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PREPARED BY/DATE

L. Humphrey, G. Pilicy
L. Felton, F. Welch
L. Goodman,

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APPROVALS

O. P. Steele III	<i>O. P. Steele III</i>	DATE	
F. H. Welch	<i>F. H. Welch</i>		8/8/74
R. M. Oliva	<i>R. M. Oliva</i>		8/16/74

AUTHORIZED
CLASSIFIER

DATE

DISTRIBUTION

* NAME	MAIL ADDR
J.G. Asquith (15)	LB02
R.W. Keaten	LB17
M. Marko	LB34
O.P. Steele III	T006
W.J. Kurzeka	T006
R.M. Oliva	LB08
F.H. Welch (3)	T006
L.H. Humphrey	T006
G.J. Pilicy	T006
R.L. Bowman	T006
S.R. Sontag	T006
W.T. Morgan	LB01
L.D. Felten	LB31
L. Goodman	NA12
J.K. Rosemary	T038
F.F. Couture	AA89
E.L. Roddy	NB13
M.E. Remley	NB08
J.P. Klostermann	T020
K. Foster	LB10
G.W. Meyers	T038

ABSTRACT

The safety aspects of the removal of sodium from non-radioactive reactor components by the alcohol process are described in detail. Pertinent properties of alcohol and hydrogen are presented.

Relevant excerpts from the Occupational Safety and Health Act safety codes are presented, and a conceptual system is shown illustrating the application of these safety measures.

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I. INTRODUCTION

This document is concerned with the safety considerations involved in liquid alcohol cleaning of reactor systems components that have been sodium wetted and drained of excess sodium. It supplements the safety specification covering this cleaning operation, and is intended to be an information source for the safety engineering of such systems. It is particularly concerned with the problems inherent in the handling of large volumes of ethyl alcohol, although relevant information about similar light alcohols and Dowanol is included.

Ethyl alcohol has been manufactured and handled at least since the days of ancient Egypt. Its ability to react with metallic sodium has been known since the early 19th century, while sodium alcoholate has been produced and used in large quantities by the chemical and food industries for much of the present century. However, the use of the sodium alcohol reaction on a large scale to clean sodium wetted hardware is an outgrowth of the nuclear industry, and consequently is fairly recent. The fact that the materials and the reaction between them are well known does not lessen the need for a well established safety program.

The removal of sodium by reacting it with alcohol has an intrinsic hazard potential. The alcohol itself is flammable, and its reaction with sodium results in the liberation of hydrogen, which is a considerably more reactive material than alcohol. In addition, alcohol containing sodium acts as caustic in contact with human tissue. In order to use the reaction in a safe manner, it is necessary to recognize and respect its potential hazards.

It is well known that many of the industries presenting the highest hazard potential (e. g. , explosives manufacture, petroleum refining, and organic synthesis), have compiled outstanding safety records. This may be attributed

to a realistic assessment of the types of incident which might be encountered, coupled with the establishment of operational safeguards which counter them. The recognition of a hazard permits the initiation of measures to neutralize it.

This document, in company with the system safety specification which it supplements, is intended to aid in the establishment of thoroughly safe sodium removal operations. It will be updated as the current development program generates new information.

Problems specifically associated with the removal of radioactive sodium will not be treated here, as such problems are currently under investigation, although consideration of radioactive handling is made throughout the report.

II. SYSTEM AND PROCESS DESCRIPTION

A. DESCRIPTION OF ALCOHOL PROCESS

Figure 1 is a schematic diagram of a typical alcohol process sodium removal loop, with regenerative capability. The tank labeled "Cleaning Vessel" contains and rigidly supports the component to be cleaned of sodium. This component is normally maintained in an inert atmosphere by a bag that is removed prior to sealing the cleaning vessel, and the vessel itself contains an inert nitrogen atmosphere during the component installation and sealing procedure. Typically, this atmosphere contains less than 2% oxygen and 0.001% water vapor by volume.

Following installation and sealing, ethyl alcohol fills the cleaning vessel. Dry nitrogen may be used as a sparge gas to improve fluid mixing, although the effect on the reaction rate appears small. A gas flow rate much lower than sparging rate may be used to dilute and sweep out the hydrogen produced in the cleaning reaction.

Figure 1. Alcohol Cleaning Loop

Most of the surface sodium present reacts as the cleaning vessel is filled with alcohol. This process continues as the alcohol is pump-circulated through the system. Following initial circulation, * decreasing rates of hydrogen evolution indicate that all sizeable sodium residues have completed reaction. At this time, cleaning is completed by heating the circulating alcohol to 140F (60C) to speed sodium removal from crevices. A constant sodium ion content in the alcohol and a hydrogen content of less than 10 ppm in the exiting sparge gas serve to verify procedure completion.

Following draining of the initial charge of alcohol, rinsing begins with either deionized water or a second charge of alcohol, depending upon the composition of the part being cleaned. Water rinsing may be conducted at temperatures up to 180F (82C) to increase the rinse effectiveness. After final rinsing, the cleaning vessel and component may be dried by hot inert gas ventilation or by evacuation.

Table I summarizes the steps involved in a typical cleaning process.

B. REACTION DATA

Ethanol reacts with sodium by mechanism 1:

This reaction sequence is exothermic, and releases about 3,500 Btu per pound of Na consumed.

Since ethanol is hygroscopic, whatever water is present reacts as:

*Time required for process completion is dependent upon component size, configuration, extent of sodium wetting, etc.

TABLE I
STEPS IN CLEANING PROCESS

Process Step	Description
1. Purge the loop environment.	Purge with dry nitrogen to 0.001 vol. % water vapor and 1 vol. % oxygen. Final nitrogen pressure is dependent upon tank design.
2. Fill system with ethyl alcohol.	Fill vessel with cleaning alcohol chilled to a minimum of 55F (13C). Sparge system with dry nitrogen during filling. Monitor hydrogen concentration in exhaust.
3. Circulate alcohol through the cleaning vessel.	After the system is filled and circulation is begun, slowly heat the alcohol to 140F (60C). Component is cleaned when the sodium ion content of the alcohol remains constant and no more hydrogen reaction gas is generated (<10 ppm by volume in exhaust gas).
4. Drain alcohol from the system and rinse the system with clean fluid (alcohol or water).	Either fresh alcohol or deionized water is used for the final system rinse. The alcohol may be heated to 140F (60C) or the water to 180F (82C) during circulation.
5. Dry the cleaning vessel and component.	The rinse fluid is drained and the system may be dried either under vacuum or by hot inert gas.

The water is then regenerated by:

Figure 2 shows the individual reaction rates of alcohol on sodium samples in 0.85 inch ID tubes at eight different Na-alcohol temperatures.*

Figure 3 shows an Arrhenius plot of the surface recession rates as a function of temperature for these test specimens. These rates should typify reaction rates for large sodium areas, while the rates currently being measured on smaller tubes should reflect problems involved in removing sodium from crevices. (In this case, liquid alcohol must penetrate crevices against an outflow of the liberated hydrogen gas.)

Figure 4 compares the reaction rates of sodium with Dowanol PM (propylene glycol methyl ether) and with ethyl alcohol. Both liquids were tested at bulk liquid temperatures of about 75F (24C), and the results illustrate the difference in the speeds of reaction between sodium and the respective alcohol.

Based on the data from Figure 3, a peak temperature of 100F (38C) or less is expected at the reaction interface while filling with 75F (24C) ethyl alcohol. This is the sort of temperature behavior anticipated at a sodium heel under relatively stagnant conditions.

