63-4-5

UNCLASSIFIED

# STUDY OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF BALLOONS AND BALLOON MATERIALS

## REPORT NO. 1

U.S. ARMY CONTRACT No.
DA-36-039-AMC-02160(E)

Department of the Army Project No.
1A0 - 25001 - A - 126 - 01 - 04

## FIRST QUARTERLY PROGRESS REPORT

1 March 1963 - 31 May 1963

U. S. Army Electronics Research & Development Laboratory
Fort Monmouth, New Jersey

Kaysam Corporation of America
27 Kentucky Avenue
Paterson 3, New Jersey

UNCLASSIFIED

# STUDY OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF BALLOONS AND BALLOON MATERIALS

## REPORT NO. 1

| | |
|---|---|
| U. S. Army Contract No.: | DA-36-039-AMC-02160(E) |
| SC Technical Requirement No.: | SCL-5205A, 26 Aug 1959<br>w/Amend. 1, 13 Sep 1961 |
| Department of the Army Project No.: | 1A0-2500--A-126-01-04 |

## FIRST QUARTERLY PROGRESS REPORT

Period covered by this report:
1 March 1963 - 31 May 1963

The object of this study is to continue the investigation of Physical and chemical characteristics of balloons and balloon materials, particularly new elastomers, as well as flight conditions and their effect on balloon performance.

Prepared by: Eric Nelson

Edited by: John Kantor

Kaysam Corporation of America
27 Kentucky Avenue
Paterson 3, New Jersey

# TABLE OF CONTENTS

## PURPOSE

The aims of this study are to improve the performance of meteorological balloons by the use of newly developed neoprene polymers specifically designed for such a purpose, by the use of other basic polymeric materials, by improved compounding and processing, and by a better understanding of atmospheric conditions during flight.

This work will be performed according to the following schedule:

### TASK A: PROPERTIES OF BALLOONS AND BALLOON FILMS

Phase 1: Study of the Literature

Phase 2: Evaluation of Raw Materials

Phase 3: Evaluation of Processing Techniques

Phase 4: Molecular Structure of Balloon Films

Phase 5: Development of Optimum Compounds

### TASK B: EFFECT OF FLIGHT CONDITIONS ON BALLOON PERFORMANCE

Phase 1: Behavior on Inflation and Rupture

Phase 2: Effect of Pre-Elongation

Phase 3: Effect of Ozone

Phase 4: Effect of Radiation

## ABSTRACT

The following is a resume of the work performed during the period from 1 March 1963 through 31 May 1963:

### TASK A: PROPERTIES OF BALLOONS AND BALLOON FILMS

#### Phase 1: Study of the Literature

The study of current literature revealed nothing of interest.

#### Phase 2: Evaluation of Raw Materials

##### Part A: Neoprene Polymers

A preliminary conference was held with the personnel of E. I. du Pont de Nemours and Company. The status of new polymer development and the most desirable characteristics of polymers were discussed.

Neoprene 673 was evaluated in a dual-purpose compound.

##### Part B: Polymers other than Neoprene

Compounds based on blends of neoprene latex and natural latex as well as compounds based on blends of neoprene latex and poly-isoprene latex were evaluated. Room-temperature and low-temperature characteristics were determined in order to measure the effectiveness of poly-isoprene as a low-temperature plasticizer.

##### Part C: Other Materials

Kadox 515, a fine-particle-size French Process Zinc Oxide, was compared with Kadox 72 which is a somewhat coarser material. Compound stability,

**ABSTRACT** (continued)

**TASK A, Phase 2, Part C** (continued)

as well as the physical properties of the films, was measured.

Butoxy Ethyl Oleate from American Chemicals was evaluated as a low-temperature plasticizer for neoprene.

**Phase 3: Evaluation of Processing Techniques**

Preliminary tests were run using felt as a filter medium for removing small agglomerates from balloon compounds in order to eliminate these possible sources of premature rupture. The results were inconclusive, and further work was indicated.

Balloons having an integral neck were prepared, and various means were adopted for closing the opening created at the end of the balloon opposite the neck. Flight tests were conducted with satisfactory results.

**Phase 4: Molecular Structure of Balloon Films**

A preliminary conference was held with Dr. Herman Newstein to organize the program of X-ray diffraction and electron-microscope studies to be conducted.

**Phase 5: Development of Optimum Compounds**

Flights were conducted with 1000-gram and 1500-gram and 2500-gram balloons made from a high-elongation compound (A5-101). Very good results were obtained with the 1000- and 1500-gram balloons.

Balloons made from compound A5-102 which contains

ABSTRACT (continued)

TASK A, Phase 5 (continued)

Kadox 515 (see Task A, Phase 2, Part C) were flown. The performance was good but little better than that of balloons made from a standard compounds in either altitude attained or consistency of performance.

Balloons weighing 1000 grams manufactured from a compound containing Butoxy Ethyl Oleate were flown with very satisfactory results.

Four balloons weighing approximately 4000 grams were flown. These balloons were made from a standard compound; and the results were encouraging, particularly insofar as consistency of performance is concerned.

TASK B: EFFECT OF FLIGHT CONDITIONS ON BALLOON PERFORMANCE

Phase 1: Behavior on Inflation and Rupture

No progress during this period.

Phase 2: Effect of Pre-Elongation

Preliminary tests were conducted to determine the effect of pre-elongation on natural-latex films. The results were inconclusive due to mechanical problems with the test equipment.

Phase 3: Effect of Ozone

The resistance to attack by ozone of compound A5-101, a high-elongation compound, was compared with that of A5-104, a standard compound. The effect of increasing the amount of antiozonant in both compounds was also determined.

**ABSTRACT** (continued)

**TASK B** (continued)

**Phase 4: Effect of Radiation**

The effect of infra-red radiation on the high-elongation compound A5-101 was studied. Its pattern of behavior was demonstrated to be basically similar to that of compound A5-104.

The effect of infra-red radiation on a natural-latex compound was also evaluated. Testing was restricted to temperatures below -40°C because of the extremely high elongations encountered at higher temperatures, resulting in the jaws reaching the end of their travel before rupture occurred.

Five compounds were designed containing materials meant to reflect infra-red radiation. Physical properties were determined with and without infra-red radiation, and the best compound was selected for future flight testing.

## PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES

No publications, lectures, or reports resulted from this study during the period covered by this report.

CONFERENCES:

February 26, 1963, at the DuPont Laboratories, Chestnut Run, Delaware.

| | | |
|---|---|---|
| Present were: | Mr. Robert Arnold | DuPont Laboratories |
| | Mr. Jack Fitch | DuPont Laboratories |
| | Mr. Donald Gorman | DuPont Laboratories |
| | Mr. Donald Thompson | DuPont Laboratories |
| | Mr. George Scott | DuPont Laboratories |
| | Mr. Eric Nelson | Kaysam Corporation |
| | Mr. Harding Wing | Kaysam Corporation |

The meeting opened with a report from Eric Nelson on the results obtained with the experimental latices submitted by DuPont, and with the commercial latices also evaluated. The importance of the shape of the stress-strain curve was emphasized, particularly as it is related to balloon inflation behavior and flight performance. It was demonstrated and agreed upon by all parties that polymers showing development of a high degree of crystallinity were unsuitable for use in meteorological balloons.

The degree of inflection shown by the stress-strain curve is a measure of the tendency for a balloon to distort during inflation. DuPont, therefore, agreed that they would endeavor to develop a polymer with the high-elongation characteristics already requested which would show this inflection condition to the least possible degree. The complete elimination of the inflection in the stress-strain curve appears to be impossible since this is a characteristic of neoprene.

PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES (continued)

CONFERENCES (continued)

There followed a general discussion on the possibilities of improving the physical characteristics of existing polymers. It was suggested that a combination of the accelerators, Thiuram 'E' and Tepidone, would result in a fast-rising compound which might have better elongation.

The possible use of Thiocarbanilide to provide a low-temperature or room-temperature cures raised the question of what aging characteristics would be expected. It was acknowledged that Thiocarbanilide-cured films will cure progressively on storage, but the extended aging characteristics are not known.

Filtering latex or latex compound through felt or through a sand bed was suggested as a means of improving the clarity and cleanliness of the film. Kaysam representatives felt this was worthy of investigation.

The possibilities of using only liquid compounding ingredients was again raised. Mr. Wing reported on the unsurpassable problems associated with using zinc resinate. Mr. Thompson suggested that Antox might offer a means of eliminating two solid compounding ingredients, i.e., Neozone 'D' and N.B.C., since it is itself a good anti-oxidant and anti-ozonant. Kaysam will evaluate this material for use in balloon film.

The meeting concluded with a summarization by Mr. Arnold of all the points discussed.

## PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES (continued)

### CONFERENCES (continued)

May 3, 1963, at the U. S. Army Electronics Research and Development Laboratory, Evans Area, Belmar, N. J.

