

# Safety & Technology News

## Grain Elevators

### *The Road to Explosion Protection*

by Brett Parker, Fike Corporation

The concept of an agricultural dust explosion dates back to 1785 when the first agricultural dust explosion was reported at a flourmill in Turin, Italy. Grain elevators face a constant risk of dust explosion. The very nature of using bucket elevators, filter collectors, grain dryers and other process equipment to process and transport grain creates an environment where fuel and oxygen exist in mechanical enclosures. Depending on what grain is being handled, a dust concentration as low as 40 grams per cubic meter is sufficient to support combustion. When grain dust is suspended inside an enclosure, like a bucket elevator or filter collector, the only thing that separates these conditions from an explosion is the absence of an ignition source. In addition, dust layers as little as 1/100 of an inch can be suspended by the pressures

*Continues on page 2*

#### **In this issue**

Grain Elevators	
The Road to	
Explosion Protection .....	1
Rupture Disc Sizing .....	4
Application Profile	
Explosion Protection of Food ....	6



Photograph courtesy of Dr. Robert W. Schoeff

generated by an explosion and can propagate a primary explosion to other equipment. Resulting secondary explosions are usually devastating and deadly. Explosibility testing has confirmed that suspended grain dust is more explosible than coal dust.

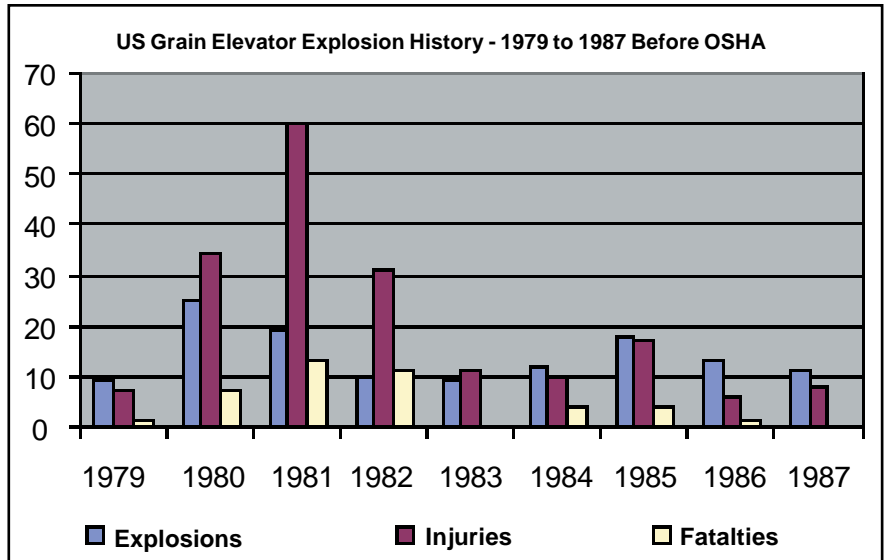
Grain elevator explosions have not been uncommon during the twentieth century. Early in the 1900s, the National Fire Protection Agency began developing a standard to address dust explosions in grain terminals and flourmills. NFPA 61 was first issued in 1923 as that standard. Since then, NFPA 61 has been revised 14 times and the 15<sup>th</sup> revision should be published later in 1999. The standard is currently titled: Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Products Facilities. Its purpose is to “prescribe requirements for safety to life and property from fire and explosion and to reduce the resulting damage if a fire or explosion occurs.” Throughout the century, the standard has provided guidelines for preventing dust explosions and reducing the damage they may cause. However, the standard still is not a legal mandate. The need for mandated prevention of dust explosions became apparent in late December of 1977 when five U.S. grain elevator explosions occurred in an eight day period. The explosions resulted in 59 fatalities, 48 injured workers and 2½ percent of the country’s export elevators being destroyed.

**Awareness:**

**The first stop on the road**

The U.S. Department of Labor had already begun collecting information on grain dust explosions, which it distributed with a hazard alert to 15,000 grain handling facilities following the explosions in late 1977.

The National Academy of Sciences also took action by hosting an international colloquium to address grain dust explosions. To be certain that the causes and mechanisms of dust explosions were completely understood, the U.S. Department of Agriculture and the U.S. De-



partment of Labor backed the formation of a Panel on the Causes and Prevention of Grain Elevator and Mill Explosions. The National Academy of Sciences directed the panel. At that time, the National Institute of Occupational Health and Safety conducted their own investigation into grain dust explosions.

