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RAPRA

Chemical Resistance Data Sheets

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Contents

DATA SHEETS

Each sheet is identified by the letters RA, RB, PA or PB, indicating the series to which it belongs, and one of the serial numbers given below:

ASTM Oil No. 1	1
ASTM Oil No. 3	2
Acetic acid (glacial)	3
Ammonium hydroxide (conc.)	4
Aniline	5
Benzaldehyde	6
Ethyl acetate	7
Ethyl alcohol	8
Hexane	9
Hydrochloric acid (10%)	10
Hydrochloric acid (conc.)	11
Methyl alcohol	12
Methyl ethyl ketone	13
Nitric acid (10%)	14
Nitric acid (70%)	15
Nitrobenzene	16
Perchloroethylene	17
Petrol	18
Phenol	19
Potassium permanganate	20
Sulphuric acid (70%)	21
Sulphuric acid (96%)	22
Toluene	23
Water (distilled)	24
Acetic acid (10%)	25
Acetone	26
Amyl acetate	27
Benzene	28
Benzyl alcohol	29
Carbon tetrachloride	30
Chlorosulphonic acid	31
Cyclohexane	32
Diethyl ether	33
Dimethyl formamide	34
Dioxane	35
Ethylene dichloride	36
Ethylene glycol	37
Formaldehyde (40%)	38
Hydrofluoric acid	39
Hydrogen peroxide	40
Oleic acid	41
Phosphoric acid (conc.)	42
Propylene oxide	43

REFERENCE SHEETS:

Introduction

In the course of its everyday work, RAPRA receives many enquiries from Member companies on specific problems of chemical attack and swelling. In dealing with these some use is made of published charts and tables which indicate in general terms which plastics or rubbers are likely to resist a given fluid. Though such qualitative tables have proved helpful, their criteria of chemical resistance are unspecified and their assessments are not clearly defined. Terms such as "resistant", "attacked", "good", "poor", and "fair" are subjective and could be applied to a fairly broad range of conditions. Furthermore, comparison of these tables sometimes reveals contradictory assessments.

POLICY

However, there also exists a considerable amount of published information giving quantitative evaluations of the behaviour of polymers in fluids, e.g. swelling tests, effects of immersion on mechanical properties, and stress-cracking studies, and we are attempting to bring together such data in a systematic form, mainly for use in answering specific enquiries. It is true that quantitative assessments themselves can, on occasion, be misleading and that the criteria used may not be the most realistic in a given situation. Nevertheless, short of first-hand experience, this is the best type of information available at present. In the end, it is the user who must decide whether a particular plastics or rubber is likely to meet the requirements of his particular application, and we feel that if he is given reliable figures for the performance of a defined material under known conditions and interprets them carefully, his decision will be made on a reasonably sure basis.

The data sheets in this volume are a by-product of the RAPRA file and must be regarded in the light of the policy indicated above: the figures quoted have been obtained from many different sources and discretion should be used in comparing the performances of the various polymers. As a general rule we have selected data for the longest period of continuous immersion of a material of known composition and characteristics in a given fluid, at room temperature and at the highest temperature for which figures are available. The values quoted are, therefore, not necessarily the best that might be achieved but they are believed to be sufficiently representative to enable an accurate opinion to be reached regarding the suitability of the material for a given application. Where insufficient information has been found in the literature, tests have been specially run in the RAPRA laboratories.

PROGRAMME

We hope to publish a series of sets of data sheets during the next few years. All will be in loose-leaf form, suitable for insertion in the special binder which is available to subscribers. The collection is expected eventually to comprise 8 sets, consisting of 24 data sheets (plus bibliographical material), each sheet listing data on the resistance of 6 plastics or rubbers to a given fluid:

Revised: January 1971

Part 1 (Serial numbers RA1 to 24): Data on a first series of 24 fluids for 6 rubbers

Part 2 (Serial numbers PA1 to 24): Data on a first series of 24 fluids for 6 plastics

Part 3 (Serial numbers RA25 to 48): Data on a second series of 24 fluids for first series of 6 rubbers

Part 4 (Serial numbers PB25 to 48): Data on a second series of 24 fluids for first series of 6 plastics

Parts 5 to 8 (Serial numbers RB, PB 1 to 48): Data on 48 Fluids for two further series of rubbers and plastics.

The fluids chosen are those for which most data are available in the literature; they are representatives of the main types of industrial chemicals: inorganic and organic acids, alkalis, salts, esters, ketones, hydrocarbons etc. Ultimately, 48 fluids in all will be covered and these are expected to correspond roughly to the fluids listed in specifications such as ISO Recommendation R175-1961 and ASTM D543-67.

The polymers selected for study are those believed to be of most interest from the point of view of chemical plant, oil-seals, tubing and hose, and similar applications. They will ultimately number 12 rubbers and 12 plastics.

In addition to the synoptic type of data sheet, it is felt that there is a need to bring together information on the chemical resistance of certain individual polymers from different sources, to enable studies to be made of the differences in results due to such factors as compounding variables, test conditions, polymer crystallinity, and so on. Consideration is, therefore, being given to the publication of "monographs" on a few of the more common plastics and rubbers, summarising whatever data we have in our files at the time of publication.

The above programme represents a formidable amount of work: to fill the weight or volume change column alone on all the data sheets will require over 2000 values. It is too much to expect that all these will be found in the published literature and RAPRA is carrying out practical work to fill some of the inevitable gaps. However, the facilities we can devote to this purpose are limited and we hope that interested Members, who may themselves have carried out tests, will be prepared to contribute their results. Some, indeed, have already done so and we expect to incorporate their data in future parts of this publication or in the monographs. Any readers interested in helping with this project are invited to write for further details.

ACKNOWLEDGEMENTS

The sources used in the compilation of the present sets of data sheets are listed in the bibliographical section. Most of them are readily available trade publications but we would particularly like to acknowledge the cooperation of Farbenfabriken Bayer AG and Imperial Chemical Industries Ltd. in allowing us to make use of publications with more restricted circulation. We also wish to thank Mr. V. Evans of Prodorite Ltd. and Mr. J.D.D. Morgan and Mr. D. Street of ICI Ltd., Mond Division for valuable comments.

Chemical Resistance of Rubbers and Plastics

The practical applications of chemical resistance so far as high polymers are concerned are so subject to variation that it would be misguided to attempt to produce a text book. For this reason, it must be emphasized that the present volume in no way seeks to do this. It is rather a compilation of reliable published data from which the chemical engineer may be helped to reach a decision on the possibility of using high polymers in the chemical environments detailed in the following pages.

The ways in which polymers can be attacked are basically two in number.

SWELLING BY INERT LIQUIDS

Recent work directed towards the prediction of a polymer's resistance to swelling fluids on theoretical grounds is well-known. For a convenient account of this, the reader's attention is directed towards the paper by Beerbower, Kaye and Pattison (1), which deals with the use of what are termed the 'three solvency indices', solubility parameter (i.e. the square root of the cohesive energy density), hydrogen bonding and dipole moment. This is not the place to deal with these concepts, but it may be remarked that although such theoretical treatment can be of great use as a preliminary sorting process, in the final analysis the practical plant designer will not be satisfied with this. It is certain that if materials for a component which is vital to the successful operation of a process have to be examined, then practical measurement of the environment's effect on physical properties is required.

CHEMICAL ATTACK

In addition to attack from swelling agents there is chemical attack by degradation, in which instance the application of 'solvency indices' is clearly of little relevance. Degradation implies an alteration of the chemical structure of the polymer, whether by simple chain scission or by more complex alteration of molecular structure. In such cases, testing is essential.