Present were:

| | |
|---|---|
| Mr. J. LeBedda | USAERDL |
| Mr. C. Bastian | USAERDL |
| Mr. M. Sharenow | USAERDL |
| Dr. H. Newstein | Drexel Institute |
| Mr. G. C. Guard | Kaysam Corporation |
| Mr. J. Kantor | Kaysam Corporation |
| Mr. E. Nelson | Kaysam Corporation |

Mr. Sharenow opened the proceedings with a brief resume of the major practical accomplishments for the past two and one-half years. These included the establishment of new altitude records, by both day and night, as well as substantial improvement in the bursting altitude and reliability of production balloons. In addition, the reliability of balloons designed to reach higher altitudes than standard production balloons has also been significantly improved.

Mr. Nelson reported on the latest conference with DuPont personnel regarding the development of new polymers for meteorological balloons. Recent findings have eliminated polymer types which show a high degree of crystallinity. DuPont has recognized the value of this information and is proceeding with the development work in this new light. The presence of a representative from the DuPont research laboratory in Louisville, who made the journey for the purpose of attending this meeting, attests to the interest being shown in this work.

The behavior of crystalline polymers has also highlighted the necessity for gaining more basic knowledge concerning the effect of the molecular structure of neoprene polymers.

CONFERENCES (continued)

Dr. Newstein undertook the study of molecular structure by means of x-ray diffraction techniques.

In response to suggestions from Messrs. LeBedda and Sharenow, it was also agreed to make a study of the shapes and sizes of compounding ingredient particles. This study will also be conducted by Dr. Newstein using the electron miscoscope.

Mr. Nelson stated that, in the meantime, an investigation of the effect of careful straining of latex compounds through felt and the elimination of all solid compounding ingredients other than Zinc Oxide was already under way. Mr. LeBedda suggested that the possibilities of straining through chamois leather should also be investigated, and it was agreed to do this. The possibility of solublizing Zinc Oxide was suggested by Mr. Kantor.

After discussion of the above points, it was agreed that a further conference with the DuPont personnel should be scheduled for the near future.

The photographic study of balloons at burst will be continued with the assistance of Dr. Newstein. It is planned to extend this study to larger balloons.

Mr. LeBedda asked if there were any plans to investigate and develop compounds for use in the Tropical and Arctic Zones. He was assured by Kaysam representatives that this line of research would be included in the study. Mr. LeBedda and Mr. Sharenow discussed the possibilities of heating the gas as

PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES (continued)

CONFERENCES (continued)

the balloon was being inflated, and also the provision of means for heating the gas in the balloon during flights.

A series of flights with aged balloons is being conducted by the Army, and it was suggested by Mr. LeBedda that the results be incorporated in this study.

The recent improvements in performance of balloons at all levels were illustrated. Compounds already developed since the initiation of this contract have produced 1000-gram balloons capable of flying in the 110,000- to 120,000-foot range with good consistency. In addition, a limited number of flights with 1500-gram balloons have reached altitudes in excess of 130,000 feet.

Also, there have been successful flights to almost 140,000 feet with 4000-gram balloons made on a new dipping form and using a standard compound. It seems reasonable to hope that a balloon capable of consistent performance above 140,000 feet will shortly be a reality when the newly-developed compounds are used for this size balloon.

Mr. LeBedda advised that an impending reduction in the cost of hydrogen by the use of field generators will permit the use of larger balloons. Work in the above directions, will, therefore, be vigorously pursued.

# FACTUAL DATA

## TASK A: PROPERTIES OF BALLOONS AND BALLOON FILMS

### Phase 1: Study of the Literature

A study of the current literature has not revealed anything of interest during this quarter.

### Phase 2: Evaluation of Raw Materials

### Part A: Neoprene Polymers

A preliminary conference with the personnel from E. I. du Pont de Nemours was held to discuss the status of the development of new polymers. The minutes of this meeting are incorporated in the section on "PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES" of this report. It was agreed that the nature of the stress-strain curve which is obtained with polymers showing a high degree of crystallinity was undesirable and that there was, apparently, little to be gained by pursuing this line of attack.

The tests previously conducted with Neoprene 673, which is typical of the crystallizing polymers, have all been based on day-flight compounds containing only a small proportion of plasticizer. Before completely abandoning this type of polymer, it was decided to evaluate at least one dual-purpose compound based on Neoprene 673. At the same time, the effect of combining such a polymer with poly-isoprene was also investigated. Two compounds, A2a-1 and A2a-2, were prepared, and their formulations are given in Table 1.

## TABLE 1

## FORMULATIONS OF COMPOUNDS CONTAINING NEOPRENE 673

| Formulation No. | A2a-1 | A2a-2 |
|---|---|---|
| Neoprene 673 | 100.0 | 100.0 |
| Poly-isoprene | - | 20.0 |
| Zinc Oxide | 5.0 | 10.0 |
| N.B.C. | 3.0 | 3.0 |
| Neozone 'D' | 2.0 | 2.0 |
| Merac | 1.0 | - |
| Accelerator 833 | - | 2.0 |
| Sunaptic Acid | 1.0 | 1.0 |
| Sulphur | - | 0.6 |
| Barak | - | 0.15 |
| Aquarex SMO | 0.5 | 0.5 |
| Dibutyl Sebacate | 10.0 | 10.0 |
| Butyl Oleate | 15.0 | 15.0 |

Plates were dipped from these compounds and cured for 60 minutes at 260°F. Physical properties were determined after 1 day, 7 days, and 14 days. The results of these tests are given in Table 2.

It is apparent from these results that the crystallizing characteristics of Neoprene 673 are still producing undesirable physical properties even in a dual-purpose compound with high plasticizer content. The addition of poly-isoprene to the compound, while delaying the crystallization, does not eliminate the condition nor does it reduce the condition to an acceptable level.

Balloons weighing 100 grams made from compound A2a-1 showed very uneven expansion upon inflation, and there can be little doubt that sounding balloons made from such a compound would have extremely poor ascensional rates and would reach much lower bursting altitudes than balloons made from compounds containing non-crystallizing polymers.

In order to complete the study, the properties of compound A2a-2 will be determined after 28 days, and the inflation pattern of 100-gram balloons will be observed. However, it seems that the previous conclusions concerning crystallizing polymers are correct and that such polymers cannot be modified by compounding to overcome this deficiency.

# TABLE 2

## PHYSICAL PROPERTIES OF COMPOUNDS A2a-1 AND A2a-2 TESTED AT ROOM TEMPERATURE AND AT -70°C

| Compound No. | Test Temp. (°C) | Interval between Curing & Testing | Modulus at 200% (psi) | Modulus at 400% (psi) | Modulus at 600% (psi) | Tensile Strength (psi) | Elongation at Break (%) |
|---|---|---|---|---|---|---|---|
| A2a-1 | +20 | 1 day | 100 | 190 | 510 | 1780 | 950 |
| | +20 | 7 days | 200 | 470 | 1200 | 2750 | 890 |
| | -70 | 1 day | 1940 | 3320 | - | 4400 | 460 |
| A2a-2 | +20 | 1 day | 70 | 110 | 320 | 1245 | 870 |
| | +20 | 4 days | 100 | 150 | 450 | 1600 | 900 |
| | +20 | 7 days | 130 | 250 | 800 | 1910 | 850 |
| | +20 | 14 days | 150 | 360 | 980 | 2250 | 820 |
| | -70 | 1 day | 1570 | 3220 | - | 4080 | 450 |

FACTUAL DATA (continued)

TASK A, Phase 2 (continued)

### Part B: Polymers Other than Neoprene

It has already been shown in a previous contract (DA-36-039-SC-90747) that Polyisoprene 200 as manufactured by the Shell Chemical Company cannot be used for the manufacture of meteorological balloons because of the gel structure which does not permit its expansion. However, the excellent low-temperature characteristics of both poly-isoprene and natural rubber suggest that these materials might have merit as polymeric, low-temperature "plasticizers."

The instability of natural latex and neoprene latex blends is well known, and an experimental compound consisting of a standard balloon compound and deammoniated natural latex showed the presence of hard coagulum after 30 days. Poly-isoprene latex, being synthetic, would appear more likely to be compatible with neoprene latex, and initial tests indicated that this was so.

Therefore, a series of compounds was prepared by successively adding sulphur, butyl oleate, and poly-isoprene to a compound whose physical properties are already well known. The formulations for these compounds are given in Table 3.

# TABLE 3

## FORMULATIONS OF COMPOUNDS DESIGNED TO DETERMINE THE EFFECT OF INCORPORATING POLY-ISOPRENE

| Formulation No. | A2b-1 | A2b-2 | A2b-3 | A2b-4 |
|---|---|---|---|---|
| Neoprene | 100.0 | 100.0 | 100.0 | 100.0 |
| Zinc Oxide | 5.0 | 5.0 | 5.0 | 5.0 |
| Wingstay 'T' | 3.0 | 3.0 | 3.0 | 3.0 |
| N.B.C. | 3.0 | 3.0 | 3.0 | 3.0 |
| Sunaptic Acid | 1.0 | 1.0 | 1.0 | 1.0 |
| Aquarex SMO | 0.5 | 0.5 | 0.5 | 0.5 |
| Accelerator 833 | 1.0 | 1.0 | 1.0 | 1.0 |
| Dibutyl Sebacate | 5.0 | 5.0 | 5.0 | 5.0 |
| Butyl Oleate | - | - | 10.0 | 10.0 |
| Poly-isoprene | - | - | - | 10.0 |
| Mistron Vapor | 10.0 | 10.0 | 10.0 | 10.0 |
| Sulphur | - | 2.0 | 2.0 | 2.0 |

**FACTUAL DATA** (continued)

**TASK A, Phase 2, Part B** (continued)

Plates were dipped according to standard procedure and cured for 60 minutes at 260°F. Physical properties were determined at room temperature, -50°C and, in the case of compound A2b-4, at -60°C. The results of these tests are given in Table 4.

