Preliminary Testing Report of Some Commercial Polymers and Their Utilisation in the Antarctic Climatic Conditions

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ABSTRACT

The effect of extreme low temperature and high wind velocity conditions existing in Antarctica have been investigated on various polymeric materials. The selection of polymeric materials ranged from simple polyolefinic polymers like Low Density Polyethylene (LDPE) and Polypropylene (PP) to engineering and speciality polymers like Acrylonitrile Butadiene Styrene Coplymer (ABS), Polycarbonate and Poly-tetrafluoroethylene (PTFE). The polymeric samples were exposed to the Antarctic climate for one month and for one year duration. The one month exposed samples were brought back and evaluated for thermal, mechanical and electrical properties. No significant changes were observed in the properties of the samples exposed for one month duration. Conclusions about the effect of Antarctic climate on the polymers, can however, be drawn only after detailed evaluation of the samples exposed for one year.

INTRODUCTION

Temperature undoubtedly has a profound effect on the matter and its properties. Materials, which possess useful properties may be rendered useless in extremely hot or cold conditions. In the climatic conditions such as prevailing in Antarctica one has to be very careful and critical about the choice of materials for specific uses. Polymers because of certain advantages have replaced to a great extent the naturally occurring materials like wood, metals and ceramics in almost all walks of life. These materials possess some properties better than the natural materials, can be moulded and fabricated with ease into desired shapes and besides this they also provide good chemical and weather resistance. They have low densities as compared to metals and ceramics. They are attractive for cryogenic applications because of low thermal conductivities and excellent mechanical properties (Javitz, 1961; Kropschot, 1962; Lacques et al., 1952; Tito et al., 1968). Many plastics, especially fluoropolymers have superior resistance to embrittlement at cryogenic temperatures. In general, polymers retain their strength at extreme low temperatures. Furthermore, laboratory evaluation of properties of some important polymers at low temperature have revealed that these properties are temperature dependent. The laboratory finding can be summonsed as follows (Herman et al., 1965).

As temperature decreases, the properties are changed as:

Tensile strength	...	increases	Hardness	...	increases
Flexural strength	...	increases	Impact strength	...	decreases
Modulus of elasticity	...	increases	Thermal conductivity	...	decreases
Total thermal contraction	...	increases	Ductility	...	decreases
Strength to weight ratio	...	increases	Elongation	...	decreases
Volume resistivity	...	increases	Coefficient of expansion	...	decreases

The main objective of undertaking the work at Antarctica was to study the usefulness of various polymeric materials for their various applications in the Antarctic climate. The materials chosen for this study were polyolefins like LDPE, Poly-propylene (PP), ABS, PVC (in rigid and flexible forms), their modified forms like PVC/NBR blend, PVC/ABS blends, filled PVC compounds, polycarbonate, polytetrafluoroethylene and thermosetting flame resistant polyesters.

These polymers were selected with a view to find out whether their existing excellent properties are retained even in the Antarctic climate.

Preliminary evaluation of the properties of polymers

The samples were exposed to the conditions prevailing in Antarctica for a period of one month to one year, and after exposure they were evaluated for physical, mechanical, electrical and thermal properties. The study has revealed that certain polymers do not possess useful properties in the Antarctic climate while their modified forms are quite useful. An attempt has been made to find out the correlation between the chemical structure and the properties in the Antarctic environment with a view to find out the polymeric materials most suitable for various applications in Antarctica.

MATERIAL AND METHODS

Both low density polyethylene (LDPE) and polypropylene (PP) were used as supplied by M/s Indian Petrochemicals Limited (IPCL), Baroda.

ABS pallets used were received from M/s Polychemicals Ltd., polycarbonate granules were supplied by M/s Baeyer Ltd., PTFE sheets were used as received from Du Pont Ltd., U.S.A., PVC (SR-10) was supplied by M/s Shriram Fertilizers & Chemicals, Kota, nitrile rubber used was of Synthetics and Chemicals, Bareilly.

PVC blends with nitrile rubber, ABS and wollestonite were prepared at Shriram Institute for Industrial Research for studying the various properties. PVC rigid pipe was procured from M/s Prakash Pipe Ltd.

Preparation of samples

The granulated samples received were moulded into sheets for evaluation by calendering and compression moulding techniques. Similarly, some samples were moulded by the injection moulding technique.

ABS, PVC/NBR, PVC/ABS and PVC wollestonite samples were initially calendared on a two roll mill at 140°C for 10 minutes. The sheets obtained were compression moulded on a hydraulic press at 160°C for 14 minutes at 5000 lbs. load.

Compression moulded sheets were subjected to various testing. LDPE, PP and polycarbonate were subjected to injection moulding into dumbell shaped samples to be tested for their mechanical properties. Similarly, these materials were compression moulded to get sheets for carrying out electrical properties.

