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Historical Perspectives on Chemical Process Safety at Texas A&M--Education, Research and Service

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ABSTRACT

The Mary Kay O=Connor Process Safety Center was formally established at Texas A&M in 1995. This presentation will outline the activities leading up to the establishment of the Center, and the subsequent activities of the center in the areas of education, research and service related to process safety.

Educational initiatives have included formal interdisciplinary course instruction for undergraduate and graduate students, laboratory instruction for undergraduates, continuing education for engineering faculty, active participation and contribution to the CCPS Undergraduate Education Committee, organization of workshops on process safety topics for the ASEE, and co-direction of a three-day Workshop on Process Safety for Chemical Engineering Faculty.

Present research activities are centered around the design of emergency relief systems for two-phase flows, and reactive (runaway) systems. A consortium involving two departments at Texas A&M, one at

Prairie View A&M, three relief valve manufacturers, and three operating companies has been formed to conduct and oversee research on viscous two-phase flow through safety relief valves, which is sponsored by DIERS (the Design Institute for Emergency Relief Systems) of the AIChE. This project involves evaluation of the current state of the art for sizing relief valves for two-phase flow with design recommendations and elucidation of unanswered questions, numerical CFD computer modeling of two-phase flow through valves, an experimental design for obtaining data required to properly validate recommended models and answer outstanding questions, and an experimental program conducted at the test facilities of Anderson, Greenwood and Company to obtain and evaluate the needed data. Reactivity studies are being initiated with an RSST calorimeter and an APTAC calorimeter (on order).

Service activities have included establishment of a library of reference meterials and software related to process safety, and a WEB site with information on publications, literature reviews, index of DIERS presentations, research abstracts, etc. Professional service includes chairing the 1996 Process Plant Safety Symposium, sponsored biennially by the South Texas Section of the AIChE, initiation of training in process safety for small and medium businesses through cooperative efforts involving the Texas Engineering Extension Service and the Center for Chemical Process Safety, etc.

1. INTRODUCTION

Since its formal establishment in October of 1995, the Mary Kay O=Connor Process Safety Center has initiated a variety of activities in the areas of process safety education, service and research. This presentation will review some of the activities leading up to the establishment of the Center and the activities initiated by the Center under the direction of its founder, Ron Darby, with emphasis on ongoing research programs.

2. PRECURSOR ACTIVITIES

Our first formal activity in process safety occurred in the summer of 1991. A good friend, Ralph Vernon, who was then director of the Safety Engineering Program in Industrial Engineering at A&M had received a contract to train 24 Indonesian engineers from Pertamina Oil Company in safety engineering in a 10 week summer program, and Ralph enlisted me to help in that activity. The book AProcess Safety Engineering@ by Dan Crowl and Joe Louvar had recently been published, and the very practical and relevant nature of the subject appealed to me, so I agreed to help with the program. We covered the entire book that summer with the Indonesian engineers, and all of us learned a lot. Also as part of this program, I arranged plant tours for the group through the Dow plant in Freeport, the Exxon refinery in Baytown, and the Mobil polymer plant in Beaumont. The personnel in these plants were most cooperative, and made some very impressive presentations to the group on the engineering and management aspects of their process safety programs. All-in-all, it was a very positive experience for all of us and, best of all, Ralph Vernon and I became even closer friends.

As a result of this experience, and the increasing emphasis being placed on process safety by the AIChE through the CCPS, I proposed to the Chemical engineering department head that I establish an elective

course in the Chemical Engineering curriculum on Chemical Process Safety. He was very reluctant at first, since the department was attempting to cope with a large increase in the undergraduate enrollment and, at the same time, reduce teaching loads for faculty to provide greater opportunity for research activities. However, he finally agreed to let me teach the course on the provision that it would be an Aoverload@ - i.e. over and above my normal teaching load. Although it was considerably more work than normal, I agreed to do this as I recognized the significance and importance of the subject. I taught the first course in the Fall of 1993, and it was very well received by the 45 or so students who signed up for the course. In fact, one of the students who took the course and graduated at the end of that semester told me that he got a job primarily on the strength of the experience that he got in the course.