If the circulating alcohol sweeps across the surface of the heel, even smaller temperature increases are expected. The sodium heel in the AI Modular Steam Generator (AI-MSG) showed no temperature increase as long

*With ethanol at a bulk temperature of 140F (60C), thermocouples embedded in the sodium of a 0.850 in. diameter sample registered a peak temperature of 178F (81C). This temperature occurred only at the transient sodium-alcohol interface, and is significantly lower than the lowest temperature at which the onset of caustic surface stress corrosion has been observed. (1)

Figure 2. Anhydrous Denatured Ethanol-Sodium Reaction Rates, 0.85 inch ID Tube

Figure 3. Reaction Rates of Metallic Sodium with Denatured
 Ethyl Alcohol 0.85 inch ID Tube

Figure 4. Comparison of Sodium Reaction with Ethanol and Dowanol PM

as the Dowanol PM flowed across the surface. However, during a test simulating such a sodium test, flow was stopped for 45 minutes, during which time the heel was submerged in Dowanol PM agitated only by convection and interface bubble formation. Under these conditions, the bulk alcohol temperature rose to 130F (54.5C).⁽²⁾

Current testing also has indicated (Figure 3) that excellent process rate control may be realized by precooling the alcohol. It is tentatively planned to minimize the initial interface temperature rise by precooling the initial charge of alcohol to ~55F (13C).

The reaction of sodium in crevices causes insignificant heat generation, since the amount of sodium is small and the sodium reaction rates are very slow. This has been effectively demonstrated both in the experiments described and in the AI-MSG cleaning process. Whatever heat is generated finds a large heat sink in the surrounding metal.

Under most conditions, heat generation during the filling process presents no problems. The combination of available heat sink capacities of the part being cleaned and of the rapidly rising, circulating cold alcohol provide adequate relief. Cleaning certain special configurations, such as long, thin walled tubes, may require additional analysis, as such configurations will provide limited heat capacity while limiting the volume of alcohol in contact with the surface.

C. SUMMARY OF A TYPICAL SYSTEM

A typical system is envisioned as consisting of three major areas: 1) the alcohol storage area; 2) a processing area, containing the actual cleaning vessel and alcohol temperature conditioning equipment, and 3) the reclamation area, containing both reclamation and used alcohol storage facilities.

The alcohol storage area will probably consist of outdoor, above ground storage tanks of conventional welded steel construction, equipped with a system to provide a dry inert gas cover. This area should also incorporate loading facilities, and all alcohol transfer should be restricted to this area.

The processing area (Figure 5) is envisioned as a consolidated indoor area containing the cleaning vessel, component handling facilities, alcohol temperature conditioning facilities, and extensive control and monitoring instrumentation to determine exact process status. This area will probably also contain the main control console for the entire process, and be the center of the safety monitoring effort.

The reclamation area concept is currently under consideration, and its final conformation will depend upon the exact process selected to remove reacted sodium from the alcohol solvent. Radiation shielding may become a most significant factor here. Provisions for waste removal from this area will be necessary, as will be tankage to store solvent awaiting processing. It may be possible to combine some of the functions of the storage and reclamation areas, or possibly co-locate these areas.

III. SAFETY CRITERIA

A. FEDERAL REGULATIONS - OCCUPATIONAL SAFETY AND HEALTH ACT (OSHA)

Increasing Government concern with safety and health problems, and with the general environment, resulted in passage of the Williams-Steiger Occupational Safety and Health Act which became Federal Law on Dec. 29, 1970. The Act establishes primary safety standards for all industry governed by Federal regulations. Its requirements, relative to chemical operations, are contained in 29CFR17, Part 1910, Occupational

Figure 5. Areas of Alcohol Use

Safety and Health Standards, 18 October 1972.⁽³⁾ Electrical regulations are contained in the National Electrical Code which was officially adopted as an OSHA standard on Feb. 16, 1972. On Atomic Energy Commission installations, the provisions of this Act are carried out under A. E. C. direction, in conjunction with additional provisions concerning control of radioactivity hazards. (See A. E. C. Appendix 0550, dated March 1974.⁽⁴⁾)

The standards and regulations are designed to achieve compliance through the application of engineering design principles. Administrative procedures are used only where engineering design does not completely attain safety and health objectives.

The following section is an abridged version of Code requirements applicable to the alcohol sodium removal process. Items were included on the basis of applicability to the majority of installations, e. g., alcohol storage in outside, above ground tanks. It is intended to illustrate the type of restrictions which the Codes impose. Actual plant design will require detailed study of the Codes themselves to assure compliance.

1) Specific Code Requirements

a) Occupational Safety and Health Regulations Federal Register,
Vol. 37, No. 202, Oct. 18, 1972

1) Section 1910.93 Air Contaminants - Acceptable ceiling concentration of vapors (maximum permissible concentration) based on an 8 hr/day, 5 day/week.

Ethyl alcohol	1000 ppm by volume
---------------	--------------------

Methyl alcohol	200 ppm by volume
----------------	-------------------

NOTE

Methyl alcohol is present in ethyl alcohol as a denaturant to a concentration of approximately 5%. Its concentration in vapor will be roughly proportional to its concentration in solution.

2) Section 1910.106 Flammable and Combustible Liquids

a) Classification

Ethyl Alcohol is classified as Class IB (liquids in this class have boiling points at or above 100F and flash-points below 73F).

b) Ventilation

Sufficient ventilation is required to prevent accumulation of vapor-air mixtures in concentrations over one-fourth of the lower flammable limit. (For ethanol, this concentration is approximately 9,000 ppm).

c) Storage Tanks

1 Construction

- a Atmospheric tanks shall be built in accordance with acceptable good standards of design. The following are recognized as acceptable standards: Underwriter's Laboratories Inc. , No. 142, Standard for Steel Above-ground Tanks for Flammable and Combustible Liquids; No. 142, Standard for Steel Underground Tanks for Flammable and Combustible Liquids.

- b Low-pressure tanks shall be built in accordance with acceptable standards of design. American Petroleum Institute Standard No. 620, "Recommended Rules for the Design and Construction of Large Welded, Low-Pressure Storage Tanks" is an acceptable standard.

2 Location

The location of alcohol tanks in relation to property lines and other buildings shall be as designated in Tables II and III.

3 Normal Venting - Above-ground Tanks

- a Tanks shall be adequately vented to prevent development of pressure or vacuum as a result of filling or emptying which exceeds design pressure.
- b Normal vents may be sized in accordance with American Petroleum Institute Standard No. 2000, "Venting Atmospheric and Low-pressure Storage Tanks."
- c Tanks storing Class IB liquids shall be equipped with venting devices which shall be normally closed, except when venting under pressure or vacuum conditions, or with approved flame arrestors.

These provisions are directed at the prevention of tank collapse or rupture due to pressure differentials caused by pumping, or thermal expansion or contraction of tank contents. Since ethanol is hygroscopic, it must be stored under a dry gas cover; use of an inert gas for

TABLE II

Table H-5, OSHA

Type of tank	Protection	Minimum distance in feet from property line which may be built upon, including the opposite side of a public way	Minimum distance in feet from nearest side of any public way or from nearest important building and shall be not less than 6 feet
Floating roof.	Protection for exposures.	1/2 times diameter of tank but need not exceed 90 ft.	1/6 times diameter of tank but need not exceed 30 ft.
	None	Diameter of tank but need not exceed 175 ft.	1/6 times diameter of tank but need not exceed 30 ft.
Vertical with weak roof to shell seam.	Approved foam or inerting system on the tank.	1/2 times diameter of tank but need not exceed 20 ft. and shall not be less than 5 ft.	1/6 times diameter of tank but need not exceed 30 ft.
	Protection for exposures.	Diameter of tank but need not exceed 175 ft.	1/3 times diameter of tank but need not exceed 60 ft.
	None	2 times diameter of tank but need not exceed 350 ft.	1/3 times diameter of tank but need not exceed 60 ft.
Horizontal and vertical, with emergency relief venting to limit pressures to 2.3 p. s. i. g.	Approved inerting system on the tank or approved foam system on vertical tanks.	1/2 times Table H-9 but shall not be less than 5 ft.	1/2 times Table H-9.
	Protection for exposures.	Table H-9	Table H-9.
	None.....	2 times Table H-9.....	Table H-9.

