position. The switch will be turned upwards and a red light will illuminate.
Step 2: Turn the key in the key lock to the unlock position.
Step 3: Push the red illuminated IGNITE button*

*** NOTE:** This will cause the LiveSpark FirePixels to ignite. The first time you ignite the FirePixels, you may need to push the OFF button then the IGNITE buttons several times to ignite and calibrate FirePixels, due to air in the lines, firmly seated valves, or other environmental factors.

12.2 Operation

FirePixels can be controlled by sending DMX, Midi, or UDP commands. See the LiveSpark Controller User Manual for operating instructions.

12.3 Normal Shutdown

To turn all flames off in a non-emergency situation, press the OFF button.

12.4 Emergency Shutdown

In an emergency, FirePixels can be rapidly extinguished by closing the Emergency Stop switch. Loss of power to the FirePixel chain will also cause the FirePixels to shut off due to their use of normally closed valves.

Appendix A - Methods and Calculations
by LiveSpark engineer Mike Thielvoldt

Failure Mode Effect Analysis (FMEA):

The control circuitry is designed to comply with section 30A of, "UL Standard for Safety for Primary Safety Controls for Gas- and Oil-Fired Appliances, UL 372" No sequence of UL-considered component faults will result in a failed-open condition.

The FirePixel passes most sections of UL372, but some of the tests have not been performed (mains-borne perturbation, electrical interference, etc.) and other sections don't apply. Actually performing the relevant tests (by LiveSpark or by a 3rd-party lab) would permit a stronger statement here without being misleading.

Output

Flow-rate of propane at maximum setting with 30psi inlet pressure is 63 L/min at 20°C. This is the same as 131 SCFH, and produces 91kW of heat, or 311,000 btu/hr.

This figure calculated based on measured 77.2 L/min of air at 30psi by LiveSpark's valve fabricator (for reverse-flow valve). Using following properties for propane:

Lower heating value for propane: 46.36 MJ/kg
Density of propane: 1.873 g/L @ 1ATM, 20°C
Specific Gravity (SG) propane: 1.522

For both choked or un-choked ($P1 < 2*P2$) flow of gas across a valve, the flow rate in volume at a standard state per unit time (such as scfh) is proportional to 1/sqrt(specific gravity). Specific gravity is simply the ratio of the densities, where SG(air) = 1. This allowed conversion from L/min

77.2 L/min air / sqrt(1.522) = <u>63 L/min</u> propane.
63 L/min propane * 1.873 g/L propane = 118 g/min propane
118 g/min propane * 46.36 kJ/g *(1min/60sec) = <u>91kW heat</u>
91kW * (3,412 btu/hr / 1 kW) = <u>311,000 btu/hr</u>
63 L/min @ 20°C, 1ATM * 289K (60°F) / 293K (20°C) * [.0353cu.ft/L]*[60min/hr] = <u>131</u>

SCFH propane.

Flame proving circuit performance

Flame proving circuit utilizes fail-safe rectification sensing and dynamic circuitry to detect the presence of a flame, automatically preventing the release of any significant quantity of unburned gas, even in adverse environments. High levels of moisture, wind, or particulates may prevent normal operation.

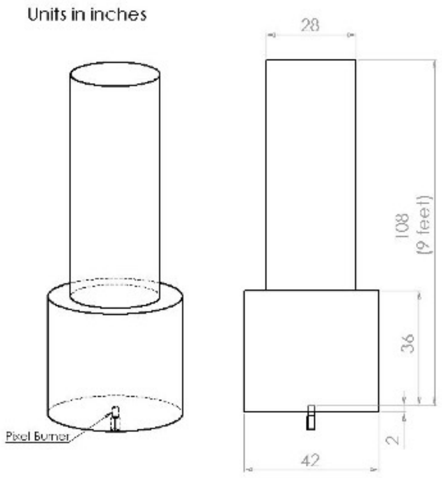
Please refer to forthcoming test data on flame rectification system.