Based on the findings of each study, it was determined that federal safety regulations may be able to reduce the frequency and severity of grain elevator explosions. In 1984, the Occupational Safety and Health Administration issued a suggested standard. The proposed standard covered many issues that would make grain elevators more safe, such as engulfment, pre-

ventative maintenance, housekeeping, training and the prevention of explosions by controlling dust accumulations, ignition sources and grain dust concentrations. The concepts of prevention are mandatory and the concepts of explosion protection, such as venting and explosion suppression are mentioned. In 1986, a final draft of the Grain Handling Standard was submitted to the U.S. Office of Budget and Management. The Occupational Safety and Health Administration has issued Standard 29 Code of Federal Regulations (CFR) 1910.272 to provide “requirements for the control of grain dust fires and explosions, and certain other safety hazards associated with grain handling facilities.” On March 30, 1988 the standard was enforced. The standard legally requires that explosion prevention techniques be followed. The techniques can be eliminated if active explosion or fire protection techniques are used. The Grain Handling Standard, 29 CFR 1910.272, is still enforced today.

In the nine years preceding the enforcement of the Grain Handling Standard, there were an average of 14 grain elevator explosions per year, 20.4 injuries per year and 4.6 fatalities per year.

Factory Mutual Engineering Corporation issued its own data sheet for the Prevention and Mitigation of Combustible Dust Explosions and Fires in August of 1996. The data sheet “provides

**A Statistical Look at the Early Years**

NFPA 61 (1942 Edition): From 1898 to 1942 in the U.S., 150 grain elevator explosions (3.4/yr.), 115 fatalities (2.6/yr.), 281 injuries (6.4/yr.).

NFPA 61 (1957 edition) From 1898 to 1956 in the U.S., 203 grain dust explosion (3.5/yr.), 134 fatalities (2.3/yr.), and 427 injuries (7.4/yr.).

U.S. Department of Agriculture 1980: From 1958 to 1979 in the U.S., 250 grain elevator explosions (11.9/yr.), 164 fatalities (7.8/yr.) and 605 injuries (28.8/yr.).

preventative measures to reduce the frequency of dust explosions and protection features to minimize damage from a combustible dust explosion.”

**Prevention: You are here**

The OSHA Grain Handling Standard specifically addresses filter collectors, grain dryers and inside bucket elevators as they represent the most probable locations for primary explosions. The code also addresses housekeeping to prevent the propagation of explosions and the prevention of ignition sources. Welding and torch cutting are the most frequently identified sources of ignition. Other ignition sources include: electrical failure, sparks from tramp metal, fires, static electricity, lightning and smoldering grain. Explosions can be ignited due to human error. The OSHA Standard requires continuing education about explosion hazards for elevator employees and for contractors working at the elevator. For filter collectors, grain dryers and bucket elevators, the standard focuses on preventing grain dust explosions by addressing the specific components required for combustion, fuel and ignition sources.

**Filter Collectors:** In order to comply with the housekeeping requirements in the standard, many grain elevators added filter collectors. The increased use of this equipment has resulted in an increasing number of primary explosions in filter collectors since March of 1988.

OSHA requires differential pressure monitoring across the filter to stop the collector in the event of a broken or clogged filter. For filter collectors installed after March 30, 1988, the collector must be installed outside or steps must be taken to prevent the release of combustion pressure inside. Inside filter collectors must be isolated from other areas of the elevator by a one hour fire wall and vented and ducted outside, or an explosion suppression system may be used for protection.

**Grain Dryers:** The trend of circumventing the country elevators and

bringing harvests directly to larger elevators has resulted in more grain drying systems at larger elevators. OSHA recognizes grain dryers as enclosures that represent a dust explosion hazard.

To address the hazard, OSHA requires that all direct heat dryers have monitors that will do two things. They must stop the fuel supply if the flame fails, or if air movement through the exhaust fan is interrupted. They must stop the grain flow if it gets too hot in the exhaust of the drying section.

Grain dryers installed after March 30, 1988 must be installed outside or protected by a fire or explosion suppression system. Inside grain dryers can also be isolated from the rest of the elevator and vented like inside filter collectors.

