ArcelorMittal

L.KLEIN SA
ACIERS FINS ET MÉTAUX
EDELSTÄHLE UND METALLE
FINE STEEL AND METALS

DURIMPHY - PHYTIME

HIGH YIELD STRENGTH ALLOYS

I. INTRODUCTION

Durimphy and Phytime are 250 and 300 KSI (kilo-pound square inch) maraging steels. In addition to very high yield strength, they offer a range of complementary properties (physical, chemical and technological) enabling them to be employed to advantage in the most varied applications.

The table below gives the chemical composition of these alloys by % weight:

	Ni	Co	Mo	Ti
Durimphy	18	9	5	0.5
Phytime	18	16.5	5	-

Annealing at around 830°C enables attainment of a softened condition with a soft martensite structure. Tempering at a moderate temperature (480°C) results in major precipitation hardening of Ni_3Ti (for Durimphy) and Fe_2Mo type intermetallic compounds. This hardening is achieved without noticeable dimensional impact. The austenitising and aging treatments applicable to these two grades are similar.

Hardening treatment can also be carried out on material in the work-hardened condition. As tempering is performed at a relatively low temperature, it is possible to benefit from both the work-hardening and the precipitation hardening, resulting in an even stronger material.

Supplied in the form of strip in a very wide range of dimensions, Durimphy and Phytime are capable of attaining identical properties to another high yield strength alloy (Phynox). Their superior formability renders them advantageous for certain applications. However, they do not possess the distinctive non-magnetic and corrosion-resistant qualities of Phynox.

Phytime is distinguished from Durimphy by its enhanced inclusionary cleanness, achieved by means of a very significant reduction in the titanium content, which is responsible for the formation of TiN type inclusions.

This grade was developed in order to surpass the fatigue limits of Durimphy.

Durimphy's and Phytime's principal characteristics are:

- Superior formability, the attainment of elevated mechanical properties by precipitation hardening heat treatment at moderate temperature, a treatment that can be carried out after forming. The hardening treatment does not induce any dimensional change.
- Absence of low-temperature embrittlement
- Excellent fatigue-resistance
- Structural stability after aging
- A low thermoelastic coefficient
- Excellent weldability. Carrying out post-weld hardening treatment enables very significant abatement of the differences in properties between welded and non-welded zones, eliminating weak spots.

ArcelorMittal | Stainless & Nickel Alloys
Innovatis
5 rue Luigi Cherubini
93212 SAINT DENIS Cedex
FRANCE
t +33 (0)1 71 92 00 00
e info@imphy.com
www.imphy.com

Durimphy and Phytime have numerous applications:

- Springs for clock motors
- Springs for rough watch movements
- Form springs for analogue quartz watches
- Springs for miscellaneous applications
- Weighing machines
- Precision bearing balls
- Ball bearing cages
- Electrical and electronic apparatus
- Plastics industry
- Defence industry
- Missile and rocket fins
- Satellites
- Automatic gearbox belt
- Printer type-carrying band

II. PHYSICAL PROPERTIES

Properties	units	Durimphy	Phytime
Melting point	**°C**	**1430 - 1460**	**1430 – 1460**
Density	**$g.cm^{-3}$**	**8,1**	**8,14**
Electrical resistivity* at 20 °C	**µΩ.cm**	**44**	**-**
Thermal conductivity*	**$W.m^{-1}.°C^{-1}$**	**19,7**	**-**
Expansion coefficient* between 0 and 100 °C	**$°C^{-1}$**	**$9,5 \times 10^{-6}$**	**$9,5 \times 10^{-6}$**
Thermoelastic coefficient* between 0 and 50 °C	**$°C^{-1}$**	**-200×10^{-6}**	**-**
Magnetic properties* : Saturation Induction **Curie Point**	**T** **°C**	**1,9** **450**	**1,9** **-**

* *These values are given for the standard temper at 480°C. They can vary very considerably according to the tempering temperature.*

III. MECHANICAL PROPERTIES

III. 1. ANNEALED CONDITION

The annealed condition is obtained following treatment at 830°C; cooling can be conducted at any rate, in other words without special precautions. This condition is only used for intermediate forming operations. Typical values are given in the following table.

