Record of Revisions:

Rev. No.	Clause No.	Details of revision	Remarks
01		Editorial correction	
02	7.4.1.3 Fig. 1 Fig. 2	Introduced Charted average deflection changed as average deflection. Final deflection changed as Test deflection	
03	3.1.2 5.3.1 9.1	Heat treatment condition added Wire dia increased from 10 to 16 mm for cold Coiling based on IBR amendment. Point No.7 added. Point No.3 and 5 clarity brought in Annexure II. Point no 9.24 added.	
04	--	Modified in entirety. UT on bars of dia > 40 mm added. New materials added.	
05	*3.1.2* *5.2.1* *5.2.11* *7.5* *8.2* *Tables I,II,III,IV & V* *Annexure II*	*Mechanical tests as applicable* *Coiling process* *Modified* *Removed* *Modified* *Modified* *Revised*	

1.0 SCOPE

1.1 This Technical Delivery Condition specifies the technical and inspection requirements for circular section wire, helical compression springs used in safety/safety relief valves. Primary considerations are for a spring designed to remain under static load with a compression load defined by (seat area X set pressure) for the major portion of its life. Load is intermittently added by virtue of the spring being compressed by the valve travel when the system pressure exceeds the valve set pressure and the valve opens. Approximately 10,000 cycles of intermittent valve openings are expected. It is the responsibility of the supplier to design, manufacture, test, certify and supply the springs as per this TDC.

2.0 APPLICABLE STANDARDS (Latest on the date of PO)

2.1 CODE REQUIREMENTS

ASME Sec-I (Boiler & Pressure Vessel Code)
ASME Sec-IV (Rules for Construction of Heating Boilers)
ASME Sec-VIII Div-1 & 2 (Rules for Construction of Pressure Vessels)
Indian Boiler Regulations: Regulation Nos: 307 to 314.
Dresser Specn MA 16.

2.2 REFERENCE STANDARDS

ASTM A-125	: Standard Specification for Steel Springs, Helical, Heat-Treated.
ASTM A-370	: Standard Test Methods and Definitions for Mechanical Testing of Steel Products.
ASTM E-6	: Standard Terminology Relating to Methods of Mechanical Testing.
ASTM E-10	: Standard Test Method for Brinell Hardness of Metallic Materials.
ASTM E-18	: Standard Test Methods for Rockwell Hardness of Metallic Materials
ASTM E-140	: Standard Hardness Conversion Tables for Metals Relationship among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness
ASTM B-456	: Standard Specification for Electrodeposited Coatings of Copper plus Nickel Plus Chromium and Nickel Plus Chromium.
IS: 7906	: Part I, II, III & IV for Hot and Cold rolled springs.

Even though the reference standards are given, the supply condition shall be in line with this TDC.

3.0 SPRING DRAWING

3.1 For each type of springs BHEL will provide a spring drawing which will be the basis for spring manufacturer. This drawing shall provide details of dimension, material and process.

3.1.1 The steel (raw material) shall be procured from Well-known Steel makers indicated by IBR with Mill TC. If the steel maker is not approved as a well known steel maker by IBR, then the raw material (wire/bar) shall be inspected and Mill Test certificates shall be countersigned by the concerned State DOB/CIB (if indigenously procured), or by the Inspecting Authorities approved by IBR (if imported).

3.1.2 Springs shall be made from steels made by basic oxygen, open-hearth process or electric furnaces. Mechanical tests shall be conducted for raw materials used for springs and shall meet the material specification requirements and these test values (YS, UTS, % Elongation, hardness *as applicable/specified in the material specification*) shall be reported in the raw material TC along with chemistry & heat treatment condition. Also, test certificate for the spring shall be furnished as per Annexure-II by the Spring Manufacturer.

4.0 DESIGN PARAMETERS

4.1 Each Spring Design shall be analyzed by the spring vendor. Calculations shall be submitted to BHEL for approval, if any change in design parameters.

4.2 SPRING RATE

4.2.1 BHEL requires springs that demonstrate the spring rate as specified in the spring drawing. If no tolerance specified in the drawing it shall not vary more than 5% of the nominal rate specified. This requires that the operating range of the spring be in the linear portion of the spring rate curve (fig 1). For a given carbon steel or low alloy spring, the linear region of the spring is generally defined to be between 15% and 85% of the total average deflection. The spring drawing is developed on the basis of an initial loading of approximately 15% deflection, then compressing the spring a given deflection (defined as test deflection) from which the load is measured. All springs shall have a load at test deflection within the limits specified in the spring drawing (See fig 2).

4.3 SPRING RATE MEASUREMENTS

4.3.1 Hysteresis as applied to a helical spring can be defined as that characteristic which causes a spring to follow a different load Vs deflection curve during a compression operation than during a relaxation operation. It is important that all load readings for the purposes of determining rate shall be made during a compression operation. If, for example a spring is inadvertently compressed beyond the 85% test load value, it is necessary to remove the load completely to zero (0) and recommence the test in order to obtain accurate results.

