## 3 . Mechanical Properties

### 3・1 Tensile Strength

The stress-strain curve when tension is applied to ASTM-D638 type 1 test piece of Iupilon / NOVAREX at a strain velocity of 5mm/min is shown in Fig. 3・1—1.

The following are the values of Iupilon / NOVAREX at room temperature.

$\sigma_y$ = 54 ~ 64 Mpa (550 ~ 650kgf/cm$^2$)

$\sigma_b$ = 59 ~ 69 Mpa (600 ~ 700kgf/cm$^2$)

$\varepsilon_y$ = 6 ~ 8%

$\varepsilon_b$ = 90 ~ 140%

The temperature characteristic of the tensile yield stress of Iupilon / NOVAREX is shown in Fig. 3・1—2.

.The influence of strain velocity is shown in Fig. 3・1—3, 4.

The relation with the tensile yield stress at a low strain velocity can be displayed by the straight line as shown in Fig. 3・1—3, but increases rapidly at a high strain velocity as shown in Fig. 3・1—4 .

The relation between molecular weight and tensile yield stress is shown in Fig. 3・1—5, 6, 7.

Iupilon / NOVAREX becomes t brittle break completely at Mv = 15000.

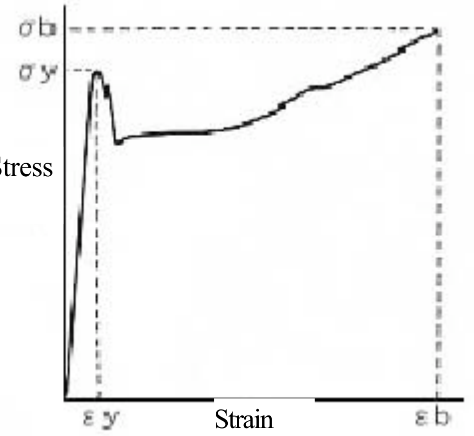



Fig. 3.1-1 Stress-Strain curve of Iupilon / NOVAREX

σ y Yield stress σ b Breaking stress

ε y Elongation at yield ε b Elongation at break

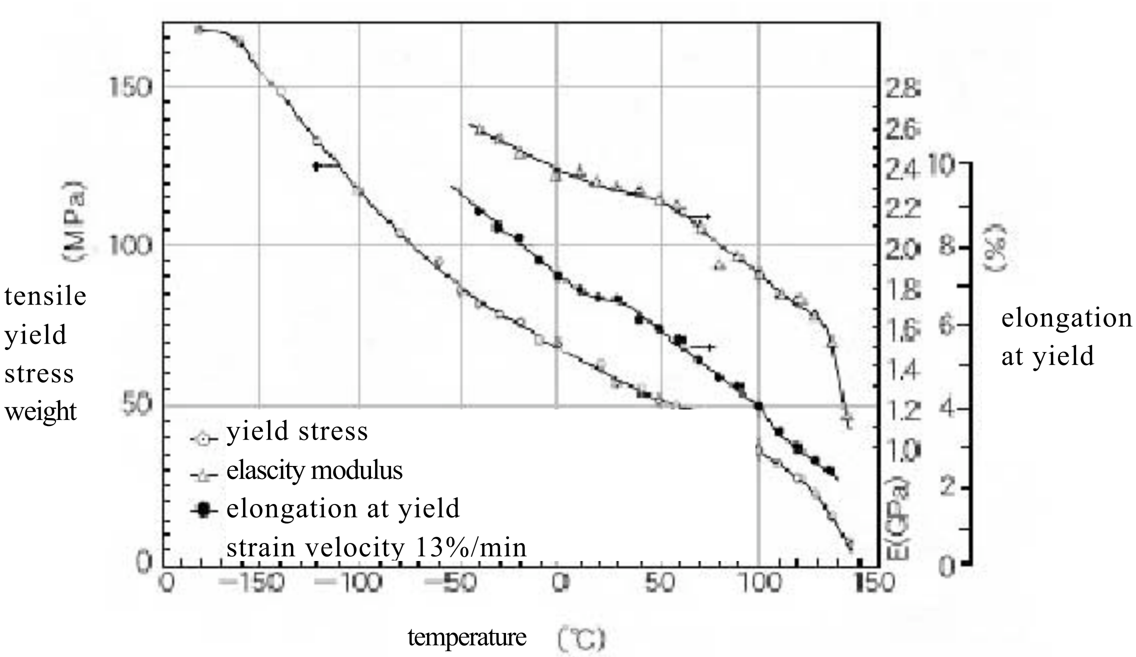



Fig. 3・1—2 Temperature characteristic curve of tensile yield stress

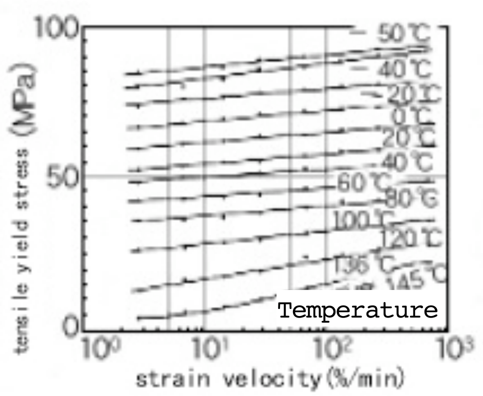



Fig. 3・1—3
Relation between strain velocity and tensile yield stress

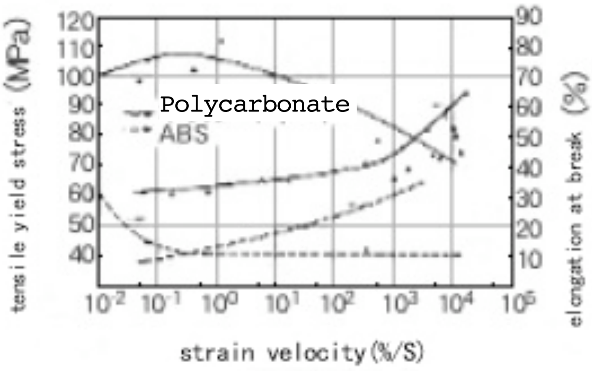



Fig. 3・1—4 Relation between strain velocity and tensile yield stress and break elongation(literature value)

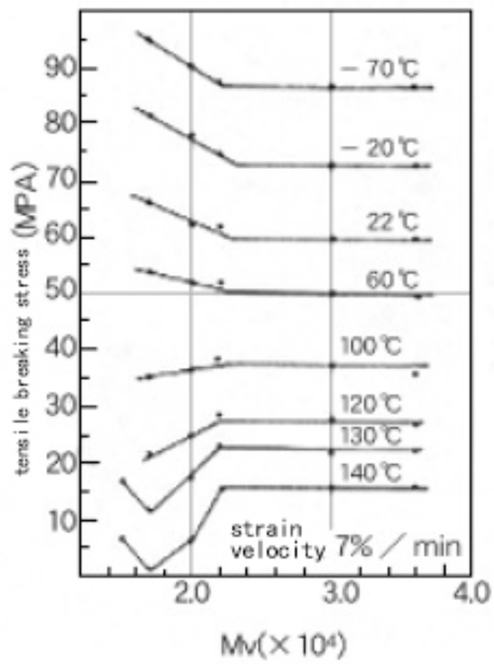



Fig. 3・1—5
Relation between molecular weight and tensile yield stress

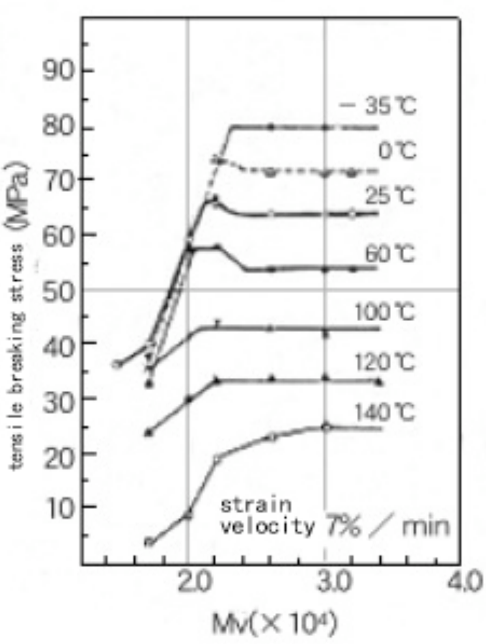



Fig. 3・1—6
Relation between molecular weight and tensile breaking stress

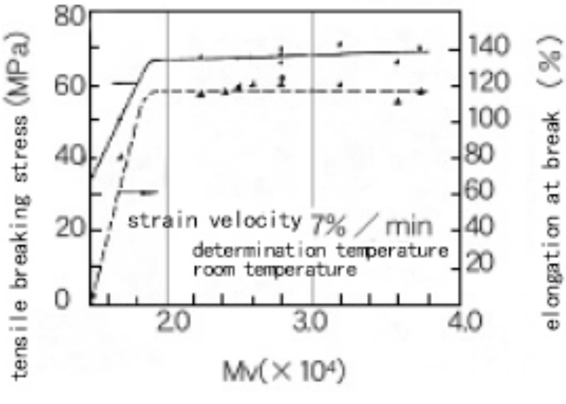



Fig. 3・1—7　Relation between molecular weight and tensile properties

When Iupilon / NOVAREX is heat-treated, the hardening phenomenon is observed as shown in Fig. 3・1−8, 9. The yield strength rises even at 50℃ but causes the hardening earliest at 130-150℃ as shown in Fig. 3・1-10.

The comparison of mechanical properties of Iupilon / NOVAREX with other resisns is as shown in Fig. 3・1−11, 12, 13 and 14.

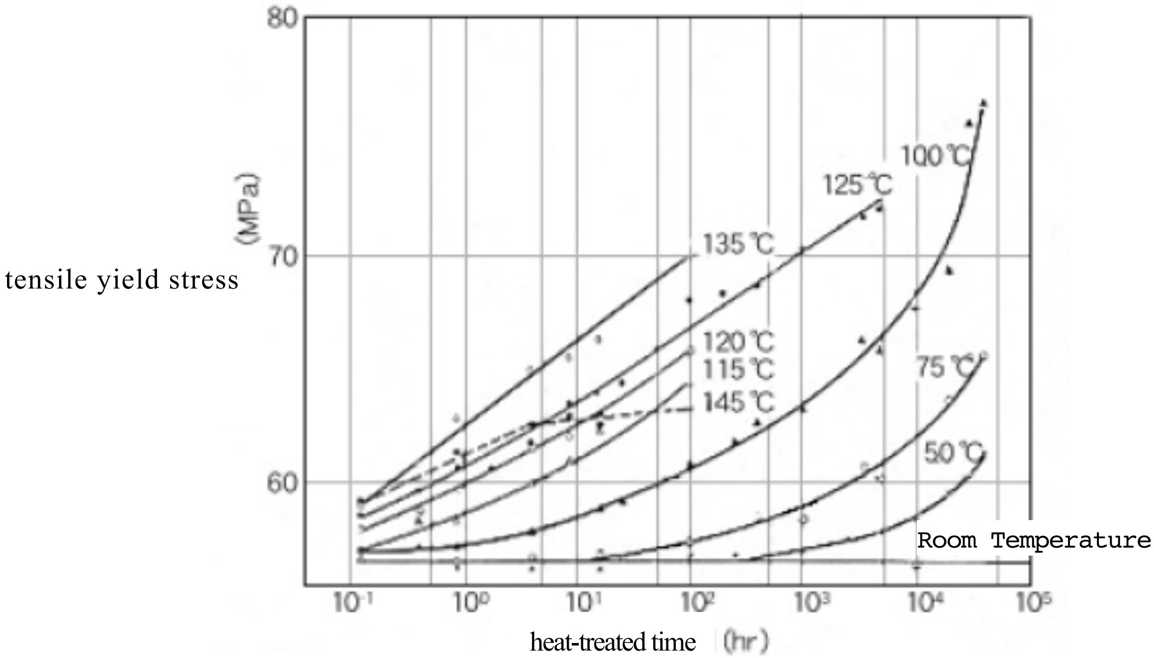



Fig. 3・1−8 Change in tensile yield stress by heat treatment
(strain velocity 7%/min)

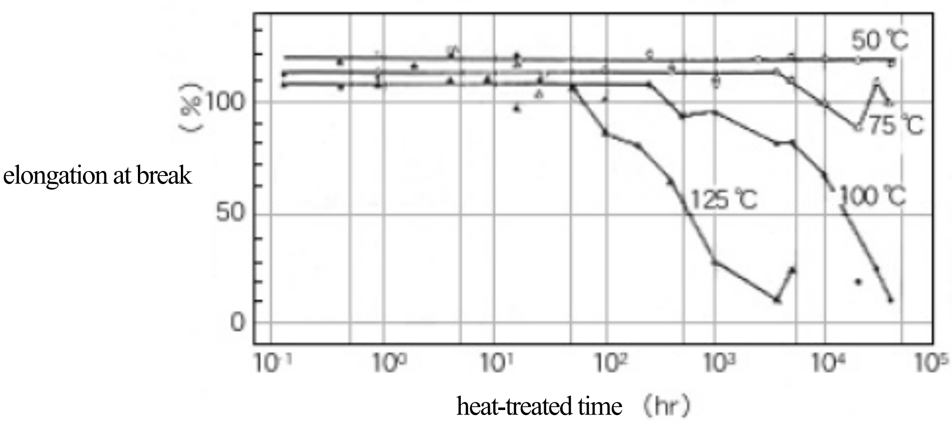



Fig. 3・1−9 Change in elongation at break by heat treatment
(strain velocity 7%/min, room temperature)

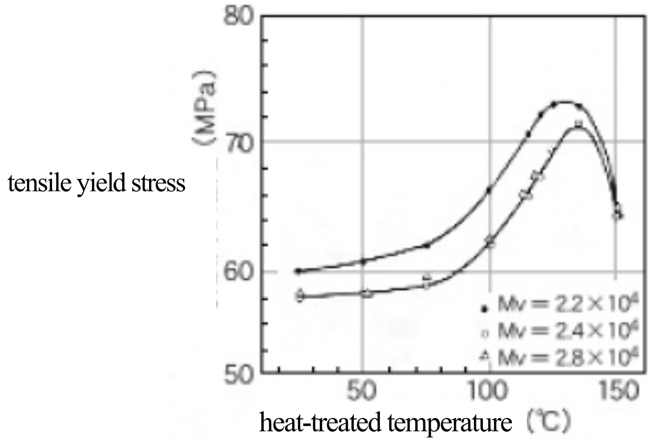



Fig. 3・1－10　Change in tensile yield stress
(strain velocity 7%/min, heat-treated time 100 hours)