**Bucket Elevators:** Present at every grain elevator, bucket elevators remain the most common ignition point for explosions. Ignition of the primary explosion occurs in the bucket elevator four times as frequently as any other location except filter collectors.

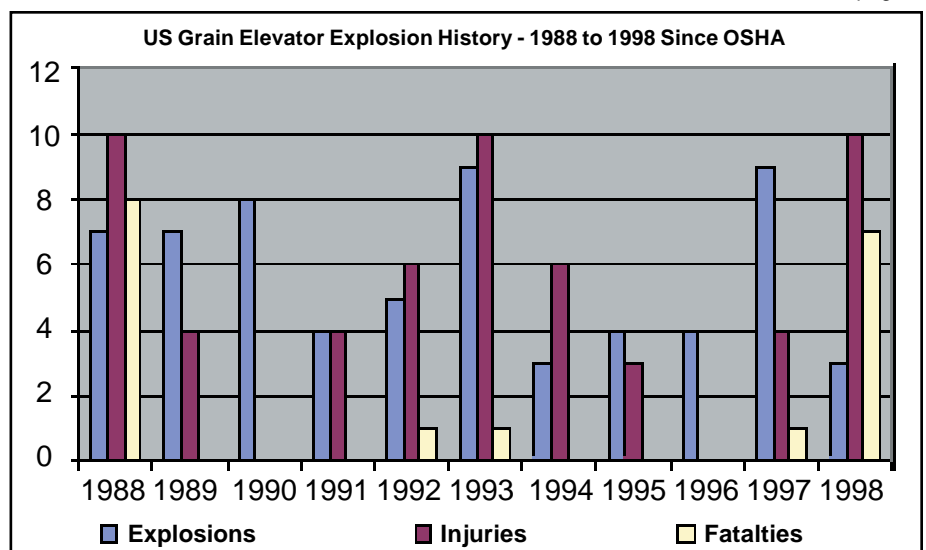
The OSHA standard does not specifically state that new bucket elevators must be located outside, but implies that by only addressing inside bucket elevators. Explosion prevention in bucket elevators begins with the same strategy employed for filter collectors and grain dryers. If the bearings are not mounted externally, temperature monitoring is required. If

there is no system that ensures proper belt alignment, belt alignment monitoring is required. In addition, belt speed monitoring is required. If the bearings get too hot or the belt’s speed decreases by more than 20%, or the belt is misaligned, the bucket elevator is turned off. (Note: Alignment and speed monitoring are not required for elevators with a storage capacity less than one million bushels if a daily visual inspection is made of the belt motion and alignment.)

To prevent the heat of friction, the standard requires that choked legs not be jogged free. Belts and laggings purchased after March 30, 1988 must be conductive to prevent static discharge from becoming an ignition source. Surface electrical resistance of the belts can not exceed 300 megohms. For preventative maintenance, clean-out and inspection, a means of access to the head pulley and the boot section is required.

The standard does not require temperature, belt speed or alignment monitoring provided that one of two possible techniques are employed. To protect the equipment in the event of an explosion, the head and boot sections can be protected by a fire or explosion suppression system. To prevent explosions, the elevator can be equipped with a system that maintains the dust concentration at least 25% below the lower explosive limit at all times during operation.

*Continues on page 7*



# Rupture Disc Sizing

## *A review of the ASME Section VIII Requirements*

by Dean Miller  
Rupture Disc Product Manager  
Fike Corporation

Changes to Section VIII, Division 1 of the ASME Code have impacted the methods used to size pressure relief systems that include rupture discs. The objective of this article is to clarify the sizing methodologies.

### **Key terminology**

- $K_D$  (Coefficient of Discharge) - This is a unit-less factor used to de-rate the theoretical flowing capacity of a device or system. For rupture discs, this value is defined by the Code as 0.62.
- $K_R$  (Resistance to Flow Factor) - This is a unit-less factor used to characterize the resistance to flow of a rupture disc device. The larger the  $K_R$  value, the more restrictive the device. The  $K_R$  value has no direct correlation to the  $K_D$ , coefficient of discharge.
- Combination Capacity Factor - This is a unit-less factor used to de-rate the capacity of a pressure relief valve, when a rupture disc is installed upstream. The combination capacity factor may be the default value of 0.9, or a higher value, if the disc/valve combination has been tested.
- MNFA (Minimum Net Flow Area) - This is a derived area based on the area of the device, and/or the piping area, and is validated during ASME certification testing. The MNFA is used only in the coefficient of discharge method.

