Millennium Challenge Account – Mongolia

WILLIAMS BUILDING COMPANY INC and GATEWAY DEVELOPMENT INTERNATIONAL

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1.1 Background

Ulaanbaatar (UB) has been experiencing high air pollution concentrations, particularly during the winter months. The degraded air quality has had a severe impact on human health for the people living in Ulaanbaatar. Following the drastic expansion of Ger areas surrounding the traditional city center, air pollution levels have and continue to steadily increase.

2.1 Purpose

In efforts to counteract air pollution and move forward in initiating a solution for cleaner air; up to 50 "heat only boiler's" (HOB's) will be selected, both publicly and privately owned, , to be replaced with new more efficient HOBs. In order to determine which HOBs to replace, emissions and (thermal and combustion) efficiency will be monitored and tested. These tests are solely for the purpose of relative ranking to establish the priority for replacement. Following these tests, the panel of HOBs will be ranked according to their operating performance as well as other factors, such as age, type, and location.

3.1 Testing Instruments

Ref. Name	Instrument	Qty	Use
A	Testo 350XL	1	Emissions- CO, CO_2, NO_2, SO_2; Combustion Efficiency- % by volume
B	Portaflow PT500	1	Energy Flow Metering- HWS & HWR Temperatures, Fluid Flow rate, & BTU/Hr
C	TSI Dust Trak 8533 w/diluter and air blower	1	Particulate Matter Counter- PM_{10}, $PM_{2.5}$
D	Infrared Thermometer	1	Temperature- Degrees (C & F)
E	Digital Scale	1	Weigh Solid Fuel Prior to Burning (0-20Kg)

3.2 Tools

A number of tools will be required to set up tests. Thus, the project testing team will assemble a tool kit including the equipment listed below.

Tool box to include:

1) Battery powered drill for making hole in combustion vent. - {1 w/extra battery}
2) Caps for covering holes when test is complete. - {100}
3) Tube of high temperature RTV for patching flues if needed. - {2}
4) Drill bits (1/2" for flue gas probe)-{5 for steel flue pipe & 2 for masonry, plus full set}
5) File for removing corrosion, etc. to prepare strap on sensor sites (12 inch Mill Bastard file). - {1}
6) Plumbers tape (sanding tape) for removing corrosion, etc. to prepare strap on sensor sites. - {1}
7) Thermal contact gel.
8) Pipe insulation, foam, two foot lengths, at each pipe size from 2 inch and up to 8 inches, for covering the strap on sensors assuring good temp readings - {2 at each size}
9) Wire ties for strapping on the insulation: 20" & 10"- {100 at each size.}
10) Coil of steel wire for various purposes. {2 spools of 50 feet}
11) General tools: Linesman's pliers, Needle nose, Channel locks, Vise grips, Socket set with drivers and extensions, Assorted screwdrivers, Hammer, small pry-bar, flashlight, wire brush, scraper and English/metric tape measure.
12) Duct tape and electrical tape

13) Gloves appropriate for handling hot boiler parts - {1}
14) Mechanics rags - {20}
15) Stop watch
16) Clip Board
17) Blank forms – {one set per HOB}

4.1 Types of Tests

4.1.1 Emissions Test

Measure emissions output by sampling flue gas. Emissions gas constituents (CO, CO_2, NO_2, SO_2) shall be measured and monitored inside the HOB flue stack continuously throughout a controlled time span four hours in duration.

4.1.2 HOB Combustion Efficiency Test

Measure boiler combustion efficiency by sampling flue gas. Test shall be conducted at 100% ± 2% of the maximum input of the boiler. If a maximum input value is not identified for the boiler then the boiler operator shall be directed to fire the boiler with coal as is normally done to supply the heat required by the building(s). The test will yield an efficiency related to the fuel combustion process within the boiler only; see boiler energy efficiency testing below.

4.1.3 HOB Energy Efficiency Test

Measure the HOB thermal energy output. Test shall consist of an ultrasonic system water flow test conducted at the HWS (Hot Water Supply Pipe) output of the boiler and temperature test points conducted at both the HWS & HWR (Hot Water Return) pipes exiting and entering the boiler. Results shall yield an accounting of energy output of the boiler. Small pipes shall be avoided as it becomes difficult to test.

Note: *a redundant heat delivery measurement may be taken on the consumer side of the circuit (after the heat exchanger). In market economies, the heat rate is always measured at this point because the consumer gets billed for this heat rate (the consumer water circuit includes flow rate and temperature measurements). However, this is not how billing takes place in Mongolia and there are very few HOBs that have a heat exchanger included. Hence, if possible given time and equipment constraints, such measurements will be taken.*

Total boiler efficiency can then be calculated based on thermal output versus coal input. This will show a lower efficiency than that provided by the combustion efficiency test since the heat loss of the boiler to the boiler room will be accounted for along with other boiler efficiency losses

Note: *the heat released by combustion relative to the maximum possible heat is defined as the release based on the fuel rate times the heating value. The factors that reduce the efficiency are (a) unburned fuel in the ash (b) CO and other partially oxidized components in the flue gas. Therefore, unburned fuel in the ash can be expected to show significant variability in the unburned fuel content of the ash. While beyond the scope work and not needed to accomplish the relative ranking requested in the scope of work, and if we can get a sample of ash that is representative of the measurement time period without adversely* *affecting our time and equipment constraints, a sample will be taken and analyzed for carbon content at either MUST or the Mining Institute.*

4.1.4 Surface Temperature Tests

Infrared temperature test points will be conducted for the surface temperature of the boiler. Measure surface temperature of the boiler at a minimum of four points, on each of the four sides of the boiler (total=16). Location should be made at the approximate center of each quadrant of the boiler wall. Though this test will not be used for efficiency calculations it will point out that the boilers are poorly insulated and can then be used as a comparator to the newer boilers. Also use this test device to test the HWR & HWS pipe temps to establish that steady state combustion has been reached (see 5.1 below).

4.1.5 Coal Input Measurement Test

Measure the HOB coal input during the test. Using the digital scale measure the coal that is fed into the boiler during the test.

5.1 Procedures

1. Each HOB is to be tested using each device listed above. Prior to following test procedures below, testing operators will need to read all relevant equipment manuals to fully understand functions and operation of each instrument. However, as the team progresses into the testing phase, it may become obvious that a redundancy exists due to the several similar boilers in one HOB Building. If the boilers are of the same “name brand” and in the same location, capacity, type of coal, and control system then only one boiler need be tested to represent all that are similar. This practice is acceptable and will help avoid redundancy.

2. Tests must be recorded by either equipment data logging or manually completed test data forms. See Diagram 1 in Appendix-2 for locations of testing instruments.

Complete **Table 1** prior to each test (see Appendix-2).

PRELIMINARY DATA (Table 1.1, see full sheet at Appendix-2)								
Building Name	**Location**	**Boiler Manufacturer**	**Boiler Model**	**Boiler Capacity [1]**	**Date (M/D/YR)**	**Tests Performed [2]**	**Start Time of Test**	**End Time of Test**
						A		
						B		
						C		
						D		
						E		

[1] Indicate whether value is input or output; from boiler ID plate or manufacturer. If not available write NA.
[2] A) Emissions, B) System Efficiencies, C) Particulate Matter, D) Surface Temperature, E) Coal Input

3. Observe combustion upon arrival and establish steady state combustion as much as possible. Direct the boiler operator to stoke the boiler normally to maintain operating conditions. If the boiler is coming up to temperature do not start the tests until the HWS temperature exiting and HWR returning to the boiler have reached a steady state condition (+/- 5 Deg. F). Use the infrared temperature test device to observe this. It is the tester’s and operator’s responsibility to judge if the combustion is in the normal range; use the infrared surface temperature tester to observe HWS & HWR pipe temperatures.

5.1.1 & 2 HOB Emissions & Combustion Efficiency Test Procedure
*(*Procedure written for Testo 350)*
(*Note: The measurement program: "solid fuel measurement" must be activated prior to test.)

STEP 1: Ensure all system components/necessary probes & sensors are properly connected.

STEP 2: Insert flue gas probe (with probe pre-filter) into the flue gas pipe. Align the probe by turning it as required. The tip of the probe must be in the center of the flue gas flow (area of the highest flue gas temperature).

STEP 3: Set measurement run time criterion to 4 hours.

STEP 4: Start pump.

STEP 5: Observe measurement values until the $O_2 < 20\%$, in order for values to be calculated.

STEP 6: Start program:"solid fuel measurement".

STEP 7: After test has finished, deactivate the measurement program, rinse and clean flue gas probe.

5.1.3 HOB Energy Efficiency Test Procedure

*(*Procedure written for Portaflow PT500)*

(*Note: For steps 1 through 6, refer to Figure 1.)

STEP 1: See Diagram 1 for location of test.

STEP 2: Ensure that the proposed location satisfies the distance requirements (straight length of pipe upstream of the transducers of at least 20 times the pipe diameter and 10 times the pipe diameter on the downstream side) otherwise the resulting accuracy of the flow readings may be affected.

STEP 3: Prepare the pipe by degreasing it and removing any loose material or flaking paint in order to obtain the best possible surface.

STEP 4: Slide the separation bar (D) into the front of the left hand guide rail, align the front edge of the guide rail with '0' on the ruler scale (E) and secure it in place by tightening the thumbscrew (C).

STEP 5: Slide the other end of the separation bar into the front of the right hand guide rail, align the front edge of the guide rail to the required separation distance (obtained from the Portaflow instrument) on the ruler (F), then secure it in place by tightening the thumbscrew.

STEP 6: On each guide rail, attach one end of a securing chain to a hook on the tensioning bar (B), wrap the chain around the pipe (G) and then attach it to the hook on the other end of the tensioning bar whilst keeping the chain as tight as possible.

STEP 7: Rotate the complete guide rail assembly so that it is approximately 45° with respect to the top of the pipe. Then tighten the chain by turning the tensioning thumb-wheel (A) on each guide block until the assembly is securely attached to the pipe.

Figure 1 (guide rail attachment)

A: Tensioning thumb-wheel.
B: Tension bar.
C: Separation bar securing screw.
D: Separation bar.
E: Ruler scale (0).
F: Set Separation distance.
G: Securing chain.

(*Note: For steps 7 through 13, refer to Figure 2.)

STEP 7: Slide the transducer cover plate (A) fully towards the outside of the guide assembly to allow sufficient access to fit the transducer.

STEP 8: Clean the face of the transducer, removing all traces of dirt and grease.

STEP 9: Apply a 1/8" (3mm) bead of ultrasonic couplant along the centre length of the transducer (E).

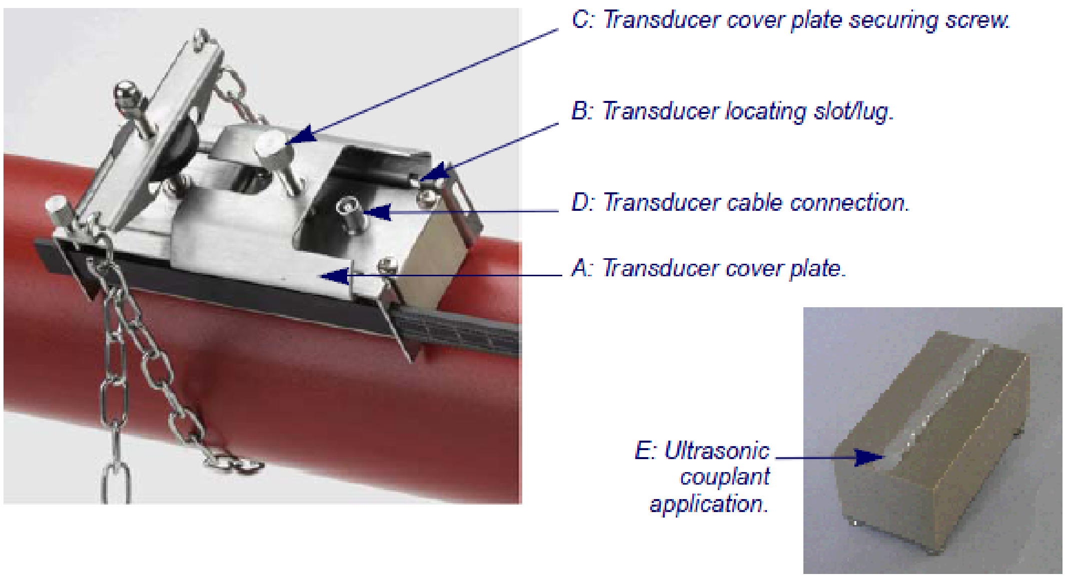
STEP 10: Fit the transducer into the guide block – ensuring the lugs on the sides of the transducer are correctly located into the slots on the sides of the guide block (B).

STEP 11: Slide the transducer cover plate (A) over the top of the transducer and tighten the thumbscrew (C) finger tight to secure the transducer in place. When securing the cover plate take care to leave sufficient room around the transducer connector (D) to connect the cable.

STEP 12: Repeat steps 8 through 12 for the second transducer.

STEP 13: Connect the transducers to the Portaflow instrument using the coaxial cables provided. The RED cable must be connected to the upstream transducer and the BLUE cable to the downstream transducer.

Figure 2 (guide rail attachment)



STEP 14: Begin testing.

5.1.4 Particulate Matter Test Procedure

*(*Procedure written for DustTrak 8533)*
*(*Note-It is assumed that DustTrak 8533 is operating with a gas chiller and diluter.)*

STEP 1: See Diagram 1 for location of test.

STEP 2: Use drill to create hole in boiler exhaust stack.

STEP 3: Insert probe into boiler exhaust stack.

STEP 4: Calibrate DustTrak 8533.

STEP 5: Set test duration of test to 4 hours at 15 minute reading intervals.

STEP 6: Start test.

5.1.5 Boiler Surface Temperature Test Procedure

STEP 1: Clean location on boiler where temperature reading is being conducted (remove flakey paint, rust, etc.). Test at four locations per each of four boiler sides, total=16. Test location should be center of each quadrant as viewed in elevation.

STEP 2: Aim infrared thermometer at selected area and take reading for five seconds.

STEP 3: Record data.

5.1.6 Coal Input Measurement Test Procedure

STEP 1: Once boiler is at steady state combustion (see 5.1-3) and the testing has begun (four hour duration) weigh and record all coal being input to the boiler.

STEP 2: Observe visual condition of coal, take and record multiple photographs.

STEP 3: Request and record the type of coal being used (Baga nuur, Nalaikh, or Shariingol)

6.1 Data & Processing

*(*Complete blank data sheets found in **Appendix 2** in case of electronic data failure.)*

At 15 minute intervals data is to be printed, from the onboard data logger, for physical records. At completion time of test (4 hours), data is to be electronically stored on testing device for extraction and transfer to a computer, at a later time. For equipment that lacks electronic data logging, such as infrared thermometer, manually record.

The following data shall be recorded:

Emissions Testing:
Time (M/D/Y; Hr:Min:Sec)
Weight of solid fuel (Lbs)
Flue gas: O_2, CO, CO_2 (%),NO_2, SO_2
Temperature of flue gas (degrees F)
Temperature of ambient air (degrees F)

System Efficiency Testing:
Time (M/D/Y; Hr:Min:Sec)
Weight of solid fuel (Lbs)
Flow rate of water in pipe (Ft/Sec)
Temperature of HWS and HWR

Particulate Matter Testing:
Time (M/D/Y; Hr:Min:Sec)
PM10
PM2.5

Surface Temperature Testing:
Time (M/D/Y; Hr:Min:Sec)
Temperature (Degrees Celcius)

Back-Up Data

As soon as possible, back up electronic data to an external hard drive for safe keeping.

7.1 Health and Safety

7.1.1 Safety Precautions

Exercise caution at all times and observe the working environment carefully before entering and proceeding with the test work. Always communicate with boiler operator prior to any action. Always work in teams of two; pay especially close attention if using a ladder or step stool. Exercise extreme caution prior to handling electrical wires, operating valves, and drilling holes.
Test duration is four hours, step outside minimum once per hour to observe conditions. Bring water and food as these cannot be obtained on site.