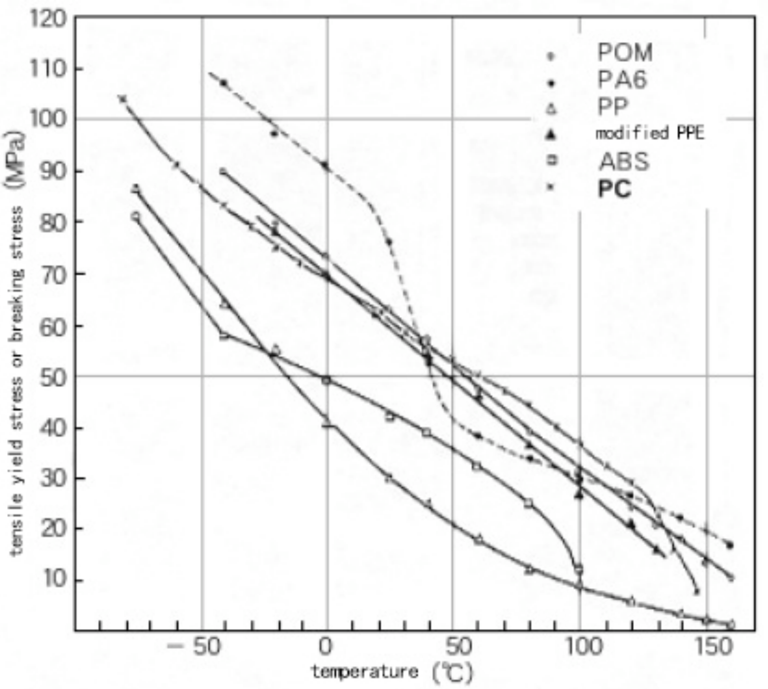



Fig. 3・1－11　Relation of Iupilon / NOVAREX with other resins

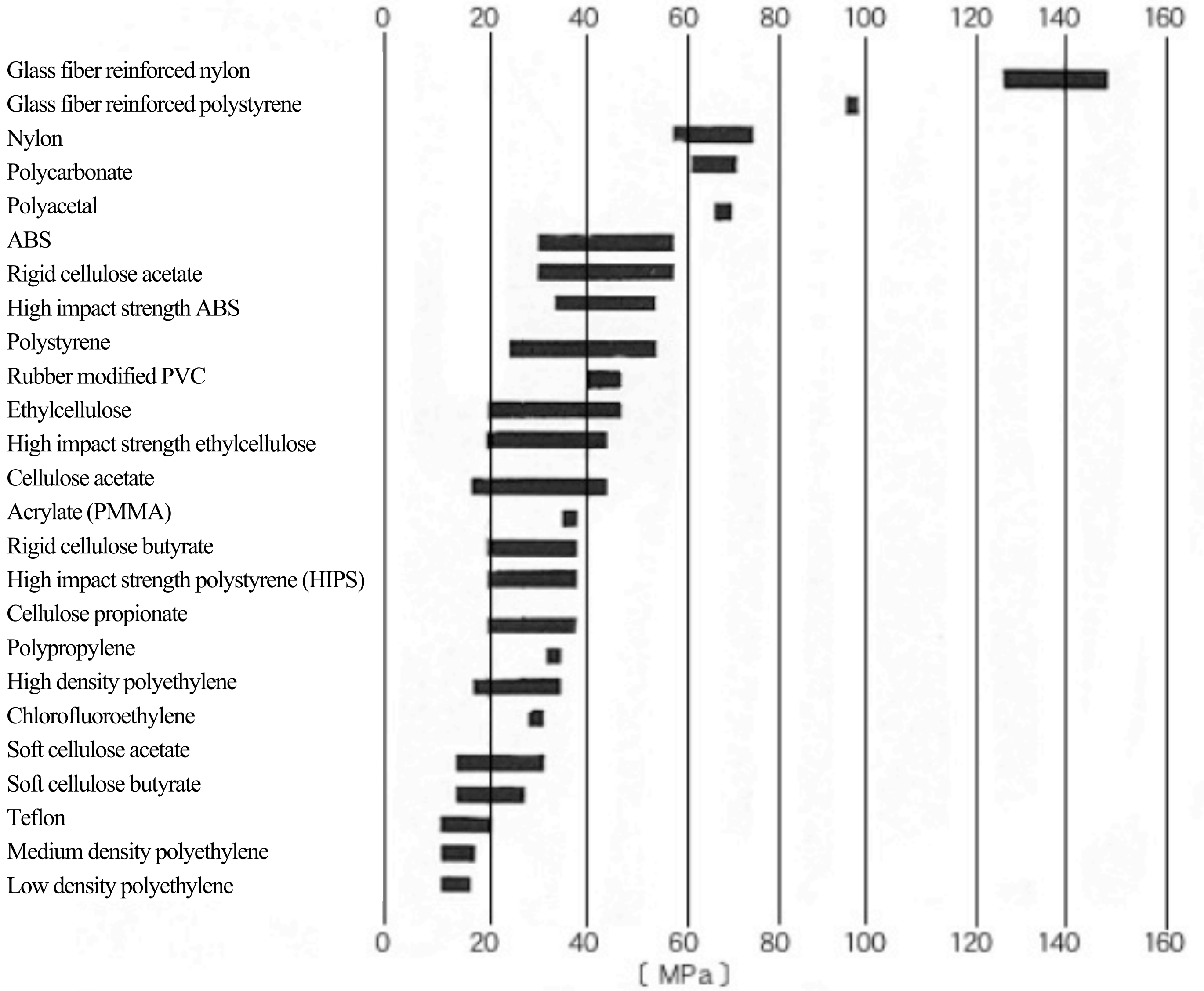
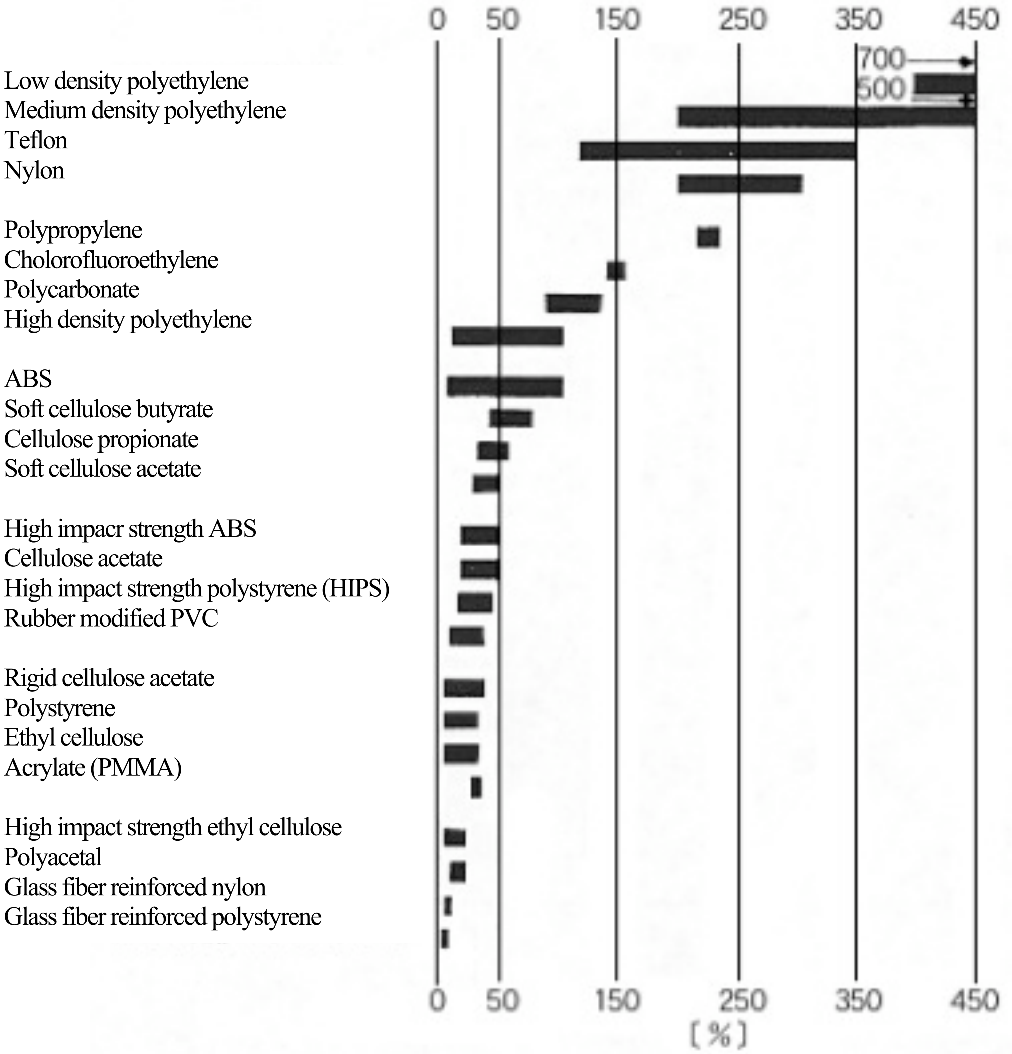



Fig. 3・1−12 Breaking stress of various resins



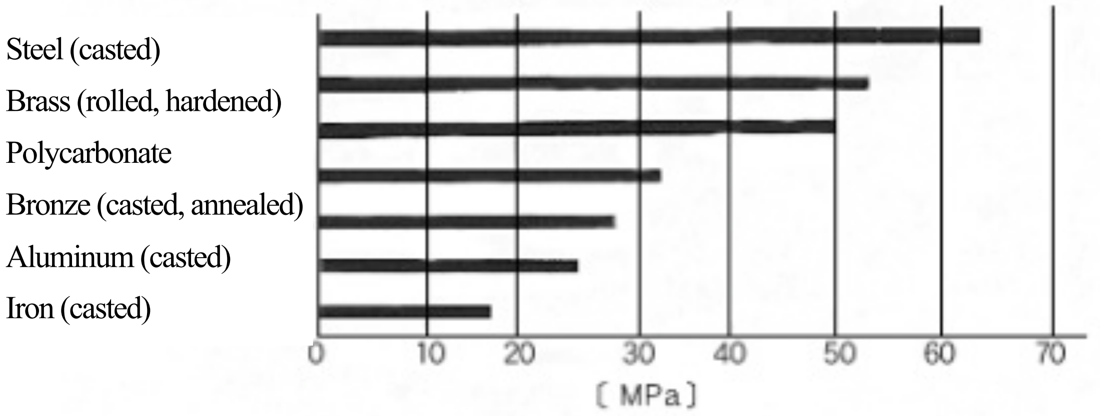




Fig. 3・1－14 Tensile strength per unit weight of Polycarbonate and metals

### 3・2 Compressive Strength

The compressive strength of Iupilon / NOVAREX is 74~88Mpa (750 ~ 900kgf/$cm^2$) and modulus of elasticity is 1.7 ~1.9Mpa ($17\times10^3$ ～$19\times10^3$kgf/$cm^2$). Also, the rate of deformation at yield is 8 ~ 10%.

The relation between compressive strength, modulus of elasticity and temperature of Iupilon / NOVAREX is shown in Fig. 3・2－1.

The Poisson's ratio of Iupilon / NOVAREX is 0.38.

A comparison with other resins is shown in Table 3・2－1.

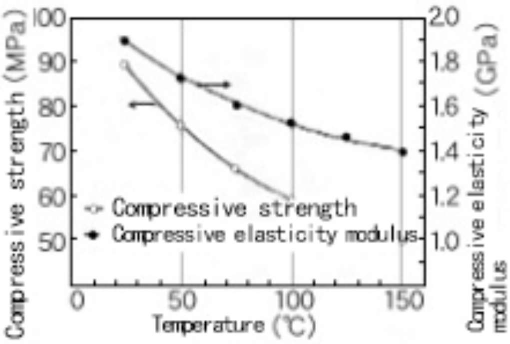



Fig. 3・2－1
Change in temperature of compressive strength and modulus of elasticity

Table 3・2－1

| Name | Compressive Strength (ASTM－D695) MPa（kgf／$cm^2$） | Name | Compressive Strength (ASTM－D695) MPa（kgf／$cm^2$） |
|---|---|---|---|
| Polycarbonate | 76.5（780） | Rigid cellulose butyrate | 53.0～154（540～1570） |
| Rubber modified PVC | 35.3～62.8（360～640） | Glass fiber reinforced polystyrene | 91.2～108（930～1100） |
| High impact strength polystyrene（HIPS） | 28.4～62.8（290～640） | Cellulose acetate | 105～176（1070～1790） |
| Cellulose propionate | 49.0～154（500～1570） | Glass fiber reinforced nylon | 112（1140） |
| High impact strength ethyl cellulose | 69.6～245（710～2500） | Rigid cellulose acetate | 133～253（1360～2580） |
| Ethyl cellulose | 69.6～245（710～2500） | Modified acrylate（MMA） | 44.1～98.1（450～1000） |
| Soft cellulose acetate | 91.2～140（930～1430） | Polyacetal | 36.3（370） |
| Soft cellulose butyrate | 53.0～154（540～1570） | Polypropylene | 59.8～69.6（610～710） |

### 3・3 Flexural Strength

The flexural strength of Iupilon / NOVAREX is 80～90Mpa (820～920kgf／$cm^2$) and the flexural modulus of elasticity is 2. 26GPa （23000kgf／$cm^2$）. Also, it does not break when bent to an angle of 80 ～$90^o$ .

The temperature characteristics and the influence of molecular weight on flexural strength are shown in Fig. 3・3－1, 2 and 3, respectively.

The change in flexural strength by heat treatment is shown in Fig. 3・3－4.

