THE SPRING RESEARCH ASSOCIATION

METRICATION IN THE SPRING INDUSTRY

by

A. J. Manning, B.A., F.L.A.

and

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Report No. 196

(December 1971)

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SUMMARY

This report summarises the information necessary to understanding and adopting SI units. The units and their multiples are described, Rigidity Modulus and Young's Modulus values are given for a range of materials and preferred wire diameters and strip thicknesses are listed.

The report also gives a typical spring design in SI units and conversion charts and factors.

The Association considers it essential that companies in the spring industry adopt the SI system as outlined in the report, and thus facilitate the changeover.

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1. INTRODUCTION

The United Kingdom Government has accepted the end of 1975 as the target date for the change over to the metric system of SI units.

The spring industry is in a somewhat difficult position as regards the changeover, standing as it does between wire suppliers on the one hand, and spring user customers on the other. The purpose of this booklet is to summarise the information necessary to understanding and adopting SI units.

If justification for making the change is necessary at this stage, three main arguments are:-

a) The exclusive adoption of metric units will lead to improved speed, accuracy and clear thought in practice. It has been shown that mechanical engineering calculations, performed long hand, can be completed up to five times more quickly in SI units than in Imperial units;

b) The fact of sharing a common technical "alphabet" will enable engineers to improve communications and facilitate exchange of technical information;

c) The change will give industry an opportunity to rationalise manufacture, reduce unnecessary variety in sizes of goods made, and increase their ability to compete overseas. Over 90% of the world's trading nations conduct their business in metric terms and there is no future in Great Britain being the "odd man out".

2. SI UNITS

Since 1875, all international matters concerning the metric system have been the responsibility of the Conférence Générale de Poids et Mesures (CGPM). This body adopted SI (International System of Units) in 1960, as a rationalised and coherent system using the following six base units:-

SI Unit	Abbreviation	Property
metre	(m)	length
kilogramme	(kg)	mass
second	(s)	time
ampere	(A)	electric current
kelvin	(K)	thermodynamic temperature
candela	(cd)	luminous intensity

From these six fundamental units, with the addition of the supplementary units the radian (rad) and the steradian (sr), it is possible to derive units for all the physical quantities used in any branch of technology. Special names have been given to some of these derived units, e.g. the unit of force is called the newton (N), and the unit of energy, or work, is called the joule (J). The factor for obtaining derived units from base units is always unity, for instance:- unit force results when unit mass is multiplied by unit acceleration -

$$1\ N = 1\ kg \times 1\ m/s^2$$

$$1\ N \times 1\ m = 1\ J$$

2.1 The Newton

In the spring industry the newton is one of the more important units, and after some initial doubt, and a change of mind by the British Standards Institution, the basic SI unit for tensile strength has been agreed as the newton per square metre (N/m^2)*. It is intended that the newton will eventually be adopted as the basic unit of force in France and Germany.

To use N/m^2 for tensile strength would give large numerical values, and to keep the figures to a reasonable size it is recommended that some sub-multiple of the basic unit be used; this would be the newton per square millimetre (N/mm^2). As 1 kgf/mm^2 = 9.81 N/mm^2 (say 10 N/mm^2) and 1 kgf/mm^2 = 0.981 hectobar (say 1 hbar) this would give a convenient size of number and a simple relationship between the units in use at present on the Continent. Conversion from Imperial units is also simple, for example
100 $tonf/in^2$ = 1544 N/mm^2 = 154.4 hbar = 157.4 kgf/mm^2

With the unit for tensile strength established as N/mm^2 the units for stress and rate follow automatically, stress being measured in N/mm^2, and rate in N/mm.

Conversion charts are given in Figs. 1 and 2, together with conversion factors.

2.2 Decimal Multiples and Sub Multiples

For most applications the use of units resulting in numerical values between 0.1 and 1000 is recommended, and to achieve this, decimal multiples and sub-multiples of the SI units are formed as follows:-

Factor by which the unit is multiplied			Prefix	Symbol
1 000 000 000 000	=	10^{12}	tera	T
1 000 000 000	=	10^{9}	giga	G
1 000 000	=	10^{6}	mega	M
1 000	=	10^{3}	kilo	k
100	=	10^{2}	hecto	h
10	=	10^{1}	deca	da
0.1	=	10^{-1}	deci	d
0.01	=	10^{-2}	centi	c
0.001	=	10^{-3}	milli	m
0.000 001	=	10^{-6}	micro	μ
0.000 000 001	=	10^{-9}	nano	n
0.000 000 000 001	=	10^{-12}	pico	p

* The name pascal (Pa) has been approved for this unit.