Characterisation techniques

Glass transition (T_g) and melting temperature (T_m) were determined by differential scanning calorimetry using Du Pont 1090 model at a heating rate of 10°C per minute in nitrogen atmosphere from ambient temperature to 400°C.

To determine the tensile properties dumbell shaped specimens of the sizes conforming to ASTM D-638, were prepared from the compression moulded sheets and injection moulded samples. Tensile properties of these samples were determined on Instron Universal Testing Machine, at a desired crosshead speed, gauge length and chart speed. From this tensile modulus and elongation at break were calculated. A set of five samples were tested in each case.

Izod impact strength testing was carried on an Impact Tester No. 72, Model IT 14. The sample strips with a notch angle of 45° were subjected to impact testing. A minimum of five samples were

tested. Hardness of the polymeric samples was measured on a Shore-D hardness tester (values 1-100).

Heat deflection temperature was determined according to ASTM D-648. Volume resistivity of the samples was determined using Ohm Meter, BPL Model conforming to ASTM D-257.

RESULTS AND DISCUSSION

The polymeric materials which were exposed to the sub-zero temperature at Antarctica were characterised for various properties. Results are given in Tables I and II and in Fig. 1 and 2; studies were restricted to the samples exposed. Samples exposed for one year are to be further evaluated.

Thermal properties

Thermal properties provide the information about the effect of temperature on the materials. Thermal properties of polymers are glass transition temperature (a temperature at which a material changes from glassy state to rubbery state); melting point (temperature when the material changes from solid to free flowing liquid); heat deflection temperature (maximum temperature upto which a polymer can be suitably used) (Turi, 1978).

The thermal properties of the samples have been given in Table I. It can be seen from Table I that there is no significant change in the glass transition temperature (T_g) of the polymeric materials. However, some changes have been observed in certain material like ABS, polycarbonate and PVC. All these polymers have high glass transition temperatures. It appears that at extreme low temperature conditions there may be some alignment of the polymeric chains and hence when the polymer is brought back to ambient conditions, there is change in the glass transition temperatures. Polypropylene has T_g-20°C and at a low temperature—40°C the polymer becomes stiff probably because amorphous polymer chains are changing themselves from rubbery to glassy phase. It is well known that embrittlement of polymers is somehow related to the mobility of polymer chain. Hence, brittle and glassy polymers need to be modified with rubbery materials which enhance there ductility. Thus, the use of nitrile rubber makes PVC suitable at low temperatures. Although it is reported in the literature that the extreme low temperature affects the crystallinity of the materials, it is evident from the Table I that there is no change in the melting temperature (T_m) of the polymers when exposed to Antarctic climate for one month. Similarly, heat deflection temperature which is an important property of the polymeric materials does not show any change after exposure.

Mechanical properties

Mechanical properties are those properties which determine the response of materials of

TABLE I

Thermal properties of polymeric before and after their exposure to Antarctic climate.

Property	ABS		PVC Rigid		PVC/ABS		PVC/NBR		LDPE		Poly propylene		Poly carbonate		Poly tetra-fluoro ethylene	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Glass Transition Tempeature (T_g)°C	110	108	75	76	75& 110	75& 110	65	63	X	X	X	X	150	155	—	—
Melting Temperature (T)°C	—	—	200	210	175	180	145	140	110	112	165	165	250	250	327	335
Heat Deflection temp. at 66 psi °C	106	108	75	75	100	100	75	75	60	62	90	92	175	178	200	205

B-Before, A-After, X-Could not be determined because of lack of cooling facility in instrument.

external mechanical influences, the ability of material to develop reversible and irreversible deformation and to resist failure. The important mechanical properties are tensile strength, modulus of elasticity, impact strength, flexural strength etc.

Machanical properties of polymers change with the temperature. For example, with the increase in temperature there is an increase in impact strength but corresponding loss occurs in tensile strength, tensile modulus, elongation and hardness. Mechanical properties of polymer samples before and after ageing for one month in the Antarctic climate are given in Table II.

Impact strength

Impact strength can be defined as the energy absorbed by a material at its failure. It is a measure of the toughness of a material (Paul and Newman, 1978). The degree of toughness or impact strength is one of the most important prerequisites for a material which is exposed to high wind velocities. It is evident from the Table II that there is no significant change in the impact strength of these polymers after ageing in Antarctica for one month. However, it was observed that some polymeric materials like PVC, polypropylene and ABS, became a bit stiff. However, it is necessary to carry out their evaluation at the site to derive conclusions. Apparently it seems that virgin rigid PVC becomes a bit brittle at low temperature. Keeping this background in view the PVC was modified by blending it with rubbery polymers like nitrile rubber andABS. The hardening of PVC (plasticized sheet) was also observed because there is possibility of plasticizer getting frozen. The low temperature leads to the contraction of polymeric material and there are sometimes chances of cracking also. However, the rubber modified PVC retains rigidity resistance to cracking and impact strength. Similarly PVC/

TABLE II

Machanical properties of polymeric samples before and after exposure to Antarctica.