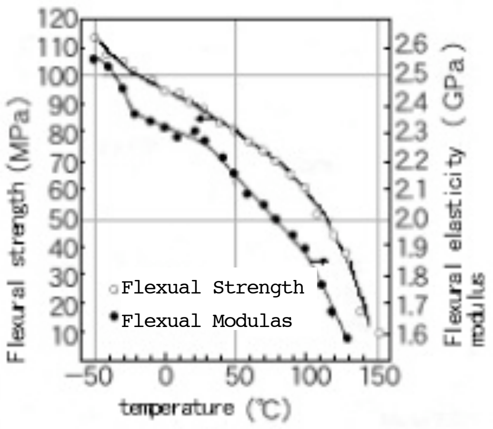



Fig. 3・3−1 Temperature characteristics of flexural strength

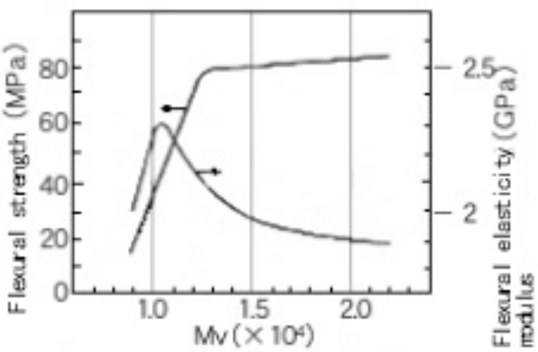



Fig. 3・3−2 Influence of average molecular weight on flexural strength (literature)

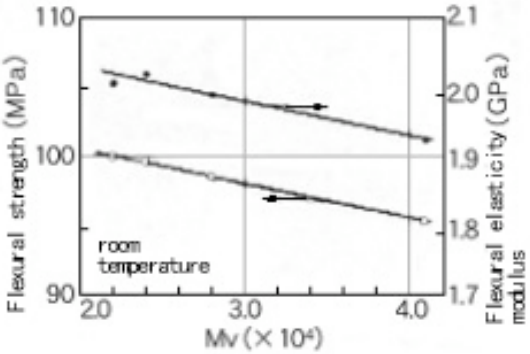



Fig. 3・3−3 Influence of average molecular weight on flexural strength

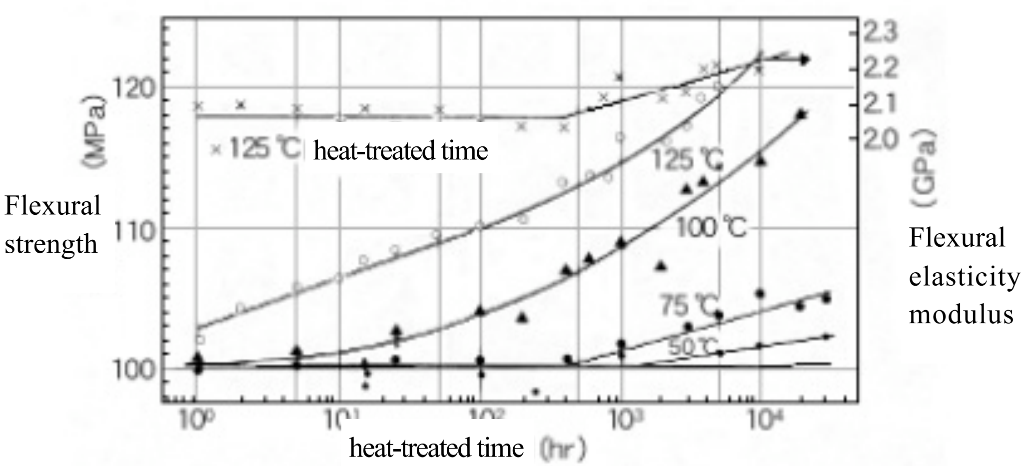



Fig. 3・3−4
Change in flexural strength by heat treatment
$(Mv = 2.8 \times 10^4)$

A comparison with other resins is shown in Fig. 3・3−5 and Table 3・3−1.

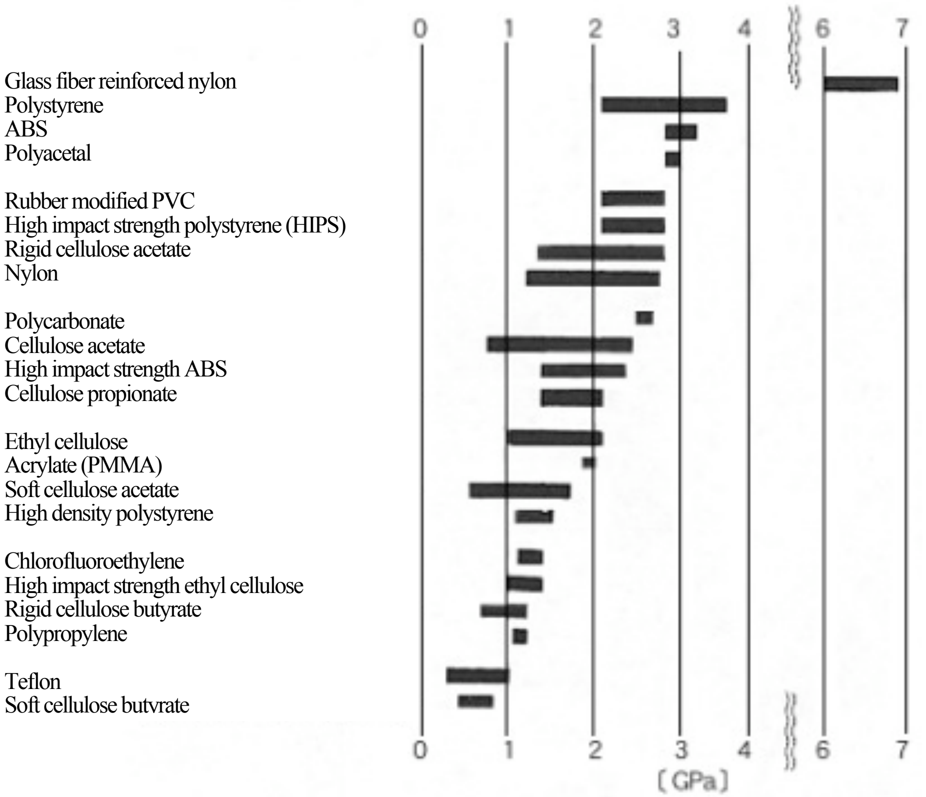



Fig. 3・3−5 Flexural modulus of elasticity of various resins

Table 3・3−1

| Name | Flexural strength (ASTM−D790) MPa (kgf／cm$^2$) | Name | Flexural strength (ASTM−D790) MPa (kgf／cm$^2$) |
|---|---|---|---|
| Polycarbonate | 80.4〜90.2$^d$ (820〜920$^d$) | Teflon | NB |
| High impact strength polystyrene (HIPS) | NB | Chlorofluoroethylene | NB |
| Cellulose propionate | 27.5〜64.7$^d$ (280〜660$^d$) | Glass fiber reinforced nylon | 140〜155 (1430〜1580) |
| High impact strength ABS | 48.1〜55.9$^d$ (490〜570) | Polystyrene | NB |
| High impact strength ethylene cellulose | 27.5〜42.2 (280〜430) | ABS | 53.0〜77.5 (540〜790) |
| Ethyl cellulose | 27.5〜70.6 (280〜720) | Rigid cellulose acetate | 41.2〜70.6$^d$ (420〜720$^d$) |
| Soft cellulose acetate | 18.6〜50.0$^d$ (190〜510$^d$) | Nylon | NB |
| Soft cellulose butyrate | 17.7〜36.3$^d$ (180〜370$^d$) | Acrylate (PMMA) | 62.8〜91.2 (640〜930) |
| Rigid cellulose butyrate | 27.5〜55.9 (280〜570) | Polyacetal | 100 (1020) |
| Glass fiber reinforced polystyrene | 113 (1150) | Polypropylene | 56.9 (580) |
| Cellulose acetate | 25.5〜58.8$^d$ (260〜600$^d$) | | |

NB＝no break, d＝yield stress

## 3・4 Impact strength

The impact values of Iupilon / NOVAREX are as follows:

Izod method, with notch (thickness 3.2mm) ASTM D256 740~1000J/m (75~102kgf.cm/cm)
Izod method, with notch (thickness 6.4mm) ASTM D256 98~250J/m (10~25kgf.cm/cm)
Izod method, without notch (thickness 3.2mm) ＞3700J/m (＞380kgf.cm/cm)
Charpy method, with notch (thickness 6.4mm) ASTM D256 15~59kJ/$m^2$ (15~60kgf.cm/$cm^2$)
Tensile impact method (thickness3.2mm) ASTMD1822 690 ~ 880 kJ/$m^2$ (700~900 kgf.cm/$cm^2$)(L)
(thickness 1.6mm) ASTMD1822 1100~1500 kJ/$m^2$ (1100~1500 kgf.cm/$cm^2$)(L)

Falling ball method (thickness 3.2mm)
Tip of ball 12.7mmR, circular support 50.8mmϕ 240~310J (24~32kgf.m)
Tip of ball 20.0mmR, circular support 90 mmϕ 170~230J (17~23kgf.m)

The temperature characteristic of the impact value of Iupilon / NOVAREX is shown in Fig. 3・4−1 and 3・4−2. The Izod impact values and the falling ball impact values indicate brittle break at the temperature around -50℃, and below -70℃, respectively. (The temperature that break shifts from ductility to brittleness is called the transition temperature). Also, as shown in Fig. 3・4−3, the brittle break is generated when the thickness becomes a constant value but the specific thickness and the state of change depend on the kind of the impact.
The influence of molecular weight on impact values are shown in Fig. 3・4−4, 5 and 6.
In the temperature region where the ductile rupture is shown, the molecular weight which shows its maximum in any test method exists.

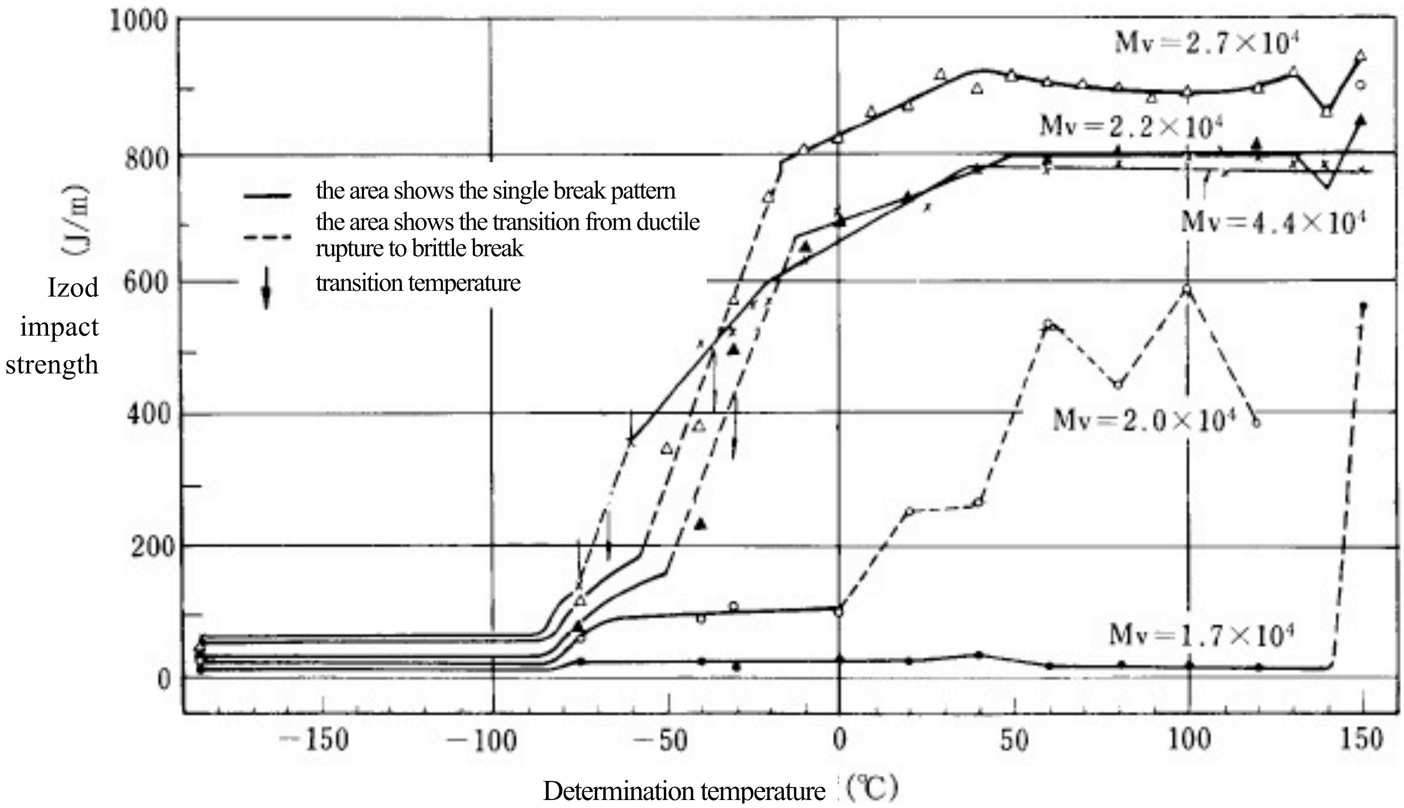



Fig. 3・4−1 Izod impact strength-temperature characteristics

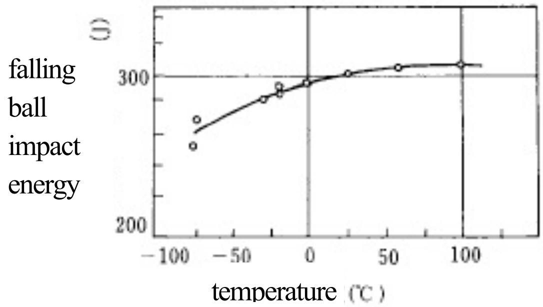



Fig. 3・4－2　Change in temperature of falling ball impact
(circular disc with thickness of 2mm)

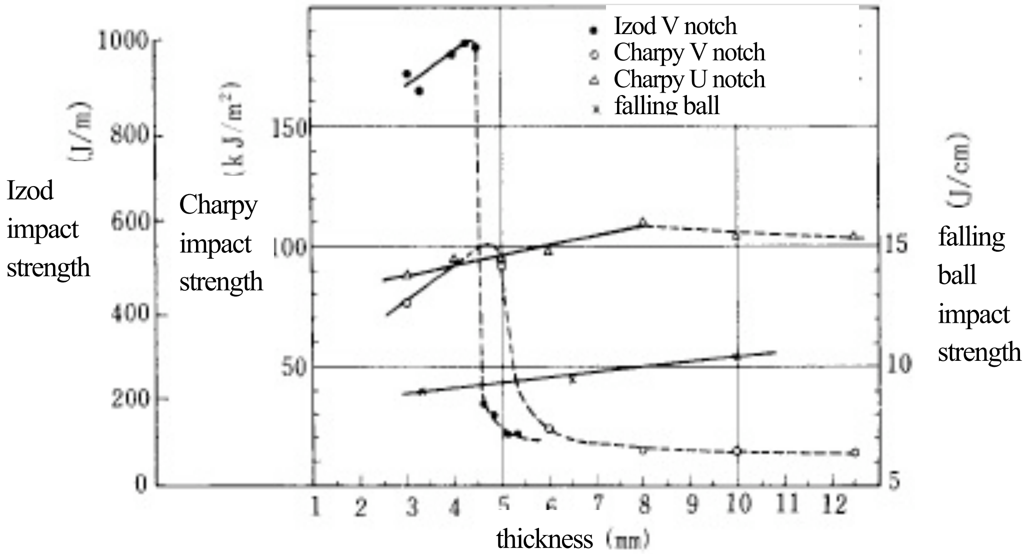



Fig. 3・4－3　Change in impact values by sample thickness (room temperature)
－ductile rupture　……brittle break