3. ESTABLISHMENT OF THE CENTER

Sometime during 1992, I received a letter from a lawyer in Houston, stating that he had an unnamed client who was interested in supporting a program in chemical Process Safety at a university, and requesting information on our interests in this area. I responded with a summary of my interests, an outline of my course, and a listing of activities in the Safety Engineering program. More than a year passed and I had forgotten about the letter when I received another letter from the lawyer stating that Mr. T. Michael O=Conner would like to set up an endowed fund to support our program in Chemical Process Safety, with an emphasis on educating engineering students in this field. Mr. O=Connor was a chemical engineer (and an alumnus of the University of Missouri at Rolla). His wife, Mary Kay O=Connor (an alumnus of the University of Missouri at Columbia and also a chemical engineer) was one of the 23 fatalities from the explosion at the Phillips Chemical plant at Pasadena, TX in October, 1989. Rather than participate in the resulting class action lawsuit, Mr. O=Connor pursued his own legal initiative, which was ultimately successful. One provision of the settlement was that a portion of the proceeds be set aside to promote education in process safety. As a result, an agreement was signed by the Texas Engineering Experiment Station and Mr. O=Connor in July of 1994. The endowment fund was set up through a private foundation, with the proceeds earned by the fund to be used for support of the process safety program.

Soon after the agreement was signed, I initiated a proposal to have the program designated formally as a Center in TEES by the Texas A&M Board of Regents. This required a description of the mission and purpose of the center, and a formal proposal to the Texas A&M Board of Regents. The proposal was presented to the Regents= meeting in the summer of 1995, and the Mary Kay O=Connor Process Safety Center was formally voted on and approved by the Regents at their meeting in October, 1995.

4. EDUCATIONAL INITIATIVES

4.1 Courses in Process Safety. The undergraduate elective course in Process Safety has already been mentioned. This course is cross-listed with the Safety Engineering program, and is open to senior engineering students from all disciplines. In 1996, a parallel graduate course was established, and these courses are both taught each Fall. The course is quite popular, despite having a reputation for being Aa lot of work@, since it provides very practical application of many of the engineering principles that are

covered in most of the previous chemical engineering courses, directed toward a very important, timely and relevant topic. The scope of the course includes the book by Crowl and Louvar, with an added feature, that turned out to be very effective being a required term paper/project. The students work together in teams of three or four on their homework assignments and also on the term project, which is done on a topic chosen from a list of topics which complement the lecture material in the course. Each group also makes a presentation to the class on their project, and many of them develop a great enthusiasm for this project. In addition, each student has been required to write an essay concerned with some aspect of incorporating process safety into the chemical engineering curriculum. Many of these essays have been excellent, and they are submitted to the CCPS Undergraduate Education Committee for the essay competition sponsored each year by the Committee. The first two years of competition, students from this class won both first place and honorable mention prizes in the competition, and the third year one received an honorable mention award.

4.2 Faculty Education in Process Safety. One of the initial problems encountered in the endeavor to educate students in process safety was first to educate the faculty on this subject. Since Process Safety has not been not an established subject taught in the typical engineering curriculum, most faculty do not understand or appreciate the scope or significance of the subject. This is somewhat ironic, because many of the students are acutely aware of the importance of the subject by virtue of their contacts with industry through their summer intern and coop industrial work experience. Therefore, one of the first formal activities as Director of the Mary Kay O=Connor Process Safety Center was to sponsor faculty participation in Continuing Education courses conducted by the CCPS program of the AIChE. A half-price Avolume discount@ was negotiated from the AIChE, and we offered to send interested faculty to a CCPS course of their choice with their only expense being travel and accommodations. A total of eight faculty from three different departments in engineering plus the medical school participated in this program starting in the Spring of 1996, each taking a different course. The incentive was to give these instructors some background training in an area of process safety that they could incorporate into the engineering courses that they teach.