Examination of these results shows that the addition of poly-isoprene does improve the low-temperature characteristics, but it is less effective than a low-temperature plasticizer. However, poly-isoprene has much less effect on the room-temperature modulus than a low-temperature plasticizer, although it does result in undesirably low room temperature tensile strength.

A further set of compounds was next prepared in which changes were made to correct the defective features already reported. The formulations of these compounds are given in Table 5.

Plates were dipped from these compounds according to standard procedure and cured for 60 minutes at 260°F. Physical properties were determined at room temperature, -60°C, -65°C, and -70°C. The results of these tests are given in Table 6.

A study of these results shows that the incorporation of poly-isoprene does tend to prevent freezing at low temperatures, although all compounds examined did freeze at -70°C.

## TABLE 4

## PHYSICAL PROPERTIES OF COMPOUNDS A2b-1, A2b-2, A2b-3, AND A2b-4 TESTED AT ROOM TEMPERATURE, AT -50°C, AND AT -60°C

| Compound No. | Test Temp. (°C) | Modulus at 200% (psi) | Modulus at 400% (psi) | Modulus at 600% (psi) | Tensile Strength (psi) | Elongation at Break (%) |
|---|---|---|---|---|---|---|
| A2b-1 | +20 | 125 | 175 | 260 | 2180 | 1150 |
|  | -50 | 1710 | 2065 | 4130 | 5000 | 640 |
| A2b-2 | +20 | 210 | 305 | 850 | 2590 | 820 |
|  | -50 | 2520 | 2750 | - | 4860 | 540 |
| A2b-3 | +20 | 150 | 180 | 370 | 1240 | 790 |
|  | -50 | 1110 | 1660 | - | 3630 | 550 |
| A2b-4 | +20 | 120 | 170 | 310 | 975 | 810 |
|  | -50 | 395 | 930 | 2220 | 3080 | 630 |
|  | -60 | 1500 | 2585 | - | 2930 | 450 |

## TABLE 5

## FORMULATIONS OF COMPOUNDS CONTAINING POLY-ISOPRENE

| Formulation No. | A2b-5 | A2b-6 | A2b-7 | A2b-8 | A2b-9 |
|---|---|---|---|---|---|
| Neoprene 750 | 90.0 | 90.0 | 90.0 | 90.0 | 100.0 |
| Neoprene 571 | 10.0 | 10.0 | 10.0 | 10.0 | - |
| Zinc Oxide | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| N.B.C. | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Neozone 'D' | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Sunaptic Acid | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Merac | 1.0 | 1.0 | 1.0 | 1.0 | - |
| Accelerator 833 | - | - | - | - | 2.0 |
| Aquarex SMO | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Dibutyl Sebacate | 6.25 | 6.25 | 6.25 | 6.25 | 6.25 |
| Butyl Oleate | 10.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| Poly-isoprene | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| Barak | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| Sulphur | 0.3 | 0.3 | 0.6 | 0.9 | 0.6 |

# TABLE 6

## PHYSICAL PROPERTIES OF COMPOUNDS A2b-5, A2b-6, A2b-7, A2b-8, AND A2b-9 TESTED AT ROOM TEMPERATURE, AT -60°C, AT -65°C, AND AT -70°C

| Compound No. | Test Temp. (°C) | Modulus at 200% (psi) | Modulus at 400% (psi) | Modulus at 600% (psi) | Tensile Strength (psi) | Elongation at Break (%) |
|---|---|---|---|---|---|---|
| A2b-5 | +20 | 90 | 130 | 200 | 1070 | 950 |
| | -60 | 2275 | 2855 | - | 4200 | 560 |
| | -65 | 2785 | 2930 | - | 3380 | 460 |
| | -70 | - | - | - | - | frozen |
| | -70 | 2010 | 2010 | 2010 | 3090 | 750 * |
| A2b-6 | +20 | 80 | 125 | 200 | 1070 | 870 |
| | -70 | 2470 | 2530 | - | 3160 | 450 |
| A2b-7 | +20 | 100 | 150 | 260 | 1210 | 820 |
| | -70 | - | - | - | - | frozen |
| | -70 | 2500 | 2500 | 3660 | 3660 | 600 * |
| A2b-8 | +20 | 100 | 150 | 280 | 1350 | 830 |
| | -70 | - | - | - | - | frozen |
| | -70 | 2470 | 2470 | 4060 | 4350 | 650 * |
| A2b-9 | +20 | 80 | 120 | 185 | 1070 | 950 |
| | -65 | 1440 | 2110 | - | 3280 | 500 |
| | -70 | - | - | - | - | frozen |
| | -70 | 1850 | 1900 | 2640 | 3440 | 660 * |

* 100% pre-elongation

**FACTUAL DATA** (continued)

**TASK A, Phase 2, Part B** (continued)

However, compound A2b-9 shows reasonably good properties at room temperature and at -65°C, and on pre-elongation it shows excellent elongation at -70°C.

The tendency to cold flow shown by most of the compounds may be a characteristic of the poly-isoprene compounds and should not necessarily be considered as objectionable. In spite of this condition, the samples always reach a satisfactory elongation which is not the case with 100%-neoprene-polymer compounds.

An additional set of plates was dipped using compound A2b-9, and these were cured for 90 minutes and 120 minutes at 260°F and 60 minutes and 90 minutes at 280°F. Physical properties were determined at room temperature and at -70°C. The results of these tests, together with the results obtained on the samples cured for 60 minutes at 260°F, are recorded in Table 7.

The results of these tests are somewhat inconclusive. Although none of the samples froze at the higher cure, they still exhibit considerable cold flow; but the samples cured 90 minutes and 120 minutes at 260°F both reached reasonably good breaking elongations.

## TABLE 7

## PHYSICAL PROPERTIES OF COMPOUND A2b-9 CURED AT 260°F AND 280°F TESTED AT ROOM TEMPERATURE AND AT -70°C

| Cure Time (mins) | Cure Temp. (°F) | Test Temp. (°C) | Modulus at 200% (psi) | Modulus at 400% (psi) | Modulus at 600% (psi) | Tensile Strength (psi) | Elongation at Break (%) |
|---|---|---|---|---|---|---|---|
| 60 | 260 | +20 | 80 | 120 | 185 | 1070 | 950 |
| | | -65 | 1440 | 2110 | - | 3280 | 500 |
| | | -70 | - | - | - | - | frozen |
| | | -70 | 1850 | 1900 | 2640 | 3440 | 660 * |
| 90 | 260 | +20 | 80 | 120 | 180 | 960 | 935 |
| | | -70 | 2360 | 2750 | - | 3860 | 490 |
| 120 | 260 | +20 | 90 | 135 | 215 | 1060 | 870 |
| | | -70 | 2125 | 2690 | - | 3660 | 490 |
| 60 | 280 | +20 | 90 | 140 | 230 | 1050 | 830 |
| | | -70 | 2930 | 3930 | - | 4260 | 430 |
| 90 | 280 | +20 | 95 | 140 | 240 | 1140 | 840 |
| | | -70 | 3120 | 3920 | - | 4200 | 470 |

* 100% pre-elongation

**FACTUAL DATA** (continued)

**TASK A, Phase 2, Part B** (continued)

It would appear that the combination of neoprene and poly-isoprene gives compounds with only moderately good physical properties. If these were 100%-neoprene-polymer compounds, they would be discarded; but since they do contain poly-isoprene, and because there is no knowledge of such a polymer combination having been used for balloons in flight, it is proposed to continue this line of investigation and make and fly balloons from compound A2b-9.

**Part C: Other Materials**

Kadox 515 is a finer particle size zinc oxide than is Kadox 72, although they are both French Process Zinc Oxides supplied by New Jersey Zinc Company. Since it has been impossible so far to solublize zinc oxide for use in neoprene latex compounds, it was thought that the use of a finer particle size material was at least a step in the right direction and might be expected to show an improvement in consistency if not in actual altitude performance. Two compounds, A2c-12 and A2c-22, were prepared, formulations for which are given in Table 8.

Plates were dipped from these compounds according to standard procedure and cured for 60, 90, and 120 minutes at 260°F. Physical properties were determined at room temperature, and the results of these tests are given in Table 9.