It is recommended that only SI units themselves should be used in calculations and not their decimal multiples and sub multiples.

It should be noted that, to avoid confusion with the decimal point, no commas are used to split large numbers. If a figure has more than four digits then a space is inserted after every third digit, reading from the decimal point, in either direction.

There are modifications to this rule where figures are in columns or tables.

2.3 Modulus Values for Spring Material

The Rigidity Modulus (G) and Young's Modulus (E) values will be expressed in kN/mm^2, and values for a range of materials are given below:-

	G (kN/mm^2)	E (kN/mm^2)
Hard drawn carbon steel	79.3	206.8
Carbon steel for hardening and tempering	79.3	206.8
Silicon manganese steel	79.3	206.8
Chromium vanadium steel	79.3	206.8
Martensitic stainless steel	79.3	206.8
Austenitic stainless steel	65.5 - 75.8	182.7 - 193.1
Phosphor bronze	43.0	103.4
Hard drawn brass wire	36.0	103.4
Copper beryllium	41.3	127.6
Monel	65.5	178.3
Inconel X750	76.0	213.7
Nimonic 90	82.7	234.4
Titanium alloys	34.5 - 41.4	110.3 - 131.0

The Appendix demonstrates a typical spring design carried out in SI units.

3. PREFERRED NUMBERS

As metrication proceeds the Imperial inch standards will be replaced by metric standards, using preferred number series, agreed by the International Standards Organisation (ISO). The Institute of Iron and Steel Wire Manufacturers has adopted as standard wire diameters, the R 40 series, and a slightly modified version, the R '40 series, which is considered adequate for most general applications.

Preferred wire diameters and strip thicknesses are given in Tables I and II.

4. CONCLUSIONS

The Spring Research Association considers it essential that companies in the spring industry adopt the SI system as outlined in this report and, by making copies available to their customers and suppliers, facilitate the changeover to SI units.

5. FURTHER INFORMATION

Further information on the metrication programme is available from:-

The Metrication Board,
22 Kingsway,
London WC23 6LE (01-242-6828)

British Standards Institution,
2 Park Street,
London W1A 2BS (01-629-9000)

and attention is drawn to the following publications:-

Change to the metric system in the United Kingdom. Report by the Standing Joint Committee on Metrication. H.M.S.O. 20p.

Changing to the metric system - background and programme. Metrication Board. Gratis.

Conversion factors and tables. B.S. 350. Part I 1959, £1-70. Part 2, 1962, £4. Additional SI conversion tables, B.S.I. £1-30.

Guide to the choice of series of preferred numbers and of series containing more rounded values of preferred number. ISO/R497. B.S.I. £2-10.

Guide to series of basic sizes for metal sheet, strip and wire. B.S. 3737: 1964. B.S.I. £1-50.

International System (SI) units. B.S. 3763: 1970. B.S.I. 50p.

Metric series for basic thicknesses of sheet and diameters of wire. ISO/R 388. B.S.I. 70p.

Metric standards published and in progress. P.D. 6286: 1969. B.S.I. £1-80.

Preferred numbers. B.S. 2045: 1965. B.S.I. 50p.

Recommendations for metric basic sizes for metal wire, sheet and strip. B.S. 4391: 1969. B.S.I. 40p.

The use of SI units. P.D. 5686: 1969. B.S.I. 20p.

Conversion slide. B.S.I. £1-20.

Readimetric converter. B.S.I. 70p.

Standard metric sizes of steel wire for use in the United Kingdom. Institute of Iron and Steel Wire Manufacturers. 10p.

Tables I and II on the following pages are reproduced from B.S. 4391, published by the British Standards Institution, 1969.

TABLE I STANDARD DIAMETERS FOR WIRE (cont.)

Diameter mm			Diameter mm		
Choice			Choice		
First (R10)	Second (R20)	Third (R40)	First (R10)	Second (R20)	Third (R40)
1.00	1.00	1.00	10.0	10.0	10.0
		1.06			10.6
	1.12	1.12		11.2	11.2
		1.18			11.8
1.25	1.25	1.25	12.5	12.5	12.5
		1.32			13.2
	1.40	1.40		14.0	14.0
		1.50			15.0
1.60	1.60	1.60	16.0	16.0	16.0
		1.70			
	1.80	1.80			
		1.90			
2.00	2.00	2.00			
		2.12			
	2.24	2.24			
		2.36			
2.50	2.50	2.50			
		2.65			
	2.80	2.80			
		3.00			
3.15	3.15	3.15			
		3.35			
	3.55	3.55			
		3.75			
4.00	4.00	4.00			
		4.25			
	4.50	4.50			
		4.75			
5.00	5.00	5.00			
		5.30			
	5.60	5.60			
		6.00			
6.30	6.30	6.30			
		6.70			
	7.10	7.10			
		7.50			
8.00	8.00	8.00			
		8.50			
	9.00	9.00			
		9.50			
10.00	10.00	10.00			

