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64th NATIONAL SAFETY CONGRESS

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Petroleum Sessions

PRINCIPLES AND LIMITATIONS OF GAS DETECTION INSTRUMENTATION

By WARREN J. RILEY
Warren Industries, Cupertino, CA

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Gas detection techniques have evolved from rather primitive methods to modern electronic instruments capable of detecting minute concentrations of combustible and toxic gases.

The basic use of gas detection equipment today is to check or monitor an area for combustible or toxic conditions.

Yet, modern gas detection remains as one of the least understood and most under-estimated safety tools available.

Gas detection equipment must be chosen, operated, and maintained carefully in line with its importance. The limitations inherent in the use of such equipment must be kept in mind at all times.

Principles used in modern-day gas detection include: CATALYTIC COMBUSTION; THERMAL CONDUCTIVITY; ELECTRO CHEMISTRY; GAS CHROMATOGRAPHY; DETECTOR TUBES; OPTICS; FLAME IONIZATION; and CHEMICAL PHYSICS. Each of these principles finds specific application in one or more detection situations.

Before a choice of detection method is made, the problem must be defined and the expectations set forth. This will usually lead to an obvious choice. Factors used in defining an application include: AREA TO BE MONITORED; TYPE OF OUTPUT NEEDED; SPECIFICITY OF SENSOR; AMBIENT CONDITIONS; RESPONSE TIME; POWER REQUIREMENTS; and PERSONNEL.

Common limitations of the typical gas detection program include: too little time

allocated to the program; little knowledge of basic gas detection definitions (LEL, TLV, etc.) on the part of operating personnel; lack of consideration for factors effecting gas detection (type of gas, sources of leaks, temperature, ventilation, gas movement, etc.; misunderstanding of accuracy vs repeatability; insufficient calibration and check-out procedures; insufficient record keeping; improper choice of operating personnel; operator belief that, through some magic, the detector can "see" a hazard; and insufficient training of engineering, operating, and maintenance personnel. While this is not a complete list, it does include some of the more common problems found in many operating gas detection programs.

Any gas detection program requires a minimum allocation of time for each of its four major phases: planning; training; equipment selection; and maintenance.

Example of time allocation:

Function	Time Spent		
	Typical*	Optimum*	Your
Planning	10%	20%	—
Equipment Selection	75%	30%	—
Training	5%	20%	—
Maintenance	10%	30%	—

Fill in the time that "Your" organization spends or has planned to spend on these four phases. Compare "Your" times with the "Optimum" values. You may find that some reconsideration is in order.

Potential limitations exist, whether you are using basic detection methods or

the most sophisticated electronic systems. A lack of understanding about these limitations can lead to incorrect readings. For example, can the equipment: Operate under ambient conditions? Give needed stability and accuracy? Be easily calibrated?

With few exceptions, the information gained from a gas detector must be interpreted and acted upon by an individual. Each person responsible for installing, using, or maintaining gas detection equipment must be knowledgeable of the limitations connected with their equipment and take proper precautions to avert trouble.

Many of the personnel problems can be solved through training of the right people at the right time. Training should include: objectives of the program; principles of operation; program limitations; operation of the specific hardware;

maintenance requirements; and record keeping. Training begins (with the engineering personnel) before the equipment is purchased and continues through commissioning. Routine retraining should then be conducted.

Modern gas detection equipment can and will provide an important source of information on the existence of potentially hazardous situations.

A clear understanding of the principles and limitations of the equipment is necessary to realize the full value of any gas detection program. This understanding could also prevent a false sense of security leading to disaster.

In the final analysis, the interpretation of readings and decisions for corrective action must be left in the hands of the responsible individual.

*Values are based on the author's evaluation of percentages stated in conversations with numerous clients.

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RECENT RESEARCH ACTIVITY ON FIRE AND EXPLOSIONS BY FACTORY MUTUAL RESEARCH

By MYRON J. MILLER

Factory Mutual Research Corp., Norwood, MA

aintenance requirements; and recording. Training begins (with the steering personnel) before the equipment is purchased and continues through commissioning. Routine training should then be conducted. Modern gas detection equipment can will provide an important source of information on the existence of potential hazardous situations.

A clear understanding of the principles and limitations of the equipment is necessary to realize the full value of any detection program. This understanding could also prevent a false sense of security leading to disaster. In the final analysis, the interpretation of readings and decisions for corrective action must be left in the hands of the responsible individual.

are based on the author's evaluation of percentages in conversations with numerous clients.

In 20 years in the loss prevention business, I have been troubled, not only by the questionable effectiveness of many protective systems, but even more so by the inadequacies in our ability to measure that effectiveness. The question "How are we doing?" may elicit a response that is satisfactory to the underwriter but hardly satisfying to the research engineers and scientists seeking a goal for systems improvement.

Consequently, in 1974, I presented a paper on the "Reliability of Fire Protection Systems" at the AIChE Loss Prevention Seminar. The paper presented some comparative statistics on apparent system performance but, more importantly, dwelt on the needs for better information. Since then, a number of efforts have been started. Some of these have been cited in my Karlsruhe paper.² New studies are presently in preparation by Factory Mutual and others for release early next year. International cooperation in this area was also discussed in Karlsruhe.

This interest in systems reliability, maintainability, and performance capability (the components of the term "effectiveness") led naturally to questions regarding the assumptions used in the design of specific systems. Since I have been involved in the development of halon systems and serve on NFPA 12A and B, this area became the first target of opportunity. Some of the changes that are being proposed in NFPA 12A/B involve pipe flow calculations and the design concentrations for flame extinguishment and inerting. I will only dwell on the latter two here.

Preprints of these revised standards are now available from the NFPA,³ and public comment must be received before December. I encourage your review.

Flame Extinguishment With Gaseous Agents

Figure 1 shows a comparison of recommended design concentrations now in the 1973 Standard with those to be voted on at the spring 1977 meeting of NFPA. As you can see, there are some significant changes. These changes have resulted from an evaluation of many large- and small-scale tests. Some comparisons of results at different scales are shown in the following two figures. Figure 2 compares dynamic experiments. Figure 3 compares total flooding experiments.

These comparisons resulted in the development of a laboratory system with which extinguishing concentration data could be obtained both economically and with a high degree of consistency. Provisions for heating both the burner and the fuel made it possible to compensate for differences in heat generation and heat transfer at large- and small-scale. The apparatus and techniques have not yet been completely standardized, but a comparison of the results from three laboratories shows reasonable agreement, as shown in Figure 4. Recommended design values have been obtained by adding a 20 per cent safety factor to the average of values from a minimum of three laboratories. To date, the Factory Mutual Research Corporation (FMRC), Du Pont, ICI, and the Ansul Company have participated in this effort. Others are encouraged to participate.

Figure 1
Comparison of Old and New
Design Values for Flame Extinguishment

	1211		1301	
	Old	New	Old	New
Acetone	4.2	5.0	—	5.0
Benzene	3.9	5.0	—	5.0
Ethanol	5.0	5.0	4.0	5.0
Ethylene	6.5	8.6	7.2	8.2
Methane	4.3	5.0	2.0	5.0
Heptane	4.3	5.0	3.7	5.0
Propane	4.8	5.8	3.2	5.2

Figure 2

	Dynamic Experiments				
	1	2	3	4	5
Methane	1.5		4.5	1.3	1.7
Heptane		4.0	4.5	3.8	
Hydrogen	17.7		27.0	18.0	18.0
Burner Size	5.4 mm ID	38.5 mm ID	28 mm ID	5 in. ID (Liq) 1 1/4 in. ID (Gas)	8 mm ID
Enclosure Size	50 mm ID	105 mm ID	105 mm ID	2 x 2 ft	105 mm ID

Figure 3

Total Flooding Tests					
6	7	8	9	10 (1211)	11
3.3	3.5	2.5	3.4	3.4	0.9
2 1/8 in. ID 3 1/8 in. ID 12 x 12 in.	2 1/8 in. ID 3 1/8 in. ID 12 x 12 in.	2 1/8 in. ID 3 1/8 in. ID	38 x 38 in.	5 ft. ² Circular	38 x 38 in.
180 ft ³	893 ft ³	1000 ft ³	9242 ft ³	2500 ft ³	9856 ft ³

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Figure 4

nd New xtinguishment	Halon 1301				Halon 1211			
	Old	New	1973 NFPA	1976 A B C	1973 NFPA	1976 A B C	1973 NFPA	1976 A B C
—	—	5.0	1.8	3.0 3.0 4.0	3.9	3.4 3.2 4.5	3.9	3.4 3.2 4.5
—	—	5.0	2.9	4.3 4.2 5.5	4.4	4.7 4.8 5.8	4.4	4.7 4.8 5.8
4.0	—	5.0	6.5	6.4 6.7 8.1	5.9	6.8 7.0 8.5	5.9	6.8 7.0 8.5
7.2	—	8.2	18.0	— 22.2+ 27.5	20.4	25.9+ 27.3+ 34.0	20.4	25.9+ 27.3+ 34.0
2.0	—	5.0	—	2.9 3.6 3.3	—	3.2 3.8 3.9	—	3.2 3.8 3.9
3.7	—	5.0	—	3.2 3.5 3.3	—	2.9 2.9 3.6	—	2.9 2.9 3.6
3.2	—	5.2	3.3	3.3 4.3 4.2	4.5	3.9 4.5 4.8	4.5	3.9 4.5 4.8
			3.4	3.7 4.5 4.5	3.9	4.0 4.4 4.6	3.9	4.0 4.4 4.6

Experiments

	4	5
5	1.3	1.7
5	3.8	
.0	18.0	18.0
n ID	5 in. ID (Liq) 1 1/4 in. ID (Gas)	8 mm ID
m ID	2 x 2 ft	105 mm ID

ests

	10 (1211)	11
4	3.4	0.9
38 in.	5 ft. ² Circular	38 x 38 in.
2 ft ³	2500 ft ³	9856 ft ³

A five per cent concentration is considered the minimum that should be used since there is always some uncertainty as to the fuel that will be present in a fire. A five per cent concentration covers a wide variety of common fuels.

The design values recommended are for a pool fire configuration only. The complications introduced by running fuel, sprays, vapor jets, or hot surfaces have not yet been completely defined, but in all probability will require higher concentrations.

Flame extinguishment concentrations of halons for all fuels are temperature dependent, many to a significant degree.

The design values recommended presume "rapid" detection and suppression within the required 10-second (or less) discharge period. The definition of "rapid" detection will depend upon the nature of the fire anticipated and may range from milliseconds to as much as several seconds. Longer detection times will generally be an invitation to trouble. Not only will the increased fire size resulting from delay increase the quantities of combustion/decomposition products, but the probability of successful suppression may decrease due to increased temperatures and generation of energy balance conditions favoring the fire.

Work is still progressing on the standardization of laboratory systems, with much of the attention to be focused upon

the effects of temperature. Many of the changes in threshold concentrations, seemingly dependent upon flow conditions, can probably be ascribed to flow-induced changes in the temperature of the air/agent mixture and resultant changes in heat transfer and stability at the flame/burner interface.

Flow and mixing phenomena and flame stabilization effects are important, however, and must also be considered in both experiment design and translation of the results to real fire situations. Some of these questions have been addressed in a report just published by S. N. Bajpai and M. A. Delichatsios of FMRC.⁴ Copies of this report should be available shortly on request.

A related experimental system was developed by Tewarson of FMRC to study the burning of plastics.⁵

Inerting Gaseous Mixtures

All that we have said about flame extinguishment can also be said about inerting, except that we have not as yet had the advantage of an interlaboratory comparison of data. A report by John Coll of Fenwal Inc.⁶ has just been issued and apparatus is being assembled by FMRC and ICI to conduct similar experiments. Round robin experiments with several other systems have preceded the choice of this apparatus. This apparatus, with a one psi pressure criterion, appears to indicate higher con-

centration requirements for inerting than previously reported using the U.S. Bureau of Mines type of tubular explosion burette.

Not only should existing inerting values for halons be viewed with suspicion, but values for traditional agents such as CO₂ and nitrogen should also be questioned. In addition, modest changes in temperature and ignition energy can result in significantly higher agent concentration requirements. A careful investigation of this dependency is needed.

The future of halon systems depends largely on the record of reliability and effectiveness yet to be established. There is, as yet, no basis for complacency, and a careful analysis of all design assumptions and data is in order.

Explosion Venting and Suppression

Just a few brief comments on explosion venting and suppression. The Factory Mutual System has just issued Loss Prevention Data Sheets 7-76 dealing with combustible dusts.⁷ Much information on explosions and venting has been considered in the preparation of this guide. Copies are available and I would appreciate any comments you might have on the utility of this document.

As Dr. Zalosh of FMRC pointed out last year in a review of explosion venting literature,⁸ there may be order-of-magnitude differences in pressures predicted by various computational methods. Much of the difference is due to the assumptions used.

For instance, in a recent series of experiments conducted by the Coast Guard in the pump room of the tanker *Rhode Island*,⁹ pressures increased from three psig to twelve psig when obstructions were added to generate turbulence. The rate of pressure increase also changes significantly.

Reproduction of the pressure curves could be obtained by changing the turbulence factor in the FMRC computer model.¹⁰ However, predicting these factors in advance still remains a problem.

The multiple pressure peaks often present in vented explosions also need better theoretical treatment.

The papers of Reynst¹¹ describing the development of pulsating combustion show that under very special conditions, a self-sustaining, self amplifying series of explosions can be generated in a vented chamber containing fuel.

Explosion suppression still remains a subject with very little publicly available information. The recent Coast Guard tests⁹ demonstrated the possibilities for using water and dry chemicals as well as halons as suppressants. Optimized combinations may also be appropriate.

In March 1976 I attended a meeting in Stockholm of the International Standards Organization (ISO) Committee on Extinguishing Agents (TC21/SCG). There was no eagerness on the part of members of this committee to address explosion suppressants, particularly since there are already many questions associated with the testing of fire extinguishants. There is as yet no standardized laboratory system for evaluating explosion suppression agents. This subject is being discussed by the ISO Committee on Explosion Suppression Systems (TC21/SC5/WG3).