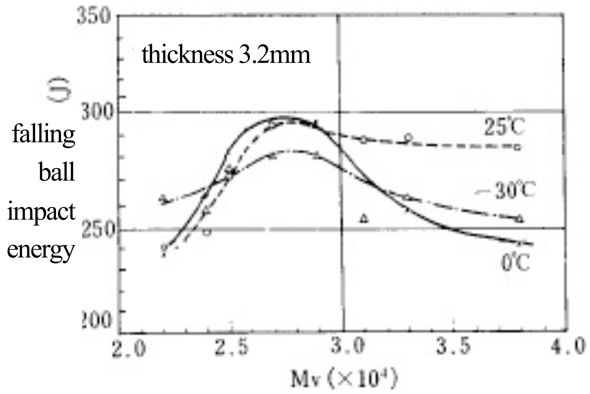



Fig. 3･4－4 Relation between molecular weight and falling ball impact energy

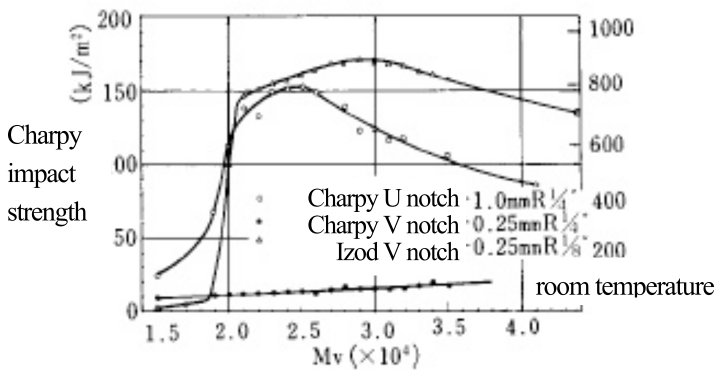



Fig. 3･4－5 Relation between molecular weight and impact values

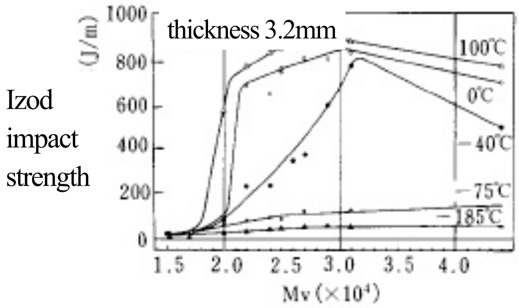



Fig. 3・4－6
Relation between molecular weight and Izod impact strength

The impact value of Iupilon / NOVAREX is known to be deteriorated by heat treatment as shown in Fig. 3. 4-7, 8, 9 and 10. It decreases rapidly in the Izod impact at 125℃, shows the deterioration even at 50℃ and 75℃ after a long time. However, it does not show the brittle break in the falling ball impact even at 125℃ and 1000hours. The change in impact character when treated at different temperature in a given time and the rapid thermal hardening at 100～140℃ are observed as shown in Fig. 3. 4-10.

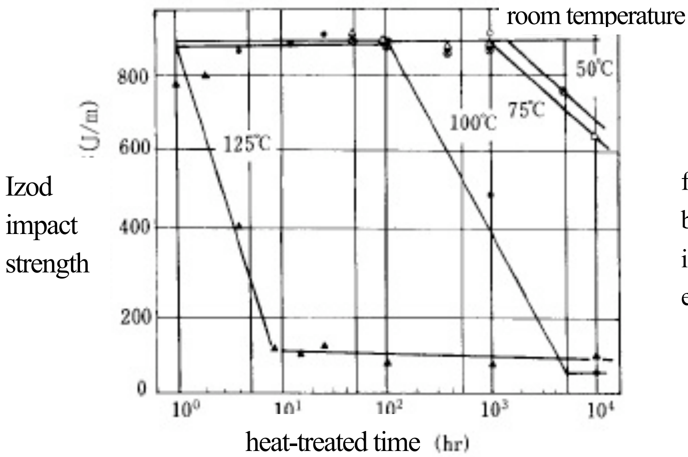



Fig. 3・4—7 Change in Izod impact strength by heat treatment

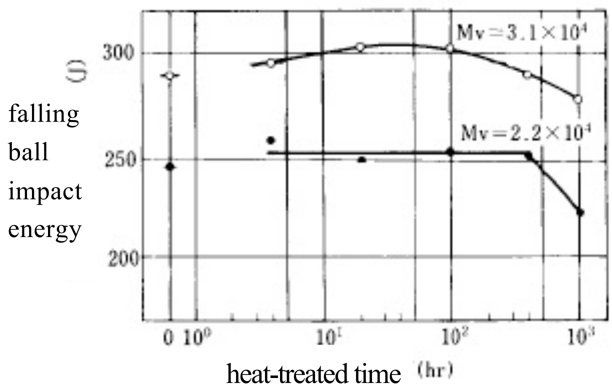



Fig. 3・4—8 Change in falling ball impact by heat treatment (125℃)

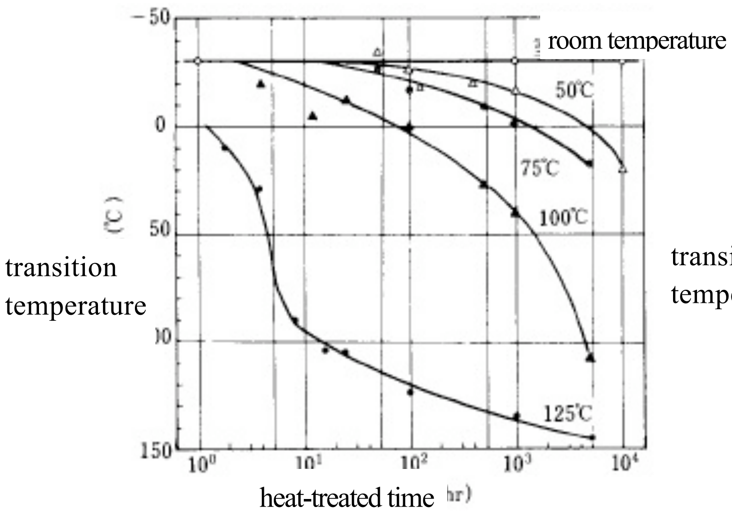



Fig. 3・4—9 Change in transition temperature by heat treatment (thickness of Izod impact test piece: 3.2mm)

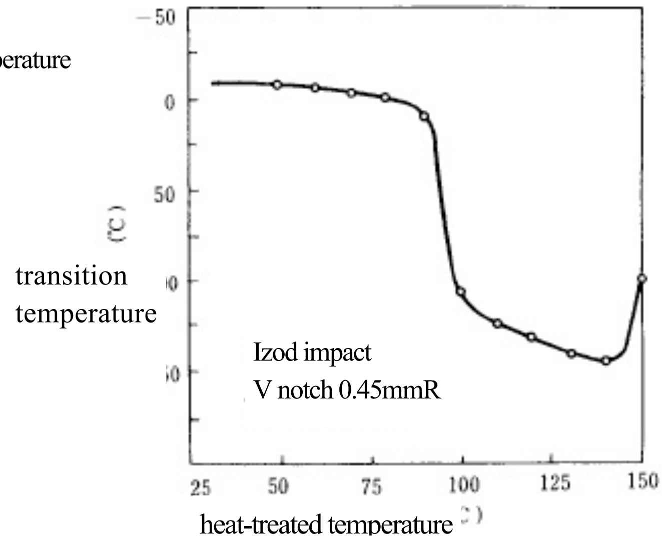



Fig. 3・4—10 Effect of heat-treated temperature (treated time, 48hr, thickness 6.4mm)

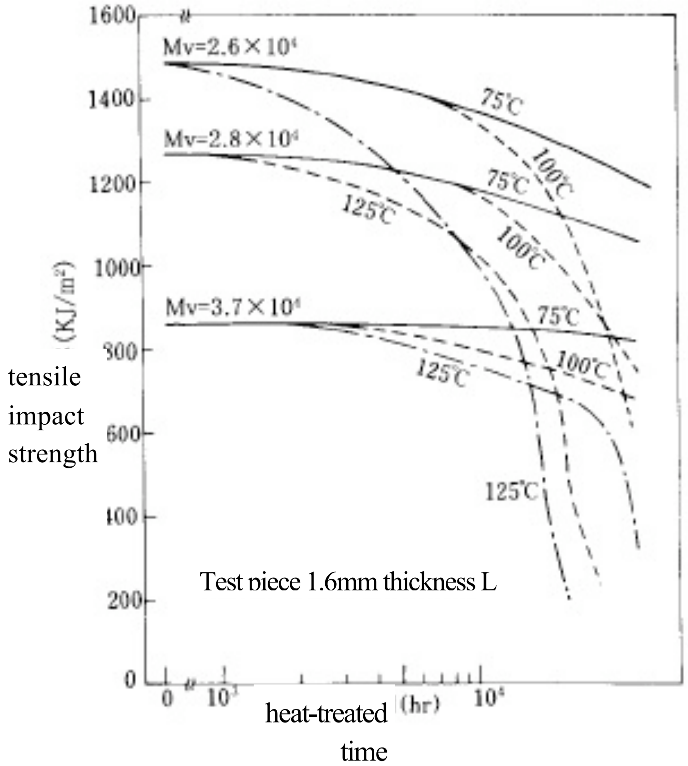



Fig. 3・4−11 Change in tensile impact strength by heat treatment − (1)

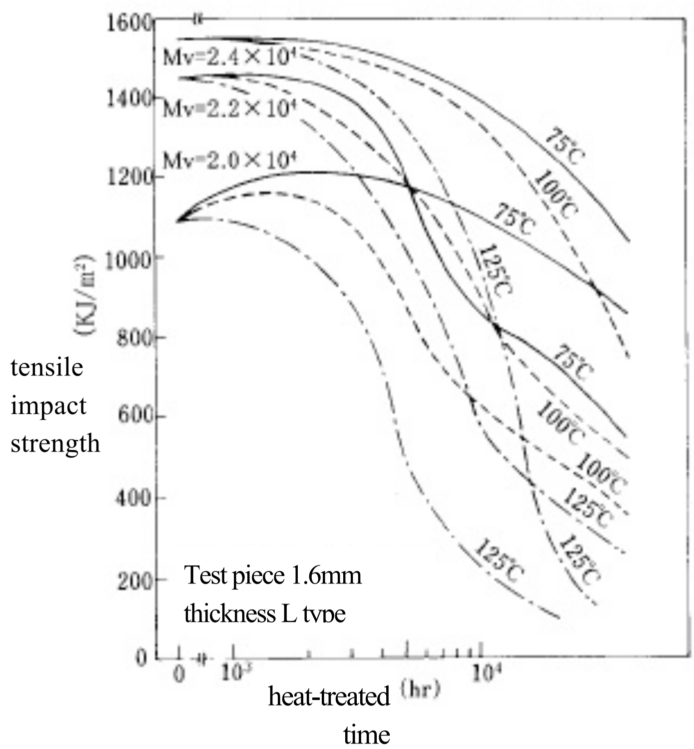



Fig. 3・4−12 Change in tensile impact strength by heat treatment − (2)

A comparison with other resins is shown in Fig. 3・4−13

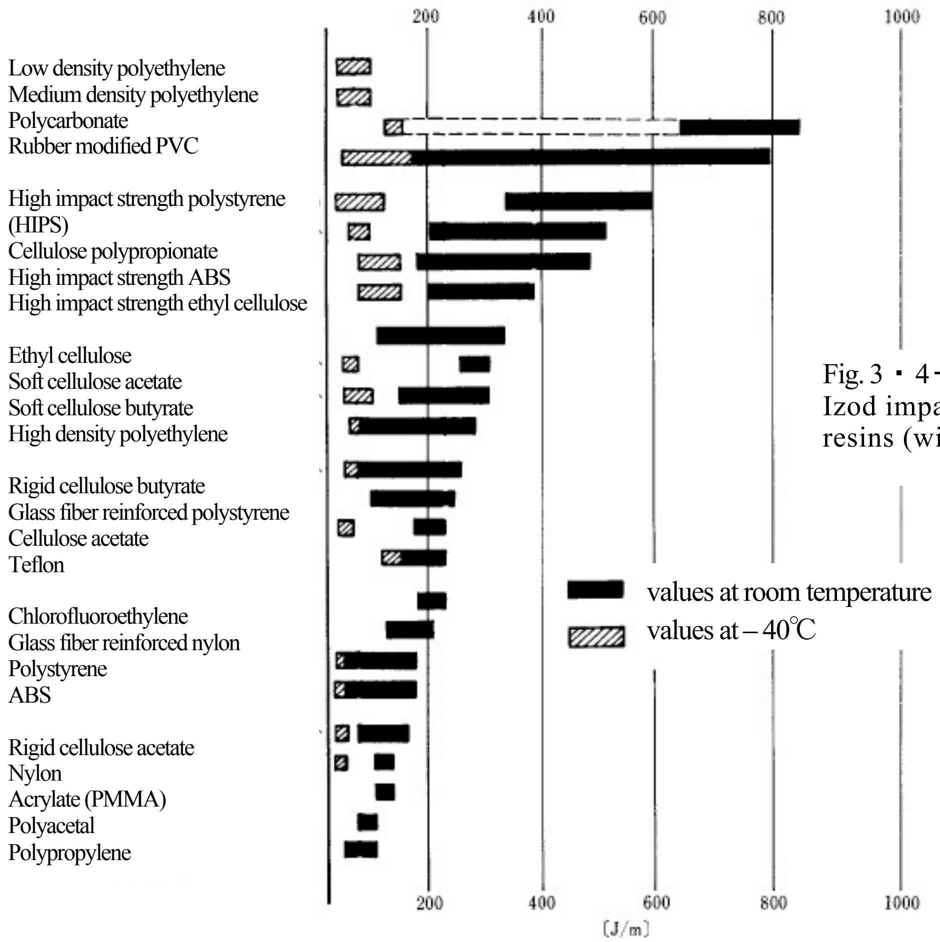



Fig. 3・4−13 Izod impact strength of various resins (with notch)

## 3・5 Hardness

The various hardnesses of Iupilon / NOVAREX are shown in Table 3・5－1.

