THE WATERPROOFING PLASTOMERIC COMPOUND INTENDED AS A "POLYMER-BITUMEN" ALLOY

History, properties and function performed on the composite structure of the waterproofing membrane of modern design.

(Abstract from the paper prepared by NOVAGLASS for the XI° IWA Congress Florence 2000.)

Author: Mr. Angiolino NOVI

PRESENTATION:

People operating in the waterproofing sector is well aware of the role performed by the waterproofing compound in the bitumen-polymer membrane.

Today, there are basically two types of waterproofing compounds:

- plastomeric, with polyolefinic polymeric base;
- elastomeric, with polymeric base with thermoplastic styrene rubbers.

The plastomeric waterproofing compounds taken into consideration in present work can assume semi-elastic properties when during the modification of the bitumen polyolefinic components having semi-elastic behaviour are used; hence the possibility to define compounds and/or membranes as plasto-elastomeric.

The history of the modification of the bitumen and the properties of the different types of waterproofing compounds are reported in Table A.

Further on, making use mainly of graphic diagrams, the following concepts are proposed:

Table B: most representative characteristics of a plastomeric waterproofing compounds, highlighting elastic behaviour, thermo-sensitivity and rheological behaviour.

Table C: diagram of modification with polypropylene of distilled bitumen.

Table D: parameters of control in the production of waterproofing compounds.
Table E: characteristics of traditional polyolefinic modifiers.
Table F: modifying capacity of traditional polymers on the bitumen.
Table G: diagram of bitumen/polymer compound processing
Table H: ageing effect on plastomeric waterproofing compounds

History and purpose of the work:

Many efforts were made in the research to improve the proprieties of the bitumen: especially the thermal susceptibility and the ageing properties. Only in the mid sixties, in Italy it was discovered that the atactic polypropylene, available as by product of the isotactic polypropylene invented by Prof. G. NATTA, was able to bestow to the bitumen required properties.

Such date represents the beginning of a new generation of membranes, defined as PLASTOMERIC from the polymer used in the modification of the bitumen, having characteristics clearly higher than the ones of the previous membranes made with oxidised bitumen with filler.

Later on, also the thermo-plastic styrene-butadiene-styrene rubbers were found suitable for the modification of the bitumen, giving birth in this way to the waterproofing compound and the membranes defined as ELASTOMERIC.

In the next research and manufacturing activities, substantial and progressive improvements were made too on the reinforcements and on the superficial finishing of the membranes.

In the particular case of the PLASTOMERIC waterproofing compounds there was an interesting development which allowed the use of functionalised polyolefins as polymers complementary to the traditional polypropylenes.

During the last years even the polyolefins produced with the new systems of metallocenic catalysis demonstrated their ability to confer to the waterproofing compound high plastomeric and elastomeric properties with high yield.

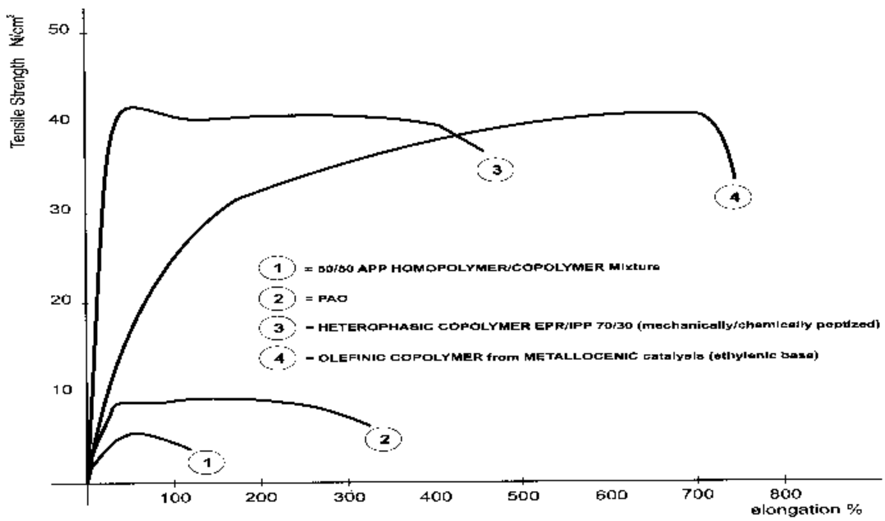
The load/deformation curves reported in the following diagram show the modifying ability expressed by the polymers currently available.