TABLE I STANDARD DIAMETERS FOR WIRE

Diameter mm			Diameter mm		
Choice			Choice		
First (R10)	Second (R20)	Third (R40)	First (R10)	Second (R20)	Third (R40)
			0.100	0.100	0.100
					0.106
				0.112	0.112
					0.118
			0.125	0.125	0.125
					0.132
				0.140	0.140
					0.150
			0.160	0.160	0.160
					0.170
				0.180	0.180
					0.190
0.020	0.020	0.020	0.200	0.200	0.200
		0.021			0.212
	0.022	0.022		0.224	0.224
		0.024			0.236
0.025	0.025	0.025	0.250	0.250	0.250
		0.026			0.265
	0.028	0.028		0.280	0.280
		0.030			0.300
0.032	0.032	0.032	0.315	0.315	0.315
		0.034			0.335
	0.036	0.036		0.355	0.355
		0.038			0.375
0.040	0.040	0.040	0.400	0.400	0.400
		0.042			0.425
	0.045	0.045		0.450	0.450
		0.048			0.475
0.050	0.050	0.050	0.500	0.500	0.500
		0.053			0.530
	0.056	0.056		0.560	0.560
		0.060			0.600
0.063	0.063	0.063	0.630	0.630	0.630
		0.067			0.670
	0.071	0.071		0.710	0.710
		0.075			0.750
0.080	0.080	0.080	0.800	0.800	0.800
		0.085			0.850
	0.090	0.090		0.900	0.900
		0.095			0.950
0.100	0.100	0.100	1.000	1.000	1.000

TABLE II STANDARD THICKNESSES FOR SHEET AND STRIP

Thickness mm		Thickness mm		Thickness mm	
Choice		Choice		Choice	
First (R"10)	Second (R"20)	First (R"10)	Second (R"20)	First (R"10)	Second (R"20)
		0.10	0.10	1.0	1.0
			0.11		1.1
		0.12	0.12	1.2	1.2
			0.14		1.4
		0.16	0.16	1.6	1.6
			0.18		1.8
0.020	0.020	0.20	0.20	2.0	2.0
	0.022		0.22		2.2
0.025	0.025	0.25	0.25	2.5	2.5
	0.028		0.28		2.8
0.030	0.030	0.30	0.30	3.0	3.0
	0.035		0.35		3.5
0.040	0.040	0.40	0.40	4.0	4.0
	0.045		0.45		4.5
0.050	0.050	0.50	0.50	5.0	5.0
	0.055		0.55		5.5
0.060	0.060	0.60	0.60	6.0	6.0
	0.070		0.70		7.0
0.080	0.080	0.80	0.80	8.0	8.0
	0.090		0.90		9.0
0.100	0.100	1.00	1.00	10.0	10.0

Note: If additional thicknesses are required, it is recommended that they be selected by interpolation from the second choice (R"20) sizes.

APPENDIX

A TYPICAL SPRING DESIGN IN SI UNITS

LEGEND

Wire diameter	=	d	mm
Mean coil diameter	=	D	mm
Active coils	=	n	
Total coils	=	n_t	
Rate	=	S	N/mm
Free length	=	lo	mm
Load	=	P	N
Stress	=	q	N/mm^2
Modulus of rigidity	=	G	N/mm^2
Stress Correction factor	=	K	
Spring Index	=	C	

EXAMPLE

Design a spring to suit the following requirements:-

I.D.	=	21	mm
Rate	=	38	N/mm
Load	=	800	N at length 28 mm
Working Stress	=	1000	N/mm^2 maximum

Formulae used are exactly the same as those used for Imperial units.