4.4 SPRING RATE CALCULATION

4.4.1 The Spring rates have been calculated using the following equation:

$$K = \frac{Gd^4}{8ND^3}$$

K = Spring rate (kg/mm)
d = Normal wire size (mm)
D = Mean Coil diameter (mm)
N = Active coils.
= Total coils - 2 for wire size < 12.7 mm.
= Total coils - 1.5 for wire size ≥ 12.7 mm
G = Torsional modulus of material (Kg/sq mm)

4.4.2 Springs shall be tested for spring rate in accordance with the requirements of Clause 6.8 of this TDC.

4.5 PERMANENT SET / SCRAGGING TEST

4.5.1 It is essential that springs be furnished in accordance with the requirements of the ASME Codes & IBR. The permanent set of the spring (defined as the difference between initial free height and free height measured 10 minutes after the spring has been compressed to its solid height 3 additional times) shall not exceed 0.5 % of the free height. Compressed solid height is defined in Annexure-I. If required, manufacturer may change the design with the approval of BHEL to meet the conditions.

4.6 FREE HEIGHT

4.6.1 The free height is a fixed parameter controlled by assembly physical considerations and subject only to the tolerance consideration as per Clause. 6.5.

4.7 INSIDE & OUTSIDE DIAMETERS

4.7.1 Assembly and machined part considerations determine whether the inside or outside diameter of the spring are critical, the spring drawing indicates the limits on the spring diameter within which a vendor can supply springs. Suggested bar size is also noted in drawing to assist in checking spring designs. It is suggested that the inside diameter be held if possible, however, a larger inside diameter is permissible. Vendors are cautioned that eccentricities, bowing, and other factors that cause an apparent change in spring dimension must be considered by the vendor in the diameter limits specified on the spring drawing.

4.8 LOAD LOSS

4.8.1 Manufacturer shall be responsible for ensuring that spring fabrication, heat treatment, stress relieving etc., are adequate to ensure to proper spring manufacturing at an ambient temperature of 35 Deg C. Because of load loss characteristic non pre-stressed springs are preferred.

4.9 DE-CARBURISATION

4.9.1 The bars shall be free from defects so that springs produced shall be free from total de-carburisation and the depth of partial de-carburisation shall not exceed as follows:
For dia > 10 mm to ≤ 20 mm = 0.08 mm.
For dia > 20 mm to ≤ 80 mm = 0.13 mm.

4.9.2 The de-carburisation shall be examined at 100X on a test specimen suitably etched and cut from full cross section of the test spring showing at least one line inch of original bar circumference.

5.0 MANUFACTURE

5.1 Material shall conform to the requirements specified in the spring drawing.

5.2 COILING

5.2.1 *Unless specified in Drawing, springs may be manufactured by cold or hot coiling process.*

5.2.2 Springs shall be made out of machined and suitably finished bars to avoid surface defects and to minimize de-carburization.

5.2.3 The bar heating and subsequent heat treatments shall be done preferably in atmosphere controlled furnace. If not available, the same shall be done only in electric furnaces. Usage of oil-fired furnaces shall be mutually agreed prior to the placement of order.

5.2.4 The depth of partial de-carburisation shall not exceed the limits specified in Clause 4.9.

5.2.5 Springs shall be uniformly & suitably heat treated as per specification for developing the required physical properties specified in spring drawing.

5.2.6 Unless otherwise agreed upon the direction of coiling shall be right hand only.

5.2.7 Pitch correction by wedging after coiling is prohibited. The correct pitches shall be obtained in the coiling process itself.

5.2.8 For transmitting axial loads on the connecting bodies the spring end shall be formed by grinding to provide smooth flat bearing surface of a minimum of 3/4 of the circumference as per fig.4.

5.2.9 The tip thickness `t' in fig.3, shall be between d/3 and d/4 approximately, where d is the diameter of wire.

5.2.10 The tips shall not protrude outside or inside of the spring. Such projections shall be ground smoothly to match the spring outside or inside diameter as the case may be. This is shown in fig.4.

5.2.11 The end coils shall have smooth consistent taper to minimize spring out of squareness under load. Common type of unacceptable and acceptable *ends* are shown in fig.5.

6.0 INSPECTION

6.1 All springs shall be 100% tested for conformance as per this TDC.

6.2 SURFACE FINISH INSPECTION

6.2.1 A visual inspection shall ensure that no projections on the inside or outside diameters exist that will exceed the nominal inner or outer spring diameters respectively. Manufacturers are responsible for ensuring that no laps, seams, folds, scaling or other defects which may act as stress risers or masked defects are present in any spring. Stress raisers are subject to evaluation by BHEL, however gas holes, pitting, or large sections where nominal spring wire diameter is reduced by more than (1.5 %) are considered unacceptable. The 1.5 % limitation also applies to surface ground flat for hardness readings.

6.3 INSIDE DIAMETER INSPECTION

6.3.1 Inside diameter shall be checked as per the spring drawing. For all springs the following tolerances apply to the diameters specified on spring drawing.