## TABLE 8

## FORMULATIONS OF COMPOUNDS CONTAINING FRENCH PROCESS ZINC OXIDES

| Formulation No. | A2c-1s | A2c-2s |
|---|---|---|
| Neoprene | 100.0 | 100.0 |
| Kadox 72 | 5.0 | - |
| Kadox 515 | - | 5.0 |
| N.B.C. | 3.0 | 3.0 |
| Neozone 'D' | 2.0 | 2.0 |
| Sunaptic Acid | 1.0 | 1.0 |
| Merac | 1.0 | 1.0 |
| Aquarex SMO | 0.5 | 0.5 |
| Dibutyl Sebacate | 6.25 | 6.25 |

## TABLE 9

## PHYSICAL PROPERTIES OF COMPOUNDS A2c-1s AND A2c-2s TESTED AT ROOM TEMPERATURE

| Compound No. | Cure Time (mins) | Cure Temp. (°F) | Modulus at 200% (psi) | Modulus at 400% (psi) | Modulus at 600% (psi) | Tensile Strength (psi) | Elongation at Break (%) |
|---|---|---|---|---|---|---|---|
| **A2c-1s** | 60 | 260 | 135 | 185 | 350 | 1290 | 760 |
| | 90 | 260 | 155 | 220 | 420 | 1550 | 790 |
| | 120 | 260 | 150 | 210 | 460 | 2300 | 850 |
| **A2c-2s** | 60 | 260 | 135 | 215 | 400 | 1800 | 850 |
| | 90 | 260 | 145 | 200 | 460 | 2160 | 840 |
| | 120 | 260 | 150 | 200 | 470 | 2100 | 850 |

**FACTUAL DATA** (continued)

**TASK A, Phase 2, Part C** (continued)

A study of these results shows that compound A2c-2z is somewhat faster curing than compound A2c-1z and is relatively insensitive to the time of cure at 260°F between limits of 60 minutes and 120 minutes.

It was also observed that the rate of settling of the zinc oxide from compound A2c-2z was very much less than from compound A2c-1z. It can reasonably be assumed, therefore, that compound A2c-2z, will produce balloons showing much better uniformity of cure throughout the balloon film. Balloons were made from this compound, and the results of the flights are recorded in Task A, Phase 5.

* * *

A sample of Butoxy Ethyl Oleate, which is chemically identical with Butyl Cellosolve Oleate, was received from American Chemicals during this quarter. A standard compound, the formulation of which follows, was prepared from this material and given the formula number A2c-3P.

| | Compound A2c-3P |
|---|---|
| Neoprene | 100.0 |
| Zinc Oxide | 5.0 |
| N.B.C. | 3.0 |
| Neozone 'D' | 2.0 |
| Sunaptic Acid | 1.0 |
| Merac | 1.0 |
| Aquarex SMO | 0.5 |
| Dibutyl Sebacate | 6.25 |
| Butoxy Ethyl Oleate | 22.5 |

**FACTUAL DATA** (continued)

**TASK A, Phase 2, Part C** (continued)

Plates were dipped and given the standard cure of 60 minutes at 260°F. Physical properties were determined at room temperature and at -70°C, and the results of these tests are given in Table 10.

### TABLE 10

### PHYSICAL PROPERTIES OF COMPOUND A2c-3P TESTED AT ROOM TEMPERATURE AND AT -70°C

| Test. Temp. (°C) | Modulus at 200% (psi) | Modulus at 400% (psi) | Modulus at 600% (psi) | Tensile Strength (psi) | Elogation at Break (%) |
|---|---|---|---|---|---|
| +20 | 120 | 225 | 300 | 1675 | 890 |
| -70 | 2220 | 2885 | - | 4580 | 540 |

These tests indicate that this material is at least equal to, if not superior to, Butyl Cellosolve Oleate. Accordingly, balloons were made from this compound, and the flight results are recorded in Task A, Phase 5.

**FACTUAL DATA** (continued)

**TASK A** (continued)

### Phase 3: Evaluation of Processing Techniques

Because of the extreme thinness of a balloon film as it approaches burst, there is the possibility that premature rupture can occur due to the presence of small agglomerates of compounding materials. These small agglomerates could exceed the thickness of the expanded balloon film and act as a point of rupture. Filtration of the latex compound through fine filter media could remove these particles, if they do exist, and should result in more uniform physical properties.

Therefore, a sample of felt, identified as Grade B/8797, was obtained from the American Felt Company. Compound A5-104, the formula for which is given in Task A, Phase 5 of this report, was prepared in the normal manner and then filtered through the felt sample. Plates were dipped from the strained compound and cured for 60 minutes at 260°F. Samples were cut from ten plates, and the physical properties were determined at room temperature. The results of these tests are given in Table 11.

A study of these results indicates that there is no improvement in uniformity compared with the unstrained compound. In addition, the tensile strength, in particular, is generally lower than is normally obtained with this compound. This suggests the possibility that straining through felt is actually removing certain ingredients necessary for obtaining the optimum physical properties.

## TABLE 11

## PHYSICAL PROPERTIES OF COMPOUND A5-104 AFTER STRAINING THROUGH FELT

| Plate No. | Modulus at 200% (psi) | Modulus at 400% (psi) | Modulus at 600% (psi) | Tensile Strength (psi) | Elongation at Break (%) |
|---|---|---|---|---|---|
| 1 | 110 | 230 | 375 | 1825 | 920 |
| 2 | 95 | 225 | 360 | 1960 | 940 |
| 3 | 105 | 260 | 340 | 1880 | 920 |
| 4 | 105 | 220 | 380 | 2010 | 930 |
| 5 | 110 | 255 | 335 | 1915 | 930 |
| 6 | 95 | 220 | 350 | 2110 | 920 |
| 7 | 100 | 235 | 355 | 1880 | 930 |
| 8 | 105 | 265 | 370 | 1925 | 940 |
| 9 | 115 | 240 | 340 | 1970 | 910 |
| 10 | 110 | 235 | 365 | 1885 | 920 |

FACTUAL DATA (continued)

TASK A, Phase 3 (continued)

Since a satisfactory cure can be obtained with only one part of zinc, it seems unlikely that the low tensile strength is the result of removal of Zinc Oxide. By the same token, the accelerator, Merac, is a liquid and cannot be removed by straining.

These initial results certainly suggest that further work must be done with strained compounds in an effort to determine the cause of the generally inferior properties and of the considerable variation which exists from plate to plate.

* * *

It is customary to attach a separate stem to meteorological balloons in order to provide the necessary small-diameter neck needed for attachment to inflation nozzles. It is possible to design a dipping form which will create a neck of the required diameter as an integral part of the balloon, but it will leave an opening at the opposite end.

This opening can be closed by capping or by simply cementing and sealing under pressure. The cementing can be accomplished either on the uncured film or on the cured film. It would seem that the integral neck would provide a stronger section in the area at which the load is attached. There would, consequently, be less danger of the separation of the radiosonde from the balloon or of rupture of the balloon in the neck area.

**FACTUAL DATA** (continued)

**TASK A, Phase 3** (continued)

Five balloons having an integral neck were manufactured from compound A5-105. This is a standard dual-purpose compound, the formulation for which is as follows:

| | Compound A5-105 |
|---|---|
| Neoprene | 100.0 |
| Zinc Oxide | 5.0 |
| N. B. C. | 3.0 |
| Neozone 'D' | 2.0 |
| Sunaptic Acid | 1.0 |
| Merac | 1.0 |
| Aquarex SMP | 0.5 |
| Dibutyl Sebacate | 6.25 |
| Butyl Cellosolve Oleate | 22.5 |

The five balloons were identified as C20-ITW, C20-2TW, C29-1TW, C29-2TW, and C29-3TW.

Balloons C20-ITW and C20-2TW were cemented after curing, using MMM's EC-880 cement. The seal was clamped for 24 hours. Balloon C29-ITW was closed by cementing a cap made from the same compound as the uncured balloon with the same cement, drying for 24 hours, and then curing. Balloon C29-2TW was closed with Dow Corning Silastic RTV732 adhesive which was allowed to cure without clamping at room temperature.

Balloon C29-3TW was closed by inserting into the opening a cardboard ring of the same type normally used at the neck end and cementing a cap over the balloon and the ring. MMM's EC-880 cement was again used on this balloon, and the balloon was then cured.

FACTUAL DATA (continued)

TASK A, Phase 3 (continued)

These five balloons were flown with a free lift of 1400 grams. Their physical characteristics and the flight results are given in Table 12.

TABLE 12

FLIGHT RESULTS - BALLOONS WITH INTEGRAL NECKS

| Balloon No. | Weight (grams) | Length (inches) | Day or Night Flight | Altitude at Burst (feet) | Ascensional Rate (feet/min.) |
|---|---|---|---|---|---|
| C20-1TW | 765 | 90 | Day | 102,700 | 1093 |
| C20-2TW | 725 | 87 | Day | 105,300 | 1121 |
| C29-1TW | 780 | 96 | Night | 107,152 | 1055 |
| C29-2TW | 750 | 91 | Night | 111,089 | 1087 |
| C29-3TW | 795 | 93 | Night | 94,600 | 1002 |

It is immediately apparent that the performance of these balloons is extremely satisfactory. Four of the five reached altitudes of more than 100,000 feet, and all balloons had ascensional rates in excess of 1000 feet per minute. In view of the fact that these balloons would normally be expected to meet an altitude specification of not more than 90,000 feet, it would seem that any of these methods of clamping the opening of the balloon is feasible.