Table 3・5－1 Mv=2.4 x $10^4$

| | |
|---|---|
| Brinell hardness after 10 sec. | 88. 3～103MPa（900～1050kg / $cm^2$） |
| DIN53456, load 0. 5kN（50kgf） after 60 sec. | 85. 3～98. 1MPa（870～1000kg / $cm^2$） |
| Rockwell hardness（ASTM－D785） | M60～80, L90～100, R122～124 |
| Shore Durometer hardness | D82 |

The Mar resistance of Iupilon / NOVAREX is shown in Table 3・5－2.

Table 3・5－2 Surface hardness of Iupilon / NOVAREX injection molded product (ASTM-D673-44)

Mv=2.4 x $10^4$

| Quantity of carborundum (g) | 200 | 400 | 800 | 1200 | 1600 |
|---|---|---|---|---|---|
| Mar resistance（%） | 90. 2 | 82. 7 | 72. 9 | 58. 5 | 56. 1 |

Also, a comparison with other resins is shown in Table 3・5－3.

Table 3・5－3 Comparison of surface hardness of Iupilon / NOVAREX with other resins (ASTM-D673-44)

Carborundum dropping quantity 500g Mv=2.4 x $10^4$

| Sample | Mar resistance（Ratio of luster before and after abrasion） |
|---|---|
| Iupilon / NOVAREX compression molded product | 84% |
| Acrylate（MMA） | 88% |
| Vinyl chloride | 85% |
| Glass sheet（crown glass） | 99% |

A comparison of Rockwell hardness of Iupilon / NOVAREX with other resins is shown in Table 3・5－4.

Table 3・5－4

| Name | Rockwell hardness（ASTM－D785） | Name | Rockwell hardness（ASTM－D785） |
|---|---|---|---|
| Low density polyethylene | D45 ～ 52＊ | Rigid cellulose butyrate | R79 ～ 114 |
| Medium density polyethylene | D45 ～ 65＊ | Glass fiber reinforced polystyrene | M91 ～ M95 |
| POLYCARBONATE | R122 | Cellulose acetate | R68 ～ 115 |
| Rubber modified PVC | RlO0 ～110 | Chlorofluoroethylene | R112 |
| High impact strength polystyrene (HIPS) | M30 ～ 65 | Glass fiber reinforced nylon | M96 ～ MlOO |
| Cellulose propionate | R20 ～ 120 | Polystyrene | M30 ～ 55 |
| High impact strength ABS | R85 ～ 100 | ABS | R85 ～ 118 |
| High impact strength ethylcellulose | R70 ～ 90 | Rigid cellulose acetate | RlO1 ～ 123 |
| Ethylcellulose | R80 ～ 120 | Nylon | RlO8 ～ 118 |
| Soft cellulose acetate | R49 ～ 103 | Acrylate (PMMA) | L58 ～ 59 |
| Soft cellulose butyrate | R47 ～ 95 | Polyacetal | R120（M94） |
| High density polyethylene | R63 ～ 70＊ | Polypropylene | R85 ～ 95 |

＊ indicates Shore hardness

The Rockwell hardness of Iupilon / NOVAREX is changed by heat treatment as shown in Fig. 3・5－1.

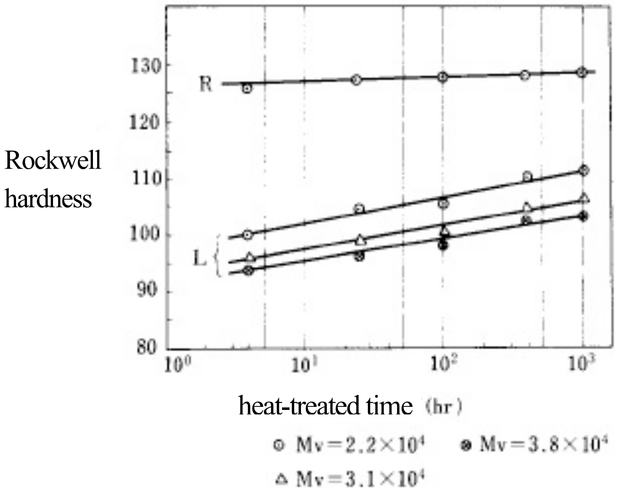



Fig. 3・5－1 Change in Rockwell hardness by heat treatment (treated temperature 125℃)

Also, the Martens scratch hardness is shown in Fig. 3・5－2.

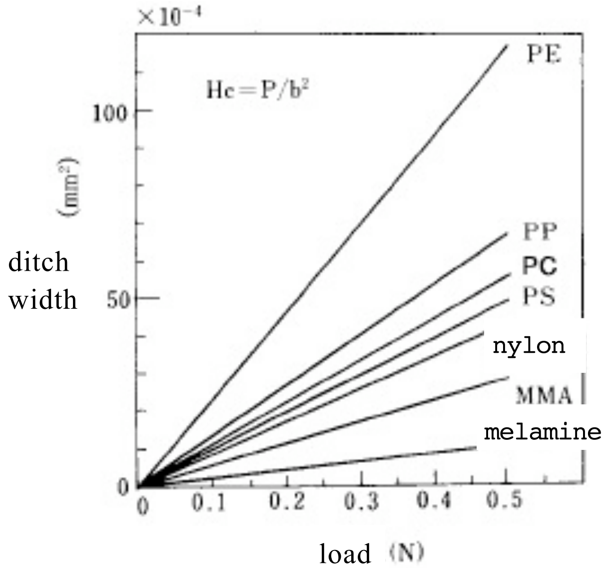



Fig. 3・5－2 Martens scratch hardness

**3・6 Abrasion Resistance and Friction Characteristics**

The amount of wear of Iupilon / NOVAREX by the Tabor-abrasion tester (CS－17wheel, ASTM－DlO44－56 was 13mg/1000 cycles.

Also, when the relation of

$$PV = 53.9 MPa \cdot cm / s$$

$$(PV = 550 kgf / cm2 \cdot cm / s)$$

exists between the contact pressure MPa（kgf／cm2）and relative velocity (Vcm/s) in the contact abrasion between Iupilon / NOVAREX and iron, this is the limit it can withstand heat of friction. This relation is shown in Fig. 3・6－1.

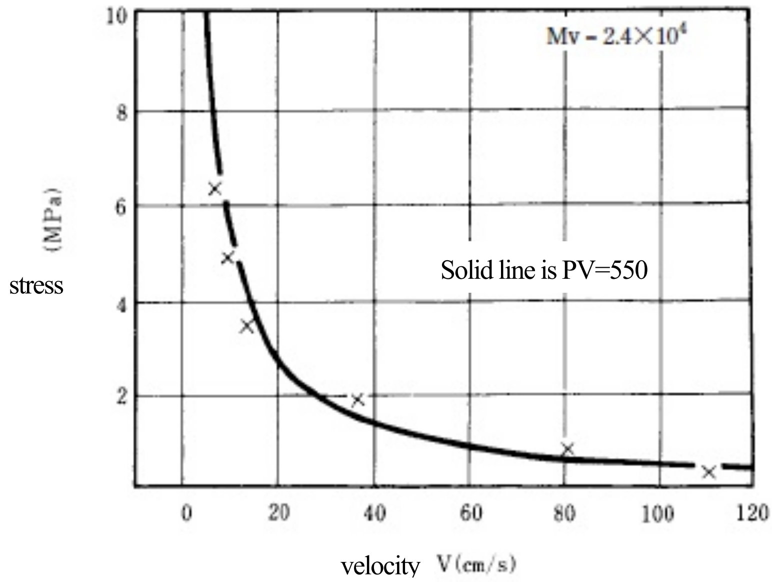



Fig. 3・6－1 PV values of Iupilon / NOVAREX

Iupilon / NOVAREX melts in the combination of P and V in the range at the upper right of the curve. In this case, the coefficient of friction was 0.5-0.6 at P=4.9MPa (50kgf/$cm^2$), V=0.01cm/s.

The coefficient of friction of polycarbonate is shown in Table 3・6－1 (not lubricated).

Table 3・6－1

| | Low velocity (1 cm / s) | High velocity (173－202 cm / s) |
|---|---|---|
| Between polycarbonates | 0. 24 | About 2. 0 |
| Polycarbonate on steel | 0. 73 | 0. 82 |
| Steel on polycarbonate | 0. 35 | 0. 45 |

A comparison of abrasion （ASTM－D1242－56）between polycarbonate and other resins is shown in Fig. 3・6－2

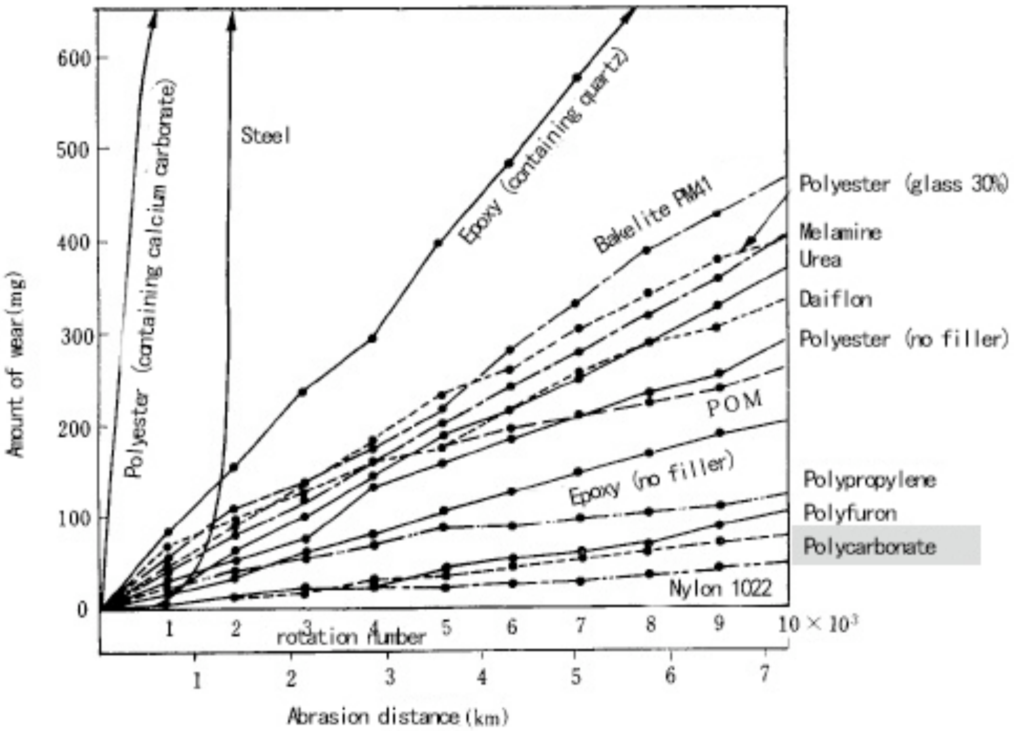



Fig. 3・6—2　Relation between abrasion distance and wear quantity of plastics
(Average abrasion velocity 0.235m/s, abrasion pressure 1.2MPa (12kgf/cm$^2$,
abrasive is alumina powder with average particle size of 170 mesh)

### 3・7　Shear Strength

The shearing yield point of Iupilon / NOVAREX is 37.3MPa (380kgf/cm$^2$) and the shear breaking stress is 64.7MPa (660kgf/cm$^2$).

The temperature characteristic of the shearing modulus of elasticity is shown in Fig. 3・7—1, from which it can be seen that Iupilon / NOVAREX is stable at high temperature and it is also stable at low temperature. As a general rule, the substance becomes brittle rapidly when the shearing modulus of elasticity (or rigidity) exceeds about 1GPa (10$^4$kgf/cm$^2$) but the low temperature characteristic of Iupilon / NOVAREX is better than those of other resins at -100℃ as it does not exceed 1GPa 10$^4$kgf/cm$^2$.

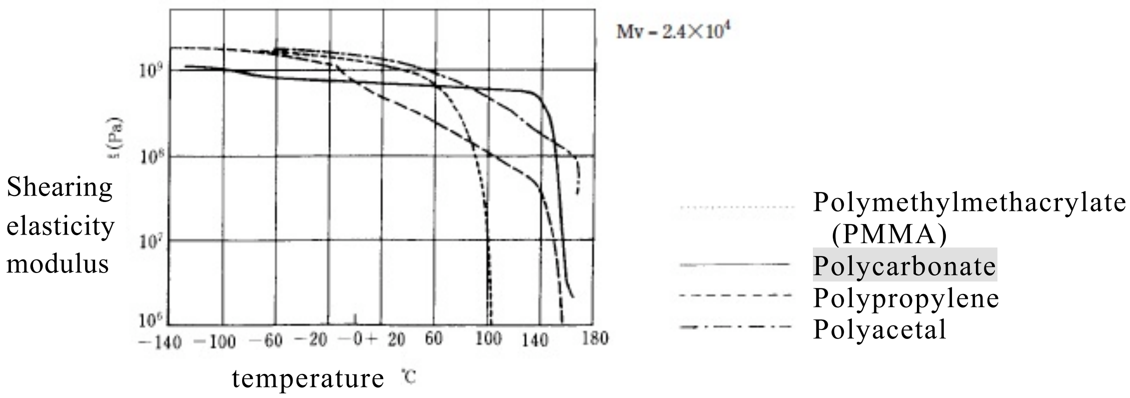



Fig.　3・7—1　Relation between temperature and shearing modulus of elasticity

## 3・8　Long Time Behaviour Under Load

### 3・8・1 Load Fatigue Characteristics

When the fatigue resistance of Iupilon / NOVAREX is examined, it becomes as shown in Fig. 3・8・1—1, 2, 3 and 4 (determination method is constant load 1000 cycle/min, room temperature). The influence of the shape of test piece at the tensile compression fatigue is shown in Fig. 3・8・1—1. The difference of the shape is obviously shown, especially the influence of cutting is shown extremely in the cutting sample. The results of tensile compression fatigue, flexural fatigue, and torsional fatigue are shown in Fig. 3・8・1—2, 3・8・1—3 and 3・8・1—4, respectively.

In any case, the fatigue resistance has improved by the increase of the molecular weight.