Inside diameter	Tolerance
25mm and smaller	+ 0.8 mm / - 0 mm
over 25mm to 50mm inclusive	+ 1.6 mm / – 0 mm
over 50mm to 100mm inclusive	+ 2.4 mm / – 0 mm
over 100mm	+ 3.2 mm / – 0 mm

6.3.2 The suggested wire diameters are indicated in the spring drawing.

6.4 END COIL INSPECTION

6.4.1 End coils should be wound closed against the adjacent full pitch coils. Deviation from this closure shall not exceed the following (Ref. Fig.3.)

Wire Size	Max. Opening
Less than 11.1mm	0.8 mm
Over 11.1 - 31.8	1.6
Over 31.8 - 44.5	3.2
Over 44.5 - 57.2	4.0
Over 57.2	4.8

6.4.2 Maximum Tip thickness shall be in accordance with Cl. 5.2.10 (Ref. Fig.3)

6.4.3 The end coils shall be in accordance with Cl.5.2.9 & Cl.5.2.12.

6.5 FREE HEIGHT INSPECTION

6.5.1 The free height is determined by placing a straight edge across the top of the spring and measuring the perpendicular distance from the plate on which the spring stands to the bottom of the straightedge at the approximate centre of the spring. Tolerances are shown below:-

Free height	Tolerance
75mm and smaller	± 0.8mm
over 75mm to 165mm inclusive	±1.6mm
over 165mm to 254mm incl.	±2.4mm
Over 254mm to 356mm incl.	±3.2mm
Over 356mm to 559mm incl.	±4.8mm

6.5.1.1 Springs which "Rock" in their free standing position are considered acceptable under the following conditions:-

(a) A reasonable determination of free height of the centre line can be made, and variation in free height is within the tolerances specified above. A spring out of square by more than 2 Deg as measured in Cl.6.6 & Cl.6.7 is considered unacceptable (This applies for springs larger than 12mm diameter wire).

(b) Check wire diameter of spring ends are within the limits specified in fig.6.

6.5.2 Permanent Set/Scragging test shall be carried out for each spring as per Cl 4.5.1. Following the three deflection tests, the free height shall be measured. The spring shall be within tolerances as specified in Clause.6.5.1. Furthermore, loss in its free height (i.e., permanent set) shall not exceed 0.5% of the free height.

6.6 SQUARENESS AND CONCENTRICITY FOR SPRINGS LARGER THAN 14 MM WIRE SIZE.

6.6.1 A centrally located ball and washer mechanism, as shown in fig.7 shall be used for testing. The end plates shall be centrally fixed and not movable during test. When under final load, the ends of the spring shall sit squarely on the test plates with the ground surface in full contact with the test plates.

6.6.2 Deflect spring to 85% of the total deflection three times prior to taking tilt measurement.

6.6.3 The total included angle of the tilted washers at final load shall not be more than 3 deg. Angular tilt at one end of the spring shall not exceed 1 - 1/2 Deg.

6.6.4 The effects of bowing, eccentricities, etc., shall be limited to the tolerances specified in Clause 6.3.

6.6.5 Tilt measurement shall be taken when the spring is loaded to 85 % of total deflection as in spring drawing.

6.7 SQUARENESS AND CONCENTRICITY FOR SPRINGS 14 MM AND LESS WIRE SIZE

6.7.1 Springs shall be checked in accordance with Fig.8. "Y" values when measured with a scale not to exceed Tan 1.5 deg. x spring length (FL : free height).

6.7.2 To accurately determine the spring end coil concentricity the actual inside diameter of either end coil must be measured. The smaller end should be placed against the surface plate. The difference between either inside diameter must be divided by 2 and this amount subtracted out of measured "Y" value.

(i.e) Condn

$$\frac{\{Y - (ID_1 - ID_2)\}}{2} < (\text{Tan } 1.5 \text{ Deg}) \times FL$$

6.8 SPRING RATE VERIFICATION

6.8.1 Springs shall be checked to verify spring rate between initial load and final load values specified. The spring drawing indicates load and deflection values required. Springs larger than 14mm wire will be checked with washers and bearing in accordance with Fig.7. Other springs may be checked between flat end plates. The testing procedure shall be as follows:

(a) Spring shall be installed and tested with the stamped code facing the tester and at the upper side of the spring. This is to ensure consistency in testing.

(b) Apply initial load specified in spring drawing, set deflection recorder to zero.

(c) Apply test deflection specified in spring drawing, observe the load at test deflection. This load should be within the limits specified in spring drawing.

6.9 NON-DESTRUCTIVE EXAMINATION

6.9.1 UT shall be done on bars (used for springs) of dia. > 40mm as per ASTM A388 & with acceptance as per ASME Sec VIII Div 2 cl 3.3.4

6.9.2 Unless and otherwise specified, each Carbon & Low alloy Springs with wire size ≥ 25mm and Tungsten springs with wire size of ≥ 19mm shall be wet magnetic particle tested & accepted at manufacturer's works as per ASME Sec VIII Div 1 Mandatory Appendix 6. Non-ferromagnetic springs shall be Penetrant tested & accepted as per ASME Sec VIII Div 1 Mandatory Appendix 8.