4.3 Laboratory Experiment on Runaway Reactions and Relief Sizing. A laboratory is being set up to evaluate the reactivity of chemicals and mixtures of chemicals, and to obtain data needed to size relief systems for runaway reactions. Center funds were used to renovate this lab, and to install a hood enclosure. An RSST (Reactive Systems Screening Tool), with associated computer for control and data analysis, was purchased from Fauske and Associates for this laboratory, and is being set up and evaluated by a student worker paid by the Center. The equipment can be used for research, or for testing as a service, but will be used primarily to run one or more AmodelA runaway reactions as an experiment in the undergraduate Unit Operations Laboratory. The experiment will be set up to illustrate the characteristics of a runaway reaction, to obtain P and T data vs time from the reaction which will be applied to size a relief device for a runaway reactor. The setup should be completed this summer.

4.4 CCPS Undergraduate Education Committee. We have been an active member of this committee (also known as SACHE - Safety in Chemical Engineering Education) since the Center was formed. The function of the SACHE program is to promote Process Safety Education and to develop teaching materials that can be used to assist the incorporation of process safety topics into the chemical

engineering curriculum. Chemical engineering departments may join the SACHE program for a fee of $300/year, for which they receive usually six @deliverables@ each year - one CCPS AGuidelines@ book, and two to four Instruction/Design/Presentation modules prepared by the Committee. The Committee has also organized and sponsored a three-day Workshop on Process Safety for chemical engineering faculty the past two years, held at BASF in Wyandotte, MI. We have had responsibility for the following Committee projects:

Instruction/Design Module on *AEmergency Relief System Design@*, by Ron Darby- This is a 75 page explanation and documentation of the principles involved in safety relief valve sizing and emergency relief system design based on the current DIERS recommended technology, with worked examples. It has been distributed to the 100+ SACHE member schools.

1998 Faculty Workshop in Process Safety - The 1998 Faculty Workshop will be held at Dow Chemical in Freeport and Anderson, Greenwood in Houston in May 1998. We are working with Dr. Ron Willey of Northeastern University to organize and conduct this workshop, along with personnel from Dow and Anderson, Greenwood.

4.5 ASEE Summer School for Chemical Engineering Faculty - Workshops on Process Safety

Approximately every four years, the ASEE sponsors a one-week summer school for chemical engineering faculty which provides instruction and workshops on new developments and emerging topics which can be integrated into the chemical engineering curriculum. As part of the ASEE Summer School in Snowbird, Utah on August 9-14, 1997, we organized five workshop presentations on various topics related to Process Safety in the ChE Curriculum which involved faculty from six different universities and two industrial concerns, The workshop topics and participants were:

AProcess Safety in the Design Course@ - W.B. Whiting, Univ. Nevada, Reno; Dan Crowl, Michigan Tech, Chuck Shepard, Louisiana Tech

AProcess Safety in the Chemical Engineering Curriculum@ - Jim Cobb, Univ. of Pittsburgh; Bob Bethea, Texas Tech

AProcess Safety - Electrostatic Hazards: Lab Demo/Experiments@ - Jack Wehman, BASF Corporation

AProcess Safety in the Unit Operations Lab@ - David Murhammer, Univ. Of Iowa; Dan Crowl, Michigan Tech; Bob Bethea, Texas Tech

AProcess Safety - Relief Design for Runaway Reactions - Lab/Demo@ - Tom Fitzsimmons, Fauske & Associates