Bitumen/Polymer Compound with 85/15 ratio having inverted structure (continuous polymeric phase and dispersed bitumen according to class 2 of Internal NG Norm 6/96 - Method A)

VB type Bitumen:	- R. & B. ASTM-D36	= 41 °C
	- Penetration ASTM-D5	=193 dmm
	- Composition - saturated	= 11 %
	- aromatics	= 56 %
	- resins	= 20 %
	- asphaltens	= 13 %

Polymer:- variable

Graph 1



Purpose of the work is to make available the knowledge developed by industrially manufacturing the finished membrane, by co-operating in the designing and realisation of waterproofing systems and by monitoring their behaviour during use.

Our reference will be the plastomeric membrane (APP) because it is the one on which we have more knowledge especially under the aspect of the processability and applicability.

The polymer-bitumen compound as polymeric alloy
Polymeric alloys originated from the inadequacy of the single polymers to satisfy requirements of higher performance in the same way the bitumen-polymer mixtures originated from the inadequacy of the properties of the bitumen to satisfy the requirements of the waterproofing sector.

Both alloys are obtained by physical mixing at high temperature. They present a morphologic structure where one of the components assumes the continuous phase conferring the characteristics to the system, while the other component remains dispersed in discontinuous form.

In common the two alloys present the thermo-plasticity, even if expressed within different ranges of temperature. The comparison in terms of mechanical properties situates the polymeric alloys at well superior levels in respect to the polymer - bitumen alloys, but this fact is justified by the different application requirements: replacement of wood, metals or similar materials in the first case, production of waterproofing sheets in the latter.

Role and functionality of the waterproofing compound in the plastomeric membrane
When associated to the reinforcement, the waterproofing compound concurs to increase the mechanical characteristics thanks to the well known synergies; furthermore, it transfers to the finished product thermoplastic and rheological properties.

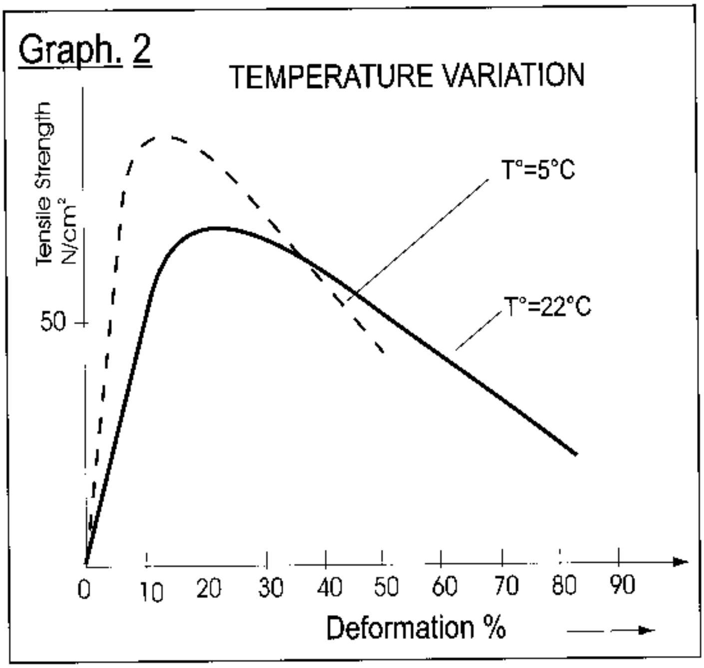
When assuming the thermoplastic properties, the membrane becomes susceptible from the functional point of view of both the temperature and the speed of deformation. The rigidity of the product as expression of the performance properties, depends always on the temperature and on the deformation time according to the following relationship:

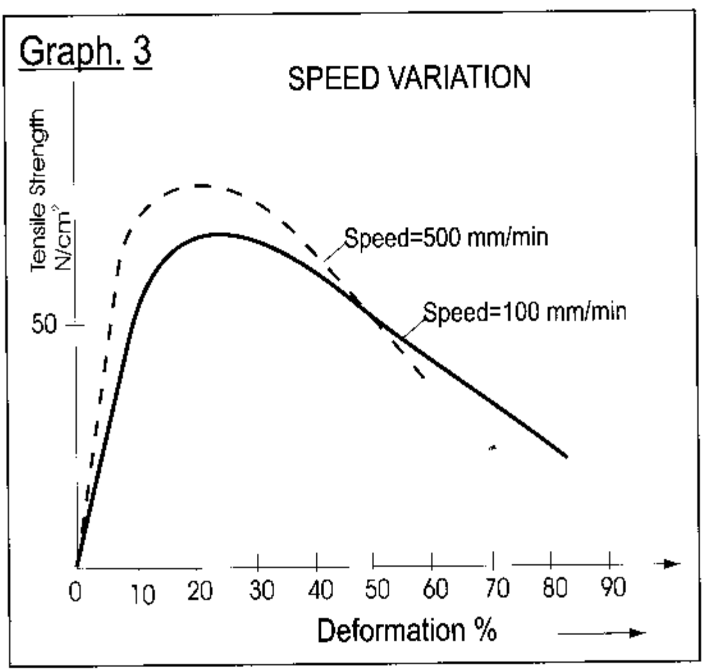
$$R\ (t \times T^{\circ}) = S/d$$

In order to correctly interpret the influence of the variables time and temperature on the behaviour of the waterproofing compound and consequently of the membrane, it is proper to show the load/deformation diagram of the compound with different times and conditions of temperature.

PLASTOMERIC COMPOUND WITH -10°C COLD FLEXIBILITY

Variation of mechanical characteristics changing temperature and speed of deformation

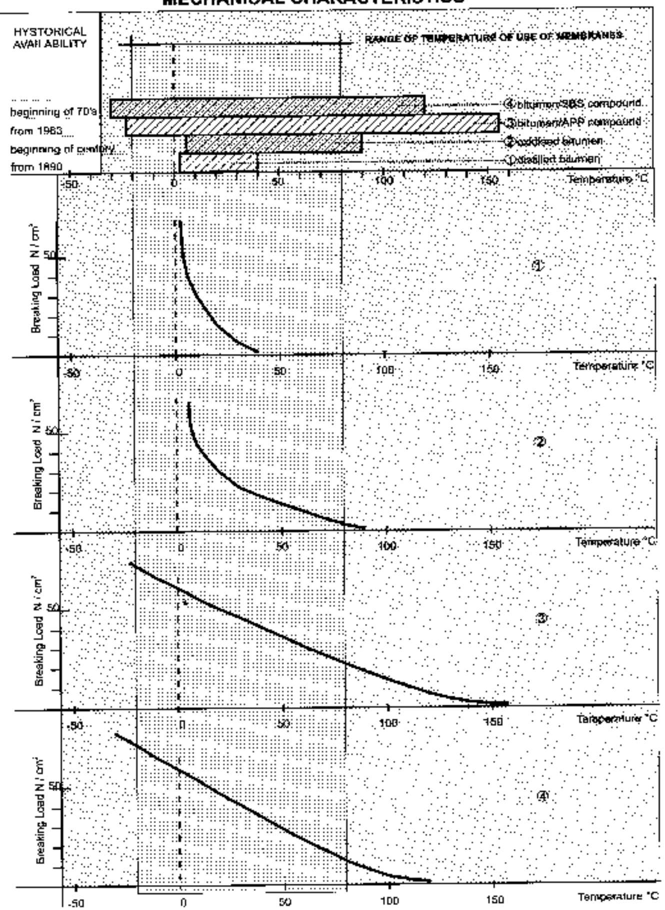




EVOLUTION IN BITUMEN MODIFICATION: GRAPHICAL REPRESENTATION

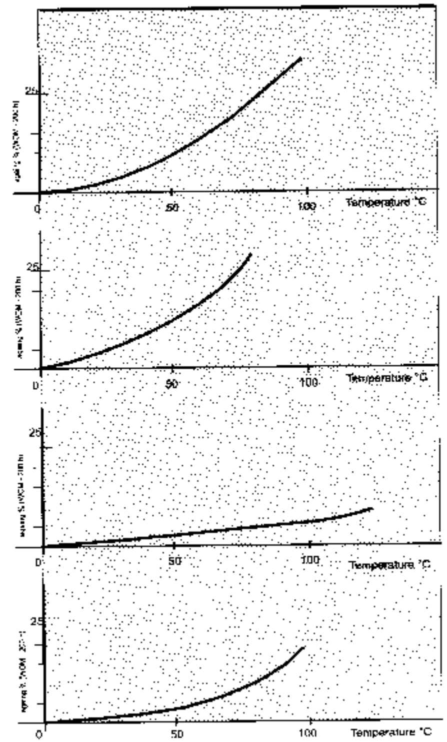
Table A

MECHANICAL CHARACTERISTICS



AGEING

The elements remarking the ageing are, in order of importance:
- cold flexibility
- behaviour at traction
- rigidity
- superficial phenomena



REMARKS

Distilled bitumen has high thermal susceptibility and does not present characteristics suitable for waterproofing applications; furthermore, it ages easily and - more importantly - shows no elasticity even at low levels of deformation (elastic limit = 0.3%). Elastic behaviour is vital in modern waterproofing products which must comply with the requirements of modern structures.