While it is our belief that the data sheets which follow will prove useful, there are certain generalisations which must be borne in mind when using them.

(i) Effects of Temperature

We have here given measurements which have been obtained at ambient and at elevated temperature. Inevitably, cases will arise where information on a polymer's behaviour at very low or high temperatures is required. In these cases, it is not sufficient to carry out a mental extrapolation. At low temperatures, a rubber hardens and its rigidity (as shown by modulus measurements) increases. This effect would be critical in an application involving its use as a seal. Similarly, a plastic material such as PVC would become more susceptible to impact, and the risk of a curtailed life thus increased.

At elevated temperatures chemical attack is accelerated and other complicating features arise, such as oxidation, cross-linking and chain scission. The accuracy of accelerated immersion tests carried out in industrial laboratories must be open to question, owing to the possible complexity of degradation processes and the complications produced by sample thicknesses, e.g. variable degrees of oxidation, although Orzhakhovskii (2) has predicted the service life of thin films in simple chemical environments by extrapolation techniques.

Similarly, in the case of inert swelling agents, temperature can affect both the penetration rate and the equilibrium swelling value. For a discussion of this aspect, the reader is referred to a paper recently published by Blow, Exley and Southwart (3).

(ii) Effects of Pressure and Stress

Polymers are not often used as constructional materials in plants which deviate greatly from ambient pressures, although their importance for ancillary purposes remains, particularly their use as sealants, when their permeability to gases has to be considered.

However, the effects of inbuilt stress on plastics being used in contact with chemical media has recently come into prominence owing to a number of plant failures. In particular stress-cracking has been observed on or near weld areas. Quite clearly, it is not possible to gain information on this point from normal immersion tests; however, the Bell Telephone Laboratories test gives a rapid relative assessment of the ability of liquids to crack polyethylenes (ASTM D 1693-66) and Manin and his co-workers (4) have proposed methods to indicate the corrosion resistance of rigid and semi-rigid plastics both under static and under dynamic oscillating loads.

(iii) Compounding and Cure of Rubber

This subject introduces many variables which, however, probably need only be taken into consideration when the question of use is not clear-cut. That is to say, when an elastomer is known to be perfectly chemically resistant to an environment compounding exerts relatively little influence; the same obviously applies in cases of severe attack. In the instances where some attack is recorded, and when no better material is available, then compounding and processing can tip the balance.

In the case of swelling agents it is evident that reduction of available rubber by an increase of compounding ingredients will in itself reduce the volume increase.

The following factors are possiblv of most importance:

(a) Fillers

Quite clearly only inert fillers must be used at any time where chemical attack is involved. When choosing between blacks on the one hand, and possible non-reinforcing alternatives on the other, it will be apparent that the former present advantages in that they are lighter and therefore more economical when purchasing by weight. Further, while siliceous fillers are normally classified as inert materials, they are susceptible to attack by certain fluorine compounds and hot concentrated alkalies.

Zuev (5) has examined the behaviour of stressed vulcanisates in corrosive media while varying the type and amount of filler used. It was found that when employing fillers which increase the chemical strength and stability of the vulcanisate a higher stress is required to cause break in a given time.

Apart from this, a comparison (6) of the behaviour of a white clay compound of EPR with a carbon black compound when immersed under no stress in a variety of fluids, both organic and inorganic, leads to the general conclusion that when attack occurs it is normally more severe in the former case. However, in the particular instance of swelling fluids, it is known that graphite, by virtue of its laminar structure can impede penetration and use of this fact has been made in, for example, certain commercially available ebonite linings.

(b) Vulcanising systems

Where resistance to heat is a prime requirement, a suitable system will automatically be employed. Insofar as pure resistance to chemical attack is concerned, it will be generally good practice to obtain the 'tightest' possible cure. A maximum of cross-links will also keep swelling to a minimum.

(c) Plasticisers and extenders

These can frequently be leached out of compounds particularly when in contact with organic fluids. The use of plasticisers is particularly widespread in the case of nitrile rubbers and when used for applications such as oil resistance considerable losses may occur. However, in practice, as long as drying out of the material does not occur failure for this cause is unlikely since the plasticiser is replaced by the fluid.

(iv) Compounding of Plastics

In general the compounding of plastics is less complex than conventional rubber compounding although plasticised PVC compounds are an exception. These are not normally employed where solvent resistance is required since, for example, plasticiser migration can readily occur. However, they are quite extensively used for linings under acid conditions, particularly in metal descaling and pickling tanks. Unplasticised PVC is extensively used in chemical plant construction, and here the factor of greatest importance will be polymer type, in particular whether it is a copolymer or whether a second polymer has been introduced for other reasons. Similarly, in the case of polyethylenes, molecular weight is a critical factor in determining resistance to environmental stress-cracking.

Use of Tables

The properties of non-metallic materials in general are not nearly so well known to engineers as those of metals. Ignorance of polymers' properties both on the part of design and plant operating engineers must be responsible for many plant failures and consequent loss of production. Whenever the factory is large enough to justify the employment of a materials specialist the engineer should turn to him for advice. In cases where there is no such person available it is worth while consulting an independent testing laboratory, the raw material supplier or a professional consultant. These tables are intended principally for the materials specialist, but other technical personnel may also find it necessary to make use of them. Many polymer manufacturers are now publishing actual test data, but to our knowledge these have not previously been gathered together in one volume.

The suitability of a polymer depends essentially on the end-use. In the important field of rubber linings Droge (7) suggests that weight changes, measured over a minimum 28 day period, may be interpreted as follows:

Less than ± 1% - practically resistant
± 1% to ± 5% - fairly resistant
± 5% to ± 12% - doubtful ("nicht besonders beständig")
Over 12% - not resistant

These are possibly a little conservative. However, an assessment of weight or volume change together with any alteration in hardness is a good guide for lining materials which do not have to stand stresses, although additional tensile tests are of great use as supporting evidence. In the case of swelling agents tests should be continued until equilibrium is attained. It is further necessary to define the surface area/volume ratio, as well as the temperature of test.

When plastics are to be used for structural purposes in chemical plant physical test data are essential. Long term rupture tests on plastics laminates should be carried out after immersion in the media. At present, figures available are mainly those derived from tensile tests, but an increasing body of opinion appears to favour the use of flexural strength determinations.

In cases where 'some attack' has been recorded the following factors should be taken into consideration: size and shape of polymeric component, whether immersion is total or partial, pressure, temperature, concentration of aggressive medium and, finally, the existence of abrasive or erosive conditions. Chemical attack can also produce by initial degradation a surface layer of modified polymer. For example, the attack of chlorine on ebonites is initially degradative, but the chlorinated surface layer finally affords protection against further attack.

A thick component will withstand both chemical attack and swelling (8) better than a thin one; similarly attack will be slower if one side only is exposed. Conditions immediately above the surface of the contained liquid may be more severe than beneath it. Many instances are known, for example, of swollen rubber linings resulting from the effects of steam given off by a liquid at a comparatively low temperature and here the obvious remedy is to use a non-permeable elastomer such as butyl. It need hardly be stressed that the design temperature and pressure of the plant should be checked against the capabilities of the polymer. Useful guidance here can often be obtained from B.S.I. and similar publications, for example, B.S. Code of Practice CP 3003: Parts I, 4, 5 & 6; B.S.S. 1973 & 3506; Engineering Equipment Users Association Handbook No. 21.

