Dance Dance Immolation
Fire Safety Plan

Interpretive Arson

Scope

This document discusses the as-built safety systems and operating procedures for the Dance Dance Immolation project.

This document does not discuss non-safety issues related to this project, such as transportation, logistics, funding, placement (except as it relates to safety), setup, or cleanup. These topics will be covered elsewhere.

This document is under constant revision, and suggestions are welcome. This version was last updated on 5/16/2007. The most current version is always available at http://www.interpretivearson.com/ddi/safety/

Project Description

Dance Dance Immolation (DDI) is an adaptation of the popular arcade video game, Dance Dance Revolution (DDR). A DDR machine consists of a pair of dance pads connected to a computer with a large display, sound system, and game software. Each game can have up to two concurrent players, one on each pad. A dance pad is a 3'x3' square, divided into nine 12" square sections. Four sections (up, down, left, and right) are buttons that the player can press with her feet.

To play the game, the player selects a song and difficulty level. During gameplay, the computer indicates a pattern in which the pad arrows should be pressed, in time to the music. The game is scored based on whether the arrows are pressed in the correct sequence, and the accuracy of the player's timing.

In Dance Dance Immolation, the player dons an insulated aluminized proximity suit, with a forced-air respirator. When she scores well, automated flame effects mounted vertically behind the screen will activate. When she scores poorly, a smaller propane effect will fire a quick burst at her face.

This is a game which looks dangerous to participants, but in reality is very safe.

Safety Overview

A complex project such as DDI requires that thorough consideration be given to all aspects of safety. While player exposure to flame effects is the most obvious risk, it is not enough to

ensure that players are adequately protected from flame. Rather, all aspects of the project have been designed with respect to safety, including hardware, crew training, and operational procedures. The major safety concerns for this project are:

1. Protecting the players from the flame effects directed at them. This will be accomplished through the use of appropriate protective clothing and ventilation systems. Large red kill switches are also within arm's reach of each player and the system operator during the game.

2. Onlooker protection and crowd control. Basic protection of onlookers is ensured by keeping spectators at an appropriate distance from flame effects. DDI employs several methods of perimeter control, including physical barriers and security personnel.

3. Crew protection. Crewmembers are specially trained and wear basic fire-safe clothing at all times.

4. Flame effect hardware. All hardware has been built to appropriate specifications and safety codes such as NFPA 160. Appropriate pressure and compatibility ratings have been observed.

5. Control Systems. DDI employs computer-controlled flame effects. Therefore the system has been designed to function safely even in the event of computer hardware or software failures. Other safety features include multiple kill-switches, positive arming procedures, manual fuel control, and automatic fail-safes.

6. Operating procedures. Definite, specific operating procedures have been established, and crewmembers have been trained appropriately. Procedures include system startup and testing, participant screening and instruction, game monitoring and control, and refueling and maintenance.

7. Emergency response and fire suppression. Being propane fueled, all system hardware can be rapidly and completely disabled by means of a master shut-off valve. Fire extinguishers and other safety equipment are also on-hand.

A detailed discussion of each of these issues follows.

Protective Clothing

Flame & Heat Protection

Each player is dressed in the pants, jacket, hood, and gloves from a firefighter's proximity suit, made of either aluminized aramid or aluminized PBI. A number of suits are available in a variety of sizes. A trained DDI crewmember is tasked with fitting a suit to the player, helping the player to dress, and checking that the suit is properly fastened.

The suit hood has been modified to increase the integrity of the hood-jacket seal using a custom-made kevlar "cape" that fits around the player's neck. The cape snaps into the hood

using a double-layer seal, much like the seal employed on the front of the suit jacket, as-manufactured.

Players are not required to wear protective booties. The energetic movement required while playing the game will necessitate good traction, which the booties would tend to impair, creating a risk of falls. The flame effects are mounted and aimed such that the fire cannot approach the player's feet, and closed-toed shoes are required.

We have performed controlled tests to verify the ability of an aluminized nomex proximity suit to resist short bursts of propane flame. It protects quite well. Additional tests have been conducted to determine the frequency with which effects can fire without causing unsafe heating inside the suit. Based on these tests, the game software imposes very conservative limits on firing frequency.

