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# CLASSIFICATION OF CHEMICAL REACTIVITY HAZARDS

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Dow Chemical Company

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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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December, 1970

# CLASSIFICATION OF CHEMICAL REACTIVITY HAZARDS

for the

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

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## FOREWORD

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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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To accomplish the classification of reactivity hazards, the 209 chemicals were separated into 60 groups according to chemical structure. A representative working chemical was chosen from each group and 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.

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 $\Delta H_D$, 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 $\Delta H_o$, the heat release when the decomposition is performed in the presence of oxygen. For a monopropellant, the difference between $\Delta H_D$ and $\Delta H_o$ 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. $\Delta H_D$ 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 $\Delta H_o$ and $\Delta H_D$ 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 $\Delta H_D$ 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 $\Delta H_D$ 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 $\Delta H_D$ 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 | $\Delta H_o$ Kcal./100 g. | $\Delta H_D$ 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.

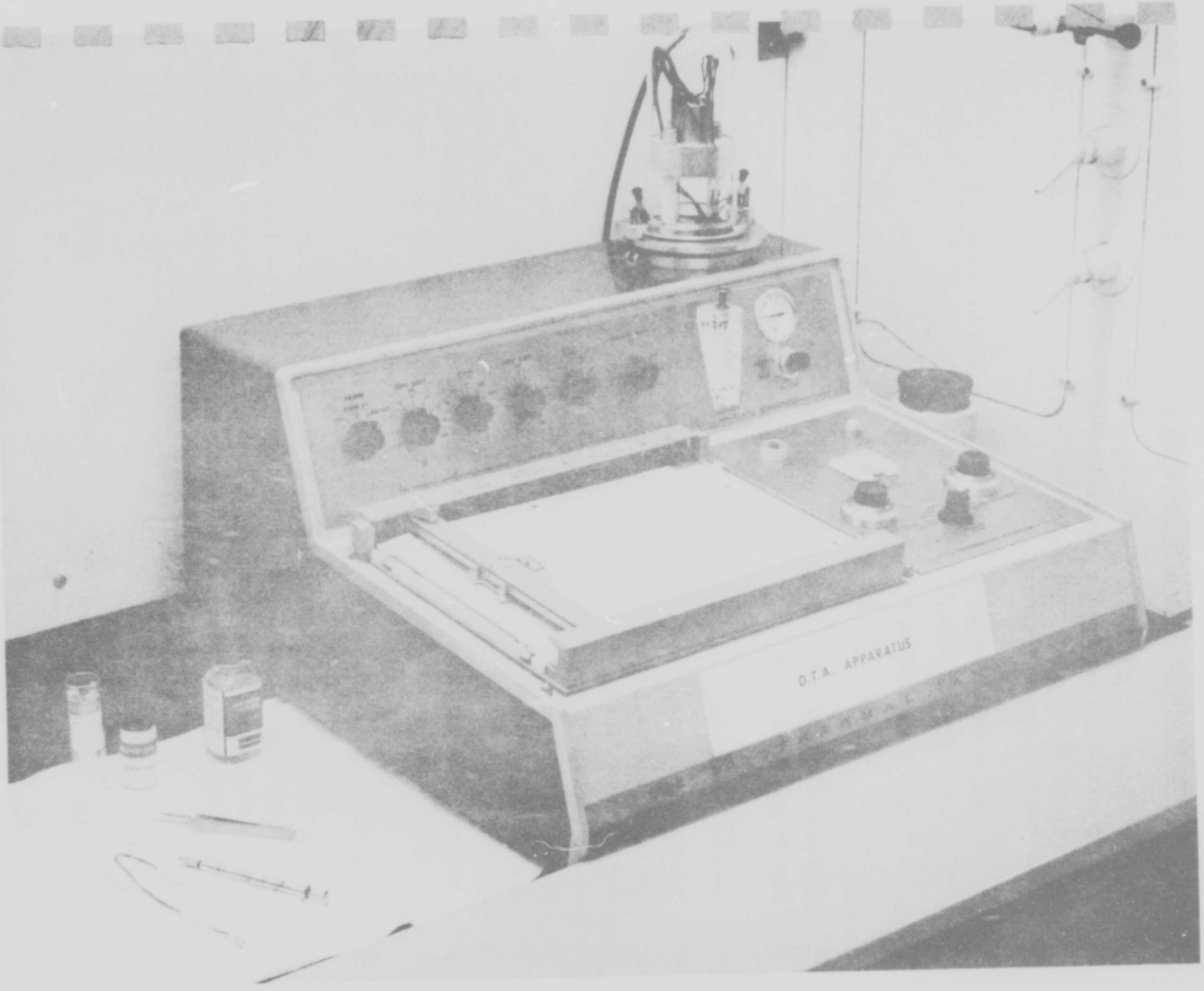


Figure 1 - Thermal Analyzer

## 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, $\Delta T$, 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.