5. SERVICE ACTIVITIES

5.1 Safety Center Office/Library/Computer. We acquired an office for the Center activities, and used the Center funds to build bookcases and to build the Center library. Besides many CCPS Guidelines publications, holdings include several hundred publications on various process safety topics, manuals and software for dispersion models, documentation and software for safety relief valve selection and sizing, SACHE Instruction Modules on various process safety topics, videotapes on hazard evaluation and safety reviews, several safety periodicals, etc. The Process Safety Center office was also equipped with a computer and printer, and software was acquired for sizing and design of safety relief systems as well as a collection of programs for vapor cloud dispersion modeling. Software in residence on the computer includes WEB page documentation, various programs for dispersion modeling, programs for relief valve sizing and two-phase flow analysis, ASPEN Plus with Polymer Plus, SuperChems for DIERS, TPHEM and others. All of these programs were obtained at no charge to the Center or the university, but some are subject to certain restricted applications by agreement with the provider. Software which was purchased with Center funds includes COREL Office Suite 7 and Microsoft Office packages.

5.2 WEB Site. A WEB site for the Mary Kay O=Connor Process Safety Center was established, which described the Center, its objectives, function, and organization. and all holdings of the library were cataloged made available on hard copy as well as on the Center=s WEB page. Also resident on the WEB site are the following:

! **Inventory of Center Library Holdings** - Cataloged by Subject Area and Author

! **Index of Papers Presented at all DIERS Users Group Meetings**

! **Literature Survey on Two-Phase Flow**

! **Summary of DIERS Research Project on Viscous Two-Phase Flow in Safety Relief Valves**

5.3. Safety Training for Small/Medium Enterprises. A program was initialed to develop a cooperative effort between the Texas Engineering Extension Service (TEEX) and the Center for Chemical Process Safety (CCPS) to provide training courses for small and medium sized enterprises which lack the resources to develop required safety programs and perform necessary safety engineering functions without assistance. This program was put on Ahold@ after re-organization of TEEX.

5.4 Professional Service - AIChE. We have been active in various AIChE activities related to process safety. In addition to membership in the AIChE=s Safety and Health Division, we have taken a leadership role in the biennial Plant Process Safety Symposia, sponsored by the South Texas Section of the AIChE, as follows:

! Symposium Chair, **1996 Plant Process Safety Symposium**

Session Chair: *AEmergency Relief Systems, I@*

Session Co-Chair: *AEmergency Relief Systems, II@*

! Organizing Committee, **1998 Plant Process Safety Symposium**

Session Chair: *AProcess Safety in University Curricula@*

6. MEMBERSHIP IN DIERS USERS GROUP

We are an Associate Member of the DIERS Users Group, which is a voluntary organization of company representatives who are concerned with developing and applying rigorous design methods for emergency relief systems and devices. The Users Group meets twice a year, and sponsors formal technical papers and informal discussions on topics related to runaway reactions and emergency relief system design and analysis. We have made four presentations at these meetings:

R. Darby, *AA Proposal for Research on Viscous Two-Phase Flow in Relief Valves@*, Houston, TX, February, 1996

R. Darby, *AThe Viscosity Correction Factor for Safety Relief Valves@*, Calgary, Alberta, Canada, September, 1996

R. Darby, *AProgress Report on Viscous Two-Phase Flow in Relief Valves@*, Scottsdale, AZ, April, 1997

R. Darby, *AState of the Art Survey on Viscous Two-Phase Flow in Relief Valves@*, Pittsburgh, PA, October, 1997

! R. Darby, *APerspectives on Safety Relief Valve Sizing for Two-Phase Flow@*, presented at the **2nd International Symposium for Runaway Reactions, Pressure Relief Design, and Effluent Handling**, New Orleans, LA, March 12, 1998.

On a related subject, a 1 2 hour presentation will be made at the 68th Annual Michigan Safety Conference (approximately 5000 industrial participants) in Lansing Michigan:

! R. Darby, *AEmergency Relief Systems@*, **68th Annual Michigan Safety Conference**, Lansing, MI, April 21, 1998.