Normally, purely chemical attack is reduced by dilution of the agressive reagent with an inert liquid. Similarly, the diffusion coefficient and the penetration rate of many swelling agents are concentration dependant, as may be illustrated by dilution with an inert liquid (3). This is, however, an ideal case and Ermolenko (9) has shown that in cases of some mixtures of nonpolar and strongly polar liquids (such as benzene and nitrobenzene) the swelling of vulcanisates reaches a maximum in the low concentration range of the polar component. The behaviour of certain rubbers and plastics in binary solvent mixtures was later examined by Bristow & Watson (10) who related the calculated cohesive energy density of the mixture range to the swelling produced, showing that swelling maxima do not occur at cohesive energy density values characteristic of the polymer.

In practice it is quite unsafe to assume that because a known swelling agent is present in small quantities in an otherwise inert environment its presence may be tolerated. There is a considerable risk that selective absorption of the agent by the polymer over a long period of time may result in eventual failure of the component.

Where there is a certain amount of degradation or swelling under abrasive or erosive conditions much thought should be given to the probability that the affected upper layers will be continually removed in service with consequent thinning of the component or protective coating. The use of thicker materials will only delay the ultimate failure and the best answer will be found by using other materials or altering the design of the system.

One additional point which is sometimes forgotten is the effect of the container or lining material on the chemicals being handled. This is not often a problem in heavy chemical production where both the low level of contamination and the final end-use can mean that this may be safely ignored. Exceptions occur, however, in the case of handling potentially explosive materials, pharmaceuticals and foodstuff. In the first instance organic materials are, as a general rule, best avoided; in the other two cases most users have their own specifications controlling the use of compounding ingredients which might be leached out during manufacture and, indeed, some countries (notably Germany and the U.S.A.) have national specifications which carry legal force.

Finally, polymers should be used with caution when handling highly toxic materials, such as cyanides, since these materials can be absorbed and retained by the lining, thus hindering maintenance and cleaning of the equipment.

References:

1. Beerbower, Kaye and Pattison - Chem. Eng. p. 121 (18-12-67).
2. Orzhakhovskii - Soviet Plastics No. 5, p. 60 (1966).
3. Blow, Exley and Southwart - J.I.R.I., 2, (6), 282 (1968).
4. Manin et al. - Soviet Plastics No. 1, p. 66 (1968).
5. Zuev & Borshchevskaya - Soviet Rubber Tech. 25, (1), 24 (1966).
6. Butt & English - Unpublished work.
7. Droge - De Nederlandse Rubberindustrie 27, (7), 1 (1966).
8. Southern - Chapter 4 "The Use of Rubber in Engineering", N.R.P.R.A. 1967.
9. Ermolenko et al. - Rubber Chem. & Tech. 28, (3), 833 (1955).
10. Bristow & Watson - Trans. I.R.I. 35, (3), 73 (1959).

Notes on Use of Data Sheets

Changes in weight or volume are positive, i.e. increases, unless otherwise indicated. As a general rule it will be found that swelling (or shrinkage) is expressed as a weight change in the case of plastics and as a volume change in the case of rubbers. Where the specific gravity of the liquid in question is close to that of the plastics or rubber, the values of weight and volume changes will not differ very greatly.

Abbreviations

EB = Elongation at break

HB = Brinell hardness (60 second reading)

NIS = Notched impact strength (nb = no break)

SBS = Shear strength in metal-metal adhesive bond.

TS = Tensile strength

All given as value retained after immersion expressed as percentage of value obtained before immersion (original value)

H = Increase (+) or decrease (-) in hardness of specimen after immersion, measured in International Rubber Hardness Degrees (IRHD) or points on the Shore A scale. For present purposes these two systems of units may be regarded as substantially identical.

The original values (before immersion) where known are given in the appropriate Reference Sheets.

ALPHABETICAL INDEX TO DATA SHEETS (including synonyms)

RAPRA Data Sheet RA 1

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ASTM Oil No. 1

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A 1	24	365	-	45.8	43.4	56.9	-23
	A 1	100	3	-	64.3	38.0	56.3	-34
Ethylene-propylene rubbers	B 3	24	365	-	90.9	47.8	43.7	-18
	B 3	100	3	-	83.1	51.7	49.5	-25
Fluorine-containing rubbers	C 4	RT	28	-	4.5	73	98	+3
	C 3	150	7	-	0.1	85	93	0
Natural rubber	D 1	24	365	-	48.1	68.9	67.7	-20
	D 1	100	3	-	77.6	38.7	70	-34
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E 1	24	365	-	-0.7	105.9	87.7	0 *
	E 1	100	3	-	-1.17	118.6	79.4	-1
Polychloroprene	F 1	24	365	-	1.1	98.9	94.2	0
	F 1	100	3	-	5.74	100	88.3	-4

***See notes overleaf**

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

NOTES

Nitrile rubber

For a detailed study of resistance to ASTM Oil No. 1 see: B.F. GOODRICH CHEM. CO., "Specification Compounding", Manual HM-5, Cleveland, 1959.

RAPRA Data Sheet RA 2

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ASTM Oil No. 3

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A 1	24	365	-	151.8	31.3	30	-32
	A 1	100	3	-	173.4	16.3	40.6	-46
Ethylene-propylene rubbers	B 3	24	365	-	144.4	42.8	36.3	-22
	B 3	100	3	-	119.9	35.9	37.2	-28
Fluorine-containing rubbers	C 4	RT	28	-	9.2	74	98	+3
	C 2	149	14	-	2.9	87	122	-3
Natural rubber	D 1	24	365	-	128.8	33.4	34.6	-23
	D 1	100	3	-	143.9	11.2	50.8	-35
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E 1	24	365	-	9	94.1	79.4	-5 *
	E 1	100	3	-	11.3	104.4	83	-7
Polychloroprene	F 1	24	365	-	43.8	78.5	79.4	-19
	F 1	100	3	-	61.7	46.1	67.3	-24

* See notes overleaf

TS = Retained Tensile Strength (%)

EB = Retained Elongation at Break (%)

H = Hardness change (IRHD)

NOTES

Nitrile rubber

For a detailed study of resistance to ASTM Oil No. 3 see: B.F. GOODRICH CHEM. CO., "Specification Compounding", Manual HM-5, Cleveland, 1959.

RAPRA Data Sheet RA 3

Acetic acid (glacial)

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Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A 1	24	365	-	10.7	88.6	92.2	-9
	A 1	100	3	-	14.7	79.5	67.2	-3
Ethylene-propylene rubbers	B 1	30	14	13	14	90	83	-4
	B 1	70	14	23	26	78	70	-2
Fluorine-containing rubbers	C 6	20	40	SEVERELY ATTACKED		29	115	-33
	C 5	50	84	59.1	-	19	46	-27
Natural rubber	D 2	RT	28	-	22.5	41	52	-11
	D 2	70	DISINTEGRATES					
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E 2	RT	90	-	31	NO NOTICEABLE CHANGE IN FLEXIBILITY		
	E 2	70	DISINTEGRATES					
Polychloroprene	F 4c	28	28	-	57	-	-	-
	F 4h	94	7	-	60	-	-	- *

* See notes overleaf

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

RA3

NOTES

Polychloroprene

Ref. F2. Values obtained after 84 days at 100°C: Wt. change: -9.6. Tensile props. "destroyed". H + 19.