In September I attended a meeting in Karlsruhe of this committee at which the need for expanded research was discussed. As a result of work done by Dr. W. Bartknecht of CIBA-Geigy¹² a program using a one-cubic-meter test chamber is being proposed. Several independent laboratories hope to participate so that results can be compared, first on explosion behavior alone and then with standardized explosion suppression systems. Factors to be investigated include type and nature of the fuel, degree of turbulence, and type of ignition. Water, halons, and ammonium phosphate will ultimately be compared using several discharge configurations. Hopefully, this work will also investigate the effects of temperature and be coordinated with our studies of inerting using gaseous agents. The question of financial

support for open.

In conclusion, new results in addition to papers, summaries, Antonio in I all. I have a bibliography of references reported in various research publications. If any of you write me and I will be available. The action of FM bibliography publication however, I comments on

Miller, M. J. Systems." *Ch* (April 1974.)
Miller, M. J.: Suppression." national Fire Germany, 22 Report No. R National Fire TCR-77-A An NFPA Pub. N Bajpai, S. N.; by Halons—Pr No. 22545 for July 1976, ir

multiple pressure peaks often present in vented explosions also need theoretical treatment.

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support for this program still remains open.

In conclusion, we have tried to publish new results as work progressed, and in addition to individual reports and papers, summaries were presented at San Antonio in 1975¹³ and at Karlsruhe² this year. I have also compiled a computerized bibliography of halon literature¹⁴ to augment references in these papers. The bibliography includes over 600 citations reported in various ways.

If any of you are interested in FMRC research publications mentioned, please write me and I will try to make copies available. This represents only a small fraction of FMRC's total research effort. A bibliography of other FMRC publications is also available.¹⁵ However, I do solicit your review and comments on any material you receive.

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UNDERWATER SAFETY

By C. H. KLUNICK

Dir. of Safety, Continental Oil Co., Houston, TX

For the past ten years, subsea operations technology has been in a dynamic state of development with an almost continuous gap existing in "what has seemed possible to do" versus "what was proven safe to do." Commercial diving and submersible service companies serving offshore oil exploration and production operations around the world have been pressed on by subsea work requirements in deeper and deeper water—with a minimum of time to adequately and safely prepare for the ever-increasing demands.

Some efforts have been made to provide uniform safety practices for the subsea work industry. In 1968, the American Bureau of Shipping prepared and issued a "Guide for the Classification of Manned Submersibles" as a supplement to the "ABS Rules for Building and Classing Steel Vessels." The ABS Manned Submersible Guide provides a general basis for standardizing the design, construction, test, certification, and, to a limited degree, operations of small submarines.

The U.S. diving industry has also recognized the desirability of having formal, industry-wide regulations to assure safer working practices. However, the job of pulling together a "universally acceptable" set of equipment design, personnel qualification, and procedural standards has been frustrated with numerous delays, largely because of the differences in technical and business requirements which exist across the diving industry and the competitiveness which has tended to restrain the free exchange of information, including safety related data.

After nearly seven years of effort, the Association of U.S. Diving Contractors (ADC) is about to submit a set of comprehensive diving standards to the

American National Standards Institute (ANSI) for review and adoption. The ADC "Manual of Safe Practices in Commercial Diving Operations" provides the basis for a universal code of diving safety with jurisdiction over diving operations in U.S. territorial waters which will also most probably have substantial impact on the spirit, if not the letter, of diving codes and regulations being promulgated around the world by various countries with offshore oil interests.

Review of the ADC Manual of Safe Practices and ABS Guidelines reveals a tendency towards "broad-minimum" rather than "specific-tough" rules to operate by, which should not be too surprising from an inter-industry consensus to accommodate the needs of the broad range of service companies involved.

The availability of comprehensive rules and regulations does not insure safety. Given the time, effort, and money, we can identify and regulate all of the risks inherent in the offshore and subsea operational environment, but the most important ingredients in accident prevention are trained, qualified, careful people on the job.

Review of Critical Subsea Work Safety Areas

As an introduction and rationale for suggested amendments to the ADC Manual and ABS Guidelines, our starting point is to review and discuss those areas where subsea work safety is most critical. In instances where the recommended safe practices or guidelines seem to have a need for strengthening or better definition, amendments have been proposed in a subsequent section for overall incorporation into the Conoco Subsea Safety Manual.

The most safety aspect

1. Pressure

of manner pressure and integrity of operations equipment testing duration, free maintenance procedures, qualification

2. Main atmosphere. Maintenance of subsea work of the correct underwater atmosphere

closed vessel the careful temperature minimization such as CO₂ atmospheric qu

3. Decompression

Although severe decompression procedures and result in varying from effort to permit decompression

thoroughly should be done

of the desired total time up personnel should be properly trained and equipped for field dive recovery for decompression

4. Communication remoteness their assistance communications

SAFETY

NICK
il Co., Houston, TX

merican National Standards Institute (ANSI) for review and adoption. The ANSI "Manual of Safe Practices in Commercial Diving Operations" provides a basis for a universal code of diving safety in U.S. territorial waters which will almost certainly have substantial impact on the spirit, if not the letter, of diving rules and regulations being promulgated around the world by various countries with offshore oil interests.

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The most critical areas to subsea safety appear to be as follows:

1. *Pressure Control.* In every aspect of manned subsea work, control of pressure and maintenance of pressure integrity are essential. Assurance of safe operations involves strict adherence to equipment design standards, adequate testing during the following construction, frequent inspection and maintenance, proper execution of diving procedures, and adequate personnel qualification and training.

2. *Maintenance of Breathing Atmosphere.* In addition to proper pressure maintenance, it is essential to provide the subsea worker a breathing atmosphere of the correct quality whether he is underwater at ambient pressure or in a closed vessel. This requirement dictates the careful selection of gases, control of temperature and humidity, and minimization of atmospheric impurities such as CO₂ and odor. Appropriate atmospheric quality is assured through the use of environmental control systems with adequate backup, insulated pressure vessels, and good operational procedures.

3. *Decompression Procedures.* Although seldom fatal, except in cases of traumatic pressure loss, improper decompression procedures can be debilitating and result in physiological impairment varying from minor short-term discomfort to permanent disability. All decompression procedures should be thoroughly tested prior to field use and should be designed to permit execution of the desired task while minimizing total time under pressure. Responsible personnel should be thoroughly trained in the proper selection of appropriate tables and schedules and their execution. Field dive reports should be monitored for decompression-related incidents, and table modifications or procedural changes should be made accordingly.

4. *Communications.* Because of the remoteness of support personnel and their assistance, clear audio communications in all situations are required

and visual communication is often desirable. This requirement affects equipment standards, testing, and maintenance operations. It also demands functional helium voice unscrambling equipment, routine and emergency communication apparatus, and good viewport visibility for submarines, diving bells, and deck chambers.

5. *Personnel Physical Condition.* To function safely in the water, the subsea worker must be in excellent physical condition; well rested, and free of undue emotional stress. Thorough, regular physical examinations are mandatory to have assurance that no physical condition may exist which would be aggravated by pressure exposure, precipitate decompression sickness, or embolism. Good pre-dive planning and scheduling, coupled with adequate diving crew size, is required to assure reasonable crew rest.

6. *Personnel Comfort.* A subsea worker who becomes physiologically overstressed and is consequently uncomfortable tends to be distracted and less efficient on the job. Depending upon the type of stress and its severity (work rate, breathing effort, respiratory and body surface heat loss), personnel safety may vary from impairment of individual safety consciousness to dangerous, uncontrollable physiological reactions. Adequate personnel comfort is primarily assured by proper selection, use, and maintenance of equipment and underwater tools, employment of proper procedures, and personnel training.

7. *Medical Treatment.* Regardless of all safety precautions which are taken, it must be anticipated that the need will exist for treatment of decompression problems and traumatic injury. All personnel engaged in or supporting ambient pressure diving operations must be properly trained to recognize the signs and symptoms of decompression sickness and embolism. Adequate treatment procedures, equipment, and therapeutic gases must be available and personnel must be trained in their use.

Aboard rigs or vessels without extensive medical facilities and corpsman personnel, the diving team must have its own adequate supply of first aid equipment and be knowledgeable in handling traumatic injuries.

8. *Minimization of Exposure Time.* Thoughtful minimization of the job time underwater reduces risks. This goal is best achieved by thorough pre-dive planning, coordination of subsea functions for maximum single dive effectiveness, and adequate post-dive recovery capabilities.

9. *Handling Safety.* Launch and retrieval of submarines and diving bells and the handling of other equipment and supplies in the diving area must be executed smoothly and safely to avoid the potential for major accidents. Lifting equipment must be built with adequate safety factors and be maintained in good working condition. Personnel must be well trained in handling procedures and associated safety considerations. Alternate lifting equipment should also be available and procedures for its use established in advance of need. Sea state is often the limiting criteria for execution of a dive due to associated handling dangers. The decision to execute or not execute a dive is the responsibility of the subsea work supervisor.

10. *Fire Safety.* Both support vessel and diving equipment fires constitute significant dangers to personnel while confined in a closed environment. The potential for fire can be significantly reduced by proper equipment design, rigorous procedures excluding flammables and ignition sources from inside pressure chambers, and the use of appropriate fire resistant clothing by personnel. The possibility of drilling rig fires resulting from blowouts and other causes must also be considered in view of dangers to pressurized personnel, and evacuation under pressure procedures must be established and understood.

11. *Deck Safety.* Accidents occurring to personnel aboard ship involved in basic operations and ship handling

chores are as frequent or perhaps more frequent than those happening to divers and others under subsea work conditions. General deck safety procedures must be rigorously followed by subsea work team personnel. Specialized procedures for securing, handling, and maintaining equipment unique to the diving operation must also be developed and implemented.

12. *Emergency Procedures Preparation.* The harmful effects of accidental situations can often be reduced or eliminated by properly preparing and practicing emergency procedures to be followed in the event of an incident. An effective accident prevention program includes a thorough review of all possible mechanical and human failures, an analysis of their causes and effects, elimination of the potential hazard by design, if possible, and adequate emergency training and practice. Emergency procedures in the form of specific plans, equipment, and training are established to provide immediate support in those instances where an acceptable but finite risk remains a part of a given operation.

13. *Documentation.* It is absolutely essential for good written communications to be available to support hazardous work situations. This includes proper documentation and maintenance of standard operational procedures, safety practices, and other specialized information, such as decompression schedules and emergency therapy. The information supporting even the simplest manned subsea operation is too voluminous and too critical to be passed on by word of mouth or to rely on memory.

Provisions to Assure the Elimination or Control of Known Potential Hazards

The recommended additions and amendments to the ADC Manual and ABS Guidelines are the result of a review and correlation of the preceding sections with the ADC Manual and ABS

Guidelines to assure the elimination or potential hazards. As revisions, a survey of summary reports of and submarine accidents over the past four years has been placed on file for use as a source of information to prevent accidents.

The Conoco "Submersible Safety Guidelines" is to be employed in conjunction with applicable national, state, and local standards, and regulations for the design, construction, and operation of diving submersible systems, production systems, and other systems in the United States and its territories. This would include provisions of the current ASME pressure vessel and boiler code, Coast Guard marine engine and the American Bureau of Shipping "Guide for the Classification of Submersibles" (1968). Foreign codes and regulations take precedence over the Conoco guidelines if their requirements are more stringent or explicit.

Although some provisions of the guidelines are applicable to the Manual of Safe Practices, the general basis for construction, test, certification of equipment used in ambient pressure diving, personnel transfer capsules, and particularly, all pressure chambers, decompression chambers (SDC's), personnel transfer capsules (PTC's), and submersibles (WHC's) will have pressure ratings and be certified according to the ASME Unfired Pressure Vessel Code and Subchapter D of the Coast Guard Marine Regulations and Materials Specifications. Similarly, the ABS Guidelines provide the general basis for construction, test, cer-

res are as frequent or perhaps more frequent than those happening to divers and others under subsea work conditions. General deck safety procedures must be rigorously followed by subsea work team personnel. Specialized procedures for securing, handling, and maintaining equipment unique to the diving operation must also be developed and implemented.

2. Emergency Procedures Preparation

The harmful effects of accidental operations can often be reduced or eliminated by properly preparing and practicing emergency procedures to be followed in the event of an incident. An effective accident prevention program includes a thorough review of all possible mechanical and human failures, an analysis of their causes and effects, identification of the potential hazards, design, if possible, and adequate emergency training and practice. Emergency procedures in the form of specific plans, equipment, and training are established to provide immediate support in those instances where an acceptable but finite risk remains a part of a given operation.

Documentation. It is absolutely essential for good written communications to be available to support rigorous work situations. This includes proper documentation and maintenance of standard operational procedures, safety practices, and other specialized information, such as decompression schedules and emergency therapy. Information supporting even the simplest manned subsea operation is too numerous and too critical to be passed by word of mouth or to rely on memory.

Provisions to Assure the Elimination or Control of Known Potential Hazards

The recommended additions and amendments to the ADC Manual and ABS Guidelines are the result of a review and correlation of the preceding sections of critical subsea work safety areas in the ADC Manual and ABS

Guidelines to assure provisions for either the elimination or control of known potential hazards. As a primary basis for revisions, a survey of available accident summary reports of commercial diving and submarine accidents over the past four years has been made, and emphasis has been placed on making recommendations to prevent a repetition of identifiable sources of these accidents.

The Conoco "Subsea Safety Manual" is to be employed in conjunction with all applicable national, state, or local laws, standards, and regulations governing the design, construction, test, certification, and operation of diving and man-rated submersible systems, including subsea production system habitats. In the United States and its territorial waters, this would include adherence to the provisions of the current revisions of the ASME pressure vessel codes, U.S. Coast Guard marine engineering regulations, and the American Bureau of Shipping "Guide for the Classification of Manned Submersibles (1968)." Supplementary foreign codes and regulations will have precedence over the Conoco safety practices if their requirements are more stringent or explicit.

