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CLASSIFICATION OF CHEMICAL REACTIVITY HAZARDS

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Dow Chemical Company

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16. Abstract The purpose of the work was to develop & use an experimental procedure to determine chemical reactivity hazards of specific chemicals & their binary mixtures. Of particular concern to the U.S. Coast Guard are the potential hazards associated with the adjacent loading of bulk chemicals on ships & barges. The data generated are to be used by the Advisory Committee to the U.S. Coast Guard in formulating regulations for bulk shipment of chemicals by water transport. The original 209 chemicals of most interest to the Coast Guard were used in the development program to classify reactivity hazards.

The developed classification procedure combined chemical information with an experimental program to measure temperature and pressure changes.

Early in the work, the use of calculated thermodynamic energies was explored for possible utility. Although such calculations have some value in determining the potential hazard of individual chemicals, they have limited use in dealing with the problem of chemical cargo compatibility.

To accomplish the classification of reactivity hazards, the 209 chemicals were seperated into 60 groups according to chemical structure. A representative working chemical was chosen from each group & subsequent experimental work was performed with only the working chemicals. Thermal stability of each working chemical was determined by differential thermal analysis. Impact and spark sensitivities were also determined.

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The contents of this report reflect the views of Dow Chemical, Company, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policy of the Coast Guard. This report does not constitute a standard, specification, or regulation.

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for the

Advisory Committee to the U. S. Coast Guard
National Academy of Sciences
Washington, D. C.

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FOREWORD

The work reported in this document was sponsored and monitored by the Committee on Hazardous Materials of the National Academy of Sciences, Advisory to the U. S. Coast Guard, under Contract Nr. CCT-40-69-15.

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I. INTRODUCTION AND SUMMARY

The purpose of the work was to develop and use an experimental procedure to determine chemical reactivity hazards of specific chemicals and their binary mixtures. Of particular concern to the U. S. Coast Guard are the potential hazards associated with the adjacent loading of bulk chemicals on ships and barges. The data generated are to be used by the Advisory Committee to the U. S. Coast Guard in formulating regulations for bulk shipment of chemicals by water transport. The original 209 chemicals of most interest to the Coast Guard were used in the development program to classify reactivity hazards.

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Following the accumulation of data on the working chemicals, an experimental procedure was developed to determine the chemical reactivity hazards from binary mixtures of the working chemicals.

The procedure was a simple, practical method that measured temperature and pressure changes and can be used with the large variety of reaction types encountered in the work. Finally, using the experimental data generated, a degree of hazard was assigned to those binary systems which exhibited reactivity between room temperature and 46°C. (115°F.).

II. DEVELOPMENT OF EXPERIMENTAL PROCEDURES

A. GROUPING OF CHEMICALS

It can be calculated that, from the original 209 chemicals under review, 21,736 binary systems are possible. To evaluate all possible binaries would represent a monumental task. However, a large reduction in the number of binaries for study was accomplished by separating the 209 chemicals into groups of similar chemical reactivity based on chemical structure. For example, chemicals having a hydroxyl group only were placed in one group; chemicals having only an amino group in another; but chemicals having both a hydroxyl and amino group were placed in a third group.

Initially, 56 groups were formulated from the 209 chemicals and group sizes varied from a single member to as many as 25. Later it was found necessary to increase the number of groups to 60.

A representative chemical was chosen for each of the 60 groups. Selection of this working chemical was based upon an expected high level of reactivity for its group and upon the ease with which it could be handled at ambient conditions.

The immediate result of the chemical grouping was to reduce the number of binaries to be studied, from 21,736 to 1770. For the present study, a further reduction was made in the number of binaries by excluding the following from the experimental program: aluminum triethyl, lead tetraethyl, chlorine, nitrous oxide, ammonia, hydrogen chloride, and hydrogen fluoride. Each of the foregoing are the working chemicals and the only members of their respective groups.

The members and working chemicals of all 60 chemical groups are presented in the Appendix.

B. ACQUISITION OF WORKING CHEMICALS

Approximately one quart samples of each of the working chemicals were acquired for the experimental work. Some of the working chemicals are products of The Dow Chemical Company and, in these cases, production samples were obtained. The others were obtained from the Curtin Scientific Company in 500-1000 g. samples of "practical" and "technical" grades which closely approximated the quality of bulk shipments. In a few cases, reagent grade materials were used. The source and quality of the working chemicals are indicated in the Appendix.

In addition, chemicals such as ethers, which are considered "peroxide formers" were analyzed for peroxide. The results are reported as parts per million of hydrogen peroxide in the Appendix.

C. SELF-REACTIVITY OF WORKING CHEMICALS

Laboratory tests were performed to determine the behavior of the individual working chemicals when subjected to thermal, compressive (impact), and electrical energy inputs. The data obtained in the work are recorded in the Appendix of Reactivity Data.

1. Thermodynamic Calculations

It is generally recognized that the sensitivity of a chemical to detonation appears to be directly related to how near its composition approaches a monopropellant. The relation is often referred to as the "oxygen balance". The concept was applied to the present work.

This concept was applied using the preliminary methods of Dr. D. R. Stull*. In Stull's method, a computer program is used to calculate ΔH_D, the equilibrium heat release upon self-decomposition of a

*"Identification of Potential Chemical Reaction Hazards," D. R. Stull, Loss Prevention, Vol. IV (1970), a CEP Technical Manual, published by the American Institute of Chemical Engineers, 435 E. 47th St., New York, New York.

material, as well as ΔH_o, the heat release when the decomposition is performed in the presence of oxygen. For a monopropellant, the difference between ΔH_D and ΔH_o is small; but for a stable, insensitive material, such as a hydrocarbon, the difference is large. When the difference, $\Delta H_o - \Delta H_D$ was plotted vs. ΔH_D for compounds for which sensitivity data are available, Stull found that zones of relative sensitivity to detonation appeared. The zones were even more apparent when the temperatures and pressures corresponding to ΔH_o and ΔH_D were used.

When the Stull technique was applied to the working chemicals, it was found that almost all the chemicals fell into the insensitive areas of the Stull diagram. There were a few cases, however, which either fell into a possible sensitive area or were marginal. The latter chemicals are shown in Table I.

Another way of using thermodynamic calculations in indicating detonability, is to view the value of ΔH_D as the energy available for propagating a detonation once a reaction is initiated. In this view, it is assumed that, for a chemical system to detonate, a certain minimum amount of energy must be available. Lack of sufficient experimental data prevents a good test of this hypothesis. Some guidelines are available, however. For example, the Dow computer program calculates a ΔH_D of -40 kcal./100 g. for ammonium nitrate which <u>can</u> be detonated under confinement when sufficient energy is applied.

Assuming that -40 kcal./100 g. energy release is near the minimum required for propagation, the values of ΔH_D for working chemicals were examined. The review showed that most of the chemicals were low-energy materials and probably were not detonable. The exceptions were acrylonitrile, nitrous oxide, ethylene cyanohydrin, and ethylenimine, which are included in the list indicated by the approach of Stull.

As will be discussed later, none of these chemicals show a sensitivity to detonation in laboratory tests.

Table I

Chemicals Selected by Thermodynamic Calculations

Group No.	Working Chemical	Structure	ΔH_o Kcal./100 g.	ΔH_D Kcal./100 g.
12	Acetonitrile	$CH_3C(=O)-C\equiv N$	-331	-36
13	Acrolein	$CH_2=CHC(=O)H$	-312	-31
14	Acrylonitrile	$CH_2=CHC\equiv N$	-336	-68
34	Epichlorohydrin	CH_2CHCH_2Cl (O)	-209	-26
36	Nitrous Oxide[a]	$N=N=O$	----	-44
43	Vinylidene Chloride	$CH_2=CCl_2$	-117	-39
46	Ethylene Cyanohydrin	$HOCH_2CH_2C\equiv N$	-294	-79
49	2-Nitropropane	$CH_3CH(NO_2)CH_3$	-257	-35
51	Propylene Oxide	$CH_3-CH-CH_2$ (O)	-357	-36
52	Ethylenimine	CH_2-CH_2 (N–H)	-394	-56

[a] Not tested in program; will detonate in vapor phase with hot wire initiation.

2. Compressive (Impact Sensitivity

The effect of compressive energy input on the stability of selected working chemicals was determined with a JANAF liquid impact tester and, in some cases, with No. 8 du Pont blasting caps. In both tests, the liquid samples are confined.

a. JANAF Impact Test

In the JANAF procedure, 0.03 ml. of the liquid to be tested is placed in a specially designed holder which is then sealed with a neoprene O-ring and stainless steel diaphragm. Impact to the sample is delivered by a free falling calibrated weight dropped from a succession of known heights. The impact energy (weight x height) is increased until the sample decomposes, reacts, or detonates. The energy required to produce a reaction 50% of the time is reported as the impact sensitivity.

Impact tests were performed on those chemicals selected on the basis of chemical structure and thermodynamic potential. Tests were run at room temperature. None of the working chemicals tested were sensitive to impact at the maximum limit of the apparatus.

b. Blasting Cap and Booster Tests

With the exception of nitrous oxide, the working chemicals listed in Table I were also subjected to a No. 8 du Pont blasting cap. In the test, about 10 ml. of liquid were placed in an aluminum holder made from 0.5" O.D. x 3" rod, by drilling a 0.219" diameter hole to within 0.25" of the bottom. The opening of the aluminum holder was enlarged to accomodate a No. 8 cap snugly. A positive test result is indicated by a shredding of the aluminum holder. No detonations of the chemicals tested were detected.

In a follow-up unconfined test on the chemicals in Table I, 146 ml. samples of the chemicals were put into 1.875" I.D. polyethylene bottles. A No. 8 du Pont blasting cap was suspended 0.5" below the surface of the liquid and supported by the container lid. The bottle and contents were placed on a lead witness plate and fired. No

detonations were detected in the experiments. The experiments were repeated using a 40 g. tetryl charge in place of the blasting cap. Again, none of the chemicals detonated, but all appeared to have burned.

3. Electrostatic Spark Sensitivity

An electrostatic spark testing apparatus described by the Bureau of Mines* was modified to blanket the sample and spark source with nitrogen. Initial tests done in air served only to ignite flammable vapor-air mixtures. Since the interest was in determining whether the decomposition or self-reaction of a chemical could be initiated by a spark, the modification was made to provide a non-reactive atmosphere.

Spark tests were performed on the working chemicals selected on the basis of their structure or the thermodynamic calculations. The only chemicals which gave a positive response below the 14 joule limit of the apparatus were trichloroethyelene (3.12 joules), vinylidene chloride (0.013 joules), sulfolane (3.13 joules), and creosote (coal tar) oil (3.13 joules). In all cases, the decomposition was non-propagative, that is, reaction only occurred in the path of the spark.

4. Thermal Sensitivity

Thermal testing of working chemicals was done with a duPont Model 900 Thermal Analyzer. About 10-12 milligrams of liquid sample were placed in a glass capillary which was then sealed by fusion. The sample was heated at a rate of 20°C./min. to 300°C. or until an exothermic reaction ruptured the glass capillary. A thermal record was obtained for each working chemical. If an exothermic self-reaction (usually decomposition) occurred with any chemical, the onset temperature was recorded and can be found in the Appendix of Reactivity Data. The thermoanalytical equipment is shown in Figure 1.

*"Sensitivity of Explosives to Initiation by Electrostatic Discharges", F. W. Brown, D. J. Kusler, and F. C. Gibson, Report of Investigations No. 5002, Bureau of Mines, 1953.

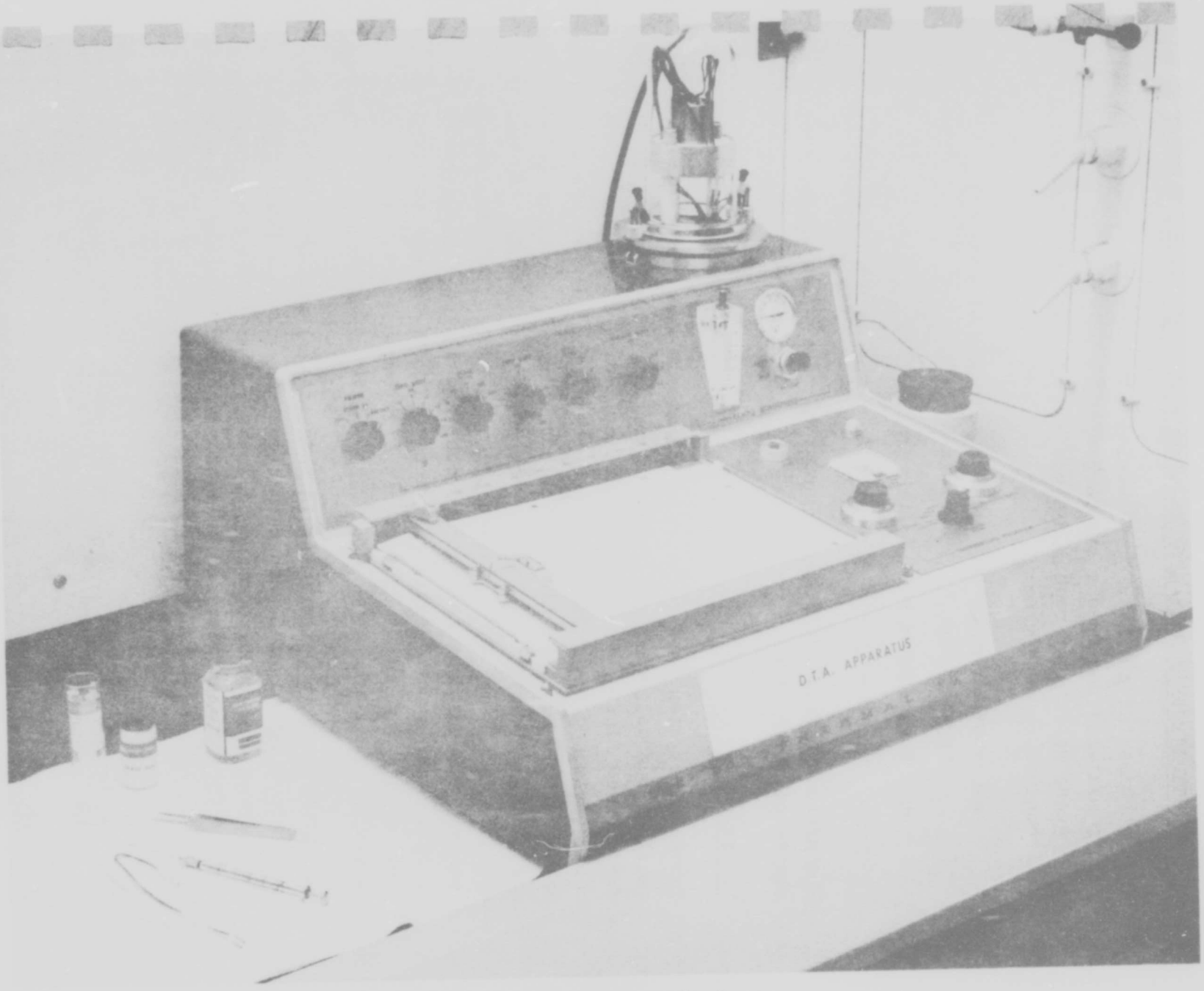

Figure 1 - Thermal Analyzer

D. REACTIVITY OF BINARY SYSTEMS OF WORKING CHEMICALS

The experimental program for determining the reactivity hazards of binary mixtures required a simple procedure which would be useful on a great variety of reaction types and rates. Specifically, it was required to determine:

a. whether an exothermic reaction occurs when two working chemicals are mixed;

b. the maximum rise in temperature, $\Delta T_{max.}$; and

c. whether gas is generated in the reaction.

The procedure developed for the study of binary reactivity consisted of three steps.

1. Step 1

In the first step, the two working chemicals were mixed together by simultaneous delivery from graduated syringes into a 300 ml. silvered Dewar flask. The working chemicals were delivered in a 1:1 molar ratio and the volumes of each calculated so that the final volume was 10 ml. The binary was thoroughly mixed with a Teflon-coated magnetic stirring bar. A No. 30 iron-constantan thermocouple, sheathed in a 2 mm. O.D. glass capillary, sensed any temperature change. Temperature was recorded continuously on a strip-chart recorder. When an exothermic reaction occurred, the maximum temperature reached was noted and the change in temperature, ΔT, was calculated.

The duration of the experiment in this initial mixing step was normally about 1-2 minutes when a reaction took place. However, all mixtures were allowed to stand at least 5-6 additional minutes to permit time for secondary or delayed reactions to occur. The equipment used in Step 1 is shown in Figure 2.