The influence of temperature in the rotation flexural fatigue (test piece is made by cutting) is shown in Fig. 3・8・1—5. It is observed that the fatigue limit rises drastically as the temperature decreases. Also, Fig. 3・8・1—6 shows the results of the fatigue of samples with notch.

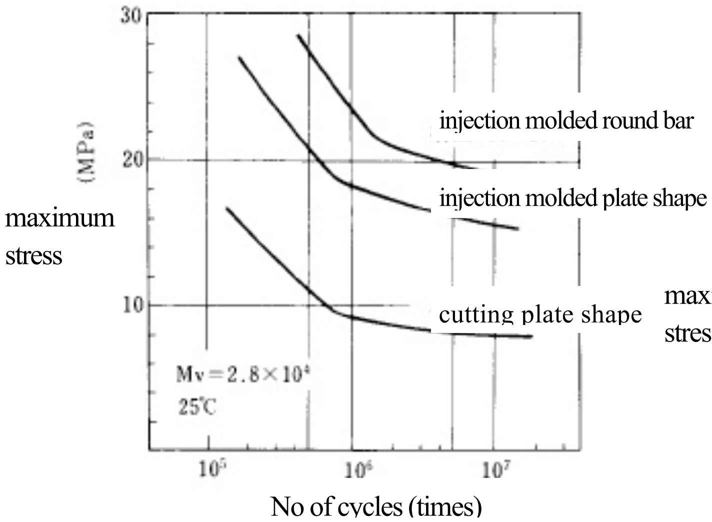



Fig. 3・8・1—1　Change in fatigue resistance by the difference of test piece shape and molding method (tensile compression)

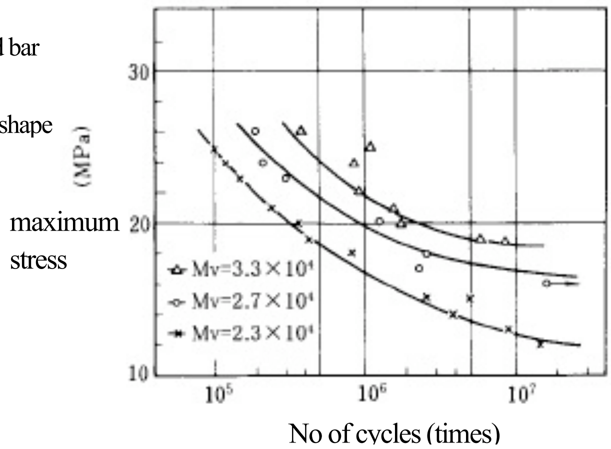



Fig. 3・8・1—2 Relation between molecular weight and fatigue resistance (tensile compression)
Injection molded piece of sample with round bar shape (determination temperature, 25℃)

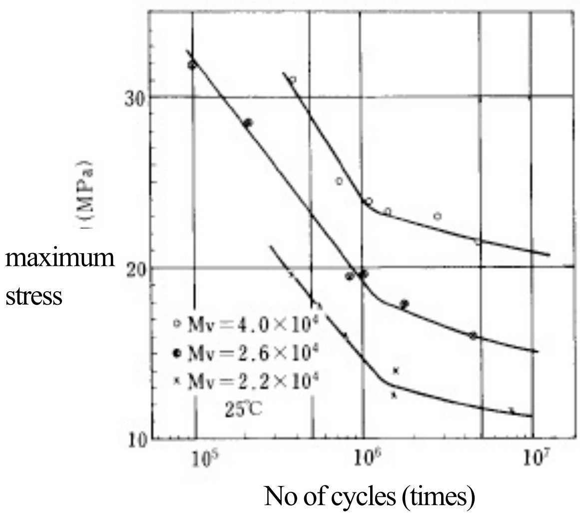



Fig. 3・8・1—3　Fatigue resistance in flexure

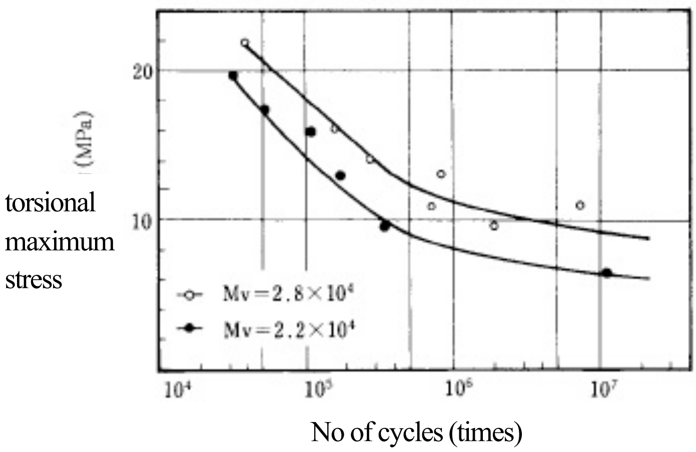



Fig. 3・8・1—4　Fatigue resistance in torsion

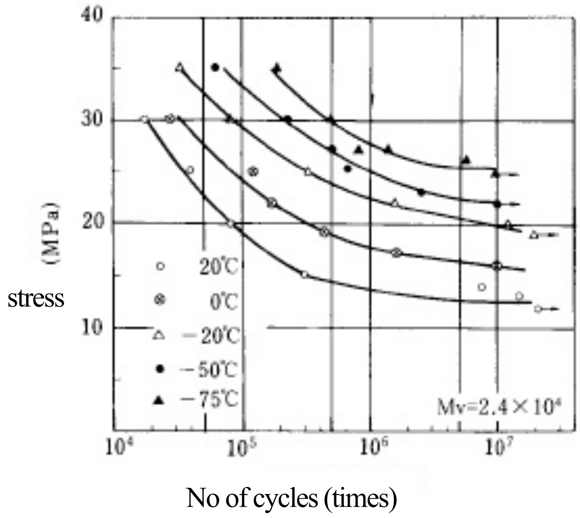



Fig. 3・8・1−5 Influence of temperature in fatigue resistance (flexure)

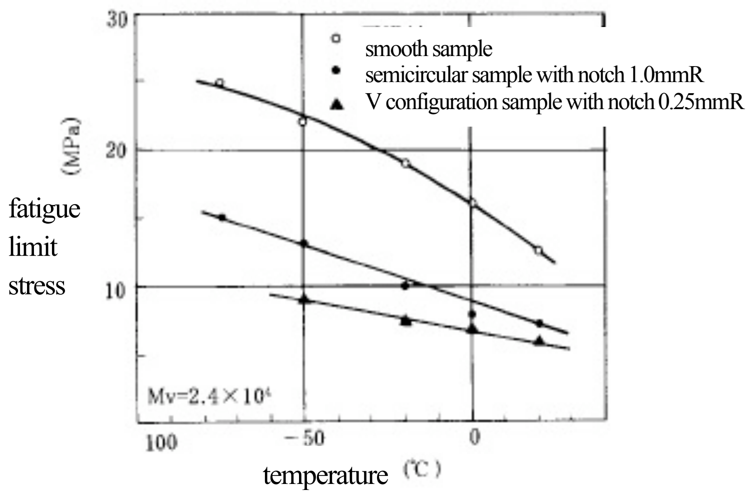



Fig. 3・8・1−6 Fatigue properties of samples with notch

The results of comparing the fatigue resistance by the Sonntag tester for various resins are shown in Table 3・8・1−1.

Table 3・8・1−1 Fatigue resistance of various resins

| Name | Break stress MPa (kgf／cm2) | | | |
|---|---|---|---|---|
| | $10^4$ cycles | $10^5$ cycles | $10^6$ cycles | $10^7$ cycles |
| Vinyl chloride (PVC) | 36. 3 (370) | 25. 5 (260) | 18. 7 (191) | 16. 7 (170) |
| Polystyrene | 24. 1 (246) | 14. 7 (150) | 10. 8 (110) | 10. 0 (102) |
| Derivatives of fibrillar system | 20. 8 (212) | 16. 2 (165) | 13. 2 (135) | 11. 1 (113) |
| Polyamide (nylon) | 15. 1 (154) | 12. 4 (126) | 12. 1 (123) | 11. 8 (120) |
| Polyethylene | 13. 7 (140) | 11. 8 (120) | 11. 3 (115) | 11. 0 (112) |
| Polypropylene | 16. 7 (170) | 13. 1 (134) | 12. 0 (122) | 11. 0 (112) |
| Acrylate (PMMA) | 30. 3 (309) | 27. 8 (283) | 27. 8 (283) | 27. 8 (283) |
| Polycarbonate | 40. 1 (409) | 26. 9 (274) | 14. 9 (152) | 9. 8 (100) |
| Polyacetal | | 32. 3 (329) | 28. 3 (289) | 26. 9 (274) |
| Polyphenylene ether (PPE) | | | | 8. 2−13. 7 (84−140) |
| Polysulphone | | | | 6. 9 (70) |
| Modified PPE | | | | 17. 2 (175) |

### 3・8・2　Creep Characteristics

The tensile creep characteristics, flexural, compression creep characteristics of Iupilon / NOVAREX are shown in Fig. 3・8・2－1, 2, 3 and 3・8・2－4, respectively. Also, a comparison with other resins is shown in Fig. 3・8・2－5 and 6.

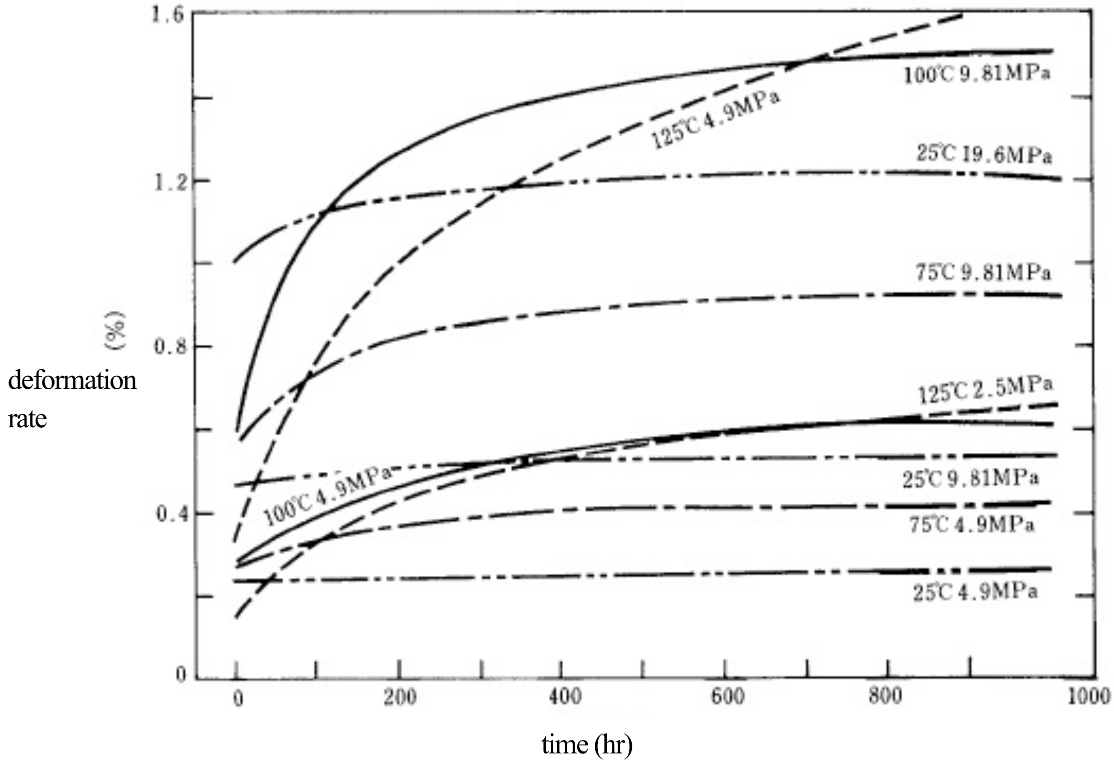



Fig. 3・8・2－1　Tensile creep of Iupilon / NOVAREX

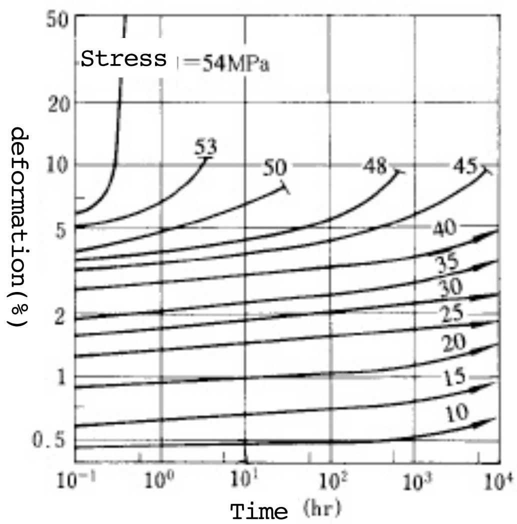



Fig. 3・8・2－2　Tensile creep of polycarbonate

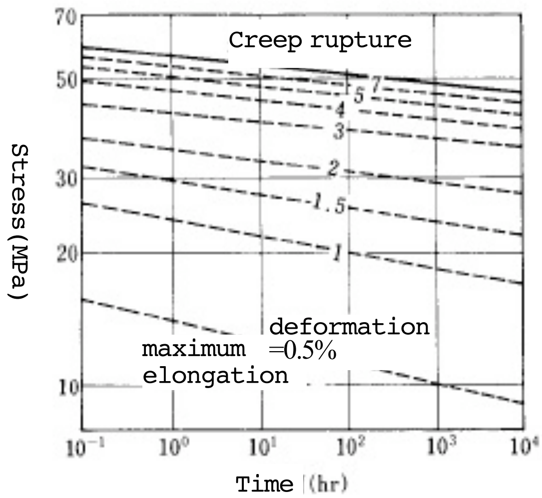



Fig. 3・8・2－3　Tensile creep of polycarbonate (22℃)