Although some provisions of the ABS Guidelines are applicable, the ADC Manual of Safe Practices will provide the general basis for the design, construction, test, certification, and operation of equipment used in support of ambient pressure diving and tethered personnel transfer capsule operations. In particular, all pressure vessels, including decompression chambers (DDC's), diving bells (SDC's), personnel transfer capsules (PTC's), and subsea habitats (WHC's) will have pressure vessels rated and certified according to Section VIII of the ASME Unfired Pressure Vessel Code and Subchapter F of the U.S. Coast Guard Marine Engineering Regulations and Material Specifications, as noted in the ADC manual.

Similarly, the ABS Guidelines will provide the general basis for the design, construction, test, certification, and

operation of manned, free swimming, or power-cable tethered submersibles. The submersible hull will be designed, constructed, and certified according to Section 2 of the ABS Guidelines. Submersibles equipped for ambient diver lockout operations will utilize pressure hulls for the diver lockout capsule which have been certified according to the aforementioned ASME code and U.S. Coast Guard regulations.

Other than the specific demarcation in the certification requirements for pressure vessels as noted above, the subsea equipment procedures, and personnel requirements for Conoco's manned subsea operations will integrate applicable portions of the referenced sections in the ADC Manual, applicable portions of the referenced sections in the ABS Guidelines, and the Conoco Additions and Amendments. In the event of a conflict occurring between the provisions of the ADC Manual, the ABS Guidelines, and the Conoco Amendments, the most stringent or explicit provision will be followed.

Manual of Safe Practices In Commercial Diving Operations

All known sources of information have been considered in preparing this manual. These sources include practices of the U.S. and foreign navies, foreign and domestic diving regulations, recommendations from industry members, U.S. Coast Guard and Industrial equipment codes, and scientific data from university, governmental and industrial sources.

Diving technology is a rapidly expanding science, and the variations in techniques and task complexity experienced throughout the industry are vast. It has taken several years to assess regional differences in practices, personnel requirements, and equipment considerations to determine a basis of safe practice. Consequently, the manual is considered to be a basic guide in the conduct of diving and may be complemented by additional procedures and

requirements as dictated by specific company operations or government rules and regulations.

The manual is intended to serve as a guide to members of the diving industry in developing those safe operating practices and procedures compatible with the prevailing circumstances inherent in each individual location and type of operation. It is not intended to provide, and in fact cannot provide, inflexible practices or procedures to be followed blindly by every operator in every activity with every type of equipment.

Drilling Rig Diving Personnel

A description of each position or job classification and duties is as follows:

Supervisor. The supervisor is in overall charge of the diving operation, decompression, and crew functions. He is generally stationed in the control area which is the central communications and control point for operation dives. When two supervisors are assigned, each man is responsible for a 12-hour shift, with one supervisor designated as the lead man.

SDC Divers. The divers use the SDC to get to the jobsite, and one man locks out to perform whatever tasks are required. The second man remains in the SDC as the safety man and tender. He is prepared to leave the SDC, if assistance is needed by the lockout diver.

Winch Operator (Diver). The winch operator operates the SDC lift winch through directions from the supervisor. (He also acts as a diver on a regular work roster.)

Umbilical Tender (Diver). The primary function of the umbilical tender is to maintain the SDC umbilical during the raising or lowering of the SDC by use of the chain stoppers. (Additionally, he is required to act as diver on a regular work roster.)

Tender (Diver). The tender is an assistant to the supervisor in making pre-dive checks, tending deck equipment during the dive, assisting umbilical tender, controlling decompression and post-dive

checks, and maintenance. (He also serves as diver on a regular work roster.)

Life Support Technicians. Life support technicians control and maintain life support equipment, including gas analysis and mixing, and control of the environment of the deck chamber complex. Technicians are rostered on 12-hour shifts. These men are required during deep dives requiring decompression of 15 hours or more and for all saturation diving.

Backup Divers. In deep dives or in two-shift saturation diving, whenever "back-to-back" diving is required, two additional divers are required. In deep diving, the first pair of divers is usually under decompression when the second dive is required, thus, the need for "backup" divers.

Emergency Procedures

The following is a discussion of situations which could occur during diving operations, requiring the implementation of emergency procedures and quite possibly the help of non-diving rig personnel. Although every emergency has a unique set of problems, familiarity with the "standard" emergency procedures listed below will increase the effectiveness of personnel helping to deal with any given situation and help to insure the safety of those involved in an incident.

Rig Power Failure. The diving system's electrical components are wired so that in the event of a rig power supply failure they will automatically be run from a standby generator. Both of these power supplies must be operable before a dive is undertaken. In the event of rig power failure, the dive will be terminated immediately and the bell hoisted to the surface using the emergency power supply. Should both supplies fail, the bell can still be hoisted to the rig using the auxiliary air winch. Battery-powered communications are available to maintain constant communications. A backup battery supply is available for the CO₂ scrubbers to insure a safe

cks, and maintenance. (He also serves as a diver on a regular work roster.)

Life Support Technicians. Life support technicians control and maintain support equipment, including gas analysis and mixing, and control of the environment of the deck chamber compartment. Technicians are rostered on 12-hour shifts. These men are required for deep dives requiring decompression for 5 hours or more and for all saturation diving.

Backup Divers. In deep dives or in shift saturation diving, whenever "back-to-back" diving is required, two additional divers are required. In deep diving, the first pair of divers is usually required for decompression when the second pair is required, thus, the need for "backup" divers.

Emergency Procedures

The following is a discussion of situations which could occur during diving operations, requiring the implementation of emergency procedures and possibly the help of non-diving personnel. Although every emergency is a unique set of problems, familiarity with the "standard" emergency procedures listed below will increase the effectiveness of personnel helping to deal with any given situation and help to insure the safety of those involved in an accident.

Rig Power Failure. The diving team's electrical components are wired so that in the event of a rig power supply failure they will automatically be run by a standby generator. Both of these power supplies must be operable before the dive is undertaken. In the event of a power failure, the dive will be terminated immediately and the bell hoisted to the surface using the emergency power supply. Should both supplies fail, the bell can still be hoisted to the rig using an auxiliary air winch. Battery-powered communications are available to maintain constant communications. A backup battery supply is available for CO₂ scrubbers to insure a safe

decompression without relying on rig power.

Communications Failure. The bell is provided with two sources of hardwire communications. One set of wires is contained in the umbilical, and one set is in the core of the strength wire or "Electroporteur" cable. In the event communications are lost, the dive will be terminated immediately, using the following procedures:

1. Normally, communications are exchanged between surface and diver/bell every five minutes. Topside and bell tender must keep note of the time of the last communications check.

2. When communications are not established at a five-minute interval, the time of last communications should be noted and a period of 20 minutes will be allowed before the bell is hoisted. In the event of communications failure, the tender must immediately bring the diver to the bell and prepare for ascent. A prearranged signal via the diver's hose will be given by the tender for the diver to return to the bell and prepare for ascent.

3. At the end of the 20-minute interval, the bell will be raised by the surface a distance of 10 feet from its bottom position as a signal to divers that ascent is imminent. After 5 minutes at this depth, the bell will complete the ascent to the surface. If sea conditions permit, the bell will ascend to a depth attainable by standby diver and stop, allowing the standby diver to ascertain the condition on the bell which will allow communications between the surface and the bell via the standby diver's communications line. The bell will then be hoisted to the surface and mated with the deck decompression chamber and normal decompression carried out.

Main Strength Wire Failure. In the unlikely event the main strength wire parts, the bell is capable of being brought to the surface by means of the bell guide wire system. If the strength wire breaks while the bell is between the deck and the wave zone (the most

probably place for such an occurrence), it is likely that the umbilical will also part, and the bell will descend to the bottom. The bell will still be attached to the dual guide wire system, which is capable of returning the bell to the surface, where a crane or tugger line can lift the bell back to the deck. The bell will be halted at a depth attainable by a standby diver to check the occupants' condition, if there is no communication. The on-board supply of gas and scrubbing capacity will enable the bell occupants to continue normal decompression in the event they are already pressurized when the accident occurs. The bell is always supplied with the necessary decompression tables for the appropriate depths at which they are working, as well as an emergency procedures list.

Main Winch Failure. As noted above, the guide wire winches will act as a backup for lifting the bell to the surface. If both of these winches fail, the strength wire can be stopped off to a crane or air tugger line and hauled to the surface.

Bell Entanglement on Bottom. As many bells will be working in water depths of 500 feet or greater and in cold and often severe sea conditions, the ability to send down a standby diver to assess the situation if the bell becomes entangled on the bottom is dangerously impractical, if not impossible. The same procedures that apply for other related emergencies will naturally apply in this situation, e.g., possible communications loss, strength wire parting, etc. The bell is equipped with cutting tools for severing wire rope, and if bell-surface communications exist, oxy-arc cutting gear can be lowered from the surface. The bell will never leave the surface without a complete complement of diving gear, even on an observation dive, and is always equipped with partial pressure and decompression tables, emergency procedures list, spare water, batteries, and lithium hydroxide CO₂ absorbent. Using the oxygen supplies on board as the limiting constraint, the survival time for the occupants of the trapped bell

would be several days. However, exposure to a cold, wet environment would be a more critical situation, and would likely limit the survival time to only a few hours once the bell is pressurized.

First Aid

Major and minor injuries may be expected in the conduct of diving operations. In many instances, qualified medical personnel and treatment facilities are not readily available. In these situations, diving contract personnel must be prepared to cope with major and minor injuries until such time as professional treatment may be rendered. It is the intention of this section to establish the minimum requirements for first aid equipment and instructions to be available on the scene of any Conoco diving operation.

As stated, these are the minimum requirements. Additional supplies and equipment may be dictated by the operations supervisor as a result of distance to complete medical facilities, weather, or other considerations unique to a given operation. If questions arise as to the need for additional supplies or treatment procedures to meet such requirements, they should be directed to either the diving company's medical director or safety director.

Those installations which already have first aid kits and instructions should

check their supplies against those listed and order additional supplies as needed.

At least two members of each operating team should have an adequate background in first aid treatment. A knowledge of first aid procedures is of value to all personnel to provide a background for coping with medical emergencies both at work and at home. All diving employees are encouraged to take advantage of free evening first aid courses offered by the Red Cross, county and city hospitals, adult education, and other programs offering first aid training and certification available throughout the world.

Field operations groups should be familiar and have copies of the new U.S. Navy Diving Manual. In this manual is a revised section on first aid treatment that should be read by all diving supervisors and others responsible for the physical well-being of personnel while working offshore and in the shop. Know this material well—you will not have time to study it if an emergency arises. In addition to these references, all operating groups should have a summary first aid chart for inclusion in their first aid kits. This chart should provide simplified instructions for recognizing symptoms and giving treatment by those personnel who do not have extensive backgrounds in first aid.

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OFFSHORE DRILLING AND ITS SAFETY PROBLEMS

By BILL GOOLSBY

Safety Dir., Delta Drilling Co., Tyler, TX

their supplies against those listed in order additional supplies as needed. At least two members of each working team should have an adequate knowledge of first aid treatment. Knowledge of first aid procedures is essential to all personnel to provide assistance in emergencies both at work and at home. Living employees are encouraged to take advantage of free evening first aid courses offered by the Red Cross, county hospitals, adult education, and programs offering first aid training certification available throughout the world.

Field operations groups should be familiar and have copies of the new U.S. Diving Manual. In this manual is a section on first aid treatment that should be read by all diving supervisors and others responsible for the physical well-being of personnel while working on shore and in the shop. Know this well—you will not have time to find it if an emergency arises. In addition to these references, all operating groups should have a summary first aid chart for inclusion in their first aid kits. The chart should provide simplified instructions for recognizing symptoms and treatment by those personnel who do not have extensive backgrounds in first aid.

A supervisor's sincerity in accident prevention must be combined with a working knowledge of the basic fundamentals of accident prevention before he can successfully control the occurrence of accidents under his supervision.

The supervisor was once charged with getting out the production, but times have changed. Today, his responsibility is to get it out economically and maintain a harmonious relationship with his crew.

The offshore rig makes for an ideal situation, with supervision readily available to schedule the work. Yet we still see accidents from the following causes: improper use and maintenance of tools; faulty practice in operating machinery; neglect in the care and maintenance of equipment; deviation from established work practices; lack of training and know-how in the part of crew members; little value placed on the value of care and accuracy; and lack of communication.

What do the above have in common? Human element type weaknesses.

Offshore crews spend considerable time handling pipe. Equipment for handling pipe consists of slings, spreader bar, pipe hooks, pipe roller, pipe chocks, wooden stripping, and pipe racks. Excessive handling of pipe as a result of poor planning has resulted in many accidents. A few points that are important in offshore pipe handling:

1. Service barge of vessel should be tied up as near to where pipe is to be racked as possible. This eliminates handling and the moving of material over people.

2. Determine if pipe is properly chocked for handling before tie downs are removed. Your method of handling

will depend on how pipe is loaded.

3. Sufficient help should be available. Crew should be instructed on load and handling methods. Which way do you want it to go on the deck or in the hold? Collars ahead? Communication can save you many headaches.

4. Be sure to rack and secure all material that is placed on drill vessel. Adverse weather can develop before you have time to secure the entire vessel.

An offshore location has characteristics that are different from most other locations. All materials and equipment used for the operation of the rig and the drilling of the well must be handled a number of times before they are used. Here is a short list of things that must be lifted on board: people, food, laundry, chemicals, water, mud, pipe, special tools, sand blasting equipment, and special equipment. The list can go on. It is nothing to see a \$1,000 TV being lifted aboard an offshore rig by the crane.

If you think a land rig has a job nipping up, just think how this can be compounded by the placing of the rig 100 ft. or more above water. Safety belts and life jackets are a must for people who are working on the nipple up operation. Points of importance in the nipping operation: be sure that all equipment is available, clean, and ready for use; handrails, belts, lifelines, and preservers must be available and used; signals and communication must be agreed on; print of stack should be available for check, as the operation proceeds; teamwork is a must when communication is difficult.

This information was presented to get you to thinking of ways to prevent your material handling accidents. Discuss your work methods and equipment with your crews.