Oxidised bitumen, compared to distilled bitumen, has better resistance at higher temperatures, is more fragile at low temperatures and is more prone to ageing, because during the oxidation process the structural plastic reserve decreases proportionally. The elastic limit is as well penalized. Therefore, it satisfies only in a limited extent the application requirements.

Bitumen/APP compound satisfactorily covers the temperature range required in waterproofing applications. Consisting of a mixture in which the polypropylene assumes the continous phase, it shows:
- low level of ageing against atmospheric agents, high resistance to bacteria, moulds and rodents;
- high level of chemical inertia against acids and bases;
- elastic behaviour at low deformations;
- good organoleptic characteristics (generally a controversial point in the use of bitumens) and therefore non-pollutant: the polypropylene is a product which is transformed into CO_2 and H_2O on combustion.

The bitumen/SBS compound covers the temperature range required in waterproofing applications. In the compound, the SBS assumes the continous phase, thus giving the following characteristics:
- elastic behaviour and high elongation at break >1500%;
- good mechanical characteristics (higher thermosensitivity than the APP compound);
- low resistance to atmospheric agents: exposed materials thus require protection

TYPICAL CHARACTERISTICS OF BITUMEN/POLYPROPYLENE POLYMERS WATERPROOFING MASS

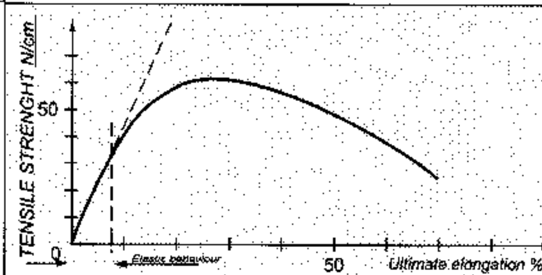
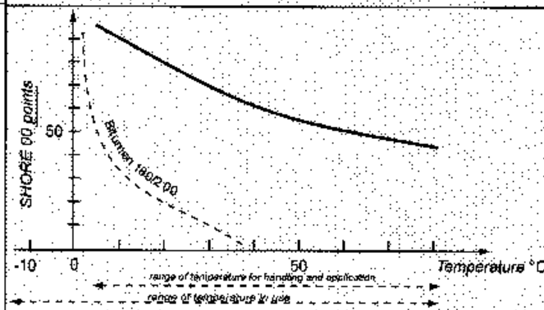
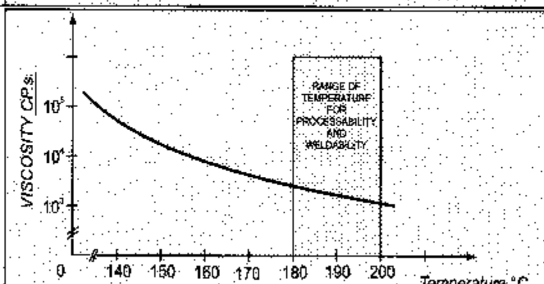
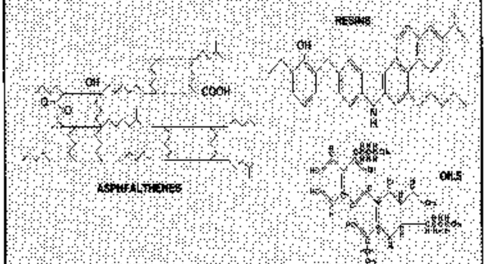
CHARACTERISTICS	STANDARD	MEASUREMENT UNIT	VALUES
- TENSILE STRENGHT (max) - ULTIMATE ELONGATION	Reference pr EN 12311/1	N/cm %	
- SENSITIVITY TO HEAT	Int. NG n°3/87	POINTS	
- BROOKFIELD VISCOSITY	ASTM D. 2669	CP.s. (m.Pa.s.)	
- SOFTENING POINT (R&B)	ASTM D. 36-76	°C	150
- DENSITY at 23°C	DIN 53479	g/cm	1,05
- COLD FLEXIBILITY	pr EN 12311/1	°C	-10
- COLD FLEXIBILITY AFTER 28 gg/80°C	pr EN 12311/1	°C	-5
- PERFORMANCE IN H_2O	UNI 8202/22	%	<1
- Q.U.V. AGING TEST	ASTM G53-77	-	Supera il test
- THERMAL CONDUCIVITY (λ)	-	Kcal/mh°C	= 0,12
- DIELECTRIC COSTANT (K)	ASTM D. 150	-	K a 1000Hz = 2,5