RAPRA Data Sheet RA 4

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Revised: January 1970

Ammonium hydroxide
(conc. = 30/35% NH_3)

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A 1	24	365	-	7.39	101.2	89.6	-3
	A 1	100	3	-	1.88	105.4	96.1	-3
Ethylene-propylene rubbers	B 1	30	14	0	-	91	95	0
	B 2	100	3 approx	-	1.6	106	79	-4
Fluorine-containing rubbers	C 1	24	28	3.5	7.5	85	100	-3
Natural rubber	D 2	RT	28	-	15.8	100	122	-5
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E 2	RT	90	-	12	NO NOTICEABLE CHANGE IN FLEXIBILITY		
	E 2	70	60	-	19	SLIGHT CHANGE IN FLEXIBILITY		
Polychloroprene	F 4c	28	28	-	4	-	-	-

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

RAPRA Data Sheet RA 5

Issued : April 1969

Aniline

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer).	A 1	24	365	-	7.33	98.8	103.9	-13
	A 1	100	3	-	7.97	98.2	109.2	-15
Ethylene-propylene rubbers	B 3	24	365	-	6.53	95	95.2	-3
	B 3	100	3	-	1.72	98.5	87.6	-1
Fluorine-containing rubbers	C 1	24	7	-	3	100	100	-1
	C 1	70	28	-	26	60	150	-29
Natural rubber	D 1	24	365	-	14.1	83.6	84.8	-7
	D 1	100	3	-	32.1	30.2	45.5	-19
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E 1	24	365	-	230.1	17.4	22.7	-28
	E 1	100	3	-	250.9	17.8	21.7	-34
Polychloroprene	F 1	24	365	-	65.9	28.2	67.3	-38
	F 1	100	3	-	143.3	22.9	58.3	-45

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

RAPRA Data Sheet RA 6

Issued : April 1969

Benzaldehyde

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A 1	24	365	-	7.28	92.2	98.6	-13
	A 1	100	3	-	12.3	94.6	102	-19
Ethylene-propylene rubbers	B 3	24	365	-	7.63	87.9	80	-4
	B 3	100	3	-	12.8	77	72.4	-10
Fluorine-containing rubbers	C 1	24	3	-	67	-	-	-17
	C 4	70	28	-	36.8	35	89	-28
Natural rubber	D 1	24	365	-	106.8	4.3	19.2	-36
	D 1	100	3	-	244.8	4.3	16.2	-25
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E 1	24	365	-	216.3	20.6	24.2	-23
	E 1	100	3	-	229.5	20.6	19.9	-28
Polychloroprene	F 1	24	365	-	190	7.4	35.9	-51
	F 1	100	3	-	61.3	25	40.4	-35

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

RAPRA Data Sheet RA 7

Ethyl acetate

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Revised: January 1970

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A1	24	365	-	8.75	78.3	88.2	-12
	A1	77	3	-	14.7	60.2	67.3	-17
Ethylene-propylene rubbers	B4	24	28	-	10	78	85	+1
	B5	70	28	-	15.8	80	72	-3
Fluorine-containing rubbers	C5	20	28	107.4	-	13	24	-10
	C4	70	28	-	258	21	45.6	-21
Natural rubber	D3	RT	28	50.3	-	66	70	-6
	D2	70	28	-	90.7	3.6	62	-
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E4	20	28	98.3	-	27	37	-14
	E2	70	60	-	112	-	-	-
Polychloroprene	F2	20	28	48.8	-	41	50	-14
	F3	70	28	-	77.2	33.5	75	-32

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

RAPRA Data Sheet RA 8

Issued : April 1969

Ethyl alcohol

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A1	24	365	-	0.89	94	96.1	-2
	A1	78	3	-	2.04	91	82.9	-3
Ethylene-propylene rubbers	B3	24	365	-	0.33	100.3	93.5	0
	B3	78	3	-	-3.47	95.6	83.6	+1
Fluorine-containing rubbers	C1	24	28	-	6	-	-	-10
	C3	70	7	-	14	48	105	-14
Natural rubber	D1	24	365	-	3.59	74.8	68.6	-2
	D1	78	3	-	2.35	78.4	78.5	0
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E1	24	365	-	14.2	81.8	75.8	-9
	E2	70	60	-	15	MODERATE CHANGE IN FLEXIBILITY		
Polychloroprene	F1	24	365	-	6.05	89.8	86.6	-4
	F1	78	3	-	2.92	85.6	79.4	-4

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

RAPRA Data Sheet RA 9

Issued : April 1969

Hexane

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A1	24	365	-	125.5	21.1	23.5	-28
	A1	69	3	-	94.4	22.3	22.2	-32
Ethylene-propylene rubbers	B3	24	365	-	128.3	30.4	29.5	-13
	B3	69	3	-	93.4	28.1	25.8	-18
Fluorine-containing rubbers	C3	25	32	-	0.6	80	103	+1
	C4	69	28	-	6.1	76	109	-1
Natural rubber	D1	24	365	-	81.7	25.3	30	-20
	D1	69	3	-	108.8	26.2	28.4	-20
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E1	24	365	-	26.9	85.8	76.9	-7
	E1	69	3	-	9.71	66.4	57.8	-9
Polychloroprene	F1	24	365	-	20.8	65.1	70.4	-13
	F1	69	3	-	24.5	78.5	80.7	-15

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

RAPRA Data Sheet RA 10

Issued : April 1969

Hydrochloric acid (10%)

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A1	24	365	-	0.37	104.8	102	+2
	A1	100	3	-	3.70	96.4	78.4	-2
Ethylene-propylene rubbers	B3	24	365	-	3.86	88	80	+1
	B3	100	3	-	14.6	74.8	60	0
Fluorine-containing rubbers	C4	RT	28	-	7.6	96	97	-2
	C4	70	28	-	90.7	-	-	-
Natural rubber	D1	24	365	-	5.06	67.2	60.1	+2
	D1	100	3	-	11.2	61	49.2	-4
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E1	24	365	-	3.25	106.3	86.6	-3
	E1	100	3	-	11.8	92.1	75.8	-4
Polychloroprene	F1	24	365	-	9.13	95.8	73.1	0
	F1	100	3	-	15.1	93.3	76.2	-8

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

RAPRA Data Sheet RA 11

Issued : April 1969
Revised: January 1970

Hydrochloric acid (conc. =37%)

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A1	24	365	-	11.2	56	88.8	-11
	A1	100	3	-	15.9	81.9	109.8	-8
Ethylene-propylene rubbers	B3	24	365	-	18.3	79.7	66.5	0
	B3	100	3	-	32.3	70.7	60.9	-8
Fluorine-containing rubbers	C2	38	1095	-	8.7	75	33	-9
	C1	110	14	-	39	-	-	-
Natural rubber	D2	RT	28	-	9.2	58	39.5	+16
				-	-		-	
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E3	RT	28	-	12.5	119	49	+4
	E2	70	60	-	31	FAILS 180° BEND TEST		
Polychloroprene	F3	RT	28	-	6.1	97	96	-4
	F4h	93	7	-	70	-	-	-

* See notes overleaf.

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

NOTES

Polychloroprene

Similar compound, cured with zinc oxide and magnesia instead of litharge, gives 120% volume swelling under same conditions.