HAZARDS OF HYDROGEN SULFIDE IN REFINING

By WES WALLACE
Vallen Corp., Houston, TX

I would like to begin this discussion of hazards of hydrogen sulfide in refining operations by quoting from one of the reference documents, "Hydrogen Sulfide Poisoning In Texas" by Dr. C. M. Aves of the then Humble Oil and Refining Company in an address before the Texas State Medical Association on May 9, 1928: "I have interviewed and examined every man possible, known to have been unconscious with the gas, and have yet to find one who has any recollection of having smelled the gas before going under its influence. The sense of smell is certainly of no assistance as a danger warning."

Hydrogen sulfide is usually referred to as a colorless, transparent gas with a characteristic rotten egg odor. The younger people of today have probably never smelled a rotten egg, so perhaps we could change the description around and say that a rotten egg smells like hydrogen sulfide. The disagreeable odor of hydrogen sulfide occurs only at relatively low concentrations.

From Paul Halley's work we learn that those who have been rendered unconscious from high concentrations and survived reported that they did not notice the so-called rotten egg odor, but rather that it had a sickening-sweet odor. Others reported that the odor was sweet and not unpleasant. Just exactly at what concentration it becomes sweet-smelling is not known, but it is believed to be in the 500 to 1000 ppm range. We should keep in mind, also, that some few people cannot detect the odor of H_2S at all, and it would be prudent to determine this in evaluating whether to allow an employee to work around potential hydrogen sulfide exposures.

Other physical properties of hydrogen

sulfide include the fact that it is flammable, with a range of 4.3 to 45.5 percent in air. A mixture of two volumes H_2S and three volumes oxygen will explode violently when ignited. Our purpose here, though, is to discuss the health hazards of H_2S rather than the hazards of fire and explosions. We are concerned with very small levels of parts per million rather than the flammable limit of 43,000 parts per million. H_2S is heavier than air, with a specific gravity of 1.192 and a molecular weight of 34.08, as compared to 29 for air. This gives us concern for low places, ditches, trenches, and similar areas. Hydrogen sulfide does not always hug the ground, however, as in higher concentrations such as 2,000 parts per million, the specific gravity or density of the mixture of air and H_2S is only 1.003. So we can see that the hydrogen sulfide may be bouyed up by air currents and carried to elevations above ground level, as it diffuses rapidly in air and may contaminate a wide area quickly or, depending upon the luck of the wind velocity and direction, it may be dispersed rapidly. H_2S is soluble in water in the proportion of about 4.4 volumes of gas to one volume of water at ambient temperatures. It will help to decontaminate an area of H_2S gas to spray the atmosphere and flush down the area with a water fog spray nozzle.

We used to believe that hydrogen sulfide was a non-cumulative poison. Recent API toxicological data leads us to state that recovery from acute H_2S poisoning is usually complete, but there will be occasional instances of lasting injury following prolonged (can we define prolonged as four minutes or longer?) oxygen deprivation of the brain due to the arrest of the breathing

process. Then the effects of and may not hours; br lymphocytosis turbances. Individuals exp become more than less; in c become accu hydrogen su posures will creasing sy prolonged exp low as 100 par chronic poison It is difficult the physiologic not subject hur and exposures for precision. E respiratory par range of 500 to more, dependi Death will occu case such as thi removed imme breathing is sta tion prior to ces A word about Hydrogen sulfi due to a caustic the alkali of the sodium sulfide. that hydrogen s anesthetic effect pains and sympt after exposure h 48 to 96 hours a should be imme Let's now t physical effects depending on th will deal here rather than volu hundred standar tabular form, we the parts per mill physical effects. we have an obv odor. For many begin at five pa

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process. There will also be cases where
the effects of the exposure are delayed
and may not become evident for several
hours: bronchial irritations,
lymphocytosis, and gastro-intestinal dis-
turbances. We now know that in-
dividuals exposed repeatedly to H₂S
become more sensitive to the gas, rather
than less; in other words, one does not
become accustomed to exposure to
hydrogen sulfide, and repeated ex-
posures will produce gradually in-
creasing symptoms. Repeated or
prolonged exposure to concentrations as
low as 100 parts per million will result in
chronic poisoning.

It is difficult to be precise on some of
the physiological effects because we do
not subject humans to the necessary tests
and exposures which would be necessary
for precision. However, we can state that
respiratory paralysis will occur in the
range of 500 to 700 parts per million or
more, depending upon the individual.
Death will occur from asphyxiation in a
case such as this unless the individual is
removed immediately to fresh air and
breathing is started by artificial respira-
tion prior to cessation of the heart beat.

A word about exposure to the eyes.
Hydrogen sulfide does affect the eyes
due to a caustic action when H₂S meets
the alkali of the cells in the eye to form
sodium sulfide. It has been theorized
that hydrogen sulfide may have a slight
anesthetic effect on the eyes, as often the
pains and symptoms do not occur until
after exposure has ceased, sometimes for
48 to 96 hours after exposure. Eye baths
should be immediately available.

Let's now tabulate some of the
physical effects of hydrogen sulfide,
depending on the concentration, and I
will deal here with parts per million
rather than volume in air or grains per
hundred standard cubic feet. Thus, in
tabular form, we have under one column
the parts per million and in the other the
physical effects. At 10 parts per million
we have an obvious and unpleasant
odor. For many people the odor will
begin at five parts per million, while

others will claim they can smell it as low
as .025 parts per million, and so forth. At
20 parts per million it is safe for eight
hours exposure, and that is the ceiling
concentration. The threshold limit value
is 10 parts per million. At 100 parts per
million it kills the smell in 3 to 15
minutes and may sting the eyes and
throat. At 200 parts per million it kills
the smell rapidly and stings the eyes and
throat. At 500 parts per million, diz-
ziness, lack of balance, judgment is im-
paired, breathing ceases in a few
minutes. Prompt artificial respiration is
indicated. At 700 parts per million the
person becomes unconscious very
quickly; death will result by asphyxiation
if not rescued promptly. At 1000 parts
per million the person becomes un-
conscious at once; this is followed by
death within minutes.

With that as a background, where in
refining operations do we need to be
concerned about hydrogen sulfide? Well,
with the amount of sour crude processed
today, I think we can begin at the dock,
if product is received via barge or tanker,
and at the gate valve if it is coming in by
pipeline. So, we have to begin by train-
ing our dock personnel, gauging and dis-
patching personnel, and by providing
protection for them.

From here the product would
generally move to storage tanks, so we
have concern with them and with the
pump houses that serve the storage area.
Then we go to the operators in the dis-
tillation unit, the gas absorption unit,
and the sulphur plant as we take our first
liquid stream off the distillation tower of
light naptha or gasoline. You will find it
will carry H₂S with it going to storage
prior to going to a reformer, or it may go
direct and the off gas can go to the
desulphurizers before going to the
reformer.

When we cut the kerosene/jet fuel we
have to be concerned at the hydroformer
and with the intermediate storage. The
heavy gas oil cut will have lesser
amounts of H₂S as it goes to the
hydrocracker. As we proceed to the cat

cracker feed stock with intermediate storage again, we will have a lesser amount of hydrogen sulfide with less concern for toxicity; at the very bottom of the crude column we will have residue, bunker C, asphalt, and so on, and primarily here we are dealing with odor.

I think we can go through certain operations and catch the worst offenders or the most likely places of hydrogen sulfide exposure:

1. Sampling, gauging, drawing water from, blinding, going on top of or working in pits near sour crude tank or sour product tank.

2. Going on top of agitators in which some stocks are being treated.

3. When drawing off caustic soda, water, or acid from treating operations. If acids come in contact with hydrogen sulfide loaded caustic soda sent to sewers, a tremendous volume of H_2S may be released at ground level.

4. Working in pump rooms where sour crude and stock pumps are located.

5. When working around gas treating plants. These plants are set up to remove H_2S from certain products.

6. Refinery flare lines almost always carry gases in which there is some hydrogen sulfide.

7. Sewer catch basins are points of hydrogen sulfide release.

8. Any excavation near any hydrogen sulfide equipment or lines that may contain H_2S . If the excavation is in excess of three feet deep, we recommend tests should be made for hydrogen sulfide.

9. H_2S in the crude when released to the atmosphere has the characteristic of expanding 40 times; that is, 80 ppm in crude, as may be reported by the marine chemist, becomes 3200 ppm in air when vaporized. This is especially true in vapor spaces above the liquid level.

One of the items on our reference material is the NIOSH work practice recommendations, and it should be emphasized these are interim work practice recommendations. NIOSH is preparing a criteria for a recommended standard on occupational exposure to

hydrogen sulfide which is scheduled to be transmitted to OSHA in early 1977. NIOSH recommends that continuous monitoring, with an automatic audible signal, be required in certain areas where sudden exposure to hydrogen sulfide is possible. Their first concern is in confined spaces such as entry into tanks, pits, process vessels, and trenches. Here they recommend that such entry be controlled by a permit system with the authorized employer representative certifying that adequate preparation has been made for entry into the confined space, that precautionary measures and personal protective equipment are adequate, and that precautions have been taken to insure that prescribed procedures will be followed. They further recommend that confined spaces which have contained hydrogen sulfide shall be inspected and tested for oxygen deficiency, H_2S , and other contaminants, and shall be thoroughly ventilated, cleaned neutralized, or washed and then retested for hydrogen sulfide and oxygen prior to and during entry. If buildup of hydrogen sulfide into the confined space when work is in progress is a possibility, then buildup shall be prevented by positive means such as forced air ventilation, securing intake valves, or disconnecting or blinding intake lines.

Individuals entering confined spaces where they may possibly be exposed to hydrogen sulfide shall wear either a combination Type C supplied-air respirator operated in the positive pressure or pressure demand mode, and an auxiliary self-contained breathing air supply, or a self-contained breathing apparatus operated in the pressure demand mode complete with a full facepiece. Each individual shall also wear a suitable harness with life lines attended by another employee outside the space who shall also be supplied with the necessary protective equipment, including a self-contained breathing apparatus of the pressure demand type. In areas labeled "suspect," job activities which could be

expected to lead to high levels of hydrogen sulfide tank gauging and line repair require adequate monitoring and personal protection.

We know that hydrogen sulfide occurs with hydrogen sulfide in the sense of being killed, and workmen to overcome concentrations. It is stated that the protection. The advice recommends find the monitoring means of continuous automatic and be used in place of hydrogen sulfide and would not such continuous.

There is further training and effectiveness of any depends on protection of the employee. I would like to include training and emergency procedure. I would like to emphasize on personal protective equipment. I would like to recommend paragraph 8.1, Safe Drilling Hydrogen Sulfide Paragraph 8.1, which are design toxic gas do not protection and safe drilling operation hydrogen sulfide environment. This same section that pressure-demand equipment, complete with alarm signal, self-contained pressure-demand equipment, with contained air supply. From this Standard Z88.2,

gen sulfide which is scheduled to be transmitted to OSHA in early 1977. NIOSH recommends that continuous monitoring, with an automatic audible alarm, be required in certain areas where there is a potential exposure to hydrogen sulfide. Their first concern is in confined spaces such as entry into tanks, process vessels, and trenches. Here we recommend that such entry be controlled by a permit system with the authorized employer representative certifying that adequate preparation has been made for entry into the confined space, that precautionary measures and additional protective equipment are adequate, and that precautions have been taken to insure that prescribed procedures will be followed. They also recommend that confined spaces which have contained hydrogen sulfide be inspected and tested for oxygen deficiency, H_2S , and other contaminants, and shall be thoroughly ventilated, cleaned, neutralized, or washed before being retested for hydrogen sulfide. If a buildup of hydrogen sulfide into the confined space when work is in progress is a possibility, then buildup shall be prevented by positive means such as air ventilation, securing intake lines, or disconnecting or blinding inlet lines.

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expected to potentially expose workers to high levels of hydrogen sulfide such as tank gauging, maintenance operations, and line repair, shall be protected by adequate monitoring, ventilation, and personal protection.

We know that olfactory nerve fatigue occurs with hydrogen sulfide and that the sense of smell is rapidly dulled or killed, and thus it is possible for workmen to enter an area where high concentrations of H_2S are present and be overcome. In our opening remarks we stated that the sense of smell was no protection. Thus, under the work practice recommendations from NIOSH, we find the monitoring requirement: "Some means of constant monitoring with an automatic audible warning device shall be used in places where sudden release of hydrogen sulfide might not be expected and would not be recognized without such continuous monitoring."

There is further work called for in training and education, as the effectiveness of any work practice program depends on proper training and education of the employees. This would include training not only in first aid and emergency procedures, but also in personal protective equipment, with special emphasis on breathing apparatus.

I would like to quote from the API recommended practice No. 49, entitled "Safe Drilling of Wells Containing Hydrogen Sulfide," Section 8, Paragraph 8.1, where we read: "Masks which are designed to merely neutralize toxic gas do not provide the necessary protection and should never be used in drilling operations when a hydrogen sulfide environment may be encountered." This same section goes on to recommend that pressure-demand fresh air breathing equipment, complete with a low-level alarm signal, should be used either in self-contained or in combination pressure-demand airline breathing equipment, with an auxiliary self-contained air supply for emergency egress. From this, and from the ANSI Standard Z88.2, I draw the conclusion

that these are the only kinds of breathing apparatus that we should be using in hydrogen sulfide service.

I know that in many gauging operations, in remote storage areas, in tank farms, and in production work in remote areas, it is a hardship for people to be asked to wear the self-contained breathing apparatus, and it is sometimes difficult for the employer to readily provide it. For this reason, compromises are made, and in certain gauging and pumping operations, canister type masks are used. I do not believe this is the best practice, but if the concentrations are known and it is not possible for the concentration to exceed the limitations of the canister, if the employer is providing an approved canister mask for hydrogen sulfide and the limitations of the equipment are expressly known to the wearer, then perhaps exceptions can be made. In refining operations, however, the use of pressure-demand self-contained or combination equipment, NIOSH-certified, is indicated.