Properties	units	Durimphy	Phytime
Vickers hardness	**HV**	**330**	**300**
$Rp_{0.2\,\%}$	**MPa**	**1010**	**1000**
Rm	**MPa**	**1040**	**1030**
Elongation	**%**	**7***	**7***

** minimum value depending on specimen thickness*

III. 2. HARDENED CONDITION

The standard hardening treatment is 3 hours at 480°C.

It causes the precipitation of intermetallic compounds. This precipitation treatment can be combined with work-hardening.

Figure 1 illustrates the variation in mechanical properties as a function of the cold work rate. It shows that:

- Hardening due to cold working only becomes significant at high levels (> 70%).
- The effect on Durimphy of the hardening treatment is virtually unrelated to the material's cold work rate.
- The effects of the hardening treatment and cold working are practically cumulative.

It is important to remember that hardening by heat treatment conducted at a moderate temperature occurs without significant dimensional change. In most cases, this enables (formed) components to be finished on soft metal without rework following heat treatment.

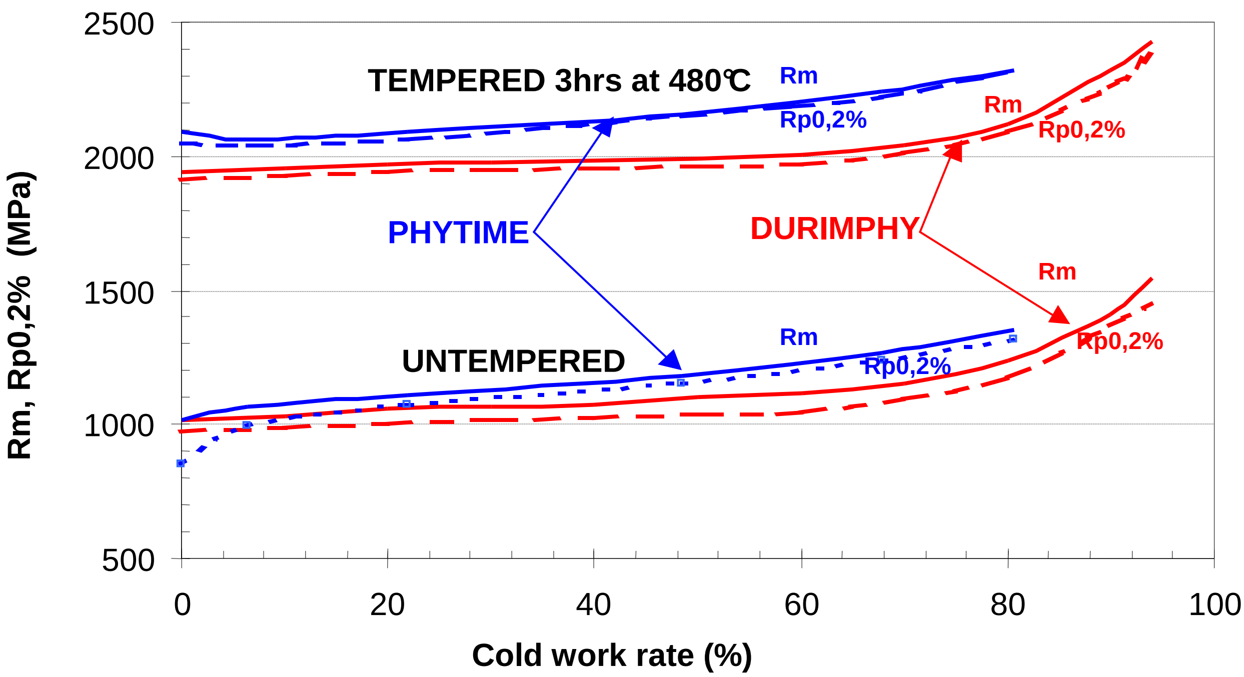


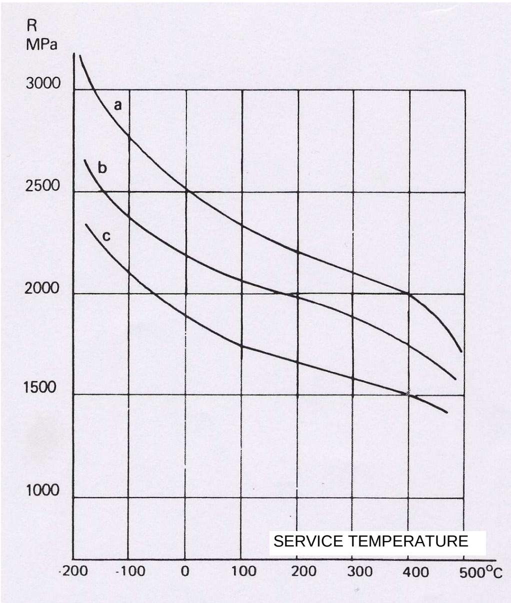
Figure 1: variation of typical longitudinal mechanical properties at 20°C as a function of cold work rate ε

Treatment in air does not impair the material's properties but spoils its appearance, as the metal takes on a blue hue. Therefore we recommend treatment for preference under deep vacuum in the order of 10^{-5} Torr or under inert atmosphere such as argon for example.

Certain atmospheres regarded as inert due to the absence of coloration are in reality chemically active and may cause the material to become extremely brittle. This is particularly so in the case of hydrogen and cracked ammonia.

III. 3. INFLUENCE OF SERVICE TEMPERATURE

Following tempering, the tensile and yield strengths of these alloys reduce more slowly with temperature than those of traditional “piano wire” type spring steels or 18-8 stainless steels (cf. figure 2). This property is due to dislocation locking by the precipitates formed during the temper hardening treatment.



a – highly cold-worked (approx. 98%) + tempered

b – moderately cold-worked (approx. 88%) + tempered

c – annealed + tempered

Figure 2 :