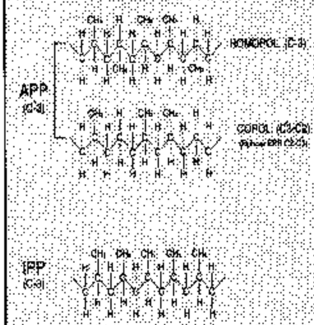
DIAGRAM OF MODIFICATION OF DISTILLED BITUMEN WITH POLYPROPYLENE

BASE COMPONENTS

BITUMEN B-200 (KG class ≈ 2,5)



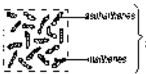
POLYPROPYLENE



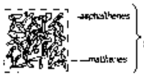
	ASPHALTHENES (non soluble in n-eptane)	MALTHENES (soluble in n-eptane)				POLYPROPYLENE	GRAND TOTAL
NATURE	polycycle / polycondensate	RESINS hetero cyclic aromatic	AROMATICS unsatured cyclic	SATURATED cyclic saturated naphthenic / linear saturated paraffinic			
EXAMPLE OF FORMULATION	80					20 (15 APP (1/3 COP.) + 4 ISO)	100
BITUMEN COMPONENTS	16	27	47	10	100	-	-
QUANTITY FOR 80 PARTS OF BITUMEN	13	21,6	37,5	8	80	20	100
PHASES FORMATION: continuous	1 (2%)	3,5 (16%)	17 (45%)	7,5 (95%)	29	20	49
PHASES FORMATION: discontinuous	12	18	20,5	0,5	51	-	51

