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TITLE	CHEMICAL CONTROL OF THE WATER-STEAM CIRCUITS OF ONCE-THROUGH BOILERS.	
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NTPC LIMITED

OPERATION AND MAINTENANCE DOCUMENTATION SYSTEM

LMI 01/CHEM/OD/OPS/CHEM/001

Rev. No. : 3 February, 2015

CHEMICAL CONTROL OF THE WATER-STEAM CIRCUITS OF ONCE-THROUGH BOILERS

All locations are required to comply with this Directive

Approved for Implementation by …HOP (LARA)…………

Date: …11/10/2017

Enquiries to : HOD (Chemistry & Environment)

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INDEX

CHEMICAL CONTROL OF THE WATER/STEAM CIRCUIT OF ONCE -THROUGH BOILERS

1.0 INTRODUCTION

The selection, optimization, and maintenance of the Cycle chemistry treatment regime establish the conditions for efficient operation of power plants. The proper cycle chemistry contributes to the high availability, efficiency, and long term reliability of power stations. If the cycle chemistry is not carefully controlled and monitored within pre-defined limits, corrosion, deposition and other forms of metal damage can result throughout the plant system. Most cycle chemistry related degradation phenomena are regarded as long term. Therefore, proper management of cycle chemistry is a key factor in the success of any power station.

The excellent cycle chemistry control means that the cycle components reach their design life without excessive forced outage cost due to corrosion, deposition, and scale, and that there will not be deterioration of cycle efficiency and plant generating capacity caused by water chemistry.

The practice of cycle chemistry control consists of purification of water outside the cycle (makeup), removal of impurities within the cycle (blowdown, air removal, condensate polishing, and chemical cleaning), addition of water treatment chemicals, and monitoring. Proper design, operation, and maintenance are also a part of the cycle chemistry control.

Thus, water chemistry impacts all equipment coming in contact with water or steam. A power generating unit cannot operate reliably without a quality water chemistry program and therefore in this document, the water chemistry limits have been derived utilizing the best available knowledge & technology.

2.0 SUPERSEDED DOCUMENTS

Operation Directive- OD/OPS/CHEM/001 Rev. No.: 2, Chemical control of the water-steam circuits of drum & once-through type boilers and HRSG dated December 2009.

3.0 SCOPE

This Directive describes the procedures for the chemical control of the water/steam circuit of Super-Critical boilers of thermal power plants. It covers general aspects, objectives and principles, and chemical control during steady state operation; together with sampling, analysis, instrumentation and chemical dosing requirements. This Directive does not apply to auxiliary circuits.

4.0 OBJECTIVES OF WATER CHEMISTRY CONTROL

The objectives of water chemistry control are:

- Prevention of corrosion in boiler, steam, condensate and feed water systems.
- Prevention of scale and deposit formation on heat transfer surfaces.
- Reducing corroding concentrations.
- Maintenance of high level of steam purity

5.0 CYCLE CHEMISTRY GOALS

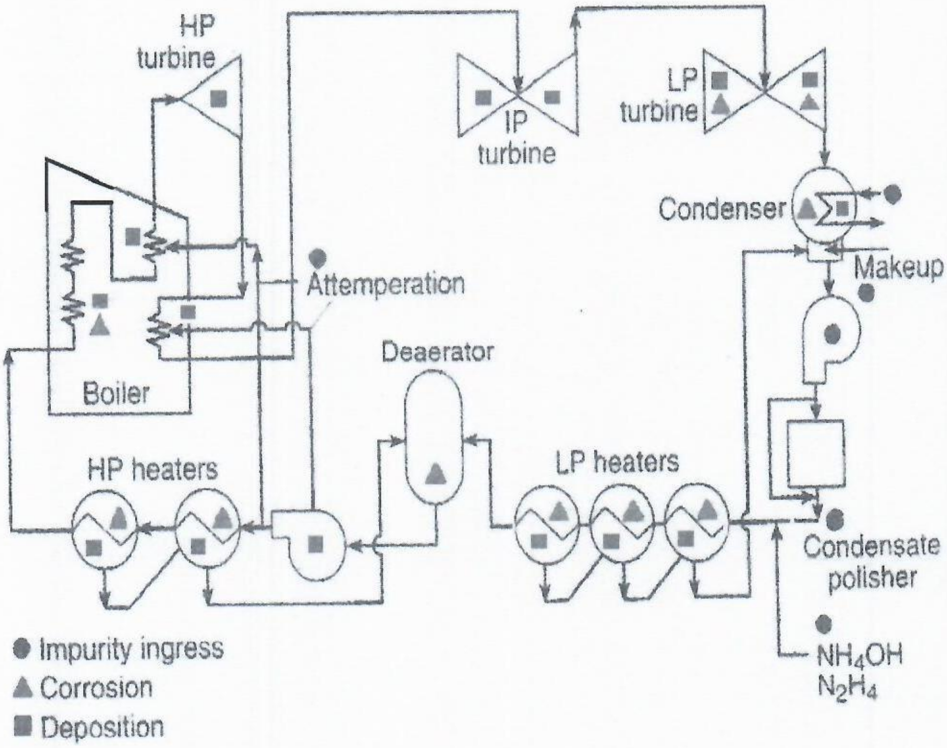
The goals which can be achieved by cycle chemistry control combined with proper design, material selection, operation, and maintenance are given below.