Respiratory Protection

We recognize that the biggest risk to a player of DDI is the inhalation of flame or superheated gas. We have taken the utmost care to minimize this risk. Primary protection is provided by the sealed hood, however given the seriousness of the potential injury, each player is also outfitted with an externally fed half-face respirator mask, worn inside the proximity suit's hood. A variety of mask sizes are available to assure a correct fit.

Even if hot gas were to enter the hood, the player cannot inhale it because he is breathing a sealed air supply at positive pressure. Additional air is fed into the hood itself to maintain positive pressure inside the hood generally, further reducing the chance of gas entry. This air also helps to keep the player cool.

The mask is fed by an umbilical attached to the player's back, which is protected from fire damage by a Nomex sleeve. This tether also includes a separate hose for feeding the pressure monitor (see below). A single high-capacity centrifugal blower supplies air to both players. The air intake is filtered for dust, and placed in a secure location away from flame effects and onlookers.

Should a loss of air pressure occur, as might be caused by a supply failure, hose kink, fitting failure, etc, a pressure-monitoring sensor immediately activates the failsafe shutoff. This failsafe has been designed will all appropriate care, including normally closed wiring to mitigate the risk of electrical failures and placement of the sensor supply connection within the player's hood at the furthest practical point downstream from the blower. It has proven itself effective and reliable in practice.

Crew Protection

Perimeter volunteers are required to wear basic flame-resistant clothing (ie. natural fibers, closed-toed shoes, etc.). Crewmembers working within the perimeter are required to wear fire-retardant clothing of class 1 or better, such as an aramid coverall with a natural fiber under-layer.

Perimeter & Crowd Control

In operation, the game is surrounded by a fenced perimeter to keep onlookers at least 20 feet from the nearest flame effect. When the flame-effect system is armed, a number of trained crewmembers are stationed along the perimeter to ensure its integrity. The number of crew in this position varies from two to four or more, depending on the size and character of the crowd.

The effect operator has access to a microphone and full control of the sound system for communication with the larger group of onlookers outside the perimeter, if necessary.

The game layout has been designed to give the effect operator the best line-of-sight between the perimeter and the effects, and the perimeter is sized to give the operator ample time to disable effects before an onlooker could put himself in harm's way, even without warning from the perimeter crew.

Flame effect hardware

All DDI flame effects are propane-fueled, and fall into Group VI, as defined by NFPA 160. Effects may be further classified as "display effects," which are mounted behind the main display screen, and "player effects," which are in proximity to players and have additional safety features.

Fuel is supplied by three of 100lb propane cylinders, located in a protected area behind the operator, well away from any source of ignition. Each tank is outfitted with a 1/4-turn ball valve mounted directly after the cylinder, before the gas manifold. Fuel supply is provided by a single rated 3/8" propane hose. The supply hose connects to the operator control panel, where the main supply shutoff valve is located.

All accumulators are repurposed propane storage cylinders with current inspections. All hardware is rated for the pressures involved and made of compatible materials.

Display effects

Three vertically firing display effects are be used in total. Two small (1/2" valve) and one large (3/4" valve) accumulator-type effects are mounted on the main display screen. Display effect accumulators are located behind the main display screen, with gas nozzles located above the screen such that the flames are directed upwards. They are filled via a hose connected to the operator control panel after the main fuel supply valve.

The main effect valves for the display effects are electrically-controlled, normally-closed solenoid valves, from the ASCO 8210 series.

Player effects

Three effects run in proximity to each player. Two small (3/8" valve) accumulator-type effects are pointed directly at the player, and flame from these effects comes in contact with the player. One effect consists of a single nozzle mounted directly in front of the player platform, and one uses a pair of nozzles to either side. The burst duration from these effects is brief, on the order of 0.5 to 2 seconds.

The burner for the third effect is a perforated semicircular tube mounted in front of the player platform, which when fired creates a "wall of flame" effect, momentarily blocking the player's view of the screen. Flame from this third effect does not come in contact with the player. It has a 3/4" valve.