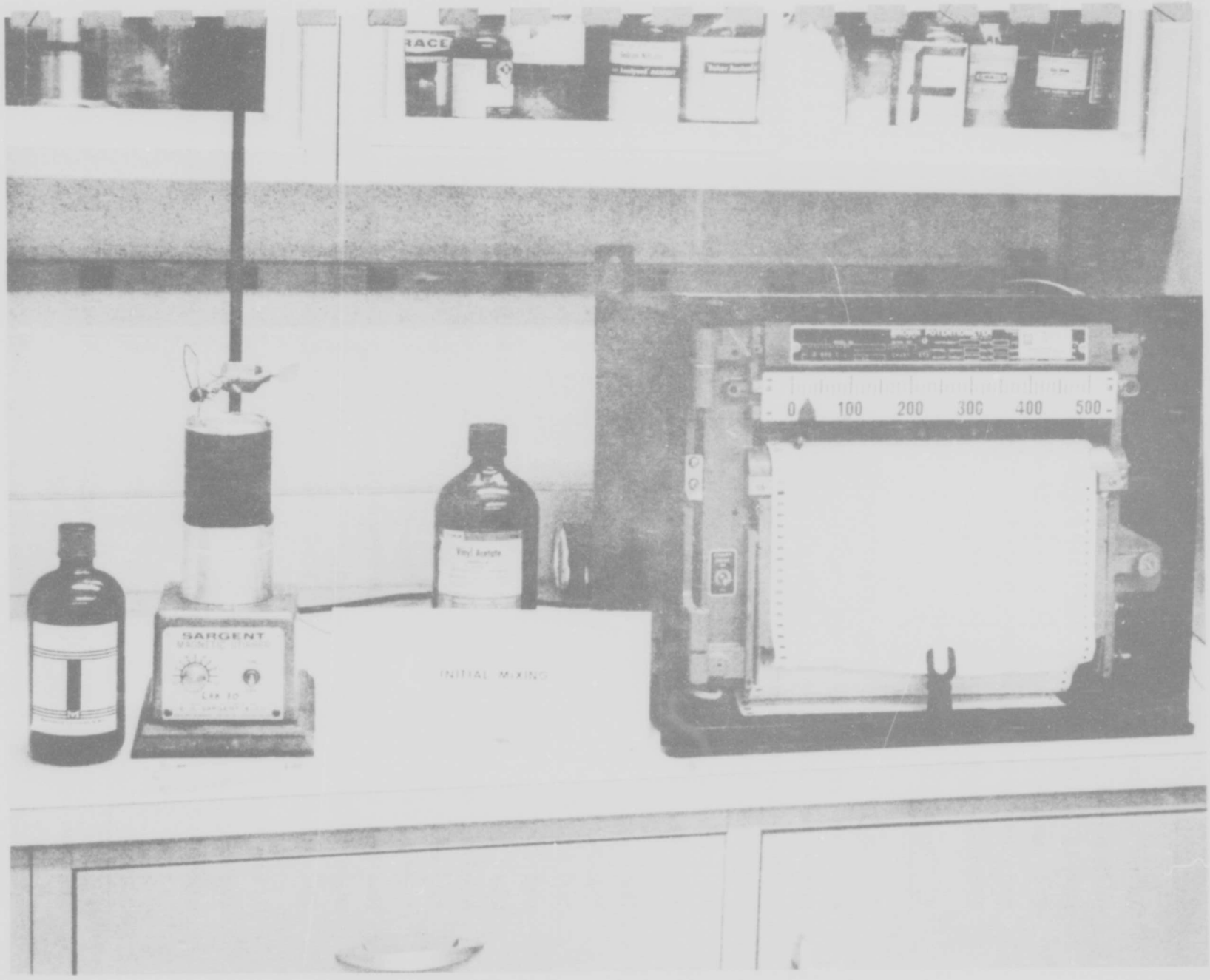


Figure 2 - Apparatus for Initial Mixing

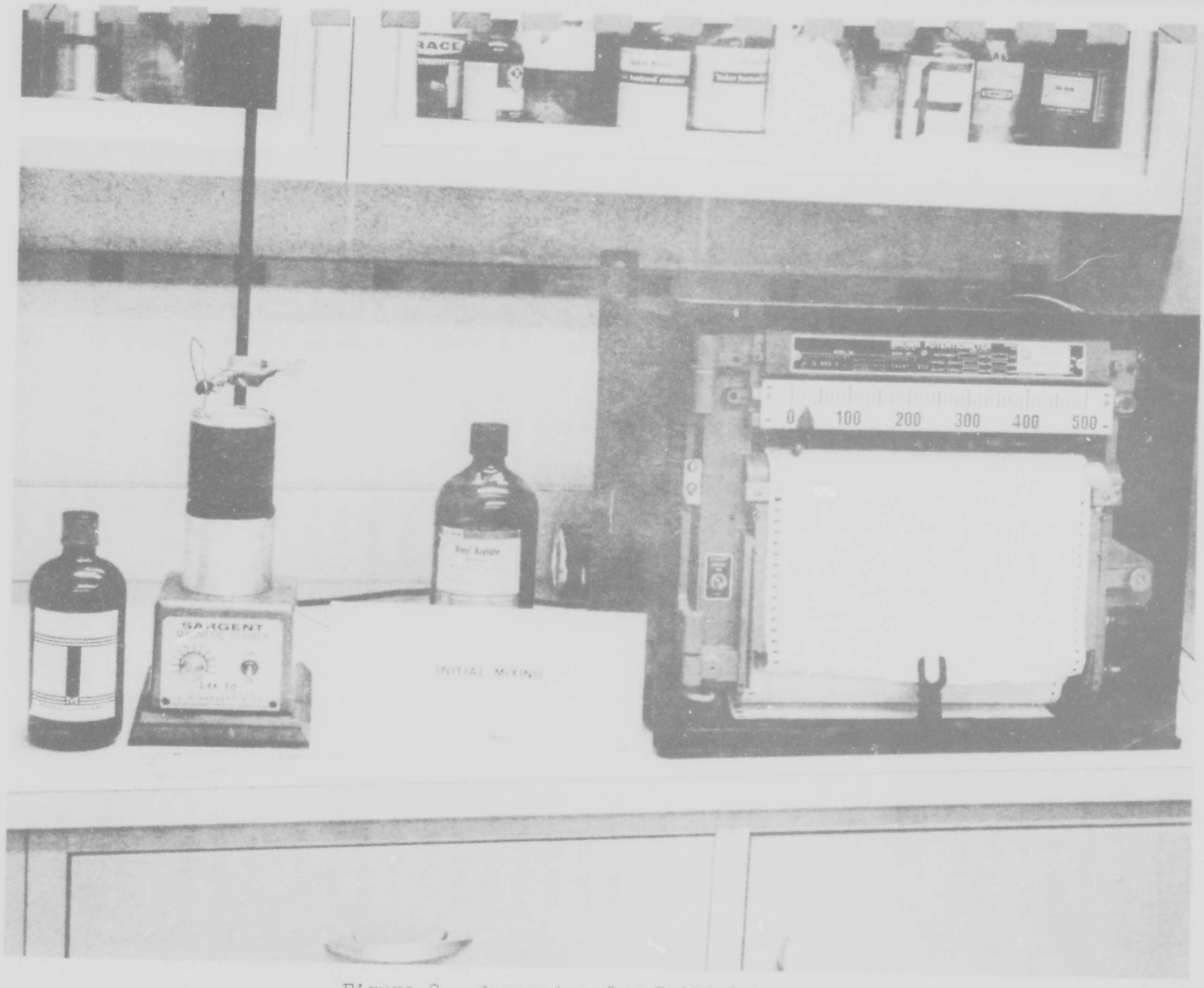


Figure 2 - Apparatus for Initial Mixing

## 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.

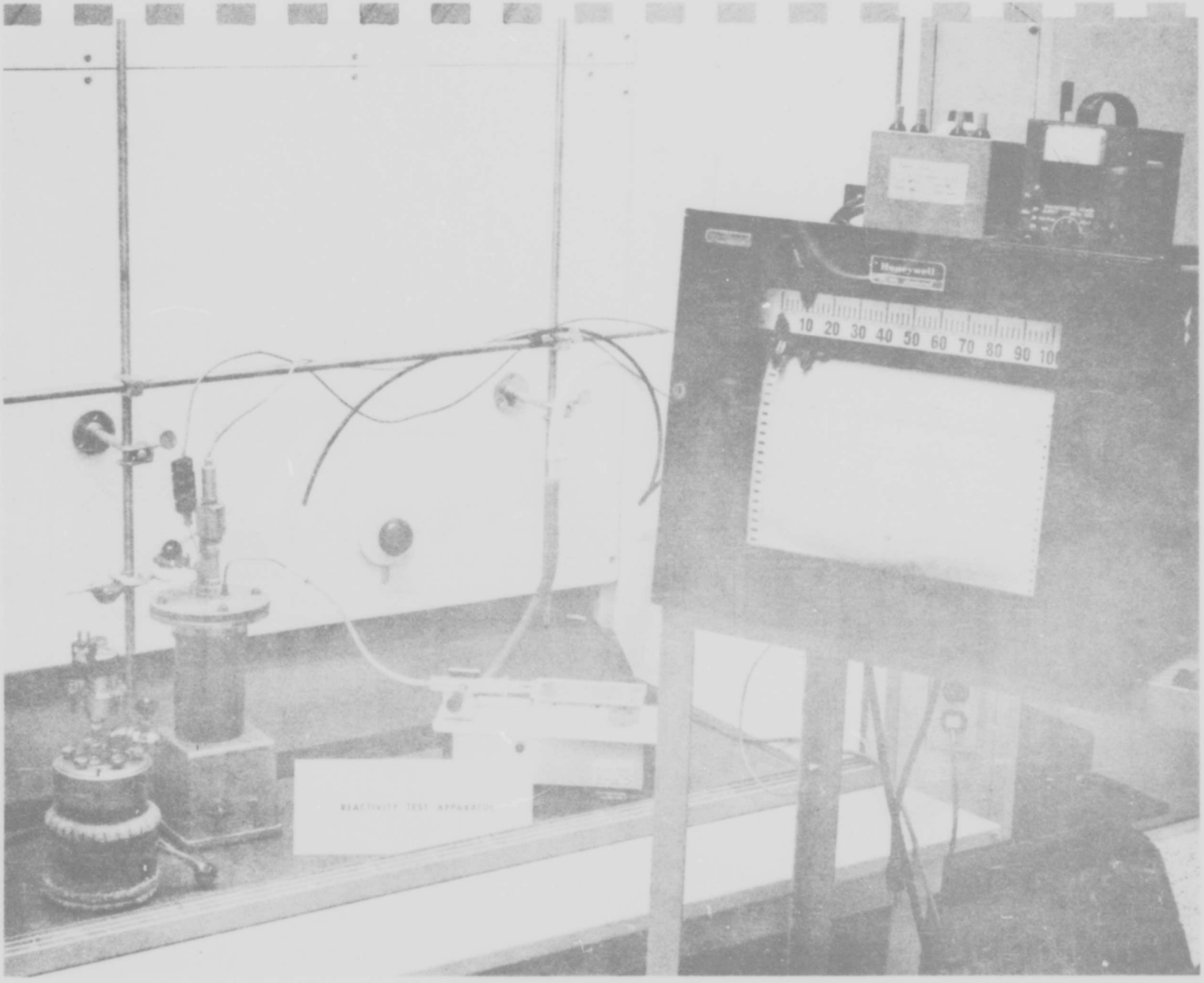