7.1.2 Safety Clothing

Clothes should reflect the hazardous and dirty conditions of the test field. Do not leave any exposed skin on arms or legs to protect from burns due to hot flue particulate/gasses or hot piping. A disposable jump suit would be sufficient.

Eyes are to be protected at all times. Non-tinted, polycarbonate safety goggles are to be worn at all times during testing.

Hands are to be protected by thick construction gloves that are able to handle hot materials. These are to be worn when handling items near hot flue gasses or handling hot piping. Use at your own discretion when operating test equipment.

Feet are to be protected by thick soled heavy duty boots (steel toe recommended).

7.1.3 Respiratory Safety

Protect from particulate inhalation by using fine particulate dust mask.

7.1.4 Safe Tool Use

Observe tool manufacturers safety precautions for all tool use.

Appendix 1: Tables and Diagrams

Table 1: Preliminary Data

PRELIMINARY DATA								
Building Name	**Location**	**Boiler Manufacturer**	**Boiler Model**	**Boiler Capacity [1]**	**Date (M/D/YR)**	**Tests Performed [2]**	**Start Time of Test**	**End Time of Test**

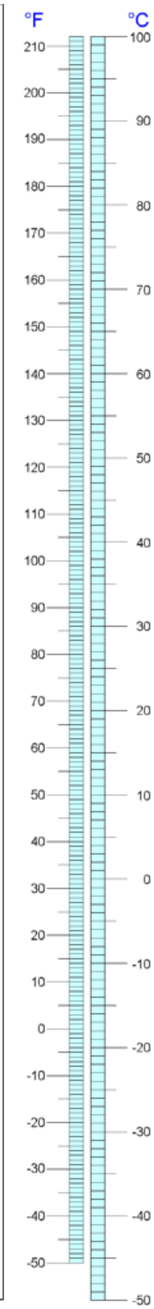
Table 2: Particulate Matter Data

PARTICULATE MATTER DATA					
I.D.	**LOCATION**	**DESIGN HEAT INPUT (MMBtu/hr)**	**FUEL BURNED**	**PM10 EMISSIONS (lb/MMBtu)**	**PM 2.5 EMISSIONS (lb/MMBtu)**
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					

Table 3: Temperature Conversion

TEMPERATURE CONVERSION TABLE

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
-40	-40	-10	14	20	68	50	122	80	176	110	230	140	284
-39	-38.2	-9	15.8	21	69.8	51	123.8	81	177.8	111	231.8	141	285.8
-38	-36.4	-8	17.6	22	71.6	52	125.6	82	179.6	112	233.6	142	287.6
-37	-34.6	-7	19.4	23	73.4	53	127.4	83	181.4	113	235.4	143	289.4
-36	-32.8	-6	21.2	24	75.2	54	129.2	84	183.2	114	237.2	144	291.2
-35	-31	-5	23	25	77	55	131	85	185	115	239	145	293
-34	29.2	-4	24.8	26	78.8	56	132.8	86	186.8	116	240.8	146	294.8
-33	-27.4	-3	26.6	27	80.6	57	134.6	87	188.6	117	242.6	147	296.6
-32	-25.6	-2	28.4	28	82.4	58	136.4	88	190.4	118	244.4	148	298.4
-31	-23.8	-1	30.2	29	84.2	59	138.2	89	192.2	119	246.2	149	300.2
-30	-22	0	32	30	86	60	140	90	194	120	248	150	302
-29	-20.2	1	33.8	31	87.8	61	141.8	91	195.8	121	249.8	151	303.8
-28	-18.4	2	35.6	32	89.6	62	143.6	92	197.6	122	251.6	152	305.6
-27	-16.6	3	37.4	33	91.4	63	145.4	93	199.4	123	253.4	153	307.4
-26	-14.8	4	39.2	34	93.2	64	147.2	94	201.2	124	255.2	154	309.2
-25	-13	5	41	35	95	65	149	95	203	125	257	155	311
-24	-11.2	6	42.8	36	96.8	66	150.8	96	204.8	126	258.8	156	312.8
-23	-9.4	7	44.6	37	98.6	67	152.6	97	206.6	127	260.6	157	314.6
-22	-7.6	8	46.4	38	100.4	68	154.4	98	208.4	128	262.4	158	316.4
-21	-5.8	9	48.2	39	102.2	69	156.2	99	210.2	129	264.2	159	318.2
-20	-4	10	50	40	104	70	158	100	212	130	266	160	320
-19	-2.2	11	51.8	41	105.8	71	159.8	101	213.8	131	267.8	161	321.8
-18	-0.4	12	53.6	42	107.6	72	161.6	102	215.6	132	269.6	162	323.6
-17	1.4	13	55.4	43	109.4	73	163.4	103	217.4	133	271.4	163	325.4
-16	3.2	14	57.2	44	111.2	74	165.2	104	219.2	134	273.2	164	327.2
-15	5	15	59	45	113	75	167	105	221	135	275	165	329
-14	6.8	16	60.8	46	114.8	76	168.8	106	222.8	136	276.8	166	330.8
-13	8.6	17	62.6	47	116.6	77	170.6	107	224.6	137	278.6	167	332.6
-12	10.4	18	64.4	48	118.4	78	172.4	108	226.4	138	280.4	168	334.4
-11	12.2	19	66.2	49	120.2	79	174.2	109	228.2	139	282.2	169	336.2



˚Celsius = 5/9(˚F-32)
˚Fahrenheit = (9/5˚C)+32

Table 4: Units and Conversions

Multiply I-P	By	To Obtain SI
acre (43,560 ft^2)	0.4047	ha
	4046.873	m^2
atmosphere (standard)	*101.325	kPa
bar	*100	kPa
barrel (42 U.S. gal, petroleum)	159.0	L
	0.1580987	m^3
Btu (International Table)	1055.056	J
Btu (thermochemical)	1054.350	J
Btu/ft^2 (International Table)	11,356.53	J/m^2
Btu/ft^3 (International Table)	37,258.951	J/m^3
Btu/gal	278,717.1765	J/m^3
Btu·ft/h·ft^2·°F	1.730735	W/(m·K)
Btu·in/h·ft^2·°F (thermal conductivity k)	0.1442279	W/(m·K)
Btu/h	0.2930711	W
Btu/h·ft^2	3.154591	W/m^2
Btu/h·ft^2·°F (overall heat transfer coefficient U)	5.678263	W/(m^2·K)
Btu/lb	*2.326	kJ/kg
Btu/lb·°F (specific heat c_p)	*4.1868	kJ/(kg·K)
bushel (dry, U.S.)	0.0352394	m^3
calorie (thermochemical)	*4.184	J
centipoise (dynamic viscosity μ)	*1.00	mPa·s
centistokes (kinematic viscosity ν)	*1.00	mm^2/s
clo	0.155	(m^2·K)/W
dyne	1.0×10^{-5}	N
dyne/cm^2	*0.100	Pa
EDR hot water (150 Btu/h)	43.9606	W
EDR steam (240 Btu/h)	70.33706	W
EER	0.293	COP
ft	*0.3048	m
	*304.8	mm
ft/min, fpm	*0.00508	m/s
ft/s, fps	*0.3048	m/s
ft of water	2989	Pa
ft of water per 100 ft pipe	98.1	Pa/m
ft^2	0.092903	m^2
ft^2·h·°F/Btu (thermal resistance R)	0.176110	(m^2·K)/W
ft^2/s (kinematic viscosity ν)	92,900	mm^2/s
ft^3	28.316846	L
	0.02832	m^3
ft^3/min, cfm	0.471947	L/s
ft^3/s, cfs	28.316845	L/s
ft·lb_f (torque or moment)	1.355818	N·m
ft·lb_f (work)	1.356	J
ft·lb_f/lb (specific energy)	2.99	J/kg
ft·lb_f/min (power)	0.0226	W
footcandle	10.76391	lx
gallon (U.S., *231 in^3)	3.785412	L
gph	1.05	mL/s
gpm	0.0631	L/s
gpm/ft^2	0.6791	L/(s·m^2)
gpm/ton refrigeration	0.0179	mL/J
grain (1/7000 lb)	0.0648	g
gr/gal	17.1	g/m^3
gr/lb	0.143	g/kg
horsepower (boiler) (33,470 Btu/h)	9.81	kW
horsepower (550 ft·lb_f/s)	0.7457	kW
inch	*25.4	mm
in. of mercury (60°F)	3.37	kPa
in. of water (60°F)	249	Pa
in/100 ft, thermal expansion	0.833	mm/m
in·lb_f (torque or moment)	113	mN·m
in^2	645.16	mm^2
in^3 (volume)	16.3874	mL
in^3/min (SCIM)	0.273117	mL/s
in^3 (section modulus)	16,387	mm^3
in^4 (section moment)	416,231	mm^4
kWh	*3.60	MJ
kW/1000 cfm	2.118880	kJ/m^3
kilopond (kg force)	9.81	N
kip (1000 lb_f)	4.45	kN
kip/in^2 (ksi)	6.895	MPa
litre	*0.001	m^3
met	58.15	W/m^2
micron (μm) of mercury (60°F)	133	mPa
mile	1.609	km
mile, nautical	*1.852	km
mile per hour (mph)	1.609344	km/h
	0.447	m/s
millibar	*0.100	kPa
mm of mercury (60°F)	0.133	kPa
mm of water (60°F)	9.80	Pa
ounce (mass, avoirdupois)	28.35	g
ounce (force or thrust)	0.278	N
ounce (liquid, U.S.)	29.6	mL
ounce inch (torque, moment)	7.06	mN·m
ounce (avoirdupois) per gallon	7.489152	kg/m^3
perm (permeance at 32°F)	5.72135×10^{-11}	kg/(Pa·s·m^2)
perm inch (permeability at 32°F)	1.45362×10^{-12}	kg/(Pa·s·m)
pint (liquid, U.S.)	4.73176×10^{-4}	m^3
pound		
lb (avoirdupois, mass)	0.453592	kg
	453.592	g
lb_f (force or thrust)	4.448222	N
lb_f/ft (uniform load)	14.59390	N/m
lb/ft·h (dynamic viscosity μ)	0.4134	mPa·s
lb/ft·s (dynamic viscosity μ)	1490	mPa·s
lb_f·s/ft^2 (dynamic viscosity μ)	47.88026	Pa·s
lb/h	0.000126	kg/s
lb/min	0.007559	kg/s
lb/h [steam at 212°F (100°C)]	0.2843	kW
lb_f/ft^2	47.9	Pa
lb/ft^2	4.88	kg/m^2
lb/ft^3 (density, ρ)	16.0	kg/m^3
lb/gallon	120	kg/m^3
ppm (by mass)	*1.00	mg/kg
psi	6.895	kPa
quad (10^{15} Btu)	1.055	EJ
quart (liquid, U.S.)	0.9463	L
square (100 ft^2)	9.29	m^2
tablespoon (approximately)	15	mL
teaspoon (approximately)	5	mL
therm (U.S.)	105.5	MJ
ton, long (2240 lb)	1.016	Mg
ton, short (2000 lb)	0.907	Mg; t (tonne)
ton, refrigeration (12,000 Btu/h)	3.517	kW
torr (1 mm Hg at 0°C)	133	Pa
watt per square foot	10.76	W/m^2
yd	*0.9144	m
yd^2	0.8361	m^2
yd^3	0.7646	m^3
To Obtain I-P	**By**	**Divide SI**

Table 5: Conversion Factors

Pressure psi	in. of water (60°F)	in. Hg (32°F)	atmosphere	mm Hg (32°F)	bar	kgf/cm^2	pascal
1	= 27.708	= 2.0360	= 0.068046	= 51.715	= 0.068948	= 0.07030696	= 6894.8
0.036091	1	0.073483	2.4559×10^{-3}	1.8665	2.4884×10^{-3}	2.537×10^{-3}	248.84
0.491154	13.609	1	0.033421	25.400	0.033864	0.034532	3386.4
14.6960	407.19	29.921	1	760.0	1.01325*	1.03323	1.01325×10^{5}*
0.0193368	0.53578	0.03937	1.31579×10^{-3}	1	1.3332×10^{-3}	1.3595×10^{-3}	133.32
14.5038	401.86	29.530	0.98692	750.062	1	1.01972*	10^{5}*
14.223	394.1	28.959	0.96784	735.559	0.980665*	1	9.80665×10^{4}*
1.45038×10^{-4}	4.0186×10^{-3}	2.953×10^{-4}	9.8692×10^{-6}	7.50×10^{-3}	10^{-5}*	1.01972×10^{-5}*	1

Mass	lb (avoir.)	grain	ounce (avoir.)	kg
	1	= 7000*	= 16*	= 0.45359
	1.4286×10^{-4}	1	2.2857×10^{-3}	6.4800×10^{-5}
	0.06250	437.5*	1	0.028350
	2.20462	1.5432×10^{4}	35.274	1

Volume	cubic inch	cubic foot	gallon	litre	cubic metre (m^3)
	1	= 5.787×10^{-4}	= 4.329×10^{-3}	= 0.0163871	= 1.63871×10^{-5}
	1728*	1	7.48052	28.317	0.028317
	231.0*	0.13368	1	3.7854	0.0037854
	61.02374	0.035315	0.264173	1	0.001*
	6.102374×10^{4}	35.315	264.173	1000*	1

Energy	Btu	ft·lb$_f$	calorie (cal)	joule (J) = watt-second (W·s)	watt-hour (W·h)
Note: MBtu, which is 1000 Btu, is confusing and is not used in the Handbook.	1	= 778.17	= 251.9958	= 1055.056	= 0.293071
	1.2851×10^{-3}	1	0.32383	1.355818	3.76616×10^{-4}
	3.9683×10^{-3}	3.08803	1	4.1868*	1.163×10^{-3}*
	9.4782×10^{-4}	0.73756	0.23885	1	2.7778×10^{-4}
	3.41214	2655.22	859.85	3600*	1

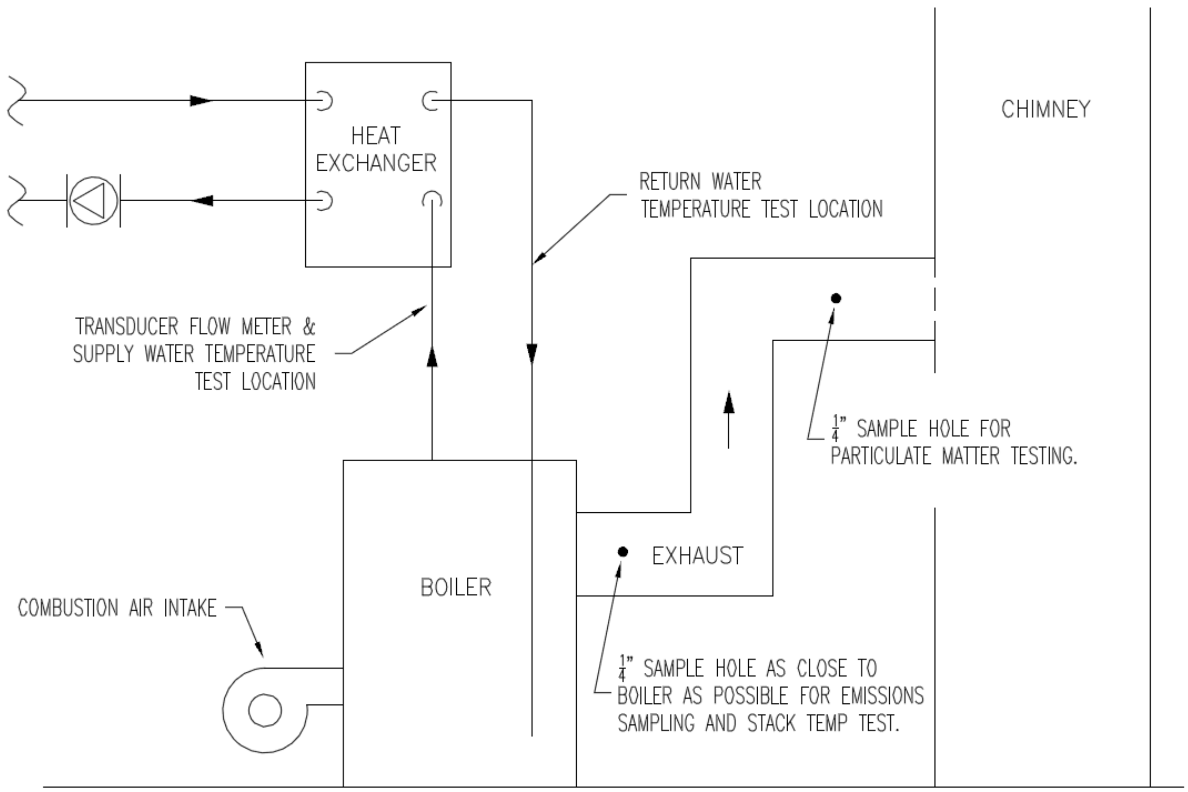
Density	lb/ft^3	lb/gal	g/cm^3	kg/m^3
	1	= 0.133680	= 0.016018	= 16.018463
	7.48055	1	0.119827	119.827
	62.4280	8.34538	1	1000*
	0.0624280	0.008345	0.001*	1