TABLE III

Table H-9, OSHA

Capacity tank gallons	Minimum distance in feet from property line which may be build upon, including the opposite side of a public way	Minimum distance in feet from nearest side of any public way or from nearest important building
275 or less	5	5
276 to 750	10	5
751 to 12,000	15	5
12,001 to 30,000	20	5
30,001 to 50,000	30	10
50,001 to 100,000	50	15
100,001 to 500,000	80	25
500,001 to 1,000,000	100	35
1,000,001 to 2,000,000 ..	135	45
2,000,001 to 3,000,000 ..	165	55
3,000,001 or more		60

this cover is an additional safety factor. Since this predicates a closed system, these specifications would be met by a pressure venting device in conjunction with a demand regulated inert gas supply system to assure a constant small inert gas overpressure.

In addition to this normal pressure adjusting system, emergency relief venting in case of exposure to fire must be supplied. Code requirements for such venting are as follows:

4 Emergency Relief Venting - Aboveground Tanks

- a Every aboveground storage tank shall have some form of construction or device that will relieve internal pressure caused by exposure to fires.
- b Construction may take the form of a floating roof, or a weak roof-to-shell seam.

c Pressure relieving devices shall be sized as shown in Table IV:

TABLE IV
Table H-10, OSHA*

Square feet	CFH	Square feet	CFH	Square feet	CFH
20	21,100	200	211,000	1,000	524,000
30	31,600	250	239,000	1,200	557,000
40	42,100	300	263,000	1,400	587,000
50	52,700	350	288,000	1,600	614,000
60	63,200	400	312,000	1,800	639,000
70	73,700	500	354,000	2,000	662,000
80	84,200	600	392,000	2,400	704,000
90	94,800	700	428,000	2,800	742,000
100	105,000	800	462,000	and	
120	126,000	900	493,000	over	
140	147,000	1,000	524,000		
160	168,000				
180	190,000				
200	211,000				

NOTE*

Wetted area is defined as 75% of the total exposed area of a horizontal tank and the first 30 feet above grade of the exposed shell area of a vertical tank.

The code also specifies the following formula as acceptable for calculation of emergency venting capacity for stable liquids such as alcohol:

$$V = \frac{1337}{L\sqrt{M}} \text{ in which}$$

V = cubic feet of free air/hour

L = latent heat of vaporization, Btu/lb

M = molecular weight of liquid

Further specifications concerning alcohol storage and handling are included below. These specifications will be seen to be normal flammable liquid specifications; alcohol requires no special handling facilities or precautions beyond those taken with other stable, flammable liquids in bulk.

5 Drainage, Dikes and Walls - Aboveground Tanks

- a The area surrounding a tank storing a Class I liquid shall be provided with drainage or shall be diked.
- b Drainage system shall terminate in vacant land or impounding basin capable of containing 150% of entire tank volume.
- c Diked area shall be capable of containing 150% of entire tank volume and shall be liquid-tight.
- d Water drains from diked areas shall be a sump or drainbox at the greatest practical distance from the tank and should be controllable from outside the dike under fire conditions.

6 Tank Fill Line

- a Fill line entering the top of a tank shall terminate within six inches of the bottom of the tank to minimize the generation of static electricity.

7 Tank Supports

Tanks shall be installed on firm foundations supported by concrete, masonry or protected steel.

d) Drum Storage - Outdoor

1 Storage Area

The storage area shall be graded to divert spills from buildings or shall be surrounded by a curb at least six inches high. Drainage shall terminate at an on-site location.

2 Location

Table V defines the restrictions on the outdoor locations.

TABLE V

Table H-16 - Outdoor Container Storage

1	2	3	4	5
Class	Maximum per pile (see note 1)	Distance between piles (see note 2)	Distance to property line that can be built upon (see notes 3 and 4)	Distance to street, alley, public way (see note 4)
	gal.	ft.	ft.	ft.
IA	1,100	5	20	10
IB (alcohol)	2,2000	5	20	10
IC	4,400	5	20	10
II	8,800	5	10	5
Combustible	22,000	5	10	5

Note 1: When 2 or more classes of materials are stored in a single pile, the maximum gallonage in that pile shall be the smallest of the 2 or more separate gallonages.

Note 2: Within 200 ft. of each container, there shall be a 10-ft. wide access way to permit approach of fire control apparatus.

Note 3: The distances listed apply to properties that have protection for exposures as defined. If there are exposures, and such protection for exposures does not exist, the distances in column 4 shall be doubled.

Note 4: When total quantity stored does not exceed 50 percent of maximum per pile, the distances in columns 4 and 5 may be reduced 50 percent, but not less than 3 ft.

3 Grounding

Containers used for Class I liquids shall be electrically bonded or grounded during transfer of liquids, to prevent the build-up of static electrical charges.

e) Transfer and Use

1 Transfer

- a Areas in which flammable liquids are transferred shall be separated from other operations in the building by construction having adequate fire resistance. Drainage shall be provided to control spills.
- b Transfer shall be through a closed piping system or via safety cans. Transfer by gas pressure on the container is prohibited to prevent the accidental rupture of the container.

2 Use

- a Usage area shall be located so as to be accessible from at least one side for fire control.
- b Location of processing vessels shall be in accordance with Table VI.

TABLE VI

Table H-20, OSHA

Processing vessels with emergency relief venting to permit pressure	Stable liquids	Unstable liquids
Not in excess of 2.5 p.s.i.g.	Table H-9	2-1/2 times Table H-9
Over 2.5 p.s.i.g.	1-1/2 times Table H-9	4 times Table H-9

- c Emergency drainage systems shall be provided. A trap will be provided if the discharge is to the sewer. This will prevent the possibility of alcohol vapor accumulating in drain-pipes, with possible attendant hazard.

3 Ventilation

Enclosed processing buildings shall be ventilated at a rate of not less than 1 cubic foot per minute per square foot of solid floor area. Discharge or exhaust will be to a safe area outside of the building. All floor areas or pits where alcohol vapors may collect will be ventilated. Explosimeter activated alarm systems may be used to continuously monitor vapor concentrations.

4 Sources of Ignition

No sources of ignition will be permitted in areas where alcohol is stored, transferred, or used. Conformance with this specification requires careful consideration of access control, use of non-sparking hand tools, selection and use of approved non-sparking power equipment, confiscation of smoking materials upon entry, etc.

5 Exits

Rooms in which alcohol is handled should have exit facilities arranged to prevent occupants from being trapped.

6 Fire Control

Portable fire extinguishing and control equipment shall be provided in such quantities and types as are needed for the special hazard of operation and storage. Standard for the installation of portable fire extinguishers, National Fire

• 2 3

3) Hydrogen

This gas will be evolved during the cleaning process, and therefore will be created in a sealed system under an inert gas atmosphere, and immediately vented from the upper end of the cleaning vessel to the atmosphere. The hydrogen venting system must conform to the following requirements from Section 1910.103 of the OSHA code:

a) Venting

- FORM 719-P REV. 3-73

B. NATIONAL ELECTRICAL CODE, CHAPTER 5

The National Electrical Code (NEC)⁽⁵⁾ has been included in its entirety within the Occupational Safety and Health Act, and provides both guidance and required standards of design, installation, and operation for electrical equipment. Excerpts of pertinent NEC sections are included here as a further part of an abridged presentation of Code requirements.

1) Article 500 - Hazardous Locations, Classification Of

Ethyl alcohol is a Class I liquid; therefore any area in which it is used is designated as Class I. It is in Group D as regards explosive characteristics. Since it will be handled in a closed system and will not be exposed to the air in normal operation, the areas adjacent to its use will be classified as Division 2 areas.

While hydrogen is also produced in this process, the methods of handling and venting should easily preclude the classification of any plant area as Class I, Division I.*

*The following descriptions are reprinted from the N.E.C., and clarify classification criteria.