- No cycle chemistry related Boiler Tube Failures.
- No cycle chemistry related steam turbine problems. (Corrosion, deposits).

- No single phase, and minimum two phase, Flow Accelerated Corrosion.
- Elimination/ Reduction of chemical cleanings for all-ferrous feed water systems.
- Shorten startup period (optimization of shutdown, layup, and start up).
- Optimized cycle chemistry for each unit [AVT(R), AVT(O), or OT]

6.0 CYCLE CHEMISTRY DIAGRAM

DRUMLESS BOILERS



7.0 FEEDWATER TREATMENTS

The three recommended feed water treatments are:

All Volatile Treatment (Reducing) AVT(R)- Reducing agent such as Hydrazine Hydrate is added at CEP discharge. pH is maintained by using ammonia. This feed water treatment is generally suggested for mixed metallurgy systems.

All Volatile Treatment (Oxidized) AVT(O)- No reducing agent is added. Ammonia is added for pH control. This feed water treatment is suggested for all-ferrous systems, especially in those units that generally have good feed water purity (ACC <0.2 μS/cm).

Oxygenated Treatment OT- Ammonia plus oxygen is added. This feed water treatment is suggested for all-ferrous systems with the ability to maintain feed water cation conductivity of less than 0.15 μS/cm.

8.0 BOILER WATER TREATMENTS

The following recommended boiler water treatments :

All-volatile treatment (AVT)- In this the feed water treatment is either AVT(R) or AVT(O) as appropriate and no further chemical treatment is applied within the boiler.

Oxygenated Treatment (OT)- In this treatment the feed water dosed with oxygen as needed for OT is used in the boiler without further treatment. OT may be used in cycles with once-through or drum type boilers, however, with the latter feed water oxygen dosing must be more carefully controlled so as to avoid possible corrosion in the boiler.

9.0 CYCLE CHEMISTRY MONITORING

The chemistry parameters monitored under the cycle chemistry guidelines fall into two general categories:

- **Core Parameters-** Monitoring of these parameters is necessary for optimum chemistry control. The core parameters are considered to be the minimum level of surveillance needed for all units. Core parameters should be monitored on a continuous basis.

- **Diagnostic Parameters-** These parameters may be monitored to facilitate the correlation of water chemistry parameters and needed for troubleshooting or during commissioning.

9.1 CORE MONITORING PARAMETERS

S.No.	PARAMETER	MONITORING POINTS
1	Cation Conductivity	Condensate pump discharge, Condenser polisher outlet , Economizer inlet, Main Steam
2	Specific Conductivity	Makeup water, Economizer inlet
3	pH	Feed water
4	Dissolved oxygen	Condensate pump discharge, Economizer inlet, Deaerator inlet & outlet
5	Sodium	Condensate pump discharge, Economizer inlet and main steam
6	Silica	Economizer inlet

9.2 DIAGNOSTIC MONITORING PARAMETERS

In customizing the cycle chemistry programs, monitoring one or more of the diagnostic parameters with on-line analysers can be done. The diagnostic monitoring parameters are listed below.