Exclusion Zone for surrounding flammable materials

To comply with NFPA 160-2011 section 10.3.3, unprotected combustible materials should not be placed in the zone shown below in Figure 1. The exclusion zone is defined by two cylinders with vertical axes, concentric with the burner of each fire-pixel. The first cylinder is 42 inches in diameter and extends 2 inches below and 60 inches above the pixel burner. The second cylinder is 28 inches in diameter and extends to 9 feet above the burner.

This exclusion zone applies to a single fire pixel operated at 20psi inlet, and continuous 100% fire output.

Figure 1: *exclusion zone for unprotected combustible materials*



"Distance above					
pixel: "	5ft	6ft	7ft	8ft	9ft
"20psi inlet					
100% duty					
continuous"	102	71	61	50	39
"30psi inlet					
100% duty					
continuous"	131	83	72	57	48
"30psi inlet					
50% duty					
.5sec period"	45	29	28	24	22
"30psi inlet					
25% duty					
.5sec period"	14	11	8	8	7

This was determined by measuring the temperature on the surface of a .75”-thick piece of black (actually appears dark-grey) polyurethane foam using an infrared thermometer. This technique for temperature measurement was chosen to allow a rapid but accurate assessment of the maximum temperature rise that could be induced in lightweight materials. This foam specifically was chosen for this experiment because it has a low specific heat (for a fast reading), low thermal conductivity through the material (for readings that depend less on lab conditions), and high emissivity, (for worst-case radiation absorption).

The foam was placed in various locations surrounding the flame, at various distances from the burner, in various wind conditions. The pixel was set to maximum output, and the IR thermometer recorded the foam surface temperature until the time-average of the readings was seen to stabilize. This usually took 10-15 seconds for each measurement.

Two positioning schemes were used. First, the foam was placed directly above the pixel, vertically aligned with a plum-bob. The height above the pixel was increased until the temperature rise was recorded to be below the allowed 117°F above ambient.

In the second scheme, a squirrel-cage blower was placed some distance away from the pixel, but at the same height as the pixel and directed at the pixel, creating a horizontal air current. The air velocity was measured with an anemometer just above the pixel burner. The foam was again used to record the temperature rise caused by the flame. This time, however, the foam was placed directly down-wind of the pixel, a measured distance away from the pixel in the horizontal direction. The height of the foam was adjusted to be approximately where the highest temperature would be expected, by visually observing the inclination of the flame.

In this wind-simulated arrangement, the distance between the blower and the pixel was varied to simulate varied wind-speeds. The horizontal distance from the pixel to the foam was also varied to determine the minimum allowable distance for each wind condition.

From these data, I was able to quantify the flame's capability to heat materials to the side of the burner under windy conditions and above the burner in quiescent air. The region directly above the flame was, as expected, found to be heated to 117°F above ambient at the greatest distance from the burner.

Temperatures of surrounding materials

The peak temperature rise (above ambient) for surrounding materials under heating by a single fire pixel in still air was taken at various distances directly above a fire pixel. the temperature rise was measured by mounting a small sheet of dark foam at the location of interest and reading the foam surface temperature with an IR thermometer. The foam sheet was mounted as a vertical wall, not as a floor, to prevent obstruction of hot gasses and to prevent reflection of radiation off the surface of the foam into the IR thermometer.

Several readings were taken to ensure stabilization of the measured temperatures. The readings were averaged once the foam was no longer appreciably warming.

Limitations:

It should be noted that this region is only a guideline, and a more appropriate exclusion region could be either smaller or larger depending on circumstances of an installation.

The foam used in this experiment represents a very heat-susceptible material. A propane tank or supply line would be less susceptible to temperature rise than the foam because it would more readily reject absorbed heat to surroundings, and to the flowing/expanding fuel. This could allow a pixel to be placed slightly inside the exclusion region of another pixel, if care is taken to monitor proper function.

However, this experiment and the resulting exclusion area does not account for the heat produced by surrounding pixels, which could be significant in a large or dense installation. A model that approximates the cumulative radiation of many pixels in a region is used in the next section, dealing with audiences. I recommend adapting this second radiation model to validate any planned installation that spaces pixels within 1 meter of more than 2 neighboring pixels.