Class I, Division 1: This classification usually includes locations where flammable volatile liquids or liquefied flammable gases are transferred from one container to another; interiors of spray booths and areas in the vicinity of spraying and painting operations where volatile flammable solvents are used; locations containing open tanks or vats of volatile flammable liquids; drying rooms or compartments for the evaporation of flammable solvents; locations containing fat and oil extraction apparatus using volatile flammable solvents; portions of cleaning and dyeing plants where hazardous liquids are used; gas generator rooms and other portions of gas manufacturing plants where flammable gas may escape; inadequately ventilated pump rooms for flammable gas or for volatile flammable liquids; and all other locations where hazardous concentrations of flammable vapors or gases are likely to occur in the course of normal operations. Continued on next page.

2) Article 501 - Class I Installations

- a) Meters, instruments, and relays installed in Class I, Division 2 areas shall have enclosures approved for Class I locations or general-purpose enclosures with current-interrupting contacts immersed in oil or enclosed within a hermetically sealed chamber, or in circuits which do not release sufficient energy for ignition.
- b) Resistors, tubes, and rectifiers used in equipment without make-and-break or sliding contacts may utilize general-purpose enclosures.
- c) Fuses may be mounted in general-purpose enclosures provided they do not exceed 3 ampere rating at 120 volts.
- d) Process control instruments may be connected if:
 - 1) A switch conforming to Part a of this section is provided to interrupt current.
 - 2) Current does not exceed 3 amperes at 120 volts.
 - 3) Power is supplied by a cord less than 3 feet long, of a type approved for extra-hard usage (or hard usage if protected), and is connected through a plug-cap and receptacle of the locking and grounding type.

Class I, Division 2: This classification usually includes locations where flammable volatile liquids or flammable gases or vapors are used, but which, in the judgment of the Code enforcing authority, would become hazardous only in case of an accident or of some unusual operating condition. The quantity of hazardous material that might escape in case of accident, the adequacy of ventilating equipment, the total area involved, and the record of the industry or business with respect to explosions or fires are all factors that should receive consideration in determining the classification and extent of each hazardous area.

4 Only the necessary receptacles are provided.

5 Receptacles carry warnings against unplugging under load.

- e) Wiring in Class I, Division 2 locations shall be threaded rigid metal conduit or Type MI, MC, ALS, or SNM cable with approved termination fittings. For limited flexibility, as at motor terminals, flexible metal fittings, flexible metal conduit with approved fittings, or flexible cord approved for extra-hard usage and provided with approved bushed fittings shall be used.
- f) Conduit sealing shall be provided for conduit passing from Class I, Division 2 areas into non-hazardous areas to prevent the communication of gases or vapors.
 - 1) The sealing fitting shall be located on or near the boundary of the hazardous area.
 - 2) The sealing compound shall be approved for the purpose.
 - 3) The thickness of the sealing compound shall not be less than the trade size of the conduit and in no case less than 5/8".
- g) Switches, circuit breakers, motor controllers and fuses may be contained in general-purpose enclosures providing that the interruption of current occurs within a hermetically sealed chamber or the current-interrupting contacts are oil-immersed.
- h) Non-explosion proof enclosed motors such as squirrel-cage induction motors, without brushes or switching mechanisms, are acceptable for Class I, Division 2 locations.
- i) Lighting fixtures shall be protected from physical damage by suitable guards.

- j) Non-explosion proof lamps must operate at a surface temperature under 80% of the auto-ignition temperature of the gas or vapor which may be present. (See Tables VII and VIII.)
- k) Exposed non-current-carrying metal parts of motors, lamps, cases and conduit shall be grounded.

This section as stated in the first paragraph, is intended as an introduction to the Safety Codes and not as a substitute for them. The Codes have been developed to a point where they cover nearly every possible set of conditions which might be encountered and give quite specific answers to most questions. In case of doubt, the Occupational Safety and Health Administration is available for advice and consultation which they are committed to provide without using the request as justification for an inspection. Questions about OSHA may be answered by the booklet "All About OSHA" which may be obtained from the U. S. Department of Labor. It is identified as OSHA 2056.⁽⁷⁾

IV. PROPERTIES OF ALCOHOL AND HYDROGEN

A. CHARACTERISTICS OF ALCOHOL

Ethyl alcohol is a flammable liquid. Some of its most important properties appear in Table VII, and additional properties are listed in Appendix A.

The flash point, or temperature at which a material will emit sufficient vapor in air to form a flame-ignitable mixture, is 55F (13C) for pure ethyl alcohol. The apparent or auto-ignition temperature is that temperature required to initiate self-sustained oxidation; for pure ethyl alcohol, this ranges between 684F (362C)⁽⁸⁾ and 799F (425C)⁽⁹⁾, varying with conditions.

TABLE VII

PROPERTIES OF ETHANOL C_2H_5OH
(ETHYL ALCOHOL, GRAIN ALCOHOL)

Molecular Weight	46.1
Specific Gravity (60F)	0.79
Boiling Point (F) ⁽⁹⁾	173
Flash Point (F) ⁽¹⁰⁾ (closed cup)	55
Apparent (Auto) Ignition Temperature (F) ⁽¹⁰⁾	738
Heat of Combustion Btu/lb (liquid) ⁽¹¹⁾	12,800
Flammable Limits in Air (vol %) ^(11,12)	3.3 - 19.0
Minimum O ₂ Required for Burning ⁽¹⁰⁾	10.6% (N ₂ Diluent) 13.0% (CO ₂ Diluent)
Saturation Vapor Pressure at >110F Puts Ethanol Air Mixture Above Upper Flammable Limit for P = 1 atm.	

In any case, all proposed alcohol cleaning processes create maximum temperatures several hundred degrees below the auto-ignition temperature for alcohol.

The actual combustion process proceeds by the relation:

This reaction releases 12,800 Btu/lb of liquid ethanol, or 13,100 Btu/lb of ethanol vapor at boiling point.

There are several factors that serve to limit or inhibit combustion. The burning rate for a pool of liquid alcohol appears in Figure 6. Note that this rate is only 30% of that for a similar pool of gasoline, illustrating the characteristically low burning rate of alcohol in large pools.⁽¹⁰⁾ Alcohol-water mixtures containing more than 20% alcohol are flammable, while mixtures containing less than 15% alcohol will not support combustion, even if heated to boiling. Alcohol and water are completely soluble in one another; a pool of burning alcohol may be extinguished by dilution with water to 15% alcohol concentration.

Such properties combine to create a fluid far safer to handle than fuel oil or even gasoline. Spilled alcohol can be immediately diluted with water to create a non-flammable fluid, while alcohol fires may be extinguished with water sprays without the scattering problems encountered with petroleum base liquid fires.

As shown by Figure 7, ethanol has both a relatively high and relatively temperature sensitive vapor pressure.⁽¹³⁾ At the planned cleaning process operating temperature, the saturation vapor pressure of ethyl alcohol is such as to cause vapor concentration above the upper flammable limit of 19% (Figure 8).⁽⁸⁾ For this reason, large spills of hot alcohol in confined spaces would rapidly create vapor-air mixtures too rich to burn at any temperature.

Figure 6. Relation Between Liquid-Burning Rate (Large-pool Diameter) and Ratio of Net Heat of Combustion to Sensible Heat of Vaporization⁽⁸⁾

Figure 7. Vapor Pressure of Ethyl Alcohol -20C to 150C

Figure 8. Limits of Flammability of Ethyl Alcohol-Carbon Dioxide-Air and Ethyl Alcohol-Nitrogen-Air Mixtures at 25C and Atmospheric Pressure (8)

Continued examination of Figure 8 will show several other combustion limits for ethanol-air mixtures. Nitrogen dilution that lowers oxygen content to 10.6 vol. % will prevent combustion for all concentrations of ethanol vapor. The presence of water vapor (36.5 vol %) or carbon dioxide (31%) produces the same effect.