Additional balloons of this type should be flown since the greater strength of the neck could conceivably result in more consistent balloon performance

FACTUAL DATA (continued)

TASK A (continued)

### Phase 4: Molecular Structure of Balloon Films

A preliminary conference was held with Dr. Herman Newstein, and a program was initiated. Dr. Newstein is at present organizing the practical work which is to be conducted with the electron microscope as well as X-ray diffraction equipment. The first results of this program will be reported at the end of the next quarter.

### Phase 5: Development of Optimum Compounds

During the closing weeks of contract DA-36-039-SC-90747, a compound was developed which showed high promise since it possessed much higher elongation at room temperature and substantially higher elongation at -40°C. than any other compound hitherto investigated.

A few flights were conducted which confirmed the evidence of the physical properties, and additional balloons in the 1000-, 1500-, and 2500- gram ranges have now been flown. The formulation, having been assigned the new number A5-101, is repeated here for ease of reference:

| | Compound A5-101 |
|---|---|
| Neoprene | 100.0 |
| Zinc Oxide | 1.0 |
| Antioxidant | 3.0 |
| N.B.C. | 3.0 |
| Sunaptic Acid | 1.0 |
| Aquarex SMO | 0.5 |
| Accelerator | 1.0 |
| Dibutyl Sebacate | 5.0 |
| Mistron Vapor | 5.0 |

FACTUAL DATA (continued)

TASK A, Phase 5 (continued)

Balloons were manufactured from this compound without difficulty in the three weight ranges already mentioned, and these were all flown with a free lift of 1600 grams. The characteristics of the balloons and their flight performance are given in Table 13.

A study of these results shows that the balloons in the 1000-gram range performed extremely well. Eleven flights were completed; and of the eleven, eight balloons (72.5%) reached altitudes of more than 110,000 feet, and five (45%) reached altitudes of more than 115,000 feet. Nine of these balloons had ascensional rates of over 1000 feet per minute, and the two balloons which were not tracked to the top of the flight also ascended at more than 1000 feet per minute.

The performance of the 1500-gram balloons is also extremely good, two of the three achieving altitudes of more than 130,000 feet and the remaining balloon failing to reach 120,000 feet by only 118 feet. In every case, the ascensional rate was more than 1100 feet per minute. It should be noted that a balloon travelling at 1100 feet per minute reaches an altitude of 121,000 feet in the same time as a balloon travelling at 1000 feet per minute reaches 110,000 feet. The higher altitude reached by the 1500-gram balloons did not, therefore, involve greater elapsed flight time.

## TABLE 13

## FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A5-101

| Balloon No. | Weight (grams) | Length (inches) | Day or Night Flight | Altitude at Burst (feet) | Ascensional Rate (feet/min.) |
|---|---|---|---|---|---|
| A9-2TJ * | 1140 | 104 | Night | 121,949 | 973 |
| A9-3TJ * | 1240 | 110 | Night | 121,129 | 1031 |
| A9-6TJ * | 1205 | 109 | Night | 113,058 | 1022 |
| B25-4TH* | 1280 | 107 | Night | 109,038 | 1062 |
| C5-1TH * | 1275 | 103 | Night | 115,940 | 1036 |
| C8-3TH * | 1225 | 101 | Night | 112,041 | 954 |
| C7-1TH * | 930 | 106 | Day | 94,250 | 1082 |
| C8-2TH * | 1000 | 100 | Day | 103,478 | 1084 |
| C8-5TH * | 1055 | 112 | Day | 120,050 | 1190 |
| A7-2TJ | 920 | 97 | Day | 92,300** | 1026 |
| A8-6TJ | 930 | 100 | Day | 118,504 | 1149 |
| A8-8TJ | 940 | 100 | Day | 114,173 | 1052 |
| A8-9TJ | 920 | 98 | Day | 95,590** | 1030 |
| F4-1TW | 1470 | 123 | Day | 119,882 | 1118 |
| F4-2TW | 1580 | 132 | Day | 132,841 | 1165 |
| F4-3TW | 1490 | 131 | Day | 136,581 | 1156 |
| A16-2AM | 2365 | 181 | Day | 120,866 | 1001 |
| A16-3AM | 2365 | 178 | Day | 38,000 | 821 |
| A16-5AM | 2435 | 180 | Day | 133,104 | 1050 |

* Balloon was post-plasticised
** Top Intelligible Data

**FACTUAL DATA** (continued)

**TASK A, Phase 5** (continued)

The performance of the 2500-gram balloons is disappointing, in general being no better than that of the 1500-gram balloons. However, the limited number of flights made with both the 1500-gram and 2500-gram balloons makes it unwise to attempt to draw any conclusions, favorable or otherwise; and additional balloons of this type will be flown during the next quarter.

* * *

Five balloons containing Kadox 515 were also flown during this quarter. These balloons were made from compound A2c-2z as given in Table 8 in Task A, Phase 2, Part C of this report, this compound now being assigned the number A5-102. The balloons were in the 1000-gram class and were flown with a free lift of 1600 grams. Their characteristics and flight performance are given in Table 14.

TABLE 14

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A5-102

| Balloon No. | Weight (grams) | Length (inches) | Day or Night Flight | Altitude at Burst (feet) | Ascensional Rate (feet/min.) |
|---|---|---|---|---|---|
| S10-1TJ | 1010 | 103 | Day | 117,471 | 1148 |
| S10-2TJ | 985 | 94 | Day | 101,500 | 1103 |
| S10-3TJ | 1025 | 94 | Day | 106,000 | 1075 |
| S10-4TJ | 995 | 97 | Day | 100,200 | 1054 |
| S10-5TJ | 1055 | 99 | Day | 115,551 | 1141 |

A study of these results shows that the performance is satisfactory but is not superior to that of balloons made from a compound containing a coarser particle size zinc oxide. In addition, the uniformity of performance is not noticeably better. However, the two longest balloons did reach the highest altitudes, and there appears to be justification for pursuing this investigation further.

* * *

A total of twelve balloons were flown from a compound containing Butoxy Ethyl Oleate. The balloons were made from compound A2c-3p, given on page 7 under Task A, Phase 2, Part C of this report, which was assigned the number A5-103.

The balloons, all in the 1000-gram class, were flown with a free lift of 1600 grams. Their characteristics and flight performance are given in Table 15.

From these results it can be seen that, excluding the balloon which burst on inflation, all balloons reached an altitude of more than 100,000 feet, and seven reached an altitude of more than 115,000 feet. All but one rose at more than 1000 feet per minute.

It may, therefore, be concluded that Butoxy Ethyl Oleate is a satisfactory low-temperature plasticizer for use in meteorological balloon compounds.

* * *

## TABLE 15

## FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A5-103

| Balloon No. | Weight (grams) | Length (inches) | Day or Night Flight | Altitude at Burst (feet) | Ascensional Rate (feet/min.) |
|---|---|---|---|---|---|
| C21-1TW | 1210 | 108 | Burst on inflation | | |
| C21-2TW | 1180 | 112 | Night | 108,694 | 1105 |
| C21-3TW | 1235 | 117 | Day | 119,902 | 1096 |
| C21-4TW | 1160 | 112 | Day | 121,063 | 1126 |
| C21-5TW | 1220 | 115 | Night | 124,311 | 1027 |
| C21-6TW | 1175 | 110 | Night | 119,226 | 1037 |
| F17-1T | 1015 | 105 | Day | 118,143 | 1134 |
| F17-2T | 1000 | 104 | Day | 100,200 | 1074 |
| F17-3T | 965 | 105 | Day | 116,339 | 1106 |
| F17-4T | 1010 | 104 | Night | 100,200 | 957 |
| F17-5T | 1005 | 101 | Night | 108,957 | 1056 |
| F17-6T | 995 | 103 | Night | 116,339 | 1036 |

**FACTUAL DATA** (continued)

**TASK A, Phase 5** (continued)

Four balloons in the 4000-gram class were manufactured from a standard compound which has been giving reliable results over the past year and a half. The formulation of this compound is as follows:

| | Compound A5-104 |
|---|---|
| Neoprene | 100.0 |
| Zinc Oxide | 5.0 |
| N.B.C. | 3.0 |
| Neozone 'D' | 2.0 |
| Sunaptic Acid | 1.0 |
| Accelerator 833 | 1.0 |
| Aquarex SMO | 0.5 |
| Dibutyl Sebacate | 6.25 |

The balloons were made on a recently acquired dipping form. They were flown with a free lift of 2000 grams, and their characteristics and flight performance are given in Table 16.