6.9.3 All Non-Destructive examination shall be done after heat treatment, and prior to Spring Testing.

7.0 SURFACE TREATMENT

7.1 All springs shall be shot blasted before MPI/PT. This blasting procedure to be approved.

7.2 Unless specified otherwise, carbon steel and low alloy steel springs shall be furnished by the manufacturer in the phosphated condition.

7.3 All tungsten alloy springs shall be aluminized, using either baked-on paint or molten aluminum.

7.4 Springs will be given special coating when specified in spring specification sheet/drawing.

8.0 IDENTIFICATION

8.1 All springs of wire size 5mm and below shall be tagged individually to show the details of spring number given in drawing, unique number of individual spring, supplier code, specification and heat no of actual material.

8.2 All springs of wire size above 5mm and below 12mm should be vibro etched/*laser marked* to indicate the spring number given in drawing, unique number of individual spring, supplier code, specification and heat no of actual material.

8.2.1 The Purchase order number should be tagged on individual spring.

8.3 All springs of wire sizes ≥ 12mm should be punched with the following details on the outside diameter of an inactive coil : Spring number given in drawing, material specification, supplier code (& supplier's symbol, if available), heat number, unique number of individual spring and spring marking as per applicable table.

9.0 RECORDS

9.1 The following records shall be furnished for each spring.

a) Spring Raw Material Test certificate (Mill TC) including UT results as per cl 6.9.1
b) Coiling and heat treatment temperature, soaking time, cooling media.
c) Dimensional report.
d) Test report of spring rate.
e) Test Report for scragging test.
f) Hardness
g) Spring Test Certificate for each spring shall be as per typical test record indicated in Annexure II duly approved by Chief Inspector of Boilers/ Director of Boiler of the respective State or by Inspecting Authorities approved by IBR.
h) Compliance certificate to IBR.

Table 1
Material: Carbon & Alloy Steels
Reference Specification ASTM A689 Carbon and Alloy Steel Bars for Springs

Material Specification	Torsional Modulus at 70^0F (x 10^6 psi)	Hardness (HRC)	Spring Marking
ASTM A231, ASTM A232	11.5	---	CR
ASTM A322 GRADE 6150 & 5160	10.5	46-50	
ASTM A304 GRADES 4161H, 5160H, 51B60H, 6150H, 9260H			
ASTM A401			
BS970 Pt2 GRADES 735A51,735H51			
BS 2803 GRADES 735A50, 685A55			
DIN 17221 GRADE 51CrMoV4			
DIN 17225 GRADE 50CrV4			
EN 10089 GRADES 51CrV4, 52CrMoV4			
EN 10270-2			
IS 4454-2			

Table 2
Material: Tungsten Alloy Steel

Material Specification	Torsional Modulus at 70^0F (x 10^6 psi)	Hardness (HRC)	Spring Marking
ASTM A681 Type H-12, H-21	11.0	44-48	E
BS 4659 TYPE BH-12, BH-21			

Table 3
Material: Stainless Steel

Material Specification	Torsional Modulus at 70^0F (x 10^6 psi)	Hardness (HRC)	Spring Marking
ASTM A313 TYPE 316	10.0	---	SY
ASTM A276 TYPE 316	9.8	---	

Table 4
Material: Non-Ferrous

Material Specification	Torsional Modulus at 70^0F (x 10^6 psi)	Hardness (HRC)	Spring Marking
ASTM B164 CLASS A (MONEL 400 FULL HARD, Spring Temper)	9.2	23-26	MO
MONEL K-500 (AMS 4676)	9.2	34-38	KM

Table 5
Material: High Temperature

Material Specification	Torsional Modulus at 70⁰F (x 10^6 psi)	Hardness (HRC)	Spring Marking
ASTM A564 TYPE 631 17-7PH CONDN C	11.0	42-46	NC
ASTM A 564 TYPE 630 17-4 PH	10.5	40-44	PH
ASTM A638 GRADE 660	10.5	40-44	C7
ASTM B166 (INCONEL 600 AND 601)	11.0	34-38	I
ASTM B637 GRADE 688 OR AMS 5699 Heat treated to AMS 5699D PARA 1.2.1	11.5	40-44	IX
ASTM B637 GRADE 688 OR AMS 5699 heat treated to AMS 5699D PARA 1.2.2	11.5	36-40	IXS
ASTM B446 GRADE 625 INCONEL 625 ROD & BARS (UNS NO: 6625)	11.5	88 HRB	I6X
AMS 5844 (MP35N UNS R30035)	11.5	44-55	MP

ANNEXURE I

DEFINITIONS

TOTAL DEFLECTION:-- The amount of deflection achieved when the Spring is compressed to its solid height.

COMPRESSED SOLID HEIGHT:- The perpendicular distance between the plates of the testing machine when the spring is compressed with a test load sufficient to bring all coils into contact.

SOLID CAPACITY:

$$P = Gd^4 F / 8 ND^3$$

Where,

G = Effective torsional modulus of elasticity (Kg/sq.mm)

d = Nominal bar diameter (mm)

D = Mean Coil or helix diameter (mm)

F = Spring deflection = free to solid (mm)

N = Active turns.