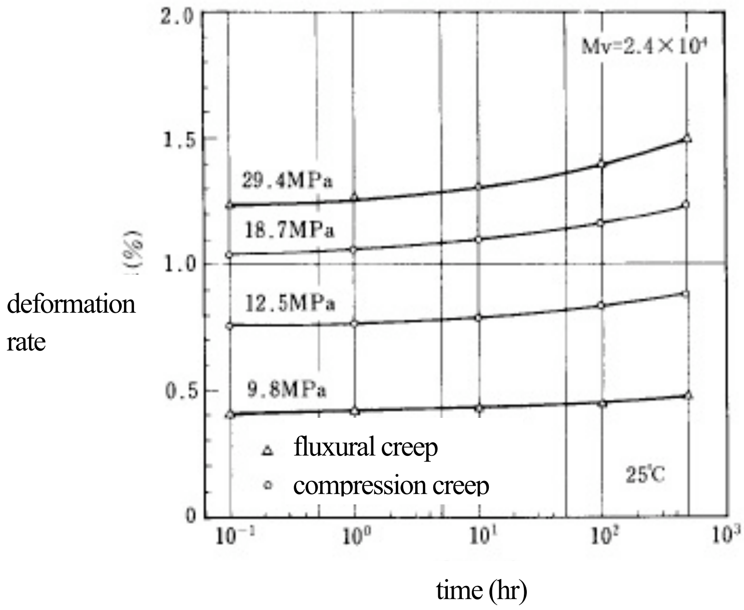



Fig. 3・8・2－4　Flexural, compression creep of Iupilon / NOVAREX

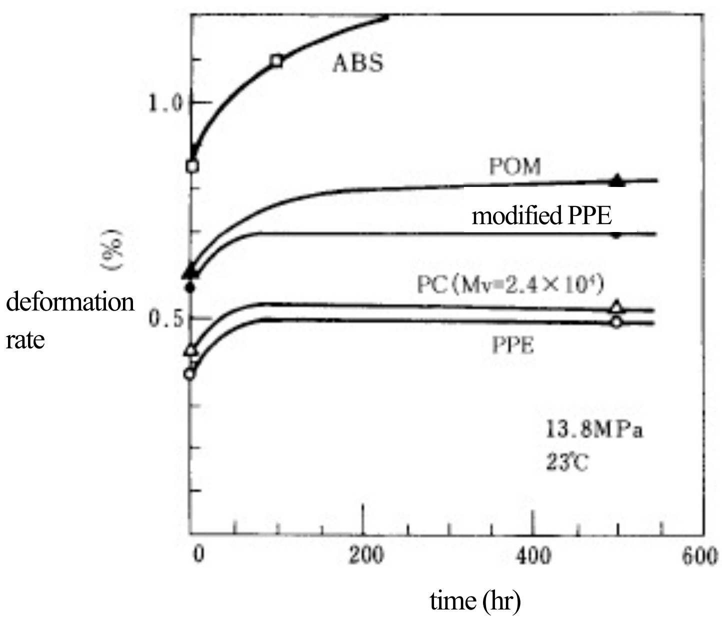



Fig. 3・8・2－5　Creep curve of other resins

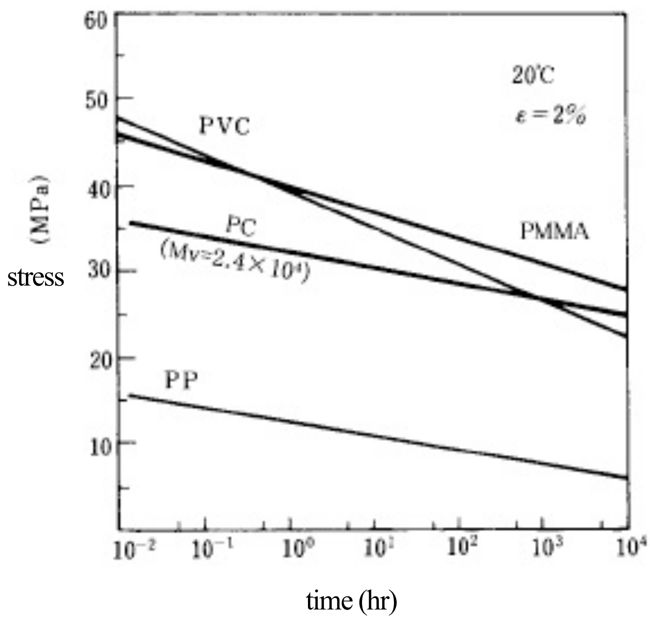



Fig. 3・8・2－6 Change by the time of stress that becomes 2 % of deformation rate

The creep rupture line of Iupilon / NOVAREX is shown in Fig. 3・8・2−7 and 8. A comparison with other resins is shown in Fig. 3・8・2−9.

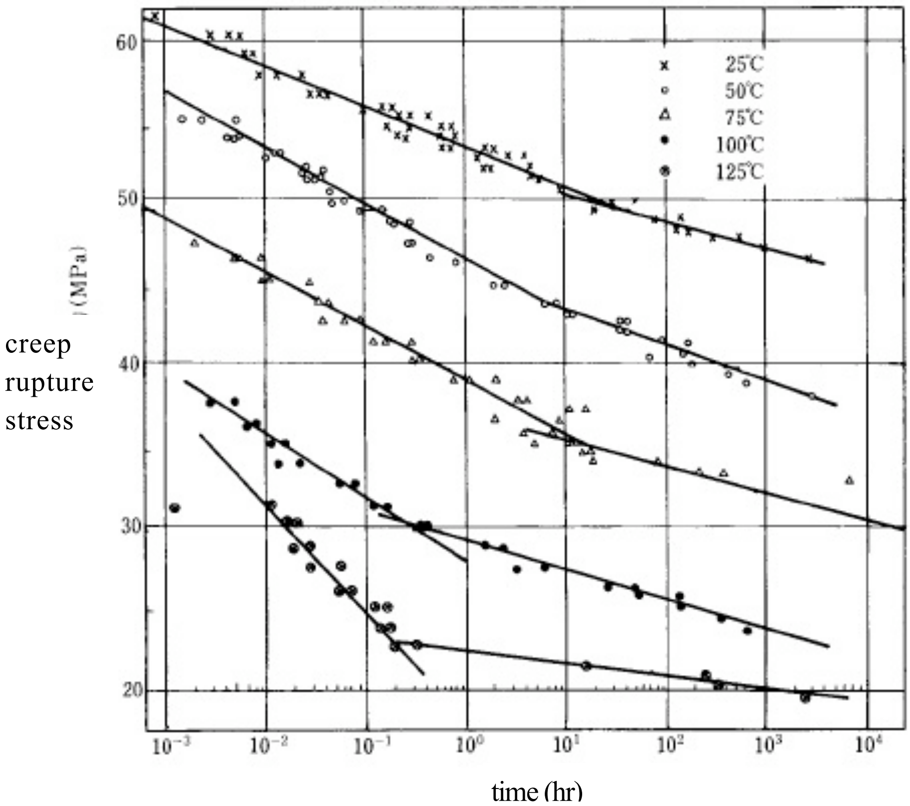



Fig. 3・8・2−7　Relation between temperature and creep rupture time（Mv=2.4 x 104）

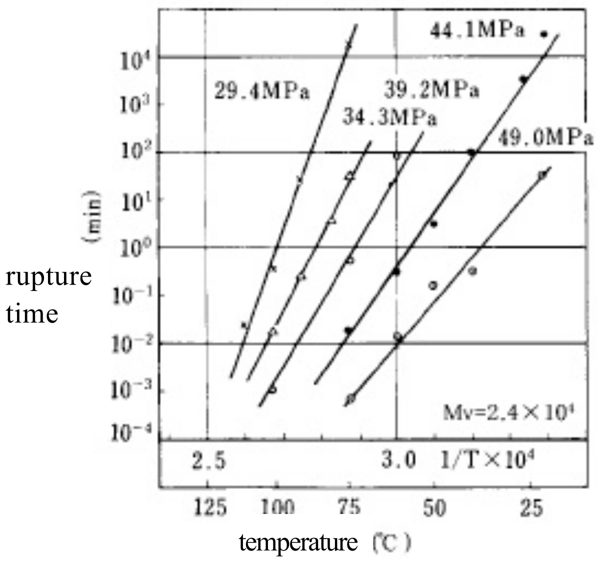



Fig. 3・8・2−8 Relation between temperature and creep rupture time

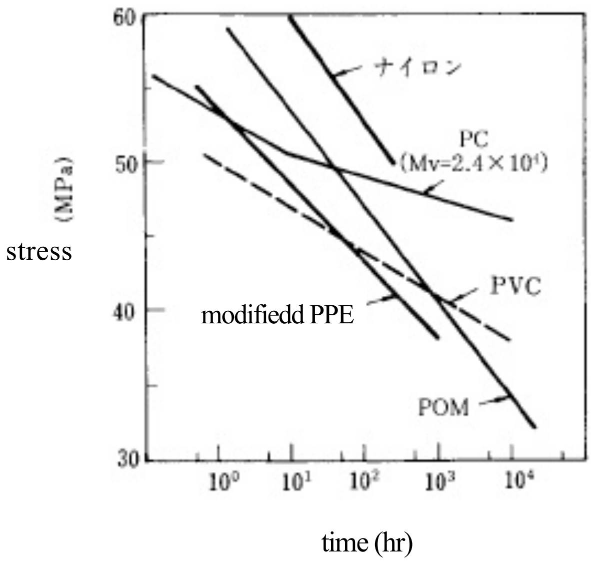



Fig. 3・8・2−9 Creep rupture curves of other resins

### 3・8・3 Deformation Under Load and Recovery

The deformation under compressive load of polycarbonate is as shown in Table 3・8・3−1.

Table 3・8・3−1

| Temperature (℃) | Load MPa (kgf／cm²) | ASTM−D621−51 Deformation after 24 hr. (%) |
|---|---|---|
| 25 | 27. 5 (280) | 0. 220 |
| 70 | 27. 5 (280) | 0. 282 |
| 25 | 13. 7 (140) | 0. 101 |
| 70 | 13. 7 (140) | 0. 080 |

Also, when a compressive load of 1.11kN (113.4kgf) on ball (φ10.16) is applied, the rate of instantaneous recovery with a deformation of 1.42mm was 97% and the recovery rate was 100% after 5 days.
The tensile deformation and recovery of polycarbonate at 100℃ are shown in Table 3・8・3−2 (see Fig. 3・8・2−1).
The tensile deformation at normal temperature and recovery in case load was removed after 1,000 hours are shown in Fig.3・8・3−1.

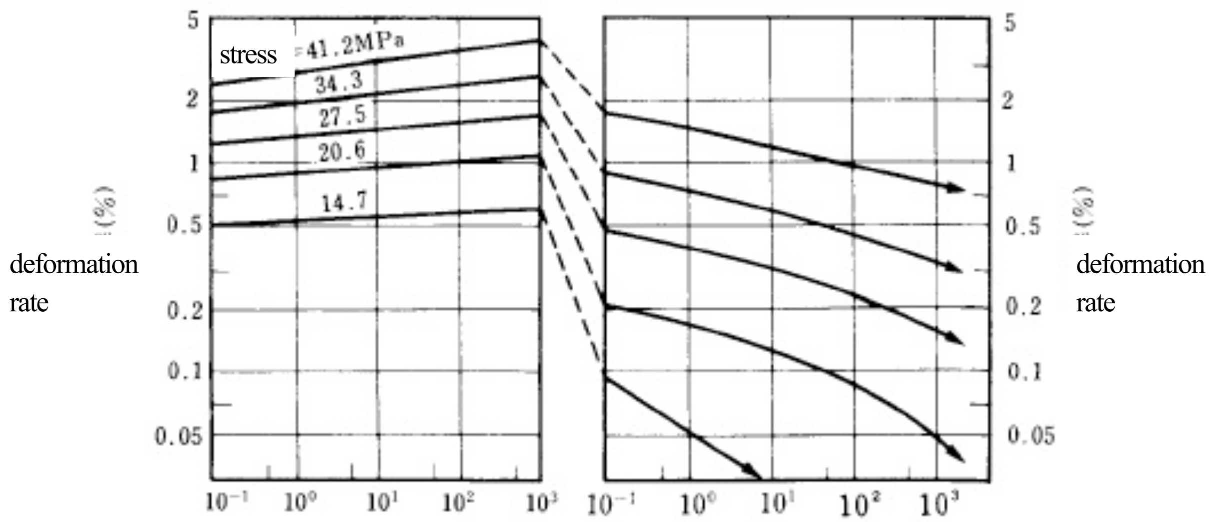



Fig. 3・8・3−1 Recovery behaviour of polycarbonate

Table 3・8・3−2

| Stress MPa (kgf／cm²) | Initial sttrain (%) | Creep after 1,000 hrs (%) | Total deformation (%) | Recovery rate (Recovery /Total deformation) (%) |
|---|---|---|---|---|
| 3. 84 (39. 2) | 0. 0298 | 0. 2797 | 0. 3095 | 38. 5 |
| 7. 70 (78. 5) | 0. 3059 | 0. 6941 | 1. 000 | 32. 2 |
| 15. 4 (157) | 0. 7267 | 1. 300 | 2. 027 | 35. 3 |
| 19. 2 (196) | 1. 162 | 3. 500 | 4. 662 | 21. 0 |

### 3・8・4　Relaxation of Stress

The relaxation curves of tensile stress of Iupilon / NOVAREX are shown in Fig. 3・8・4－1.