RAPRA Data Sheet RA 12

Methyl alcohol

Issued : April 1969
Revised: January 1970

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A1	24	365	-	1.64	97.6	96.1	-2
	A1	65	3	-	0.63	98.2	91.6	+2
Ethylene-propylene rubbers	B1	30	14	1	-	87	85	-1
	B5	70	28	-	7.6	108	88	-2
Fluorine-containing rubbers	C2	24	7	-	42	-	-	-
	C5	50	20	36.1	-	24	54	-21
Natural rubber	D2	RT	28	-	0	74	94	-1
	D3	50	20	0.3	-	87	82	+6
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E2	RT	90	-	3	-	-	-
	E4	50	20	14.1	-	62	64	-8
Polychloroprene	F4d	25	60	-	6	-	-	-
	F2	50	20	12.2	-	89	70	-10

* See notes overleaf

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

NOTES

Fluorine-containing rubbers

Ref. C4: Effects on properties after 28 days at RT:- TS 40.5; EB 88.2; H - 32.

Nitrile rubber

Ref. E3: Effects on properties after 28 days at RT:- TS 76; EB 68; H - 7.

Polychloroprene

Ref. F3: Effects on properties after 28 days at RT:- TS 80.5; EB 86.5; H - 4.

RAPRA Data Sheet RA 13

Issued : April 1969

Methyl ethyl ketone

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A1	24	365	-	8.60	83.1	88.8	-11
	A1	80	3	-	15.7	48.8	53.5	-18
Ethylene-propylene rubbers	B3	24	365	-	2.04	74.6	73.5	-1
	B3	80	3	-	5.15	72.1	73.5	-7
Fluorine-containing rubbers	C5	20	20	100.8	-	13	33	-13
	C5	50	20	97.3	-	9	22	-11
Natural rubber	D1	24	365	-	47.2	44.6	51.5	-21
	D1	80	3	-	57	13.4	32.3	-30
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E1	24	365	-	151.6	24.9	25.3	-24
	E1	80	3	-	108.8	25.7	24.2	-24
Polychloroprene	F1	24	365	-	94.4	21.5	55.2	-38
	F1	80	3	-	72.3	32.4	52.5	-28

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

RAPRA Data Sheet RA 14

Issued : April 1969

Revised: January 1970

Nitric acid (10%)

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A 1	24	365	-	1.64	101.2	101.4	0
	A 1	100	3	-	9.09	-	-	-
Ethylene-propylene rubbers	B 5	RT	28	-	1.5	100	114	-2
	B 5	70	28	-	110	33.5	69	*
Fluorine-containing rubbers	C 4	RT	28	-	22.5	100	100	-4
	C 4	70	28	-	186	17	208	-
Natural rubber	D 2	RT	28	-	0	61	94	0
	D 2	70	28	DISINTEGRATES				
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E 3	RT	28	-	12.5	68	76	+3
	E 3	70	28	DISINTEGRATES				
Polychloroprene	F3	RT	28	-	3.0	72	75	-2
	F3	70	28	*DISINTEGRATES*				

*** See notes overleaf**

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

NOTES

Butyl rubber

Surface of sample very tacky.

Ethylene-propylene rubber

Surface of sample eroded; too soft to measure hardness.

RAPRA Data Sheet RA 15

Issued : April 1969
Revised: January 1970

Nitric acid (70%)

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on * properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A4	25	7	16	-	14.1	42.5	-
	A2	70	28	DISINTEGRATES				
Ethylene-propylene rubbers	B4	24	28	-	20	-	-	-47
	B5	70	28	DISINTEGRATES				
Fluorine-containing rubbers	C2	38	365	-	38	2	510	-35
	C2	70	3	-	28	38	375	-35
Natural rubber	D2	RT	28	DISINTEGRATES				
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E3	RT	28	DISINTEGRATES				
Polychloroprene	F3	RT	28	DISINTEGRATES				

* See notes overleaf

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

NOTES

No high temperature tests were carried out in the cases of natural and nitrile rubbers, or polychloroprene; on the basis of behaviour at room temperature it is assumed that disintegration will also occur at higher temperatures.

Butyl rubber

Values overleaf are for low unsaturation rubber. Similar compound based on high unsaturation rubber (3.0 mole %) gives following results:- Wt. increase (%): 7.5. Retained properties (%):- TS 29.5, EB 61.

RAPRA Data Sheet RA 16

Issued : April 1969

Revised: January 1970

Nitrobenzene

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A1	24	365	-	3.36	94.6	101.4	-11
	A1	100	3	-	11.9	101.2	106.9	-20
Ethylene-propylene rubbers	B5	RT	28	-	1.5	100	114	-2
	B5	70	28	-	0	101	99	-6
Fluorine-containing rubbers	C2	24	10	-	15	-	-	-
	C5	50	28	37.5	-	32	45	-14
Natural rubber	D2	RT	28	-	68.5	23.5	46	-23
	D2	70	28	DISINTEGRATES				
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E2	RT	15	-	246	-	-	-
	E4	50	28	255.7	-	19	22	-17
Polychloroprene	F4b	28	28	-	140	-	-	-
	F3	70	28	-	174	0	3.5	-

* See notes overleaf

TS = Retained Tensile Strength (%)

EB = Retained Elongation at Break (%)

H = Hardness change (IRHD)

NOTES

Fluorine-containing rubbers

Ref. C4: Effects on properties after 28 days at RT:- TS 31.3; EB 91; H - 27.

Nitrile rubber

Ref. E3: Effects on properties after 28 days at RT:- TS 24.8; EB 24.8; H - 22.

Polychloroprene

Ref. F3: Effects on properties after 28 days at RT:- TS 17; EB 29: H - 35. Sample too soft to measure hardness after 28 days at 70°C.

RAPRA Data Sheet RA 17

Issued : April 1969

Perchloroethylene

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A1	24	365	-	200.5	16.3	18.2	-33
	A1	100	3	-	194.3	12.7	17.1	-46
Ethylene-propylene rubbers	B3	24	365	-	75.9	32.7	31.5	-14
	B3	100	3	-	109.7	20.7	31.4	-27
Fluorine-containing rubbers	C5	20	28	1.4	-	82	66	-2
	C3	70	7	-	7	80	113	-7
Natural rubber	D1	24	365	-	211.4	13.1	19.2	-30
	D1	100	3	-	465.4	3.6	17.8	-43
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E1	24	365	-	59.6	57.7	55.2	-18
	E1	100	3	-	51.4	43.5	48	-22
Polychloroprene	F1	24	365	-	147.5	25	37.2	-31
	F1	100	3	-	242.9	22.9	42.6	-38

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

RAPRA Data Sheet RA 18

Issued : April 1969

Petrol

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A 1	24	365	-	183.4	18.7	21.6	-31
	A 1	Boiling	3	-	181.9	15.7	20.2	-39
Ethylene-propylene rubbers	B 3	24	365	-	110.4	38.7	36.3	-18
	B 3	Boiling	3	-	121.8	35.5	38	-25
Fluorine-containing rubbers	C 3	25	7	-	0.5 to 0.85	90 to 95	95 to 115	+2
	C 6	50	40	-	-	109	92	0
Natural rubber								
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E 1	24	365	-	27.6	72.7	72.2	-14
	E 1	Boiling	3	-	29.1	62.9	62.9	-16
Polychloroprene	F 1	24	365	-	54.6	47.9	67.3	-23
	F 1	Boiling	3	-	69.6	41.2	58.3	-28

***See notes overleaf**

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

NOTES

A lead-containing RON 99 petrol was used in tests on Butyl, ethylene-propylene, and nitrile rubbers, and polychloroprene.

For a more detailed study of petrol resistance in nitrile rubbers and polychloroprene see:

THIOKOL CHEMICAL CORP.: "Study of the effects of high aromatic fuels on elastomers", Polysulfide Rubber Bulletin, Trenton, 1957.