Figure 3 - Reactivity Test Apparatus

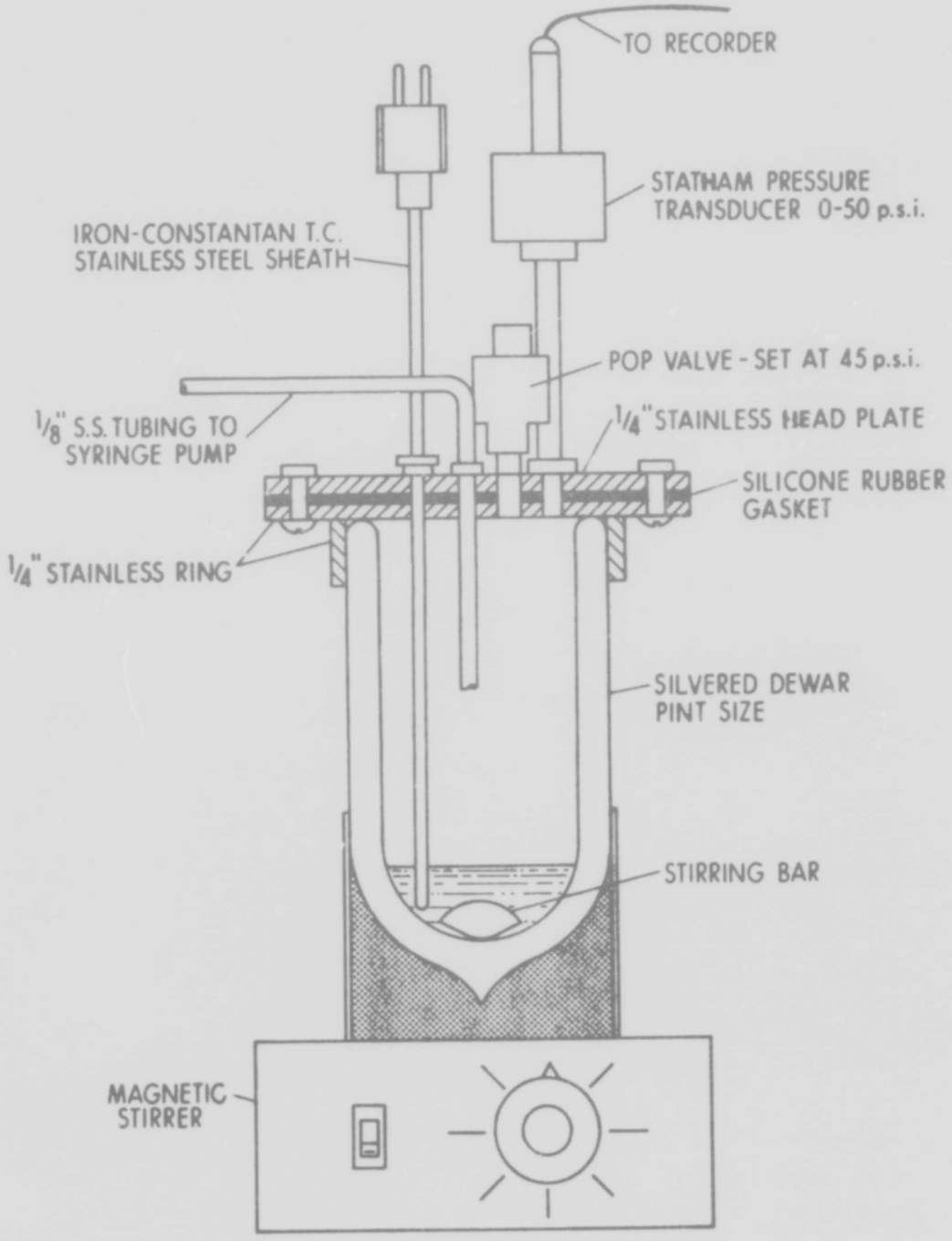


Figure 4 - Design Details of Reactivity Apparatus

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 ($\Delta P$) was made during the addition and mixing of chemicals. The maximum temperature ($\Delta T$ max.) attained was recorded for each reaction studied and compared to the value of $\Delta T$ 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 $\Delta T$ 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