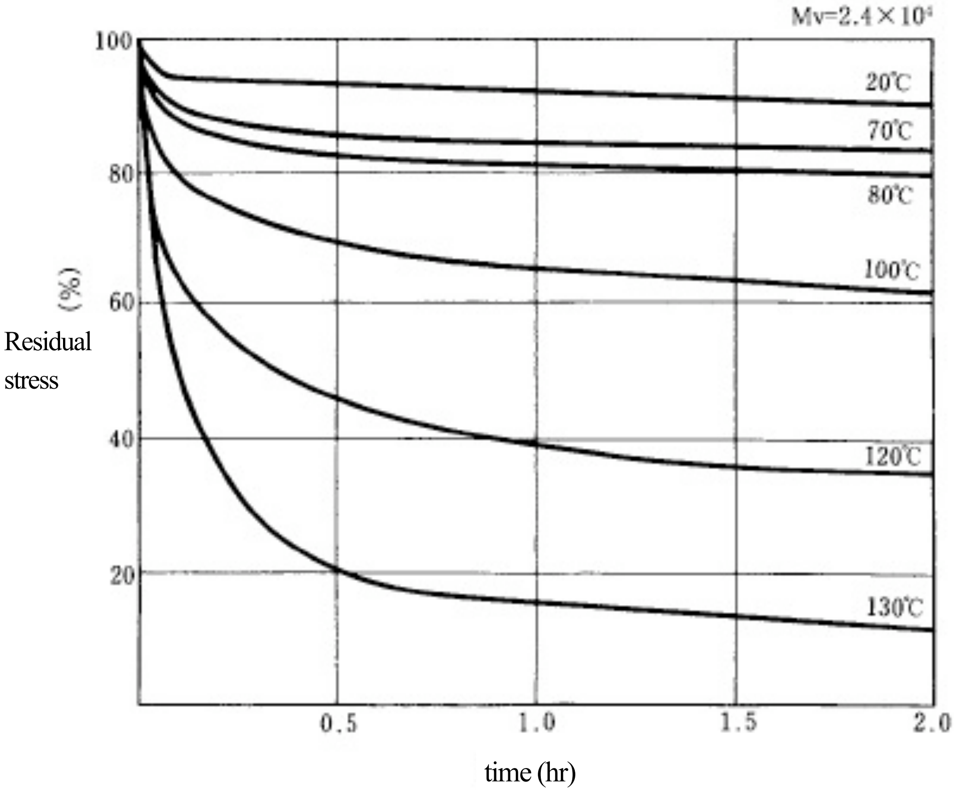



Fig. 3・8・4－1　Relaxation of tensile stress of Iupilon / NOVAREX
(Initial load 9.8MPa, however, 4.9MPa in case of temperature of 120℃ and 130℃)

### 3・8・5　Practical Permissible Stress

Table 3・8・5－1

| | Practical Permissible StressMPa（kgf／cm²） | |
|---|---|---|
| | Tensile | Compressive |
| Intermittent load（room temperature） | 27. 5（280） | 41. 2（420） |
| Intermittent load（in 52℃ air） | 23. 5（240） | 23. 5（240） |
| Intermittent load（in 100℃ air） | 20. 6（210） | 20. 6（210） |
| Intermittent load（room temperature, in moisture, vapor） | 27. 5（280） | 41. 2（420） |
| Permanent load（room temperature） | 13. 7（140） | 13. 7（140） |
| Repeating or oscillating | 6. 9（70） | 6. 9（70） |

## 3・9 Stress Crack

When plastic is used for practical items, it sometimes encounters the phenomenon in which craze and crack are generated. There are two cases, that is, the generation of this craze and crack when only stress was added (stress crack), and by a microstress under the coexistence with foreign substance (environmental stress crack). Also, the craze and crack are clearly distinguished by the transmission electron microscope observation etc. That is, as for the craze, the density of the molecular chain is low by the local orientation and it becomes the structure that contains void like the sponge while the crack forms a complete space. However, because the craze and crack can not be strictly distinguished by the naked eye, the crack is also included in the craze of this report which was observed by the naked eye.

When adding a flexural load or flexure to the flexural test piece of Iupilon / NOVAREX, the craze is generated after a certain induction period (it can be considered that craze is generated in case of uniaxial stress). After that, the growth and termination of the generated craze or the generation of new craze etc. is observed. The knowledge about the induction period of craze generation becomes a very important issue from the practical view.

The relation between the induction period of craze generation and the flexural stress under constant load of Iupilon / NOVAREX was shown in Fig. 3・9-1. The induction period shifts to the extended period of time with the decrease of stress and becomes infinite finally. However, in case of Iupilon / NOVAREX, approximately 29.4MPa (300kgf/$cm^2$) at Mv＝2.4~$3.0\times10^4$, approximately 19.6MPa (200kgf/$cm^2$) at Mv＝$2.2\times10^4$ become the stress that the craze is not generated.

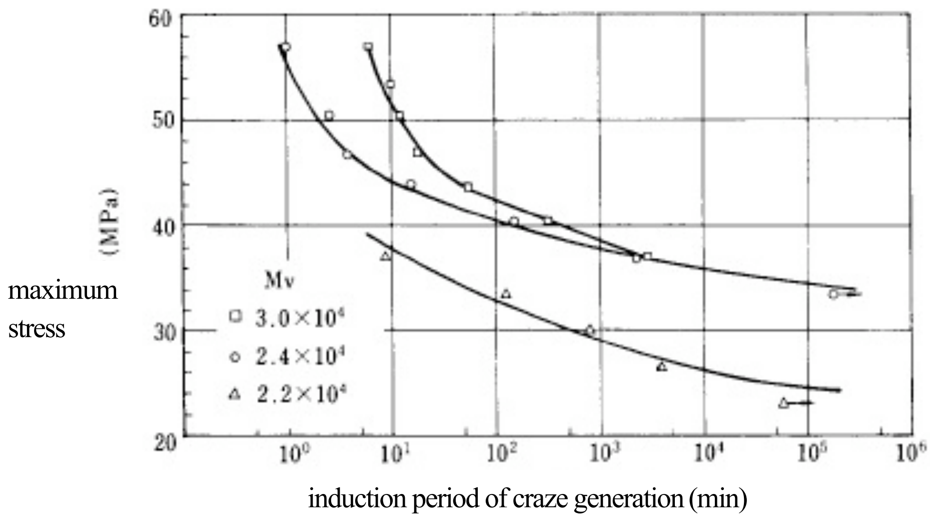



Fig. 3・9−1 Change in induction period of craze generation by flexural stress

The influence of heat treatment or additives on the craze generation is shown in Fig. 3・9−2. The craze generation by heat treatment becomes easy as indicated in this figure. The behaviour of the craze generation near the room temperature was shown in Fig. 3・9−3. As indicated in this figure, the rate of the craze generation rapidly becomes low at low temperature zone.

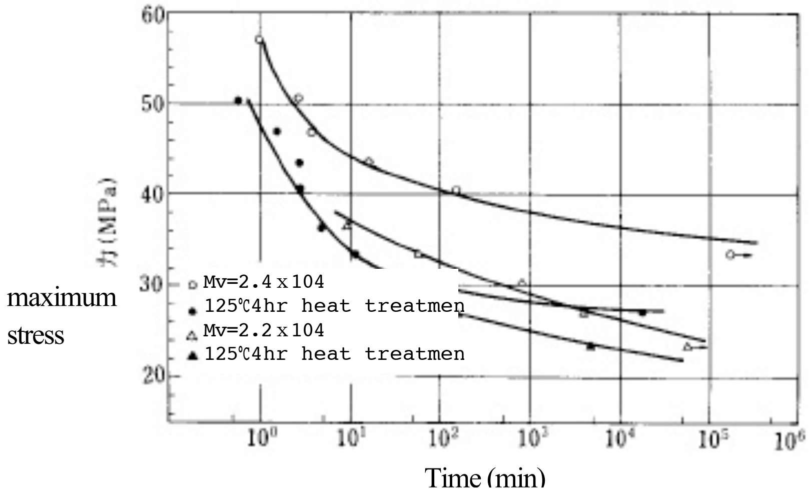



Fig. 3・9−2　Change in induction period of induction period of craze generation (min) on temperature: room temperature)

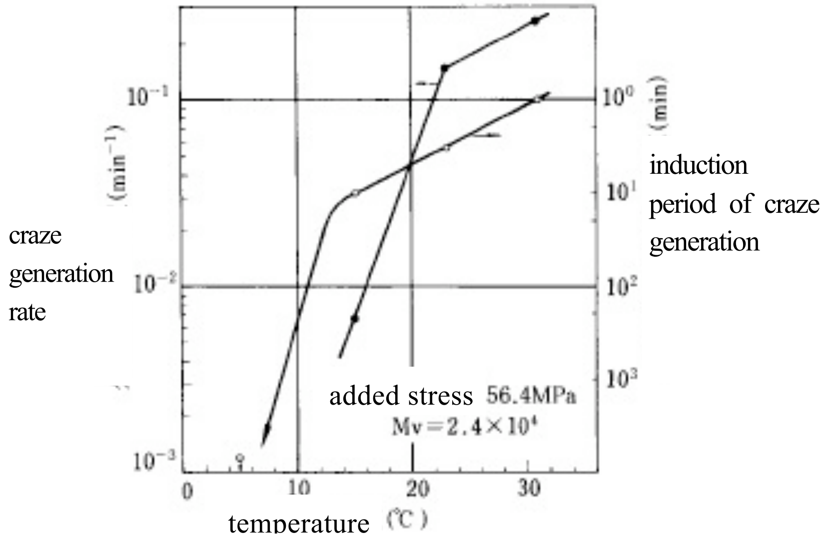



Fig. 3・9−3　Behaviour of craze generation in the vicinity of room temperature

The behaviour of craze generation in case of adding the constant strain to flexural test piece of Iupilon/ NOVAREX was shown in Fig. 3・9−4, 5, 6, 7 and 8. The influence of temperature was shown in Fig. 3・9−4, 5, the craze generation becomes easy with the increase of atmosphere temperature.

The influence of the molecular weight was shown in Fig. 3・9−6. The influence of heat treatment was shown in Fig. 3・9−7 and 8. The craze generation becomes easy as the case of the constant load.

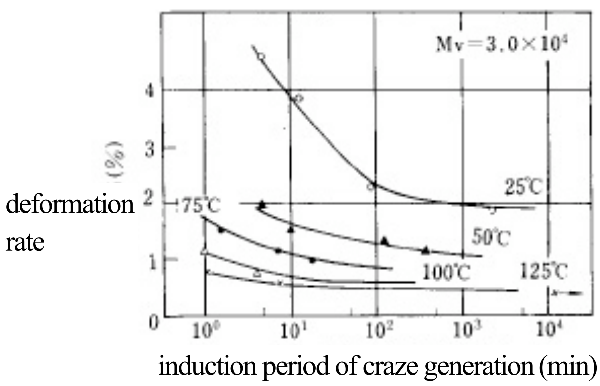



Fig. 3・9−4　Induction period of craze generation under constant strain

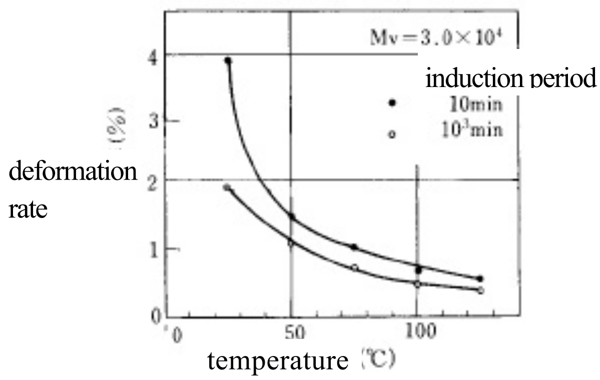



Fig. 3・9−5　Influence of temperature on induction period of craze generation

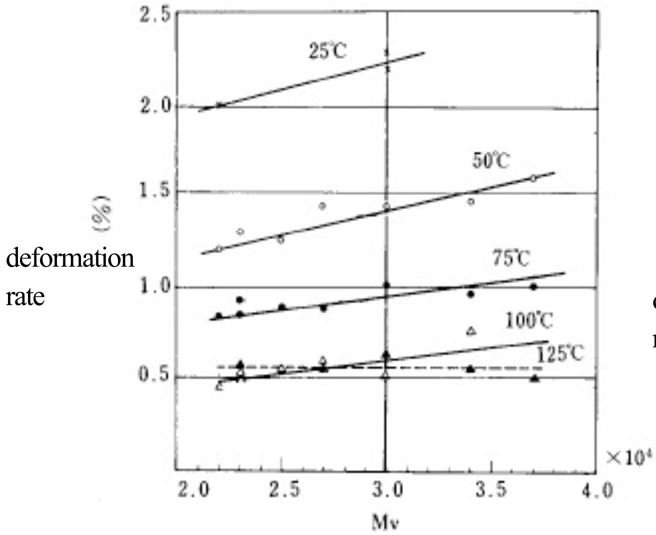



Fig. 3・9－6　Influence of molecular weight on induction period of craze generation (when the induction period becomes100min.)

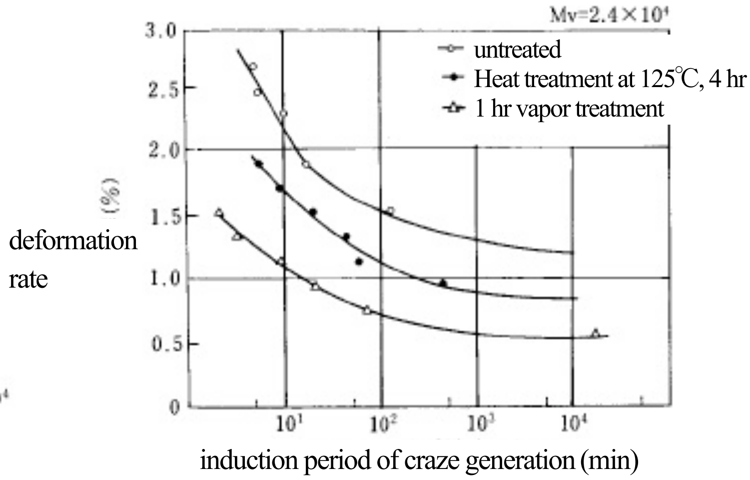
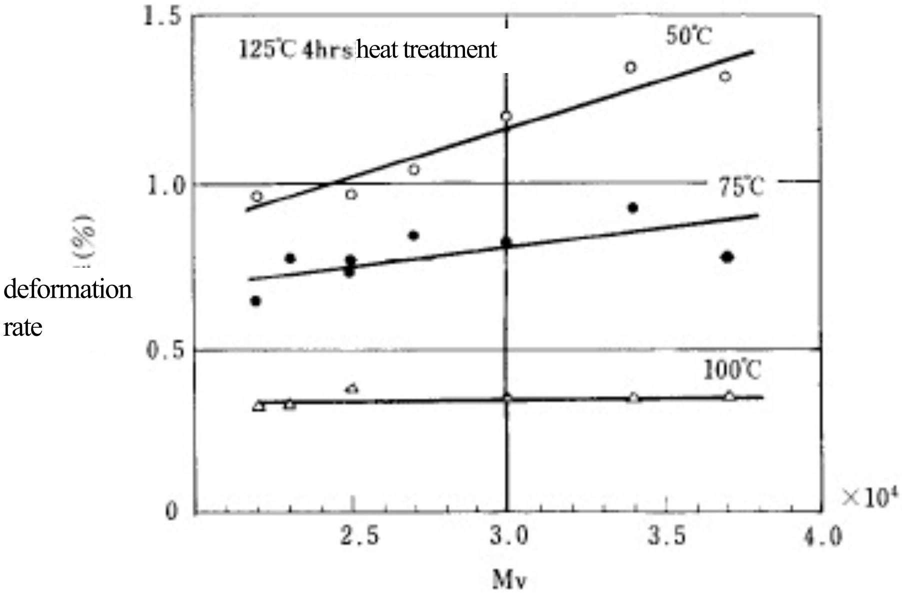



Fig. 3・9－7 Change in induction period of craze generation by heat treatment (determinationtemperature:50℃)




Fig, 3・9－8 Influence of molecular weight on induction period (100min) of craze generation of heat-treated sample