Rate S $= \dfrac{Gd^4}{8nD^3}$ - - - - (1)

Stress q $= \dfrac{8PDK}{\pi d^3}$ - - - - (2)

Free length = 28 + 800/38 = 49 mm

By substitution of wire sizes in equation (2) it is found that 4 mm wire will carry the required load with a stress of 980 N/mm^2.

$$\text{Spring Index} = \frac{25}{4} = 6.25$$

$$k = \frac{C + 0.2}{C - 1} = 1.23$$

$$\text{Active coils} = n = \frac{Gd^4}{8SD^3}$$

$$G \text{ (for steel)} = 79\ 000\ N/mm^2$$

$$\text{Thus } n = \frac{79\ 000 \times 4^4}{8 \times 38 \times 25^3} = 4.2$$

$$n_t = n + 2.0 = 6.2$$

$$\text{Solid length} = (n + 1.5) \times d = 22.8 \text{ mm}$$

$$\text{Solid load} = (\text{Free length} - \text{solid length}) \times \text{Rate}$$

$$= (49 - 22.8) \times 38 = 1000 \text{ N}$$

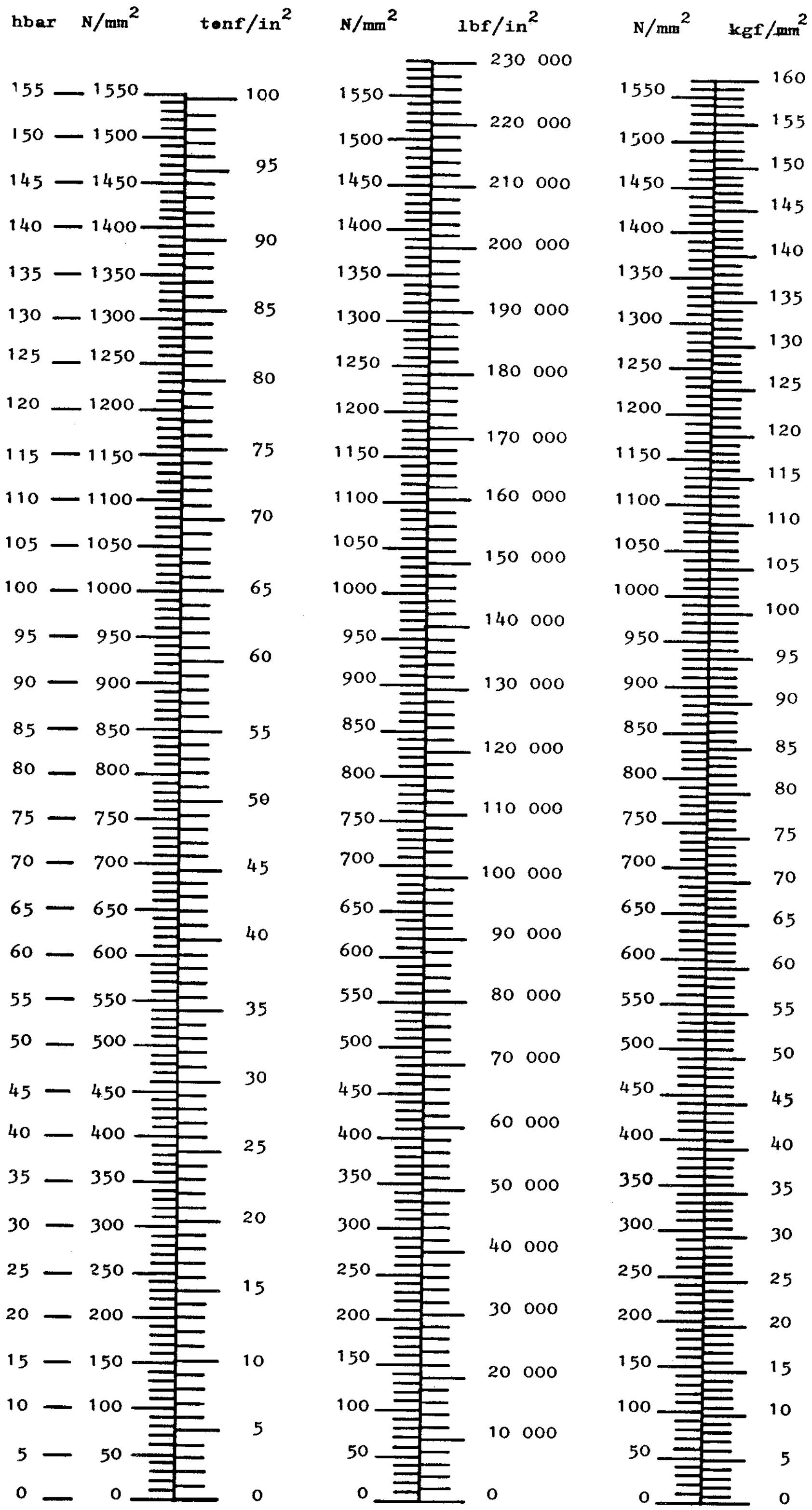
From equation (2)

$$\text{Solid stress} = \frac{8 \times 1000 \times 25 \times 1.23}{\pi \times 4^3}$$

$$= 1217\ N/mm^2$$

Final details of the spring are as follows:-

Wire diameter	4	mm
Mean coil diameter	25	mm
Active coils	4.2	
Total coils	6.2	
Rate	38	N/mm
Free length	49	mm
Working load	800	N
Working stress	980	N/mm^2
Solid stress	1217	N/mm^2