Audience proximity to fire pixels

To comply with NFPA 160 2011, section A.7.1.2, which addresses exposure of audiences to radiant thermal energy, audiences should be located no closer to the fire pixels than is specified in the table below.

Table 1: *proximity of audience to a horizontal row of fire pixels*

Fire pixel spacing	***Minimum horizontal separation from audience***
1ft	*8ft*
2ft	*5ft*

The above table applies when the following is true:

- *The nearest group of pixels to the audience is a horizontal row of pixels with consistent pixel-pixel spacing.*
- *The audience is at approximately the same height as the flame produced by the nearest row of pixels.*
- *Pixels are operated at no more than a 30% duty cycle over any 30-second period.*
- *Pixels do not remain above 50% output for longer than 10 seconds.*
- *Then next nearest group of pixels is at least 8 feet further from the audience than the*

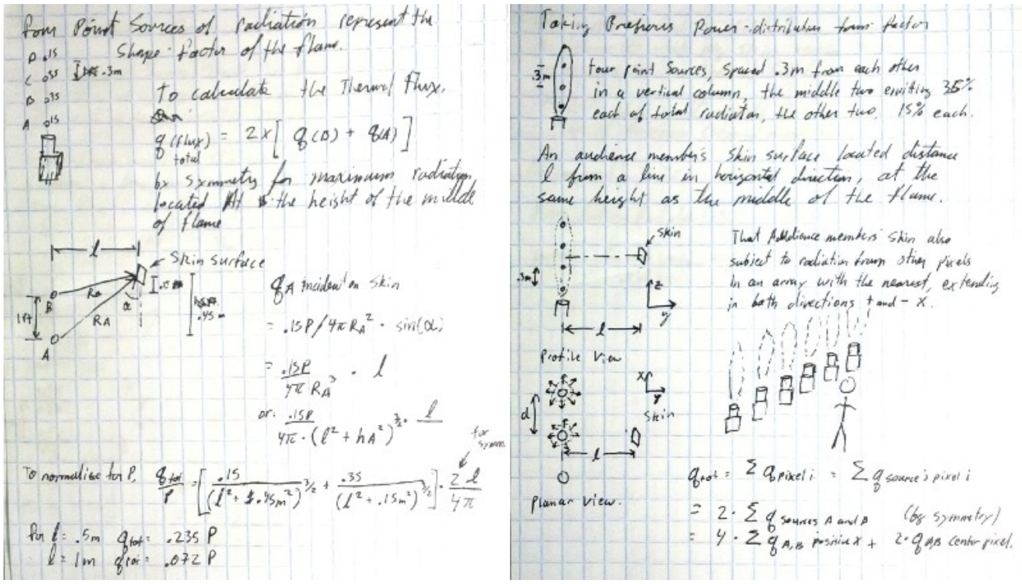
nearest group.

Higher planned duty cycles, longer periods of high output, different arrangements of pixels, and hot weather may each require greater separation than that specified in Table 1. An infrared thermometer should always be available to verify compliance in the field.

This was determined by modeling each fire pixel as four vertically-spaced point-sources of thermal radiation, and using this model to extrapolate the measured effect of one fire pixel on skin temperature to the effect of a row of pixels on skin temperature at a greater distance.

The four-point-source model was chosen because it represents a balance of simplicity and accuracy. The purpose of this model is to simplify the calculation of radiant flux at a small surface more than a meter from the flame, while maintaining general adherence to the radiant behavior of a real flame. Four points, each spaced .3 meters from its neighbors, with varied power weights, the middle two each representing 35% and the outer two each representing 15% of the total flame power, seemed a good approximation based on available still images of fire-pixel flames.

Because I was comparing the flux from one pixel to more of the same pixel, I did not need to find the power or radiant flux produced by a pixel in absolute terms. I therefore worked in units normalized to the maximum power from one pixel.



Four Point Sources of radiation represent the Shape-Factor of the flame.