- Ammonia
- Chloride
- Hydrazine
- Iron and Copper
- Total Organic Carbon
- Oxidation-reduction potential (ORP)

9.3 DESCRIPTION OF MONITORING PARAMETERS

9.3.1 CONDUCTIVITY

There are three types of conductivity measurements:

- Specific conductivity
- Cation conductivity (ACC)
- Degassed Cation Conductivity

Conductivity, more specifically After Cation conductivity (ACC) is a Core Monitoring parameter. ACC is continually monitored on-line to indicate the ionic concentration in the solution being monitored and to warn of contaminant in-leakage. These three types of conductivity are monitored for one or more of the following reasons:

- To maintain conductivity levels within acceptable limits.
- To facilitate the correlation of a water chemistry parameter (e.g., pH , conductivity, ammonia correlation).
- To check the accuracy of water chemistry control (such as ammonia or pH).

- To warn of condenser tube leakage/ seepage.
- To warn of condensate polisher malfunction.
- To provide feedback signal for automated process control.
- To facilitate demineralizer system operation and/or regeneration.
- To monitor for the intrusion of volatile contaminates (e.g., CO2 or volatile organics).

Specific conductivity, cation conductivity, or degassed cation conductivity measurements are affected by the temperature of sample being measured. By convention, conductivity is routinely reported corrected to 25^0C. Even minor temperature differences from 25^0C can have a significant error on observed conductivity measurements.

9.3.2 pH

In boiler water, pH is a Core Monitoring Parameter. It should be continuously monitored on-line to check the acceptability of the water chemistry, thereby ensuring that corrosion rates are kept at low levels.
In steam-water cycle pH is monitored for one or more of the following reasons:

- To maintain pH levels within acceptable limits.
- Corrosion of metals and alloys is a function of pH.
- Alkaline pH values increase the stability of the oxide film and reduce oxide solubility in water.
- To facilitate the correlation between two or more water chemistry parameter (e.g., pH, conductivity, ammonia correlation).
- To provide a feedback signal for automated chemical dosing and process control.
- To warn of in-leakage of contaminants.
- To warn of condensate polisher malfunction

9.3.3 DISSOLVED OXYGEN

Dissolved oxygen (DO) is a Core Monitoring Parameter. It should be monitored continuously on-line to ensure that dissolved oxygen is maintained at acceptable levels. DO is monitored for one or more of the following reasons:

- To maintain dissolved oxygen levels within acceptable limits.
- To check the accuracy of water chemistry control, so ensuring that corrosion rates are kept at acceptable low levels.
- To facilitate the correlation of a water chemistry parameter with plant operating variables, with an aim to optimizing operations (e.g., condenser air removal or deaerator operations).
- To provide feedback stimulus for automated process control, e.g., for oxygen control on oxygenated treatment (OT).
- To monitor for condensate pump seal leakage.
- During and following changes in feed water treatment.

9.3.4 SODIUM

Sodium is a Core Monitoring Parameter. It should be monitored continuously on-line to check the acceptability of water chemistry, thereby ensuring that corrosion rates are kept at low levels.

Sodium is monitored for one or more of the following reasons:

- To maintain sodium levels within acceptable limits.
- To warn of in-leakage of contaminants.
- To warn of boiler water carryover.
- To identify cooling water in-leakage at the main steam condenser.
- To warn of condensate polisher malfunction.

9.3.5 SILICA

Elevated silica concentrations in steam can lead to silica deposition in the low pressure turbine so it is desirable to control the silica content of boiler water. The graph and table for silica concentration in boiler water versus operating pressure to maintain silica in steam to < 20 ppb are given in Annexure-1 & 2. It is monitored in the plant for the following reasons :-

- To maintain silica levels within acceptable limits.
- To warn of in-leakage of contaminants.
- To facilitate the correlation of a water chemistry parameter with plant operating variables, with an aim to optimizing operations.
- To check the accuracy of water chemistry control (for silica), so ensuring that carry-over and deposit rates are kept at acceptable low levels.
- To warn of condensate polisher malfunction.

9.3.6 AMMONIA

Ammonia is monitored to :-

- Check the accuracy of water chemistry control, so ensuring that corrosion rates are kept at acceptable low levels.
- Facilitate the correlation of ammonia with other chemistry parameters (i.e., pH and specific conductivity).

Ammonia content can be approximated from Specific Conductivity curves when analysing high purity water.

9.3.7 CHLORIDE

Its analysis is recommended as a troubleshooting tool and for commissioning purposes. Elevated chloride concentrations in the boiler can lead to corrosive conditions which can damage the water-wall tubes.