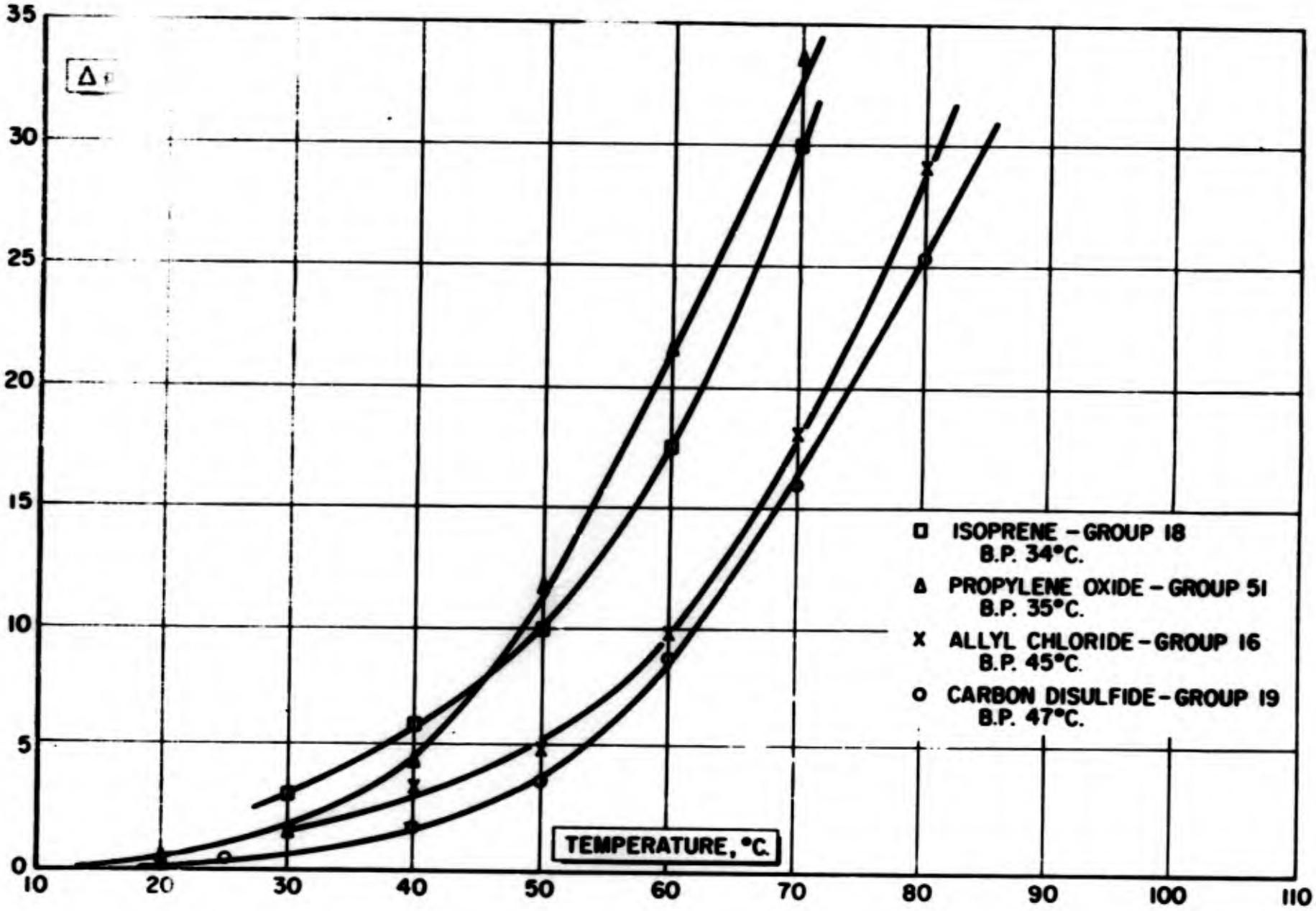


Figure 5 - Vapor Pressure Curves on Working Chemicals

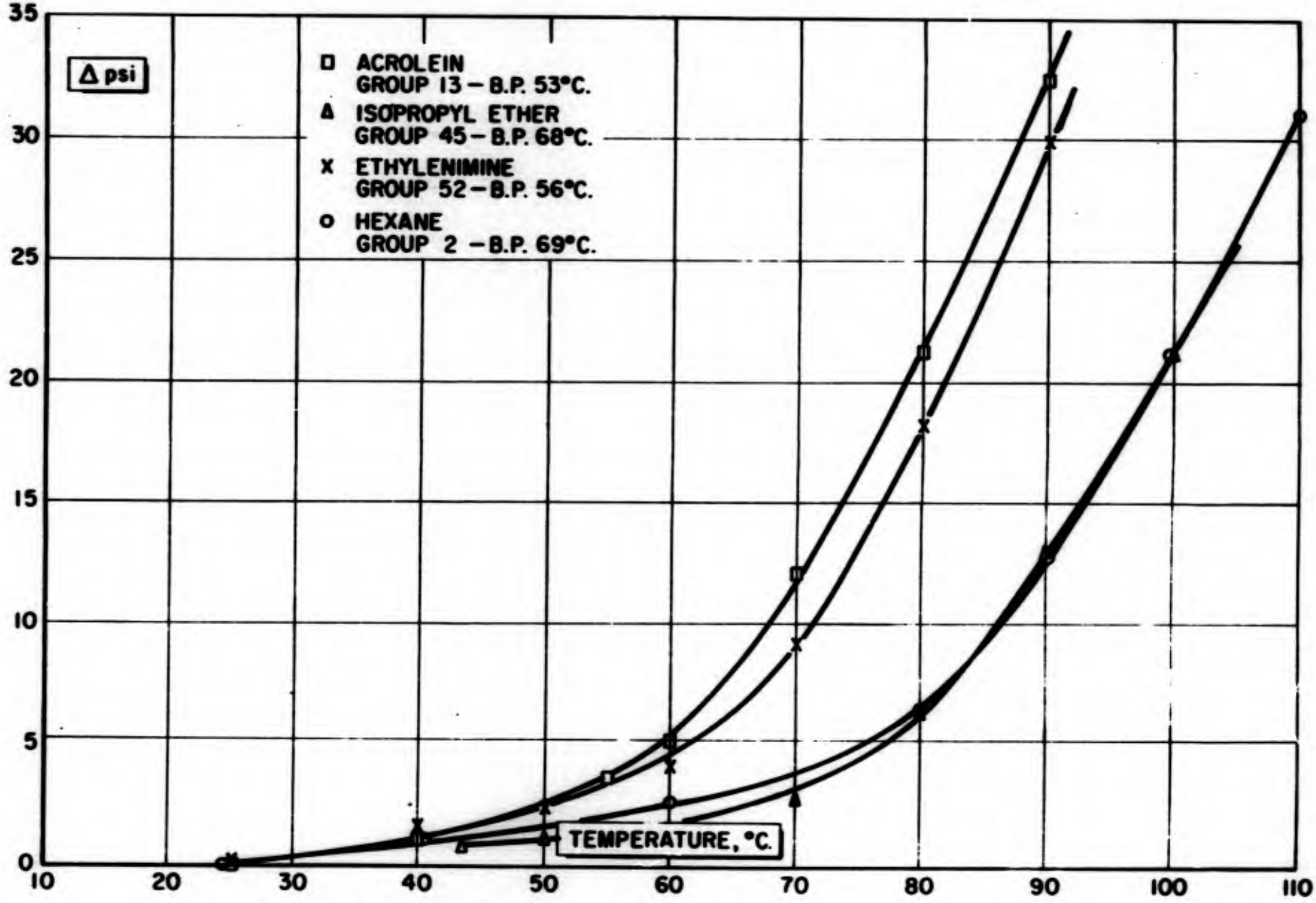


Figure 6 - Vapor Pressure Curves on Working Chemicals

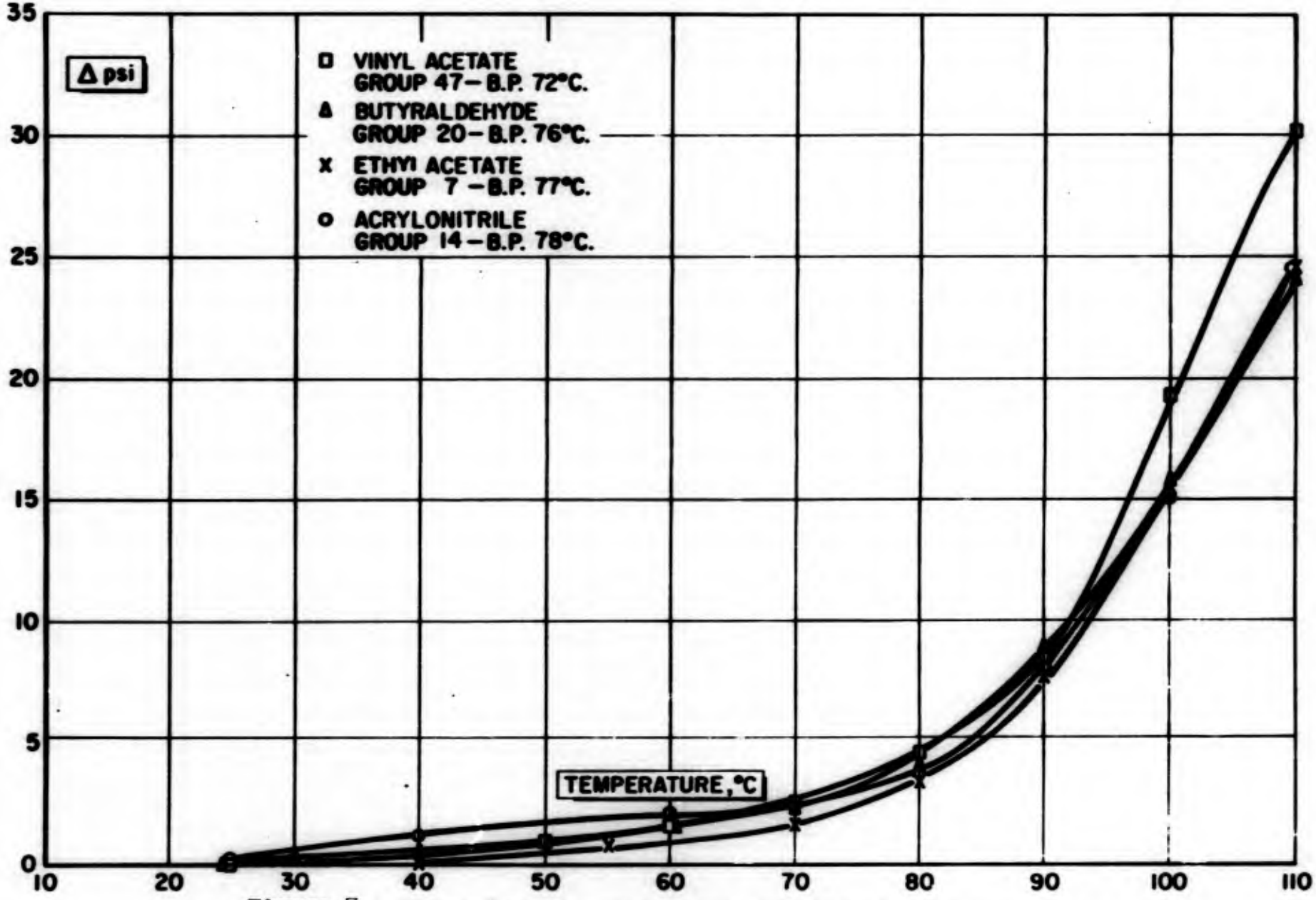


Figure 7 - Vapor Pressure Curves on Working Chemicals

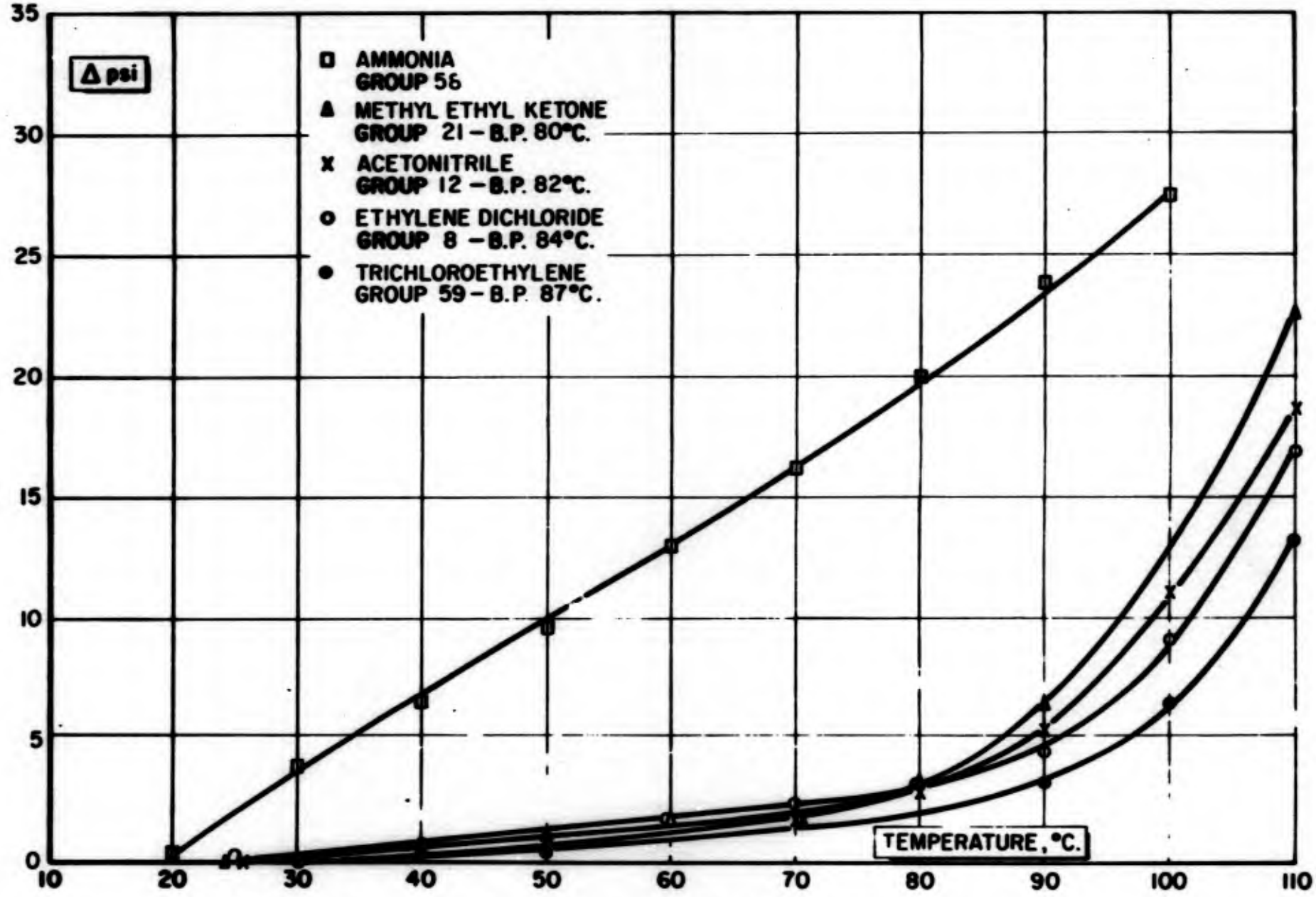


Figure 8 - Vapor Pressure Curves on Working Chemicals

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. | $\Delta$T. max °C. | $\Delta$P, 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

## INDEX OF CHEMICALS

## INDEX OF CHEMICALS

## INDEX OF CHEMICALS (Contd.)

| Chemical | Group No. |
|---|---|
| Butylbenzyl phthalate | 7 |
| Butylene Glycol | 26 |
| Butyraldehyde, n- | 20 |