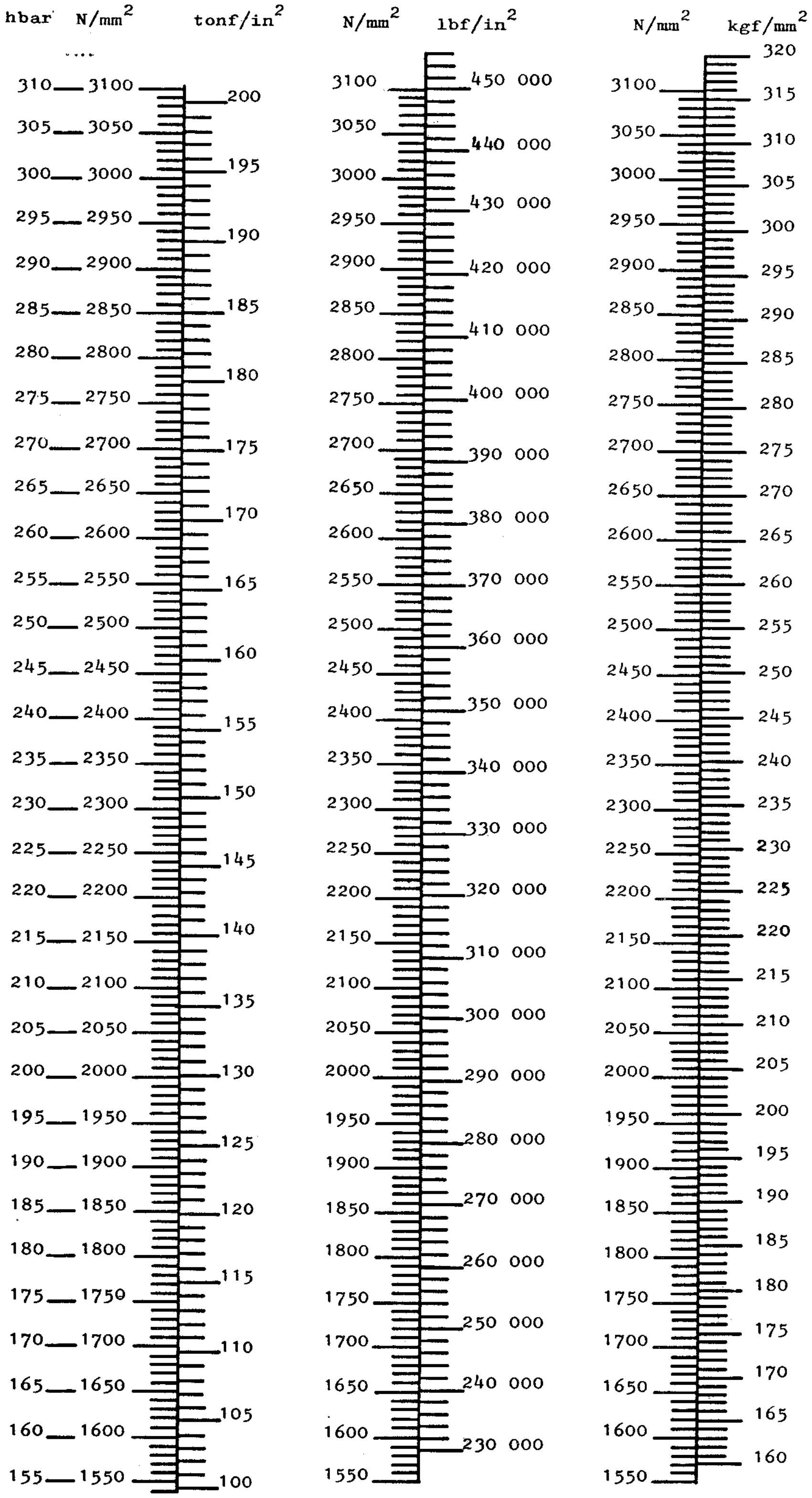


CONVERSION FACTORS

1 N/mm² = 10 bar = 0.1 hbar = 1 MN/m²

= 0.064749 tonf/in² = 145.038 lbf/in² = 0.101972 kgf/mm²

FIGURE 1 CONVERSION CHART



CONVERSION FACTORS

1 N = 2.2046 kgf = 0.2248 lbf = 0.00010036 tonf

FIGURE 2 CONVERSION CHART