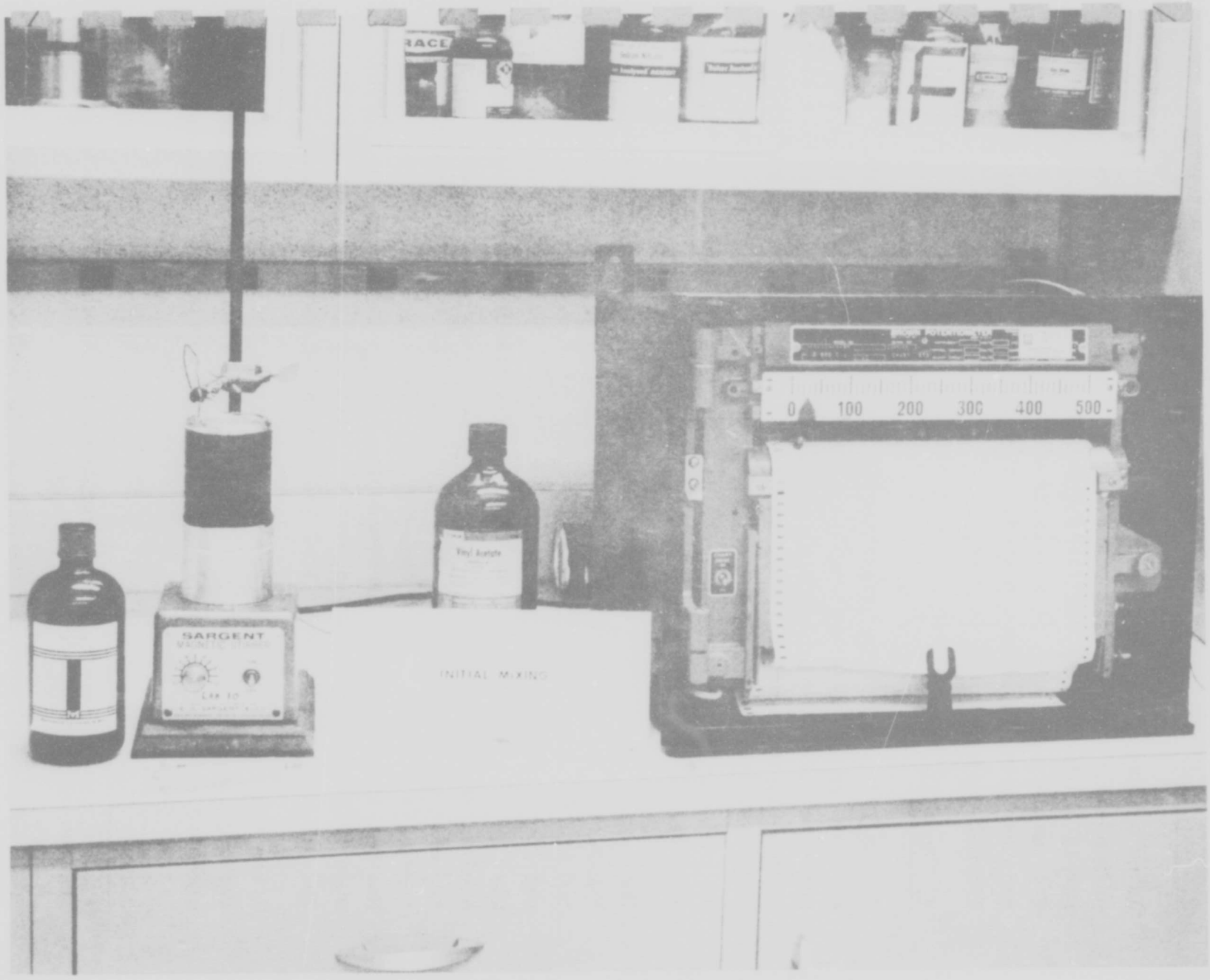

Figure 2 - Apparatus for Initial Mixing

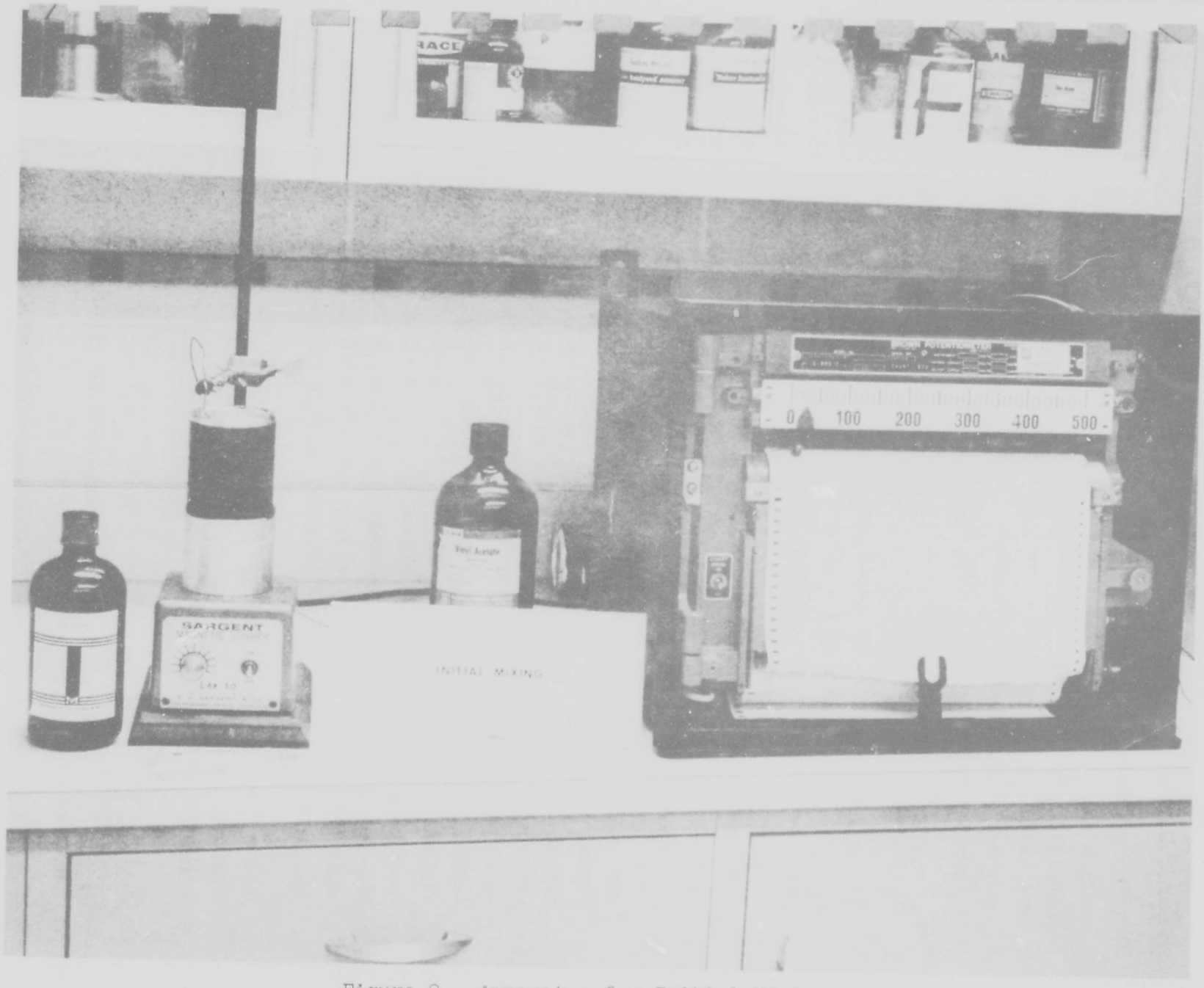

Figure 2 - Apparatus for Initial Mixing

2. Step 2

If no exothermic reaction occurred in the mixing experiment, or if only a small exotherm was observed and a liquid mixture remained, a sample of the mixture was taken for differential thermal analysis. The sample was heated at a rate of 20°/min. to 300°C. or until an exothermic reaction took place*. Figure 1 is a photograph of the Thermal Analyzer used in Step 2.

3. Step 3

In the last step of the experimental procedure, measurements of pressure and temperature increases were made on those binaries found reactive between room temperature and 46°C. (115°F.). For the measurements, the reactivity apparatuses shown in Figure 3 were constructed. Measurements on most reactive binaries were performed in an instrumented Dewar flask, whereas the violent reactions were run in a Parr bomb.

The design details of the Dewar reactivity apparatus are shown in Figure 4. The stainless steel retaining ring was fastened onto the 300 ml. silvered Dewar flask with epoxy resin cured in place. The retaining ring served as the means by which a stainless steel head plate was bolted to the Dewar flask. A silicone rubber gasket was used between the retaining ring and head plate. The head has four threaded openings to accomodate: (i) an inlet tube for addition of chemicals to the reaction vessel; (ii) a stainless steel sheathed, No. 30, iron-constantan thermocouple; (iii) a 0-50 psig range pressure transducer; and (iv) a vent arm with pop-valve set at 40 psig. The 310 ml. capacity Parr bomb was similarly instrumented.

After the reaction vessel was charged with a measured volume of one working chemical (normally less than 5 ml. of the more volatile or the more reactive chemical), the apparatus was bolted together. The

*Toward the end of the study, samples were taken to 200°C. to hasten completion of the work.

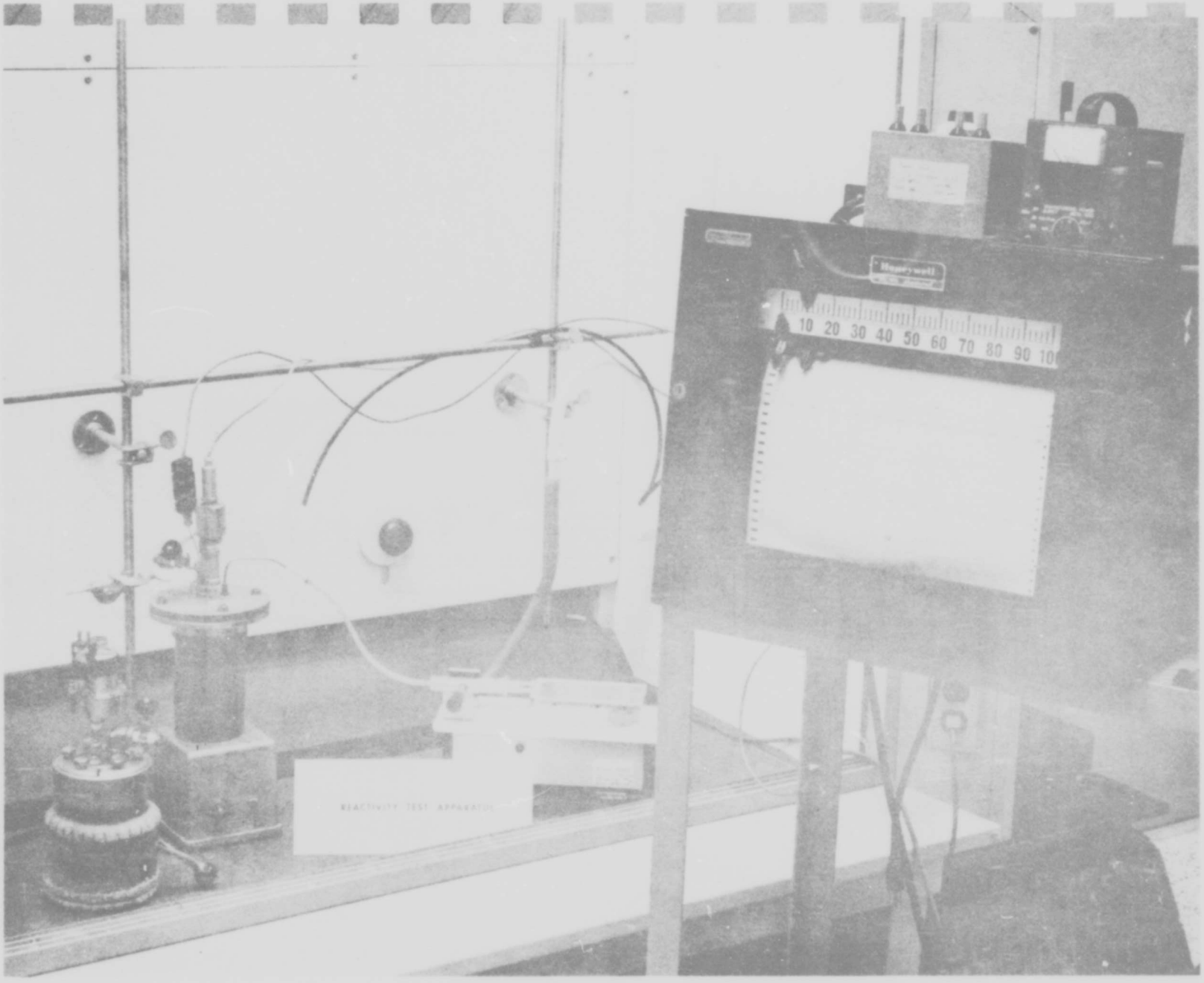

Figure 3 - Reactivity Test Apparatus

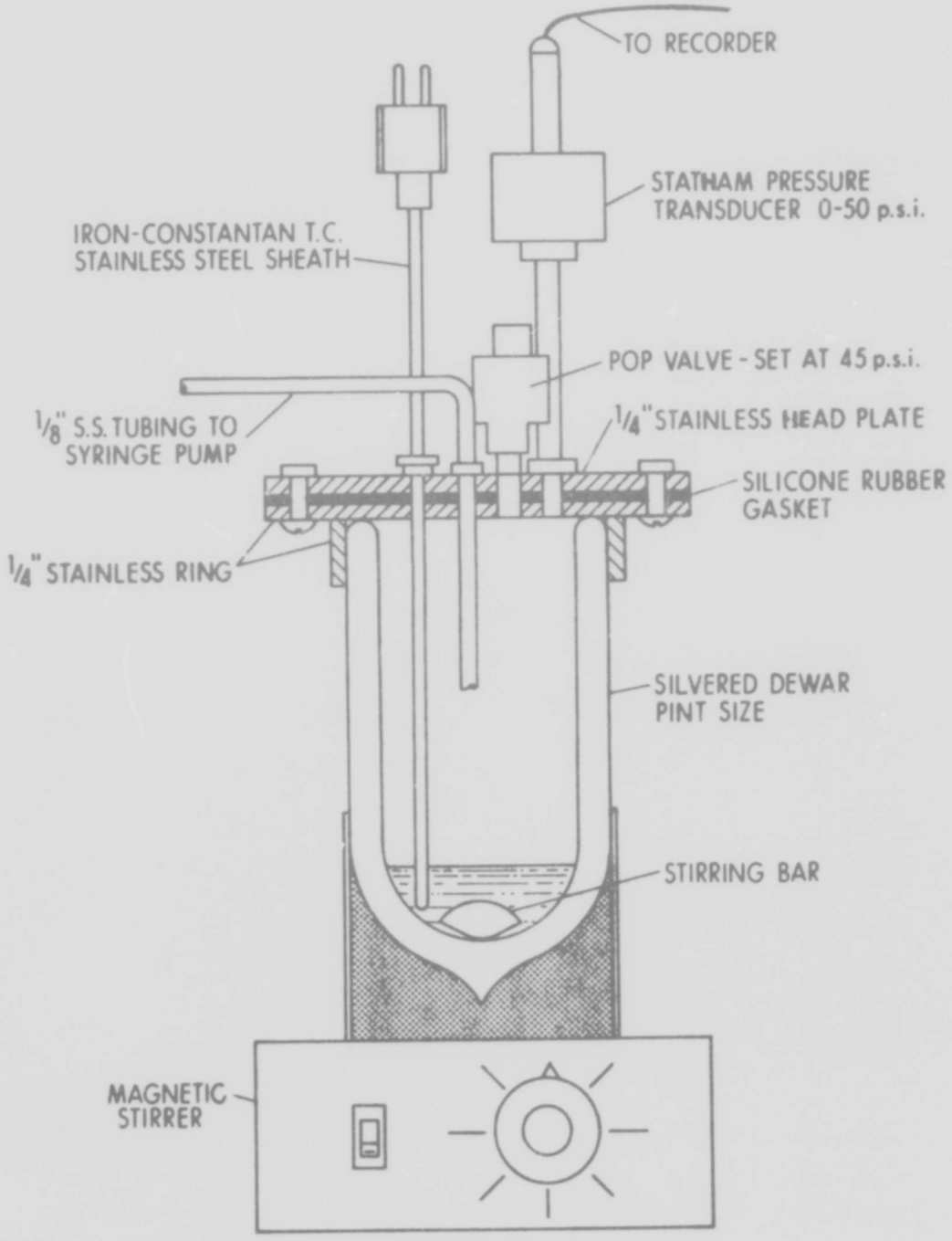

Figure 4 - Design Details of Reactivity Apparatus

second working chemical was then added in known amounts through the inlet tube by means of a syringe pump. Final volumes were kept close to 10 ml. for uniformity of the ullage to sample volume ratio. Agitation was provided by a Teflon-coated magnetic stirring bar. Time to run experiments varied from 20 to 45 minutes, depending upon the nature of the reaction.