TABLE 16

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A5-104

| Balloon No. | Weight (grams) | Length (inches) | Day or Night Flight | Altitude at Burst (feet) | Ascensional Rate (feet/min.) |
|---|---|---|---|---|---|
| C22-1AM | 4490 | 245 | Day | 98,300* | 967 |
| C22-2AM | 4425 | 235 | Day | 129,134 | 1061 |
| F2-2AM | 4220 | 244 | Day | 139,009 | 1101 |
| F2-3AM | 4335 | 245 | Day | 136,549 | 1061 |

* Top Intelligible Data

FACTUAL DATA (continued)

TASK A, Phase 5 (continued)

Although somewhat higher altitudes were anticipated, these results are, nevertheless, encouraging. It has generally been the case, in the past, that the consistency of performance with balloons of this size is very poor. The results in Table 16 indicate that consistency can now be achieved, and it is particularly interesting to note that the shortest balloon was the one which failed to exceed 130,000 feet. Had this balloon been 10 inches longer, as were the others, it is reasonable to assume that it would have reached an altitude of at least 135,000 feet.

The possibilities of achieving consistent performance at these levels now seem very much brighter.

## TASK B: EFFECT OF FLIGHT CONDITIONS ON BALLOON PERFORMANCE

### Phase 1: Behavior on Inflation and Rupture

No progress during this period.

### Phase 2: Effect of Pre-Elongation

The effect of pre-elongation on neoprene compounds is well known. Since polymers other than neoprene, particularly natural rubber and poly-isoprene, are being investigated at this time, it becomes necessary to determine whether or not pre-elongation of these films also results in greater breaking elongations at low temperatures.

Preliminary tests using a natural-latex compound indicated that there is no change in the breaking elongation at -60°C when the test piece is pre-elongated 100%. However, certain difficulties were experienced during these tests, the major problem being that most of the test pieces broke at the head instead of the center of the test piece as is normally the case.

Further work with natural-latex films and with neoprene, poly-isoprene blends will, therefore, be conducted. It is not possible to draw any conclusions at this time.

### Phase 3: Effect of Ozone

Balloons weighing 1000 grams manufactured from compound A5-101 performed extremely well, reaching altitudes substantially higher than is normal for this size balloon. The limited number of flights with 1500-gram balloons made from the same compound also performed extremely well.

It has already been shown that this compound has higher elongation at low temperatures than any other compound previously evaluated. In order to complete the information regarding this compound, its resistance to attack by ozone was determined and compared with that of compound A5-104.

The effect of increasing the amount of anti-ozonant in the compound was also investigated, and tests were conducted on compound A5-101 to which had been added an additional 3 parts and 5 parts of N.B.C. Both dumbbell test pieces and inflated patches were examined. Samples were elongated 50%, 100%,200%, 300%, 400%, 500%, and 600%, and the time to rupture was measured using an ozone concentration of 40 parts per million. Results of these tests are given in Table 17.

A study of these results shows that at all elongations, regardless of whether dumbbells or patches are used, compound A5-104 is superior to A5-101. However, addition of a further 3 parts of anti-ozonant to A5-101 renders it equal or superior to A5-104 when dumbbells are tested and almost identical to A5-104 in patch testing. Addition of a further 2 parts of anti-ozonant improves the ozone resistance when dumbbells are tested but appears not to improve the ozone resistance of patches, and there are some indications that the ozone resistance becomes poorer.

It is not possible to directly correlate life in the ozone chamber with flight performance. All that can be said is that the ozone resistance of A5-104 is quite satisfactory. The ozone resistance of A5-101, which is only slightly inferior to that of A5-104, is probably also satisfactory, and it can clearly be raised to the same level as A5-104. There should, therefore, be no difficulties encountered when flying balloons made from A5-101 due to insufficient resistance to attack by ozone.

## TABLE 17

## OZONE RESISTANCE OF COMPOUND A5-101 WITH ADDITIONAL ANTIOZONANT COMPARED WITH COMPOUND A5-104

| Compound No. | Test Piece | Time to failure in minutes at elongation of | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 50% | 100% | 200% | 300% | 400% | 500% | 600% |
| A5-104 | Dumbbell | 73 | 68 | 58 | 54 | 35 | 35 | 55 |
| A5-101 | Dumbbell | 46 | 39 | 36 | 33 | 27 | 25 | 28 |
| A5-101 plus 3 parts NBC | Dumbbell | 117 | 109 | 83 | 66 | 57 | 58 | 59 |
| A5-101 plus 5 parts NBC | Dumbbell | 123 | 150 | 95 | 80 | 55 | 54 | 72 |
| A5-104 | Patch | 95 | 32 | 15 | 18 | 17 | 17 | 15 |
| A5-101 | Patch | 45 | 30 | 8 | 10 | 10 | 12 | 8 |
| A5-101 plus 3 parts NBC | Patch | 90 | 32 | 19 | 17 | 12 | 14 | 12 |
| A5-101 plus 5 parts NBC | Patch | 60 | 38 | 24 | 20 | 16 | 12 | 9 |

FACTUAL DATA (continued)

TASK B (continued)

### Phase 4: Effect of Radiation

In order to complete the evaluation of compound A5-101, its behavior on exposure to infra-red radiation was observed. Samples made from compound A5-101 were cured for 90 minutes at 260°F, and some of the films were post-plasticized after curing.

Physical properties were determined at zero, -20°C, and -40°C on the unpost-plasticized films, and at zero, -20°C, -40°C, -60°C, and -70°C on the post-plasticized films. The tests were conducted without and in the presence of infra-red radiation. The results are recorded in Table 18.

A study of this table shows that, in the case of the unpost-plasticized film, infra-red radiation has no effect on the elongation at zero and increases the elongation at -20°C and -40°C. There is little effect on tensile strength or modulus at zero, and relatively litte effect at -20°C. However, at -40°C, there is a substantial drop in modulus and tensile strength. This characteristic is calculated to result in uneven expansion under certain conditions of daytime flight and may produce erratice performance, particularly in balloons designed for very high altitudes. There is, however, no reason to believe that this compound will perform any worse than A5-104.

## TABLE 18

## EFFECT OF INFRA-RED RADIATION ON HIGH-ELONGATION COMPOUND A5-101

| Post-Plasticized | Test Temp. (°C) | Infra-Red Radiation | Modulus at 200% (psi) | Modulus at 400% (psi) | Modulus at 600% (psi) | Tensile Strength (psi) | Elongation at Break (%) |
|---|---|---|---|---|---|---|---|
| No | 0 | No | 215 | 260 | 495 | 2110 | 1000 |
| No | -20 | No | 250 | 375 | 1000 | 2710 | 800 |
| No | -40 | No | 500 | 915 | 3710 | 4085 | 640 |
| No | 0 | Yes | 210 | 270 | 435 | 1940 | 990 |
| No | -20 | Yes | 235 | 345 | 690 | 2305 | 860 |
| No | -40 | Yes | 325 | 585 | 1815 | 2865 | 730 |
| Yes | 0 | No | 110 | 130 | 160 | 685 | 1010 |
| Yes | -20 | No | 135 | 155 | 215 | 1015 | 990 |
| Yes | -40 | No | 160 | 210 | 335 | 1250 | 890 |
| Yes | -60 | No | 255 | 440 | 1915 | 2930 | 700 |
| Yes | -70 | No | 1505 | 2500 | - | 3640 | 510 |
| Yes | 0 | Yes | 95 | 115 | 170 | 475 | 1010 |
| Yes | -20 | Yes | 115 | 150 | 190 | 530 | 930 |
| Yes | -40 | Yes | 155 | 175 | 295 | 740 | 830 |
| Yes | -60 | Yes | 200 | 285 | 775 | 1845 | 730 |
| Yes | -70 | Yes | 460 | 625 | - | 1765 | 580 |

After post-plasticizing, infra-red radiation has no effect at zero except to reduce the tensile strength. At -20°C and -40°C, the elongation is reduced on irradiation which is an unusual condition. This is accompanied by relatively little change in modulus but a sharp drop in tensile strength. At -60°C, the elongation increases slightly, and there is a considerable drop in modulus and tensile strength. At -70°C, there is a sharp increase in elongation, and a very great drop in modulus and a substantial drop in tensile strength.

Generally speaking, these characteristics are similar to those usually encountered, and there is no reason to believe that balloons made from this compound should be any less reliable than those made from compounds being used in production at the present time. They can, of course, be expected to achieve higher altitudes because of higher low-temperature elongations.

* * *

The effect of infra-red radiation on a natural-latex compound was also determined. This compound was cured for 90 minutes at 212°F and 90 minutes at 230°F, and tests were conducted at -40°C, -50°C, -60°C, and -70°C. The results of these tests are given in Table 19.