Player effect accumulators are located at the operator station. Accumulator output is combined through a single 1.5" proof-of-closure ball valve, mounted on the operator control panel. This valve is closed after each game. The solenoids for the player effects are connected downstream from this valve.

This design ensures that the master shutoff valve completely disconnects the player effects from the fuel supply and all accumulators when closed. Further, a pressure-controlled solenoid valve automatically vents any remaining line pressure into the display effects whenever the master valve is closed. An effect-side pressure gauge on the operator control panel provides positive indication that it is safe to approach the player effects.

The master shutoff valve therefore effects a single-point hard disconnect of the player effects.

Ignition

Effects are ignited using a stable, redundant, venturi-type propane pilot system. Each effect is equipped with three separate, wind-resistant pilot nozzles. In the unlikely event that a single pilot blows out, the other two will re-light it instantly. Pilot gas is supplied via the display effect fuel system. All pilot feeds are equipped with pressure regulators to minimize the effect of transient pressure drops as the display effects are fired.

Control Systems

Overview

Once a game is underway, all flame effects are triggered automatically under software control. This fact is central to game play, but creates the risk of unintended firing. Appropriate system design is required to mitigate this risk. DDI accomplishes this with a multiple-level system of software rate limiting, discrete arming electronics, arming alarms, and emergency manual overrides.

DDI also employs a manual arming procedure, which requires the cooperation of the system operator and each player. Upon power-up and between games, the system is in an un-armed state and the player effect solenoid valves are physically disconnected from their power supply, via the

master arm relay (discussed below). Arming commences when the operator presses the Arm button on the operator control panel. Arming lights then illuminate on both the operator and player control panels. Each player must then press their own Arm button on their individual control panel to complete the arming sequence, at which point the master arm relay closes and latches. A klaxon then sounds and the lighting in the game area changes from blue to red, giving a positive indication of arm status to the operator, players, and everyone nearby. Finally, the operator must manually open the master shutoff ball valve to complete the propane feed.

A large, red, illuminated emergency stop button is within reach of the operator and each player at all times. When any of these buttons are pressed, the master arm relay opens and the entire arming sequence must be repeated to resume game play. The system can also be disarmed under computer control, or by several system failsafes, such as loss of ventilation pressure or wiring failures.

Hardware

The operator runs the system via a control panel at the operator station. Each player also has a smaller control panel mounted within arm's reach. The operator control panel contains all control electronics for the entire system. It connects to the computer via USB and RS-232 serial interfaces, and, when armed, translates computer commands into valve actuation.

Power to all player effect valve systems is controlled through the Master Arm relay, a single high-reliability electromechanical relay of appropriate rating. It is located on a safety electronics board inside the operator control panel, which manages the arming sequence logic, emergency stop systems, and automatic failsafes. This board is built from a small number of discrete components. It is not under computer control, except that the computer is able to issue an irrevocable disarm command. All kill switches and other failsafe sensors are of the normally-closed type, thus preventing against wiring or connection failures. In general, all wiring and circuitry has been designed to be immune to single-point component failures, to fail safe, and to be self-diagnosing when possible. In particular, most failures will prevent the arm sequence from completing successfully.

The master shutoff valve is not under electrical control and must be physically opened by the operator to enable the player flame effects. Between games, it is kept closed. To help ensure compliance with this procedure, a loud annoying buzzer sounds when the system is un-armed but the valve is open, such as when a game ends or a stop button has been pressed.

Software

As discussed in the control panel section, the system cannot be armed by the computer. However, once armed, all flame effects are under software control and so appropriate software is important. The main safety feature of the software is a rate throttling system for the player flame effects. This is implemented in the low-level driver for the flame effects, and tracks total firing time over a recent time interval. If the player flame effects have been fired more than, for example, one second out of the previous ten seconds, any fire commands from higher-level software modules are ignored. This prevents overheating of the interior of the proximity suits.

The exact parameters of the rate-limiting software have been determined from tests performed during system development.