RAPRA Data Sheet RA 19

Phenol

Issued : April 1969

Revised: January 1970

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A1	24	365	-	4.50	98.8	109.8	-14
	A1	100	3	-	-7.54	116.3	110.4	-7
Ethylene-propylene rubbers	B1	30	14	-	3,5	86	78	-4
	B5	70	28	-	3.0	95	125	-3
Fluorine-containing rubbers	C1	24	3	-	0	-	-	0
	C1	149	28	13	24	57	210	-19
Natural rubber	D2	RT	28	-	9.2	86	112	-10
	D2	70	28	-	12.5	17.2	71	*
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E3	RT	28	-	205	19.6	18.2	-19
	E3	70	28	-	231	8.1	25.5	*
Polychloroprene	F4b	28	28	-	25	-	-	-
	F4a	70	28	-	210	-	-	-

* See notes overleaf

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

NOTES

Samples too soft to measure hardness in cases of natural and nitrile rubbers.

RAPRA Data Sheet RA 20

Issued : April 1969

Potassium permanganate (25%) *

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A1	24	365	-	8.34	80.7	87.7	-3
	A1	100	3	-	0.58	93.4	84.3	-6
Ethylene-propylene rubbers	B3	24	365	-	2.46	101.8	93.4	+2
	B3	100	3	-	1.65	99.5	78	+1
Fluorine-containing rubbers	C4	RT	28	-	3.0	70	77	+3
	C4	70	28	-	6.1	58	114	+5
Natural rubber	D1	24	365	-	1.29	71.2	67	-3
	D1	100	3	-	3.15	54.4	49.2	-1
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E1	24	365	-	1.92	97.2	89.2	-6
	E1	100	3	-	-5.87	83	57.8	+1
Polychloroprene	F1	24	365	-	13	90.5	70.4	-4
	F1	100	3	-	3.07	89.1	71.8	+2

* See notes overleaf

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

NOTES

25% concentration (25g/100g of solution) is attainable only at or above c. 75° presumably when the solution was used at lower temperatures some of the so had separated, leaving a less concentrated (saturated) solution as indicated b

Temp., °C	Concentration, g/100g solu
20	6.0
25	7.6
75	24.5

RAPRA Data Sheet RA 21

Issued : April 1969
Revised: January 1970

Sulphuric acid (70%)

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A 2	RT	28	-	9.2	80	106	-9
	A 3	50	84	18.5	-	17.8	116	-23
Ethylene-propylene rubbers	B5	RT	28	-	0		93	-5
	B 6	100	84	36.7	-	9	20	+28
Fluorine-containing rubbers	C 4	RT	28	-	3.0	78	47.5	+7
	C 5	100	84	24.8	-	79	63	0
Natural rubber	D2	RT	28	-	3	6.5	4.9	+18
	D 3	50	1	4.2	-	18	21	+28
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E 2	RT	90	-	87	-	-	-
	E 2	70	7	DISINTEGRATES				
Polychloroprene	F3	RT	28	-	0	71.5	63.8	-5
	F2	50	1	0.2	-	19	11	+22

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

RAPRA Data Sheet RA 22

Issued : April 1969
Revised: January 1970

Sulphuric acid (98%)

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A 2	RT	DISINTEGRATES					
Ethylene-propylene rubbers	B 1	30	14	19	-	63	76	-6
	B 1	70	14	8.5	-	30	40	+3
Fluorine-containing rubbers	C 3	25	7	-	2.1	99	98	-3
	C 3	70	7	-	8	80	94	-4
Natural rubber	D 2	RT	DISINTEGRATES					
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E 3	RT	DISINTEGRATES					
Polychloroprene	F3	RT	DISINTEGRATES					

*** See notes overleaf**

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

NOTES

No high temperature tests were carried out in the cases of Butyl, natural, and nitrile rubbers, or polychloroprene; on the basis of behaviour at room temperature it is assumed that disintegration will also occur at higher temperatures.

RAPRA Data Sheet RA 23

Issued : April 1969

Toluene

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A1	24	365	-	128.5	18.7	26.1	-31
	A1	100	3	-	198	10.2	26.1	-51
Ethylene-propylene rubbers	B5	RT	28	-	174	38	38	-15
	B5	70	28	-	238	27	49.5	-7
Fluorine-containing rubbers	C3	25	7	-	25	40	80	-15
	C5	50	28	10.3	-	40	41	-7
Natural rubber	D1	24	365	-	187.6	12.5	20.8	-22
	D1	100	3	DISINTEGRATES				
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E1	24	365	-	110.2	24.5	28.9	-24
	E1	100	3	-	124.8	10.7	17	-31
Polychloroprene	F1	24	365	-	171.5	20.4	35.9	-34
	F1	100	3	-	209.1	15.9	37.2	-44

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

RAPRA Data Sheet RA 24

Issued : April 1969

Water (distilled)

Polymer	Ref. No.	Temp. (°C)	Time (days)	Change (%) in:		Effects on properties		
				Weight	Volume	TS	EB	H
Butyl rubber (Isobutylene-isoprene copolymer)	A1	24	365	-	0.78	95.2	96.1	+3
	A1	100	3	-	0.78	95.8	81.8	+1
Ethylene-propylene rubbers	B3	24	365	-	1.92	103.6	44.3	0
	B3	100	3	-	1.1	104.7	85	0
Fluorine-containing rubbers	C4	RT	28	-	6.1	98	110	+3
	C1	100	30	-	11	80.5	104	0
Natural rubber	D1	24	365	-	4.54	92.1	84.8	4
	D1	100	3	-	6.14	89.2	78.5	-3
Nitrile rubber (Butadiene-acrylonitrile copolymer)	E1	24	365	-	6.92	108.3	92.8	-3
	E1	100	3	-	7.16	117.4	97.5	-5
Polychloroprene	F1	24	365	-	18.7	79.6	70.4	-8
	F1	100	3	-	9.34	97.2	85.2	-4

TS = Retained Tensile Strength (%)
EB = Retained Elongation at Break (%)
H = Hardness change (IRHD)

Reference Sheet A

Issued : April 1969

Butyl rubber

Ref. No.	Compound formulation	Original vulcanisate characteristics	Source
A 1	Enjay Butyl 218 100 (1.5 mole % unsaturation) MPC black 20 SRF black 50 Flexon 765 (Process oil) 5 Zinc oxide 5 Stearic acid 1 Sulphur 1.5 TDEDC 1.5 MBTS 1 Antioxidant 2246 1	Cure: 30 mins. / 160°C Tensile strength 116.2 kg/cm^2 Elongation at break 510% Hardness (Shore A) 67	**ENJAY CHEMICAL CO.: "Enjay Butyl Rubber Chemical Resistance Handbook", Publn. SYN-64-1082, New York 1965.**
A 2	Polysar Butyl 300 100 (1.76 mole % unsaturation) HAF black 20 SRF black 50 Naphthalene/ Paraffin oil 5 Zinc oxide 5 Stearic acid 1 MBTS 1 TDEDC 1.5 Sulphur 1.5 PBN 1	Cure: 30 mins. / 160°C Tensile strength 114.1 kg/cm^2 Elongation at break 565% Hardness (IRHD) 61	**RAPRA compound specially prepared for this project, 1968.**
A 3	Polysar Butyl 400 100 (2.2 mole % unsaturation) FEF black 40 Stearic acid 1 Zinc oxide 5 Sulphur 2 TMTDS/MBT mixture 1.5 ZDEDC 1	Cure: 30 mins. / 153°C Tensile strength 115 kg/cm^2 Elongation at break 366% Hardness (Shore A) 61	**H-J. JAHN: "Die Quellbeständigkeit von Vulkanisaten verschiedener Elastomerer", Farb. Bayer AG, Rept. AN 471, Leverkusen, 1961**

Reference Sheet A cont.