It was not possible to conduct tests at higher temperatures than -40°C since the breaking elongation was such that

## TABLE 19

## EFFECT OF INFRA-RED RADIATION ON NATURAL-LATEX BALLOON COMPOUNDS

| Cure Time (mins) | Cure Temp. (°F) | Test Temp. (°C) | Infra-Red Radiation | Modulus at 200% (psi) | Modulus at 400% (psi) | Modulus at 600% (psi) | Tensile Strength (psi) | Elongation at Break (%) |
|---|---|---|---|---|---|---|---|---|
| 90 | 212 | -40 | No | 125 | 700 | 3200 | 4010 | 620 |
| 90 | 212 | -40 | Yes | 135 | 790 | 3015 | 3475 | 640 |
| 90 | 212 | -50 | No | 190 | 1120 | 3300 | 4100 | 620 |
| 90 | 212 | -50 | Yes | 200 | 1130 | - | 3930 | 560 |
| 90 | 212 | -60 | No | 320 | 960 | 2360 | 3810 | 650 |
| 90 | 212 | -60 | Yes | 330 | 995 | - | 2130 | 580 |
| 90 | 212 | -70 | No | 1425 | 2195 | - | 4000 | 500 |
| 90 | 212 | -70 | Yes | 965 | 1190 | 3200 | 3700 | 620 |
| 90 | 230 | -50 | No | 225 | 645 | 2330 | 3250* | 700* |
| 90 | 230 | -50 | Yes | 225 | 620 | 2325 | 3940 | 700 |
| 90 | 230 | -60 | No | 300 | 600 | 2000 | 2950 | 700 |
| 90 | 230 | -60 | Yes | 150 | 225 | 1820 | 2725* | 680* |
| 90 | 230 | -70 | No | 1470 | 2560 | - | 3575 | 500 |
| 90 | 230 | -70 | Yes | 480 | 505 | 1730 | 2500* | 660* |

* Sample stretched beyond scale limits.

**FACTUAL DATA** (continued)

**TASK B, Phase 4** (continued)

the jaws reached the end of the travel before the specimen broke. Modifications to the jaws are being made in order to continue this study.

Analysis of Table 19 shows that natural-latex films are much less susceptible to the effects of infra-red radiation than are neoprene films. In all cases there is very little difference between the elongation, tensile strength, and modulus recorded with and without infra-red radiation.

It would seem, therefore, insofar as this characteristic is concerned, that natural-rubber balloons might be expected to have more consistent performance than neoprene balloons. In fact, this characteristic, coupled with the excellent low-temperature properties of natural rubber, indicates that this material should make extremely good meteorological balloons.

Unfortunately, the extremely poor ozone resistance of natural rubber more than offsets these advantages, rendering balloons liable to attack and rupture at approximately 90,000 feet. Improvement in the ozone resistance should lead to much better altitudes, and this line of investigation should be pursued if only from an academic viewpoint.

* * *

TASK B, Phase 4 (continued)

The possibilities of reducing the effect of infra-red radiation by incorporation of infra-red reflecting materials was examined during the course of Contracts DA-36-039-SC-84925 and DA-36-039-SC-90747.

A few flights were conducted with balloons made from a compound which showed much less effect on irradiation than the standard compound. There was no improvement in altitude, but this need not be an unexpected result; for if the balloon reflects infra-red radiation to a greater degree, then it is a natural result for its temperature, and therefore its breaking elongation, to be reduced.

Additional work along these lines was undertaken; and five compounds were prepared, the formulations for which are given in Table 20.

Plates were dipped from each of these compounds and cured for 60 minutes at 260°F. Physical properties were determined at -40°C with and without infra-red radiation, and the results of these tests are given in Table 21.

A study of these results shows that a compound indicating the highest reflectance of infra-red radiation is B-4a-2. It is, therefore, proposed to manufacture balloons from this compound and to conduct flight tests using balloons made from a standard compound containing less Zinc Oxide as controls.

## TABLE 20

## FORMULATIONS OF COMPOUNDS CONTAINING INFRA-RED REFLECTING MATERIALS

| Formulation No. | B4a-1 | B4a-2 | B4a-3 | B4a-4 | B4a-5 |
|---|---|---|---|---|---|
| Neoprene 750 | 90.0 | 90.0 | 90.0 | 90.0 | 90.0 |
| Neoprene 571 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| Zinc Oxide | 5.0 | 10.0 | 5.0 | 10.0 | 5.0 |
| N.B.C. | - | - | - | 3.0 | 3.0 |
| Neozone 'D' | - | - | - | 2.0 | 2.0 |
| DPPD | 2.0 | 2.0 | 2.0 | - | - |
| Merac | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Sunaptic Acid | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Aquarex SMO | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Dibutyl Sebacate | 6.25 | 6.25 | 6.25 | 6.25 | 6.25 |
| Titanium Dioxide | - | - | 5.0 | - | 5.0 |

## TABLE 21

### EFFECT OF INFRA-RED RADIATION ON COMPOUNDS B4a-1 THROUGH B4a-5 TESTED AT -40°C

| Compound No. | Infra-Red Radiation | Modulus at 200% (psi) | Modulus at 400% (psi) | Modulus at 600% (psi) | Tensile Strength (psi) | Elongation at Break (%) |
|---|---|---|---|---|---|---|
| B4a-1 | No | 260 | 640 | 3325 | 3760 | 620 |
| | Yes | 120 | 290 | 2120 | 2880 | 620 |
| B4a-2 | No | 480 | 1210 | - | 3730 | 580 |
| | Yes | 445 | 800 | 3330 | 3330 | 600 |
| B4a-3 | No | 385 | 795 | 3990 | 3990 | 600 |
| | Yes | 330 | 495 | 2510 | 3660 | 650 |
| B4a-4 | No | 430 | 800 | 3450 | 4150 | 640 |
| | Yes | 300 | 500 | 2100 | 2970 | 660 |
| B4a-5 | No | 290 | 640 | 2950 | 3700 | 610 |
| | Yes | 300 | 420 | 1895 | 3290 | 670 |

# CONCLUSIONS

## TASK A: PROPERTIES OF BALLOONS AND BALLOON FILMS

### Phase 1: Study of the Literature

Nothing of interest was revealed by the study of current literature.

### Phase 2: Evaluation of Raw Materials

### Part A: Neoprene Polymers

At a conference with E. I. du Pont de Nemours personnel, new standards for meteorological balloon polymers were established, and Du Pont promised to attempt the production of the desired material.

Previous results obtained with Neoprene 673 were confirmed in a dual-purpose compound, and it was clearly established that highly crystalline polymers of this type are completely unsatisfactory for meteorological balloons.

### Part B: Polymers other than Neoprene

Compounds based on a blend of neoprene and poly-isoprene were shown to be stable, and it was also shown that addition of poly-isoprene improved the low-temperature characteristics. Although the physical properties otherwise seem to be inferior to those of neoprene compounds which do not contain poly-isoprene, it is, nevertheless, proposed to continue this evaluation.

CONCLUSIONS (continued)

TASK A, Phase 2 (continued)

Part C: Other Materials

A compound containing Zinc Oxide--Kadox 515--was shown to settle much more slowly than one containing Zinc Oxide--Kadox 72. This can be expected to provide greater uniformity of cure throughout a balloon film since the distribution of Zinc Oxide from top to bottom of the balloon will be more uniform.

Butoxy Ethyl Oleate from American Chemicals was shown to give compounds with low-temperature characteristics at least equal to those obtained by the use of Butyl Cellosolve Oleate.

Phase 3: Evaluation of Processing Techniques

The results obtained using felt as a filter medium for latex compounds were erratic and inconclusive, and additional work is indicated.

Balloons having an integral neck were flown with very satisfactory results. It would appear that an acceptable method of producing this type of balloon is almost developed.

Phase 4: Molecular Structure of Balloon Films

A program of X-ray diffraction and electron microscope studies of balloon films was inaugurated with the assistance of Dr. Herman Newstein.

## CONCLUSIONS (continued)

## TASK A (continued)

### Phase 5: Development of Optimum Compounds

Flights conducted with 1000-gram balloons made from high-elongation compounds demonstrated the feasibility of consistently reaching altitudes of at least 110,000 feet with balloons of this size.

Altitudes in excess of 130,000 feet were achieved with 1500-gram balloons made from the same compounds, but the performance of 2500-gram balloons was no better than that of similar balloons made from standard compounds.

Balloons weighing 1000 grams made from a compound containing Kadox 515 performed satisfactorily but showed no improvement in consistency over standard balloons.

Balloons weighing 1000 grams made from a compound containing Butoxy Ethyl Oleate also performed very satisfactorily.

Four balloons weighing 4000 grams made from a standard compound were flown and showed better consistency than has heretofore been obtained with balloons of this size, although the altitudes were not as high as anticipated.

## TASK B: EFFECT OF FLIGHT CONDITIONS ON BALLOON PERFORMANCE

### Phase 1: Behavior on Inflation and Rupture

No progress during this period.

### Phase 2: Effect of Pre- Elongation

Difficulties with the test equipment rendered inconclusive the preliminary results obtained of the effect of pre-elongation on natural-latex films.

## CONCLUSIONS (continued)

## TASK B (continued)

### Phase 3: Effect of Ozone

The ozone resistance of the recently developed, high-elongation compound was shown to be inferior to that of a standard compound. However, it was also shown that this deficiency can easily be corrected by increasing the amount of antiozonant in the compound.

### Phase 4: Effect of Radiation

The effect of infra-red radiation on the same high-elongation compound referred to in Phase 3 was shown to be virtually the same as that on a standard compound.