Specific Volume	ft^3/lb	gal/lb	cm^3/g	m^3/kg
	1	= 7.48055	= 62.4280	= 0.0624280
	0.133680	1	8.34538	0.008345
	0.016018	0.119827	1	0.001*
	16.018463	119.827	1000*	1

Viscosity (absolute)	1 poise = 1 dyne-sec/cm^2 = 0.1 Pa·s = 1 g/(cm·s)				
	poise	lb$_f$·s/ft^2	lb$_f$·h/ft^2	kg/(m·s) = N·s/m^2	lb$_m$/ft·s
	1	= 2.0885×10^{-3}	= 5.8014×10^{-7}	= 0.1*	= 0.0671955
	478.8026	1	2.7778×10^{-4}	47.88026	32.17405
	1.72369×10^{6}	3600*	1	1.72369×10^{5}	1.15827×10^{5}
	10*	0.020885	5.8014×10^{-6}	1	0.0671955
	14.8819	0.031081	8.6336×10^{-6}	1.4882	1

Temperature Scale		Temperature K	°C	°R	°F		Temperature Interval K	°C	°R	°F
Kelvin	x K =	x	$x - 273.15$	$1.8x$	$1.8x - 459.67$	1 K =	1	1	9/5 = 1.8	9/5 = 1.8
Celsius	x°C =	$x + 273.15$	x	$1.8x + 491.67$	$1.8x + 32$	1°C =	1	1	9/5 = 1.8	9/5 = 1.8
Rankine	x°R =	$x/1.8$	$(x - 491.67)/1.8$	x	$x - 459.67$	1°R =	5/9	5/9	1	1
Fahrenheit	x°F =	$(x + 459.67)/1.8$	$(x - 32)/1.8$	$x + 459.67$	x	1°F =	5/9	5/9	1	1

Diagram 1: Testing Locations



INVESTMENT DEPARTMENT OF THE CAPITAL CITY

EXPERIMENT AND RESEARCH CENTER FOR BOILER OF THE MUST

HOB TEST REPORT FOR KHOYULAA KHUU AT THE KHAN-UUL DISTRICT

Date:	**Developed by:** **Experiment and research center for boiler of the MUST**	**Tseyen-Oidov. O**
Date:	**Approved by:** **Investment Department of the Capital City**	**Zayamandakh. O**
Date:	**Accepted by:** **EEP, MCA-M**	**Mangal. S**

2012

1. Executive summary

Emission test of the newly installed HOB was conducted through "The Research and Experiment Center for Boilers" regarding contract between IDCC and the center.

2. Purpose

The objectives of the testing are:

(i) to verify proper functioning of the equipment/system after installation; and

(ii) to verify that the performance of the installed equipment/systems meet with the specified performance specification.

(iii) to capture and record performance data of the whole installation as the baseline for future operation and maintenance.

3. General information

- **Testing team**

No	***Position***	***Name***	***Profession***
1	Testing team leader	J. Tseyen-Oidov	Thermal engineer
2	Testing team member	B. Battur	Thermal engineer
3	Testing team member	Sh. Jambaltsanjid	Thermal engineer
4	Testing team member	A. Tumenbayar	Thermal engineer
5	Testing team member	B. Ganzorig	HVAC engineer

- Site information

HOB emission and efficiency test was conducted at the Khoyulaa khuu at the Khan Uul district. Old HP18-54 HOB was replaced with new DZL-0.7 HOB at the site by the Khurd Co., Ltd.

- Testing equipment

Following described equipments were used in the testing.

Num	Equipment name or mark	Measurement description	Calibration due date
1	Testo 350	Emissions- CO, CO2, NOx, SOx, O2 Combustion Efficiency- % by volume	December 2012
2	TSI Dust Trak 8533 w/diluter and air blower	Particulate Matter Counter- PM10, PM2.5	Calibrated before every test
3	Portaflow PT500	Energy Flow Metering- HWS & HWR Temperatures, Fluid Flow rate, & BTU/Hr	July 2013
4	Gravimetric filter	Particulate Matter TSP	Calibrated before every test
5	Testo 405 anemometer	Air speed to determine combustion air	August 2013
6	Electric scale	To weigh coal to be fed	July 2013
7	Infrared thermometer	To determine boiler surface temperature (Boiler tightness)	May 2014

- Testing procedure

Testing was conducted on 18.09.2012

Outdoor temperature during testing was approximately 10.5 ^{o}C

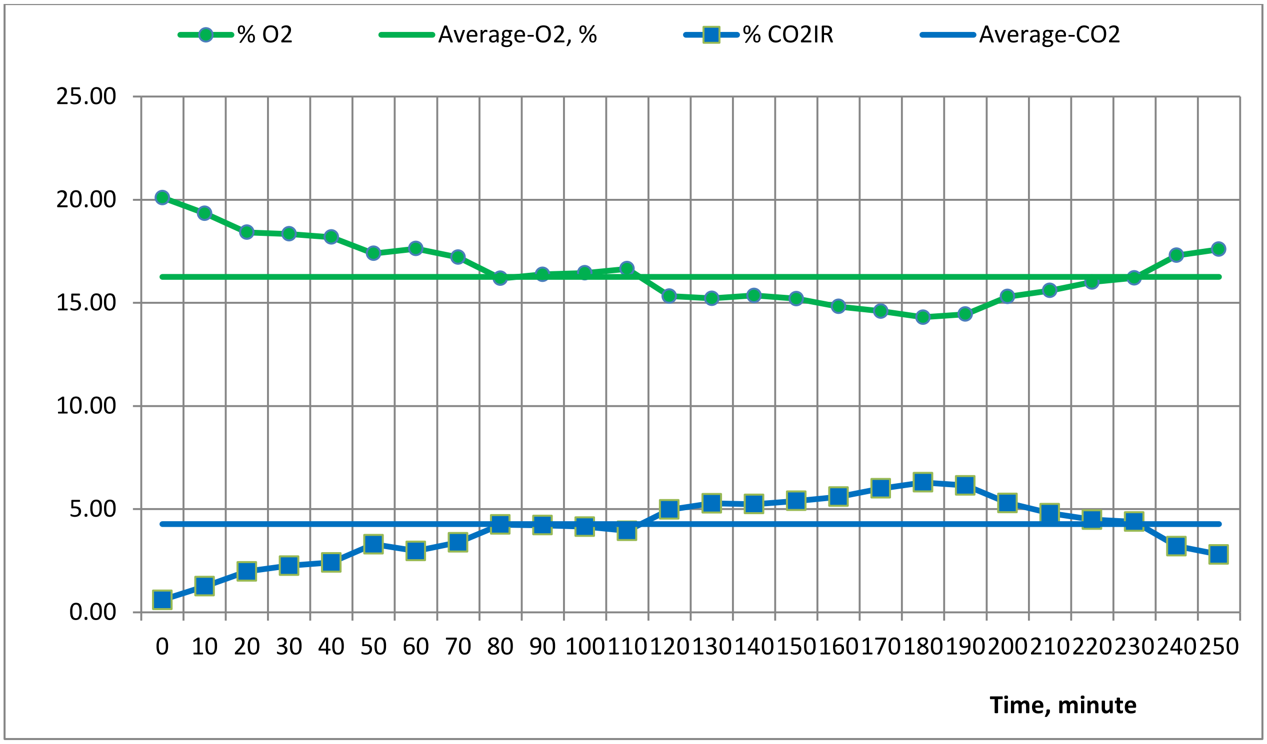
Boilers were fired for 4 hours starting 22:30 completing at 02:30 am. The DZL-0.7 boilers are mechanically fed rate of 100 kg per hour and 105.5 kg per hour. The ashes were removed continuously. DZL- 1.4 boiler is the mechanic boiler that removes ash continuously and feeds coal continuously. Boilers were tested at the same time with two sets of equipment. The scrubber was operated throughout testing procedure. Weather was warm the day test conducted. So the boilers were not fired at full their full capacity. Winter the boilers capacity will increase due to cold temperature. Coal consumption will increase related to capacity but emission concentration will not be changed. Capacity does not reflect to boiler emission directly.

4. Test result

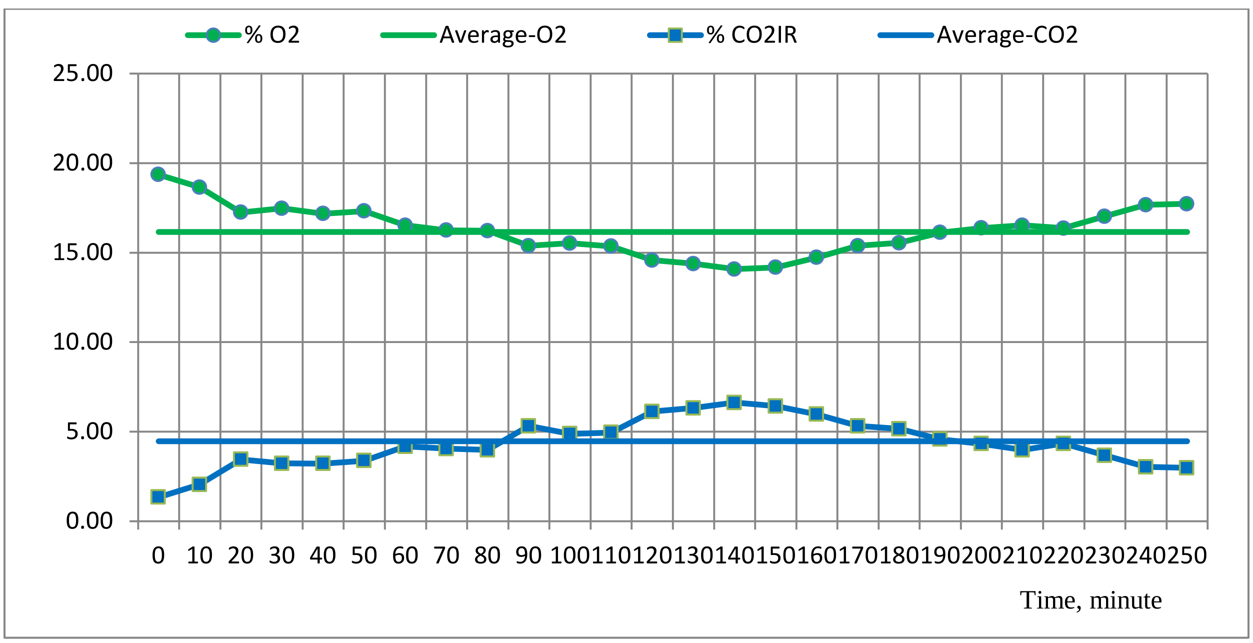
- Emission test result

Equip	Emission	Unit	Measured Value		Standard value/ Perf Spec value	Note
			Boiler No1	Boiler No2		
Testo 350 XL	O2	%	16.26	16.15	NA	-
	CO2	%	4.28	4.46	NA	-
	CO	mg/m3	1143.25	1173.56	2000/2500	Passed/Passed
		kg/t	26.97	26.87	30.0	Passed
	NO	mg/m3	238.75	253.12	400	Passed
		kg/t	5.25	5.17	6.0	Passed
	SO2	mg/m3	324.13	319.2	600	Passed
		kg/t	6.99	6.58	9	Passed
TSI Dust Trak 8533	PM 10	mg/m3	3.708	3.199	300/200	Passed/Passed
		kg/t	0.01435	0.01357	4.5	Passed
	PM 2.5	mg/m3	3.606	3.154	300/200	Passed/Passed
		kg/t	0.01398	0.01323	4.5	Passed
Gravimetric filter	TSP	mg/m3	43.795	38.32	300/200	Passed/Passed
		kg/t	0.5628	0.4152	4.5	Passed
Infrared thermo	Stack temp	˚C	125.1	124.83		-
Testo 350 XL	Excess air level	%	196.0	238.1		-

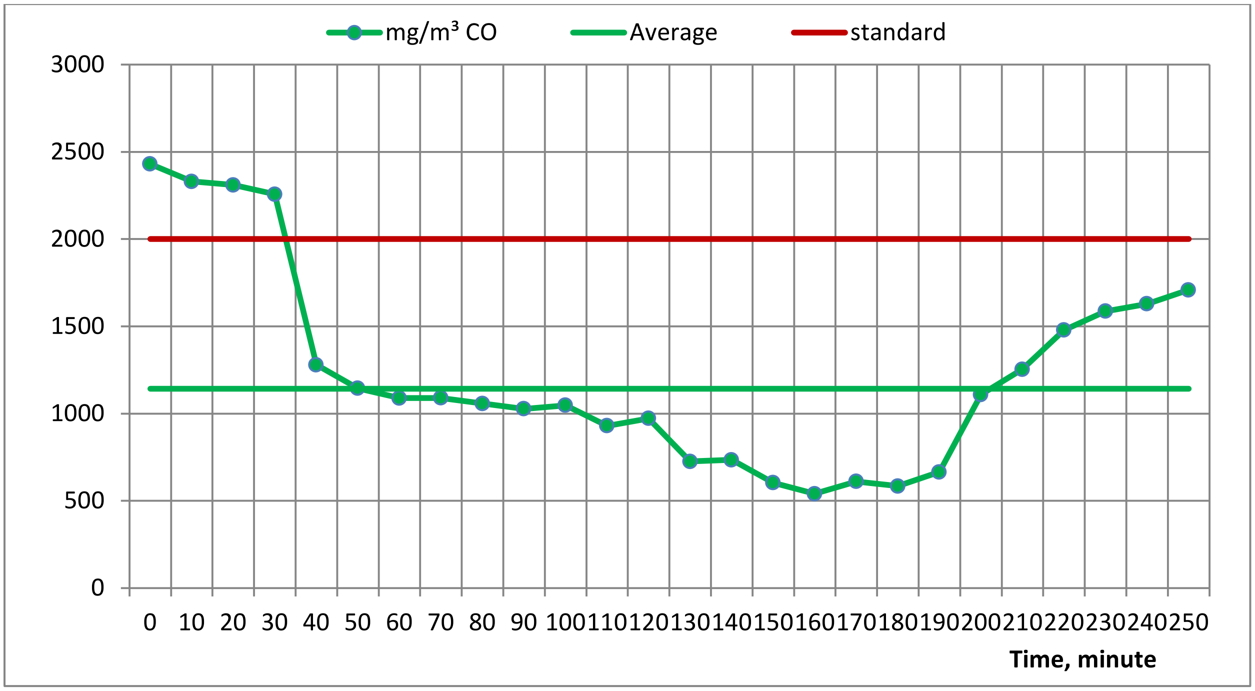
Test result shows converted calculation of the actual test result that assumes excess air level at 25%.