Carry over can degrade steam purity,lead to build-up on turbine components and promote corrosion mechanisms. Minimizing this carryover is an additional reason to control the chloride content of boiler water. Chloride is monitored in the plant for the following reasons:-

- Carryover can degrade steam purity, lead to build-up on turbine.
- To warn of in-leakage of contaminants (primarily condenser cooling water ingress).
- To facilitate the correlation with other chemistry parameters (i.e., cation conductivity).
- To check the accuracy of water chemistry control (for chloride), so ensuring that carryover and deposit rates are kept at acceptable low levels.
- To warn of condensate polisher malfunction.
- To warn of make-up demineralizer malfunction.

9.3.8 HYDRAZINE

Hydrazine is monitored in mixed metallurgy feed-water cycles using reducing All Volatile Treatment -AVT(R). It is monitored in the plant for the following reasons:

- To maintain hydrazine levels within acceptable limits.
- To evaluation of other chemistry parameters (i.e., ORP and dissolved oxygen).
- To provide feedback stimulus for automated process control.

9.3.9 IRON AND COPPER

Iron and copper are analysed periodically to measure corrosion product levels in the steam-water cycle. Corrosion product monitoring in the plant is conducted primarily for the following reasons:

- To facilitate the correlation of a water chemistry parameter with plant operating variables.
- To check the accuracy of water chemistry control (such as reducing agent, oxygen, ammonia or pH), so ensuring that corrosion rates are kept at acceptable low levels.

9.3.10 TOTAL ORGANIC CARBON

Total organic carbon (TOC) is monitored in make-up water treatment systems and within the steam-water cycle. TOC is monitored in the plant for one or more of the following reasons:

- To provide additional temporary information for troubleshooting with unusual problems.
- To warn of in-leakage of contaminants.
- To monitor make-up water quality for organic carbon content.

9.3.11 OXIDATION-REDUCTION POTENTIAL (ORP)

Oxidation-reduction potential (ORP) is monitored in units on ATV(R) and OT. The purpose for monitoring ORP is to ensure that feed water is in a reducing condition as needed to minimize copper transport when operating with AVT(R) chemistry and in oxidizing condition as needed to minimize iron transport and FAC when operating with OT in all ferrous feed water units and supercritical units.

10.0 CHEMICAL CONTROL LIMITS OF STEAM-WATER CYCLE FOR NTPC UNITS

10.1 FEED WATER

S.No.	PARAMETER	ONCE THROUGH UNITS-AVT (O)	ONCE THROUGH UNITS-OT
1	pH at 25^0C	9.2- 9.6	8.5- 9.0
2	Cation Conductivity, μS/cm, at 25^0C, max	0.2	0.15
3	Dissolved O2, μg/l, max	1- 10	30- 150
4	Silica, μg/l, max	20	20
5	Total Fe, μg/l, max	10	5
6	Sodium , μg/l, max	2	2
7	ORP at Deaerator inlet, (mv)	-	+100 to +150

NOTE

1. AVT(O)- All Volatile Treatment, Oxidizing- No Hydrazine dosing.
2. OT- Oxygenated Treatment, Oxygen dosing at CPU outlet/ Deaerator outlet.
3. Limit for TOC will be 200 µg/l, max. It will be tested as per requirement for diagnostic & troubleshooting of chemistry problems.
4. Wherever parameter limit is specified as a range, it is suggested to maintain the mid value of the specified range e.g., if the limit is given in the range 9.2 – 9.6, it is preferable to maintain the value at 9.4.

10.2 STEAM

S.No.	PARAMETER	ONCE THROUGH UNITS-AVT (O)	ONCE THROUGH UNITS-OT
1	pH at 25^0C	9.2- 9.6	8.5- 9.0
2	Cation Conductivity, µS/cm, at 25^0C, max	0.2	0.15
3	Silica, µg/l, max	20	20
4	Sodium ,µg/l, max	2	2

NOTE

1. Wherever parameter limit is specified as a range, it is suggested to maintain the mid value of the specified range e.g., if the limit is given in the range 9.2 – 9.6, it is preferable to maintain the value at 9.4.

10.3 CONDENSATE

S.No.	PARAMETER	ONCE THROUGH UNITS-AVT (O)	ONCE THROUGH UNITS-OT
1	pH at 25^0C	9.2- 9.6	8.5- 9.0
2	Cation Conductivity, µS/cm, at 25^0C, max	0.2	0.15
3	Dissolved O2, µ g/l, max	20	20
4	Silica, µg/l, max	20	20
5	Sodium,µg/l, max	2	2

NOTE

1. Wherever parameter limit is specified as a range, it is suggested to maintain the mid value of the specified range e.g., if the limit is given in the range 9.2 – 9.6, it is preferable to maintain the value at 9.4.