SCHEMATIC REPRESENTATION OF BITUMEN IN MIXING PHASES

RAW BITUMEN Type A

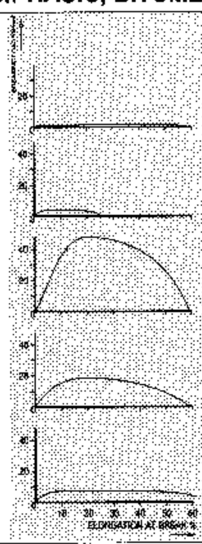


MODIFIED BITUMEN Type B — loss: 95% resins, 45% aromatics, 16% resins



BITUMEN/APP - ISO COMPOUND

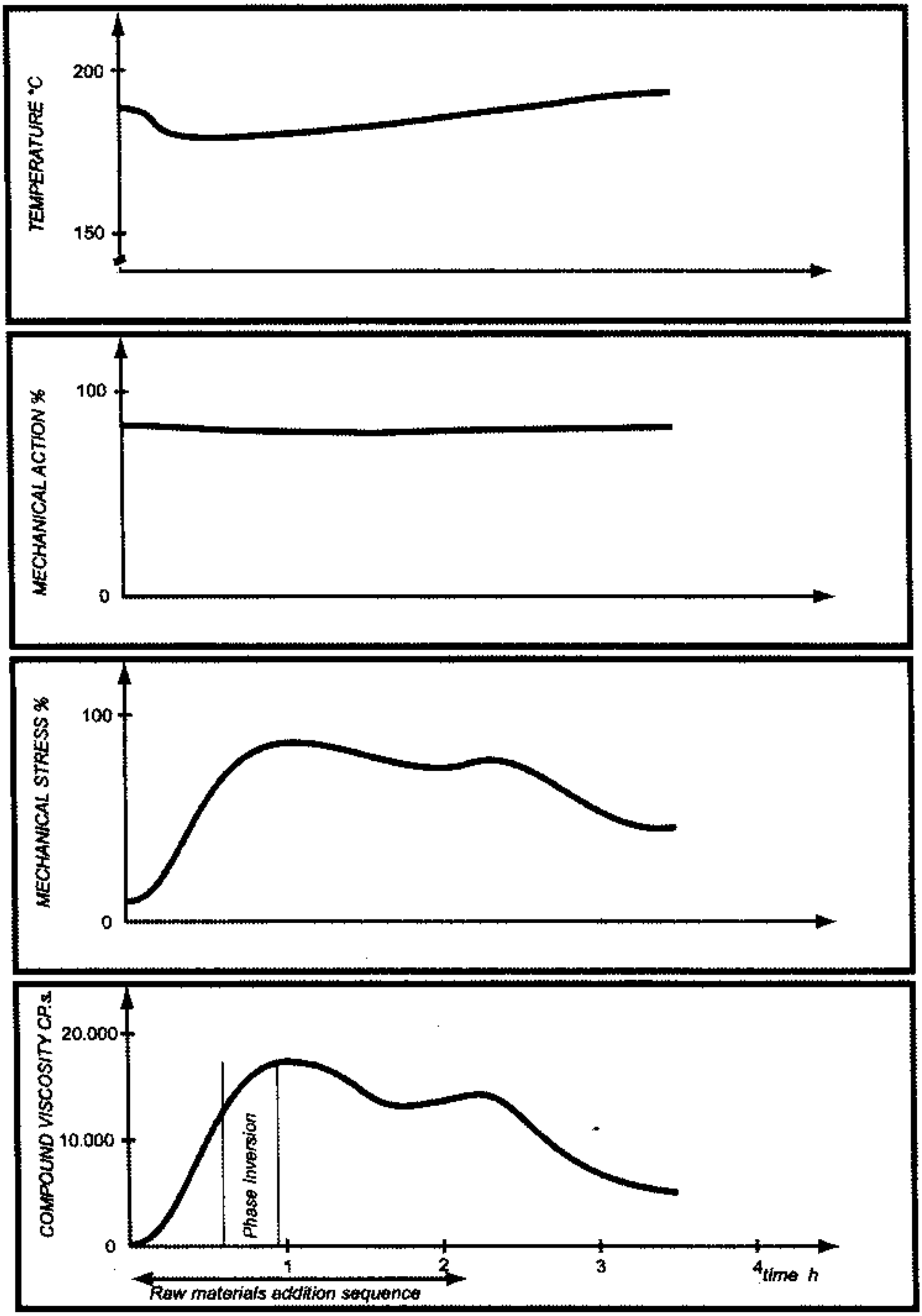
EVOLUTION OF CHARACTERISTICS OF COMPONENTS TO ARRIVE TO THE BIPHASIC, BITUMEN/POLYMER COMPOUND



	BROOKFIELD VISCOSITY at 180 °C mPa·s (ASTM - 2983)	COLD FLEXIBILITY °C (UNI 8202/15)	R & B °C (ASTM - D 2878)	HEAT FLOW TEST (UNI - 8202/18)
RAW BITUMEN Type A	30 ÷ 40	+2	40	-
MODIFIED BITUMEN Type B	60 ÷ 80	4	70	-
APP+IPP (average values considering the degrade due to thermal/mechanical effect)	80.000 ÷ 90.000	< -25	165	-
APP+IPP +MALTHENES	25.000 ÷ 30.000	< -25	160	-
COMPOUND	3.000 ÷ 5.000	-10	155	> 2 hours (120 °C)

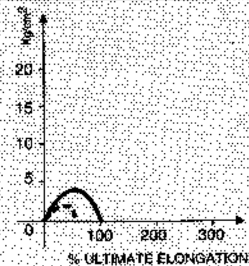
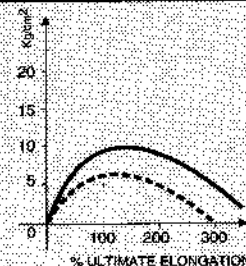
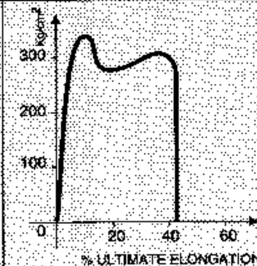
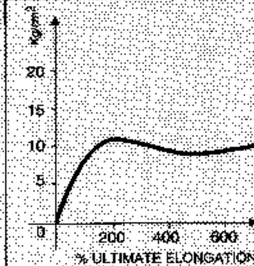
Table D