### **Sizing methodologies**

The code describes three methods to provide adequate relieving capacity for a pressure vessel. These methodologies are applied based on the characteristics of the relieving system, not individual components.

When a rupture disc is installed upstream of a pressure relief valve, the Code requires the capacity of the valve be de-rated by a factor of 0.9, or by a **combination capacity factor** determined by test for that disc/valve combination. This method assumes the disc has a capacity equal to or greater than the valve, and does not interfere with the normal functioning of the valve. From the rupture disc standpoint, this means the rupture disc should be the same nominal size as the relief valve inlet (or larger), and that the disc be of a full opening design. This method is unchanged from the previous versions of Section VIII.

The **coefficient of discharge method ( $K_D$ )** is not a rupture disc sizing method, but a method for sizing a relatively simple relief system. The calculations for this method remain unchanged from previous versions of the Code, but guidelines for use have been added. This method calculates the theoretical capacity of system, and de-rates it by the coefficient of discharge,  $K_D = 0.62$ . This method is used only

when each of the following conditions is true:

- 1) the rupture disc discharges to atmosphere
- 2) the rupture disc is installed within 8 pipe diameters of the vessel
- 3) there are no more than 5 pipe diameters of discharge piping on the outlet of the device.

The reason this is considered a system analysis method is because it takes into account the entrance conditions from the vessel to the discharge piping, 8 pipe diameters of piping to the rupture disc, and 5 pipe diameters of piping, from the rupture disc to the atmosphere.

The **resistance to flow method ( $K_R$ )** is used if neither of the first two methods apply, such as systems with long runs of piping, or discharging into manifolds, or flare systems. The resistance to flow method is not a rupture disc sizing method, but a system sizing method. This analysis takes into account the resistance to flow of all of the elements within the relieving system, including the

*Continued on page 8*

Fitting	K
Globe valve, open	9.7
Angle valve, open	4.6
Swing check valve, open	2.3
Fike HOV rupture disc	2.02
90 degree mitered elbow	1.72
Rupture disc (equiv. to L/D of 75)	1.50
Welded tee flowing through branch	1.37
15 feet of 3" sch 40 pipe	1.04
Fike SRX rupture disc	0.99
90 degree std threaded elbow	0.93
90 degree long sweep elbow	0.59
Fike SRL rupture disc	0.38

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# Application Profile:

## Explosion Protection of Food Processing

*Editors note: Fike is typically called upon for consideration of explosion protection, only after a company experiences the destructive effects of an industrial explosion. We think this is because industry at large does not have a clear understanding of the possible hazards, and the available prevention, and protection strategies. Every month, the news reports on 3 to 10 industrial explosions somewhere in the world. In February 1999, we recorded six (6) industrial explosions, using only media reports, and reports found on the Internet. Sharing our knowledge of these events, hazards, and the existing prevention and protection strategies has been the "cornerstone" editorial purpose of Safety & Technology News, now in its 11<sup>th</sup> year. It is our intention, with articles such as this, to raise awareness of processes at risk, and demonstrate available protection strategies. The rest is up to you.*

### Problem:

Food processing companies mill, weigh, screen, dry, mix, and pneumatically convey many explosive agricultural products. These processes are inherently at risk for industrial explosions because most of the necessary elements to produce an explosion are present under normal conditions: fuel (processed ingredients), oxidant (air), confinement (process equipment). All that is necessary is a spark, or upset condition, to initiate the explosion. In this example, Fike was called upon (after an explosion) to provide protection strategies for a company that mills sugar from granular to powdered form. Powdered sugar is explosive, and is often used in mixes to make everything from marshmallows to frosting. In this case, the equipment at risk was the grinding mill, and filter receiving bin.