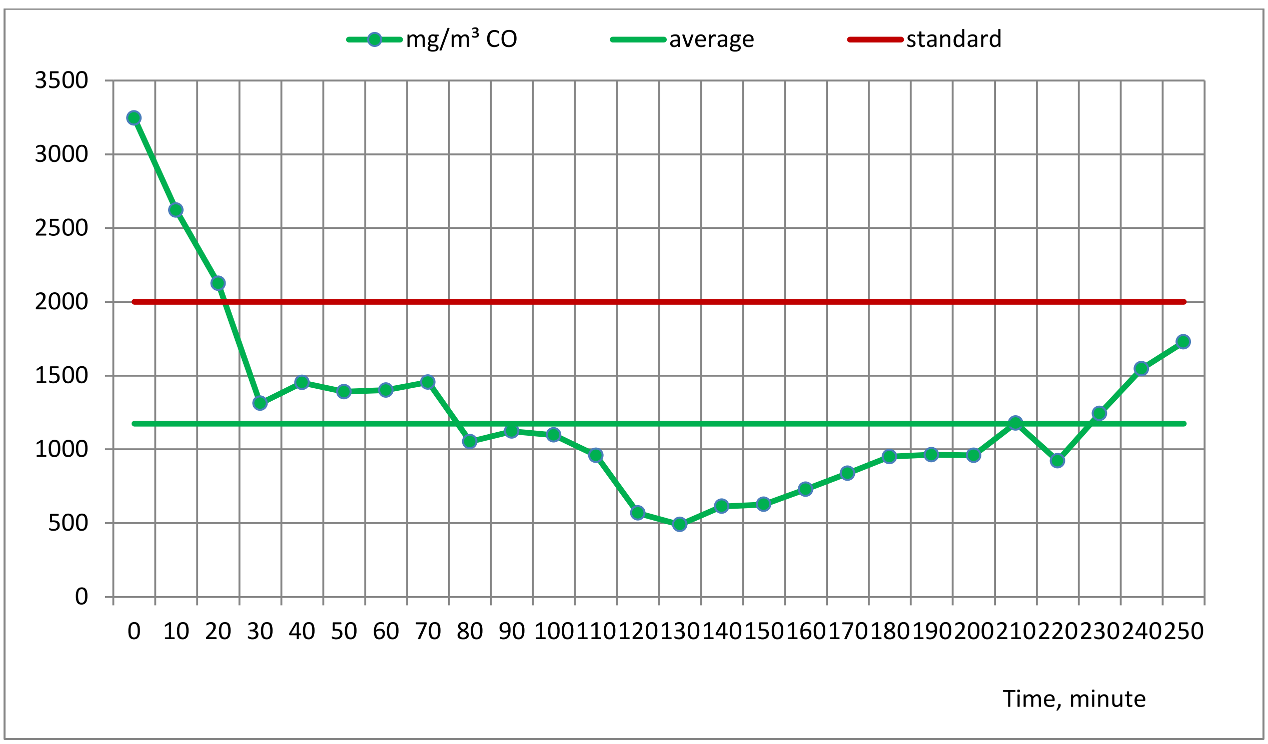
Graph1. O2 and CO2 emissions' results throughout testing for boiler No1



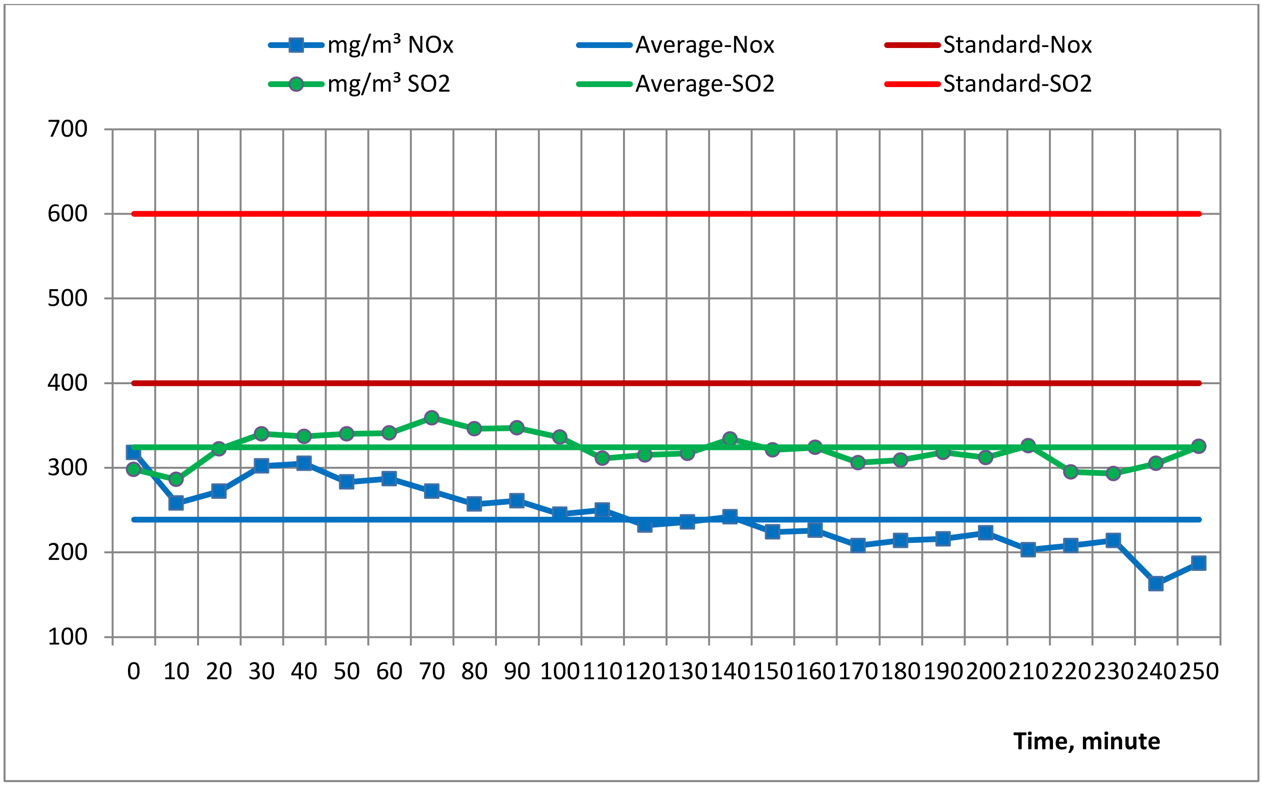
Graph2. O2 and CO2 emissions' results throughout testing for boiler No2



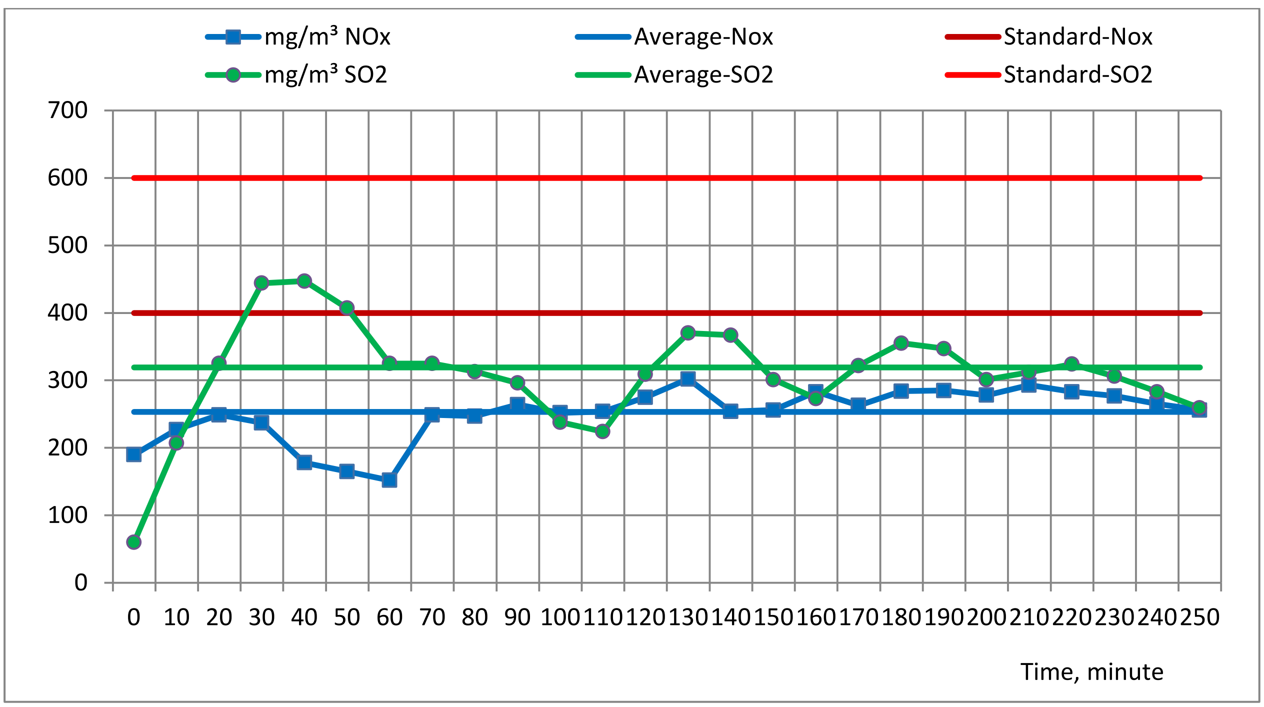
Graph3. CO emission result throughout testing for boiler No1



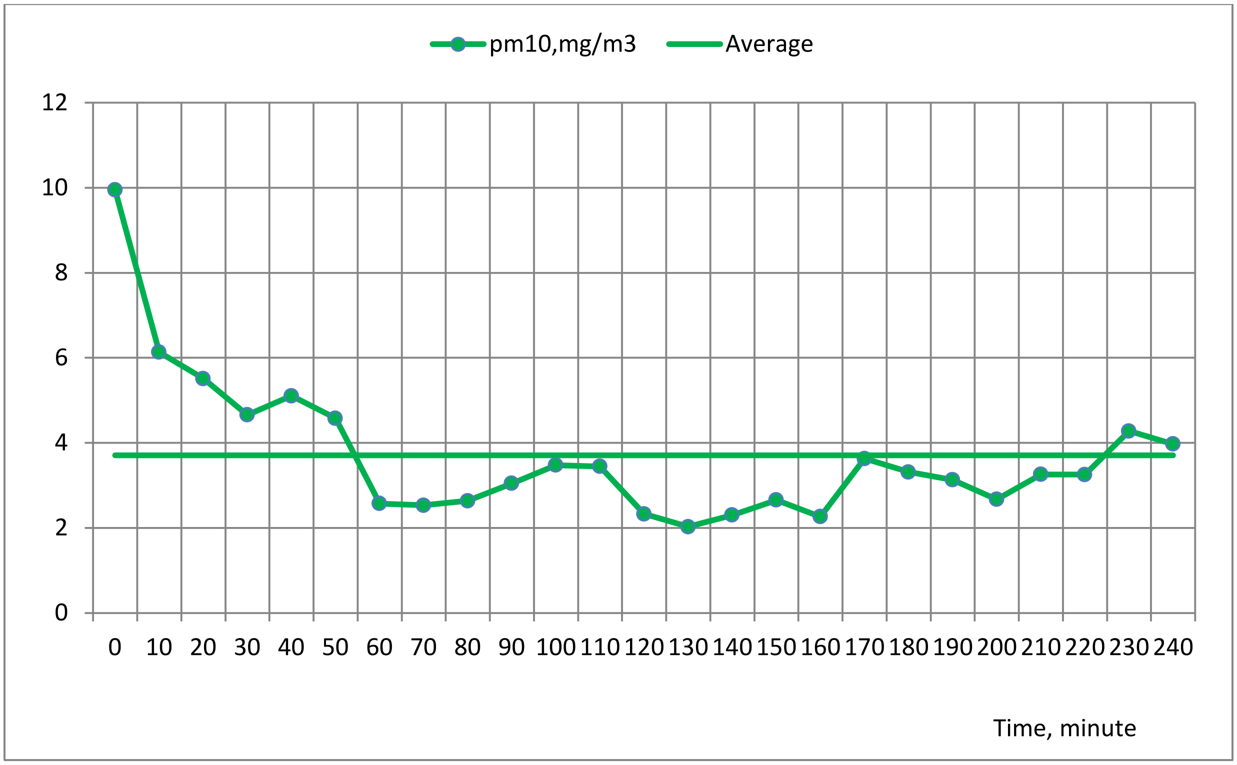
Graph4. CO emission result throughout testing of boiler No2



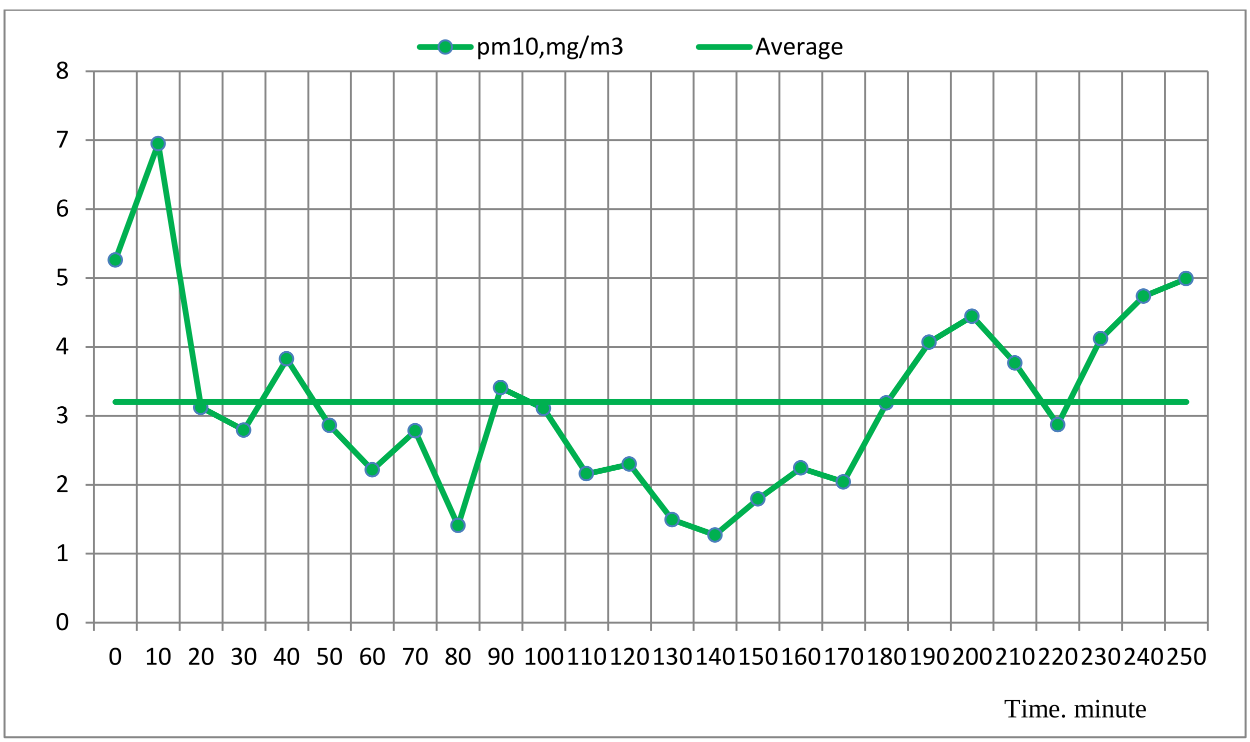
Graph5. SO2 and NOx emissions' results throughout testing for boiler No1



Graph6. SO2 and NOx emissions' results throughout testing for boiler No2



Graph7. PM10 emission result throughout testing for boiler No1



Graph8. PM10 emission result throughout testing for boiler No2

- **Laboratory Results of Coal Used for Boiler Fuel:**

Standard	Description	Coal source/ value		
				Nalaikh
MNS 655-79	Moisture %			23.1
MNS ISO 0652-79	Ash %			20.6
MNS 0669-87	Heat unit kcal/kg			6198.7
	Heat unit /tested/ kcal/kg			3180
MNS 0669-87	Heat unit kj/kg			25972.7
	Heat unit /tested/ kj/kg			13324
MNS 0669-87	Heat unit Btu/kg			24,617.4
	Heat unit /tested/ Btu/kg			12,628.8

Note: Coal to be used was tested.