Now for the instruments that will monitor or detect hydrogen sulfide gas. One of our best devices is the detector tube method, and I think of such trade names as Draeger, MSA, Kitagawa, and Gastec, all of whom have NIOSH-certified tubes for measurement of hydrogen sulfide in air in the toxic range. Detector tubes and pumps can be used by almost anyone, with little training required. They give a quick, almost instantaneous reading with low initial cost. Standard combustible gas indicators will not read in the very low ranges required; in fact, some of the popular brands are actually poisoned by hydrogen sulfide. There are a variety of so-called super-sensitive instruments which will read hydrogen sulfide in the parts-per-million range.

As we have drilled deeper, as we have depleted reservoirs, as we have gone into secondary and tertiary recovery, and especially as we have imported larger and larger amounts of foreign crude, we are encountering more and more exposures

to hydrogen sulfide. Luckily, the scientific effort has kept pace, and we now have portable and line-powered instrumentation for the detection and monitoring of hydrogen sulfide which are much more convenient to use and much more reliable than earlier methods.

Certainly, no discussion of hydrogen sulfide detection would be complete without mention of lead acetate ampules and lead acetate tape, both of which have been used for many, many years in the petroleum industry.

We know that upon exposure of lead acetate paper to hydrogen sulfide the tape will turn silvery black to black and that the degree and speed of blackening depends on the concentration of the hydrogen sulfide, moisture, exposure time, or volume. With the ampules, we have to be careful not to use them in too prolonged a test because they lose their sensitivity as they dry out.

One of the more popular newer methods employs the use of a metal oxide semi-conductor, generally operating on the diffusion principle. Another method of detection employs an electrochemical cell which gives almost an immediate readout on a display meter in terms of parts per million. This unit has the additional advantage of very fast recovery so that successive tests can be made very quickly. It lends itself to line power and sequential sampling, and thus it is possible to have it not only in por-

table form for use on the body as a detector, but it can be built into systems for use in monitoring a plant or production area.

There has been a great deal of controversy and question revolving around the newer instrumentation. Admittedly, in terms of years, it is rather new, and there have been some false starts and incomplete tests. Fortunately, the manufacturers who have lent their efforts in this area are exceedingly reliable, and they are aware of the necessity of providing instrumentation which will err on the safe side and which can operate for long periods of time with little or no maintenance. While more expensive than the typical combustible gas indicator with which we are all familiar, I believe it is necessary to bear in mind that we are asking the instrument to respond to very minute quantities of gas and to provide some sort of output signal, so we are now dealing with a quite sophisticated solid state device. More important, the reliability is there!

I can end this discussion as I began it, by referring to that talk of long ago to the Texas Medical Society where Dr. Aves made the statement: "I have interviewed and examined every man possible, known to have been unconscious with the gas, and have yet to find one who has any recollection of having smelled the gas before going under its influence. The sense of smell is certainly of no assistance as a danger warning."

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INDUSTRIAL HYGIENE CONSIDERATIONS IN REFINERY OPERATIONS

By MELITON M. GARCIA

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A refinery is a masterpiece of engineering skill—in this maze of vessels and pipelines a marvelous transformation of crude oil is taking place; a great variety of petroleum and petrochemical products which have a great effect on the economy of this country and on the world are being produced.

To the casual observer or to a person not trained in occupational health, the only possible hazard they associate with the refinery is a fire or an explosion. To the novice industrial hygienist, the presence of occupational health hazards, with the exception of the noise, is also obscure. The only evidence that some "toxic" agent is lurking in the background is the "refinery odor" that can be detected at all areas. To the refinery worker, to the owner of the refinery, and to the community members that depend on the jobs provided by the refinery, the "odor" is affectionately referred to as "the smell of money."

During normal operating conditions in a refinery, the potential for exposure to occupational health hazards in an operating unit is at a minimum. The reason for this is that very few personnel are in the unit and the products are all in a closed system. The greatest potential for exposure occurs during turn around of a unit or units. At this time vessels are opened, catalyst is replaced, surfaces on tanks, pressure vessels, pipes, etc., are cleaned and welded, and insulation is stripped and replaced. A high potential for exposure continues until all units are back on stream.

The workmen experiencing the greatest exposure potential are the maintenance personnel who are assigned to perform their labors in the refinery complex. The personnel least exposed

are probably the unit operators. Automation and centralization of control instrumentation have contributed greatly to the reduction of operating personnel exposures. Of course, during turn around, most refinery personnel become involved and the exposure risk increases. At this time, contract personnel are brought in to perform all types of work and they are also exposed to the potentially harmful agents.

The major occupational health hazards that can be identified in refinery operation include noise, dusts, chemicals, and sanitation.

Noise

Noise is the most obvious and pervasive harmful agent. It is generated by electric motors, steam turbines, cooling fans, forced draft fans, primary and secondary air intakes for burners, steam leaks, high pressure air and steam let-downs, pressure control valves, power generators, compressors, sand blasting, fluid transmission pipes, flares, and mechanical equipment needing maintenance or replacement. Sources like the high pressure steam and air let-down can generate 125 dBA at a distance of 50 feet from the outlet. In a typical refinery, at least 75 per cent of the area bounded by the battery lines of the whole refinery complex may exceed 85 dBA.

Past and present activity in noise control by industry and the enforcement of the OSHA noise standard has resulted in the development and installation of various noise control devices in refinery operations. For example: flares have been equipped with silencers; cooling fans have been designed with more blades and operate at slower speeds;

forced draft fans on boilers or stacks have been equipped with silencers; pipelines have been lagged with acoustical materials; electric motors of the totally enclosed fan cooled (TEFC) variety have been equipped with mufflers; primary intake air openings on burners have been equipped with mutes; acoustic plenums have been constructed around the secondary air intakes for burners; turbines, pumps, and motors have been enclosed in acoustic booths; high pressure steam and air let-down outlets have been equipped with silencers; greater attention has been given to the repair of steam leaks, to the replacement or repair of bad bearings and to dampening of vibrating equipment; control valves are being replaced with "trim or drag" valves that drastically reduce the noise at the valve body and eliminate transmission of the noise along the pipeline.

Adoption of one or more of the noise control techniques has resulted in significant reduction of noise levels at the source and significant changes in the quality of the ambient noise at the unit and refinery as a whole.

Dusts

The dusts to which a refinery worker can be exposed, especially the maintenance and crafts personnel (company or contractor), include asbestos, silica, catalyst, coke, and residue or scale accumulated inside vessels or pipes.

Exposure to asbestos occurs when the old insulation is stripped from the vessels and pipes, when the new insulation is trimmed to fit the vessel or pipes, and during clean up of the waste insulation and debris. Preventing exposures requires that the material to be stripped be wetted down before stripping begins, that the scrap be disposed of in closed and labeled containers, that dust-producing operations such as trimming and grinding be done with the use of exhaust ventilation, and that personnel wear respiratory protective devices when conditions warrant it.

Exposure to silica occurs when the vessels and pipelines are sandblasted. Not only is the person doing the sandblasting exposed, but so are the refinery workers who may be working in an area downwind from the sandblasting operation. Recent studies by contractors for NIOSH have shown that sandblasters are definitely exposed even though they are wearing the common sandblasting hood and supply air.

To ameliorate exposure to silica, many employers have changed from river sand to fine fused slag known as "Black Beauty" and "Stan-Blast." Better respiratory protective hoods are also being used.

When a unit is shut down for turn around, catalyst beds are changed. Exposure occurs when the workmen enter the confined spaces to remove the catalyst or when the vessel is being charged. Toxic substances that may be found in the catalyst include: silica, nickel, vanadium, iron, cobalt, and other substances. Use of appropriate protective clothing will reduce the exposure to catalyst dust. General and/or local exhaust ventilation must be used in confined spaces.

Chemicals

The chemicals to which refinery personnel can be exposed, either in the gaseous or liquid state, are legion. These chemicals can be raw products, intermediate products, or final saleable products. The following are examples of some of the common potential exposures to be anticipated:

1. Operating personnel who sample the product streams, check the product storage tanks, and open drain pipes on various vessels or water knock-out tanks are exposed to varying concentrations of hydrocarbon vapors.

2. Personnel at the product loading locations, tankers and barges may, depending upon the prevailing atmospheric conditions, experience significant exposures to hydrocarbon vapors. A recent study conducted by Shell Oil of

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the potential exposure of personnel attending to the loading operations experienced their highest exposure when loading tankers with top loading and no vapor recovery systems.

3. Laboratory personnel who analyze the many samples are exposed to the hydrocarbon vapors; most laboratories are ill-equipped as far as local exhaust capabilities are concerned.

4. Personnel who work with anti-knock additives for gasoline must constantly be on the alert to prevent exposure to those extra-hazardous agents. Proper protective clothing must be worn by personnel, adequate local exhaust ventilation must be provided when working with these agents in confined spaces, and an adequate supply of kerosene must be available in the event that decontamination of the skin or clothing is necessary.

5. Personnel working in the alkylation unit, especially if hydrogen fluoride is used as the catalyst, must observe very strict precautions if contact with this very corrosive agent is to be avoided. Impervious clothing must be worn; the extent of protection needed is dictated by the work to be performed and the location in the unit.

6. When sour crude is processed, exposure to hydrogen sulfide can occur at the crude storage tanks or anywhere on the closed system prior to its removal at the sweetening unit; from this point, exposures can occur in the closed system leading to and at the sulfur plant.

7. Exposures to toxic substances used in ancillary operations include: elemental lead used to seal the connecting joints in vessels, or lead fumes generated while welding or burning on painted surfaces; lead oxide used as a primer paint on the outside surfaces of vessels and piping; elemental mercury used in pressure sensing devices; water treatment chemicals that include chromates, acids, and caustic materials; radioactive sources used as level gauges and density sensors; fumes from welding or brazing operations, especially when working in

confined spaces or on contaminated surfaces.

Sanitation

Refineries are show places when it comes to housekeeping and outward appearance in the units. Unfortunately, this zeal for cleanliness is lost when it comes to lunch rooms, restrooms, water fountains, change rooms, and places where food is prepared and served in the unit.

If occupational health hazards in petroleum refining operations are to be identified, quantified and controlled and if prevention of exposures are the objectives of the management, a comprehensive industrial hygiene program must be instituted to accomplish the following:

1. Examine the work environment and environs: (a) study work operations, processes, and materials to assess the nature of the potential for exposure to harmful conditions. This will require an assessment of work habits, equipment use, materials used as raw and intermediate materials or products and by-products, number of persons exposed, duration of exposure, and mode of exposure; (b) make appropriate measurements to establish the concentration of contaminant or magnitude of exposure.

2. Interpret results of field studies, examinations, and measurements to determine the ability of the stresses to cause illness and the degree of hazard potential created by these stresses.

3. Make specific recommendations as to the need for and type of control measures necessary to minimize or eliminate exposure. These measures may include one or more of the following: isolation of the process or work operation to reduce the number of exposed personnel; substitution of a hazardous material with one of no known hazard or at least one of lesser hazard; alteration of the process or work cycle to minimize human exposure; appropriate application of ventilation practices and equipment to provide an atmosphere safe for

human occupancy; provide shielding or enclosures and limit the time of exposure and distance between the stress agent and the worker; good housekeeping practices, including cleanliness of the work place, proper waste disposal, adequate washing, toilet, and restroom facilities, healthful domestic water supply and lunch room facilities, and control of insects and rodents; appropriate personal protective devices such as respirators, hearing protectors, and other special clothing consistent with the nature of the hazard.

4. Review plans for new or modified expansion of facilities or processes; review engineering designs of facilities and health hazard control methods; and review and approve materials purchased for use in process or operation. This practice will assure that occupational health hazards are recognized and eliminated while in the planning or design stages rather than retrofitting after the fact.

5. Prepare realistic rules, regulations, standards, or operating procedures to conduct work in a health-safe manner.

6. Prepare appropriate methods of alerting the worker to the hazards associated with the materials or process. This should include material safety data sheets, warning labels for bulk and small containers, placards at the site of potential exposure, and hazard control bulletins.

7. Develop and conduct programs for

the education of managers and plant employees in the prevention of occupational diseases.

8. Conduct epidemiologic studies among workers and similar industries to discover the possibilities of the presence of occupational diseases. Correlation of plant studies, worker exposures, and incidence of disease will help in guiding the development of realistic standards by governmental agencies.

9. Coordinate with various company organizations such as manufacturing, production, safety, fire protection, medical, employee relations, engineering, etc., on matters relating to the use of hazardous substances and control of personnel exposures.

Conclusion

To the casual observer who tours an oil refinery while it is in full operation, the presence of occupational health hazards and the potential for personnel exposures are not obvious. However, to the professional industrial hygienist, the subtle exposures that occur while the refinery is operating smoothly and while the refinery units are on turn-around are real and present cause for action. Maintenance personnel have the highest risk potential and turnaround operations pose the greatest opportunities for exposure. Noise and chemical dusts, mists, and vapors are the hazardous agents of greatest concern.

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SERVICE STATION SAFETY— WHAT CAN YOU DO? THINK ABOUT IT!

By C. W. HAVEN

Safety Coordinator, Marketing Department,
The Standard Oil Co. (Ohio), Cleveland, OH

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Sohio's safety program starts with the commitment of the chairman of the board to "strive to create a working climate that establishes safe operation as a fundamental way of running the business." In order to insure that these high ideals become an operational part of Sohio's philosophy, the concept was further translated into the statement that "accident prevention is a control function of management. It must be accepted as such by all levels of management." In short, Sohio's management has accepted and is committed to the challenge of creating a safe working climate.

This commitment has been in effect for more than 25 years. It is not an outgrowth of OSHA nor any other government imposed programs. Each year a safety program is developed by the corporate safety department. The purpose of this program is to provide general accident prevention guidelines throughout the company. In addition, each department manager is encouraged to develop his own program reflecting the specific needs of his department. During 1976 the corporate program emphasized motivation of the front line manager (i.e., foreman or supervisor). The logo selected was the international traffic sign for "Prohibit Movement" with the word "Accidents" superimposed on the face.