Property	ABS		Rigid PVC		PVC Wollestonite		PVC/NBR Blend		PVC/ABS Blend	
	Before	After	Before	After	Before	After	Before	After	Before	After
Tensile strength psi	5000	5200	5900	6000	6200	6250	3200	3300	3500	3650
Elongation at break %	.25	25	10	10	10	10	75	70	25	25
Tensile modulus X 10^3 psi	1150	150.5	400	428	450	460	250	253	345	355
Izod impact strength ft.lb/inch	15	14.5	0.5	0.5	0.5	0.5	9.5	10	12.5	14
Shore D hardness	70	70	85	85	90	92	70	75	75	75

TABLE II (Contd.)

Property	LDPE		PP		Polycarbonate		PTFE	
	After	Before	After	Before	After	Before	After	Before
Tensile strength psi	2000	2000	4500	4560	9500	9600	3000	3200
Elongation at break %	125	130	100	95	90	75	*150	120
Tensile modulus X 10^3 psi	45	48	150	160	345	370	65	70
Izod impact strength ft.lb/inch	N.B.*	N.B.	2.5	2.5	16.0	15.5	3.5	3.5
Shore D hardness	44	43	62	65	90	90	55	58

*No break

ABS polymer blend can also be regarded as suitable engineering material for low temperature applications. Polycarbonate and PTFE showed no apparent change.

Tensile properties

Tensile strength or the ultimate strength of a material is the stress at failure. Different polymeric materials show different failure behaviour depending upon their structure and constitution. The stress applied on a material produces strain and this stress-strain data give the elastic modulus of a polymer. Tensile properties of polymers given in Table II reveal, that there is no significant change in the tensile properties after ageing for one month in Antarctica. The hardening observed with polymers like PVC, ABS and polypropylene suggest, that there might have been an increase in the tensile modulus at the low temperature. Tensile modulus has a relationship with stress and strain of a material. At low temperature with high stress rate the % strain (elongation) decreases with the result that there is an increase in the tensile modulus. However, rubber modified polymers exhibited the same phenomenon of retaining their stress-strain properties.

Hardness

Hardness (shore-D) is a measure of the rigidity of polymers which is also related to the tensile properties of the polymers. Hardness tests were carried out before taking the samples to Antarctica, at Antarctica and after bringing them back. These results are shown in Table II and Fig. 1. It can be seen from Fig. 1 that there is an appreciable increase in the shore-D hardness in the case of almost all the polymers except PTFE. Furthermore, the original values are restored when they were retested at ambient temperatures. It can also be seen that there is an increase in hardness in the virgin PVC while it is not pronounced in the modified PVC.

It is evident from the above observations that the exposure of polymers to the Antarctic climate for one month in summer do not have any significant effect and wherever some effects have been found they can be countered by making suitable modifications in the polymers.

Electrical properties

Volume resistivity: Polymers are mostly insulators and their insulating property makes them useful for a number of applications. The insulation property of polymers can be determined from the resistance measurements. Volume resistivity behaviour of the polymeric materials is shown in Fig. 2. The figure reveals that when there is an increase in the temperature the volume resistivity of almost all the plastics, except PTFE decrease. Similarly, when the temperature decreases the volume resistivity is enhanced. Polypropylene, LDPE and PVC possess excellent volume resistivity and hence exhibit better insulation properties at low temperatures. This property will make them useful for cable and other electrical equipment to be used in Antarctica.

CONCLUSIONS AND SCOPE FOR FUTURE WORK

It can be concluded from the study that polymeric materials do not undergo any significant change in their physico-mechanical properties after exposing them to the Antarctic environment for one month. Brittle and glassy polymers can be made useful at low temperature by making certain modifications like rubber modification etc. Because of superior properties of the polymers over wood and metals these can find diverse uses in the Antarctic environment.