A continuous record of change in temperature and pressure (ΔP) was made during the addition and mixing of chemicals. The maximum temperature (ΔT max.) attained was recorded for each reaction studied and compared to the value of ΔT max. obtained in the initial mixing step. The two values were not always the same, because the maximum temperature need not be that measured in Step 1 where a 1:1 molar ratio was used in all experiments and where heat loss by volatilization was sometimes a factor. In the third step, a "titration" of one chemical with another occurred, and if a greater temperature rise took place at a molar ratio other than 1:1, it was observed. In all cases, the largest value of ΔT recorded in the experiments is reported in the Appendix of Reactivity Data.

III. DISCUSSION OF RESULTS

A. PRESENTATION OF DATA

Data on the self-reactivity of working chemicals and reactivity of binary systems formed by the working chemicals are presented in the Appendix of Reactivity Data.

1. Data on Working Chemicals

With the exceptions noted in Section IIA, the name, source, and description are given for each of the working chemicals. In those cases where a peroxide analysis was obtained, the analytical results are reported. The potential energy release upon equilibrium self-decomposition is given in terms of kilocalories per mole and per gram.

Thermal sensitivity is reported if an exothermic reaction is observed during differential thermal analysis to 200° or 300°C., as noted. Where obtained, sensitivity to spark and impact energy inputs are also given.

Finally, a list of the chemicals represented by the working chemical is presented.

2. Data on Binary Systems

The reactivity data on binary systems of working chemicals are presented in a concise manner by using the number of each chemical group. If a binary system was found to be immiscible, the subscript "I" was used on the group number.

The binary reactivity of each group is given in order of decreasing reactivity, as the initiation of measureable reactivity is affected by temperature.

Presented first for each group's working chemical are those groups with which it was found to have an exothermic reaction between room temperature and 46°C. For these reactions, the temperature and

pressure data obtained in the reactivity apparatus are shown in the second and third columns of the table. It is this temperature category which contains the most probable hazards from reactivity and is the one of most concern.

Following the category of room temperature to 46°C., are the categories: 46°-100°C., 100°-200°C., and 200°-300°C. As mentioned earlier, late in the program thermal analysis was taken to 200°C. rather than 300°C. For the latter binary systems, there are no data for the 200°-300°C. category.

If a binary system was found to have exothermic reactions in more than one temperature range, it is reported in every range it was found to be reactive. Therefore, in using the Appendix, attention should be given to all temperature categories*.

B. ASSIGNMENT OF HAZARD DEGREE

Not all binary systems which exhibit an exothermic reaction should be considered hazardous. Many reactions were found to raise the temperature of binary mixtures incrementally and did not evolve gases. Reactions such as these cannot be considered a transportation hazard. On the other hand, a binary reaction may produce very little exothermic effect but evolves gases in the reaction. Since reactions producing gases can quickly lead to overpressurization of containers, they should be considered a high hazard.

Accordingly, a ranking system was devised for those binaries found to react between room temperature and 46°C. (115°F.). The system suggested to the Advisory Committee is based upon the temperature and pressure data obtained during the course of the work and uses

*The effect of keeping the binary at a temperature for a long time was not studied. It was judged that the thermal analyses, which were run to relatively high temperature, would uncover hazardous chemical reactivity. Binaries containing nitric acid and unsaturated compounds may be an important exception. The only detonation experienced in the work occurred with a mixture of 70% nitric acid and acrylonitrile at approximately 90°C. under dynamic heating conditions. It is very possible that detonation could occur at a much lower temperature following a long delay period.

the hazard degrees: None; Low; Medium; and High. The definitions are as follows:

a. Hazard degree "None" is given those reactive binaries having a $\Delta T_{max.}$ which does not exceed 25°C. and with no gas evolution.

b. Hazard degree "Low" is given those reactive binaries having a $\Delta T_{max.}$ which is greater than 25°C. but does not exceed 50°C. and with no gas evolution.

c. Hazard degree "Medium" is given those reactive binaries having a $\Delta T_{max.}$ which is greater than 50°C. but does not exceed 75°C. and with no gas evolution.

d. Hazard degree "High" is given those reactive binaries having a $\Delta T_{max.}$ which exceeds 75°C. or having gas evolution regardless of the value of $\Delta T_{max.}$

The above system was used to compile the fourth column of the tables in the Appendix of Reactivity Data.

In determining whether gas evolution occurred during reactions, Figures 5, 6, 7, and 8 were helpful. The data for the vapor pressure curves shown in the Figures were obtained by the rapid heating, in the reactivity apparatus, of 5 ml. samples of each of the materials shown. Heating times were about 6 to 12 minutes. The vapor pressure data were obtained on a selected group of working chemicals which represented the variety of chemical and physical properties encountered in the study. The number of gas-generating reactions encountered in the work were small, and most of the observed pressure changes were due to vapor pressure increases caused by temperature rises.

C. INTEGRITY OF CHEMICAL GROUPS

At the start of the program, 56 chemical groups were formed from the 209 chemicals presented for study. Later, propiolactone and 40% glyoxal, originally grouped with aliphatic esters and saturated aldehydes, respectively, were studied separately. Sufficient