It was shown that natural-latex compounds are much less affected by infra-red radiation than are neoprene compounds.

Incorporation of materials designed to reflect infra-red radiation was again shown to be possible, and one compound was selected for further evaluation in balloon flight testing.

## PROGRAM FOR THE NEXT INTERVAL

### TASK A: PROPERTIES OF BALLOONS AND BALLOON FILMS

#### Phase 1: Study of the Literature

The study of current literature will be continued.

#### Phase 2: Evaluation of Raw Materials

##### Part A: Neoprene Polymers

At least one sample of a new neoprene polymer will be submitted by Du Pont and will be evaluated during the coming quarter.

##### Part B: Polymers other than Neoprene

The evaluation of natural-latex and poly-isoprene latex will be continued, particularly the use of the latter in combination with neoprene.

The investigation of acrylic latices as reinforcing materials will be initiated.

##### Part C: Other Materials

The evaluation of liquid compounding ingredients as replacements for solid antiozonants and anti-oxidants will be inaugurated. These will be used in conjunction with the fine-particle-size zinc oxides.

Further work with Thiocarbanilide as a low-temperature curing agent will also be carried out.

#### Phase 3: Evaluation of Processing Techniques

The investigation of various filter media for straining compounds will be continued and extended.

Additional balloons with integral necks will be manufactured and submitted for flight testing. These will not necessarily be restricted to the same type as already flown.

PROGRAM FOR THE NEXT INTERVAL (continued)

TASK A (continued)

Phase 4: Molecular Structure of Balloon Films

The program for the study of X-ray diffraction and electron-microscope pictures will be begun during this quarter.

Phase 5: Development of Optimum Compounds

Additional new compounds will be prepared on the basis of the information obtained in other phases of this study, and balloons will be prepared for flight testing.

In particular, further balloons in the 1500- and 2500-gram ranges will be made from the high-elongation compound, and 4000-gram balloons made from this compound will be submitted for testing. The performance of the 1000-gram balloon will be confirmed by additional flights.

TASK B: EFFECT OF FLIGHT CONDITIONS ON BALLOON PERFORMANCE

Phase 1: Behavior on Inflation and Rupture

Photographic studies of the inflation and rupture of balloons will be undertaken during this period.

Phase 2: Effect of Pre-Elongation

The effect of pre-elongation on all compounds which contain hitherto unevaluated polymers will be determined. In addition, further work will be carried out on the effect of pre-elongation on natural-latex compounds.

**PROGRAM FOR THE NEXT INTERVAL** (continued)

**TASK B** (continued)

**Phase 3:** **Effect of Ozone**

The ozone resistance of all newly examined polymers will be determined, and the use of liquid antiozonants will be evaluated as already mentioned in Task A, Phase 2, Part C.

**Phase 4:** **Effect of Radiation**

Balloons will be made from the compound showing the lowest infra-red absorption. If 1000-gram balloons perform satisfactorily, this investigation will be extended to larger balloons in order to determine whether or not high infra-red absorption at very high altitudes is responsible for the general failure of big balloons to reach their theoretical altitudes. The more consistent performance of large balloons recently obtained renders such a program much more feasible, and the results obtained should be of very considerable value.

## IDENTIFICATION OF KEY TECHNICAL PERSONNEL

| **Name** | **Number of Hours** |
|---|---|
| Alvin Jampole | 318 |
| Eric Nelson | 241 |
| Harding Wing | 193 |

AD____________________ Accession No.____________________
Kaysam Corporation of America, Paterson, N. J.
Study of Physical and Chemical Characteristics
of Balloons and Balloon Materials
By Eric Nelson, Edited by John Kantor
First Quarterly Progress Report, 31 May 1963
Pages,42-Tables, 21
Signal Corps Contract No. DA-36-039-AMC-02160(E)
Dept. of the Army Project No. 1AD-25001A-126-0104
Unclassified Report

Work was conducted on the following tasks:
TASK A: Properties of Balloons and Balloon Films. The literature was continually reviewed and a conference was held with E. I. du Pont de Nemours on neoprene polymers. Neoprene 673, natural latex and blends of neoprene and poly-isoprene were investigated. Fine particle size zinc oxide and a new plasticizer were examined and the effect of straining compounds through felt was evaluated. A method of making balloons with integral necks was examined. A program for X-ray diffraction and electron microscope study of balloon film was initiated. Balloons were flight tested to correlate laboratory results with flight performance and very good results were obtained with balloons made from a high elonation compound. Very high altitude balloons also performed well.
TASK B: The Effect of Flight Conditions on Balloon Performance. The effect of pre-elongation, ozone and infra-red radiation on newly developed neoprene compounds and natural latex and poly-isoprene-neoprene blends was measured. Compounds designed to show little infra-red radiation absorption were formulated and evaluated.

Unclassified

Meteorological
Balloon Film
Development

USAERDL
Contract No.
DA-36-039-
AMC-02160(E)

METEOROLOGICAL DIVISION
SURVEILLANCE DEPARTMENT
U. S. ARMY SIGNAL RESEARCH & DEVELOPMENT LABORATORY

## DISTRIBUTION

| Organization | No. of Copies |
|---|---|
| Commanding General<br>U. S. Army Electronics Command<br>ATTN: AMSEL-MS<br>Fort Monmouth, New Jersey | 1 |
| Commanding General<br>U. S. Army Electronics Command<br>ATTN: AMSEL-RE-C<br>Fort Monmouth, New Jersey | 1 |
| Chief Signal Officer<br>Department of the Army<br>Washington 25, D. C. | 1 |
| Commander<br>Wright Air Development Division<br>ATTN: WWAD Library<br>Wright-Patterson Air Force Base, Ohio | 1 |
| Commander<br>Rome Air Development Center<br>ATTN: RAOIL-2<br>Griffiss Air Force Base, New York | 1 |
| Hqs, Air Weather Service (MATS)<br>U. S. Air Force<br>ATTN: AWSSS/SIPD<br>Scott Air Force Base, Illinois | 1 |
| Commander<br>Air Force Cambridge Research Laboratories<br>ATTN: CRZW<br>L. G. Hanscom Field<br>Bedford, Massachusetts | 1 |
| Commander<br>Air Force Command and Control Division<br>ATTN: CRO<br>L. G. Hanscom Field<br>Bedford, Massachusetts | 1 |
| Commander<br>Defense Documentation Center<br>ATTN: TISIA<br>Cameron Station, Bldg. 5<br>Alexandria, Virginia 22314 | 10 |

DISTRIBUTION (continued)

| Organization | No. of Copies |
|---|---|
| Director<br>U. S. Naval Research Laboratory<br>ATTN: Code 2027<br>Washington 25, D. C. | 1 |
| Office of the Assistant Secretary of Defense<br>(Research and Engineering)<br>ATTN: Technical Library<br>Room 3E1065, the Pentagon<br>Washington 25, D. C. | 1 |
| Chief<br>Bureau of Naval Weapons (FAME)<br>U. S. Navy Department<br>ATTN: Head, Aerology Branch (MA-5)<br>Washington 25, D. C. | 1 |
| Director, Bureau of Research and Development<br>Federal Aviation Agency<br>Washington 25, D. C. | 1 |
| Commander<br>Hq. Air Research and Development Command (RDRS)<br>Andrews Air Force Base<br>Washington 25, D. C. | 1 |
| Office of Chief of Research and Development<br>Department of the Army<br>ATTN: CRD/M<br>Washington 25, D. C. | 1 |
| Chief<br>United States Army Security Agency<br>ATTN: ACofs, G4 (Technical Library)<br>Cameron Station, Bldg. 5<br>Alexandria, Virginia 22314 | 1 |
| Commanding Officer<br>U. S. Army Electronics R & D Activity<br>ATTN: Meteorological Department<br>Fort Huachuca, Arizona | 1 |
| Library, Boulder Laboratories<br>National Bureau of Standards<br>Boulder, Colorado | 1 |
| Commanding Officer<br>U. S. Army Electronics Material Support Agency<br>ATTN: SELMA-ADJ<br>Fort Monmouth, New Jersey | 1 |

DISTRIBUTION (continued)

| Organization | No. of Copies |
|---|---|
| Commanding Officer<br>U. S. Army Electronics Research and Development Laboratory<br>ATTN: Director of Research<br>Fort Monmouth, New Jersey | 1 |
| Commanding Officer<br>U. S. Army Electronics Research and Development Laboratory<br>ATTN: Chief, Technical Information Division<br>Fort Monmouth, New Jersey | 1 |
| Commanding Officer<br>U. S. Army Electronics Research and Development Laboratory<br>ATTN: Adjutant Branch, Mail File and Records<br>Fort Monmouth, New Jersey | 1 |
| Transportation Officer for Activity Supply Officer<br>USAELRDL, Logistics Division<br>Bldg.#2504, Charles Wood Area<br>Fort Monmouth, New Jersey<br>ATTN: SELRA/SMS<br>Contract No. DA36-039-AMC-02160(E) | 4 |