11.0 ACTION LEVELS

There are four action levels which have been developed based on the following criteria:

- **Normal Values** - Within Normal target values which are consistent with long term system reliability.

- **Action Level 1-** (2 x Normal target value): **Minor disturbance occurred requiring investigation, diagnosis and optimization.** There is a potential for the accumulation of contaminants and corrosion. Return values to normal levels within 1 week.

- **Action Level 2-** (2 x Action level 1 value): **Serious disturbance in chemical control took place, requires diagnosis and action to eliminate the cause.** The accumulation of impurities and corrosion will occur. Return values to normal levels within 24 hours.

- **Action Level 3-** (> Action level 2 value): **Very serious disturbance took place requiring substantial intervention, such as load reduction, or plant shut-down.** Rapid corrosion can occur. Shutdown the unit within 4 hours.

- **Immediate shutdown-** Rapid boiler tube damage can occur by low boiler water pH (below 7.0). Immediate shutdown is required in an orderly manner. In case of supercritical units when economizer inlet pH drops below 7.0, the unit should be tripped immediately.

If the problem is not corrected within time allotted to each action level, the next higher action level takes effect. In drum boilers one way to respond to an action level condition is to reduce the boiler pressure.

12.0 REVIEW

The Head of Corporate Operation Services will be responsible for reviewing this document on a 3-yearly basis or as necessary.

13.0 REFERENCES

- Cycle chemistry guidelines for fossil plants: All volatile treatment, Revision-1, November- 2002 (TR-1004187).
- Cycle chemistry guidelines for fossil plants: Phosphate continuum and caustic treatment, January- 2004 (TR-1004188).
- Phosphate and NaOH treatments for the steam-water circuits of drum boilers of fossil and combined cycle/HRSG power plants, IAPWS, September-2011.
- Cycle chemistry guidelines for fossil plants: Oxygenated treatment, March- 2005 (TR-1004925).
- Cycle chemistry guidelines for combined cycle/HRSGs, March-2006 (TR-1010438).
- Recommendations of the various Cycle chemistry workshops and CPU training program conducted during 2003-2006 in association with EPRI under cycle chemistry improvement plan.
- Recommendations (dated 22-04-2014 & 28-07-2014) of the committee, formed on 01-04-2014, on review of Operation Directive, Chemical control of the water-steam circuits of drum & once-through type boilers and HRSG, Rev. 0, Dec-2009.