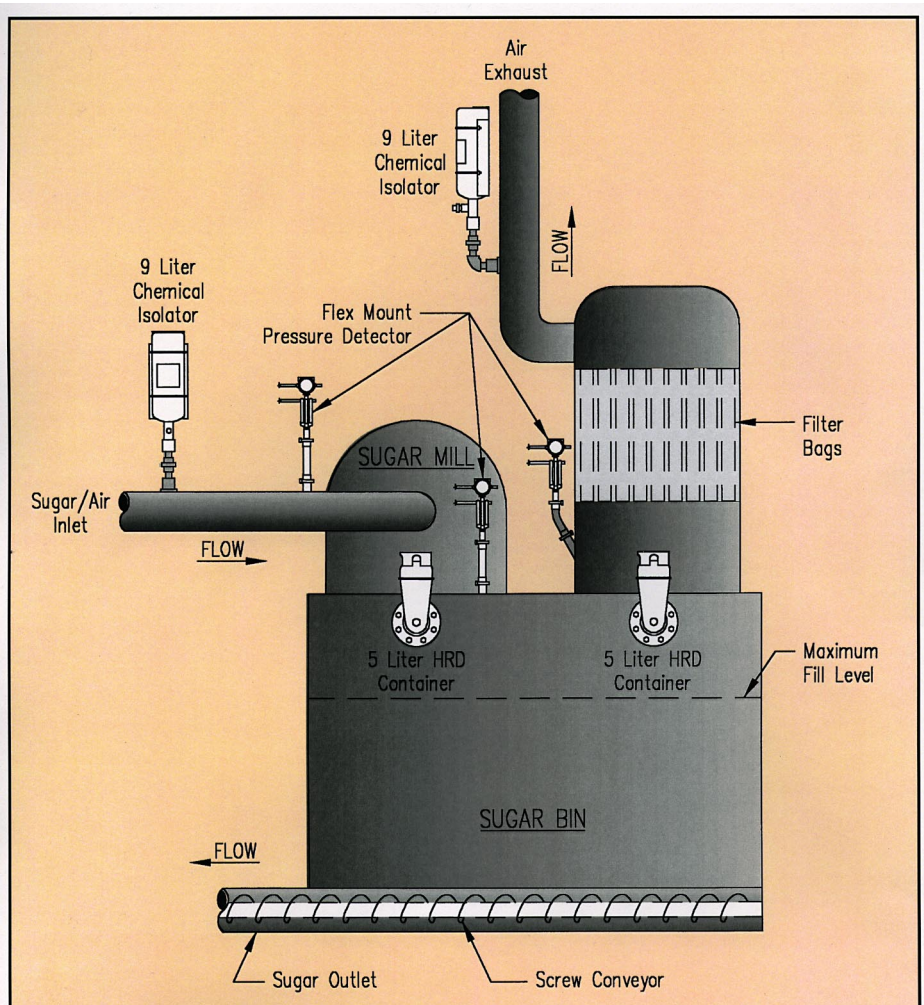
### Solution:

Since the equipment was located indoors and required clean, food grade attachments, the strategy was explosion suppression using hygienic system components. The explosion protection solution shown is on the sugar mill. The concern was that a spark generated in the mill could ignite a dust cloud in the bin below. Ignition in the mill could also cause a deflagration to propagate upstream, so a pressure detector and chemical isolation container was positioned upstream of the mill inlet.

### Successful System Activation

On January 31, 1997, an explosion occurred in the sugar milling process

at a food plant in Cedar Rapids, Iowa. The sugar mill cooling system had been shut down in error, and allowed the temperature in the grinder to rise to 250° F, which provided the necessary heat for ignition. The Fike Explosion Suppression and Isolation System detected the explosion in its incipient stages, and activated as designed, mitigating the effects of the explosion. Instead of a news feature covering an industrial explosion at their facility, this food processing company experienced only a short downtime to recharge and reset the system, and was quickly back in production.



Other food processing operations that typically handle explosive agricultural materials include bakeries, breakfast cereals, spices, sweeteners, candy, etc. They use mills/grinders, weigh bins, bulk bag unloaders, filter receivers, dust collectors, spray dryers/coolers, cyclones, screeners, mixers/blenders, and other "at risk" equipment. Additional examples of explosive materials in these environments include starches, flours, powdered milk, artificial sweeteners, oats, rice, malted dextrose, and many more. These processes are at high risk because of the presence of explosive dust, and the ever-present possibility of an ignition source.

People are generally at risk, because the equipment is typically located indoors.