- **Laboratory Results of Ash Sample:**

№	Name of the location	% of flammable substance in the slag	% of flammable substance in the ash
1	Boiler No1	19.77	18.9
2	Boiler No2	8.86	7.38

- **Flow meter test result**

Description	Unit	Value	
		Boiler No1	Boiler No2
Water was moving thru boiler at the rate	t/h	15.65	15.54
Supply water temperature leaving boiler	˚C	90.71	92.73
Return water temperature entering boiler	˚C	74.85	75.8
Temperature differential	˚C	15.86	16.93
Thermal output	kW	288.4	305.6

- **Efficiency calculation**

Description	Unit	Value	
		Boiler No1	Boiler No2
Available heat content	kJ/kg	13324	13324.0
Rate	kg/h	100	105.5
Heating potential	kW	370.11	390.46
Heat output	kW	288.4	305.6
Heat loss	kW	81.71	84.86
Efficiency (output/potential)	%	77.9	78.26

Heat content lost thru incomplete coal combustions and stack are the difference between input and output, in these cases 81.71 and 84.86 kW are wasted heat energy accordingly. 22.1 % and 21.74 % of the potential heat energies are wasted accordingly. Approximately 16.5 % and 15.44 % of the coals remain unburned in ashes removed from boilers.

5. Conclusion

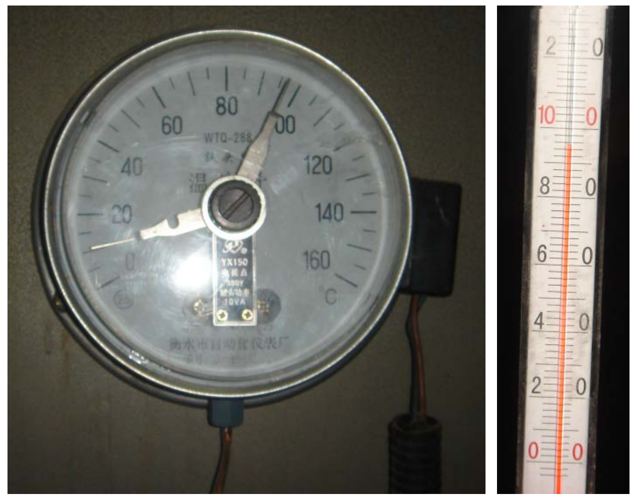
1. Climate of testing day was warm. So return water temperatures were high due to less heat consumption. Regarding to those reason boilers were not fueled with their full capacities. This does not affect boiler emission and efficiency performance tests' results.
2. The Khoyulaa Khuu at the Khan Uul district site has received a very good performing boilers as confirmed by test results. Test result shows that the boilers are met with performance specification requirements as well as standard requirements.
3. Higher than standard efficiencies are experienced by current configuration. For each unit of money spent in heat energy of coal 78.26% of that unit is used, the remaining 21.74% is lost in waste for the boiler number 2. For each unit of money spent in heat energy of coal 77.9% of that unit is used, the remaining 22.1% is lost in waste for the boiler number1.
4. DZL-0.7 boiler tightness and body insulation is very good which reduces heat loss and improves its performance.
5. The TSP was reduced due to installation of a scrubber.

Followings are photo to show testing procedure at the Khoyulaa khuu at the Khan Uul district

Photo 1. Coal weighting

Photo 2. Coal combustion

a.



b.

Photo 3. a. Inlet water temperature b. Outlet water temperature

Photo 4. PM measurement

Photo 5. TSP measurement

Photo 6. Gas analyze.

Photo 7. Air velocity measurement

INVESTMENT DEPARTMENT OF THE CAPITAL CITY

EXPERIMENT AND RESEARCH CENTER FOR BOILER OF THE MUST

HOB TEST REPORT FOR TALST ERCHIM

Date:	**Developed by:** **Experiment and research center for boiler of the MUST**	**Tseyen-Oidov. O**
Date:	**Approved by:** **Investment Department of the Capital City**	**Zayamandakh. O**
Date:	**Accepted by:** **EEP, MCA-M**	**Mangal. S**

2012

1. Executive summary

Emission test of the newly installed HOB was conducted through “The Research and Experiment Center for Boilers” regarding contract between IDCC and the center.

2. Purpose

The objectives of the testing are:

(i) to verify proper functioning of the equipment/system after installation; and

(ii) to verify that the performance of the installed equipment/systems meet with the specified performance specification.

(iii) to capture and record performance data of the whole installation as the baseline for future operation and maintenance.

3. General information

- **Testing team**

No	*Position*	*Name*	*Profession*
1	Testing team leader	J. Tseyen-Oidov	Thermal engineer
2	Testing team member	B. Battur	Thermal engineer
3	Testing team member	Sh. Jambaltsanjid	Thermal engineer
4	Testing team member	A. Tumenbayar	Thermal engineer
5	Testing team member	B. Ganzorig	HVAC engineer

- Site information

HOB emission and efficiency test was conducted at the Talst erchim. Old BZUI-100 HOBs were replaced with new DZL-1.4 HOB at the site by the Khurd LLC.

- Testing equipment

Following described equipments were used in the testing.

Num	Equipment name or mark	Measurement description	Calibration due date
1	Testo 350	Emissions- CO, CO2, NOx, SOx, O2 Combustion Efficiency- % by volume	December 2012
2	TSI Dust Trak 8533 w/diluter and air blower	Particulate Matter Counter- PM10, PM2.5	Calibrated before every test
3	Portaflow PT500	Energy Flow Metering- HWS & HWR Temperatures, Fluid Flow rate, & BTU/Hr	July 2013
4	Gravimetric filter	Particulate Matter TSP	Calibrated before every test
5	Testo 405 anemometer	Air speed to determine combustion air	August 2013
6	Electric scale	To weigh coal to be fed	July 2013
7	Infrared thermometer	To determine boiler surface temperature (Boiler tightness)	May 2014

- Testing procedure

Testing was conducted on 18.09.2012

Outdoor temperature during testing was approximately 17.5 ^{o}C

Boilers were fired for 4 hours starting 17:40 completing at 21:40 pm. The DZL-1.4 boilers are mechanically fed rate of 210 kg per hour and 202.5 kg per hour. The ashes were removed continuously. DZL- 1.4 boiler is the mechanic boiler that removes ash continuously and feeds coal continuously.

Boilers were tested at the same time with 2 sets of equipment. The scrubber was operated throughout testing procedure.

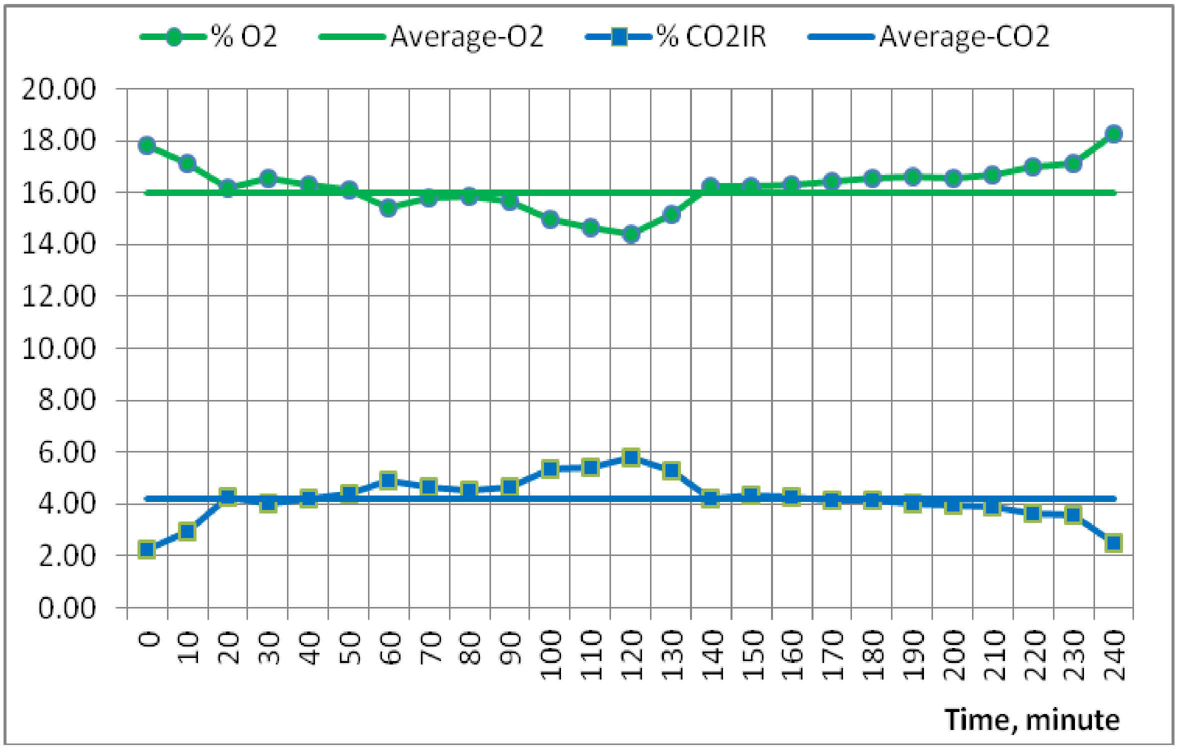
Weather was warm the day test conducted. So the boilers were not fired at full their full capacity. Winter the boilers capacity will increase due to cold temperature. Coal consumption will increase related to capacity but emission concentration will not be changed. Capacity does not reflect to boiler emission directly.

4. Test result

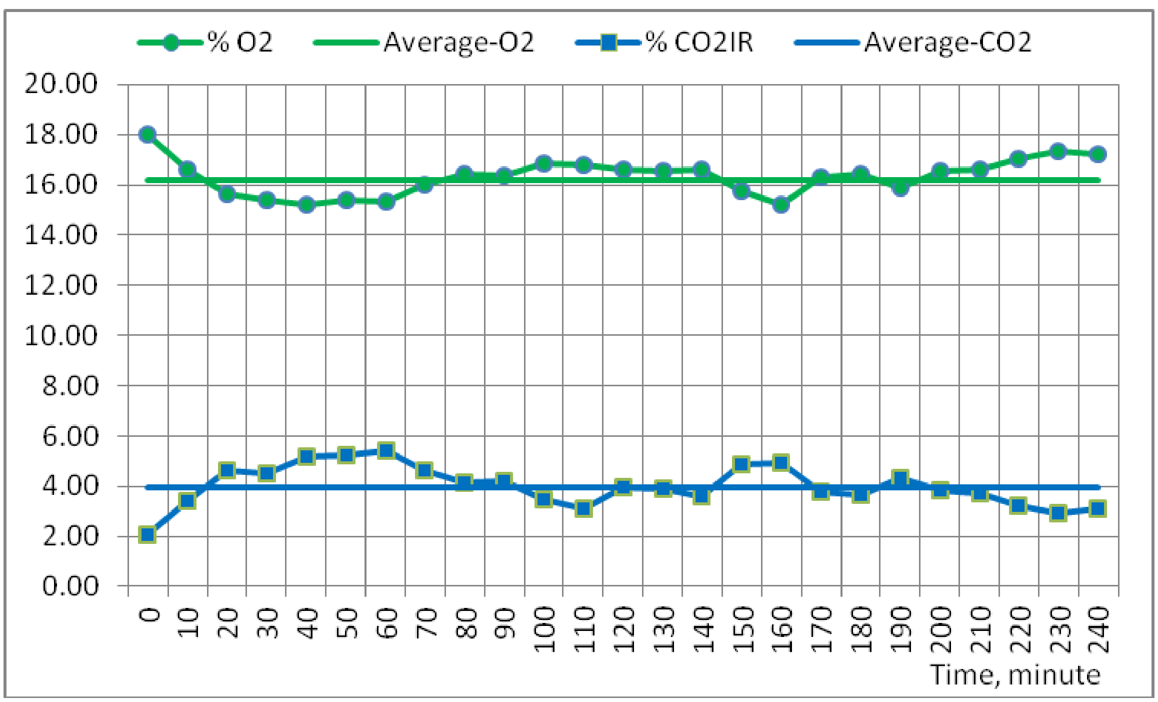
- Emission test result

Equip	Emission	Unit	Measured Value		Standard value/ Perf Spec value	Note
			Boiler No1	Boiler No2		
Testo 350 XL	O2	%	16.23	16.18	NA	-
	CO2	%	4.22	3.98	NA	-
	CO	mg/m3	1112.04	1203.28	2000/2500	Passed/Passed
		kg/t	22.81	24.34	30.0	Passed
	NO	mg/m3	248.28	257.64	400	Passed
		kg/t	4.75	5.07	6.0	Passed
	SO2	mg/m3	370.96	382.96	600	Passed
		kg/t	7.15	7.54	9	Passed
TSI Dust Trak 8533	PM 10*	mg/m3	13.945	14.806	300/200	Passed/Passed
		kg/t	0.0636	0.0643	4.5	Passed
	PM 2.5*	mg/m3	13.694	15.159	300/200	Passed/Passed
		kg/t	0.0626	0.0628	4.5	Passed
Gravimetric filter	TSP	mg/m3	37.485	42.154	300/200	Passed/Passed
		kg/t	0.4165	0.4864	4.5	Passed
Infrared	Stack temp	˚C	108.6	107.9		-
Testo 350 XL	Excess air level	%	206.9	201.25		-

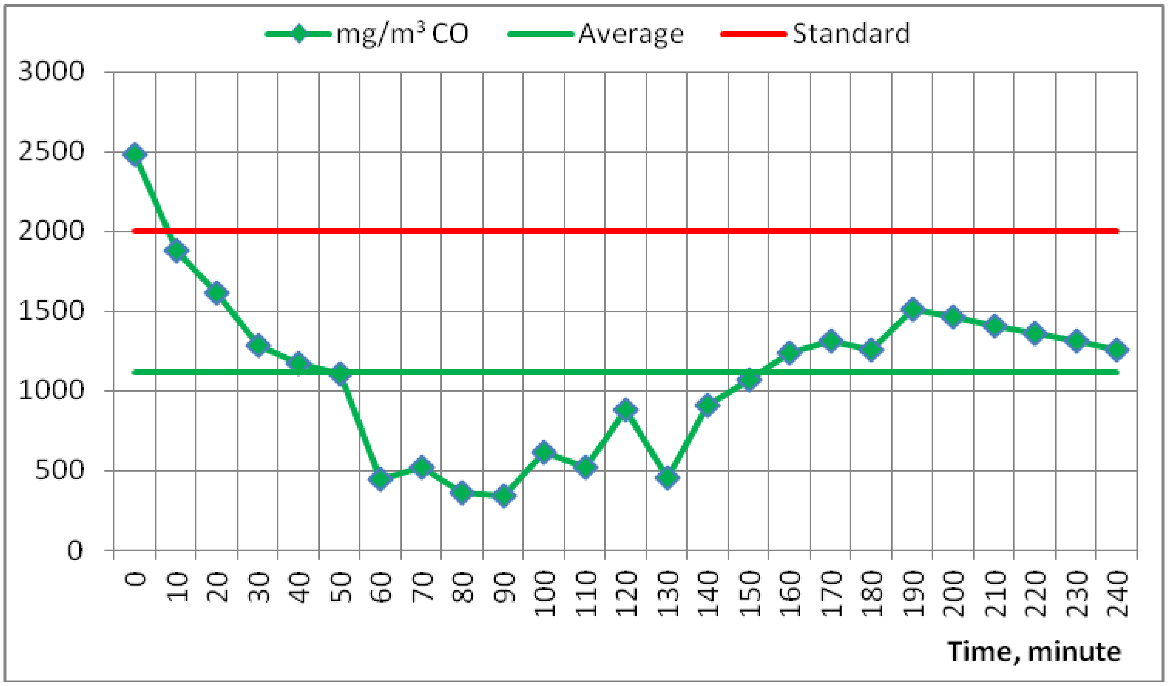
Test result shows converted calculation of the actual test result that assumes excess air level at 25%.