Issued : April 1969

Butyl rubber

Ref. No.	Compound formulation	Original vulcanisate characteristics	Source
A 4	Polysar Butyl 100 100 (0.7 mole % unsaturation) EPC black 50 Zinc oxide 5 Stearic acid 1 MBTS 0.5 TMTDS 1 Sulphur 2	Cure: 40 mins/ 153°C Tensile strength 211 kg/cm^2 Elongation at break 825% Hardness (Shore A2) 49	POLYMER CORPN. LTD.: "Polysar Butyl Handbook", Sarnia, 1966.

Reference Sheet B

Ethylene-propylene rubbers

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Ref. No.	Compound formulation	Original vulcanisate characteristics	Source
B 1	Dutral N (copolymer) 100 SRF black 50 Process oil 5 Sulphur 0.4 Peroximon F40 (peroxide curing agent) 5.25 Flectol H (antioxidant) 0.5	Cure: 40 mins / 165°C Tensile strength 100 kg/cm^2 Elongation at break 440% Hardness (Shore A) 60	**MONTESHELL PETROCHIMICA: "Dutral EPM Resistance to Chemicals". Publn. ELAS 03(E) Milan, 1966.**
B 2	Shell ECP 900 (terpolymer) 100 FEF black 50 Zinc oxide 5 Stearic acid 1 MBT 0.5 TMTMS 1.5 Sulphur 1.5	Cure: 30 mins / 160°C Tensile strength 185.5 kg/cm^2 Elongation at break 380% Hardness (Shore A) 72	**SHELL CHEMICAL CO.: "Shell EPDM Chemical and Solvent Resistance". London 1966.**
B 3	Vistalon 3509 (terpolymer) 100 MPC black 20 SRF black 50 Flexon 765 (Process oil) 25 Zinc oxide 5 Stearic acid 1 MBT 0.5 TMTDS 1.5 Sulphur 1.5	Cure: 30 mins / 160°C Tensile strength 151.9 kg/cm^2 Elongation at break 350% Hardness (Shore A) 63	**ENJAY CHEMICAL CO.: "Chemical Resistance of Vistalon Rubber Compounds", Rubber Technical Bulletin No. 6, New York 1967.**
B 4	Nordel 1070 (terpolymer) 100 FEF black 60 Zinc oxide 5 Stearic acid 1 TMTMS 1.5 MBT 0.5 Sulphur 2	Cure: 30 mins. / 160°C Tensile strength 175 kg/cm^2 Elongation at break 330% Hardness (Shore A) 69	**E.I. DU PONT DE NEMOURS & CO.: "Nordel Hydrocarbon Rubber, a Sulfur-curable, Ethylene-propylene Elastomer", Wilmington, 1964.**

Reference Sheet B cont.

Ethylene-propylene rubbers

Issued : April 1969
Revised: January 1970

Ref. No.	Compound formulation	Original vulcanisate characteristics	Source
B 5	Dutral N (copolymer) 100 HAF black 20 SRF black 50 Naphthene/ paraffin oil 5 Sulphur 0.4 Retilox F-40 (peroxide curing agent) 5.25 Flectol H (antioxidant) 0.5	Cure: 60 mins. / 160°C Tensile strength 95.1 kgf/cm^2 Elongation at break 485% Hardness (IRHD) 63	RAPRA compound specially prepared for this project, 1968.
B 6	Dutral (copolymer) 100 FEF black 40 Stearic acid 1 Sulphur 0.3 Dicumyl peroxide/ calcium carbonate mixture 6	Cure: 30 mins. / 153°C Tensile strength 169 kgf/cm^2 Elongation at break 673% Hardness (Shore A) 47	H-J. JAHN: "Die Quellbeständigkeit von Vulkanisaten verschiedener Elastomerer", Farb. Bayer AG, Rept. AN 471, Leverkusen, 1961.

Reference Sheet C

Fluorine-containing rubbers

Issued : April 1969
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Ref. No.	Compound formulation	Original vulcanisate characteristics	Source
C 1	Not known. Several compounds used, probably based on the following typical composition: Viton A (vinylidene fluoride-hexafluoropropylene copolymer) 100 Magnesia / litharge 15 MT black 20 Diak No. 3 3	Not given in Viton Bull. 15; Rept. BL 356 gives details as follows:- Cure: 30 mins. / 150°C (press); 24 hrs. /204°C Tensile strength 161 - 168 kgf/cm^2 Elongation at break 200 - 220% Hardness (Shore A) 70 - 72	R.C. DESKIN, L. CONFORTI: "Fluid Resistance of Viton". Du Pont Viton Bulletin No. 15, Wilmington, 1965; E. TUFTS: "Fluid Resistance of Viton". Du Pont Rept. BL-356, Wilmington, 1959.
C 2	As above but based on Viton B		
C 3	Tecnoflon (vinylidene fluoride-1-hydropentafluoropropene copolymer) 100 MT black 20 Magnesia * 15 Tecnocin A 3.5 * Replaced by lead monoxide in tests using inorganic acids	Cure: 30 mins. / 150°C (press) followed by oven step cure; 4 hrs. to reach 200°C, then 20 hrs. at 200°C Tensile strength 220-240 kgf/cm^2 Elongation at break 270-300 % Hardness (IRHD) ca. 70	MONTESUD PETROCHIMICA SpA: "Tecnoflon SL·SH", Milan, 1966.
C 4	Viton B 100 MT black 20 Magnesia 15 Diak No. 3 3	Cure: 25 mins. / 160°C followed by air post cure of 24 hrs. at 250°C Tensile strength 183.7 kgf/cm^2 Elongation at break 285% Hardness (IRHD) 74	RAPRA compound specially prepared for this project, 1968.

Reference Sheet C cont.

Issued : April 1969

Fluorine-containing rubbers

Ref. No.	Compound formulation	Original vulcanisate characteristics	Source
C 5	Viton A 100 MT black 25 Magnesia 15 Diak No. 1 1.5	Cure: 30 mins. / 151°C (press) followed by 24 hrs. at 200°C Tensile strength 168 kg/cm^2 Elongation at break 229% Hardness (Shore A) 72	H-J. JAHN: "Die Quellbeständigkeit von Vulkanisaten verschiedener Elastomerer", Farb. Bayer AG, Rept. AN 471, Leverkusen, 1961.
C 6	Viton A compound, details of composition not known	Tensile strength 126 kg/cm^2 Elongation at break (%) 435 Hardness (IRHD) 78	L.T. BUTT: "The Resistance of Viton A to Heat and Chemicals", ICI Agricultural Divn., Engng. Developments Dept., Non-Metallic Materials Section, Rept. No. B 124-100, 10/6/1960.