7. RESEARCH ACTIVITIES

7.1 The Gulf Coast Consortium for Emergency Relief Valves. We are one of the founders and the leading participant in this consortium, which is composed of university and industrial members in the Gulf Coast area with a common interest in research on safety relief valve performance for two-phase flow applications. Members of the Consortium are:

Texas A&M University, Chemical Engineering, Ron Darby

Texas A&M University, Mechanical Engineering, Malcolm Andrews

Prairie View A&M University, Jorge Gabitto

Keystone Anderson, Greenwood, Mike McNeely

Dresser Valves and Controls Division, Kam Molavi

Kvaerner Systems, Vic Edwards

Bechtel Engineers and Constructors, Freeman Self

Dow Chemical Texas Division, Val Janecek

Shell Technology Westhollow, Marc Levin

Teledyne Faris Valves, Y.S. Lai

The function of the Consortium is to oversee and to provide direction and advice on the DIERS sponsored research program on AViscous Two-Phase Flow Through Safety Relief Valves@, which is administered by TEES and directed primarily by Ron Darby, which is described below.

7.2 AViscous Two-Phase Flow in Safety Relief Valves@ (DIERS). In 1996, in response to an RFP from the DIERS Users Group for research on viscous two-phase flow in relief valves, we responded with a proposal and oral presentation on behalf of the Gulf Coast Relief Valve Consortium. The proposal was presented at the February,1996 meeting of the DIERS Users Group, along with competing proposals from A.D. Little and Crosby Valve Co. We were selected by the group for the contract. I am the principal contact with primary responsibility for the contract (through TEES), although J. Gabitto at Prairie View is listed as the Principal Investigator. The contract covers the expenses of two graduate students (one at A&M and one at Prairie View), and involves four phases:

! Summary and Evaluation of AState-of-the-Art@ Design Methods for Sizing Safety Relief Valves for Two-Phase Flow

! Computational Fluid Dynamics (CFD) - Predictions of Valve Pressure-Flow Behavior for Viscous Single and Two-Phase Flow

! Experimental Design for Obtaining a Reliable Data Base for Verifying Models for Viscous Single and Two-Phase Flow in Safety Relief Valves

! Experimental Data Base - Experiments on Valve Nozzles and Valves at Anderson, Greenwood Test Facilities near El Campo, TX

The experimental portion is supported by Anderson, Greenwood and Co. and is being conducted in their test facilities in Stafford, Texas and in El Campo.

The following publications have resulted so far from this work:

R. Darby and K. Molavi, *AViscosity Correction Factor for Safety Relief Valves@*, ***Process safety Progress***, v. 16, no. 2, pp 80-82, 1997

R. Darby, *AViscous Two-Phase Flow in Safety Relief Valves - Phase I, Present Status and Recommended Design Procedures@* , AIChE, November, 1997

R. Darby, *AViscous Two-Phase Flow in Safety Relief Valves - Phase II, Experimental Design@*, AIChE, October, 1997 (in revision)

R.Darby,*A Perspectiveson Safety Relief Valve Sizing for Two-Phase Flow@*, 2nd International Symposium on runaway Reactions, Pressure Relief Design and Effluent Handling@, AIChE, New Orleans, LA, March 11-13, 1998

One graduate student at Texas A&M and one at Prairie View are being supported on this project.

7.3 Research Summary - Viscous Two-Phase Flow in Safety Relief Valves. It is extremely important that relief devices and associated piping and vessels be sized correctly. If the device is too small the excess pressure cannot be relieved properly, with possibly disastrous results. If the device is too large, the downstream piping may be insufficient to handle the load of the discharged effluent and/or improper operation including unstable response and damage to the relief valve can result.

The procedure for properly sizing a relief valve involves prediction of the valve capacity from a theoretical model (e.g. an isentropic nozzle), and supplementing this result by a measured Acorrection factor@ or discharge coefficient to account for deviation of the valve capacity from the theoretical nozzle capacity. The nozzle models, and corresponding values of the discharge coefficients, are well documented for low viscosity single-phase fluids (i.e. air, water and steam). However, there are no data on the pressure-flow characteristics of safety relief valves under conditions of high viscosity (low Reynolds number) flow. API 520 includes a K_v Acorrection factor@ to be applied to the valve discharge coefficient to correct for this condition, but this factor has been adopted from prior work on control valves, which differ significantly in design from relief valves. K. Molavi has performed CFD calculations on an actual safety relief valve geometry over a wide range of Reynolds numbers and two widely different nozzle diameters, and Darby and Molavi (1997) have reduced these results to a quantitative expression which expresses the correction factor K_v as a function of Reynolds number and nozzle β = d/D ratio.