P = Solid capacity (kgf)

UNCORRECTED SOLID STRESS -

$$S = 8 PD / 3.1416 d^3$$

FINAL DEFLECTION: - A distance specified on the SD sheet for a particular spring which reflects a percentage of the average deflection. The value is used for rate measuring purpose only, within the linear region.

LINEAR REGION:- The part of the load /deflection curve of a particular spring in which deflection increases linearly with increased load. For this purposes of this specification of this range is defined as between 15% and 80% of nominal solid deflection for carbon and low alloy springs.

FREE HEIGHT:- The perpendicular height of the spring measured along the centerline after pressing to solid once and releasing.

PERMANENT SET/ SCRAGGING:- The difference between the free heights measured before and after the spring has been compressed to its solid height and released, 3 times.

ANNEXURE II

TEST CERTIFICATE FOR SAFETY VALVE /SAFETY RELIEF VALVE SPRINGS

Inspection Report No : Date:

1 Name of Manufacturer :
2 PO Number and Date :
3 Quantity :
4 Drawing No :
5 Type of spring :
6 Spring Number :
7 Coiling Practice :
8 Spring record :

Sl. No	Description	Required	Actual	Remarks
9.1	Unique number of spring			
9.2	Material Specn. *of Raw Material Used*			
9.3	Melt no			
9.4	Raw Matl TC No			
9.5	Wire dia			
9.6	Outside dia			
9.7	Inside dia			
9.8	No of Active turns			
9.9	Solid Height			
9.10	Squareness			
9.11	Spring Rate			
9.12	Free Height			
9.13	*Final Load*			
9.14	Permanent set/Scragging			
9.15	Hardness			
9.16	MPI Results for Springs			
9.17	MPI Report to be submitted			
9.18	Surface Coating			
9.19	Depth of De-Carburisation			
9.20	Others Pl Specify			
9.21	Note to be added to verify compliance to IBR			

Inspected by

NOTE: THE ABOVE CERTIFICATE SHALL BE APPROVED BY CHIEF INSPECTOR OF BOILERS/DIRECTOR OF BOILERS IN THE STATE OF MANUFACTURER/ IBR APPROVED INPSEPCTING AUTHORITY.

Figure – 1

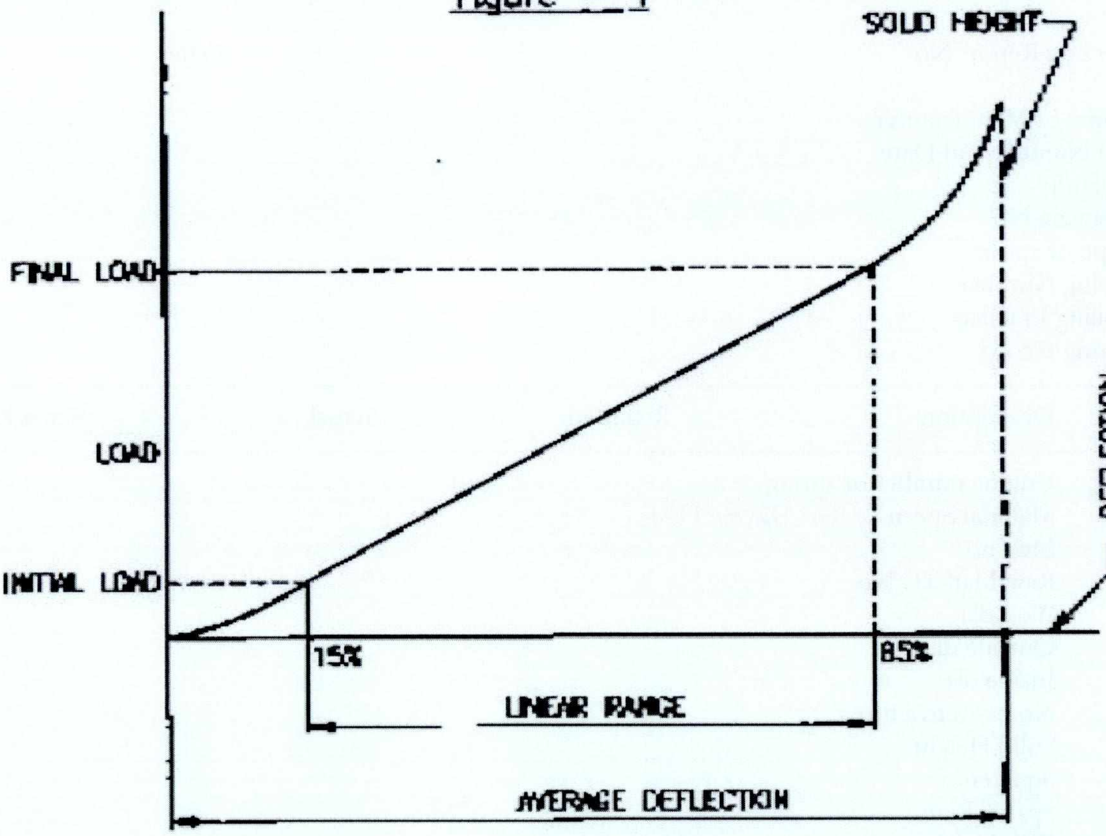
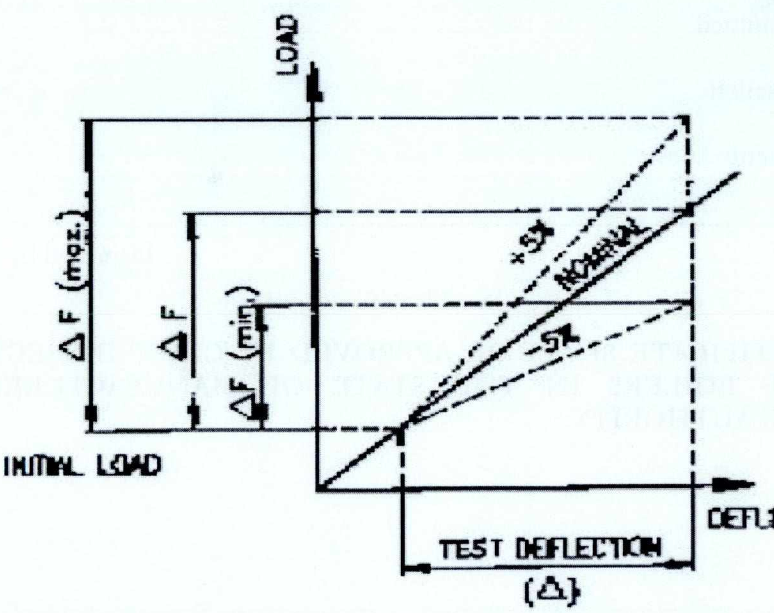