Reference Sheet D

Issued : April 1969

Natural rubber

Ref. No.	Compound formulation	Original vulcanisate characteristics	Source
D 1	RSS 1 100 MPC black 20 SRF black 50 Flexon 765 (Process oil) 5 Zinc oxide 5 Stearic acid 1 Sulphur 2.75 MBTS 1 TMTDS 0.1 Antioxidant 2246 1	Cure: 10 mins. / 160°C Tensile strength 213.5 kg/cm^2 Elongation at break 430% Hardness (Shore A) 70	ENJAY CHEMICAL CO.: "Enjay Butyl Rubber Chemical Resistance Handbook", Publn. SYN-64-1082. New York 1965.
D 2	RSS 1 or SMRS 100 HAF black 20 SRF black 50 Naphthalene/paraffin oil 5 Zinc oxide 5 Stearic acid 1 Sulphur 2.6 MBTS 0.8 TMTDS 1 PBN 1	Cure: 10 mins. / 160°C Tensile strength 224.8 kg/cm^2 Elongation at break 415% Hardness (IRHD) 63	RAPRA compound specially prepared for this project, 1968.
D 3	Smoked sheets 100 FEF black 40 Zinc oxide 5 Stearic acid 1 CBS 0.8 Sulphur 2.5 PAN 1.5	Cure: 10 mins. / 153°C Tensile strength 280 kg/cm^2 Elongation at break 575% Hardness (Shore A) 57	H-J. JAHN: "Die Quellbeständigkeit von Vulkanisaten verschiedener Elastomerer", Farb. Bayer AG, Rept. AN 471, Leverkussen, 1961.

Reference Sheet E

Issued : April 1969

Nitrile rubber

Ref. No.	Compound formulation	Original vulcanisate characteristics	Source
E 1	Hycar 1042 (28-34% acrylonitrile content) 100 MPC black 20 SRF black 50 Flexon 640 (Process oil) 5 Zinc oxide 5 Stearic acid 1 Sulphur 1.75 MBTS 1.5 TMTDS 0.1 Antioxidant 2246 1	Cure: 20 mins. / 160°C Tensile strength 177.1 kg/cm^2 Elongation at break 280% Hardness (Shore A) 78	ENJAY CHEMICAL CO.: "Enjay Butyl Rubber Chemical Resistance Handbook", Publn. SYN-64-1082, New York, 1965.
E 2	Hycar 1002 (28-34% acrylonitrile content) 100 FT black 50 SRF black 40 Dibutyl phthalate 10 Coumarone-indene resin 10 Zinc oxide 5 Stearic acid 1.5 Sulphur 1.75 TMTMS 0.5 Paraffin wax 1.0	Cure: 15-45 mins. / 154°C Tensile strength 154-166.3 kg/cm^2 Elongation at break 500-360% Hardness (Shore A) 61-65	B.F. GOODRICH CHEMICAL CO.: "Resistance of Hycar Rubber to Immersion Media", Manual HM-6 Revised, Cleveland 1967.

Reference Sheet E cont.

Nitrile rubbers

Issued : April 1969
Revised: January 1970

Ref. No.	Compound formulation	Original vulcanisate characteristics	Source
E 3	Breon 1042 100 (35.5 - 37% acrylonitrile content) HAF black 20 SRF black 50 Naphthene / paraffin oil 5 Zinc oxide 5 Stearic acid 1 Sulphur 1.5 MBTS 1 TMTDS 0.25 PBN 1	Cure: 20 mins. / 160°C Tensile strength 187.2 kgf/cm^2 Elongation at break 275% Hardness (IRHD) 71	RAPRA compound specially prepared for this project, 1968.
E 4	Perbunan N 3310 100 (33% acrylonitrile content) FEF black 40 Zinc oxide 5 Stearic acid 1 Sulphur 1.8 CBS 1.2 PAN 1.5	Cure: 20 mins. / 153°C Tensile strength 226 kgf/cm^2 Elongation at break 437% Hardness (Shore A) 69	H-J. JAHN: "Die Quellbeständigkeit von Vulkanisaten verschiedener Elastomerer", Farb. Bayer AG, Rept. AN 471, Leverkusen, 1961.

Reference Sheet F

Polychloroprene

Issued : April 1969
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Ref. No.	Compound formulation	Original vulcanisate characteristics	Source
F 1	Neoprene W 100 MPC black 20 SRF black 50 Flexon 765 (Process oil) 5 Zinc oxide 5 Magnesium oxide 4 Stearic acid 1 Sulphur 1 TMTMS 1 DOTG 1 Antioxidant 2246 1	Cure: 20 mins. / 160°C Tensile strength 198.9 kgf/cm^2 Elongation at break 220% Hardness (Shore A) 79	ENJAY CHEMICAL CO. : "Enjay Butyl Rubber Chemical Resistance Handbook", Publn. SYN-64-1082, New York, 1965.
F 2	Perbunan C 110 100 FEF black 40 Zinc oxide 5 Magnesia 4 Stearic acid 1 Vulkacit NP 0.6 PAN 1.5	Cure: 20 mins. / 153°C Tensile strength 237 kgf/cm^2 Elongation at break 380% Hardness (Shore A) 71	H-J. JAHN: 'Die Quellbeständigkeit von Vulkanisaten verschiedener Elastomerer", Farb. Bayer AG, Rept. AN 471, Leverkusen, 1961
F 3	Neoprene W 100 HAF black 20 SRF black 50 Naphthene / paraffin oil 5 Red lead 20 TMTMS 1 Sulphur 1 PBN 1	Cure: 20 mins. / 160°C Tensile strength 246 kgf/cm^2 Elongation at break 240% Hardness (IRHD) 76	RAPRA compound specially prepared for this project, 1968

Reference Sheet F cont.

Polychloroprene

Issued : April 1969
Revised: January 1970

Ref. No.	Compound formulation	Original vulcanisate characteristics	Source
F 4a	Neoprene GN 100 MPC black 36 Tricresyl phosphate 2.5 Zinc oxide 5 Magnesia 4 Stearic acid 2.5 PBN 2	Cure: 30 mins. / 141°C	R. W. MALCOLMSON, D. Ç. THOMPSON: "Swelling of Neoprene in Chemicals, Oils and Solvents", Du Pont Report No. 56-2, Wilmington, 1956.
F 4b	Neoprene GN 100 Soft carbon black 100 Magnesia 4 Zinc oxide 5 Stearic acid 0.5 PAN 2	Cure: 30 mins. / 142°C	
F 4c	As 4b but cured with 20 parts litharge instead of magnesia and zinc oxide		
F 4d	Neoprene GN 100 EPC black 35 Zinc oxide 5 Magnesia 4 PAN 2	Not known	
F 4e	Neoprene GN 100 SRF black 36 Zinc oxide 4 Magnesia 3.2 Stearic acid 0.8	Cure: 50 mins. / 145°C	

Reference Sheet F cont.

Issued : April 1969
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Polychloroprene

Ref. No.	Compound formulation	Original vulcanisate characteristics	Source
F 4f	Neoprene GN 100 Magnesia 7 Zinc oxide 5 Stearic acid 0.5 PBN 1	Cure: 30 mins. / 153°C	(As above)
F 4g	Neoprene GN 100 SRF black 35.3 Circo oil 12 Red lead 20 Stearic acid 0.75 PAN 2 Heliozone 3	Cure: 15 mins. / 153°C	
F 4h	Neoprene GN 100 MT black 100 Circo oil 10 Zinc oxide 10 Litharge 20 Stearic acid 0.5 PAN 2	Cure: 20 mins. 153°C	
F 4i	Neoprene W 100 SRF black 50 Magnesia 2 Zinc oxide 5 Stearic acid 1 2-Mercaptoimidazoline 0.75 PBN 1	Cure: 10 mins. / 148°C	