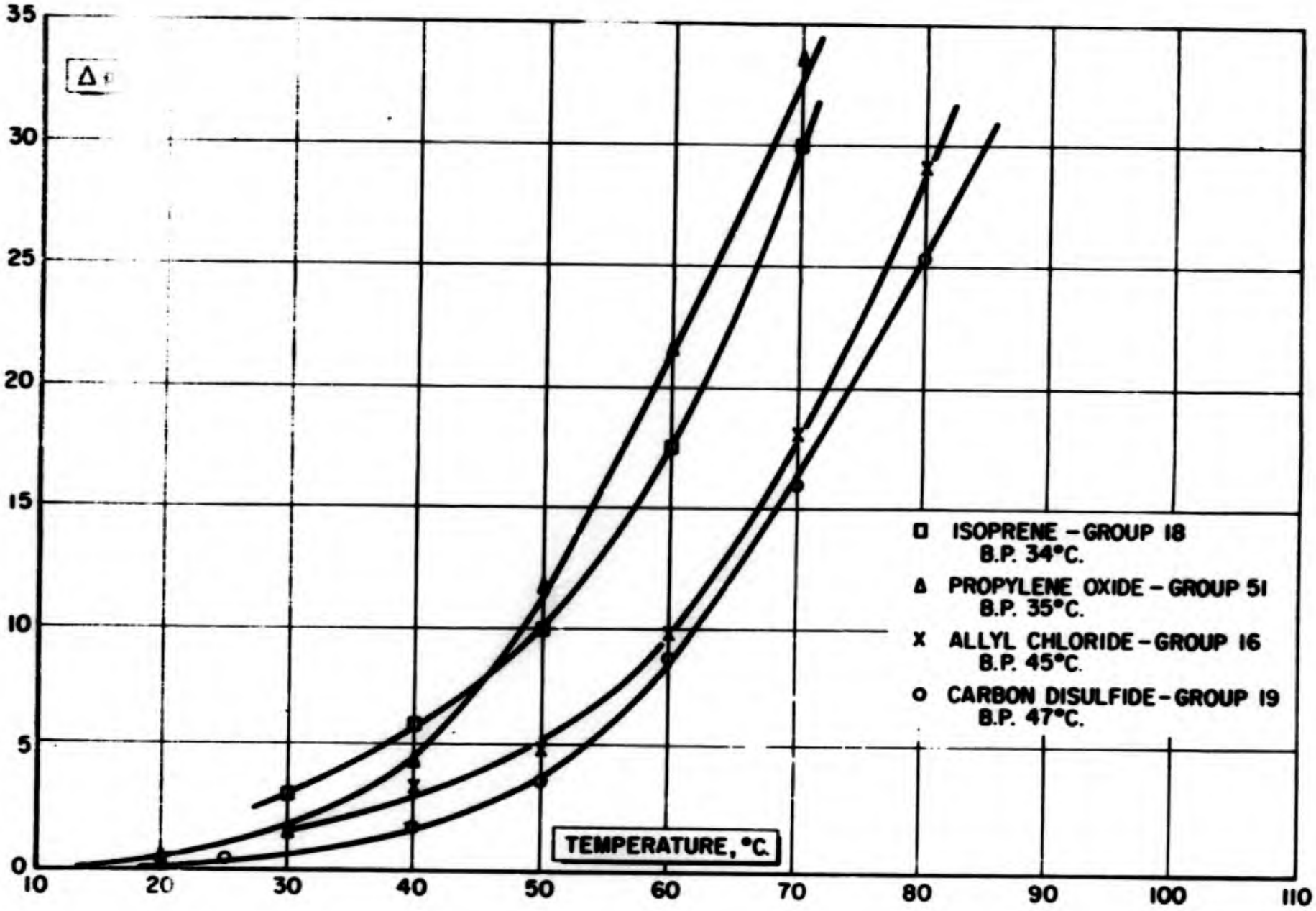

Figure 5 - Vapor Pressure Curves on Working Chemicals

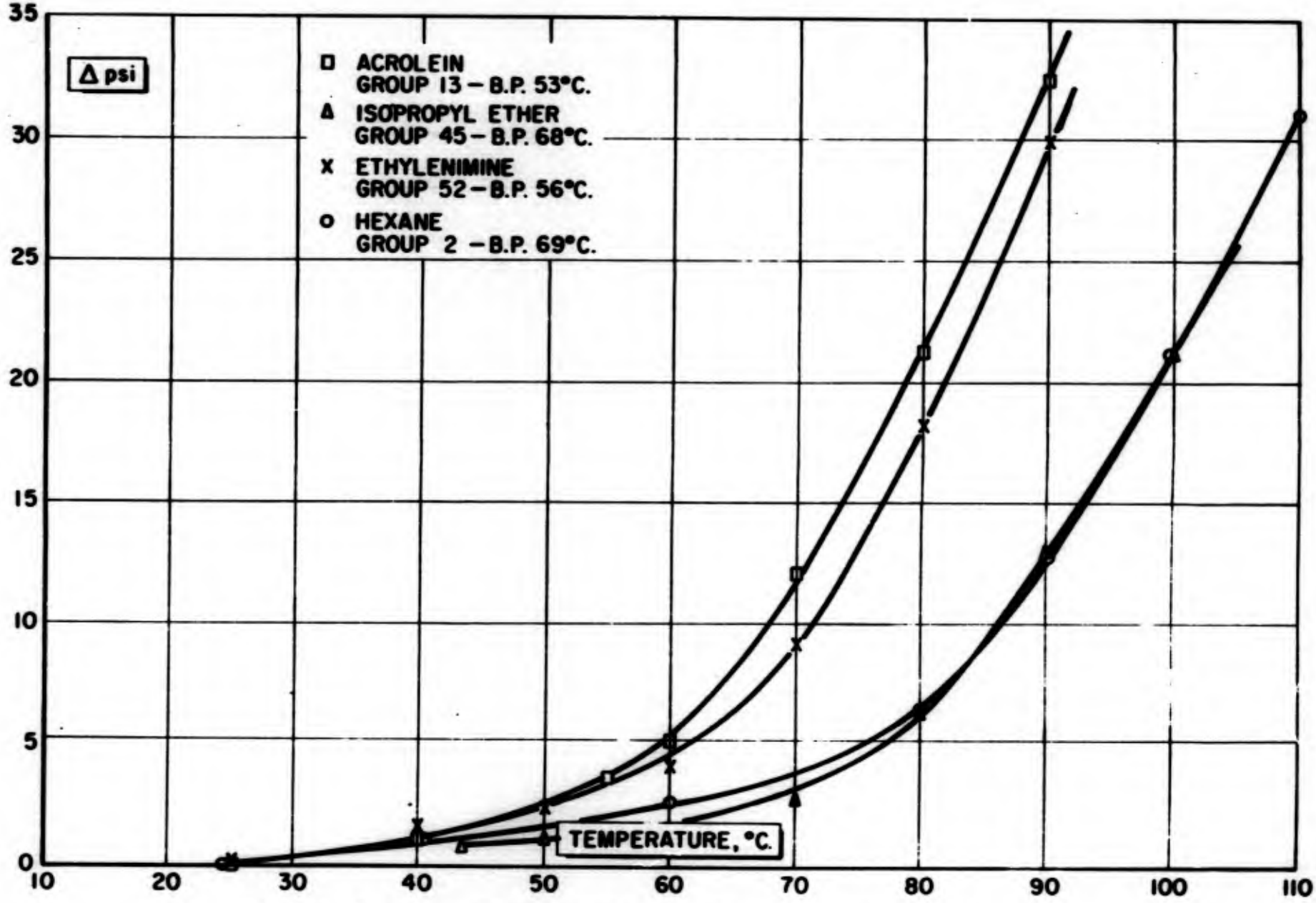

Figure 6 - Vapor Pressure Curves on Working Chemicals

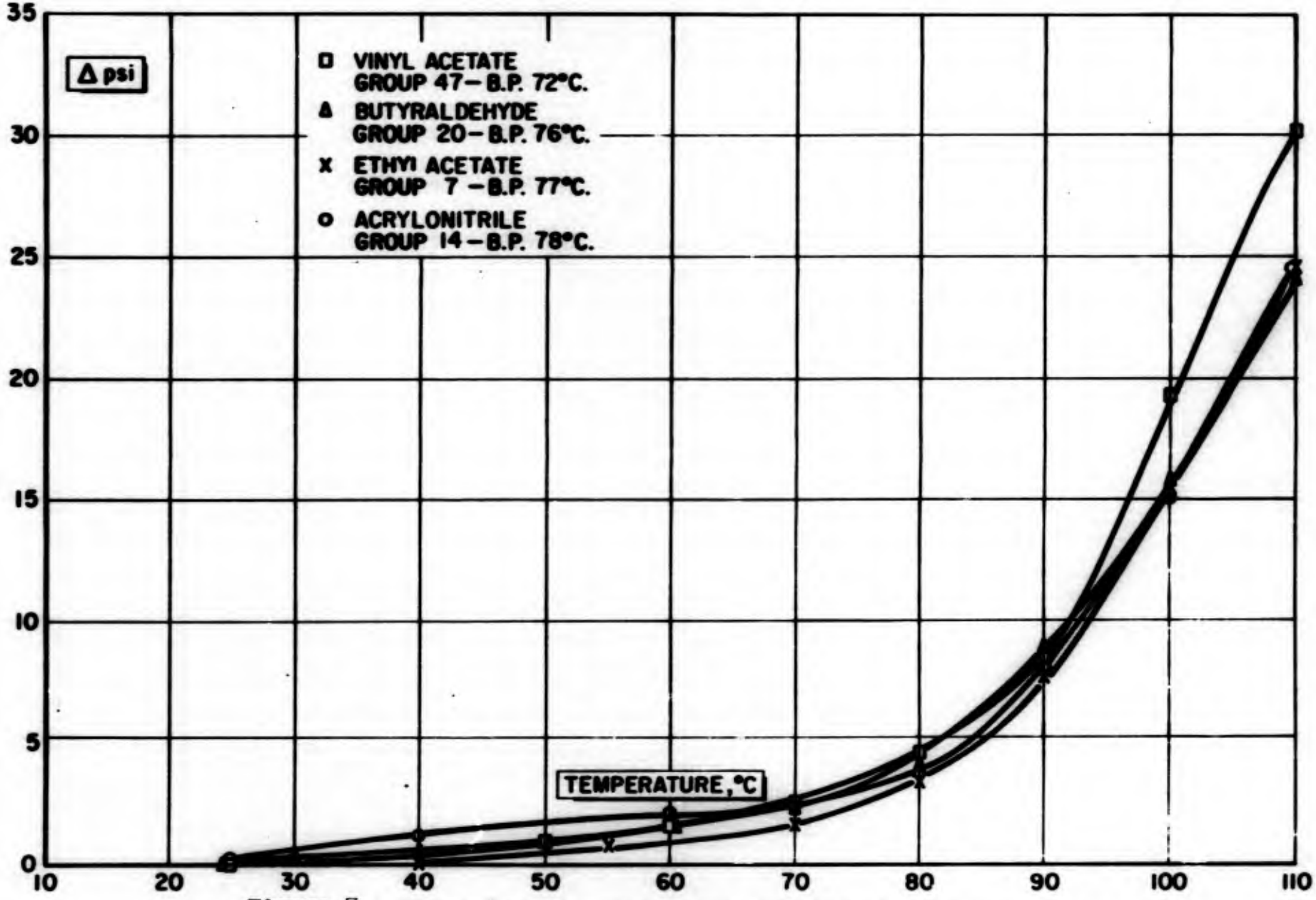

Figure 7 - Vapor Pressure Curves on Working Chemicals

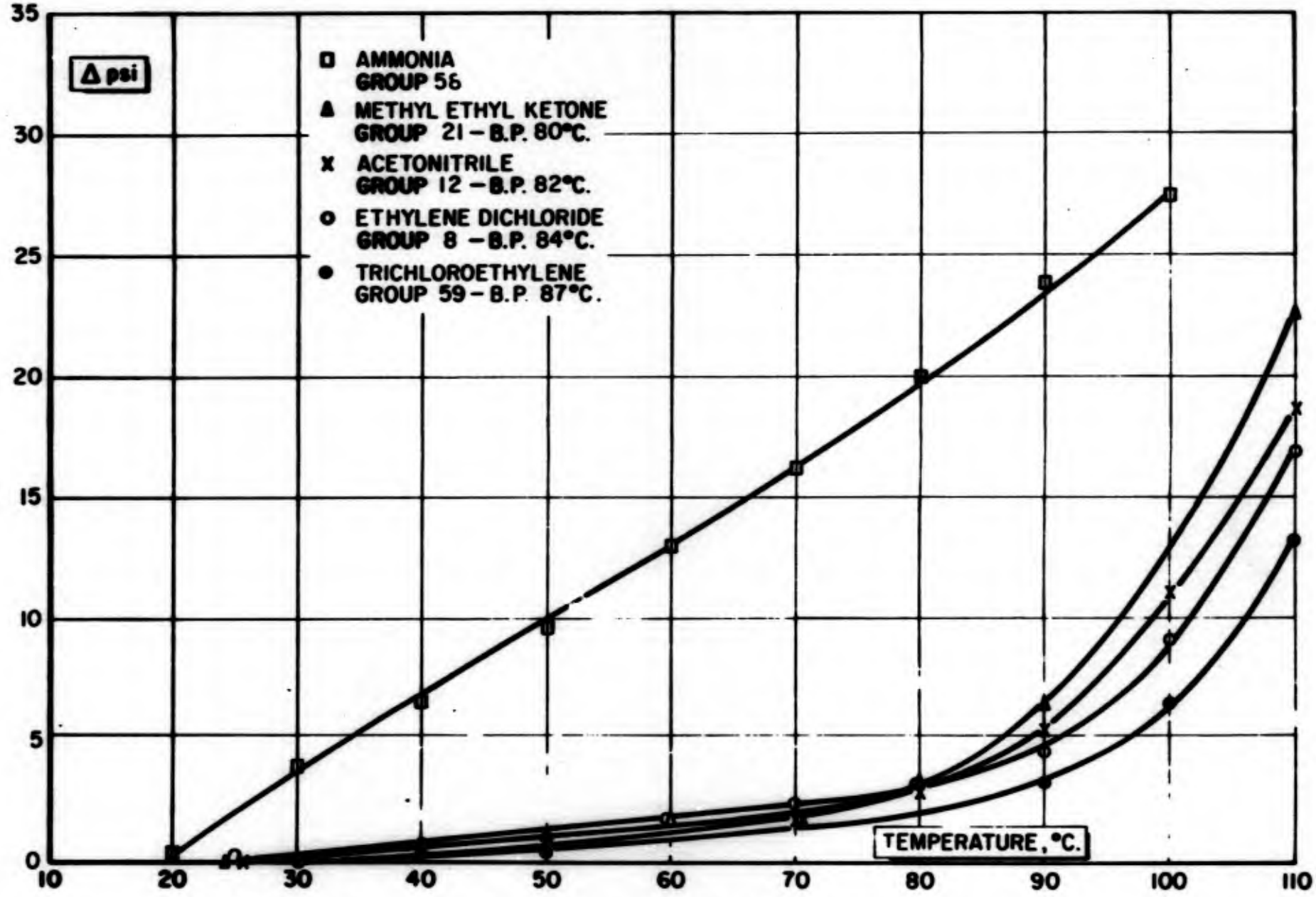

Figure 8 - Vapor Pressure Curves on Working Chemicals

reactivity differences from the working chemical of the respective groups were found that new groups were made. In addition, members of the Advisory Committee suggested that anhydrous ammonia and aqueous ammonia be in separate groups, and that perchloroethylene and trichloroethylene be placed in a separate group.

Toward the end of the program, the reactivity of the chlorobenzenes was found to be different toward chlorosulfonic acid than the working chemical of the group, namely, ethylene dichloride (See Group 8 in Appendix).

Time did not permit further testing of group integrity.

D. REDUCTION OF CHEMICAL GROUPS

A large number of chemical groups were formulated for the reactivity study on binary systems. As stated earlier, this was done to reduce the number of binary systems for experimental review. On the other hand, the 60 groups used in the study is a considerably larger number than the 24 groups currently used by the Coast Guard in its tentative compatibility guide. For convenient use, it would be helpful to reduce the 60 groups by combining groups to the extent allowed by the reactivity data.

The extent to which group combinations can be made is limited by two restrictions:

1. The group combinations can only be done within the context of the 209 chemicals reviewed in the work. The addition of a chemical not on the list could require some alterations. For example, molten sodium, not included in the 209 chemicals, would require the formation of a new group since it cannot be placed in any of the present 60 groups.
2. The extent to which groups can be combined also depends on how the limits of hazard degrees are set (See Section IIIB). The more restrictive

the limits, the larger the number of groups that are necessary. If the number of groups are reduced too much, more exceptions will occur to the group generalization.

In Table II the results are shown of a review of the binary reactivity data for 23 group combinations. The combinations were chosen from those suggested by the September, 1969 revision of the Compatibility Guide of the Advisory Committee.

The first column of Table II gives the numbers of the groups under comparison and the second column gives the total number of reactive binary systems found for the working chemicals of the corresponding groups. In the third column, a comparison is made of the reactive binary systems which are <u>different</u> and <u>similar</u>, according to degree of hazard as explained in Section IIIB. The only temperature category used in the comparison was that between room temperature and 46°C.

Although the number of differences noted in Table II for each combination appear to discourage the combining of groups, a different view is obtained when the actual differences are considered in detail. For the most part (but not entirely), the differences noted in the third column arise from two sources:

1. A non-reactivity of one group and a reactivity of the other such that the latter falls in the hazard degree "None".
2. A reactivity on the part of both groups that is different because of where each is placed in the degrees of "Low", "Medium", or "High" hazard.

An example of the above is the comparison of Groups Nos. 26 and 28 (glycols and glycol ethers). A total of eight differences are noted in the table. Of the eight, six are due to the reactivity of Group No. 28 with Group Nos. 1, 3, 27, 46, 58, and 59, and the non-reactivity of Group No. 26 with the same groups. However, in

Table II

Data Comparison for Combining of Groups

Combined Groups		Number of Reactive Binary Systems		Hazard Degree	
A	B	A	B	Different	Similar
18	33	4	3	1	3
22	23	9	13	8	6
26	28	13	19	8	11
8	25	2	5	5	1
31[a]	32[a]	33	31	10	23
31	52	33	30	11	23
32	52	31	30	14	19
53	54	28	25	10	19
11	30	4	20	18	2
8	59	2	3	5	0
1[a]	57[a]	19	15	10	10
41[a]	48[a]	44	46	23	24
13	20	12	18	13	5
12	14	3	6	3	3
15	26	8	13	6	7
7	29	7	10	3	7
10	34	10	9	8	2
6[a]	58[a]	24	17	18	9
22	27	9	14	6	8
18	39	4	4	1	3
44	47	9	10	10	1
2	17	0	4	4	0
33	39	3	4	1	3

[a]Working chemicals react with each other.

the case of Group No. 28, the degree of hazard is "None" in every case by definition. The reactivity found with Group Nos. 6 and 41 provide the other two differences. In the case of Group No. 6, one hazard degree is ranked "None" and the other "Low". With Group No. 41, the corresponding ranks are "Low" and "High.

The foregoing analysis of the "differences" now would indicate that the two groups could be combined if the ranks of Low, Medium, and High were considered equivalent, and Group No. 28 was placed under the same restrictions as Group No. 26 when it came to Group No. 6.

A similar analysis can be made for the other group combinations in Table II. In some cases, if the groups are combined, exceptions will have to be noted in a compatibility guide for the Coast Guard. However, since data are available for the individual groups, combinations may not be necessary.

IV. CONCLUSIONS AND RECOMMENDATIONS

A chemical reactivity study was made on bulk chemicals to obtain data for cargo compatibility.

The 209 specific chemicals were separated into 60 groups of similar chemical structure and a working chemical chosen for each group. Later, 7 chemicals representing 7 groups, were excluded from the program. Experimental work was performed with only the working chemicals.

An experimental procedure, consisting of three steps, was developed to obtain chemical reactivity data on binary mixtures of the working chemicals. The simple, practical method that measures temperature and pressure changes can be used with a large variety of reaction types.

From the data obtained in the study, a degree of hazard was assigned to binary systems found reactive between room temperature and 115°F.

Although the formation of groups and selection of working chemicals were done with care, the integrity of some groups should be examined. For example, the large Group No. 2 is a possible source of reactivity differences because it contains members which are mixtures of compounds, or compositions can vary. The procedures developed in the work can be applied to questionable cases to test for hazardous reactivity.

The reduction of the 60 chemical groups to some lesser number for use in a simplified cargo compatibility guide must be approached with caution. In general, it is not a recommendation of this report to combine groups at this time. The present study encompassed only 209 of the chemicals shipped in bulk quantities. Additional chemicals or new chemicals not fitting into the 60 proposed groups should be tested with all the working chemicals for complete shipping hazard definition.

V. APPENDICES

APPENDIX A

CHEMICAL REACTIVITY DATA

WORKING CHEMICALS OF THE 60 GROUPS

1. Aniline
2. Hexane
3. Glyoxal (40% aqueous)
4. Aluminum triethyl*
5. NH_3 (anhyd.)*
6. NaOH Soln. (50%)
7. Ethyl acetate
8. Ethylene dichloride
9. Cl_2*
10. Chlorohydrin
11. Coal tar oil
12. Acetonitrile
13. Acrolein
14. Acrylonitrile
15. Allyl alcohol
16. Allyl chloride
17. Isopropylbenzene
18. Isoprene
19. Carbon disulfide
20. n-Butraldehyde
21. Methylethyl ketone
22. Acetic acid
23. Acetic anhydride
24. Mesityl oxide
25. Dichloroethyl ether
26. Ethylene glycol
27. Acrylic acid
28. Diethyleneglycol monoethyl ether
29. Ethyleneglycol monoethyl ether acetate
30. Cresol (ortho)
31. Ethylene diamine
32. Monoethanolamine
33. Diisobutylene
34. Epichlorohydrin
35. Hydrogen fluoride (anhyd.)*
36. Nitrous oxide*
37. Oleum
38. Phosphorus, White
39. Styrene monomer
40. Sulfur
41. Sulfuric acid (98%)
42. Tetraethyl lead*
43. Vinylidene chloride
44. Ethyl acrylate
45. Isopropyl ether
46. Ethylene cyanohydrin
47. Vinyl acetate
48. Chlorosulfonic acid
49. 2-Nitropropane
50. Sulfolane
51. Propylene oxide
52. Ethylenimine
53. HCl (35% aqueous)
54. HF (70% aqueous)
55. HCl (anhyd.)*
56. Nitric acid (70%)
57. Pyridine
58. Ammonia (aqueous)
59. Trichloroethylene
60. Propiolactone

*Excluded from the reactivity study. Each of these seven chemicals were the only member of its group.

Working Chemical: Aniline

Group No. 1

Source: The Dow Chemical Company

Description: Technical grade

Boiling point: 185°C.

Heat of self-decomposition: -0.25 Kcal./gm.; -23.7 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: not tested.

Group Members

Aniline

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔTmax. °C.	ΔP, psi	Hazard
3	7	0	None
13	72	9.0	Medium
20	32	1.4	Low
22	13	0	None
23	120	3.0	High
27	24	0.9	None
28	8	0	None
30	5	0.6	None
31	6	0.6	None
37	45	-- *	High
41	87	3.3	High
46	5	0.5	None
48	152	-- *	High
52	6	Vac.	None
53	23	0.8	None
54	45	-- *	Low
56	101	18.0	High
57	6	0	None
60	188	-- *	High

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 10, 16, 25, 34, and 44.

4. Reactivity between 200° and 300°C. with Group Nos. 43, 47, and 51.

5. No reactivity found below 200°C. with Group Nos. 2_I, 8, 15, 17, 19, 21, 24, 26, 29, 32, 45, 49, 58, and 59.

6. No reactivity found below 300°C. with Group Nos. 6_I, 11, 12, 14, 18, 33_I, 39, and 50.

7. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: n-Hexane

Group No. 2

Source: Burdick and Jackson

Description: Industrial grade

Boiling point: 68-69°C.

Heat of self-decomposition: -0.15 Kcal./gm.; -12.8 Kcal./mole.

Sensitivity

Thermal: small exotherm at 235°C.

Impact: Not tested.

Spark: Not tested.

Group Members

Asphalt (typical)
Butane, commercial
Casinghead (natural) gasoline
Crude oil (petroleum)
Cyclohexane
Gasoline, commercial
Heptane, n-
Hexane, n-
Jet fuel, JP-3
Jet fuel, JP-4
Jet fuel, JP-5
Kerosene
Methane
Pentane, n-
Pentane, iso-
Petroleum ether
Propane, commercial
Nonane
Mineral spirits No. 10

1. The working chemical of this group showed no reactivity between room temperature and 46°C. with the working chemicals of the other groups.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 48_I and 56_I.

4. Reactivity between 200° and 300°C. with Group Nos. 22 and 41.

5. No reactivity found below 200°C. with Group Nos. 1_I, 3_I, 6_I, 7, 8, 11, 12_I, 14, 15, 17, 18, 19, 20, 21, 24, 25, 26_I, 28_I, 29, 30, 31_I, 32_I, 33, 37_I, 39, 43, 44, 45, 46_I, 47, 49, 50_I, 51, 52, 53_I, 57, 58_I, 59, and 60_I.

6. No reactivity found below 300°C. with Group Nos. 10_I, 13, 16, 23, 27_I, and 34.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I and below 65°C. with Group No. 54_I.

Working Chemical: Glyoxal (40% soln.) Group No. 3

Source: J. T. Baker Chemical Company

Description: Technical grade

Boiling point: >50°C.

Heat of Self-decomposition: +0.24 Kcal./gm.; +39.0 Kcal./mole.

Sensitivity

Thermal: exotherm beginning at 107°C.

Impact: not tested.

Spark: not tested.

Group Members

Glyoxal (40% soln.)

Formaldehyde (37-50% soln.)

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	7	0	None
6	70	-- *	High
28	9	0.5	None
31	72	3.0	Medium
32	50	1.1	Low
37	-- *	-- *	High
41	51	1.8	Medium
48	-- *	-- *	High
52	113	10.0	High
56	64	-- *	High
58	25	1.5	None

*Measurements not made; high temperature or gases generated in reaction.

2. Reactivity between 46° and 100°C. with Group No. 60.

3. Reactivity between 100° and 200°C. with Group Nos. 10_I, 11_I, 13_I, 14, 16_I, 18_I, 20_I, 21_I, 23_I, 26, 30_I, 34_I, 44_I, 46_I, 49_I, 51_I, and 53.

4. Reactivity between 200° and 300°C. with Group Nos. 12, 15, 22, 25_I, 27, 39_I, and 50.

5. No reactivity found below 200°C. with Group Nos. 2_I, 7_I, 8_I, 17_I, 19_I, 24_I, 29_I, 33_I, 45_I, 47_I, 58, and 59_I.

6. No reactivity found below 300°C. with Group No. 57.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I, and below 100°C. with Group No. 54.

Working Chemical: 50% Caustic soda Group No. 6

Source: Fisher Scientic Company

Description: Lab. prepared soln.

Boiling point:

Heat of self-decomposition: +1.39 Kcal./gm.; +111.1 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: not tested.

Group Members

Caustic potash solution

Caustic soda solution

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups.

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
3	70	-- *	High
10	34	22.6	High
13	84	4.0	High
20	61	5.4	Medium
22	89	3.6	High
23	127	13.3	High
24	13	0.8	None
26	34	1.3	Low
27	25	0.8	None
28	8	0	None
29	3	0	None
30	36	1.0	Low
31	6	0.4	None
32	10	0	None
37	-- *	-- *	High
40_I**	None (sample discolored)	--	None
41	101	15.7	High
46	31	6.3	High
48	145	76.0	High
53	80	3.9	High
54	--*	--	High
56	90	7.9	High
58	18	4.6	None
60	93	--*	High

*Measurement not made; high temperature or gases generated in reaction.

**Molten sulfur (130°C.).

2. Reactivity between 46° and 100°C. with Group No. 49_I.

3. Reactivity between 100° and 200°C. with Group Nos. 7_I, 12_I, 14_I, 15, 21_I, 34_I, 44_I, 47_I.

4. Reactivity between 200° and 300°C. with no groups.

5. No reactivity found below 200°C. with Group Nos. 2_I, 8, 11_I, 16_I, 17_I, 18_I, 33_I, 43_I, 45_I, 50_I, 51_I, 52, 57_I, and 59_I.

6. No reactivity found below 300°C. with Group Nos. 1_I, 25_I, and 39_I.

7. No reactivity found below 60°C. with Group No. 38_I.

Working Chemical: Ethyl acetate Group No. 7

Source: U. S. Industrial Chemicals

Description: Technical grade

Boiling point: 77°C.