Facilities are constructed according to sound engineering practices with reference to API, NFPA, NEC, etc.

All employees are provided with safety booklets. These booklets are used by the service station managers as part of the employees' on-the-job training. The books are periodically reviewed and updated.

All accidents—personal injury, vehicle

accidents, fire, third party incidents—are promptly investigated and reported. The rules governing chargeability are those found in ANSI Z16.1, Z15.1, OSHA, and API. Information developed from an analysis of the accident reports (all accidents regardless of severity) is used to pin-point trouble areas and to provide specific information for accident prevention programs, and quarterly and monthly safety meetings. Until this year, analysis of the accident reports was carried out manually. We have developed a computer program which we are now using to assist in this analysis.

Specific objectives for disabling injuries, index injuries, and vehicle accidents are established each year and approved by the marketing vice president for each operating division. Every month a report is published showing performance to date as compared to objectives. The method used to establish these objectives is a least squares curve calculation based upon past performance with zero accidents at infinity as the ultimate objective. For example, the disabling injury objective for this year is 1.8. Currently we are at 2.1 and working hard to meet this objective by year end.

In addition to the pocket safety booklet, there is also the service station safety poster. We recognize the problem of providing a safety program for company-operated locations spread through 13 states. This problem is compounded by a high turn-over of personnel, mostly in the 18- to 25-year old group.

To offset this problem a program was developed with the single purpose of providing station employees with infor-

mation on the types of accidents he may be involved in and a means by which he himself could avoid injury.

On the surface, this might appear very elementary. However, accident analysis confirmed by the recent computer data demonstrates that failure of the employee to recognize hazards and to take personal action accounts for 95 per cent of the personal injuries in the Sohio marketing department.

This has led us to the development of an audio visual program for use at the station level. This program is entitled: "Service Station Safety—What Can you Do? Think About It!" The program consists of 30 slides covering three separate sections and a cassette which runs 18 minutes. The sections covered are: On the Driveway; In the Lube Bay; Fire Prevention.

Following are ten subjects which I feel are frequently overlooked in discussions of service station safety. This is the way these ten subjects are presented at the service station.

1. Blow Backs. Factors relating to weather conditions, the condition of the customer's gas tank, etc., lead to the condition known as blow back. Simply, gasoline blows back out the fill opening. The major danger of this type of incident is that this may develop into a serious burn case. When you have gasoline on your clothing, you are a potential walking torch. You can be set on fire either by your own actions or by a customer or another employee.

What can you do? Avoid standing directly in front of the fill opening. Stand to the side. Should you get gasoline on your clothing and/or skin, remove the clothing immediately and wash the skin area with soap and water. Stay away from anything that can ignite gasoline vapors.

Think about it! Would you like a vacation in the burn ward? Remember, gasoline-soaked clothing can burn like a torch.

2. Struck By Customer's Vehicle. Being struck by a car either on the driveway

or at the pumps is a constant danger. What can you do? Never assume that a customer is a skilled driver. Also, never assume that the customer's vehicle can stop when it should. Be polite and tactful; however, stand out of the danger zone until the vehicle has stopped and its engine is turned off. Think about it! Are a few weeks in traction worth the risk?

3. Cuts. Many vehicles on the road today are poorly maintained and are loaded with sharp edges waiting to rip open an unwary finger, hand, or leg. The sharp edges themselves cannot jump out and attack you; only your failure to recognize them can cause you to be hurt.

What can you do? Recognize the potential danger of broken head lights, rusty torn fenders, loose chrome, or sharp edges on license plates. And having recognized them, stay clear of them. Think about it! A cut hurts, but the stitches will hurt even more.

4. Radiator Burns. Modern pressurized cooling systems operate normally at temperatures of about 240 °F. The temperature is above the boiling point of the coolant. This is the reason for the pressure under the cap. If the cap is opened under these conditions, there is a good chance the coolant will boil out.

What can you do? Do not check a radiator unless the customer absolutely insists. If you must check a radiator, then let it cool for at least one-half hour. Place the radiator safety tarp over the cap before you attempt to open it. Work on top of, not under, the tarp.

Think about it! Scalds are extremely painful. Do you want one? If you should ever be burned, remember the best first aid for a burn is to cool it down with cold water for 15 minutes by the clock; then go to a doctor or hospital emergency room.

5. Slips. Another way to have a bad fall in a service station is to slip on oily, greasy, wet, or soapy floors. Oil and grease are a part of service station operations; however, they do not belong as spots on the floor. Spills, when they happen, must be cleaned up im-

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pumps is a constant danger. What do you do? Never assume that a customer is a skilled driver. Also, never assume that the customer's vehicle cannot do what it should. Be polite and tactful. However, stand out of the danger zone. When the vehicle has stopped and its engine is turned off. Think about it! Are the wheels in traction worth the risk?

Many vehicles on the road are poorly maintained and are like sharp edges waiting to rip your arm, finger, hand, or leg. They can hurt themselves cannot jump out from under you; only your failure to recognize the danger of broken head lights, bad fenders, loose chrome, or loose bolts on license plates. And having noticed them, stay clear of them. Think about it! A cut hurts, but the fall will hurt even more.

Radiator Burns. Modern engine cooling systems operate at normal temperatures of about 240 °F. If the temperature is above the boiling point of the coolant. This is the reason for the pressure under the cap. If the cap is removed under these conditions, there is a chance the coolant will boil out. What can you do? Do not check a radiator unless the customer absolutely insists. You must check a radiator, and if you do, cool for at least one-half hour. Put a radiator safety tarp over the radiator before you attempt to open it. Work from the side, not under, the tarp. Think about it! Scalds are extremely painful. Do you want one? If you should get burned, remember the best first aid for a burn is to cool it down with water for 15 minutes by the clock; then take it to a doctor or hospital emergency room.

Another way to have a bad accident at a service station is to slip on oily, greasy, or soapy floors. Oil and grease are a part of service station life; however, they do not belong on the floor. Spills, when they occur, must be cleaned up immediately.

Wet or soapy floors are also a part of service station operation. They have never caused a fall; they do contribute to falls when they are left unattended and when proper caution is not used.

What can you do? Clean up oil, grease, and water spills when they happen. When scrubbing floors, stay alert and caution others (other employees and customers) to stay clear. You have a responsibility to yourself and others to avoid this type of accident.

Think about it! Are the months in traction worth the few seconds supposedly saved by not cleaning up a spill?

6. Struck By Customer's Car. Every year several of our employees are pinned in the lube bay by the customer. When you stand in front of a car with the motor running and a driver behind the wheel, you are gambling with your life. You are assuming the driver knows how to drive and that the car will stop. Frankly, both assumptions are completely false.

What can you do? Stand off to the side, preferably the driver's side; but always remember, give yourself running room. Never stand directly in front of or, for that matter, behind a vehicle when guiding it.

Think about it! Which is better? Standing off to the side or risk having your legs crushed?

7. Working Under Lifts. When working under a car on the lift, you are always exposed to the possibility of foreign materials falling into your eyes. The dirt, road salts, rust, metal chips, stones, etc. will fall down. You're looking up only inches away from the falling materials. Where do you think they will go?

Other equipment in the lube bay that can cause eye injuries are the bench grinder, tools with mushroom heads, the impact wrench, the tire machine, and the air chisel.

What can you do? Wear eye protection in the lube bay. Don't wait until something is in your eye before you decide to wear eye protection.

Think about it! How valuable are your

eyes? If you don't know, ask a blind man.

8. Wearing Jewelry. Have you ever met anyone with the ring finger on their hand missing? Chances are the finger is gone because they wore a ring while working. Ring fingers have been lost because of contact with electric circuits, catching on moving machinery, or catching on projections while using a wrench.

What can you do? Isn't it obvious? Don't wear jewelry while at work. This includes rings, metal watch bands, earrings, and necklaces.

Think about it! You have ten fingers. Would you like to try for less?

9. Servicing Batteries. Every year at least 100 batteries explode in our stations. The general reason given is a defective battery. However, the real cause is that someone created a spark near the battery. Batteries give off an explosive mixture of gases, and a spark can set it off. The most common mistake happens when taking a battery out of a car or when installing one. Do it right; take the ground off first, and put the ground on last. This eliminates the danger of a spark caused by the wrench shorting out. Also, do not smoke near batteries.

What can you do? Follow the rule—ground off first, ground on last.

10. Smoking. Have you ever smoked in the lube bay? Did you ever realize the risk you are taking? If gasoline spills from a ruptured gas line, a spilled gas can, a leaking tank, or any one of many possibilities, that smoke could be your last. A spill without a source of ignition is a mess to clean up. A spill with a source of ignition can result in an explosion or a fire.

What can you do? Don't smoke in the lube bay. Don't permit anyone (customers or other employees) to smoke in the lube bay.

Think about it! If you survive the explosion or fire, you're in for a long vacation in a burn ward. Is it worth lighting up?

PIPELINE EXPLOSION — BACK IN THE "NOT-SO" GOOD OLD DAYS

By WAYNE KINISON
Safety Supvr., Shell Pipe Line Corp., Houston, TX

On December 12, 1939, a section of 26.8 miles of 10-inch crude oil pipeline was literally blown out of the ground in eight minutes time with explosions or detonations running up to 60 to 70 per mile. This section of line is in Shell Pipe Line Corporation's McCamey, Texas—Cushing, Oklahoma 10-inch, a part of the system that furnished crude oil to Shell's Wood River, Illinois and East Chicago, Indiana Refineries. Specifically, the damaged section was between Archer Station in Texas and Ryan Station in Oklahoma.

At the time of the explosions, compressed air was being used to push scrapers to displace the crude oil in the pipeline. This practice, with some variations, had been used by other organizations in the industry.

Immediately after the disaster, an investigating committee was appointed and sent to the scene to make a complete investigation. The facts and conclusions presented here are, for the most part, those of this committee as taken from their official report.

The reason for displacement of the oil with air was to find and repair external corrosion leaks in the Pipeline. The soil was extremely dry, and leaks in the line had been difficult to locate. The oil loss was significant. On many occasions, the oil would disappear into the dry ground without evidence of a leak on the surface. The decision to use air to displace the oil and to test the line for leaks was based upon: (1) the failure of locating all the leaks by other standard methods tried; (2) the lack of available water to use water for pressuring the line—the difficulty and time limitation in obtaining water from the Brazos or Red Rivers, the only available sources where

it was economically available; (3) the ease of locating and detecting leaks by using air when the air is odorized with ethyl mercaptan; (4) the ease of detecting air escaping from leaks by using an audiophone; (5) the disproportionate cost of other test methods; and (6) the presumption that displacement of oil by air was a common and safe practice in the oil pipeline industry.

About two weeks before the air tests, Go-Devil type scrapers were run in the oil stream to clear the line of debris. The first scraper stuck in one section of the line, but was freed by striking the line with a wooden skid. It was believed an accumulation of debris had stopped the scraper. Other scrapers ran without delays.

The air procedure was started at Baylor Station, and a 38-mile section of the line to Archer Station was air pressured, oil vacated, and leaks found and repaired. The procedure was to insert two hard rubber disc scrapers into the line. The hard rubber discs were the same diameter as the inside of the 10-inch pipe. Air was then forced into the line back of the scrapers by five air compressors with a capacity totaling approximately 600 cubic feet of air per minute at a maximum discharge pressure of 90-95 psi. The lubricator of one of the compressors was used to feed ethyl mercaptan into the line. As the air column moved the scraper through the line, maintenance men followed them to keep track of their position and to search for leaks. As each successive point of leakage was passed, with resulting loss of air, the scrapers moved more slowly and finally stopped 27 miles from Baylor Station at 10 A.M. December 9, 1939.

Eight leaks had been found. They were

dug out and clamps, when travel. Plugging shutdown of compressors at moved at full speed) and 3 miles from Baylor

The following was removed stream side further cleaned the scraper to number of runs and a substantial Most of the had been rolled the size of bird

Next, a Go-Devil type scraper was run in the oil stream to clear the line of debris. The first scraper stuck in one section of the line, but was freed by striking the line with a wooden skid. It was believed an accumulation of debris had stopped the scraper. Other scrapers ran without delays.

The maintenance men followed the scrapers all night miles per hour. The line at Baylor Station at 8:14 A.M. on December 9, 1939. At 8:00 A.M. gauge showed 19,000 barrels of crude oil in the line, pushed the scraper to within 27 miles of Archer Station and the front scraper stopped at Ryan Station.

On the morning of December 10, 1939, the division superintendent with the crew. Crews were positioned 100 feet ahead of the scrapers (one being the superintendent's and the other the fourth man on the scraper). The line was standing on top of a mile away, where the explosion occurred. The line was driven up and

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dug out and repaired with leak repair clamps, whereupon the scrapers resumed travel. Plugging the eight leaks permitted shutdown of three of the five air compressors at Baylor. The scrapers then moved at four m.p.h. (double former speed) and reached Archer Station, 38 miles from Baylor, on December 10.

The following day, the leading scraper was removed and reinserted in the up-stream side of Archer Station. It had further cleaned the line by carrying into the scraper trap and strainers a large number of rocks and metallic objects, and a substantial amount of sludge. Most of the latter, largely iron oxide, had been rolled into small pellets about the size of bird shot.

Next, a Go-Devil type scraper was inserted at Baylor Station behind the air column at 6:15 P.M., December 11, and crude oil was started through the line in back of the scraper. Now the air was being forced out of the Baylor-Archer section by the oil and, in turn, air was being forced into the Archer-Ryan section of the line.

The maintenance crews followed the scraper all night, averaging about two miles per hour. Oil was pumped into the line at Baylor without interruption until 8:14 A.M. on December 12, 1939. The 8:00 A.M. gauge showed that just over 19,000 barrels of oil had been put into the line, pushing the rear Go-Devil scraper to within one-half mile of Archer and the front scraper to within nine miles of Ryan Station.