14.0 DISTRIBUTION LIST

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2		GM (O&M)
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4		AGM (EMD)
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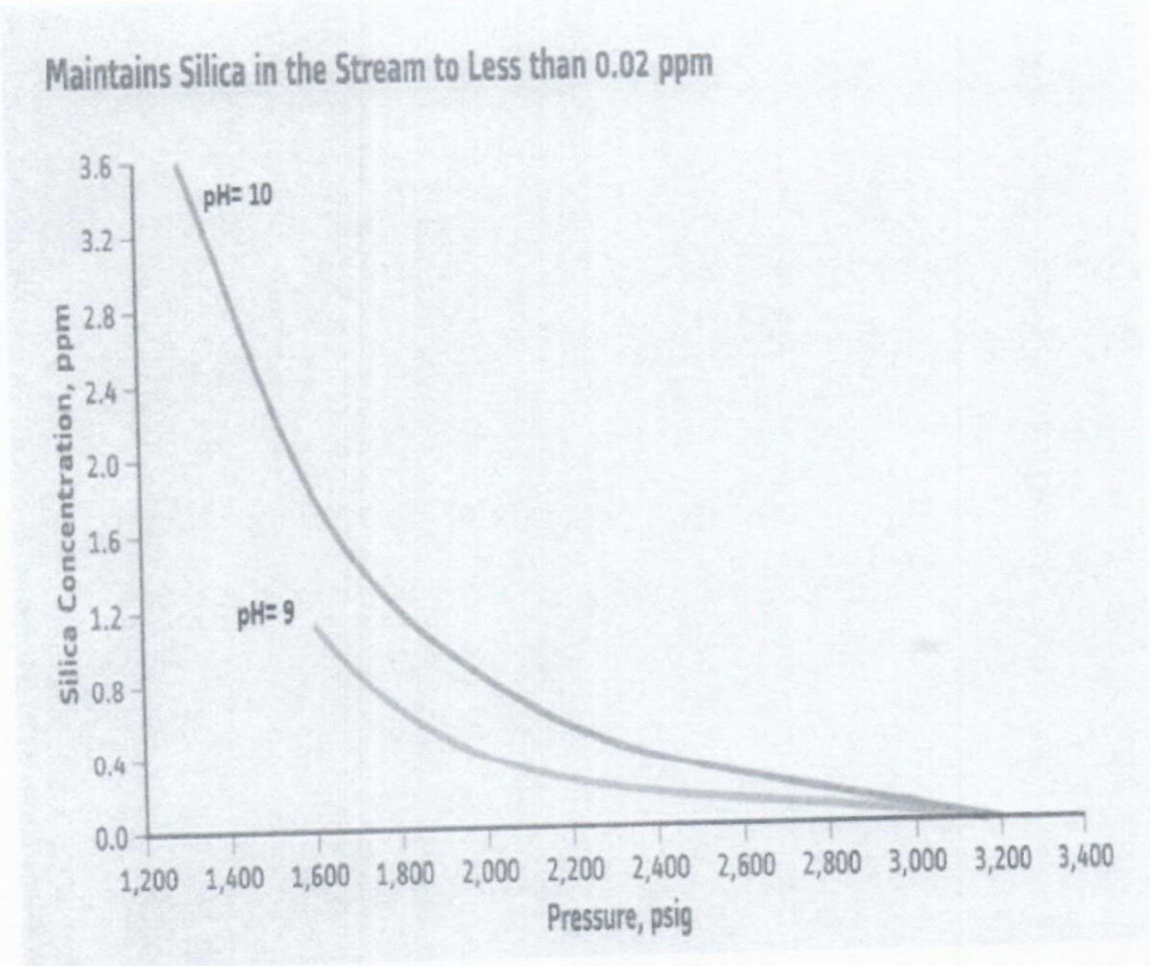
6		AGM (OPERATION)
7		AGM (BMD)
8		AGM (C & I)
9		AGM (TMD)
10		AGM (MTP)

ANNEXURE- 1

SILICA CONCENTRATION IN BOILER WATER VERSUS OPERATING PRESSURE GRAPH AT pH= 9 and 10 TO MAINTAIN < 0.02 PPM SILICA IN STEAM



ANNEXURE- 2

SILICA CONCENTRATION IN BOILER WATER VERSUS OPERATING PRESSURE TABLE FOR pH= 9 to 10 TO MAINTAIN < 0.02 PPM SILICA IN STEAM

S. No.	Drum pressure		Boiler water silica (ppm)					
	psig	Ksc	pH= 9.0	pH= 9.2	pH= 9.4	pH= 9.6	pH= 9.8	pH= 10
1.	1300	91.4	2.400	2.640	2.880	3.120	3.360	3.600
2.	1400	98.4	1.900	2.120	2.340	2.560	2.780	3.000
3.	1500	105.5	1.500	1.670	1.840	2.010	2.180	2.350
4.	1600	112.5	1.100	1.240	1.380	1.520	1.660	1.800
5.	1700	119.5	0.850	0.970	1.090	1.210	1.330	1.450
6.	1800	126.5	0.650	0.760	0.870	0.980	1.090	1.200
7.	1900	133.6	0.500	0.590	0.680	0.770	0.860	0.950
8.	2000	140.6	0.400	0.485	0.570	0.655	0.740	0.825
9.	2100	147.6	0.375	0.435	0.495	0.555	0.615	0.675
10.	2200	154.7	0.250	0.310	0.370	0.430	0.490	0.550
11.	2300	161.7	0.210	0.260	0.310	0.360	0.410	0.460
12.	2400	168.7	0.200	0.240	0.280	0.320	0.360	0.400
13.	2500	175.8	0.175	0.210	0.245	0.280	0.315	0.350
14.	2600	182.8	0.150	0.180	0.210	0.240	0.270	0.300
15.	2700	189.8	0.110	0.130	0.150	0.170	0.190	0.210
16.	2800	196.8	0.090	0.110	0.130	0.150	0.170	0.190
17.	2900	203.9	0.075	0.090	0.105	0.120	0.135	0.150
18.	3000	210.9	0.050	0.060	0.070	0.080	0.090	0.100