Due to these factors, alcohol fires are extremely vulnerable to atmospheric dilution by inert gases, to water sprays, and to carbon dioxide fire extinguisher systems.

Any areas within which humans work have a further safeguard in the form of human sensitivity to alcohol. The lower flammable limit of alcohol in air is about 30, 000 ppm. One-fifth of this concentration, or 6,000 ppm, has been found to be intolerable to humans, causing severe mucus membrane and eye irritation. Therefore workers constitute an effective sub-flammable vapor level detection system, although no attempt should be made to use the worker as a detector in the system since individual tolerances vary widely.

The preceding flammability characteristics apply fairly well to the two glycol compounds, Dowanol EB, (ethylene glycol butyl ether: $C_4H_9OC_2H_4OH$) and Dowanol PM, (propylene glycol methyl ether; $C_2H_4OHCH_2OCH_3$), which have seen service for sodium compound cleaning.⁽²⁾ The PM solvent is non-toxic, has a flash point of 100F (38C), and, in concentrations above 1000 ppm, exhibits a highly disagreeable odor. EB has a flash point of 165F (71C), and a threshold limit value (TLV) of only 50 ppm in air.

Both solvents are similar to ethanol inasmuch as all three are completely miscible in water, and are hygroscopic.

B. CHARACTERISTICS OF HYDROGEN

The alcohol-sodium reaction creates free hydrogen gas, several characteristics of which appear in Table VIII.

Hydrogen gas is highly flammable in air, burning according to equation (5)

and releasing 61,000 Btu/lb H_2 for liquid water formation, or 52,000 Btu/lb for water vapor formation.

Auto ignition temperature values for the above reaction range from 752F (400C)⁽⁸⁾ to 1085F (585C).⁽¹⁴⁾ (The lowest of these is several hundred degrees above the highest temperatures encountered in the sodium cleaning process, and are somewhat higher than the temperature of 738F⁽⁸⁾ given for ethanol.)

Table VIII presents flammable limits for hydrogen in air at standard temperature and pressure. Note that, if the oxygen content is reduced to less than 5% by nitrogen dilution, hydrogen will not burn at any concentration. Figure 9 shows the variation in the hydrogen flammable range as a function of carbon dioxide and nitrogen diluents.

It should be emphasized that the characteristics of hydrogen are included in this document primarily for completeness of treatment: free hydrogen at no time should be present in the plant. The system will be so designed that hydrogen can be evolved only within the sealed cleaning vessel, and only when this vessel contains an inert atmosphere. The resulting inert mixture of hydrogen and cover gas will be conducted directly to the atmosphere at the highest point of the structure. This removal process will take advantage of gaseous hydrogen's extremely low density and molecular weight, and consequent high buoyancy in air, to cause immediate dissipation of any hydrogen created.

TABLE VIII
PROPERTIES OF HYDROGEN H₂

Molecular Weight	2.0
Specific Gravity (60F)	0.000085
Boiling Point (F)	-423
Flash Point	(Gas)
Apparent (Auto) Ignition Temperature (F) ^(8,11)	750-1060
Heat of Combustion Btu/lb H ₂ (Gas) ⁽¹¹⁾	61,000
Flammable Limits in Air vol % ^(11,12)	4.0 - 74.2
Minimum O ₂ Required for Burning ⁽¹⁵⁾	5.0% (N ₂ Diluent) 5.9% (CO ₂ Diluent)

C. FIRE PROTECTION TECHNIQUES

Since the point of exit for hydrogen gas is at the highest point of the structure, and it is generated within a sealed steel chamber containing an inert atmosphere, it is difficult to conceive of a situation involving combating a hydrogen fire. However, again in the interests of completeness, the following information is presented: Fires from a gas, such as hydrogen, are best extinguished by creating an inert atmosphere to eliminate oxygen and by shutting off the source of flammable gas. Small gas fires may sometimes be extinguished with CO₂ or water spray. Table VIII and Figure 9 show that dilution of an atmosphere to either 5% O₂ with nitrogen or 5.9% O₂ with CO₂ will extinguish a hydrogen fire. A water spray is very effective in keeping the surroundings cool until the gas fire can be extinguished.⁽¹⁶⁾

Figure 9. Limits of Inflammability of Hydrogen in Air Diluted with CO_2 and N_2 Room Temperature and Atmospheric Pressure⁽¹⁵⁾

A somewhat more believable occurrence than a hydrogen fire would be an alcohol fire. Handling such a fire is a fairly standard procedure and is well documented. An ethyl alcohol fire can be extinguished by creating an inert environment. The oxygen must be diluted either to 10.6% by nitrogen dilution or to 13.0% by CO₂ dilution to stop combustion (Table VII and Figure 8). Water, particularly when finely sprayed, is very effective in reducing the burning intensity. In addition, the fire can be extinguished by diluting the liquid alcohol to a 15% concentration water. An alcohol fire can be smothered with CO₂, dry chemical, or an "alcohol-type" foam sprayed directly over the liquid. Alcohol will react destructively with some fire suppressant foams; consequently, special foams are available for alcohol fires.

With reasonable employment of techniques of fire prevention, alcohol fires are most unlikely in the first place. A major element in alcohol fire prevention in this process involves prevention of static electricity discharges. All alcohol storage tanks, transmission lines, and other system components should be grounded. Tank inlet lines should be dip lines to prevent induced static electric charge. When alcohol is transferred between containers, the two containers should be electrically connected. Because of its relatively high electrical conductivity, (10^{-9} Ohm⁻¹cm⁻¹), ethanol does not build up a dangerous charge while flowing through pipes and filters, or while spraying into a tank,⁽¹⁷⁾ so electrical bonding of the vessels involved prevents static electricity hazards. Explosion-proof electrical equipment should be used in areas in which local alcohol vapor concentrations may exceed lower flammable limits.

In general, standard fuel dump precautions and procedures should be observed. Flammable material should be removed from alcohol storage areas, and spills should be promptly diluted and cleaned up. Overpressure relief valves communicating to the atmosphere should be mounted on flame arrestors.

Sodium will be present during the cleaning procedure in the form of a very thin ($\sim .008$ in.) film on the surfaces of the component to be cleaned, with the possibility of larger accumulations in undrained component cavitites. Solid sodium does not react spontaneously with air, and sodium fires are extremely unlikely, especially sodium fires of any magnitude and dimension. In the event that a sodium fire does occur, it should be known that hot sodium and CO_2 react violently, as shown by the reaction equation:

(For an excess of Na, the reaction continues to Na_2O and elemental carbon.) For this reason, CO_2 may not be used on a sodium fire, unless the sodium is submerged in a hydrocarbon liquid.

Water and water-containing mixtures, such as foam and soda acid, react violently with sodium at all temperatures, as do carbon tetrachloride and many other halogenated hydrocarbons. All of these materials are, therefore, unusable in sodium firefighting.

A second effective technique is the creation of an inert atmosphere through nitrogen dilution. An approved fire extinguishing agent (Na-X) is available for sodium fires. The agent is supplied in bulk or in hand extinguishers and consists basically of sodium carbonate containing a maximum of 0.03% chloride impurity.

V. SAFETY EQUIPMENT

The safety equipment included in the sodium cleaning process equipment operates on three levels of accident prevention and control.

On the first level, through safety features of design, operating procedures, and physical location of components, hazardous situations fail to arise. Carefully planned and well maintained pressure reliefs, flame arrestors, mechanical interlocks, and automatic ventilators provide

examples of mechanical devices that operate on this level, while safety-oriented operating procedures and hazard-preventing physical arrangement of work areas are examples of accident-preventing personnel factors.

The second level of safety equipment activity is concerned with warning of an impending hazardous situation, and taking automatic steps to reverse this trend. This level is exemplified by alarm systems activated by explosimeters, vapor detectors, leak detectors, temperature and pressure sensors, and security sensors. Where feasible, these alarm systems may also be designed to automatically take action to reduce hazard by stopping pumps, activating ventilating fans, etc.