We are not relying on software or computer systems for safety. This is why all arming and safety electronics are discrete and isolated. Conceivably, a software malfunction could still result in unintended player flame exposure. However, the suits provide a tremendous margin of flame and heat protection. Based on our tests, we have found that the proximity suits can safely tolerate at least fifteen seconds of continuous flame exposure from the type of small flame effects we are using, more than enough time for the operator or either player to shut off the system in an event of a serious malfunction.

Electronic Failsafes

The system is automatically disarmed in any of the following events:

- Operator or player stop button pressed
- Ventilation pressure loss
- Game over
- Power loss
- Player air and electronics tether disconnect
- Master shut-off valve closed
- Wiring or connection failures throughout the system

Operating Procedure

Player Requirements

Prospective players must meet several minimum requirements. First, players must not be visibly intoxicated. They must be capable of understanding the safety instructions given to them. Appropriate clothing must be worn including closed-toed shoes and flame-resistant fabrics. (We will have extra clothing on hand for those who need it.) They must fit properly into one of the variously sized proximity suits that we have on hand. Minors are not allowed to play.

Crew requirement

A DDI crew typically consists of eight people: The operator has overall responsibility for system control and monitoring, and is highly trained in all technical and operational aspects of the system. A dresser screens participants, fits appropriate protective clothing and dresses players, and provides a safety briefing to each player. When running at full capacity (2 players playing, 2 preparing), four dressers are needed. The dresser for the active player is responsible for watching the player for signs of distress, and paying attention to that side of the perimeter. One person is tasked with maintaining the player signup list at the gate. An MC operates the game software and interacts with the crowd via the microphone, leaving the operator free to run the main control panel, pay attention to players, and watch for onlookers entering the perimeter. Finally, the game coordinator is tasked with maintaining communication between gate, operator, and dressers, speaking with members of the crowd, and performing any immediate maintenance tasks. Finally, the game coordinator manages communication between other crewmembers,

schedules different parts of the run, and maintains machine systems.

Operator Procedures

Each operator is trained in all aspects of system function and maintenance. This includes:

- Start up and test procedures. It is necessary to pressurize the system, boot the computer, power the control electronics and perform basic functional tests before each system run. Exact startup and test procedures have been formalized as a startup checklist. The goal is to test all aspects of system functioning before each operating run.

- Arming procedures. The operator is trained to complete the system arming sequence as described above.

- In-game procedures. Although the system safety features are largely automated, the operator is required to observe the status of a number of items as a backup. These include system power, fuel pressure, ventilation pressure, and valve operation, as well as closely observing the players for any signs of distress.

- Emergency procedures. The operator is trained in the use of system kill switches and tiered shutoff options including manual master valve operation, fuel supply shutoff, and system purging.

- Maintenance. All operators are capable of performing basic system maintenance between runs, to ensure continued safe operation.

Dresser Procedures

The dresser's main responsibility is safe screening, dressing, and instruction of players.

Each player is helped into an appropriately sized suit selected by the dresser. Basic clothing safety features are explained to the participant, such as the operation of the respirator mask, suit seals, etc. While players are not required to fully understand their protective gear, it is prudent to familiarize them regardless. While waiting for the game in progress to complete, the prospective players receive instruction regarding the arming procedure and status indicators, and the use of the emergency stop button. Each player is also given an overview of how to play the game, if needed. At the appropriate time, a dresser accompanies each player to their stage and re-familiarizes them with arming and stop procedures, this time with reference to the actual player control panel equipment. Finally, the dresser fastens each player's hood and connects the ventilation and control tether before retreating to a safe distance.

Emergency response & fire suppression

First aid

Basic first aid and burn treatment supplies are kept on-hand.

Fire suppression

Due to the proximity of players to flame sources, carbon dioxide extinguishers are unsuitable because of their frostbite risk. As such, type ABC (ammonium phosphate) dry-chemical fire extinguishers are placed throughout the game area.

A number of fire extinguishers are distributed within the perimeter, to assure that each crewmember has an extinguisher within reach at all times. All crewmembers are trained in the proper use of the extinguishers.

Further Information

For further information, please contact Interpretive Arson at firesafety@interpretivearson.com.