PARAMETERS OF CONTROL IN THE PRODUCTION OF PLASTOMERIC WATERPROOFING COMPOUND



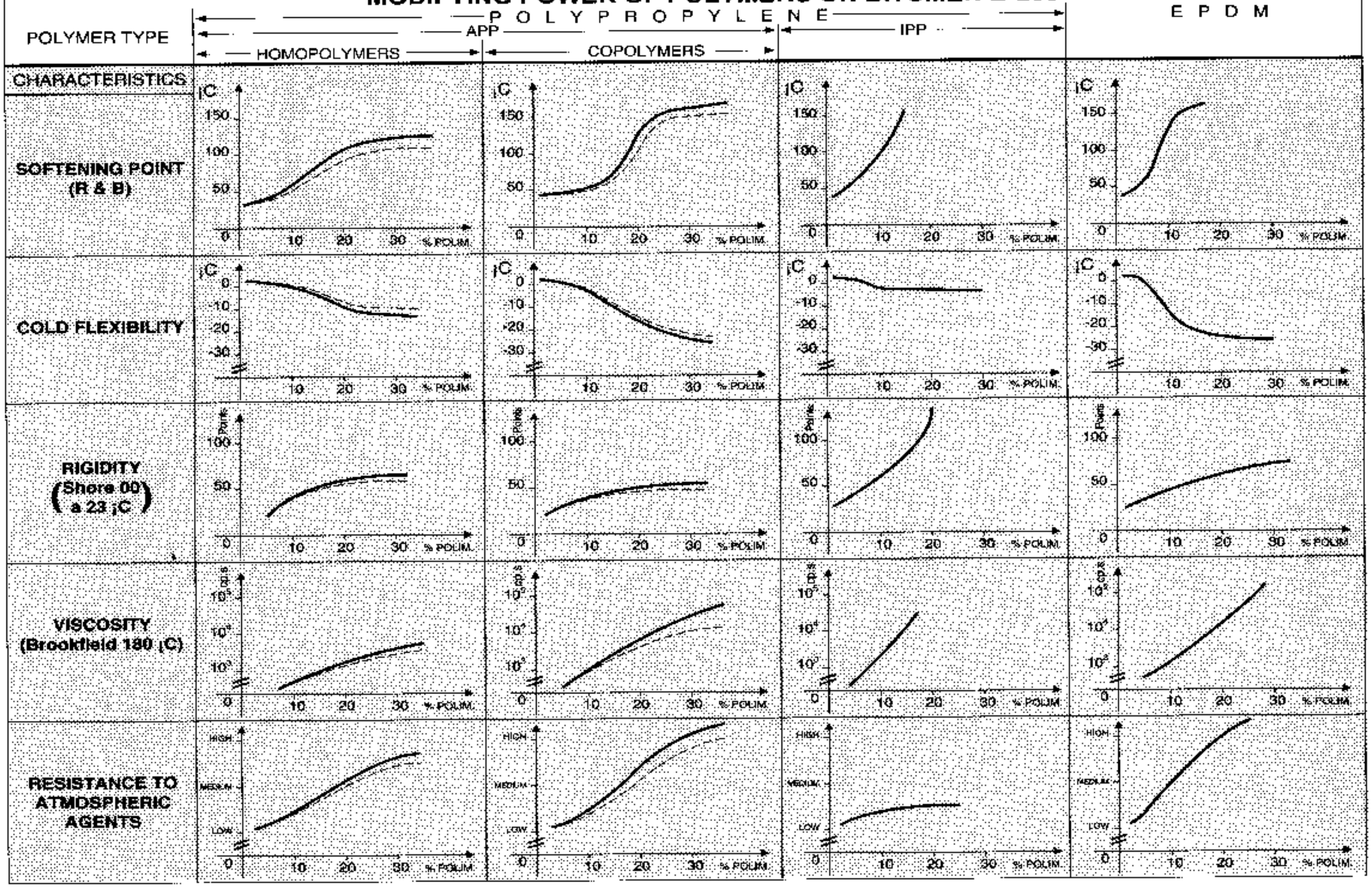
CHARACTERISTICS OF BITUMEN MODIFYING POLYMERS

Table E

POLYMER TYPE			POLYPROPYLENE			EPDM
			APP		IPP	
			HOMOPOLYMERS	COPOLYMERS		
CHARACTERISTICS	STANDARD	MEASUREMENT UNIT				
TENSILE STRENGTH	REFERENCE Rif.to pr EN 12311/1	kg/cm²				
ULTIMATE ELONGATION	"	%				
M.I. - 230/2	ASTM D-1238	g/10'	-	-	4 6	-
BROOKFIELD VISCOSITY 180 ¡C	ASTM D-2669	cp.s	2.000–500	300.000–50.000	-	-
" 200 ¡C	"	"	900–300	200.000–35.000	-	>5.000.000
SOFTENING POINT (R & B)	ASTM D-36/76	¡C	>130	>150	-	>180
COLD FLEXIBILITY	pr EN 1109	¡C	-5 -10	-20 -30	-3	-50
AGING DUE TO ATMOSPHERIC AGENTS (12-month exposure)	NG	-	good	very good	satisfactory	very good
RESISTANCE TO ACID-BASIC SOLUTIONS (12-month exposure)	NG	-	good	very good	very good	very good
DISPERSIBILITY IN BITUMEN B-200	NG	-	very good	satisfactory	satisfactory	difficult