The third and final level of safety equipment activity is concerned with minimizing the effects of an accident that is occurring or has occurred. This equipment is exemplified by automatic and manual fire extinguishers, personal protective equipment, fire and blast doors, and first aid gear. While not hardware, fire and accident plans, and drills are a necessary complement to equipment in this category.

Apparent in this hierarchy is the "two failure" philosophy. To arrive at the accident of level three, there must occur simultaneous and related failures in levels one and two.

A. DETECTION

Commercial explosivity meters suitable for detection of explosive air-alcohol and/or air-hydrogen mixtures are readily available.

These meters have the following general operating sequence: sample gas is constantly drawn over a heated wire, and any combustible substances present burn on the surface of the wire. The heat released by combustion further heats the wire, a resistance change occurs, and the subsequent

current variation is detected by a galvanometer in a Wheatstone bridge circuit. The output may be amplified and used to drive a recorder and/or an alarm circuit, or read directly.

Explosimeters can be calibrated for each combustible gas expected, or for various combinations. (Commercial units are usually calibrated with pentane, whose lower explosive limit of 2% is roughly half that of either alcohol or hydrogen.)

All approved commercial explosimeters have explosion proof circuitry and flashback flame arrestors, so there is no chance of the instrument becoming an ignition source if properly installed.

Explosivity meters may be used to detect the presence of potentially explosive mixtures in tanks, cleaning vessels, system vent stacks, operating areas, storage areas, and areas that could become possible vapor traps in the event of system leakage.

Atmosphere sampling lines to these locations will usually be permanent installations. All lines should be equipped with a shut-off valve to aid in isolation procedures, and lines leading to the inside of vessels should have shut-offs to protect sampling equipment. Sampling lines to areas at significantly different temperatures than detector ambient should be insulated and/or heated to prevent vapor condensation and subsequent false readings.

There appear to be no standards for number of detectors required per unit volume. One detector per 10^4 Ft³ of continuous, connected volume currently seems sufficient. Smaller volumes that are enclosed by partitions such as small storage rooms, etc. , should have either detectors or sampling lines leading to central detectors. Portable explosimeters should be used in routine area surveys, and in surveys following any incident involving possible leakage.

The lower flammable limits of alcohol and hydrogen in air are 3.3 and 4.0 volume % respectively. . OSHA, Sec. 1910.106 a-31 states that the highest permissible concentration of explosive vapor in air is 1/4 of the lower explosive limit. Therefore, explosimeters must be capable of registering concentrations of at least 1.0% hydrogen and 0.8% alcohol.

B. TOXIC VAPOR DETECTION

There are four basic categories of instruments available for detection of possible irritant and toxic materials present in the alcohol sodium cleaning process.

The first and most accurate of these, and the only one suitable for continuous monitoring of specific locations, is a gas chromatograph. Such an instrument, which is extremely accurate, is also expensive to purchase and to maintain, requires a trained operator, and is usually not readily portable. Its output may be read directly or used to drive recorders and/or alarm circuits.

An explosivity meter may be specially calibrated and used for any flammable toxic material whose TLV's are greater than 5% of the lower explosive limit. Explosimeters are much less expensive than gas chromatographs, are rugged, simple in operation, and readily portable.

An extremely compact and readily portable, but not especially accurate device, is a prepackage colorimetric test kit. Such a device contains single-use disposable chemical test samples that change color upon exposure to specific airborne toxics. Such a kit is very inexpensive, but requires considerable operator experience to achieve results of even mediocre accuracy.

As long as ethanol is used in the cleaning process, the human sense of smell is useful to detect pre-toxic levels of vapor concentration. The

probable ratio of ethyl to methyl alcohols in the solvent will be about 20:1, and the threshold limit values (TLF) for these alcohols are 1000 and 200 ppm respectively. Humans can smell ethyl alcohol at concentrations around 500 ppm, which would mean an accompanying concentration of 25 ppm of methanol. Both of these levels are well within safe limits. However, due to individual variations in olfactory ability, and the dulling effect of fatigue, cold, etc., this method should not be the sole indicator of alcohol vapor concentration in occupied areas, although, as a practical example, at 5,000 ppm, (250 ppm methanol), the combination of odor, and eye and mucus membrane irritation become intolerable, and humans are forced from the area before any appreciable exposure results.

Instruments should be set to allow the widest possible safety margin. (Since this system is envisioned as a closed system, the presence of any vapor at all should be considered reason for careful inspection.)

As long as the cleaning solvent remains >95% ethanol, (as determined by receipt chemical assay), detection of 500 ppm ethanol is sufficient for safe operation. This is within the limits of a modified explosimeter, and is also at or near the lower range of the human sense of smell. The toxic levels are very evident, and consequently their detection presents little difficulty.

Hydrogen is non-toxic in any amount less than the lower explosive limit, so is not a concern here.

C. DETECTION AND MONITORING OF SYSTEM FLOW

It is necessary to know of all flammable liquid motion, whether it be by continuous or sporadic flow. The types and models of flowmeters are legion, and their general principles need not be described here. For flammable fluid, an accurate, economical meter is acceptable as long as it exhibits no leakage, has no electrical signals in the wetted area, and creates minimal frictional heating.

Meter output should be used to drive a continuous chart-type recorder to provide permanent flow records.

At a minimum, an alcohol sodium cleaning system should have flow meters at the following locations:

- 1) All pump discharges
- 2) Sparge gas inlet lines
- 3) Cleaning tank inlet lines, and
- 4) Fire and flooding mains.

For very large systems associated with reactor complexes and operating on a full-time schedule, additional flow meters with a remote reading capability in a central control room may become useful. Depending upon the individual installation design rationale, it may be desirable to have some flow meters activate alarms.

D. MONITORING OF LIQUID LEVELS IN TANKS

There are at least as many types of liquid level indicators as there are flowmeters, working on a variety of principles. As long as they conform to the constraints placed on flowmeters in the previous section, and are accurate, specific instrument choice will be determined by the particular requirements of a given installation. Careful consideration should be given to the use of glass sight gauges in systems containing flammable and/or toxic liquids, and the possible effects of a broken sight glass.

Radiation or sonic type detectors are particularly well adapted to accurate continuous readings on vessels whose levels fluctuate frequently, while upper and lower float devices are sufficient for vessels that are usually either completely filled or empty, as long as partial filling of these vessels has no bearing on system safety.

Careful consideration must be given to interlocking fluid level sensors with tank inlet valves, feed pumps, and alarms. Specific control logic schemes will be functions of individual system designs, but the basic consideration should be an automatic system to prevent overfilling any tank.

E. TEMPERATURE MONITORING

The most practical temperature monitoring system for the sodium cleaning process is a system of thermocouples strategically located throughout the system, and connected to a continuous recording system. Thermocouple inputs from critical locations may also activate alarm and/or shut-down processes to prevent hazardous conditions from occurring.

The four critical locations for thermocouples in the cleaning process are: (1) solvent preparation tank, (2) solvent inlet to cleaning vessel, (3) solvent outlet from cleaning vessel, and (4) solvent in the vicinity of the object being cleaned. Readings from these thermocouples will indicate the dynamics of the cleaning process and allow time for corrective action to be taken at the onset of unusual conditions.

As a safety system backup, thermocouples should be located in the effluent collection tank, and in each of the main storage tanks.

F. PRESSURE MONITORING AND CONTROL

System pressures may be monitored either directly or remotely with classic Bourdon tube pressure gauges and appropriate circuitry. As a bare minimum, however, system relief valves and vents should be equipped with tripper switch devices to signal when venting or valving is underway. Where applicable, these signals may initiate shutdowns and/or alarms. This becomes an especially significant consideration if a radioactive part is undergoing treatment and emergency venting or pressure relief comes into play.