Many actual applications involve the discharge of complex viscous two-phase gas-liquid mixtures, for which neither the appropriate model nor the discharge coefficient have been confirmed. The objective of this program is: (1) to survey and evaluate the theoretical and experimental work that has been don relevant to two-phase flow in relief valves: (2) establish what appears to be the present Astate of the art@ for sizing valves for two-phase flow; (3) recommend an experimental design for acquiring the data necessary to validate the appropriate sizing relations; and (4) conduct the necessary experiments to establish the data base and use it to compare and evaluate the various sizing methods.

It has been estimated that there over 50,000 papers in the literature dealing with two-phase flow. Approximately 350 of these references which apply most directly to either the theoretical or experimental evaluation of the flow through relief valves and associated systems were surveyed and evaluated. There are many factors that must be considered in a two phase system that are not present in single phase flows with regard to the phase distribution, interaction between the phases (e.g. slip, non-equilibrium, etc.), the presence or absence of a phase change (e.g. flashing), etc., as well as the physical/ thermal properties of the two-phase mixture. Based on this evaluation, a report was written summarizing the Astate of the art@, with recommendations for valve sizing procedures for a variety of flow conditions.

The uncertainties and unknowns in the present state of the art were considered in designing an experimental study to address these unknowns. The unknowns relate to both the extent to which existing models for the isentropic nozzle represent actual nozzle flow behavior, as well as how well the nozzle model represents actual valve behavior. The experimental program is designed to address unverified effects of high viscosity (low Reynolds number) in single-phase as well as two-phase flows in both nozzles and valves, and the effect of gas-liquid ratio and non-equilibrium effects in both nozzles and valves. The experiments will be conducted in the test facilities of Anderson, Greenwood and Co., which are officially qualified for certifying relief valve flow capacities. The results will be compared to various existing models and computer methods in order to determine which of these provide the best methods for predicting the two-phase flow behavior in valves as a function of the physical properties and thermodynamic state of each of the phases, the relative amounts of the phases, and the operating conditions (pressure and temperature)

The basic problem is establishing the proper calculational procedure to use to determine the valve nozzle area. This is determined by the required mass relieving rate and the mass flux capacity of the nozzle, as follows:

The valve mass flux, in turn, is determined from a theoretical model for an isentropic nozzle, multiplied by a Acorrection factor@ or discharge coefficient:

The discharge coefficient accounts for (1) deviations of the ideal nozzle model from the performance of a real nozzle, and; (2) deviations of the flow behavior in a nozzle from that in an actual valve. A summary of what is known (or documented) and what isn=t is given below.

KNOWNS

Single Phase Flow

Liquids - Low Viscosity (High Reynolds Number)

Model - Bernoulli

$\mathbf{K_D}$ = 0.6 - 0.8 (ARed Book@)

Gas - Critical (Choked)

Model - Ideal Gas

$\mathbf{K_D}$ .0.98 (ARed Book@)

UNKNOWNS

Single Phase Flow

Liquids - High Viscosity (Low Reynolds Number)

Model - Bernoulli

$\mathbf{K_v}$ Correction to K_D

(Determined from CFD Calculations and Control Valve Data - **No Data** for Relief Valves)

Gas - Sub-Critical

Model - Ideal Gas

$\mathbf{K_D}$. 0.6 - 0.8 (Valve Body Effect not Documented)

Two-Phase Flow - (No Established Data Base or Verified Models - 40,000 publications)

Frozen (Constant Quality)

Model (?)