Keeping in view the above findings there is an ample scope to carry out further work with respect to polymers in Antarctica. The Antarctic climate is beset with strong surface winds as well as low temperature. Thus, the selection of materials becomes critical because these should have resistance to both. To make the study more elaborate it is useful to carry out the evaluation of the samples

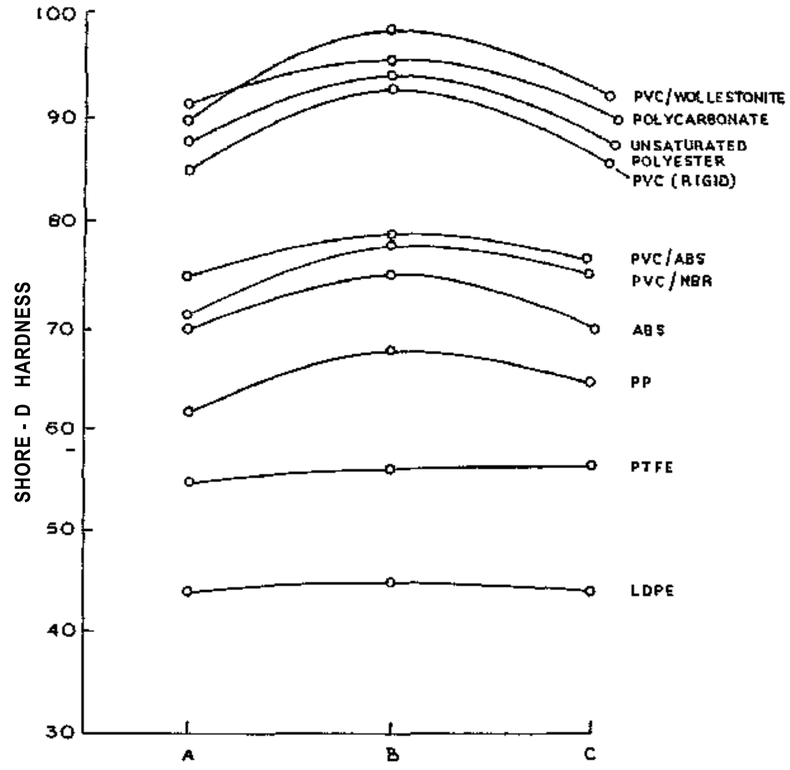

Fig. 1. **Plot showing shore D hardness of various polymers at three exposed temperatures.**

A 25°C Before exposing
B -30°C Antarctic environment
C 25°C After exposing

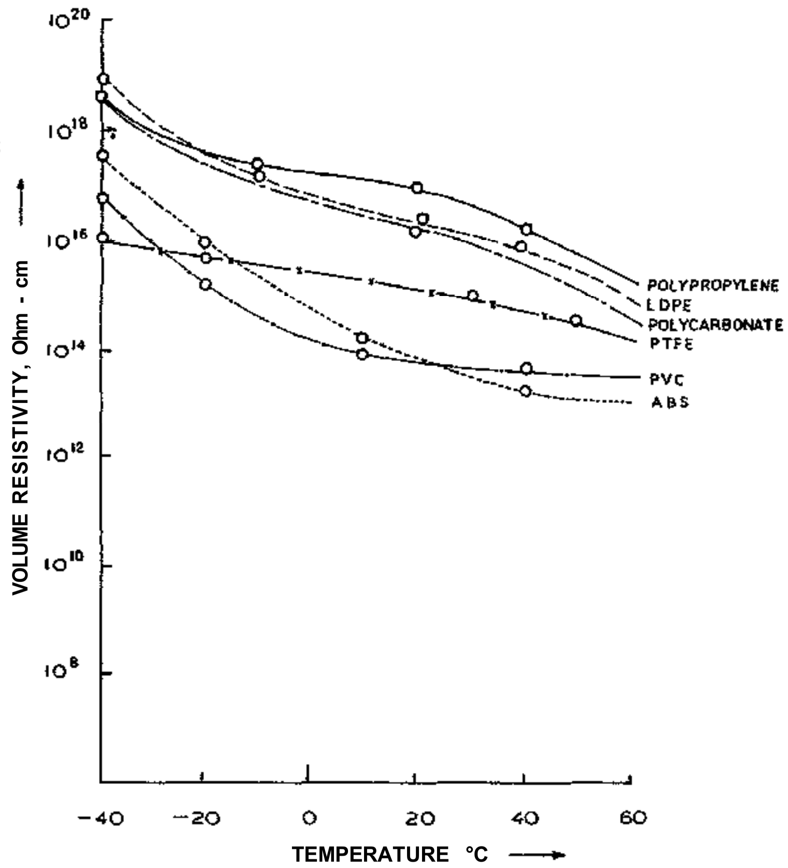

Fig. 2. **Plot showing the effect of temperature on volume resistivity of polymers.**

which have been exposed for one year. Similarly, more tests can be made at the site itself to collect more information. It is also necessary to modify the polymers further in the light of the data collected and then to evaluate them after exposing to the Antarctic climate.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the constant guidance and encouragement received from Dr. S.Z. Qasim, Secretary, Department of Ocean Development, Govt, of India. It is a pleasure to thank Dr. J.K. Nigam, Director, Shriram Institute for Industrial Research for his co-operation and guidance. Thanks are also due to X.N. Verlencar for looking after our polymeric samples in Antarctica during the winter.

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