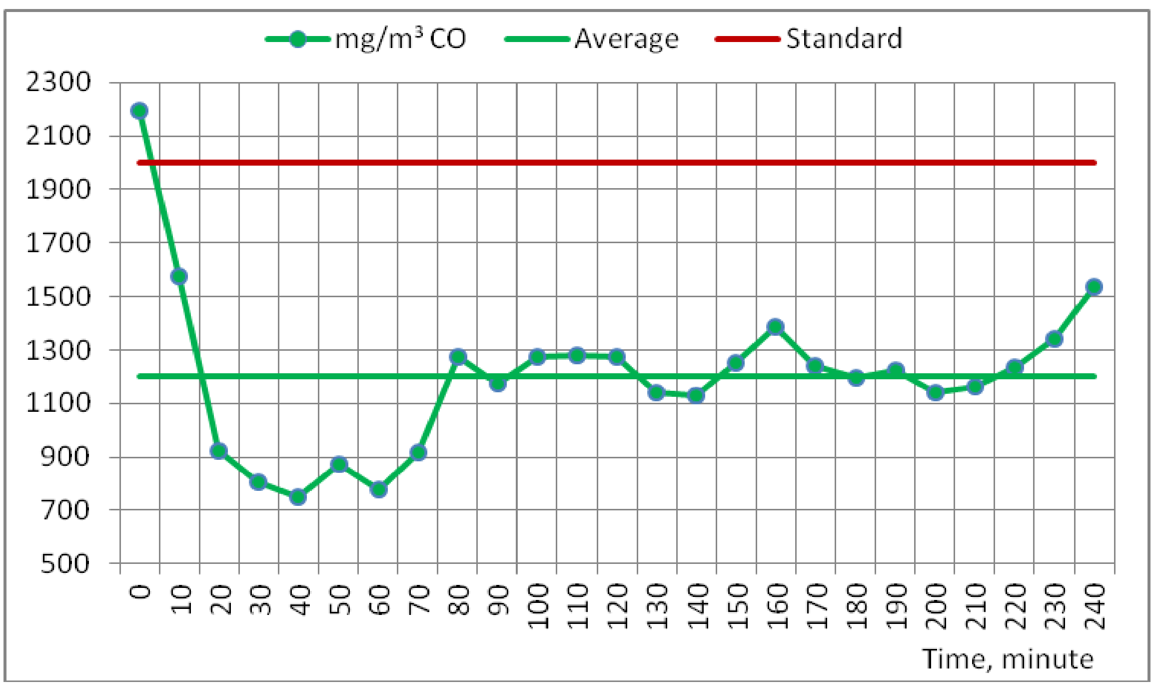
Graph1. O2 and CO2 emissions' results throughout testing for boiler No1



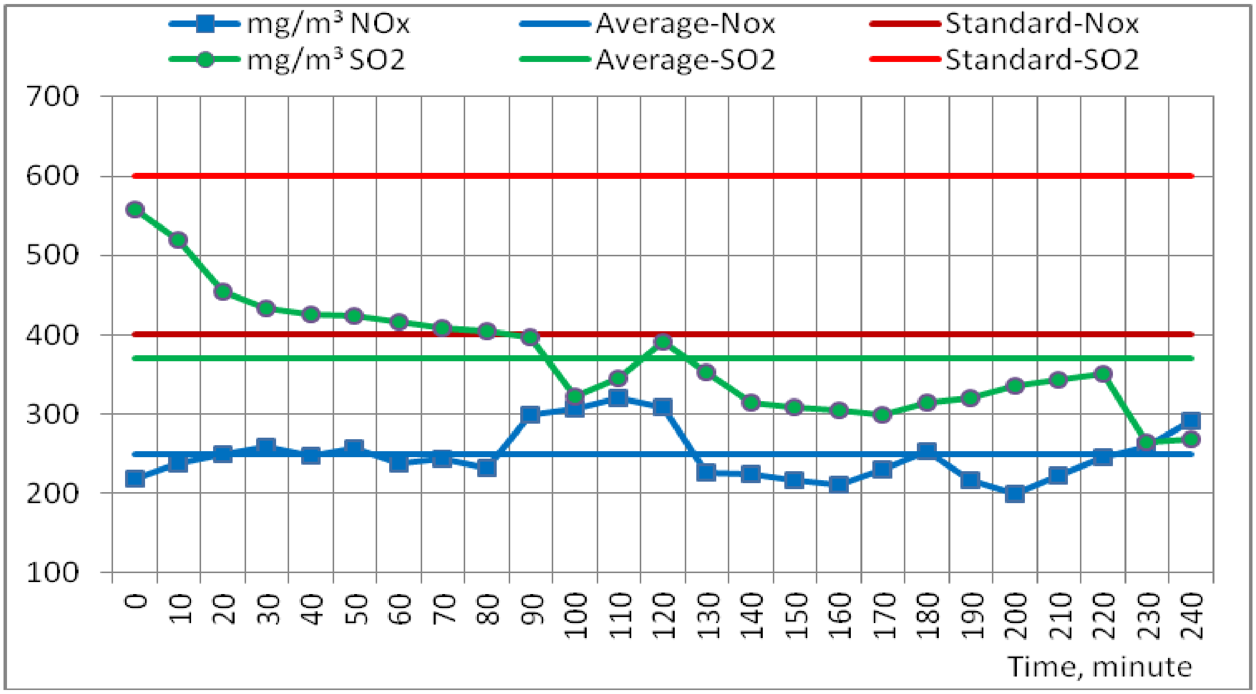
Graph2. O2 and CO2 emissions' results throughout testing for boiler No2



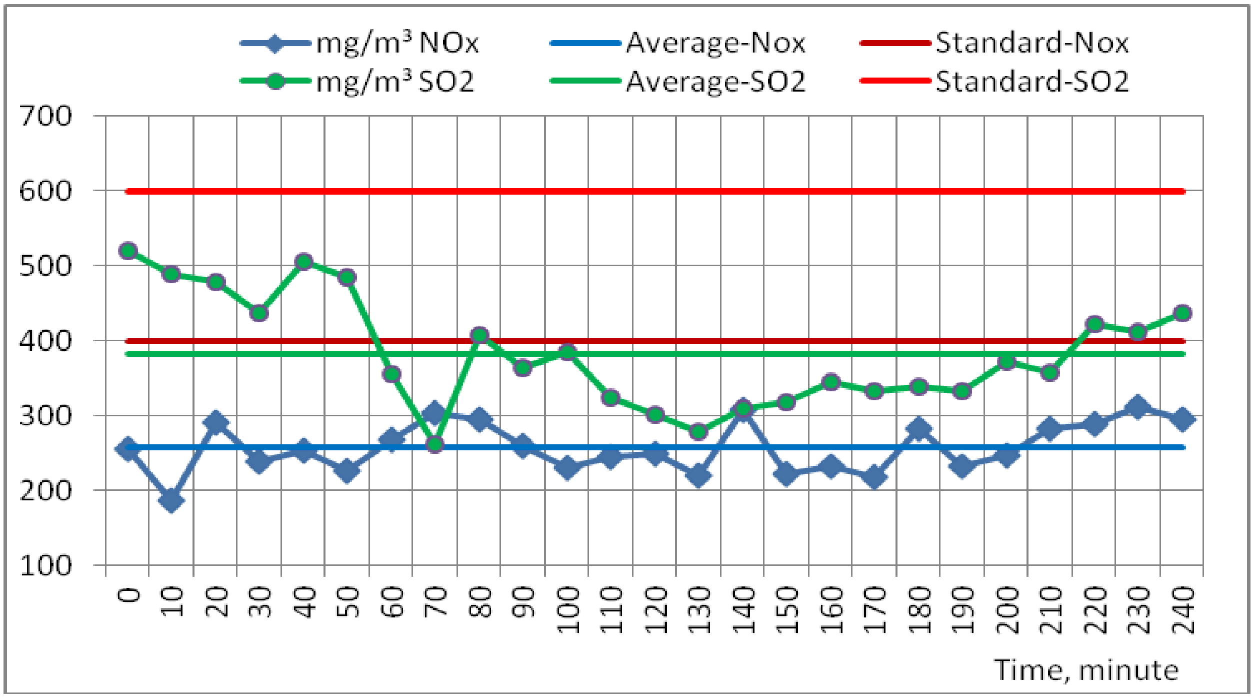
Graph3. CO emission result throughout testing for boiler No1



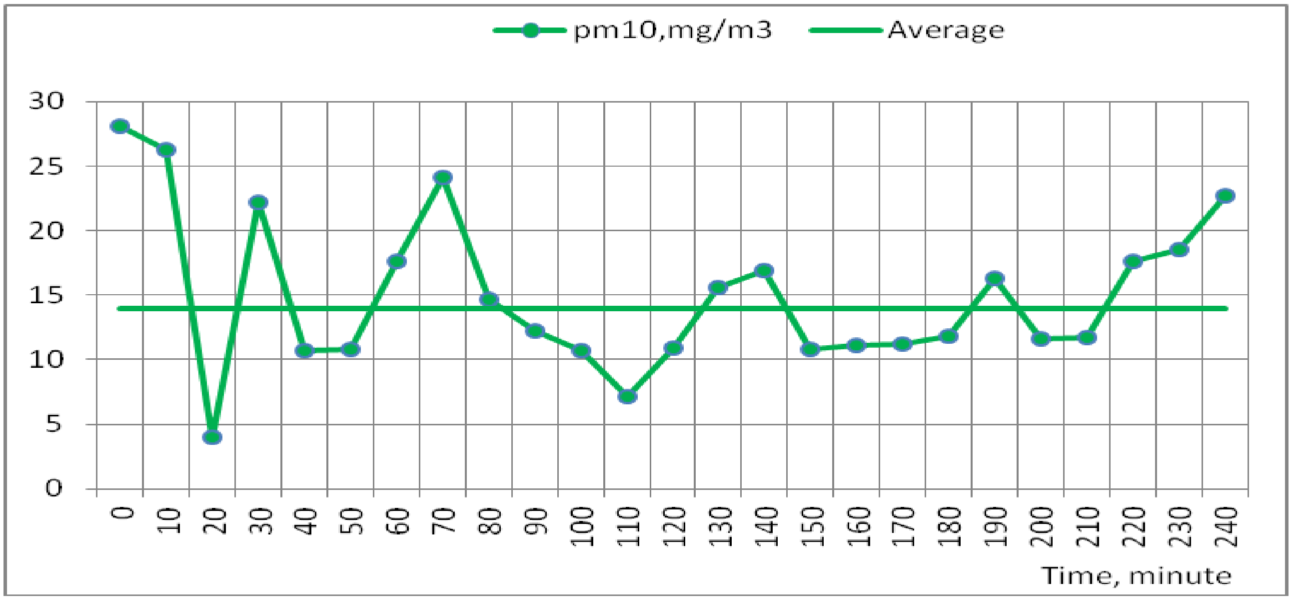
Graph4. CO emission result throughout testing for boiler No2



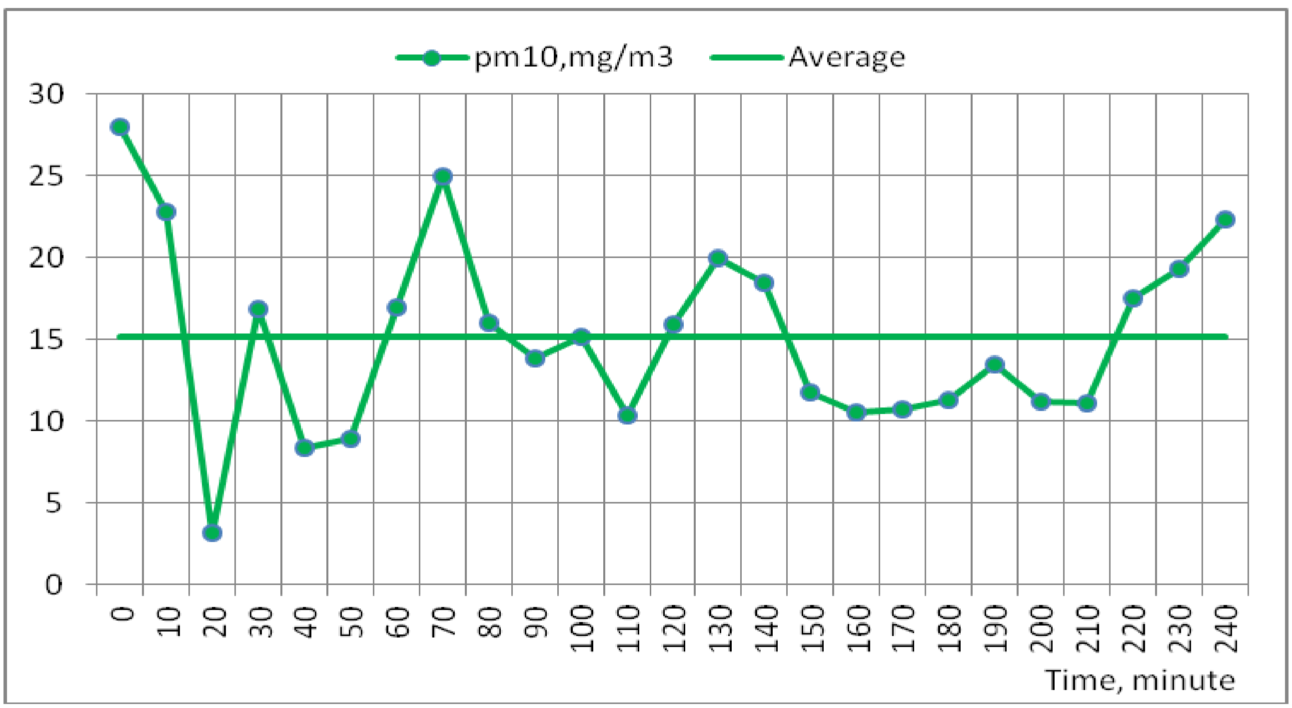
Graph5. SO2 and NOx emissions' results throughout testing for boiler No1



Graph6. SO2 and NOx emissions' results throughout testing for boiler No2



Graph7. PM10 emission result throughout testing for boiler No1



Graph8. PM10 emission result throughout testing for boiler No2

- **Laboratory Results of Coal Used for Boiler Fuel:**

Standard	Description	Coal source/ value		
				Nalaikh
MNS 655-79	Moisture %			25.9
MNS ISO 0652-79	Ash %			21.08
MNS 0669-87	Heat unit kcal/kg			6297.8
	Heat unit /tested/ kcal/kg			3209
MNS 0669-87	Heat unit kj/kg			25760
	Heat unit /tested/ kj/kg			13446
MNS 0669-87	Heat unit Btu/kg			24,415.3
	Heat unit /tested/ Btu/kg			12,744.1

Note: Coal to be used was tested.