Slip (?), No Slip (?)

Analytical (?), Numerical (?)

Mixture Properties (?); Viscous (?), Inviscid (?)

$\mathbf{K_D}$ = ?

Flashing (Variable Quality)

Model (?)

Sub-Cooled (?), Saturated (?)

Homogeneous (?), Non-Homogeneous (?)

Equilibrium (?) - (Long Nozzle)

Non-Equilibrium (?) - (Short Nozzle)

Analytical (?), Numerical (?)

Fluid Mixture Properties (?)

Viscous (?), Inviscid (?)

$\mathbf{K_D}$ = ?

The research program is designed to address these unknown factors.

A Historical Perspectives on Chemical Process Safety at Texas A&M@

Education, Research and Service

Ron Darby
Professor of Chemical Engineering
Texas A&M University

FORMATION OF THE

MARY KAY O'CONNOR PROCESS SAFETY CENTER

Precursor Activities

Summer 1991 - Safety Course for

24 Pertamina Engineers

Fall 1993 - First Elective Course -

CHEN 455 PROCESS SAFETY

Establishment of the Center

1993 - First Inquiry

1994 - Agreement Signed

1995 - Center Formally Approved by Texas A&M Regents

Center Initiatives

Education, Research, Service

EDUCATION

Courses in Process Safety

Undergraduate - CHEN/SENG 455- Process Safety

Lectures/Team Projects/Essays

(Two AFirsts@, Three AHonorables@)

Graduate - CHEN 655 - Process Safety

Lectures/Design Projects/Essays

Faculty Education in Process Safety

Seven Faculty sent to various CCPS Courses in Process Safety

Laboratory Experiment - UG Unit Ops Lab

RSST - Runaway Reactions/Relief Sizing

CCPS Undergraduate Education Committee

R. Darby, *ADesign Module on Emergency Relief Systems@*, AIChE, 1997 (ISSBN 0-8169-07218)

AChE Faculty Workshop on Process Safety@ - with Ron Willey, NEU, Freeport/Stafford, TX, May 1998

! Reactivity ! P H A ! Emergency Relief Systems

ASEE Summer School for

Chemical Engineering Faculty

Snowbird, Utah, August 1997

Five Workshops:

AProcess Safety in the Design Course@ - W. B. Whiting, Univ. Nevada, Reno; Dan Crowl, Michigan Tech, Chuck Shepard, Louisiana Tech

AProcess Safety in the Chemical Engineering Curriculum@ - Jim Cobb, Univ. of Pittsburgh; Bob Bethea, Texas Tech

AProcess Safety - Electrostatic Hazards: Lab Demo/Experiments@ - Jack Wehman, BASF Corporation

AProcess Safety in the Unit Operations Lab@ - David Murhammer, Univ. Of Iowa; Dan Crowl, Michigan Tech; Bob Bethea, Texas Tech

AProcess Safety - Relief Design for Runaway Reactions - Lab/Demo@ - Tom Fitzsimmons, Fauske & Associates

SERVICE ACTIVITIES

Safety Center Office/Library/Computer

WEB Site:

! Inventory of Center Library Holdings

! Index of Papers Presented at all DIERS Users Group Meetings

! Literature Survey on Two-Phase Flow

! Summary of DIERS Research Project on Viscous Two-Phase Flow in Safety Relief Valves

Safety Training for Small/Medium Enterprises

Professional Service - AIChE:

! Symposium Chair, **1996 Plant Process Safety Symposium**=

Session Chair: ***AEmergency Relief Systems, I@***

Session Co-Chair: ***AEmergency Relief Systems, II@***

! Organizing Committee, **1998 Plant Process Safety Symposium**

Session Chair: ***AProcess Safety in University Curricula@***

MEMBERSHIP IN

DIERS USERS GROUP

Presentations:

R. Darby, *AA Proposal for Research on Viscous Two-Phase Flow in Relief Valves@*, Houston, TX, February, 1996

R. Darby, *AThe Viscosity Correction Factor for Safety Relief Valves@*, Calgary, Alberta, Canada, September, 1996

R. Darby, *AProgress Report on Viscous Two-Phase Flow in Relief Valves@*, Scottsdale, AZ, April, 1997

R. Darby, *AState of the Art Survey on Viscous Two-Phase Flow in Relief Valves@*, Pittsburgh, PA, October, 1997

! R. Darby, *APerspectives on Safety Relief Valve Sizing for Two-Phase Flow@*, presented at the **2nd International Symposium for Runaway Reactions, Pressure Relief Design, and Effluent Handling**, New Orleans, LA, March 12, 1998.

Also:

! R. Darby, *AEmergency Relief Systems@*, **68th Annual Michigan Safety Conference**, Lansing, MI, April 21, 1998.

RESEARCH ACTIVITIES

The Gulf Coast Consortium for Emergency Relief Systems

Texas A&M University, Chemical Engineering

Ron Darby

Texas A&M University, Mechanical Engineering *Malcolm Andrews*

Prairie View A&M University
Jorge Gabitto

Anderson, Greenwood & Company

Mike McNeely

Dresser Valves and Controls Division

Kam Molavi

Kvaerner Systems

Vic Edwards

Bechtel Engineers and Constructors

Freeman Self

Dow Chemical Texas Division

Val Janecek

Shell Technology Westhollow

Marc Levin

Teledyne Farris Fluid Systems

Y.S. Lai

A*Viscous Two-Phase Flow in Safety Relief Valves@* (DIERS)

Four Phases:

! Summary and Evaluation of AState-of-the-Art@ Design Methods for Sizing Safety Relief Valves for Two-Phase Flow

! Computational Fluid Dynamics (CFD) - Predictions of Valve Pressure-Flow Behavior for Viscous Single and Two-Phase Flow

! Experimental Design for Obtaining a Reliable Data Base for Verifying Models for Viscous Single and Two-Phase Flow in Safety Relief Valves

! Experimental Data Base - Experiments on Valve Nozzles and Valves at Anderson, Greenwood Test Facilities near El Campo, TX

THE PROBLEM

Valve Nozzle Area:

Knowns

Single Phase Flow

Liquids - Low Viscosity (High Reynolds Number)

Model - Bernoulli

K_D = 0.6 - 0.8 (ARed Book@)

Gas - Critical (Choked)

Model - Ideal Gas

K_D .0.98 (ARed Book@)

Unknowns

Single Phase Flow

Liquids - High Viscosity (Low Reynold Number)

Model - Bernoulli

K_v Correction to K_D

(Determined from CFD Calculations and Control Valve Data - **No Data** for Relief

Valves)

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Verified Models - 40,000 publications)

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Viscous (?), Inviscid (?)

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Equilibrium (?) - (Long Nozzle)

Non-Equilibrium (?) - (Short Nozzle)

Analytical (?), Numerical (?)

Fluid Mixture Properties (?)

Viscous (?), Inviscid (?)

K_D = ?

PUBLICATIONS

R. Darby and K. Molavi, ***AViscosity Correction Factor for Safety Relief Valves@***, Process Safety Progress, v. 16, no. 2, pp 80-82, 1997

R. Darby, ***AViscous Two-Phase Flow in Safety Relief Valves - Phase I, Present Status and Recommended Design Procedures@*** , AIChE (DIERS), November, 1997

R. Darby, ***AViscous Two-Phase Flow in Safety Relief Valves - Phase II, Experimental Design@***, AIChE, (DIERS), October, 1997 (in review)

R. Darby, ***APerspectives on Safety Relief Valve Sizing for Two-Phase Flow@***, 2nd International Symposium on runaway Reactions, Pressure Relief Design and Effluent Handling@, G.H.

Melham and H.G. Fisher (Eds), AIChE,
New Orleans, LA, March 11-13, 1998

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