To calculate the Thermal flux,

$q_{total}(flux) = 2 \times [\, q(B) + q(A)\,]$

by symmetry for maximum radiation located the height of the middle of flame

q_A incident on skin

$= .15P / 4\pi R_A^2 \cdot \sin(\alpha)$

$= \frac{.15P}{4\pi R_A^3} \cdot l$

or: $\frac{.15P}{4\pi \cdot (l^2 + h_A^2)^{3/2}} \cdot l$

for symm.

To normalize for P, $\frac{q_{tot}}{P} = \left[\frac{.15}{(l^2 + .45m^2)^{3/2}} + \frac{.35}{(l^2 + .15m^2)^{3/2}} \right] \cdot \frac{2l}{4\pi}$

for $l = .5m$ $q_{tot} = .235P$

$l = 1m$ $q_{tot} = .072P$

Taking Previous Power-distribution from factor

four point Sources, Spaced .3m from each other in a vertical column, the middle two emitting 35% each of total radiation, the other two 15% each.

An audience member's Skin surface located distance l from a line in horizontal direction, at the same height as the middle of the flame.

That Audience members' Skin also subject to radiation from other pixels in an array with the nearest, extending in both directions + and − X.

$q_{tot} = \sum q_{pixel\ i} = \sum q_{sources\ pixel\ i}$

$= 2 \cdot \sum q_{sources\ A\ and\ B}$ (by symmetry)

$= 4 \cdot \sum q_{A,B\ positive\ x} + 2 \cdot q_{AB\ center\ pixel}$

Matlab model of pixel radiation for audience separation calculation.

```
function [ flux ] = RadiantFlux( l, d, n_pixels )
%AudienceRadiation Calculates the incident thermal flux on a small area
%subject to radiative heat transfer from a row of fire pixels.
%  The flame of each fire pixel is modeled as four point-sources of
%  raidation, the top and bottom each emittiing 15% and both middle
%  point-sources emitting 35% each of the total radiation from the pixel.

r_a = (.45^2 + l.^2).^.5;    % radius to bottom point source, pixel 0
r_b = (.15^2 + l.^2).^.5;    % radius to lower middle point source, pixel 0
flux = l/2/pi.*(.15./r_a.^3 + .35./r_b.^3);  % flux from nearest pixel

if ~exist('n_pixels') || n_pixels == 0
    return
end

for(i=1:n_pixels)
    r_a = (.45^2 + l.^2 + (d*i)^2).^.5;  % radius to bottom source, pixel i
    r_b = (.15^2 + l.^2 + (d*i)^2).^.5;  % radius to lower middle source, pixel i
    flux = flux + l/pi.*(.15./r_a.^3 + .35./r_b.^3);
end
```

```
%AudienceDistance script calculates the minimum separation of an audience
%from a horizontal array of fire pixels, given a measured minimum
%distance from one fire pixel.

%  Returns a table of minimum audience separation values corresponding to
%  arrays of pixels with various pixel-pixel spacings.
%  This is calculated based on a geometric approximation of a flame's
%  radiant power distribution.  See RadiantFlux() function.
%  SI units (meters, seconds)
```

```
% minimum distance for skin to remain below 44C during 10 seconds of
% exposure to one pixel at full output for 10 seconds.  This was measured
% using a stopwatch, tape-measure, IR thermometer and Mike's arm.
single_pixel_dist = .508;    %(meters)

% number of pixels in array on either side of target audience member.
array_N = 500;    % 50 corresponds to 101 pixels in array.

% pixel spacings to calculate minimum audience separations for.
pixel_spacing = [.3 .61 .91 1.22];  % (meters), = 1, 2, 3, 4 feet.
separation = zeros(1,length(pixel_spacing));

% calculate the flux from one pixel at measured single pixel distance.
% This is the flux limit that will be used to calculate the minimum
% separations for higher numbers of pixels.
max_flux = RadiantFlux(single_pixel_dist);

for i = 1:length(pixel_spacing)
    %use newtons-method solver to find separation distances that give the
    %same flux as max_flux for 101 pixel arrays and varied pixel spacing.
    separation(i) = fzero(@(x) RadiantFlux(x,pixel_spacing(i),array_N)-max_flux, ...
        2/pixel_spacing(i));

end
separation;
separation_ft = separation./.0254./12   %convert meters to feet and output
```