MODIFYING POWER OF POLYMERS ON BITUMEN B-200

Table F



BITUMEN/POLYPROPYLENE POLYMERS COMPOUNDING PROCESS DIAGRAM

Table G

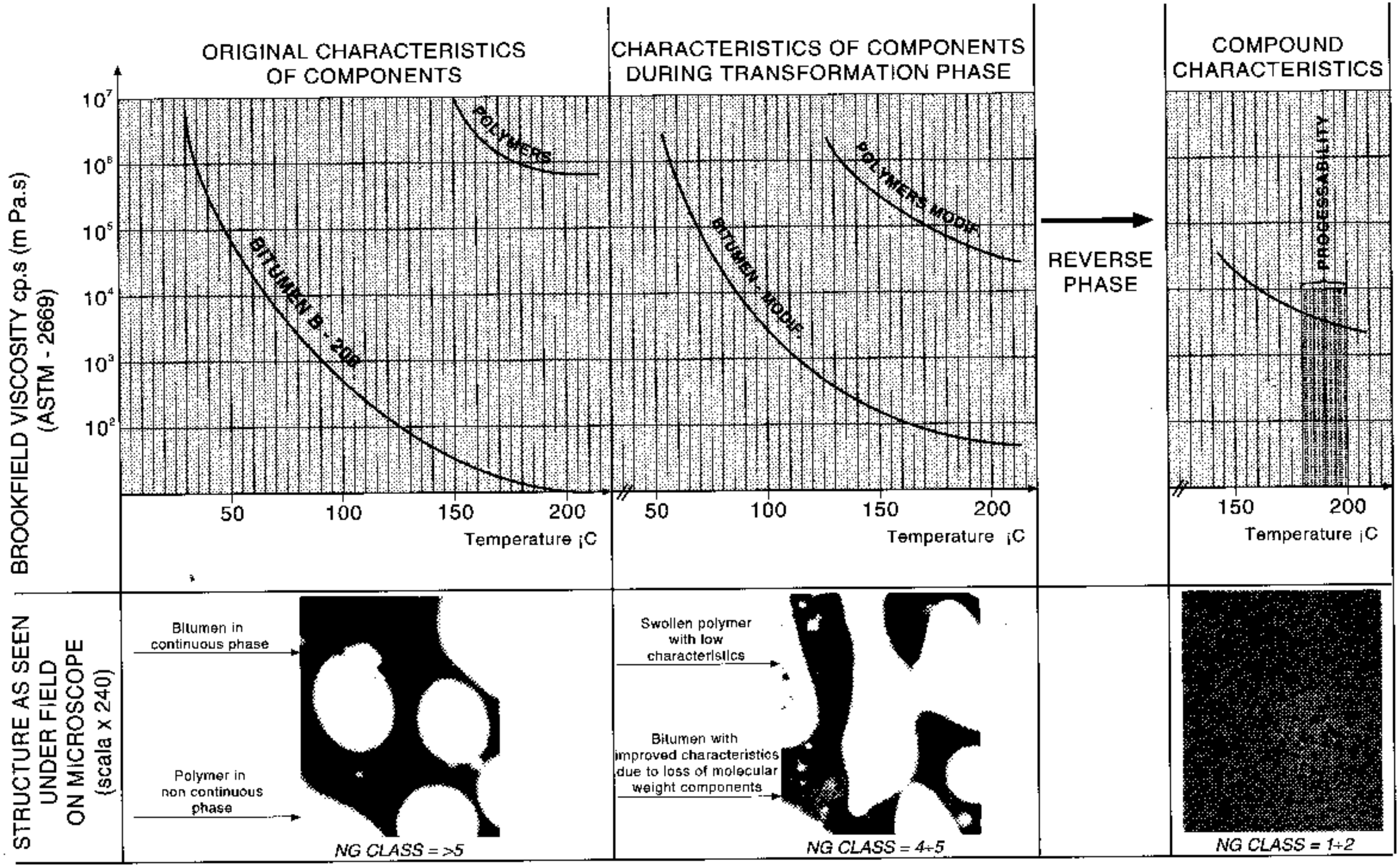


Table H

EFFECT OF AGEING ON BEHAVIOUR PROPERTIES OF WATERPROOFING PLASTOMERIC COMPOUNDS HAVING -10 °C COLD FLEXIBILITY