Heat of self-decomposition: -0.16 Kcal./gm.; -14.0 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: negative

Group Members

Amyl acetate, iso-
Amyl acetate, n-
Butyl acetate, n-
Butyl acetate, sec.-
Ethyl acetate
Isobutyl acetate
Isopropyl acetate
Propyl acetate, n-
Methyl acetate
Methyl amyl acetate
Dibutyl-o-phthalate
Butylbenzyl phthalate
Glycol diacetate

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups.

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
30	8	0.9	None
37	38	3.0	High
41	44	1.5	Low
48	65	6.4	High
53	9	0.9	None
54	6	--	None
56	10	1.1	None

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group No. 6_I.

4. Reactivity between 200° and 300°C. with Group Nos. 19, 44, 49, and 52.

5. No reactivity found below 200°C. with Group Nos. 1, 2, 3, 8, 11, 13, 16, 17, 18, 24, 25, 27, 29, 32_I, 33, 43, 46, 47, 50, 51, 57, 59, and 60.

6. No reactivity found below 300°C. with Group Nos. 10, 12, 14, 15, 20, 21, 22, 23, 26_I, 28, 31, 34, 39, and 58.

7. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Ethylene dichloride Group No. 8

Source: The Dow Chemical Company

Description: Technical grade

Boiling point: 84°C.

Heat of self-decomposition: -0.11 Kcal./gm.; -11.2 Kcal./mole.

Sensitivity

Thermal: none <300°C.
Impact: not tested
Spark: negative

Group Members

Carbon tetrachloride
Chloroform
1,2-Dichloropropane
Ethyl chloride
Ethylene dichloride
Ethylene dibromide
Methyl bromide
Methyl chloride
Methylene chloride
Monochlorodifluoromethane
1,1,1-Trichloroethane
Dichlorodifluoromethane
Dichlorobenzene*
1,2,4-Trichlorobenzene*
Chlorobenzene*

*Differ from the working chemical in that they are reactive with Group No. 48.

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups.

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
37_I	4	3.2	High

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 18, 31, 32, 44, 52, 56_I, and 57.

4. Reactivity between 200° and 300°C. with Group No. 46.

5. No reactivity found below 200°C. with Group Nos. 1, 2, 3_I, 6_I, 7, 10, 11, 15, 16, 17, 23, 24, 25, 26_I, 27, 28, 29, 39, 45, 49, 50, 51, 53_I, 58_I, 59, and 60.

6. No reactivity found below 300°C. with Group Nos. 12, 13, 14, 19, 20, 21, 22, 30, 33, 34, 41_I, 43, 47, and 48.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I, and below 75°C. with Group No. 54_I.

Working Chemical: Ethylene chlorohydrin Group No. 10

Source: The Dow Chemical Company

Description: Technical grade

Boiling point: 129°C.

Heat of self-decomposition: -0.14 Kcal./gm.; -15.1 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: not tested.

Group Members

Ethylene chlorohydrin

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups.

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
6	34	22.6	High
31	194	13.5	High
32	8	0.4	None
37	54	0.9	Medium
41	41	0.6	Low
48	52	78.0	High
52	15	0	None
53	7	Vac.	None
56	6	0.8	None
57	9	0.8	None

2. Reactivity between 46° and 100°C. with Group Nos. 32 and 52.

3. Reactivity between 100° and 200°C. with Group Nos. 1, 3_I, 18, 23, 56, 57, and 58.

4. Reactivity between 200° and 300°C. with Group Nos. 12, 13, 14, 43, 46, ... 49, and 51.

5. No reactivity found below 200°C. with Group Nos. 8, 15, 19_I, 22, 24, 25, 26, 27, 28, 29, 34, 39, 45, and 59.

6. No reactivity found below 300°C. with Group Nos. 2_I, 7, 11, 16, 17, 20, 21, 30, 33_I, 44, and 50.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I, and below 110°C. with Group No. 54.

Working Chemical: Creosote oil Group No. 11

Source: Reilly Tar and Chemical Company

Description: A.W.P.A. #1

Boiling point: none

Heat of self-decomposition: -0.33 (est.) Kcal./gm.; -35.3 (est.) Kcal./mole.

Sensitivity

Thermal: None <300°C.

Impact: not tested.

Spark: 3.12 joules.

Group Members

Creosote oil

Creosote, coal tar

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
37	22	0.7	None
41	24	0.6	None
48	84	-- *	High
56	72	10.2	High

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with Group No. 60.

3. Reactivity between 100° and 200°C. with Group Nos. 3_I, 18, 19, and 27.

4. Reactivity between 200° and 300°C. with Group Nos. 13, 14, 16, and 43.

5. No reactivity found below 200°C. with Group Nos. 2, 6, 7, 8, 15, 17, 23, 24, 25, 26_I, 28, 29, 32, 45, 46, 47, 49, 53_I, and 59.

6. No reactivity found below 300°C. with Group Nos. 1, 10, 12, 20, 21, 22, 30, 31, 33, 34, 39, 44, 50, 51, 52, 57, and 58_I.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I and below 120°C. with Group No. 54_I.

Working Chemical: Acetonitrile — Group No. 12
Source: Eastman Organic Chemical
Description: Practical grade
Boiling point: 82°C.
Heat of self-decomposition: -0.36 Kcal./gm.; -14.7 Kcal./mole.

Sensitivity

Thermal: none <300°C.
Impact: negative to No. 8 cap and 40 gm. tetryl.
Spark: negative

Group Members

Acetonitrile
Adiponitrile

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups.

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
37	155	--*	High
41	173	>20	High
48	150	14	High

*Measurement not made, gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 6_I, 53 and 56.

4. Reactivity between 200° and 300°C. with Group Nos. 3, 10, 13, 43, 44 and 49.

5. No reactivity found below 200°C. with Group Nos. 2_I, 17, 24, 27, 29, 33, 45, 46 and 47.

6. No reactivity found below 300°C. with Group Nos. 1, 7, 8, 11, 14, 15, 16, 18, 19_I, 20, 21, 22, 23, 25, 26, 28, 30, 31, 32, 34, 39, 50, 51, 52, 57, 58 and 59.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I and below 70°C. with Group No. 54.

Working Chemical: Acrolein Group No. 13

Source: Eastman Organic Chemical

Description: Practical grade, inhibited with Hydroquinone

Boiling point: 52.5°C.

Heat of self-decomposition: -0.31 Kc. ./gm.; -17.3 Kcal./mole.

Sensitivity

Thermal: exotherm beginning at 210°C.

Impact: negative to No. 8 cap and 40 gm. tetryl

Spark: negative

Group Members

Acrolein
Crotonaldehyde
2-Ethyl-3-propylacrolein

Reactivity Date on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups.

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	72	9.0	Med.
6	84	4.0	High
31	98	8.0	High
32	95	--*	High
37	80	--*	High
41	144	19.2	High
48	96	--*	High
52	161	22.2	High
53	33	1.9	Low
54	10	--	None
56	82	--*	High
58	106	14.8	High

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 3_I, 17, 18 and 39.

4. Reactivity between 200° and 300°C. with Group Nos. 10, 11, 12, 14, 15, 16, 20, 22, 25, 26, 27, 43, 44 and 49.

5. No reactivity found below 200°C. with Group Nos. 7, 24, 29, 34, 45, 46, 47 and 60.

6. No reactivity found below 300°C. with Group Nos. 5, 8, 19_I, 21, 23, 28, 30, 33, 50, 51, 57 and 59.

7. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Acrylonitrile
Source: Eastman Organic Chemical
Description: Practical grade
Boiling point: 78.5°C.
Heat of self-decomposition: -0.68 Kcal./gm.; -35.9 Kcal./mole.

Sensitivity

Thermal: exotherm beginning at 270°C.
Impact: negative to No. 8 cap and 40 gm. tetryl.
Spark: negative

Group Members

Acrylonitrile

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups.

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
31	106	3.2	High
32	95	3.9	High
37	137	--*	High
41	205	49.4	High
48	121	--*	High
52	34	3.1	Low

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with Group No. 56 (mixture detonates at 90°C.).

3. Reactivity between 100° and 200°C. with Group Nos. 3, 6I, 18, 22 and 39.

4. Reactivity between 200° and 300°C. with Group Nos. 10, 11, 13, 16, 43 and 51.

5. No reactivity found below 200°C. with Group Nos. 2, 15, 17, 24, 27, 28, 29, 45, 46 and 47.

6. No reactivity found below 300°C. with Group Nos. 1, 7, 8, 12, 19, 20, 21, 23, 25, 26_I, 30, 33, 34, 44, 49, 50, 53, 57, 58_I and 59.

7. No hazardous reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I, and below 90°C. with Group No. 54.

4. Reactivity between 200° and 300°C. with Group Nos. 10, 11, 13, 16, 43 and 51.

5. No reactivity found below 200°C. with Group Nos. 2, 15, 17, 24, 27, 28, 29, 45, 46 and 47.

6. No reactivity found below 300°C. with Group Nos. 1, 7, 8, 12, 19, 20, 21, 23, 25, 26_I, 30, 33, 34, 44, 49, 50, 53, 57, 58_I and 59.

7. No hazardous reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I, and below 90°C. with Group No. 54.

Working Chemical: Allyl alcohol
Source: The Dow Chemical Company
Description: Technical grade
Boiling point: 96°C.
Heat of self-decomposition: -0.27 Kcal./gm.; -16.7 Kcal./mole.

Sensitivity

Thermal: exotherm beginning at 280°C.
Impact: negative to 300 Kg-cm.
Spark: negative

Group Members

Allyl alcohol

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups.

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
20	13	0.6	None
31	16	0	None
37	161	--*	High
41	153	--*	High
48	150	--*	High
52	11	Vac.	None
53	9	0	None
56	77	--*	High

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 6 and 23.

4. Reactivity between 200° and 300°C. with Group Nos 3_I and 13.

5. No reactivity found below 200°C. with Group Nos. 1, 2, 8, 10, 11, 14, 16, 17, 18, 24, 25, 26, 27, 28, 29, 30, 32, 33, 43, 45, 46, 47, 49, 50, 51, 57, 58 and 59.

6. No reactivity found below 300°C. with Group Nos. 7, 12, 19, 21, 22, 34, 39 and 44.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I, and below 100°C. with Group No. 54.

Working Chemical: Allyl Chloride Group No. 16

Source: Eastman Organic Chemical

Description: Technical grade

Boiling point: 45°C.

Heat of self-decomposition: -0.31 Kcal./gm.; -23.6 Kcal./mole.

Sensitivity

Thermal: exotherm beginning at 230°C.

Impact: negative to No. 8 cap and 40 gm. tetryl.

Spark: negative

Group Members

Allyl chloride

Dichloropropene

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
31	110	22.0	High
32	56	14.9	Medium
37	35	34.4	High
41	45	15.7	High
48	60	--*	High
52	176	38.2	High
56_I (exotherm begins at 45°C.)		--*	High

*Measurement not made, gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 1, 3_I, 22, 44, 47 and 57.

4. Reactivity between 200° and 300°C. with Group Nos. 7, 11, 13, 14, 27, 43, 46_I, 51_I, 53_I and 60.

5. No reactivity found below 200°C. with Group Nos. 6, 8, 15, 19, 24, 25, 26_I, 28, 29, 34, 39, 49, 58 and 59.

6. No reactivity found below 300°C. with Group Nos. 2, 10, 12, 17, 18, 20, 21, 23, 30, 33, 45 and 50.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I and below 45°C. with Group No. 54_I.

Working Chemical : Cumene Group No. 17

Source: J. T. Baker Chemical Company

Description: Baker grade (high purity)

Boiling point: 152°C.

Heat of self-decomposition: -0.24 Kcal./gm.; -28.4 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: not tested.

Group Members

Benzene
Napthhthalene, molten
Cymene, p-
Diethylbenzene
Etnyl benzene
Tetrahydronaphthalene
Toluene
Triethylbenzene
Xylene,
Xylene, o-
Xylene, p-
Cumene (isopropylbenzene)
Dodecylbenzene, commercial

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
37	35	--*	High
41_I	6	0.6	None
48	51	34.8	High
56	7	1.1	High

*Measurement not made, gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 13, 27 and 39.

4. Reactivity between 200° and 300°C. with no groups.

5. No reactivity found below 200°C. with Group Nos. 1, 2, 3, 6_I, 7, 8, 11, 12, 14, 15, 18, 19, 20, 21, 22, 24, 25, 26_I, 28, 29, 30, 31_I, 32_I, 33, 43, 44, 45, 46_I, 47, 49, 50, 51, 52, 53_I, 57, 58_I, 59 and 60.

6. No reactivity found below 300°C. with Group Nos. 10, 16, 23 and 34.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I, and below 100°C. with Group No. 54_I.

Working Chemical: Isoprene Group No. 18

Source: J. T. Baker Chemical Company

Description: Baker grade (high purity)

Boiling point: 34°C.

Heat of self-decomposition: -0.37 Kcal./gm.; -25.3 Kcal./mole.

Sensitivity

Thermal: exotherm beginning at 200°C.

Impact: not tested.

Spark: negative

Group Members

Butadiene (inhibited)

Isoprene

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
37	118	--*	High
41	117	--*	High
48	89	>40	High
56	90	--*	High

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 3_I, 8, 10, 11, 13, 14, 25, 27, 44 and 60.

4. Reactivity between 200° and 300°C. with Group Nos. 30 and 50.

5. No reactivity found below 200°C. with Group Nos. 2, 6_I, 7, 15 17, 19, 24, 26_I, 28, 29, 33, 39, 46, 47, 49 and 53_I.

6. No reactivity found below 300°C. with Group Nos. 1, 12, 16, 20, 21, 22, 23, 31, 32_I, 34, 43, 45, 51, 52, 57, 58_I and 59.

7. No reactivity found below 60°C. with Group No. 38_I° below 130°C. with Group No. 40_I, and below 34°C. with Group No. 54_I.

Working Chemical: Carbon disulfide — Group No. 19

Source: Western Solvents

Description: Technical grade

Boiling point: 46.5°C.

Heat of self-decomposition: -15.4 Kcal./mole (est.)

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Friction: not tested.

Group Members

Carbon disulfide

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
31	90	>20	High
32_I	32	7.4	Low
52	130	>40	High

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 11 and 44.

4. Reactivity between 200° and 300°C. with Group Nos. 7, 48_I, 51, 56_I and 58_I.

5. No reactivity found below 200°C. with Group Nos. 1, 2, 3_I, 6_I, 10_I, 16, 17, 18, 20, 23_I, 24, 25, 27_I, 29, 30, 33, 37_I, 41_I, 43, 46, 47, 48_I, 50_I, 57 and 60_I.

6. No reactivity found below 300°C. with Group Nos. 8, 12_I, 13_I, 14, 15, 21, 22, 26_I, 28, 34, 39, 49, 53_I and 59.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40, and below 45°C. with Group No. 54_I.

Working Chemical: n-Butyraldehyde Group No. 20

Source: Eastman Organic Chemical

Description: Technical grade

Boiling point: 76°C.

Heat of self-decomposition: -0.24 Kcal./gm.; -17.2 Kcal./mole.

Sensitivity

Thermal: slight exotherm beginning at 268°C.

Impact: not tested.

Spark: not tested.

Group Members

Acetaldehyde
Butyraldehyde, n-
Isobutyraldehyde
Isodecaldehyde
Isooctyl aldehyde
Propionaldehyde
Valeraldehyde
Furfural
Methyl formal
Methyl butyraldehyde

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups.

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	32	1.4	Low
6	61	5.4	Medium
15	13	0.6	None
25	11	0.4	None
26	20	2.7	None
28	10	0.5	None
31	74	1.9	Medium
32	65	3.5	Medium
37	124	-- *	High
41	121	11.1	High
46	6	1.9	None
48	114	-- *	High
52	60	0	Medium
53_I	19	1.8	None
54_I	30	--	Low
56_I	73	>40	High.
58	26	2.2	High
59	14	0	None

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 3_I and 44.

4. Reactivity between 200° and 300°C. with Group Nos. 13, 19, 21, 22, 43, 49, 50, 51 and 60.

5. No reactivity found below 200°C. with Group Nos. 2, 17, 23, 24, 29, 45 and 47.

6. No reactivity found below 300°C. with Group Nos. 7, 8, 10, 11, 12, 14, 16, 18, 27, 30, 33, 34, 39 and 57.

7. No reactivity found below 60°C. with Group No. 38_I, and below 130°C. with Group No. 40_I.

Working Chemical: Methylethyl ketone Group No. 21

Source: Fisher Scientific Company

Description: Fisher certified grade

Boiling point: 80°C.

Heat of self-decomposition: -0.19 Kcal./gm.; -13.8 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: not tested.

Group Members

Cyclohexanone
Acetone
Camphor oil
Methylethyl ketone
Methylisobutyl ketone
Diisobutyl ketone

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups.