On the morning of the accident, the division superintendent was walking with the crew. One man was walking 25 feet ahead of the scraper, two men with the scraper (one on each side of the line, one being the superintendent), and the fourth man was driving the superintendent's car about 20 feet behind the scraper. The owner of the ranch which the line traversed at this point was standing on top of a hill three-quarters of a mile away, where he had a full view of the explosion scene. The foreman had driven up and left his truck and was

walking toward the group about 500 feet away at the time of the explosion. Suddenly, the scraper stopped, the superintendent motioned the car driver to stop, which he did and shut off the engine. The two men knelt down to try to pick up any sound of the scraper. Within an estimated 10-15 seconds, there was a muffled explosion right under them and almost immediately a second explosion. The first muffled explosion occurred at the scraper and merely bulged the pipe but did not burst it. The second explosion, or rupture in the pipe, occurred directly under the car. The car, with the driver in it, was hurled ahead in the direction the scraper had been traveling and over the heads of the two men listening for the scraper. The car landed on its side 145 measured feet from its previous position and about 20 feet off the pipeline. When it landed, it was facing in the opposite direction.

While the car was in the air, a third explosion occurred toward Ryan Station about 145 feet from the second explosion and just 20 feet from where the car landed. Almost simultaneous with the third explosion, a similar eruption occurred some 240 feet back of the scraper and in the direction of Archer Station. Other explosions then occurred, traveling at a high rate of speed the entire almost 27 miles back to Archer Station.

At about the time of the explosion, the foreman glanced at his watch and noticed it was 7:50 A.M. He ran to his truck, drove a short distance to the company telephone line which paralleled the pipeline, and tried to ring Archer Station but was unable to get them because the explosions had torn down the telephone lines. However, in the other direction the telephone lines were intact and he was able to get the dispatcher at Cushing, who called Archer Station on the Bell System. While the dispatcher was issuing instructions to the Archer Station operator, the line blew up in the station yard. The records at Archer Station showed there was an elapsed time of about eight minutes between the initial

and final explosion, indicating an average velocity of about 300 feet per second for the 26.8 miles.

The ranch owner previously mentioned, who was standing on a hill with a good view of the scene of the first series of explosions, stated that they threw up great clouds of dust and "traveled faster than an airplane." He was about three-quarters of a mile from the line and saw the last visible eruption go over a hill to the west, a distance of 1½ miles, before he heard the sound of any explosions.

Two men who worked for a gas company were driving down a highway. They said the explosions threw dust and white smoke 60 feet into the air and "looked like a locomotive coming down the line belching white smoke, but traveling much faster than a locomotive."

There was only one slight injury in this accident, and it was a minor one. It wasn't the driver of the superintendent's car. He was not injured at all but plenty scared. The injured person was a WPA worker on his way to work on the road. He drove into one of the big craters that had blown out in the pipeline road crossing. He was taken to a hospital, examined, treated for minor injuries and shock, and dismissed. However, his 1931 Studebaker car was pretty well wrecked.

Several theories as to the cause were examined; however, the theory that seems to correspond most precisely to all the known facts is that the scraper, propelled by air estimated to have been compressed under approximately 125 psi at the point of explosion, struck and attempted to pass a large wooden object in the bottom of the line; namely, a pipe skid, originally 4" x 4" x 36" long but tapered to 2" x 4" at one end due to wear. The scraper was an insulated metallic object, by virtue of the four neoprene discs and the oil film on the wall of the pipe. This object was electrostatically charged by slight leakage of high pressure air at high velocity. The wedge effect of the wooden obstruction was sufficient to fracture the sleeve on the shaft of the scraper, thereby presenting, at the

moment of fracture, two very clean and bright irregular metallic surfaces which were ideal for the discharge of an electrostatic spark, and which had not previously occurred in this section of the line.

The resulting spark ignited a combustible mixture of hydrocarbons and air, which started the instantaneous propagation of a flame in both directions and caused a muffled explosion at the scraper. This first explosion was not sufficient to rupture the pipe but bulged the bottom of it. The flame, traveling at the relatively slow rate of approximately two feet per second, ignited a highly combustible gaseous mixture approximately 16 feet back of the scraper, and produced an extremely violent explosion which deformed the scraper plates, burst the pipeline, and threw the automobile about 145 feet along the line toward Ryan Station. Furthermore, it produced tremendous pressure waves along the inside of the pipe in each direction, resulting in a series of explosions which reached Archer Station, 26.8 miles to the southwest, about eight minutes later. In addition, it caused an explosion some 145 feet toward Ryan Station. However, the waves from this explosion encountered a body of oil which prevented their further propagation in that direction. The reactive pressure surge through the blasted open end of the pipe carried with it a few barrels of oil which were sprayed against the car and upon the superintendent, and also upon the nearby ground.

Conclusion

1. It is evident from the resulting explosions and detonations that the line contained a concentration of hydrocarbons in the explosive range.

2. Although further investigation indicated that several other companies had used air to clear short sections of petroleum lines in a similar fashion, it was not an industry-wide practice.

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Mines experiments, have proven that the use of air under pressure to displace liquid hydrocarbons in a pipeline is not a safe procedure. Instead, the use of water or an inert gas such as nitrogen is recommended.

4. You can be sure that in our safety procedures, we forbid the use of compressed air to vacate pipelines after they have been in liquid hydrocarbon use.

In Section B-94 of our Pipeline Safety Procedures Manual we read: "Pipelines

have literally been blown out of the ground for many miles by injecting air into them to replace the crude, product, or gas. Therefore, pipeline scrapers, pigs, or balls must not be forced through a line with air after the line has been in crude or product service, nor shall air ever be injected into a pipeline which contains or has contained a flammable liquid or gas. Only water or an inert gas such as nitrogen may be used safely for such purposes."

HIGH LEVEL TANK ALARMS ON PIPELINE TANKS

By R. L. JOHNSON

Dir., Safety & Environmental Affairs,
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In September 1972 Conoco experienced a catastrophic fire at a product terminal. The subsequent accident investigation revealed that the cause of the fire was the overfilling of a gasoline storage tank while receiving a pipeline delivery. The investigation also revealed that the overfill may have been caused by utilizing the tank tables for a 26,000 barrel tank in the calculation of space available in a 20,000 barrel tank. While the exact reason for the miscalculation was not definitely known, it was apparent that a human failure did occur in this case.

Following this accident, we reviewed our entire operations and discovered that overfills into terminal and pipeline tankage were not as infrequent as we would have supposed. An in-depth investigation as to the causes of tank overfills was launched and came up with basically two categories of human failures. The first category was human failure on the part of terminal employees in calculating the amount of space available in terminal tankage to receive pipeline deliveries. The second was an area of communication between pipeline operators and terminal operators.

Under the category of human failures on the part of terminal operators, we isolated the following possibilities:

1. Incorrect tank gauges or incorrect recording of tank gauges. Anyone who has ever gauged tanks has occasionally made errors in reading the gauge tape or in recording the gauge in the gauge book. For some reason it seems to be extremely easy to look at a tape gauge and see a gauge of 10 feet 6 inches and somehow write down in the gauge book 6 feet 10 inches.

2. Improper outage calculations. This

encompasses errors in calculating space available for delivery by the use of the wrong tank table and also simple subtraction errors. For instance, the safe fill level for a tank may be 80,107 barrels and the gauge is 32,433 barrels; when the latter is subtracted from the former, the answer, which should be 47,674, can sometimes come out 57,674.

The problems in the category of communication between pipeline operators and terminal or tankage operators involves changes in the pipeline schedules or rate changes during a delivery. These problems are illustrated as follows:

1. A terminal operator may be anticipating a 65,000 barrel delivery as indicated by the pipeline delivery schedule; however, the tender arrangement may have changed since the schedule was published and the proposed delivery may have grown to, say 72,000 barrels. It is easy to see that, without proper communication between the pipeline operating personnel and the terminal operating personnel, you can arrive at a situation where the pipeline is trying to stick 72,000 barrels into tankage that only has space for something slightly over 65,000 barrels.

2. Varying pipeline rates, if not communicated to the terminal operators, can result in earlier than anticipated switches at a terminal. For example, a terminal operator, based upon a pipeline delivery rate of 3600 barrels per hour, may figure that he can continue the delivery into a given storage tank until, say, 8:00 A.M. the next morning. However, if during the evening the pipeline rate increases to 4200 barrels per hour, it may be that the terminal operator will be out of tank space at 7:00 A.M. rather than 8:00 A.M.

ALARMS TANKS

National Affairs,
Houston, TX

esses errors in calculating space for delivery by the use of the tank table and also simple subtraction errors. For instance, the safe fill of a tank may be 80,107 barrels; gauge is 32,433 barrels; when the gauge is subtracted from the former, the result which should be 47,674, can easily come out 57,674.

Problems in the category of communication between pipeline operators and terminal or tankage operators in changes in the pipeline schedules during a delivery. These are illustrated as follows:

The terminal operator may be arranging a 65,000 barrel delivery as indicated by the pipeline delivery schedule; however, the tender arrangement may be changed since the schedule was changed and the proposed delivery may now be, say 72,000 barrels. It is seen that, without proper communication between the pipeline delivery personnel and the terminal operator, you can arrive at a situation where the pipeline is trying to deliver 65,000 barrels into tankage that has space for something slightly less than 65,000 barrels.

Changing pipeline rates, if not communicated to the terminal operators, can result in earlier than anticipated switches in terminal. For example, a terminal operator, based upon a pipeline delivery rate of 600 barrels per hour, may figure he can continue the delivery into a storage tank until, say, 8:00 A.M. the next morning. However, if during the night the pipeline rate increases to 800 barrels per hour, it may be that the terminal operator will be out of tank at 7:00 A.M. rather than 8:00

The above examples are somewhat exaggerated for the purpose of illustration, but these are basically the factors we ran into when we investigated the problem.

Our solution to the problem was two-fold. We initiated procedural changes which, if followed, would eliminate the communication problem as well as minimize exposure to calculation errors. The second part of our solution was the installation of high level alarms on terminal tankage. We feel that both facets of the solution are equally important, because we recognize that we can still have failures in both personnel and equipment. By super-imposing the alarm system on our procedural changes, we feel that the odds are increased that both type of failures would not occur simultaneously.

The procedural changes which were initiated are as follows:

1. One or two days prior to a scheduled pipeline delivery, the terminal operator will gauge the tank into which the delivery will be received and calculates the space available for the delivery.

2. The terminal operator then gives the tank gauge, in feet and inches, to the pipeline delivery personnel. The pipeline deliveryman, who has been furnished copies of the tank tables, then recalculates the space available for the delivery and assures himself that the tank will accommodate the scheduled delivery.

3. On the day of the delivery, the terminal operator regauges the tank to receive the delivery and recalculates the space available.

4. The terminal operator then again furnishes the gauge information to the pipeline delivery personnel and they recheck the outage available in the tank against their scheduled delivery and the pipeline delivery personnel and the terminal operator discuss rates, exact time of delivery, and all details of the delivery.

This procedure varies somewhat between pipelines and terminals. At our

operated terminals which are served by Continental Pipe Line Systems, the pipeline dispatchers keep an updated record of terminal stocks and thus could quickly spot any gauging or calculation errors. Where our operated terminals are served by other pipeline companies, some of the companies follow the above procedures and some vary from these procedures.

Reinforcing the above procedures is our system of high level tank alarms which have been installed on all of our product terminal tankage. Most of the installations which we have made involve the installation of a standpipe external to the tank. This standpipe is generally 1½-inch diameter pipe connected to the tank by couplings which have been welded to the shell of the tank near the bottom of the tank and at some point near the top of the tank. Two float switches are mounted in the standpipe. The first switch will give a warning alarm. The second switch is positioned at the safe fill level of the tank and gives a final alarm. The first switch is positioned such that after it activates, the pipeline and terminal personnel have a minimum of 15 minutes to switch tanks or close out the pipeline delivery. When the final alarm sounds, the instructions are to shut down the delivery immediately.

Valves are installed in the connection to the tank and an outlet is provided at the bottom of the standpipe for testing purposes.

At some of our installations we have utilized auxiliary contacts on the ground reading automatic gauges instead of the standpipe arrangement. On these installations we also have a warning level and a critical alarm level.

The standpipe method of installing the alarm switches on the tankage encountered some problems at facilities subject to extreme temperatures. The problems were incurred primarily on fuel oil tanks during extremely cold weather. The temperature of the fuel oil in the standpipe would be much lower than the temperature in the tank itself and

problems resulted in getting a representative level in the standpipe due to the increased viscosity of the fuel oil in extreme temperatures. This problem has been solved by installing insulation on the standpipes.

Alarm annunciators were installed in the terminal offices which give visual as well as an audible indication of both the warning level and final alarm condition. Alarm annunciators were also generally installed in the local pipeline delivery office and in many cases were tied into leased line circuits and taken back to the pipeline operating center.

The alarm points of the product level in the tanks were selected based upon maximum pipeline delivery rates and safe fill levels. The 15-minute period between the warning alarm and critical alarm gives adequate time to the pipeline as well as the terminal personnel to make the necessary valve lineups and switches.

There is some variation in the points to which these tank alarms are fed. At terminals served by Continental Pipe Line Company systems, the alarms are all brought into the centralized control center, as well as having local indication at the terminal. At terminals served by other pipelines, we have brought the alarms into the dispatching centers where practical. In all cases this has not been possible, and in most cases they are at least brought into the local pipeline delivery facility. In a very few cases where the delivering pipeline carrier could not monitor the alarms, we have brought tank alarms into Conoco's centralized control center and monitored the alarms in that fashion.

A testing procedure has been initiated

under which all of the tank alarms are actuated on a frequent basis to assure that the alarm devices are properly working. These tests also check the transmission of the alarm indications and the alarm displays at the various points remote from the terminal. When testing the standpipe type installations, the standpipe is isolated from the tank by closing the valves on the connections to the tank and then pumping product into the stand pipe with a hand pump until the product level reaches the alarm points. On the ground reading automatic gauges, an alarm level is manually simulated. In both cases, the whole alarm system is tested.