Figure – 2



$$K_{NOM} = \frac{\Delta F}{\Delta}$$

$$K_{Max} = \frac{\Delta F\ Max}{\Delta}$$

$$K_{Min} = \frac{\Delta F\ Min}{\Delta}$$

Figure – 3

SIDE VIEW OF SPRING

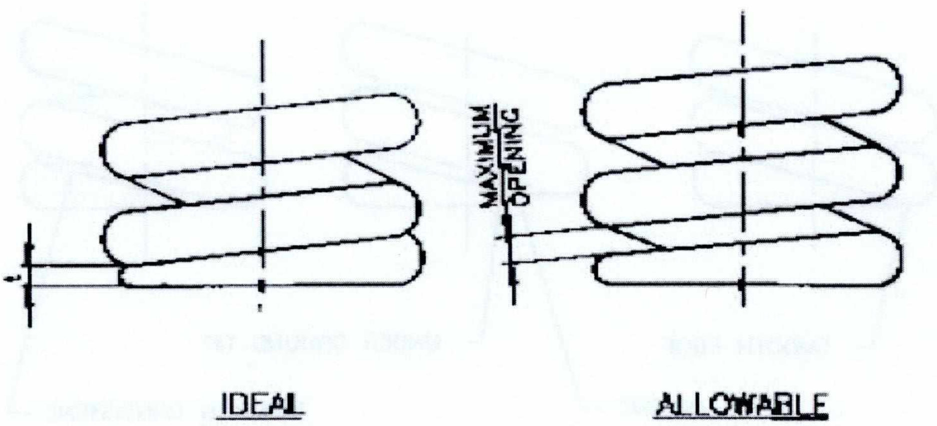


Figure – 4