While pressure is not nearly as significant in process rate control as is flow rate, pressure variation is an early and accurate indication of system abnormality.

The cleaning vessel should be equipped with a pressure sensor reading in psi to serve as a backup for the in-vessel thermocouple as a process monitor. The rest of the system will be equipped with assorted vents and pressure relief valves which also serve as pressure indicators. The opening of any pressure relief should be automatically signalled to the control room. The opening of any pump relief should activate an alarm system

G. LEAK DETECTION

In a large volume system, sufficient alcohol to cause a safety hazard may leak without registering on flowmeters, level indicators, etc. For this reason, all possible sumps, scuppers, etc. should be equipped with leak detectors. These are inexpensive, commercially available devices operating upon the principle of electrical resistivity between contacts changing as a function of the medium between the contacts. Approved leak detectors are explosion proof, and are equipped with flame arrestors and shielded circuitry.

Leak detectors are essentially off/on devices, and are not adjustable except as to sensitivity to particular liquid resistivity. All leak detectors should be verified operative with the least conductive liquid present in the system.

Any sump, drain, scupper, dike footing, or low spot where small, but significant, amounts of alcohol may collect, should be equipped with a leak detector. Similarly, low points within any insulation on alcohol lines should have leak detectors. Granted these detectors will also respond to the presence of water, which, upon consideration, will appear a desirable

characteristic, inasmuch as the detector would indicate a flooding of the area which might reduce the capability of the sump, dike, etc. to contain the design volume of alcohol in the event of a spill.

H. FIREFIGHTING EQUIPMENT

In the event of simultaneous personnel error and/or equipment failure on both the first and second levels of hazard prevention, it is possible for the system to sustain an accident. Such an accident is most improbable; however, the most likely form of such an accident will be an alcohol fire. (The only other significant combustible produced by the process is hydrogen, for which extensive venting is provided, and which rises and dissipates rapidly.)

Alcohol in large pools burns at about 1/3 the rate of gasoline, and is amenable to most standard firefighting techniques. The two key criteria in handling such fires are: (1) early detection and (2) rapid response. This response must both contain and extinguish the fire.

1) Detection and Alarm

All areas involved with the alcohol cleaning process should be equipped with manually activated fire alarm stations, connected to a central alarm station at plant Security Headquarters. In addition, all roofed areas, and areas around storage tanks, should be equipped with automatic sensors, tied into the central alarm system.

Automatic sensors operate either through chemical response to combustion products, electrical response to temperature level, or electrical response to rate of temperature increase. Selection of system components will be influenced by considerations of specific area requirements and compatibility with the overall plant system. However, a sensitive detector operating on the rate-of-temperature rise system will provide the earliest possible fire detection.

Fire detection and reporting should be stressed in personnel training and orientation. Emphasis should be placed upon immediate turning in of an alarm before attempting any personnel action.

2) Stationary Firefighting Equipment

Unlike gasoline, alcohol fires may be extinguished with water, since water and alcohol are mutually miscible. The NFC, Vol. 7, Sect. 15, describes standards for water sprinkler systems designed to distribute a fine spray. Such systems should have both a manual and automatic activation capability, and should be tied in with the central alarm system.

Fixed sprinkler systems require careful planning to be effectively used. Careful attention must be given to requirements in the NFC for water supply, clearance from electrical equipment, rate of flow per unit area, and nozzle design. A solid stream striking a pool of burning liquid can spread fire over a large area. Equally careful planning must attend the sprinkler system activation process. There should be provisions whereby only sufficient sprinkler heads are activated to deal with the fire without flooding adjacent areas and causing extensive water damage.

Alcohol-compatible foams are available, but require considerable special equipment to be included in a fixed fire fighting system (NFC Vol. 7). It will probably be found that the low overall hazard, combined with the expense, system complexity, and maintenance load, preclude such a system.

Perhaps the best fixed system employs CO₂. The NFC No. 12 recognizes four standards: (1) Total Flooding Systems, (2) Local Application Systems, (3) Hand Line Hose Systems, and (4) Standpipe Systems and Mobile Supply.

Such systems, or combinations thereof, may be integrated with an automatic alarm system, and fulfill all the requirements of a water or foam system, especially in an enclosed area. The use of CO₂ systems is free from the problems of water damage and electrical hazard attendant upon water sprinkler systems.

Personnel must be made aware, however, that CO₂, although non-toxic, operates by dilution of oxygen below combustion level. Therefore, personnel entering or remaining in an area flooded with CO₂ must have and use correctly self-contained breathing apparatus.

One further special consideration must be mentioned for this system. Water reacts explosively with sodium; CO₂ reacts violently with hot sodium. Since the quantity of sodium involved will be relatively small, and will be within containment throughout the process, this is a very minor consideration, but one which should be included in personnel training.

3) Portable Firefighting Equipment

A complete volume, Vol. 8, of the NFC is devoted to portable and manual fire control equipment, and any attempt to summarize this volume here would be futile. The quantity and placement of hand fire extinguishers, respirators, fire axes and wrecking bars, stretchers, etc., must be determined on the basis of plant and crew size, physical layout, local fire laws, and availability of professional firefighters and equipment, to list but a few considerations.

The suggested standard type of hand fire extinguisher is the standard CO₂ bottle, sized to suit location. If a central CO₂ system is used, CO₂ hand lines are practical and convenient. Use of foam, soda acid, or any other water-type fire extinguisher presents electrical hazards to the user. Furthermore, special alcohol-compatible foams must be used in foam extinguishers.

Areas in which sodium fires are a possibility, no matter how remote, should be supplied with approved dry power (Na-X) hand extinguishers, which must be distinctly marked to differentiate them from CO₂ extinguishers.

4) Training

Fire fighting equipment can do more harm than good if personnel are not trained and drilled in its use. A written and tested fire plan is an indispensable component of a fire protection system. The NFC, Vol. 8, Sec. 27, presents standards for the organization of private fire brigades, which may consist only of a designated senior individual and his assistants. These individuals will minimally be trained in the handling of firefighting equipment available in their area, and procedures to prevent additional alcohol from entering the fire area. The extent of training beyond this must be determined for each individual facility. Facilities associated with sites having on-site professional fire companies will not require as extensive facility personnel fire training and equipment as will facilities that must depend upon off-site municipal or county brigades.

VI. CONCEPTUAL SYSTEM

The system pictured (Figure 10-12) is designed to illustrate one approach to a safe alcohol sodium removal system. It embodies some fundamental concepts which should be incorporated in all systems, as well as several for which many options are available.

This system may best be described by examining a typically conceived cleaning process. The component to be cleaned arrives sealed in an inert gas-filled bag. Lift and tiedown connections protrude from this bag to allow efficient handling. The component is transferred by crane, still

Figure 10. Cleaning Facility Structure

Figure 11. Typical Alcohol Storage Facility

Figure 12. Alcohol Storage Area Schematic

bagged, to the handling hoist located in the Loading Cupola, (Figure 10). The Loading Cupola is equipped with a weatherproof closure, which is sealed before the Cleaning Vessel is opened. This precludes the possibility of a rain-initiated sodium fire and possible component thermal damage.

Following sealing of the weatherproof closure, the inert quality of the Cleaning Vessel atmosphere is experimentally verified by the Gas Chromatograph (Figure 10) shown permanently connected to the Cleaning Chamber Vent Pipe (Figure 10). With the ventilating system in operation, the Removable Cover (Figure 10) is moved clear of the Cleaning Vessel top, the component is lowered, and the bag is secured to the vessel. The component is lowered into the support structure (the bag collapses during this process maintaining the inert atmosphere). The bag is removed and the Removable Cover is closed and sealed. During this operation, the vessel is purged with inert gas, and the entire process from this point is conceived to be carried out in an inert atmosphere within a sealed system.

Alcohol is pumped from the Alcohol Storage Area, (Figure 11, 12) into the Heat Exchanger (Figure 10). The alcohol side of the Heat Exchanger is always maintained under an inert gas cover.