Variations in longitudinal tensile strength with service temperature for strip in various conditions.

Variations in the modulus of elasticity as a function of temperature are indistinguishable from those of other alloys.

Durimphy and Phytime do not undergo any structural change down to the lowest temperatures and does not exhibit any particular cold-brittleness.

IV. CORROSION-RESISTANCE

Although these alloys are not stainless alloys, they withstand the normally humid atmospheres of temperate climates better than carbon and low-alloy steels. In the case of harsher atmospheres, Durimphy and Phytime must be protected. Precautions should be taken in the case of electroplating in order to avoid the risk of hydrogen embrittlement.

V. TECHNOLOGICAL DATA

V. 1. MACHINING – FORMING

Formability is dependent on the degree of work-hardening, which must be suited to the user's requirements:

- In the annealed condition, Durimphy and Phytime possess excellent formability.
- In the moderately work-hardened condition, formability remains good, particularly in the case of bending.
- Even in highly work-hardened conditions, severe bending can be performed perpendicular to the direction of rolling (e.g. for clock and watch springs).

In the case of some deep drawing forming operations, deformability can be improved by means of a partial austenitising treatment at around 670℃.

Durimphy and Phytime respond well to chemical machining.

Durimphy and Phytime can be surface-hardened by nitriding.

V. 2. WELDING –BRAZING

Durimphy and Phytime weld well: electric spot-welding, electron beam welding, argon arc welding (generally TIG). Durimphy can be brazed.
It should be noted that the weld bead zone can be hardened similarly to the parent metal by means of a simple heat treatment at 480℃. When wel ding work-hardened metal, the advantage of the work-hardening in the heat-affected zone is lost. Localised (spot-welding) or low-impact (electron beam) techniques can be employed.

V. 3. PICKLING

Durimphy and Phytime can be chemically pickled (for example in an 18% solution of H_2SO_4 at 65℃). As these alloys are most often employed for their high yield strength, it is advisable to carry out the pickling operation in such a way as to avoid forming fracture initiation sites.