| Butyric Acid, n- | 22 |
| Camphor Oil (light) | 21 |
| Carbon Disulfide | 19 |
| Carbon Tetrachloride | 8 |
| 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 |
| Cymene, p- | 17 |
| Decyl Alcohol, n- | 26 |
| Dibutyl-o-phthalate | 7 |
| Dicyclopentadiene | 33 |
| Dichlorobenzene | 8 |
| Dichlorodifluoromethane | 8 |
| Dichloroethylether | 25 |
| 1,2-Dichloropropane | 8 |

## INDEX OF CHEMICALS (Contd.)

## INDEX OF CHEMICALS (Contd.)

## INDEX OF CHEMICALS (Contd.)

| Chemical | Group No. |
|---|---|
| Isooctanol | 26 |
| Isooctyl Aldehyde | 20 |
| Isoprene | 18 |
| Jet Fuel, JP-3 | 2 |
| Jet Fuel, JP-4 | 2 |
| Jet Fuel, JP-5 | 2 |
| Kerosene | 2 |
| Methane | 2 |
| Methyl Amyl Alcohol | 26 |
| Methyl Acetate | 7 |
| Methyl Acrylate (inhibited) | 44 |
| Methyl Alcohol | 26 |
| Methyl Bromide | 8 |
| Methylbutyraldehyde | 20 |
| Methyl Chloride | 8 |
| Methyl Ethyl Pyridine | 57 |
| Methyl Formal | 20 |
| Mesityl Oxide | 24 |
| Methyl Methacrylate (inhibited) | 44 |
| Methyl Amyl Acetate | 7 |
| Methylene Chloride | 8 |
| Methyl Ethyl Ketone | 21 |
| Methyl Isobutyl Ketone | 21 |
| Mineral Spirits No. 10 | 2 |
| Monochlorodifluoromethane | 8 |
| Monoethanolamine | 32 |
| Monoisopropanolamine | 32 |
| Morpholine | 31 |
| Naphthalene, Molten | 17 |
| Nitropropane | 49 |
| Nitric Acid, Conc. | 56 |

## INDEX OF CHEMICALS (Contd.)

| Chemical | Group No. |
|---|---|
| Nitrous Oxide | 36 |
| Nonyl Alcohol | 26 |
| Nonane | 2 |
| Nonyl Phenol | 30 |
| Oleum | 37 |
| Pentane, n- | 2 |
| Pentane, iso- | 2 |
| Perchloroethylene | 59 |
| Petroleum Ether | 2 |
| Phenol | 30 |
| Phosphoric Acid (75-85%) | 53 |
| Phosphorus, Elemental | 38 |
| Propane, Commercial | 2 |
| Propionaldehyde | 20 |
| Propiolactone, β- | 60 |
| Propionic Anhydride | 23 |
| Propionic Acid | 22 |
| Propyl Acetate, n- | 7 |
| Propyl Alcohol, n- | 26 |
| Propylene | 33 |
| Propylene Glycol | 26 |
| Propylene Oxide | 51 |
| Propyl Acetate | 7 |
| Propylene | 33 |
| Pyridine | 57 |
| Styrene Monomer | 39 |
| Sulfur, Molten | 40 |
| Sulfonane | 50 |
| Sulfuric Acid (77-98%) | 41 |

## INDEX OF CHEMICALS (Contd.)





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