- **Laboratory Results of Ash Sample:**

№	Name of the location	% of flammable substance in the slag	% of flammable substance in the ash
1	Boiler No1	21.23	22.04
2	Boiler No2	9.34	8.98

- **Flow meter test result**

Description	Unit	Value	
		Boiler No1	Boiler No2
Water was moving thru boiler at the rate	t/h	42.64	43.89
Supply water temperature leaving boiler	˚C	87.36	85.96
Return water temperature entering boiler	˚C	74.96	74.48
Temperature differential	˚C	12.4	11.48
Thermal output	kW	615.23	586.4

- **Efficiency calculation**

Description	Unit	Value	
		Boiler No1	Boiler No2
Available heat content	kJ/kg	13446	13446
Rate	kg/h	210	202.5
Heating potential	kW	784.35	756.34
Heat output	kW	615.23	586.4
Heat loss	kW	169.12	169.94
Efficiency (output/potential)	%	78.4	77.53

Heat content lost thru incomplete coal combustions and stack are the difference between input and output, in these cases 169.12 kW and 169.94 kW are wasted heat energy accordingly. 21.6 % and 22.46 % of the potential heat energies are wasted accordingly. Approximately 17.66 % and 18.12 % of the coals remain unburned in ashes removed from boilers.

5. Conclusion

1. Climate of testing day was warm. So return water temperatures were high due to less heat consumption. Regarding to those reason boilers were not fueled with their full capacities. This does not affect boiler emission and efficiency performance tests' results.
2. The Tlast Erchim site has received very good performing boilers as confirmed by test results. Test result shows that the boilers are met with performance specification requirements as well as standard requirements.
3. Higher than standard efficiencies are experienced by current configuration. For each unit of money spent in heat energy of coal 77.53% of that unit is used, the remaining 22.47% is lost in waste for the boiler number 2. For each unit of money spent in heat energy of coal 78.4% of that unit is used, the remaining 21.6% is lost in waste for the boiler number1.
4. DZL-1.4 boiler tightness and body insulation is very good which reduces heat loss and improves its performance.
5. The TSP was reduced due to installation of a scrubber.

Followings are photos to show testing procedure at the Talst Erchim site.

Photo. 1. Coal weighting

Photo. 2. Coal combustion

a.

b.

Photo 3. a. Inlet water temperature; b.Outlet water temperature.

Photo 4. PM measurement

Photo 5. TSP measurement

Photo 6. Gas analyze.

Photo 7. Water rate measurement

Photo 8. Air velocity measurement

INVESTMENT DEPARTMENT OF THE CAPITAL CITY

EXPERIMENT AND RESEARCH CENTER FOR BOILER OF THE MUST

HOB TEST REPORT FOR KHOYULAA KHUU AT THE BAYANZURKH

Date:		
	Developed by: **Experiment and research center for boiler of the MUST**	**Tseyen-Oidov. O**
Date:	**Approved by:** **Investment Department of the Capital City**	**Zayamandakh. O**
Date:	**Accepted by:** **EEP, MCA-M**	**Mangal. S**

2012

1. Executive summary

Emission test of the newly installed HOB was conducted through “The Research and Experiment Center for Boilers” regarding contract between IDCC and the center.

2. Purpose

The objectives of the testing are:

(i) to verify proper functioning of the equipment/system after installation; and

(ii) to verify that the performance of the installed equipment/systems meet with the specified performance specification.

(iii) to capture and record performance data of the whole installation as the baseline for future operation and maintenance.

3. General information

- **Testing team**

No	*Position*	*Name*	*Profession*
1	Testing team leader	J. Tseyen-Oidov	Thermal engineer
2	Testing team member	B. Battur	Thermal engineer
3	Testing team member	Sh. Jambaltsanjid	Thermal engineer
4	Testing team member	A. Tumenbayar	Thermal engineer
5	Testing team member	B. Ganzorig	HVAC engineer

- Site information

HOB emission and efficiency test was conducted at the Khoyulaa khuu at the Bayanzurkh district. Old HP18-54 HOB was replaced with new DZL-0.7 HOB at the site by the Khurd Co., Ltd.

- Testing equipment

Following described equipments were used in the testing.

Num	Equipment name or mark	Measurement description	Calibration due date
1	Testo 350	Emissions- CO, CO2, NOx, SOx, O2 Combustion Efficiency- % by volume	December 2012
2	TSI Dust Trak 8533 w/diluter and air blower	Particulate Matter Counter- PM10, PM2.5	Calibrated before every test
3	Portaflow PT500	Energy Flow Metering- HWS & HWR Temperatures, Fluid Flow rate, & BTU/Hr	July 2013
4	Gravimetric filter	Particulate Matter TSP	Calibrated before every test
5	Testo 405 anemometer	Air speed to determine combustion air	August 2013
6	Electric scale	To weigh coal to be fed	July 2013
7	Infrared thermometer	To determine boiler surface temperature (Boiler tightness)	May 2014

- Testing procedure

Testing was conducted on 19.09.2012

Outdoor temperature during testing was approximately 9.5 ^{o}C

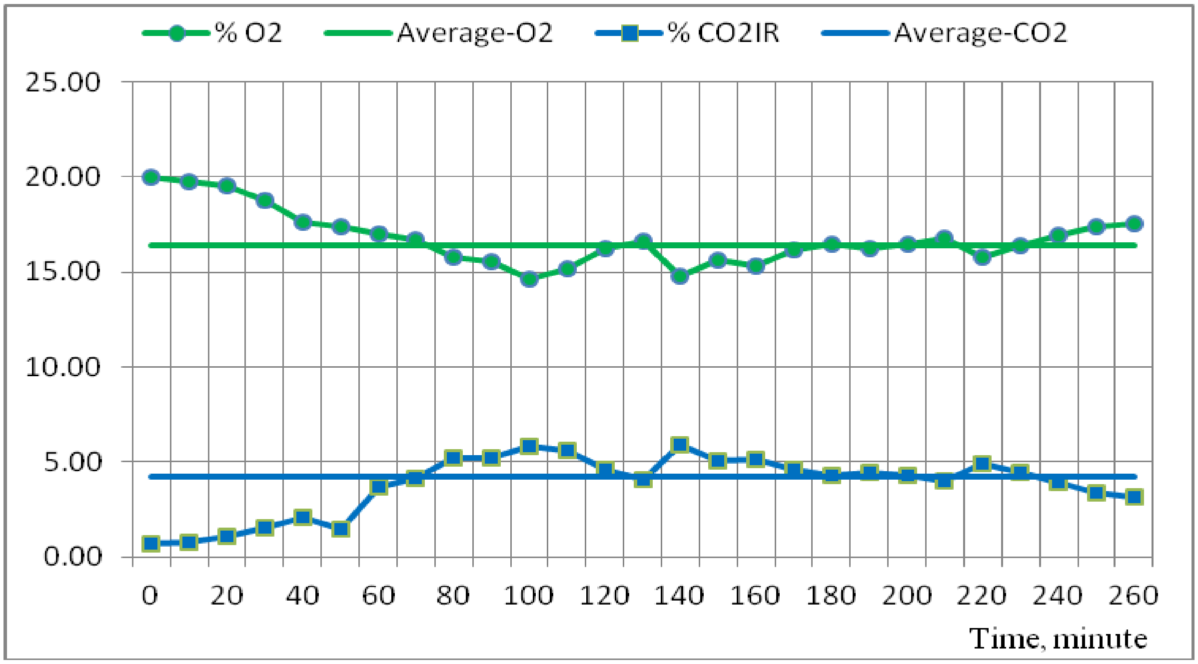
Boilers were fired for 4 hours starting 23:00 completing at 03:20 am. The DZL-0.7 boilers are mechanically fed rate of 101.25 kg per hour and 106.25 kg per hour. The ashes were removed continuously. DZL- 1.4 boiler is the mechanic boiler that removes ash continuously and feeds coal continuously. Boilers were tested at the same time with two sets of equipment. The scrubber was operated throughout testing procedure. Weather was warm the day test conducted. So the boilers were not fired at full their full capacity. Winter the boilers capacity will increase due to cold temperature. Coal consumption will increase related to capacity but emission concentration will not be changed. Capacity does not reflect to boiler emission directly.

4. Test result

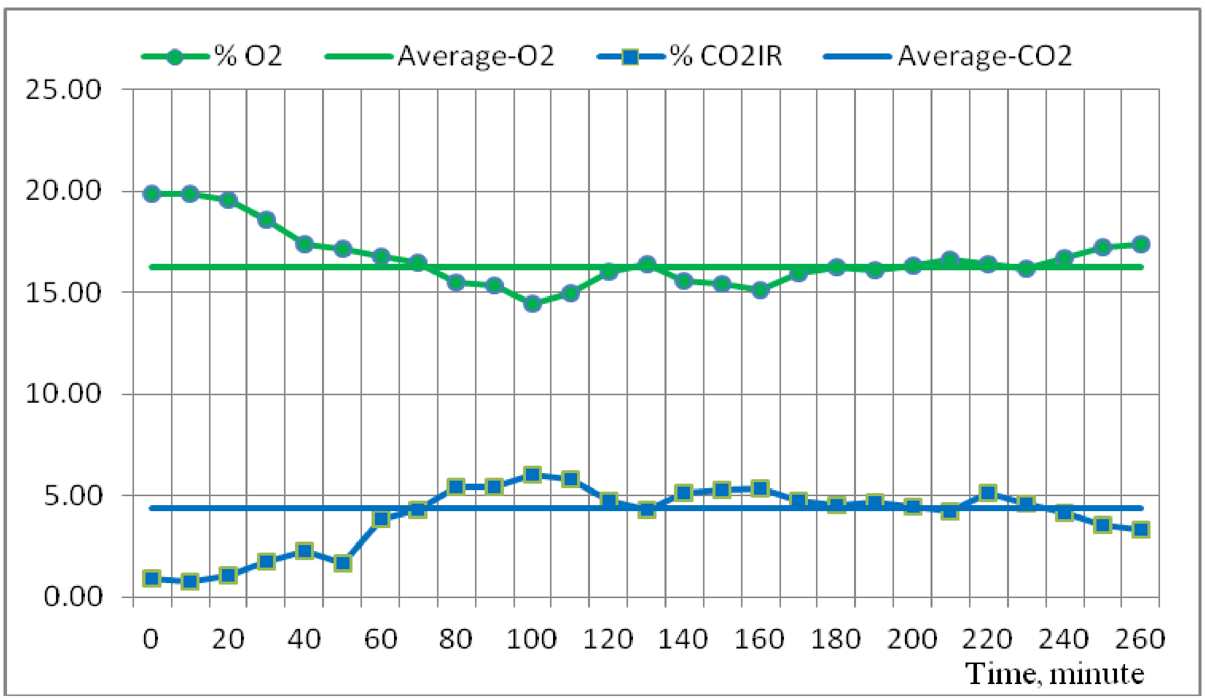
- Emission test result

Equip	Emission	Unit	Measured Value		Standard value/ Perf Spec value	Note
			Boiler No1	Boiler No2		
Testo 350 XL	O_2	%	16.39	16.25	NA	-
	CO_2	%	4.2	4.37	NA	-
	CO	mg/m3	1233.7	1225.5	2000/2500	Passed/Passed
		kg/t	23.65	22.69	30.0	Passed
	NO	mg/m3	239.58	229.83	400	Passed
		kg/t	4.63	4.34	6.0	Passed
	SO_2	mg/m3	357.83	371	600	Passed
		kg/t	7.04	7.02	9	Passed
TSI Dust Trak 8533	PM 10	mg/m3	3.203	3.598	300/200	Passed
		kg/t	0.0109	0.01164	4.5	Passed/Passed
	PM 2.5	mg/m3	3.102	3.659	300/200	Passed/Passed
		kg/t	0.01122	0.01183	4.5	Passed
Gravimetric filter	TSP	mg/m3	58.15	67.96	300/200	Passed/Passed
		kg/t	0.55	0.6086	4.5	Passed
Infrared thermometer	Stack temp	˚C	120.93	125.9	-	-
Testo 350 XL	Excess air level	%	260.5	266.7	-	-

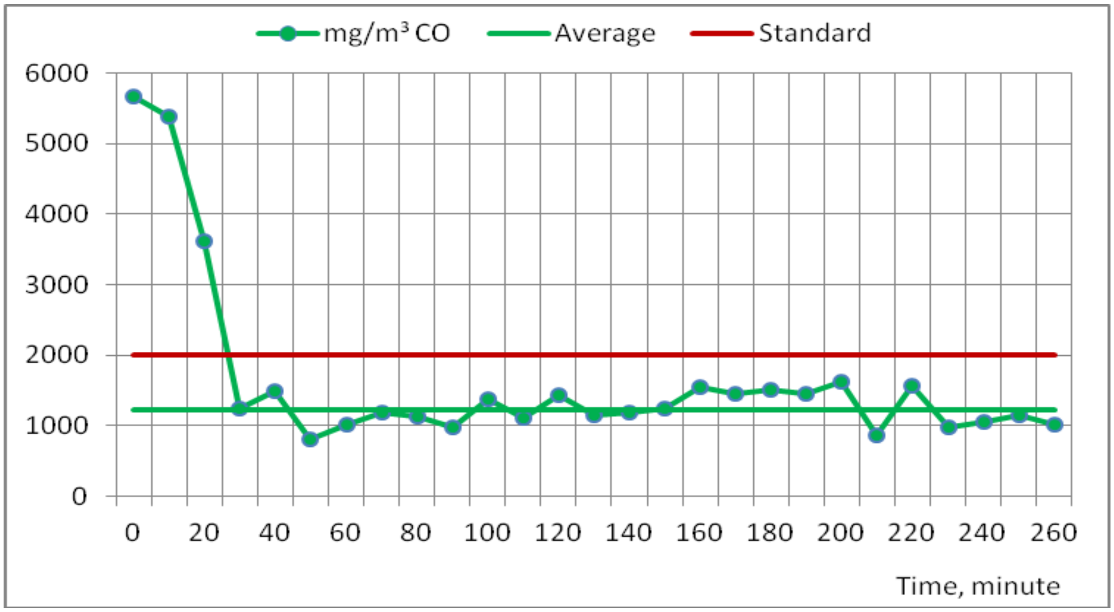
Test result shows converted calculation of the actual test result that assumes excess air level at 25%.