#### **Other food processes protected by Fike:**

- Cheese powder (macaroni & cheese), powdered beverage mixes, marshmallows
- Frosting
- Oatmeal, and breakfast cereals
- Various candies
- Coffee roasting
- Aspartame (ingredient in artificial sweeteners)
- Spices and flavorings
- Chocolate chip and other cookies
- Health foods, vitamins

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**Effectiveness of OSHA:** Implementation of the OSHA Grain Handling Standard has had a significant impact on grain elevator explosion statistics. The average number of grain elevator explosions has been reduced to 6.5 per year (down from 14 per year in the 9 years preceding OSHA). Injuries have been reduced to 5.8 per year (down from 20.4 per year) and fatalities have been reduced to 1.6 per year (down from 4.6 per year). Although each of these averages is down since the OSHA regulation has been enforced, 1998 represented a ten year high in explosions with 11, injuries with 13 and fatalities with 7. The ten year high for each category has reopened the idea of explosion protection for many who earlier had deemed it to be too expensive.

#### **Where do we go from here?**

##### **Protection**

Twenty years ago, federal regulations were proposed in order to reduce the frequency and severity of grain dust explosions. The current OSHA requirements have been so effective at reducing the frequency of grain dust explosions that their effectiveness at reducing the severity of explosions has never really been an issue. Two severe explosions in 1988 (one before OSHA enforced the standard) made that the only year in which injuries and fatalities exceeded the number of explosions until 1998. Good fortune seemed to favor the severity of explosions until 1998 when a single explosion claimed seven lives and severely damaged one of the country's largest elevators.

Without question, explosion prevention has effectively reduced the frequency of grain dust explosions. However, to truly reduce the severity of these explosions, explosion protection techniques will need to be employed. The next issue of Safety & Technology News will outline techniques to suppress and isolate grain dust explosions.



*Explosion suppression system installed on a spray dryer.*

## **Explosion Protection Engineering Workshops**

To learn more about industrial explosions, how and where they happen, and what can be done about them, consider attending one of Fike's Explosion Protection Engineering Workshops, or Seminars. We currently plan a 2-day workshop at our World Headquarters in Blue Springs, Missouri on June 17 & 18, 1999, complete with live, full-scale explosion demonstrations. Attendees

will earn 13 hours of professional development credits, and will receive a certificate of completion.

Details and online registration can be found at <http://www.fike.com/scripts/wrkshp.asp>. Details of all available seminar and workshop options are also available at this site. You may inquire by marking the workshop request on the business reply mailer in this newsletter, as well.

Continued from page 4

resistance of the rupture disc. The Code then requires that the system capacity then be de-rated by a factor of 0.9 to account for uncertainties in the method.

The code does not describe the detailed analysis method, other than to say "accepted engineering practices". Commonly used references for this type of analysis are: API RP521 Guide for Pressure Relieving, and Depressuring Systems or Crane Paper 410.

As a point of reference, the following table is an excerpt from

API RP521 listing typical K values for various piping components. The rupture disc  $K_R$  values available from the manufacturer are used in the same way as the K values for these common piping components. In many cases the rupture disc is not a limiting or even significant factor in the capacity of a relieving system. Note the API generic rupture disc K value listed here is not necessarily conservative and actual tested values may be significantly higher or lower than 1.5.

## Safety & Technology News

*... is published by Fike Corporation in the interest of communication and service to those involved with process and industrial safety. We welcome your comments and suggestions. If you would like to continue receiving this newsletter, please complete and return the enclosed Subscriber Qualification Form.*

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## NEWS OF NOTE

### FIKE ASME UD STAMP AUTHORIZED

Fike Metal Products received ASME UD Stamp Accreditation and Authorization the week of September 28, 1998. Fike is now authorized to apply the UD Stamp in accordance with the ASME Code Section VIII, Division I changes for 1998.

### Fike Metal Products 1999 trade show schedule:

Powder & Bulk Solids Conference,  
Chicago, IL; May 11 – 13, 1999, #1508

Powdex Show, Atlanta, GA;  
October 27 & 28, 1999, #208

The Chem Show, New York, NY;  
November 16, 17 & 18, 1999, #1352

Contact Bill Copelin at Fike Corporation for VIP Passes to attend any of these shows.



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