Group No.	ΔT. max. °C.	ΔP, psi	Hazard
30	8	1.2	None
31	27	2.6	Low
32	14	1.9	None
37	76	--*	High
41	46	1.1	Low
48	60	34	High
52	12	Vac.	None
53	16	0.9	None
54	12	--	None
56	13	1.1	None

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 3_I, 6_I, 27 and 43.

4. Reactivity between 200° and 300°C. with Group Nos. 20, 43 and 49.

5. No reactivity found below 200°C. with Group Nos. 1, 2, 17, 21, 23, 24, 29, 33, 45, 47, 51 and 59.

6. No reactivity found below 300°C. with Group Nos. 7, 8, 10, 11, 12, 13, 14, 15, 16, 18, 19, 22, 25, 26, 28, 34, 39, 50, 57 and 58_I.

7. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Acetic acid, glacial Group No. 22
Source: Fisher Scientific Company
Description: A.C.S. grade
Boiling point: 118°C.
Heat of self-decomposition: +0.01 Kcal./gm.; +0.7 Kcal./mole

Sensitivity

Thermal: none <300°C.
Impact: not tested.
Spark: not tested.

Group Members

Acetic acid, glacial
Formic acid
Propionic acid
n-Butyric acid

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	13	0	None
6	89	3.6	High
31	96	2.4	High
32	105	-- *	High
37	56	-- *	High
41	38	0.7	Low
48	75	7.2	High
52	189	33.5	High
57	20	0	None

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 14, 16, 51, 56 and 60.

4. Reactivity between 200° and 300°C. with Group Nos. 2, 3, 13, 20, 49 and 58.

5. No reactivity found below 200°C. with Group Nos. 10, 17, 23, 24, 27, 29, 39, 45, 46 and 50

6. No reactivity found below 300°C. with Group Nos. 7, 8, 11, 12, 15, 18, 19, 21, 25, 26, 28, 30, 33, 34, 43, 44, 47, 53 and 59.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I, and below 110°C. with Group No. 54.

Group No. 23

Working Chemical: Acetic anhydride
Source: Fisher Scientific Company
Description: A.C.S. grade
Boiling point: 139°C.
Heat of self-decomposition: -0.16 Kcal./gm.; -16.3 Kcal./mole.

Sensitivity

Thermal: none <300°C.
Impact: not tested.
Spark: negative

Group Members

Acetic anhydride
Propionic anhydride

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups.

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	120	3.0	High
6	127	13.3	High
30	8	0.3	None
31	148	7.5	High
32	144	--*	High
37	97	--*	High
41	106	3.6	High
48	77	41.4	High
52	153	22.8	High
53	53	12.2	High
54	53	--	High
56	80	2.0	High
58	17	1.5	None

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with Group No. 58.

3. Reactivity between 100° and 200°C. with Group Nos. 3_I, 10, 15, 26 and 44.

4. Reactivity between 200° and 300°C. with Group Nos. 34, 43, 49 and 51.

5. No reactivity found below 200°C. with Group Nos. 8, 11, 19_I, 20, 21, 22, 24, 27, 28, 29, 45, 50, 57, 59 and 60.

6. No reactivity found below 300°C. with Group Nos. 2_I, 7, 12, 13, 14, 16, 17, 18, 33_I, 39, 46 and 47.

7. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Mesityl oxide Group No. 24

Source: Metheson, Coleman and Bell

Description: MX415; unknown quality

Boiling point: 128°-130°C.

Heat of self-decomposition: -0.23 Kcal./gm.; -22.3 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: negative to 300 Kg. cm.

Spark: negative

Group Members

Isophorone

Mesityl oxide

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
6	13	0.8	None
30	12	0.4	None
31	70	-- *	High
32	30	2.8	High
37	130	-- *	High
41	94	-- *	High
48	100	-- *	High
52	35	1.5	Low
53	19	Vac.	None
54	10	--	None
56	18	-- *	High

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group No. 44.

4. Reactivity between 200° and 300°C. with no groups.

5. No reactivity found below 200°C. with Group Nos. 1, 2, 3_I, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28, 29, 33, 34, 39, 43, 45, 46, 47, 49, 50, 51, 57, 58_I, 59 and 60.

6. No reactivity found below 60°C. with Group No. 38_I, and below 130°C. with Group No. 40_I.

Working Chemical: Dichloroethyl ether Group No. 25
Source: K & K Laboratories; Eastman Kodak
Description: Practical grades
Boiling point: 178°C.
Heat of self-decomposition: -0.15 Kcal./gm.; -21.4 Kcal./mole.

Sensitivity

Thermal: none <300°C.
Impact: not tested.
Spark: negative

Group Members

Dichloroethyl ether

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups.

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
20	11	0.4	None
37	40	-- *	High
41	26	0.5	Low
48	30	1.2	High
56	4	0.7	None

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 1, 18, 31, 32_I, 52 and 56.

4. Reactivity between 200° and 300°C. with Group Nos. 3_I, 13, 43 and 46.

5. No reactivity found below 200°C. with Group Nos. 2, 7, 8, 10, 11, 15, 16, 17, 19, 23, 24, 26_I, 27, 28, 29, 30, 34, 39, 45, 49, 50, 51, 53, 57, 59 and 60.

6. No reactivity found below 300°C. with Group Nos. 6_I, 12, 14, 21, 22, 33, 44, 47 and 58_I.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I and below 110°C. with Group No. 54_I.

Working Chemical: Ethylene glycol Group No. 26

Source: The Dow Chemical Company

Description: Industrial grade, <10 ppm H_2O_2

Boiling point: 198°C.

Heat of self-decomposition: -0.17 Kcal./gm.; -10.7 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: not tested.

Group Members

Amyl alcohol, n-
Butyl alcohol, n-
Butyl alcohol, sec-
Butyl alcohol, tert-
Butyl alcohol, iso-
Decyl alcohol, n-
Diethylene glycol
Dipropylene glycol
Ethyl alcohol
1,3-Butylene glycol
Ethylene glycol
Furfuryl alcohol
Glycerine
Hexylene glycol
Isopropyl alcohol
Isooctanol
Methylamyl alcohol
Methyl alcohol
Propyl alcohol, n-
Propylene glycol
Tridecanol
2-ethyl-1-hexanol
Isodecanol
Nonyl alcohol
Cyclohexanol

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups.

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
6	34	1.3	Low
20	20	2.7	None
30	6	2.7	None
31	25	0.7	None
32	10	0.6	None
37	110	-- *	High
41	80	1.7	High
48	66	84	High
52	13	Vac.	None
53	14	Vac.	None
54	6	--	None
56	14	0.8	None
57	7	0	None

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 1, 3, 23 and 52.

4. Reactivity between 200° and 300°C. with Group Nos. 13 and 49_I.

5. No reactivity found below 200°C. with Group Nos. 2_I, 8_I, 10, 11, 15, 16_I, 17_I, 18_I, 24, 25_I, 27, 28, 29_I, 33_I, 38_I, 43_I, 45_I, 46, 47_I, 50, 51 and 59_I.

6. No reactivity found below 300°C. with Group Nos. 7_I, 12, 14_I, 19_I, 21, 22, 34_I, 39_I, 44_I and 58.

7. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Acrylic acid

Group No. 27

Source: The Dow Chemical Company

Description: Industrial grade; inhibited with 200 ppm MEHQ

Boiling point: 141°C.

Heat of self-decomposition: -0.20 Kcal./gm.; 14.1 Kcal./mole

Sensitivity

Thermal: exotherm begins at 180°C.

Impact: negative to 300 Kg-cm.

Spark: negative

Group Members

Acrylic acid

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	24	0.9	None
6	25	0.8	None
28	7	0.6	None
29	4	0.5	None
30	3	0.6	None
31	161	--*	High
32	109	--*	High
37	60	--*	High
41	36	0.8	Low
48	146	--*	High
52	111	16.4	High
56	4	0.5	None
57	23	1.5	None
58	12	--*	High

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 11, 17, 18, 21, 33, 39, 56 and 60.

4. Reactivity between 200° and 300°C. with Group Nos. 3, 13, 16, 43 and 46.

5. No reactivity found below 200°C. with Group Nos. 7, 8, 10, 12, 14, 15, 19_I, 22, 23, 24, 25, 26, 34, 45, 49, 50, 51 and 59.

6. No reactivity found below 300°C. with Group Nos. 2_I, 20, 44, 47 and 53.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I, and below 100°C. with Group No. 54_I.

Working Chemical: Diethylene glycol monomethyl ether
Source: J. T. Baker Chemical Company
Description: Baker grade; 10 ppm H_2O_2
Boiling point: 193°C.
Heat of self-decomposition: -0.22 Kcal./gm.; -28.9 Kcal./mole.

Sensitivity

Thermal: none <300°C.
Impact: not tested
Spark: not tested

Group Members

Ethylene glycol monobutyl ether
Diethylene glycol monobutyl ether
Ethylene glycol monoethyl ether
Diethylene glycol monoethyl ether
Ethylene glycol monomethyl ether
Diethylene glycol monomethyl ether
Triethylene glycol
Ethoxytriglycol
Tetraethylene glycol

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	8	0	None
3	9	0.5	None
6	8	0	None
20	10	0.5	None
27	7	0.6	None
30	14	0.7	None
31	13	0.6	None
32	5	0.6	None
37	>94	-- *	High
41	47	0.8	Low
46	8	0.4	None
48	68	50.0	High
52	6	0	None
53	19	0	None
54	16	--	None
56	21	0.7	None
57	6	0	None
58	8	0.8	None
59	5	0	None

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with no groups.

4. No reactivity found below 200°C. with Group Nos. 2_I, 8, 10, 11, 14, 15, 16, 17, 18, 23, 24, 25, 26, 29, 33, 43, 45, 50, 51 and 60.

5. No reactivity found below 300°C. with Group Nos. 7, 12, 13, 19, 21, 22, 34, 39, 44, 47 and 49.

6. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Ethylene glycol monoethyl ether acetate
Source: Union Carbide Chemical Company
Description: Technical grade; 340 ppm H_2O_2
Boiling point: 156°C.
Heat of self-decomposition: -0.19 Kcal./gm.; 25.7 Kcal./mole.

Sensitivity

Thermal: none <300°C.
Impact: not tested.
Spark: not tested.

Group Members

Ethylene glycol monoethyl ether acetate

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 45°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
6	3	0	None
27	4	0.5	None
30	9	0.7	None
37	77	--*	High
41	32	0	Low
48	33	--*	High
53	12	0	None
54	9	--	None
56	14	0	None
59	4	0.5	None

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with no groups.

4. No reactivity found below 200°C. with Group Nos. 1, 2, 3, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26_I, 27, 28, 31, 32_I, 33, 34, 39, 43, 44, 45, 46, 47, 49, 50 51, 52, 57, 58_I and 60.

5. No reactivity found below 60° with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Cresols, mixed isomers Group No. 30
Source: Mallinckrodt Chemical Works
Description: U.S.P. grade
Boiling point: >200°C.
Heat of self-decomposition: -0.22 Kcal./gm.; -23.6 Kcal./mole.

Sensitivity

Thermal: exotherm begins at 290°C.
Impact: not tested.
Spark: not tested.

Group Members

Cresols
Nonyl phenol
Phenol

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	5	0.6	None
6	36	1.0	Low
7	8	0.9	None
21	8	1.2	None
23	8	0.3	None
24	12	0.4	None
26	6	0	None
27	3	0.6	None
28	14	0.7	None
29	9	0.7	None
31	28	0.9	Low
32	16	0.8	None
37	56	--*	High
41	35	0.7	Low
44	4	0	None
45	11	1.5	None
48	92	--*	High
52	32	1.3	Low
56	87	--*	High
57	28	0.8	Low

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 3_I, 51, 52 and 60.

4. Reactivity between 200° and 300°C. with Group Nos. 18 and 39.

5. No reactivity found below 200°C. with Group Nos. 2, 15, 17, 19, 25, 46, 49 and 53_I.

6. No reactivity found below 300° with Group Nos. 8, 10, 11, 12, 13, 14, 16, 20, 22, 33, 34, 43, 47, 50, 58_I and 59.

7. No reactivity found below 60° with Group No. 38_I, below 130°C. with Group No. 40_I, and below 108°C. with Group No. 54_I.

Working Chemical: Ethylene diamine Group No. 31

Source: Fisher Scientific Company

Description: A.C.S. grade

Boiling point: 117°C.

Heat of self-decomposition: -0.27 Kcal./gm.; -16.4 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: not tested.

Group Members

Diethylene triamine
Dimethylamine
Ethylene diamine
Diethylamine
Triethylene tetramine
Morpholine

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	6	0.6	None
3	72	3.0	Medium
6	6	0.4	None
10	194	13.5	High
13	98	8.0	High
14	106	3.2	High
15	16	0	None
16	110	22.0	High
19	90	>20	High
20	74	1.9	Medium
21	27	2.6	Low
22	96	2.4	High
23	148	7.5	High
24	70	-- [a]	High
26	25	0.7	None
27	161	-- [a]	High
28	13	0.6	None
30	28	0.9	Low
32	6	0	None
34	180	15.3	High
37	250	-- [a]	High
38[b]	None	(Mixture darkened)	None
40_I[c]	None	(Sulfur blackened)	None
41	111	11.1	High
44	69	1.4	Medium
46	36	1.0	Low

Continued

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
47	116	11.7	High
48	164	26.1	High
49	28	1.0	Low
53	81	3.5	High
54	98	--	High
56	90	6.6	High
60	117	-- [a]	High

[a]Measurement not made; gases generated in reaction
[b]Molten, 60°C.
[c]Molten, 130°C.

2. Reactivity between 46° and 100°C. with Group No. 51.

3. Reactivity between 100° and 200°C. with Group Nos. 8 and 25.

4. Reactivity between 200° and 300°C. with Group Nos. 43 and 59.

5. No reactivity found below 200°C. with Group Nos. 2_I, 17, 29, 45_I, 52 and 58.

6. No reactivity found below 300°C. with Group Nos. 7, 11, 12, 18, 33_I, 39, 50 and 57.

Working Chemical: Monoethanolamine Group No. 32

Source: The Dow Chemical Company

Description: Industrial grade

Boiling point: 171°C.

Heat of self-decomposition: -0.17 Kcal./gm.; -10.7 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: negative at 300 Kg.-cm.

Spark: not tested.

Group Members

Diethanolamine
Monoethanolamine
Monoisopropanolamine
Triethanolamine
Amino ethyl ethanolamine
Diisopropanolamine

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the groups on the following page.

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
3	50	1.1	Low
6	10	0	None
10	8	0.4	None
13	95	--[a]	High
14	95	3.9	High
16	56	14.9	Medium
19_I	32	7.4	Low
20	65	3.5	Medium
21	14	1.9	None
22	105	--[a]	High
23	144	--[a]	High
24	30	2.8	High
26	10	0.6	None
27	109	--[a]	High
28	5	0.6	None
30	16	0.8	None
31	6	0	None
34	240	--[a]	High
37	206	--[a]	High
38_I[b]	None	(mixture darkened)	None
40_I[c]	None	(mixture darkened)	None
41	182	--[a]	High
44	60	2.0	Medium
46	13	0.6	None
47	122	22.5	High
48	--[a]	--[a]	High
49	15	0.7	None
53	80	--[a]	High
54	98	--[a]	High
56	101	--[a]	High
60	170	--[a]	High

[a]Measurement not made; high temperature or gases generated in reaction.

[b]Molten, 60°C.

[c]Molten, 130°C.

2. Reactivity between 46° and 100°C. with Group Nos. 10 and 51.

3. Reactivity between 100° and 200°C. with Group Nos. 8, 25_I and 43_I.

4. No reactivity found below 200°C. with Group Nos. 1, 2_I, 7_I, 11, 15, 17_I, 29_I, 45_I, 50, 52, 57, 58 and 59_I.

5. No reactivity found below 300° with Group Nos. 12, 18_I, 33_I and 39_I.

Working Chemical: Diisobutylene Group No. 33

Source: J. T. Baker Chemical Company

Description: Practical grade; 300 ppm H_2O_2

Boiling point: 105°C.

Heat of self-decomposition: -0.22 Kcal./gm.; -25.1 Kcal./mole.

Sensitivity

Thermal: none <300°C.
Impact: not tested.
Spark: not tested.

Group Members

Diisobutylene	Dipentene
Ethylene	Heptene
Propylene	Nonene, isomers
Tetrapropylene	Turpentine
Tripropylene	Dicyclopentadiene

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
37	61	11.2	High
41_I	34	2.6	High
48	46	45.2	High

2. Reactivity between 46° and 100°C. with Group No. 56_I.

3. Reactivity between 100° and 200°C. with Group Nos. 27_I, 58 and 60.

4. No reactivity found below 200°C. with Group Nos. 2, 3_I, 6_I, 7, 12, 15, 17, 18, 19, 21, 24, 26_I, 28, 29, 39, 44, 46_I, 47, 49 and 53_I.

5. No reactivity found below 300°C. with Group Nos. 1_I, 8, 10_I, 11, 13, 14, 16, 20, 22, 23_I, 25, 30, 31_I, 32_I, 34, 43, 45, 50_I, 51, 52, 57 and 59.

6. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I and below 84°C. with Group No. 54_I.

Working Chemical: Epichlorohydrin

Group No. 34

Source: The Dow Chemical Company

Description: Industrial grade

Boiling point, 117°C.

Heat of self-decomposition: -0.26 Kcal./gm.; 24.3 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: negative to No. 8 cap and 40 gm. tetryl.

Spark: negative

Group Members

Epichlorohydrin

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
31	180	15.3	High
32	240	--*	High
37	164	--*	High
41	240	>17.5	High
48	146	36	High
52	Exotherm begins 43°C.	--	High
53	75	2.9	Medium
54	75	--	Medium
56	104	5.0	High

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 1, 3_I, 6_I, 44 and 57.

4. Reactivity between 200° and 300°C. with Group Nos. 23, 43, 46 and 60.

5. No reactivity found below 200°C. with Group Nos. 10, 13, 16, 24, 25, 27, 29, 45, 50 and 58_I.

6. No reactivity found below 300° with Group Nos. 2, 7, 8, 11, 12, 14, 15, 17, 18, 19, 20, 21, 22, 26_I, 28, 30, 33, 39, 47, 49, 51 and 59.

7. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Oleum Group No. 37

Source: J. T. Baker Chemical Company

Description: A.C.S. grade; 15-18% free SO_3

Boiling point: decomposes

Heat of self-decomposition: +0.32 Kcal./gm.; +57.4 Kcal./mole.

Sensitivity

Thermal: decomposes

Impact: not tested.

Spark: not tested.

Group Members

Oleum

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the groups on the following page.

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	45	--[a]	High
3	--[a]	--[a]	High
6	--[a]	--[a]	High
7	38	3.0	High
8_I	4	3.2	High
10	54	0.9	Medium
11	22	0.7	None
12	155	--[a]	High
13	80	--[a]	High
14	137	--[a]	High
15	161	--[a]	High
16	35	34.4	High
17	35	--[a]	High
18	118	--[a]	High
20	124	--[a]	High
21	76	--[a]	High
22	56	--[a]	High
23	97	--[a]	High
24	130	--[a]	High
25	40	--[a]	High
26	110	--[a]	High
27	60	--[a]	High
28	>94	--[a]	High
29	77	--[a]	High
30	56	--[a]	High
31	250	--[a]	High
32	206	--[a]	High
33	61	11.2	High
34	164	--[a]	High
38[b]	11	--	None
39	91	--[a]	High
40[b]	None(mix darkened)	--	None

[a]Measurement not made; heat and gases generated in reaction.
[b]Molten phosphorus (60°C.) and Sulfur (130°C.)

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
41	11	1.2	High
43	23	33.4	High
44	55	2.0	Medium
45	97	--[a]	High
46	186	--[a]	High
47	127	--[a]	High
49	43	7.8	High
50	22	--[a]	High
51	>130	--[a]	High
52	240[b]	--[a]	High
53	44[b]	--[a]	High
54	--[a]	--[a]	High
56	73	--[a]	High
58	>106	--[a]	High
60	156	--[a]	High

[a]Measurement not made, heat and gases generated in reaction.

[b]Evolved gases ignited.

2. Reactivity between 46° and 100°C. with no group.

3. Reactivity between 100° and 200°C. with no groups.

4. No reactivity found below 200°C. with Group Nos. 2_I, 19_I, 48 and 59_I.

Working Chemical: Phosphorus, elemental, white Group No. 38
Source: J. T. Baker Chemical Company
Description: White elemental, purified
Boiling point: 280°C.
Heat of self-decomposition: 0

Sensitivity

Thermal: not tested.
Impact: not tested.
Spark: not tested.

Group Members

Phosphorus, elemental, white

Reactivity Data on Binary Systems

1. The working chemical of this group reacted at 60°C. (molten phosphorus) with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
31	None (mixture darkened)	--	None
32_I	None (Gp. 32 blackened)	--	None
37	11	--	None
48	74	--	Medium
56	111	--*	High

*Measurement not made; gases generated in reaction.

2. No reactivity found at 60°C. (molten phosphorus) with Group Nos. 1_I, 2_I, 3_I, 6_I, 7_I, 8_I, 10_I, 11_I, 12_I, 13_I, 14_I, 15_I, 16_I, 17_I, 18_I, 19_I, 20_I, 21_I, 22_I, 23_I, 24_I, 25_I, 26_I, 27_I, 28_I, 29_I, 30_I, 33_I, 34_I, 39_I, 40, 41_I, 43_I, 44_I, 45_I, 46_I, 47_I, 49_I, 50_I, 51_I, 52_I, 53_I, 54_I, 57_I, 58_I, 59_I, and 60_I.

Working Chemical: Styrene monomer — Group No. 39

Source: The Dow Chemical Company

Description: Industrial grade, inhibited with 6 ppm t-butyl catechol

Boiling point: 146°C.

Heat of self-decomposition: -0.34 Kcal./gm.; -35.1 Kcal./mole

Sensitivity

Thermal: exotherm beginning at 190°C.

Impact: not tested.

Spark: negative

Group Members

Styrene monomer (inhibited)
Vinyl toluene (meta and para, inhibited)

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
37	91	-- *	High
41	148	4.3	High
48	156	36.0	High
56_I	6	0	None

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 13, 14, 17, 22, 27, 44 and 56.

4. Reactivity between 200° and 300°C. with Group Nos. 3_I, 6_I, 30, 49, 52, 57 and 58_I.

5. No reactivity found below 200°C. with Group Nos. 2, 8, 10, 16, 18, 24, 25, 29, 33, 43, 46_I, 47, 50, 51, 59 and 60.

6. No reactivity found below 300°C. with Group Nos. 1, 7, 11, 12, 15, 19, 20, 21, 23, 26_I, 28, 31, 32_I, 34, 45, 52 and 53_I.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I and below 100°C. with Group No. 54_I.

Working Chemical: Sulfur, molten Group No. 40

Source: Fisher Scientific Company

Description: precipitated (lac sulfur); U.S.P.

Boiling point: 445°C.

Heat of self-decomposition: +0.48 Kcal./gm.; +15.4 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: not tested.

Group Members

Sulfur, molten

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
6_I	None (Gp. #6 colored)	--	None
31_I	None (sulfur blackened)	--	None
32_I	None (Gp. #32 phase blackened)	--	None
37	None (mix blackened)	--	None
52_I	None (sulfur blackened)	--	None
56	None	-- *	High

*Measurement not made; gases generated in reaction.

2. No reactivity found at 130°C. with Group Nos. 1_I, 2_I, 3_I, 7_I, 10_I, 11_I, 12_I, 13_I, 14_I, 15_I, 16_I, 17_I, 18_I, 19, 20_I, 21_I, 22_I, 23_I, 24_I, 25_I, 26_I, 27_I, 28_I, 29_I, 30_I, 33_I, 34_I, 39_I, 41, 43_I, 44_I, 45_I, 46_I, 47_I, 48_I, 49_I, 50_I, 51_I, 53_I, 54_I, 57_I, 58_I, 59 and 60_I.

3. No reactivity found below 60°C. with Group No. 38.

Working Chemical: Sulfuric acid (96%) Group No. 41

Source: du Pont

Description: A.C.S. grade

Boiling point: ca. 290°C.

Heat of self-decomposition: +0.46 Kcal./gm.; +45.8 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: not tested.

Group Members

Sulfuric acid (77 to 98%)

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	87	3.3	High
3	51	1.8	Medium
6	101	15.7	High
7	44	1.5	Low
10	41	0.6	Low
11	24	0.6	None
12	173	>20.0	High
13	144	19.2	High
14	205	49.5	High
15	153	--*	High
16	45	0.6	Low
17_I	6	0.6	None
18	117	--*	High
20	121	11.1	High
21	46	1.1	Low

Continued

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
22	38	0.7	Low
23	106	3.6	High
24	94	--*	High
25	26	0.5	Low
26	80	1.7	High
27	36	0.8	Low
28	47	0.8	Low
29	32	0	Low
30	35	0.7	Low
31	111	11.1	High
32	182	--*	High
33_I	34	2.6	Low
34	240	>17.5	High
37	11	1.2	High
39	148	4.3	High
44	33	1.5	Low
45	37	3.2	Low
46	216	--*	High
47	110	--*	High
48	Slight exot.	24.0	High
49	9	0.4	None
50	20	0	None
51	>110	--*	High
52	252	--*	High
53	18	17.7	High
54	38	--*	High
56	30	1.9	Low
57	106	5.0	High
58	84	--*	High
60	127	--*	High

*Measurement not made, gases generated in reaction.

2. Reactivity between 46° and 100°C. with Group No. 10.

3. Reactivity between 100° and 200°C. with no groups.

4. Reactivity between 200° and 300°C. with Group No. 2_I.

5. No reactivity found below 200°C. with Group Nos. 19_I and 43_I.

6. No reactivity found below 300°C. with Group Nos. 8_I and 59.

7. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40.

Working Chemical: Vinylidene chloride Group No. 43

Source: J. T. Baker Chemical Company

Description: Practical grade, inhibited with methyl hydroquinone

Boiling point: 32°C.

Heat of self-decomposition: -0.39 Kcal./gm.; -37.6 Kcal./mole.

Sensitivity

Thermal: exotherm beginning at 260°C.

Impact: negative to No. 8 cap and 40 gm. tetryl.

Spark: localized decomposition at 0.0125 joules.

Group Members

Vinyl chloride

Vinylidene chloride (inhibited)

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
37	23	33.4	High
48	19	59.0	High
56_I	Exotherm begins at 35°C.	-- *	High

*Dangerous combination - nitric acid and unsaturated compound.

2. Reactivity between 46° and 100°C. with Group No. 60.

3. Reactivity between 100° and 200°C. with Group Nos. 3_I, 32_I and 52.

4. Reactivity between 200° and 300°C. with Group Nos. 1, 10, 11, 12, 13, 14, 16, 20, 21, 23, 25, 27, 31, 34, 44, 46_I, 47, 50 51, 53_I, 57 and 58.

5. No reactivity found below 200°C. with Group Nos. 2, 6_I, 7, 8, 15, 17, 19, 24, 26_I, 28, 29, 39, 41_I, 49 and 59.

6. No reactivity found below 300°C. with Group Nos. 18, 22, 30, 33 and 45.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I and below 30°C. with Group No. 54_I.

Working Chemical: Ethyl acrylate Group No. 44

Source: Matheson Coleman and Bell

Description: Inhibited with 15 ppm methylethyl hydroquinone

Boiling point: 99°C.

Heat of self-decomposition: -0.25 Kcal./gm.; -25.3 Kcal./mole.

Sensitivity

Thermal: exotherm beginning at 230°C.

Impact: not tested

Spark: negative

Group Members

Ethyl acrylate (inhibited)
Methyl acrylate (inhibited)
Methyl methacrylate (monomer, inhibited)
n-Butyl acrylate (inhibited)
2-Ethylhexyl acrylate (inhibited)

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
30	4	0	None
31	69	1.4	Medium
32	60	2.0	Medium
37	55	2.0	Medium
41	33	1.5	Low
48	116	2.0	High
52	26	1.9	Low
54 I	4	--	None
56	55	2.0	Medium

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 1, 3_I, 6_I, 8, 16, 18, 19, 20, 21, 23, 24, 34, 39, 45, 49, 50, 51, 58_I and 59.

4. Reactivity between 200° and 300°C. with Group Nos. 7, 12 and 13.

5. No reactivity found below 200°C. with Group Nos. 2, 17, 29, 33, 43, 46 and 60.

6. No reactivity found below 300°C. with Group Nos. 10, 11, 14, 15, 22, 25, 26_I, 27, 28, 47, 53_I and 57.

7. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Isopropyl ether Group No. 45

Source: J. T. Baker Chemical Company

Description: Reagent grade; 50 ppm H_2O_2

Boiling point: 68°C.

Heat of self-decomposition: -0.20 Kcal./gm.; -20.0 Kcal./mole.

Sensitivity

Thermal: exotherm at about 230°C.
Impart: not tested.
Spark: not tested.

Group Members

Ethyl ether
Isopropyl ether

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
30	11	1.5	None
37	97	--*	High
41	37	3.2	Low
48	40	--*	High
53_I	8	2.0	None
54_I	8	--	None
56	>100	>35.0	High

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group No. 44.

4. No reactivity found below 200°C. with Group Nos. 1, 2, 3_I, 6_I, 7, 8, 10, 11, 12, 13, 14, 15, 17, 19, 20, 21, 22, 23, 24, 25, 26_I, 27, 28, 29, 31_I, 32_I, 34, 46_I, 47, 49, 50, 51, 52, 57, 58_I, 59 and 60.

5. No reactivity found below 300°C. and Group Nos. 16, 18, 33, 39 and 43.

6. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Ethylene cyanohydrin Group No. 46
Source: J. T. Baker Chemical Company
Description: Baker grade (high purity)
Boiling point: 221°C.
Heat of self-decomposition: -0.79 Kcal./gm.; -56.4 Kcal./mole.

Sensitivity

Thermal: none <300°C.
Impact: not tested.
Spark: not tested.

Group Members

Ethylene cyanohydrin
Acetone cyanohydrin

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	5	0.5	None
6	31	6.3	High
20	6	1.9	None
28	8	0.4	None
31	36	1.0	Low
32	13	0.6	None
37	186	-- *	High
41	216	-- *	High
48	194	>80	High
52	28	2.1	Low
53	11	0.5	None
54	5	--	None
56	13	0.7	None
57	12	0.6	None

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 3, 52, 53, 56 and 60.

4. Reactivity between 200° and 300°C. with Group Nos. 8, 10, 16_I, 22, 25, 27, 34 and 43_I.

5. No reactivity found below 200°C. with Group Nos. 2_I, 7, 11, 12, 13, 14, 15, 17_I, 18, 19, 21, 23, 24, 29, 30, 33_I, 39_I, 44, 45_I, 47, 49, 50, 51 and 58.

6. No reactivity found below 300°C. with Group Nos. 23 and 59_I.

7. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Vinyl acetate Group No. 47

Source: Eastman Organic Chemical

Description: Practical grade; stabilized

Boiling point: 72°C.

Heat of self-decomposition: -0.25 Kcal./gm.; -21.5 Kcal./mole.

Sensitivity

Thermal: exotherm at 180°C.

Impact: negative to 300 Kg.-cm.

Spark: negative

Group Members

Vinyl acetate (stabilized)

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT. max °C.	ΔP, psi	Hazard
31	116	11.7	High
32	122	22.5	High
37	127	--[a]	High
41	110	--[a]	High
48	76	75.0	High
52	180	>40.0	High
53	55	13.0	High
54	Exotherm beginning 42°C.	--	High[b]
56	130	>40.0	High
58	43	4.7	Low

[a]Measurement not made; gases generated in reaction.

[b]By analogy with Group No. 53.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 6_I and 16.

4. Reactivity between 200° and 300°C. with Group Nos. 1, 10 and 43.

5. No reactivity found below 200°C. with Group Nos. 2, 3_I, 7, 11, 12, 13, 14, 15, 17, 18, 19, 20, 21, 24, 26_I, 29, 33, 39, 45, 46, 49, 50 and 60.

6. No reactivity found below 300°C. with Group Nos. 8, 22, 23, 25, 27, 28, 30, 34, 44, 51, 57 and 59.

7. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Chlorosulfonic acid Group No. 48

Source: Eastman Organic Chemical

Description: Practical grade

Boiling point: 152°C.

Heat of self-decomposition: +0.23 Kcal./gm.; 27.2 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: not tested.

Group Members

Chlorosulfonic acid

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	152	--[a]	High
3	--[a]	--[a]	High
6	145	76.0	High
7	65	6.4	High
8[b]	43	--[a]	High
10	52	78.0	High
11	84	--[a]	High
12	150	14.0	High
13	96	--[a]	High
14	121	--[a]	High
15	150	--[a]	High
16	60	--[a]	High
17	51	34.8	High
18	89	>40.0	High
20	114	--[a]	High
21	60	34.0	High

Continued

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
22	75	7.2	High
23	77	41.4	High
24	100	--[a]	High
25	30	1.2	High
26	66	84.0	High
27	146	--[a]	High
28	68	50.0	High
29	33	--[a]	High
30	92	--[a]	High
31	164	26.1	High
32	--[a]	--[a]	High
33	46	45.2	High
34	146	36.0	High
38_I[c]	74	--[a]	High
39	156	36.0	High
41	Slight exot.	24.0	High
43	19	59.0	High
44	116	2.0	High
45	40	--[a]	High
46	194	>80.0	High
47	76	75.0	High
49	137	>20.0	High
50	33	2.6	High
51	132	--[a]	High
52	158	--[a]	High
53	25	122.0	High
54	--[a]	--[a]	High
56	37	56.0	High
57	146	--[a]	High
58	--[a]	--[a]	High
60	127	--[a]	High

[a]Measurement not made, heat and gases generated in reaction.
[b]Reactive only with the halogenated aromatics of Gp. 8.
[c]Molten phosphorus (60°C.).