END VIEW OF SPRING

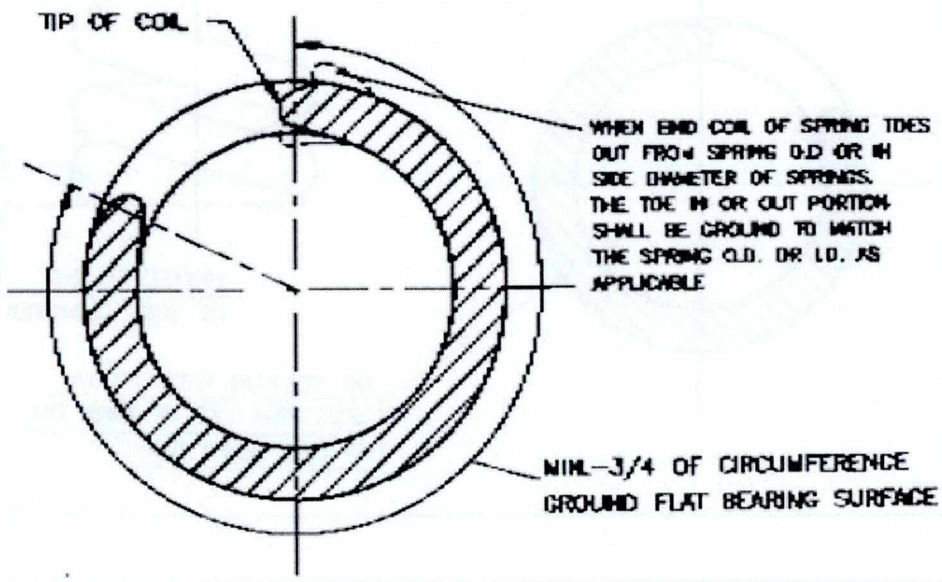


Figure – 5

SIDE VIEW OF SPRING

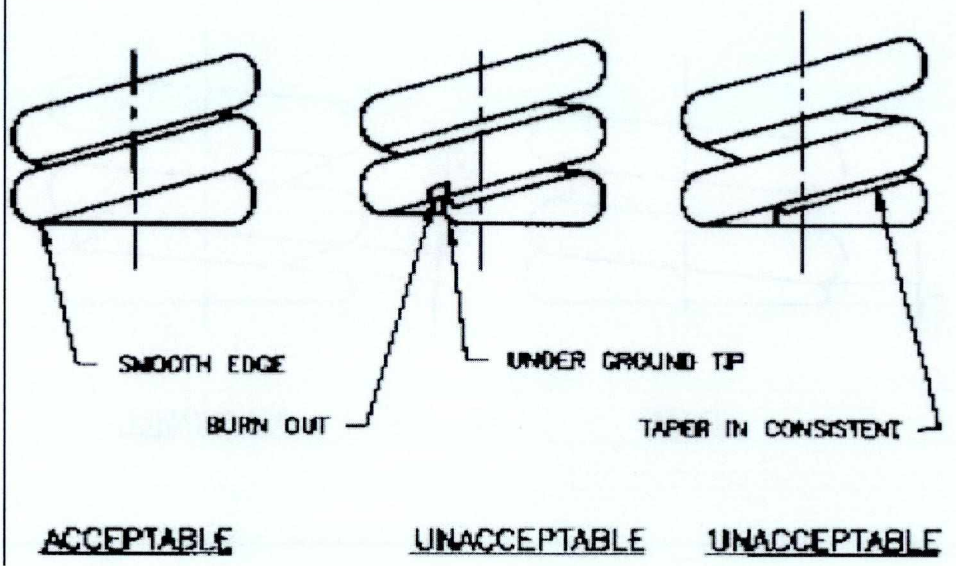


Figure – 6

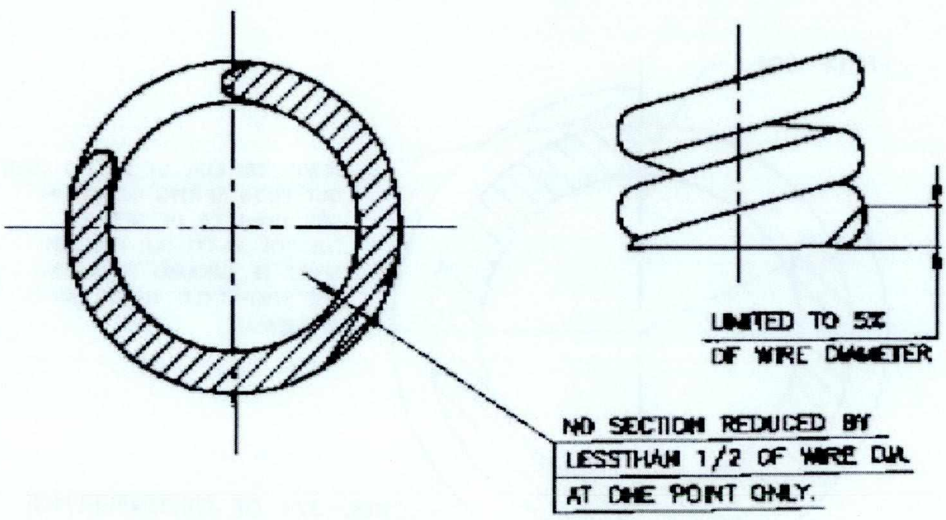
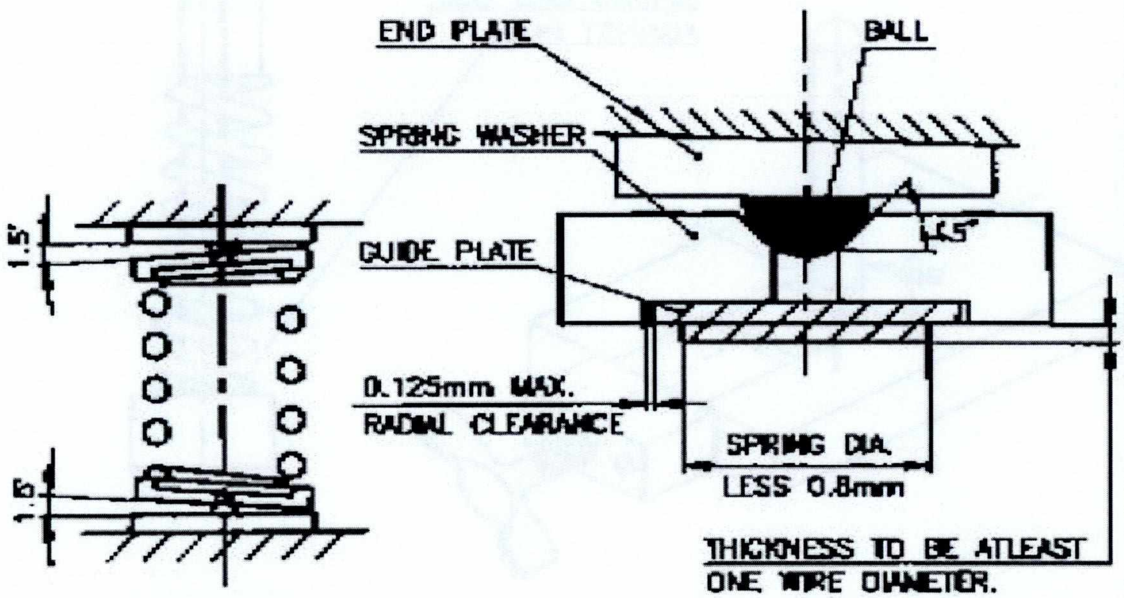