Following temperature conditioning in the Heat Exchanger, the alcohol is tested for composition and transferred to the Cleaning Vessel by the Circulating Pump (Figure 10). Sparge gas is bubbled through the rapidly rising alcohol, and is vented with entrained hydrogen through the Cleaning Chamber Vent Pipe. The alcohol level rises to the Cleaning Vessel Alcohol Return Line, and remains at the point while being circulated by the Circulating Pump. Alcohol vapor enroute to the Cleaning Vessel Vent Pipe is condensed and returned to the Circulating Pump intake side by the Condenser (Figure 10).

Process completion is indicated by a chemical analysis of sodium content of the circulating alcohol, and chromatographic analysis of the hydrogen concentration in the exhaust gas. (A constant level of sodium alcoholate and a negligible level of hydrogen generation indicate the end of reaction.)

Following process completion, alcohol in the Cleaning Vessel and Heat Exchanger are pumped to the Used Alcohol Storage Tank (Figure 12) via the Alcohol Return Line (Figure 10).

If specified for a particular process, the Deionized Water Line (Figure 10) is now connected to the Cleaning Vessel, and the component is rinsed. As a safety and positive process control measure, the deionized water line may only be connected to the Cleaning Vessel with a special hose equipped with non-standard hose fittings. This hose should be a controlled access item, to prevent any inadvertent admission of water to the cleaning cycle, with possible attendant component damage. Sparge gas flow is continued during rinsing. (In fact, it is envisioned that sufficient inert gas flow will be maintained at all times to render the evolved hydrogen so diluted as to be non-flammable should it be released to the atmosphere inadvertently.)

Following rinsing, the water is drained from the Cleaning Vessel via the Water Drain, (Figure 10), and the component is dried with hot inert gas.

Following drying, the Cleaning Vessel is opened, the bag reinstalled, and the component removed in the reverse order of installation.

The ventilation system mentioned throughout this process is composed of inlet blowers capable of ingesting 1 CFM/ft² floor area, and outlet fans located on top of the Loading Cupola. Such an air flow, coupled with an upward sloping roof surrounding the cleaning vessel enclosure, precludes any possible hydrogen accumulation within the cleaning facility. In addition,

Hydrogen Monitors (Figure 10) are located at the highest enclosed level in the system. All lighting fixtures, motors and other spark producing apparatus are located below this level.

At the other extreme, all spark producing machinery, electrical conduits, etc. are mounted at least 3-1/2 feet above the floor. This procedure takes advantage of the fact that alcohol vapor is more dense than air, and tends to sink. Alcohol Monitors and Alarms (Figure 10) are mounted at the lowest point in the system.

In addition, all sumps are provided with forced ventilation to prevent vapor accumulation. All sumps are designed to accept 150% of the volume of any vessel or vessels that may empty into them, to provide volume for water from fire protection systems. All sumps should be equipped with permanently installed pumps to rapidly move any accumulated liquid to an impoundment basin for eventual disposal.

A key safety concept in this design is the projected use of a centralized Control Console, rather than local control facilities. In addition to consolidation of control functions to eliminate communication and coordination problems, such a console should also be equipped with readouts and alarms indicating status of all ventilators, continuous gas chromatograph readings of cleaning vessel vent gas composition (hydrogen content indicating process rate, oxygen content indicating possible system leaks or contamination of inert gas), and current status of all pumps, tank and vessel liquid levels, vents, fire and flooding valves, and thermal sensors. In short, any instrument monitoring any condition that may influence system safety should have at least a readout upon the Control Console, if not an audible or flashing alarm output.

The same general safety features are forecast throughout the system. Examination of Figures 11 and 12 show elevated electrical components, flame arrestors, inert gas cover feed lines, and tank oxygen analyzers to prevent both local ignition sources and flammable vapors from occurring. Dikes capable of retaining 150% of total tank capacity, and complete security fences, again reflect the emphasis on keeping possible ignition sources separated from possible flammable atmosphere. Throughout the system, extensive use of electrical grounding and interconnection is envisioned to prevent possible static electrical discharges from occurring. All tanks are equipped with fill lines extending to within six inches of the tank bottom to prevent friction and splash generation of electric changes.

Inspection of Figure 10 will show permanent fire extinguishers as part of the system. In addition, portable extinguishers, including sodium-fire approved Na-X extinguishers, (not shown) are considered system components.

Complete written procedures should be formulated for all phases of the process and all operating personnel should be made completely familiar with their aspects of the operation. Such procedures should be multi-level; that is, there should be corresponding general procedures for supervisory personnel and detailed, step-by-step, checklist procedures for operating personnel.

Procedures should be written for routine accessory equipment and maintenance activities and adhered to rigorously. All procedures should include provisions for personnel and equipment accountability; only personnel engaged in a specific activity normally will be present during the cleaning activity. A visitor-access program should be used.

It cannot be overemphasized that all procedures should include the required presence of a qualified operator at the Control Console, and complete written job notification supplied to this operator and the personnel involved.

Positive verbal communication should be maintained between operating personnel and the control console operator.

No description of this system would be complete without a restatement of the philosophy behind all system safety features. Anywhere within this system there must be at least two simultaneous failures for a hazardous condition to be created. It is expected that, with reasonable care, effective routine inspection and maintenance, and consistent adherence to procedures, hazardous conditions need not arise in facilities designed under this concept.

VII. CONCLUSION

The foregoing report has extensively discussed the equipment requirements, the code restrictions and the facility design philosophy required for the safe handling of large volumes of ethyl alcohol. The need for these precautions is very real, but it should be noted that in excess of 280,000,000 gallons of synthetic (non-beverage) ethyl alcohol are used in manufacturing industries in the United States each year with an extremely low incidence of problem occurrence. This would indicate that the precautionary measures and safeguards, developed by long experience, are very effective.

The problem of disposing of the hydrogen evolved by the sodium removal is not as extensively treated, since its disposal is a routine process. However, were it allowed to collect, its significant explosive potential would make it a far more serious hazard than alcohol vapor. The disposal of hydrogen plus monitoring for its presence dictates major consideration in the design of facilities.

The intent of this document will be fulfilled if it imparts an enhanced consciousness of safety considerations to personnel charged with the planning and operating of alcohol sodium removal facilities. With realistic management and employee attitudes, and well documented procedures, there is no reason why ethyl alcohol sodium removal should not be a thoroughly routine operation.

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APPENDIX A

PHYSICAL PROPERTIES OF ETHYL ALCOHOL (ETHANOL)⁽¹⁹⁾

Appearance	Clear, colorless liquid
Odor	Characteristic nonresidual
Molecular weight	46.07
Boiling point (750 mm Hg)	78.3C, 173F
Freezing point	-114C, -173F
Coefficient of expansion	0.0006 per F
Critical temperature	243.1C or 469.6F
Critical pressure	63.1 atm
Density (20C)	0.789 gm/ml or 6.59 lb/gal
Heat of combustion (25C)	326,700 cal/gm mole
Heat of formation (25C)	-66,350 cal/gm mole
Heat of fusion	1187 cal/gm mole
Heat of vaporization (173F)	9400 cal/gm mole
Heat capacity (25C)	0.58 cal/gm C (Btu/lb F)
Thermal conductivity (20C)	0.00165 watts/cm C or 0.096 Btu/ cu ft F
Refractive index (20C)	1.3614
Surface tension (20C)	22.3 dynes/cm
Viscosity (20C)	1.2 centipoise
Dielectric constant (20C)	25.7
Electrical conductivity (25C)	1.35×10^{-9} per ohm cm

APPENDIX B

LATENT HEAT OF VAPORIZATION OF ETHYL ALCOHOL⁽¹³⁾

APPENDIX C

HEAT CAPACITY, C_p , OF ETHYL ALCOHOL
AT VARIOUS TEMPERATURES