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group No. 2_I.

4. Reactivity between 200° and 300°C. with Group Nos. 19_I and 59.

5. No reactivity found below 200°C. with Group No. 37.

6. No reactivity found below 300° with Group No. 8.

7. No reactivity found below 130°C. with Group No. 40.

Working Chemical: 2-Nitropropane Group No. 49
Source: Eastman Organic Chemical
Description: Practical grade
Boiling point: 120°C.
Heat of self-decomposition: -0.35 Kcal./gm.; -31.6 Kcal./mole.

Sensitivity

Thermal: exotherm beginning at 175°C.
Impact: negative to No. 8 cap and 40 gm. tetryl.
Spark: negative

Group Members

2-Nitropropane

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
31	28	1.0	Low
32_I	15	0.7	None
37	43	7.8	High
41	9	0.4	None
48	137	>20.0	High

2. Reactivity between 46° and 100°C. with Group No. 6_I.

3. Reactivity between 100° and 200°C. with Group Nos. 3_I, 44, 52, 53_I and 58_I.

4. Reactivity between 200° and 300°C. with Group Nos. 7, 10, 12, 13, 20, 21, 22, 23, 26_I, 39 and 51.

5. No reactivity found below 200°C. with Group Nos. 1, 2, 8, 11, 15, 16, 17, 18, 24, 25, 27, 29, 30, 33, 43, 45, 46, 47, 50, 56, 57, 59 and 60.

6. No reactivity found below 300°C. with Group Nos. 14, 19, 28 and 34.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I and below 100°C. with Group No. 54_I.

Working Chemical: Sulfolane Group No. 50

Source: Phillips Petroleum

Description: Unknown quality

Boiling point: 285°C.

Heat of self-decomposition: -0.18 Kcal./gm.; -21.2 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: localized decomposition at 3.125 joules

Group Members

Sulfolane

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT. max. °C.	ΔP, psi	Hazard
87	22	--*	High
41	20	0	None
48	33	2.6	High
56	10	0.8	None

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 44, 52, 56 and 60.

4. Reactivity between 200° and 300°C. with Group Nos. 3, 18, 20 and 43.

5. No reactivity found below 200°C. with Group Nos. 2_I, 6_I, 7, 8, 15, 17, 19_I, 22, 23, 24, 25, 26, 27, 28, 29, 32, 34, 39, 45_I, 46, 47, 49, 53 and 59.

6. No reactivity found below 300°C. with Group Nos. 1, 10, 11, 12, 13, 14, 16, 21, 30, 31, 33, 51, 57 and 58.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I, and below 110°C. with Group No. 54.

Working Chemical: Propylene oxide Group No. 51

Source: Eastman Organic Chemical

Description: Unknown quality

Boiling point: 35°C.

Heat of self-decomposition: -0.36 Kcal./gm.; -21.0 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: negative to No. 8 cap and 40 gm. tetryl.

Spark: negative

Group Members

Ethylene oxide

Propylene oxide

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
37	>130	--*	High
41	>110	--*	High
48	132	--*	High
53	64	--*	High
54	70	--*	High
56	--*	--*	High
58_I	Exot. begins at 42°C.(DTA)	0	None

*Measurement not made; high temperatore or gases generated in reaction.

2. Reactivity between 46° and 100°C. with Group Nos. 31 and 32.

3. Reactivity between 100° and 200°C. with Group Nos. 3_I, 22, 30, 44, 52 and 60.

4. Reactivity between 200° and 300°C. with Group Nos. 1, 10, 14, 16, 19, 20, 23, 43, 49 and 57.

5. No reactivity found below 200°C. with Group Nos. 2, 6_I, 7, 8, 15, 17, 21, 24, 25, 26_I, 27, 28, 29, 39, 45, 46 and 59.

6. No reactivity found below 300° with Group Nos. 11, 12, 13, 18, 33, 34, 47 and 50.

7. No reactivity found below 60° with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Ethylenimine

Group No. 52

Source: Matheson, Coleman and Bell

Description: Stabilized with KOH

Boiling point: 55.5°-57.5°C.

Heat of self-decomposition: -0.54 Kcal./gm.; -23.3 Kcal./mole.

Sensitivity

Thermal: exotherm beginning at 260°C.

Impact: negative to 40 gm. tetryl.

Spark: negative

Group Members

Ethylenimine

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following group:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	6	Vac.	None
3	113	10.0	High
10	15	0	None
13	161	22.2	High
14	34	3.1	Low
15	11	Vac.	None
16	176	38.2	High
19	130	>40	High.
20	60	0	Medium
21	12	Vac.	None
22	189	33.5	High
23	153	22.8	High
24	35	1.5	Low
26	13	Vac.	None
27	111	16.4	High

Continued

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
28	6	0	None
30	32	1.3	Low
34	-- *	-- *	High
37	240	-- *	High (fire)
40_I** (Sulfur blackened)	None	--	None
41	252	-- *	High
44	26	1.9	Low
46	28	2.1	Low
47	180	>40	High
48	158	-- *	High
53	84	-- *	High
54	100	-- *	High
56	-- *	-- *	High
58_I	10	2.7	None
60	200	-- *	High

*Measurement not made; high temperature or gases generated in reaction.

**Molten sulfur (130°C.).

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 8, 25, 26, 30, 43, 46, 49, 50 and 51.

4. Reactivity between 200° and 300°C. with Group Nos. 7 and 39.

5. No reactivity found below 200°C. with Group Nos. 2, 6, 17, 29, 31, 32, 45 and 59.

6. No reactivity found below 300°C. with Group Nos. 11, 12, 18, 33 and 57.

7. No reactivity found below 60°C. with Group No. 38_I.

Working Chemical: Hydrochloric acid Group No. 53

Source: E. I. du Pont

Description: 36% acid

Boiling point: ca. 110°C.

Heat of self-decomposition: +0.43 Kcal./gm.; +43.7 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: not tested

Group Members

Hydrochloric acid (28%-36% aqueous)

Phosphoric acid (75%-85% aqueous)

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	23	0.8	None
6	80	3.9	High
7	9	0.9	None
10	7	Vac.	None
13	33	1.9	Low
15	9	0	None
20_I	19	1.8	None
21	16	0.9	None
23	53	12.2	High
24	19	Vac.	None
26	14	Vac.	None
28	19	0	None
29	12	0	None
31	81	3.5	High
32	80	-- *	High
34	75	2.9	Medium
37	44	-- *	High
41	18	17.7	High
45_I	8	2.0	None
46	11	0.5	None
47	55	13.0	High
48	25	122	High
51	64	-- *	High
52	84	-- *	High
56	4	2.6	None
57	61	Vac.	Medium
58	58	-- *	High
60	77	3.8	High

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 3, 12, 46 and 49_I.

4. Reactivity between 200° and 300°C. with Group Nos. 16_I and 43_I.

5. No reactivity found below 200°C. with Group Nos. 2_I, 8_I, 11_I, 17_I, 18_I, 25, 30_I, 33_I, 50 and 59.

6. No reactivity found below 300°C. with Group Nos. 14, 19_I, 22, 27, 39_I and 44_I.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I, and below 100°C. with Group No. 54.

Working Chemical: Hydrofluoric acid Group No. 54

Source: J. T. Baker Chemical Company

Description: 48.7% acid, A.C.S. grade

Boiling point: ca. 120°C.

Heat of self-decomposition: +0.41 Kcal./gm.; +11.8 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: not tested.

Group Members

Hydrofluoric acid (48% aqueous)

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	45	--	Low
6	--*	--*	High
13	10	--	None
20_I	30	--	Low
21	12	--	None
23	53	--*	High
24	10	--	None
26	6	--	None
28	16	--	None
29	9	--	None
31	98	--*	High
32	98	--*	High
34	75	--	Medium
37	--*	--*	High
41	38	--*	High
44_I	4	--	None
45_I	8	--	None
46	5	--	None
47	exotherm begins 42°C.	--	High
48	--*	--*	High
51	70	--*	High
52	100	--*	High
57	47	--	Low
58	56	--*	High
60	80	--	High

*Measurement not made; high temperature or gases generated in reaction.

2. No reactivity found below 100°C. with Group Nos. 3, 10, 11_I, 15, 17_I, 22, 25_I, 27_I, 30_I, 39_I, 40_I, 49_I, 50_I, 53 and 56.

3. No reactivity found with Group Nos. 2_I (to 65°C.), 8_I (to 75°C.), 12 (to 70°C.), 14 (to 90°C.), 16_I (to 45°C.), 18_I (to 34°C.), 19_I (to 45°C.), 33_I (to 84°C.), 38_I (to 60°C.), 43_I (to 31°C.), and 59_I (to 80°C.).

Working Chemical: Nitric acid (70% soln.) Group No. 56

Source: E. I. du Pont

Description: Reagent grade

Boiling point: <100°C.

Heat of self-decomposition: +0.30 Kcal./gm.; +26.4 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: not tested.

Group Members

Nitric acid (58%-68%, aqueous)

Nitric acid (95% aqueous)

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	101	18	High
3	64	-- *	High
6	90	7.9	High
7	10	1.1	None
10	6	0.8	None
11	72	10.2	High
13	82	-- *	High
15	77	-- *	High
16_I	Exotherm begins 45°C.	--	High
17	7	1.1	High
18	90	-- *	High
20_I	73	>40	High
21	13	1.1	None
23	80	2.0	High
24	18	-- *	High
25	4	0.7	None
26	14	0.8	None
27	4	0.5	None
28	21	0.7	None
29	14	0	None
30	87	-- *	High
31	90	6.6	High
32	101	-- *	High
34	104	5.0	High
37	73	-- *	High
38**	111	-- *	High
39_I	6	0	None
40**	--	-- *	High

Continued

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
41	30	1.9	Low
43	Exotherm begins 35°C.	--	High
44	7	0.8	None
45	>100	>40	High
46	13	0.7	None
47	130	>40	High
48	37	56	High
50	10	0.8	None
51	-- *	-- *	High
52	-- *	-- *	High
53	4	2.6	None
57	79	3.2	High
58	-- *	-- *	High
60	85	4.0	High

*Measurement not made; high temperature or gases generated in reaction.

**Molten sulfur (130°C.) or molten phosphorus (60°C.).

2. Reactivity between 46° and 100°C. with Group Nos. 14 (detonates at 90°C.), 24, 33_I and 47.

3. Reactivity between 100° and 200°C. with Group Nos. 2_I, 8_I, 10, 12, 22, 25, 27, 39, 46, 50 and 59.

4. Reactivity between 200° and 300°C. with Group No. 19_I.

5. No reactivity found below 200°C. with Group No. 49.

6. No reactivity found below 100°C. with Group No. 54.

Working Chemical: Pyridine

Group No. 57

Source: Matheson Coleman and Bell

Description: Unknown quality

Boiling point: 115°C.

Heat of self-decomposition: -0.20 Kcal./gm.; -15.5 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested

Spark: not tested.

Group Members

Pyridine

2-Methyl-5-ethyl pyridine

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	6	0	None
10	9	0.8	None
22	20	0	None
26	7	0	None
27	23	1.5	None
28	6	0	None
30	28	0.8	Low.
37	131	--*	High
41	106	5.0	High
46	12	0.6	None
48	146	--*	High
53	61	Vac.	Medium
54	47	--	Low
56	79	3.2	High
60	114	--*	High

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 8, 10, 16, and 34.

4. Reactivity between 200° and 300°C. with Group Nos. 39, 43 and 51.

5. No reactivity found below 200°C. with Group Nos. 2, 6, 7, 15, 17, 19, 23, 24, 25, 29, 32, 45, 49, 58 and 59.

6. No reactivity found below 300°C. with Group Nos. 3, 11, 12, 13, 14, 18, 20, 21, 31, 33, 44, 47, 50 and 52.

7. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Ammonia (28% aqueous) Group No. 58
Source: E. I. duPont
Description: Reagent grade
Boiling point: None
Heat of self-decomposition: +0.56 Kcal./gm.; +33.9 Kcal./mole.

Sensitivity

Thermal: none <300°C.
Impact: not tested.
Spark: not tested.

Group Members

Ammonia (28% aqueous)

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
3	25	1.5	None
6	18	4.6	None
13	106	14.8	High
20	26	2.2	Low
23	17	1.5	None
27	12	--*	High
28	8	0.8	None
37	>106	--*	High
41	84	--*	High
47	43	4.7	Low
48	--*	--*	High
51_I	(exotherm begins 42°)	--	High
52_I	10	2.7	None
53	58	--*	High
54	56	--*	High
56	--*	--*	High
60	100	15.0	High

*Measurement not made; high temperature or gases generated in reaction.

2. Reactivity between 46° and 100°C. with Group No. 23.

3. Reactivity between 100° and 200°C. with Group Nos. 10, 33, 44_I and 49_I.

4. Reactivity between 200° and 300°C. with Group Nos. 19_I, 22, 39_I and 43.

5. No. reactivity found below 200°C. with Group Nos. 1, 2_I, 8_I, 15, 16_I, 17_I, 24_I, 29_I, 31, 32, 34_I, 45_I, 46 and 59.

6. No reactivity found below 300°C. with Group Nos. 7_I, 11_I, 12, 14_I, 18_I, 21_I, 25_I, 26, 30_I, 50 and 57.

7. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

Working Chemical: Trichlorethylene Group No. 59

Source: The Dow Chemical Company

Description: Industrial grade

Boiling point: 87°C.

Heat of self-decomposition: -0.10 Kcal./gm.; -12.9 Kcal./mole.

Sensitivity

Thermal: none <300°C.

Impact: not tested.

Spark: localized decomposition at 3.125 joules.

Group Members

Tetrachloroethylene (Perchloroethylene)

Trichloroethylene

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
20	14	0	None
28	5	0	None
29	4	0.5	None

2. Reactivity between 46° and 100°C. with no groups.

3. Reactivity between 100° and 200°C. with Group Nos. 44, 56 and 60.

4. Reactivity between 200° and 300°C. with Group Nos. 31 and 48.

5. No reactivity found below 200°C. with Group Nos. 1, 2, 3_I, 6_I, 7, 8, 10, 11, 15, 16, 17, 21, 23, 24, 25, 26_I, 27, 32_I, 37_I, 39, 43, 45, 49, 50, 51, 52, 53, 57 and 58.

6. No reactivity found below 300°C. with Group Nos. 12, 13, 14, 18, 19, 22, 30, 33, 34, 41, 46_I and 47.

7. No reactivity found below 60°C. with Group No. 38_I, below 130°C. with Group No. 40_I, and below 80°C. with Group No. 54_I.

Working Chemical: Propiolactone Group No. 60

Source: K and K Laboratories and Eastman Organic Chemical

Description: Unknown grade

Boiling point: Decomposes

Heat of self-decomposition: -0.24 Kcal./gm.; -17.6 Kcal./mole.

Sensitivity

Thermal: exotherm begins at 150°-155°C.

Impact: not tested.

Spark: negative.

Group Members

Propiolactone

Reactivity Data on Binary Systems

1. The working chemical of this group reacted between room temperature and 46°C. with the working chemicals of each of the following groups:

Group No.	ΔT, max. °C.	ΔP, psi	Hazard
1	188	-- *	High
6	93	-- *	High
31	117	-- *	High
32	170	-- *	High
37	156	-- *	High
41	127	-- *	High
48	127	-- *	High
52	200	-- *	High
53	77	3.8	High
54	80	--	High
56	85	4.0	High
57	114	-- *	High
58	100	15	High

*Measurement not made; gases generated in reaction.

2. Reactivity between 46° and 100°C. with Group Nos. 3, 11 and 43.

3. Reactivity between 100° and 200°C. with Group Nos. 10, 18, 22, 26, 30, 33, 46, 50, 51 and 59.

4. Reactivity between 200° and 300°C. with Group Nos. 16 and 34.

5. No reactivity found below 200°C. with Group Nos. 2_I, 7, 8, 12, 13, 14, 15, 17, 19_I, 20, 21, 23, 24, 25, 27, 28, 29, 39, 44, 45, 47 and 49.

6. No reactivity found below 60°C. with Group No. 38_I and below 130°C. with Group No. 40_I.

APPENDIX B

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Casinghead (natural) Gasline	2
Caustic Potash Solution	6
Caustic Soda Solution	6
Chlorine	9
Chlorobenzene	8
Chloroform	8
Chlorohydrins, Crude	10
Chlorosulfonic Acid	48
Coal Tar Oil	11
Cresols (mixed isomers)	30
Creosote, Coal Tar	11
Crotonaldehyde	13
Crude Oil (petroleum)	2
Cumene (isopropylbenzene)	17
Cyclohexane	2
Cyclohexanone	21
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INDEX OF CHEMICALS (Contd.)

INDEX OF CHEMICALS (Contd.)

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Methyl Alcohol	26
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Methyl Ethyl Pyridine	57
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Methyl Amyl Acetate	7
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Propylene Glycol	26
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