Figure – 7

FOR WIRD DIAMETER ABOVE 14MM



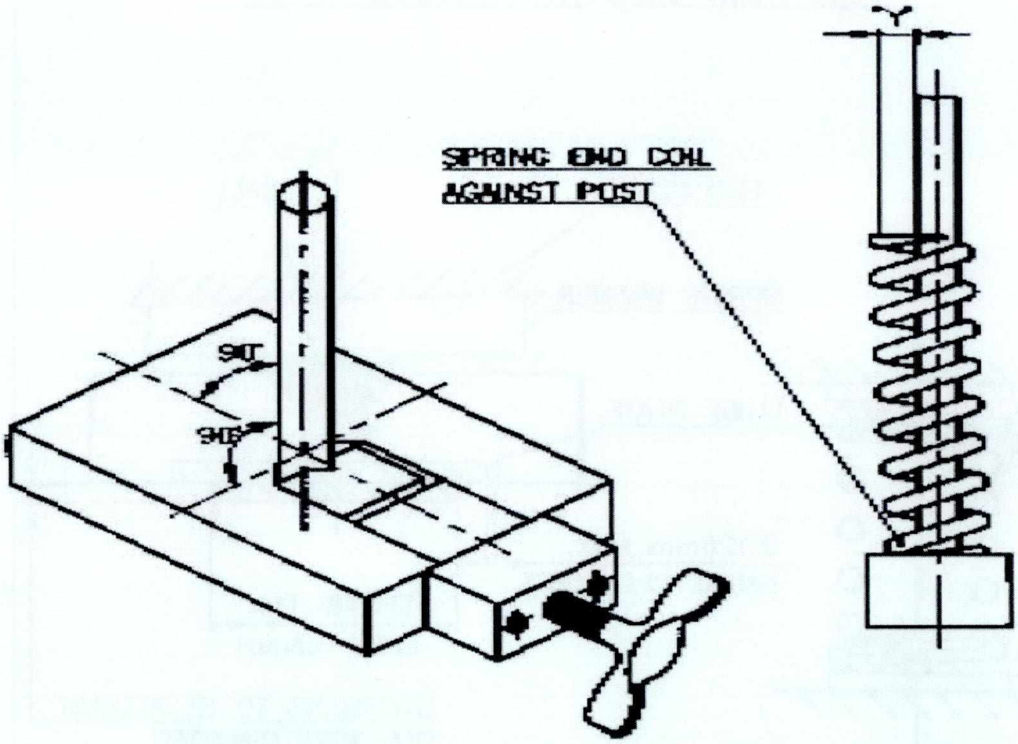
SQUARENESS CHECK
for WIRE DIA. 14mm
and ABOVE

TYPICAL UPPER AND LOWER
ENDS OF SPRING TEST
WASHERS

NOTES:

1. ENDS PLATES TO BE CENTRALLY FIXED AND NOT MOVABLE DURING TEST.
2. SPRING WASHER AND BALL SIZES DEPEND ON LOADS BEING TESTED. SURFACES SHOULD BE ANTI-GALLING AND HAVE [illegible] FINISH. LUBRICATE WITH MOLY-KOTE. IT IS SUGGESTED THIS BEARING SURFACES BE HARDENED.

Figure – 8



APPARATUS SET UP

CHECKING CONCENTRICITY AND SQUARENESS OF ENDCOILS

(WIRE DIA 14mm AND BELOW)

NOTES:

1. "Y" VALUES WHEN MEASURED WITH A SCALE SHALL NOT EXCEED TAN 1.5° MULTIPLIED BY SPRING LENGTH.
2. TO ACCURATELY DETERMINE SPRING END COIL CONCENTRICITY THE ACTUAL INSIDE DIAMETER OF EITHER END COIL MUST BE MEASURED. THE SMALLER END SHOULD BE PLACED AGAINST THE SURFACE PLATE.
3. THE DIFFERENCE BETWEEN EITHER INSIDE DIAMETER MUST BE DIVIDED BY 2 AND THIS AMOUNT SUBTRACTED OUT OF MEASURED "Y" VALUE.