In summary, we feel that the procedural changes, as well as the installation of the high tank level alarms, served to minimize our exposure to tank overfills on our systems. At some times in the past, there has been talk by various regulatory agencies of requiring automatic capabilities for shutting a pipeline stream out of a tank in a high level alarm position. We have purposely avoided this concept in our systems because we feel strongly that any system utilizing a high tank level alarm for the purpose of automatically closing a valve to terminate a delivery does nothing to solve the real problem, but merely displaces the problem from the area of the terminal to the area of the pipeline. In other words, we could visualize an automatic system as providing the ultimate in protection for terminals, but resulting in pipeline overpressure conditions and subsequent ruptures, which could result in worse problems.

Explosive volumes expected had the fire potential staggered.

There are systems in place today, but very small area, where a sor can be scale supplied area had n. The U.S. Coast Guard, ready a series of

The pump 18,000 cubic feet was four feet area was for piping, and ship had been service. The door and that type are were closed.

The purpose is possible such a large what type of how the valve would react

Pressure because of pressure and 1301 with high concentration successful, most successful

I want to research project design a code

EXPLOSION SUPPRESSION OF LARGE TURBULENT AREAS

By W. A. CROSLLEY

Executive Vice Pres., Detector Electronics Corp.,
Minneapolis, MN

Each all of the tank alarms are on a frequent basis to assure alarm devices are properly

These tests also check the operation of the alarm indications alarm displays at the various note from the terminal. When the standpipe type installations, pipe is isolated from the tank; the valves on the connections; and then pumping product; stand pipe with a hand pump; product level reaches the alarm; the ground reading automatic; an alarm level is manually; 1. In both cases, the whole system is tested.

Primary, we feel that the alarm changes, as well as the indication of the high tank level alarms, minimize our exposure to tanks in our systems. At some times, first, there has been talk by regulatory agencies of requiring capabilities for shutting a stream out of a tank in a high position. We have purposely this concept in our systems. We feel strongly that any system high tank level alarm for the fire automatically closing a valve is a delivery does nothing to real problem, but merely displaces the problem from the area of the tank to the area of the pipeline. In order, we could visualize an alarm system as providing the ultimate protection for terminals, but in pipeline overpressure conditions subsequent ruptures, which result in worse problems.

Explosion suppression for large volumes in which turbulence can be expected has to be the greatest challenge in the fire protection field today. However, the potential need for just such a system staggers the imagination.

There are explosion suppression systems in service throughout the world today, but in almost every case it is a very small volume or an unobstructed area, where the mechanical pressure sensor can be used successfully. A large-scale suppression test in an obstructed area had never been tested until last year. The U.S. Coast Guard made available an old, ready-for-the-scrap-heap tanker for a series of tests.

The pump-room had a volume of 18,000 cubic feet when the bilge water was four feet below the bottom deck. The area was filled with the original pumps, piping, and valving in place the way the ship had been during its long period of service. The ventings were the hatch door and normal leakage in a ship of that type and vintage. The exhaust vents were closed during the tests.

The purpose of the test was to see if it is possible to suppress an explosion in such a large area, and also to determine what type of detection was the best and how the various types of extinguishants would react.

Pressure sensors were not successful because of the time it took to receive a pressure actuation. Halon 1211, 2402, and 1301 were successful, but in fairly high concentrations. Water was partially successful, and dry chemical was the most successful on a concentration basis.

I want to emphasize this was a research program to gain information to design a complete suppression system

with a capability of suppressing explosions in large as well as small enclosures. Work is being done by our company to accomplish this, and next year we expect to have such a system, but none is available at this time. Dry chemical cannons used in these tests are experimental devices.

I will now describe how the test was conducted and the information that was obtained from these tests.

It is extremely important to detect the exploding fireball in less than 75 milliseconds after ignition, if the explosion is to be suppressed. If it takes longer than that, the explosion will travel faster than the extinguishing agent can handle, and the result will be no suppression or possibly a partial suppression.

In a turbulent area, the only type sensor that can be used is a radiation type. It was proven during these tests that pressure sensors are not suitable. If the area was unobstructed and if there was no turbulence, the pressure sensor with a 1/2 psi pressure setting would have been suitable. However, there are very few large-volume applications that do not have obstructions in them.

The detector best suited for this application is an ultraviolet radiation type. Photo cells and infrared sensors are just as fast, but are subject to false fire signals from artificial light, sunlight, hot bodies, and other heat producing bodies. The UV system has spurious signals also, but they are much more controllable.

UV is generated by a flame in combustion; however, the following subjects also generate UV and care must be taken to eliminate these signals from the detector.

1. Since most hazardous areas do not

allow welding without a safety permit, this can easily be controlled by placing the system in bypass during this period and having a guard stand by with a manual override system during the welding operation.

2. X-rays and gamma rays—if there are enough rays present to cause an actuation, there are enough rays to injure personnel, thus again a safety permit would be required. The system would be put into bypass during the period x-rays and gamma rays were being used.

3. Cosmic radiation is very short in duration, and UV detection systems have built-in compensation. Cosmic radiation does not become a concern.

4. High electrostatic forces could be a problem in some unusual application, but again this signal will not be a problem if the detection equipment is electrically shielded properly during the installation.

5. A UV sensor that is only sensitive to a narrow band of UV, such as from 1850° to 2450° Angstrom, is not affected by solar radiation on earth. The ozone layer attenuates all wave lengths below 2800° Angstrom.

In a basic UV detector system, once UV from an exploding fireball enters the sensor's 90° cone of vision, a solid-state switch will close in less than 10 milliseconds.

A UV detection system, like any man-made product, is subject to failure. These could be tube failure, electronic or wiring failure, or optical system failure.

There are two ways to overcome this probability; one is to have redundant systems with periodic tests. A second way is to have continuous automatic examination of the detector's electronic component, tube, and optical surfaces. This has been accomplished by designing a small UV source lamp and locating it inside the detector housing next to the UV sensor, but completely screened from the sensor. Every few seconds the UV source lamp pulses briefly, generating UV which can only reach the sensor by passing through the window,

ricocheting off a beveled ring, and then re-entering the detector housing through the center of the window, striking the UV sensor and creating a small signal which enters the signal processing section of the electronics.

The signal generated by the UV source lamp enters the UV sensor in the same location when the UV from a fireball enters it. The signal processing portion determines which signal it is. It causes either the solid state relays to actuate the extinguishing agent or, if it is only the signal from the UV source lamp, it signals to the system that everything is in operation from the detector window through the UV sensor and through the electronics. If the signal from the UV source lamp fails to get through, the fault relay de-energizes, warning the operator of a malfunction.

In a detection/suppression sequence, the UV detector responded between 18 and 25 milliseconds after ignition.

The first contact of the agent with the fireball occurred at less than 100 milliseconds after ignition, and the peak of the suppressed pressure curve occurred at 150 milliseconds at a .2 psi overpressure.

The following is a description of the test site and how the equipment was located. The pump room from the top decks to the bilge water consists of a trunk which is approximately half the width of the ship and is located on its center line. Two wing spaces open in the lower quarter of the trunk and extend the full beam of the ship, port and starboard.

A limitation inherent in full-scale explosion testing is the inability to exactly duplicate all of the variables which affect the explosion. This leads to the lack of repeatability of the results. In this test, all efforts were made to control quantity of fuel, quantity of suppression agent, and explosion venting ratio (0.1 ft.² per 100 ft.³). Variables which could not be controlled include environmental factors such as temperature (varied between 70°F and 90°F) and relative humidity.

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Also, most important, they did not want to blow up the ship.

Test explosions could not be designed for a stoichiometric mixture of propane and air throughout the entire volume of the pump room because this would produce approximately 120 psig. Based on the design limitations for the pump room bulkheads, it was decided that the pump room could withstand a maximum of 15 psig. Calculations show that if the stoichiometric mixture of a hydrocarbon field were placed in 10 per cent of the volume and ignited, then the expansion of the explosion into the remaining 90 per cent of the volume would limit the theoretical maximum pressure to 12 psig.

Also, a successful explosion suppression should hold the maximum explosion pressure to substantially less than five psig. Thus, it was reasoned that the total volume would produce realistic results for explosion suppression purposes.

One would expect the test explosion to follow the typical pressure versus time for stoichiometric mixture of propane and air curves up to approximately 10 psig. One can further rationalize that this method is realistic, considering the explosion from the fireball's point of view. As it is ignited and begins to grow, it consumes only stoichiometric fuel air mixture at its exterior surfaces. It is not until the fireball has expanded to fully encompass the mixture that it realizes the entire volume of the pump room is not included.

The Coast Guard then proceeded to run unsuppressed tests and produced the predicted maximum pressures on the order of 12 psig.

The first attempted suppression test used pressure sensors set at one-half psi to trigger the suppression system, and they were unsuccessful. The pressure rise was much more rapid than theoretically predicted, and thus no more than 25 milliseconds were left from the time of detection to maximum pressure. The suppression system requires at least 100

milliseconds to distribute the agent.

This rapid pressure rise was finally attributed to obstruction creating turbulence which increased the flame speed and thus the rate of pressure rise. The evidence is dramatically depicted in the motion pictures of flame being forced between obstructions and is further verified by the reduction in maximum pressure and rate of pressure rise in tests U-29 and U-30.

In these tests, the independent variable obstructions were reduced by bringing the bilge water above the machinery in the lower portion of the pump room where almost all of the obstructions were located, and this reduced the volume to 15,000 cubic feet. This conclusion has a pronounced effect on the time available for detection and actuators of explosion suppression systems. It was found that the UV detectors used in these tests could detect the incipient explosion from 110 to 400+ milliseconds before a pressure sensor set for ½ psig could detect the explosion.

The Det-Tronics UV sensors were then employed in the remainder of the suppression tests.

Two explosion suppression systems were tested. They were based on the following principles:

1. UV detector sees incipient explosion.
2. It signals the control circuitry which fires an electrically actuated blasting device.
3. The initiators rupture a restraining diaphragm, causing the release of a suppressing agent.
4. Driving force throws the agent at the flame front.
5. The flame is extinguished; the explosion suppressed.

One system consisted of spherical high-rate discharge extinguishers to contain the agent. The driving force was provided by pressurizing the charged extinguisher to 325 psig with dry nitrogen. The Detector Electronics UV sensor was used for the detection of the fireball, and various suppression agents were used in

this system. They included water, Halon 2402, Halon 1211, and Halon 1301.

The other system consisted of cylindrical cannons to contain the agent. The driving force was provided by pressurizing the charged cannon to 600 psig with dry nitrogen. Again, the Detector Electronics UV detectors were used to sense the fireball, and the suppression agent used was the dry-chemical Purple K.

In analyzing these tests, the following factors were considered: size of fireball at agent contact; degree of agent breakdown; after burning subsequent to the initial suppression; and maximum pressure developed. The analysis indicates that successful suppression requires the listed minimum application densities for the suppression of explosion of a propane to air mixture in obstructed spaces similar to a ship's pump room.

Water. This agent was only partially successful at application densities of .075 and .071 pounds per cubic foot. While it did reduce the pressure to five psig, it was felt considerably higher application densities would be required to achieve suppression comparable to other agents tested.

Halon 2402. This agent successfully suppressed explosions at densities of .071 and .116 pounds per cubic foot, but two factors indicated that these lower densities were approaching the threshold level for suppression: (1) agent breakdown evidenced by the orange-yellow smoke observed; (2) severe after burning occurred. Agent reached fireball in .09 seconds; however, it took 1.03 seconds to obliterate the flame.

Halon 1211. This agent was successful at .06 and .09 pounds per cubic foot densities. While the maximum pressure developed during these tests were slightly higher than Halon 2402, it is not significant since they were still less than one

psig. There was no indication from the data that the threshold application density had been approached.

Halon 1301. This agent was successful at application densities of .034, .051 and .077 pounds per cubic foot. The lowest application density appeared to approach the threshold for suppression. The evidence was similar to Halon 2402. There was severe after burning for .56 seconds after the initial suppression.

Purple K. The dry chemical successfully suppressed the propane explosion at an application density of .009 pounds per cubic foot. Suppression was marginal at .006 and unsuccessful at .003 pounds per cubic foot. No after burning occurred in any of the three tests.

The maximum pressure obtained during these dry chemical tests are plotted against agent application densities. It indicates that an application density of .007 pounds per cubic foot or greater is required to maintain the pressure below one psig. Increases in density above .01 pounds per cubic foot do not produce a significant reduction in the maximum pressure.

In the dry chemical tests, 18 cannons were used. These are the same cannons that Consolidated Coal Corporation used in their methane suppression study for the U.S. Bureau of Mines contract. These are experimental extinguishers, and no off-the-shelf hardware.

However, the UV detection system is commercially available at this time.

Ten UV detectors were installed throughout the entire pump room, the same as would be necessary in an actual installation. If any one of these testers sees UV radiation, it will fire all 18 cannons. The circuitry was designed to indicate at any time if there was an electrical malfunction in the wiring to any of the cannon detonators.

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There was no indication from the test that the threshold application density had been approached.

301. This agent was successful at application densities of .034, .051 and .068 lbs per cubic foot. The lowest application density appeared to approach the threshold for suppression. The response was similar to Halon 2402. The response was severe after burning for .56 seconds after the initial suppression.

302. K. The dry chemical agent suppressed the propane explosion at an application density of .009 lbs per cubic foot. Suppression was not achieved at .006 and unsuccessful at .003 lbs per cubic foot. No after burning occurred in any of the three tests.

303. The maximum pressure obtained during dry chemical tests are plotted against application densities. It indicates that an application density of .01 lbs per cubic foot or greater is required to maintain the pressure below 15 psi. Increases in density above .01 lbs per cubic foot do not produce a further reduction in the maximum

pressure. Dry chemical tests, 18 cannons were used. These are the same cannons used in the Consolidated Coal Corporation's methane suppression study. U.S. Bureau of Mines contract. The experimental extinguishers, off-the-shelf hardware.

304. However, the UV detection system is not fully available at this time.

305. UV detectors were installed throughout the entire pump room, the possibility would be necessary in an actual explosion. If any one of these testers is activated, it will fire all 18 cannons. The circuitry was designed to initiate any time if there was an electrical function in the wiring to any of the detonators.

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