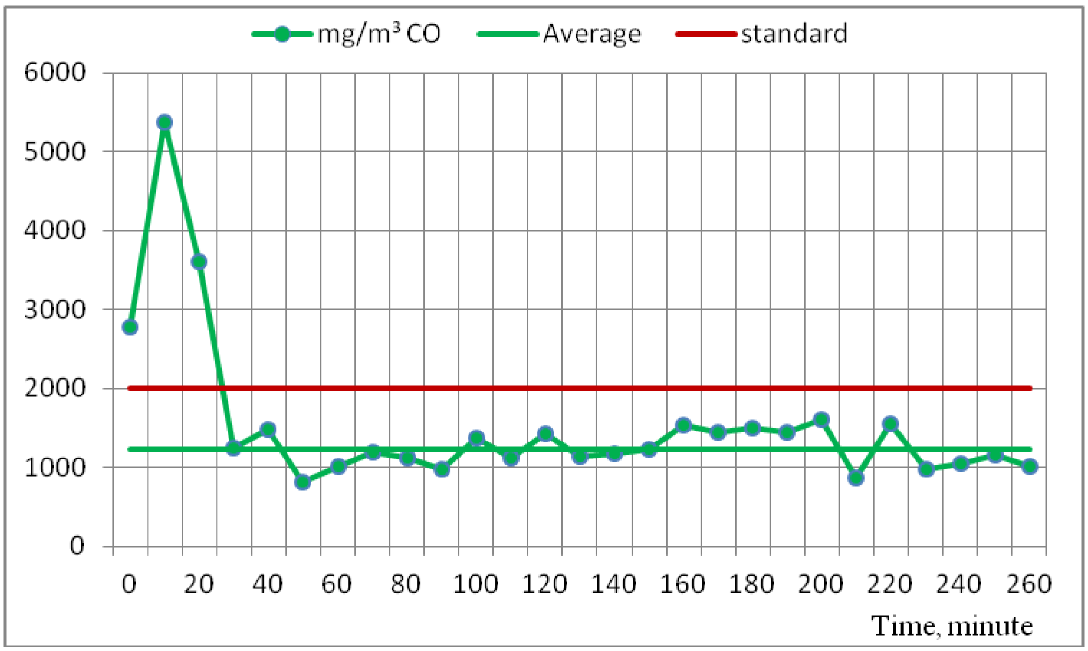
Graph1. O2 and CO2 emissions' results throughout testing for boiler No1



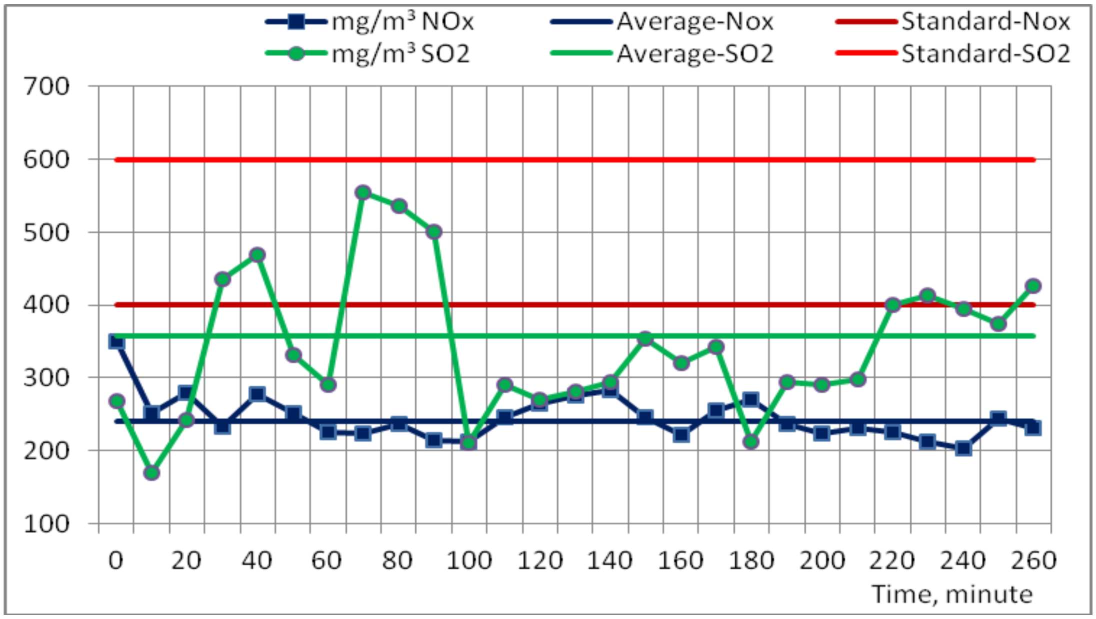
Graph2. O2 and CO2 emissions' results throughout testing for boiler No2



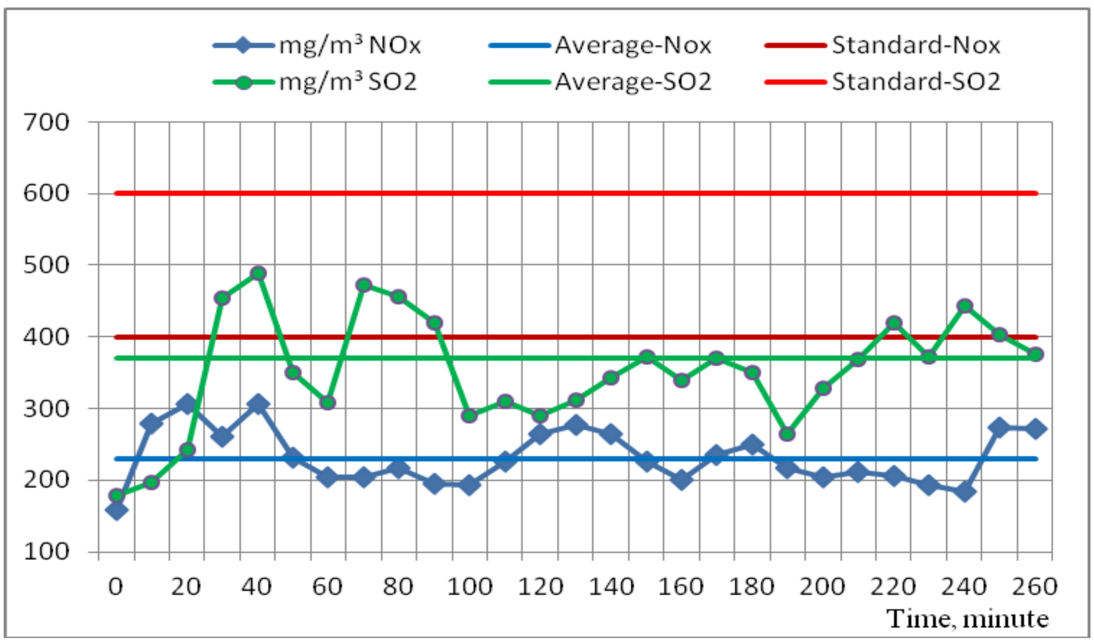
Graph3. CO emission result throughout testing for boiler No1



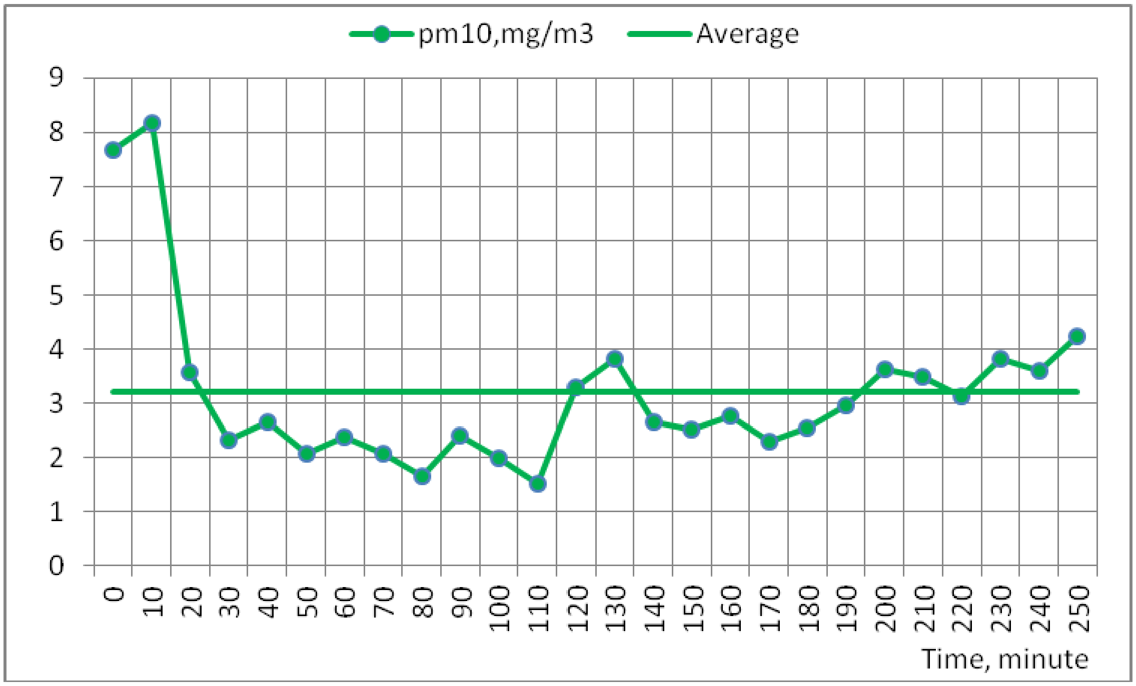
Graph4. CO emission result throughout testing for boiler No2



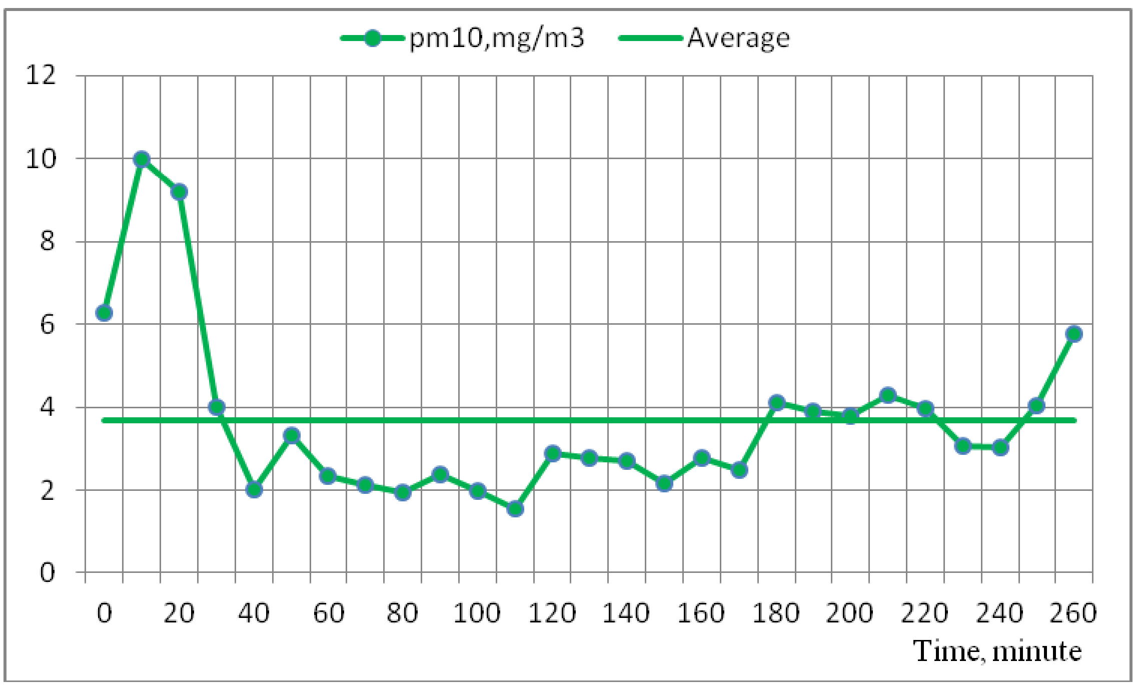
Graph5. SO2 and NOx emissions' results throughout testing for boiler No1



Graph6. SO2 and NOx emissions' results throughout testing for boiler No2



Graph7. PM10 emission result throughout testing for boiler No1



Graph8. PM10 emission result throughout testing for boiler No2

- **Laboratory Results of Coal Used for Boiler Fuel:**

Standard	Description	Coal source/ value		
				Nalaikh
MNS 655-79	Moisture %			22.5
MNS ISO 0652-79	Ash %			26.7
MNS 0669-87	Heat unit kcal/kg			5883.2
	Heat unit /tested/ kcal/kg			2871
MNS 0669-87	Heat unit kj/kg			24650.6
	Heat unit /tested/ kj/kg			12029.5
MNS 0669-87	Heat unit Btu/kg			23,364.3
	Heat unit /tested/ Btu/kg			11,401.8

Note: Coal to be used was tested.

- **Laboratory Results of Ash Sample:**

№	Name of the location	% of flammable substance in the slag	% of flammable substance in the ash
1	Boiler No1	14.1	9.05
2	Boiler No2	14.56	9.71

- **Flow meter test result**

Description	Unit	Value	
		Boiler No1	Boiler No2
Water was moving thru boiler at the rate	t/h	15.55	15.9
Supply water temperature leaving boiler	˚C	85.14	84.5
Return water temperature entering boiler	˚C	70.78	69.57
Temperature differential	˚C	14.36	14.93
Thermal output	kW	260.9	276.49

- **Efficiency calculation**

Description	Unit	Value	
		Boiler No1	Boiler No2
Available heat content	kJ/kg	12029.5	12029.5
Rate	kg/h	101.25	106.25
Heating potential	kW	338.33	355.037
Heat output	kW	260.9	276.49
Heat loss	kW	77.43	78.547
Efficiency (output/potential)	%	77.1	77.87

Heat content lost thru incomplete coal combustions and stack are the difference between input and output, in these cases 77.43 and 78.547 kW are wasted heat energy accordingly. 22.9 % and 22.13 % of the potential heat energies are wasted accordingly. Approximately 12.59 % and 13.1 % of the coals remain unburned in ashes removed from boilers.

5. Conclusion

1. Climate of testing day was warm. So return water temperatures were high due to less heat consumption. Regarding to those reason boilers were not fueled with their full capacities. This does not affect boiler emission and efficiency performance tests' results.
2. The Khoyulaa Khuu at the Bayanzurkh district site has received very good performing boilers as confirmed by test results. Test result shows the boilers are met with performance specification requirements as well as standard requirements.
3. Higher than standard efficiencies are experienced by current configuration. For each unit of money spent in heat energy of coal 77.8% of that unit is used, the remaining 22.2% is lost in waste for the boiler number 2. For each unit of money spent in heat energy of coal 77.1% of that unit is used, the remaining 22.9% is lost in waste for the boiler number1.
4. DZL-0.7 boiler tightness and body insulation is very good which reduces heat loss and improves its performance.
5. The TSP was reduced due to installation of a scrubber.

Followings are photos to show testing procedure at the Khoyulaa Khuu at the Bayanzurkh district.

Photo. 1. Coal weighting

Photo. 2. Coal combustion in the furnace

a. b.

Photo 3. a. Inlet water temperature, b. Outlet water temperature

Photo. 5. PM measurement

Photo. 6. TSP measurement

Photo. 7. Gas analyze.

Photo.8. Air velocity measurement

INVESTMENT DEPARTMENT OF THE CAPITAL CITY

EXPERIMENT AND RESEARCH CENTER FOR BOILER OF THE MUST

HOB TEST REPORT FOR IKH ZASAG LAW DEPARTMENT

Date:	**Developed by:** **Experiment and research center for boiler of the MUST**	**Tseyen-Oidov. O**
Date:	**Approved by:** **Investment Department of the Capital City**	**Zayamandakh. O**
Date:	**Accepted by:** **EEP, MCA-M**	**Mangal. S**

2012

1. Executive summary

Emission test of the newly installed HOB was conducted through "The Research and Experiment Center for Boilers" regarding contract between IDCC and the center.

2. Purpose

The objectives of the testing are:

(i) to verify proper functioning of the equipment/system after installation; and

(ii) to verify that the performance of the installed equipment/systems meet with the specified performance specification.

(iii) to capture and record performance data of the whole installation as the baseline for future operation and maintenance.

3. General information

- **Testing team**

No	*Position*	*Name*	*Profession*
1	Testing team leader	J. Tseyen-Oidov	Thermal engineer
2	Testing team member	B. Battur	Thermal engineer
3	Testing team member	Sh. Jambaltsanjid	Thermal engineer
4	Testing team member	A. Tumenbayar	Thermal engineer
5	Testing team member	B. Ganzorig	HVAC engineer

- Site information

HOB emission and efficiency test was conducted at the Ikh zasag University Law Department. Old DZL-1.4 HOB was replaced with new DZL-1.4 HOB at the site by the San and NRGM joint partner.

- Testing equipment

Following described equipments were used in the testing.

Num	Equipment name or mark	Measurement description	Calibration due date
1	Testo 350	Emissions- CO, CO2, NOx, SOx, O2 Combustion Efficiency- % by volume	December 2012
2	TSI Dust Trak 8533 w/diluter and air blower	Particulate Matter Counter- PM10, PM2.5	Calibrated before every test
3	Portaflow PT500	Energy Flow Metering- HWS & HWR Temperatures, Fluid Flow rate, & BTU/Hr	July 2013
4	Gravimetric filter	Particulate Matter TSP	Calibrated before every test
5	Testo 405 anemometer	Air speed to determine combustion air	August 2013
6	Electric scale	To weigh coal to be fed	July 2013
7	Infrared thermometer	To determine boiler surface temperature (Boiler tightness)	May 2014

Testing procedure

Testing was conducted on 09.09.2012

Outdoor temperature during testing was approximately 16.5 ^{o}C

Boiler was fired for 4 hours starting 18:00 completing at 22:00. The DZL-1.4 boiler is mechanically fed rate of 153.75 kg per hour. The ash was removed continuously.

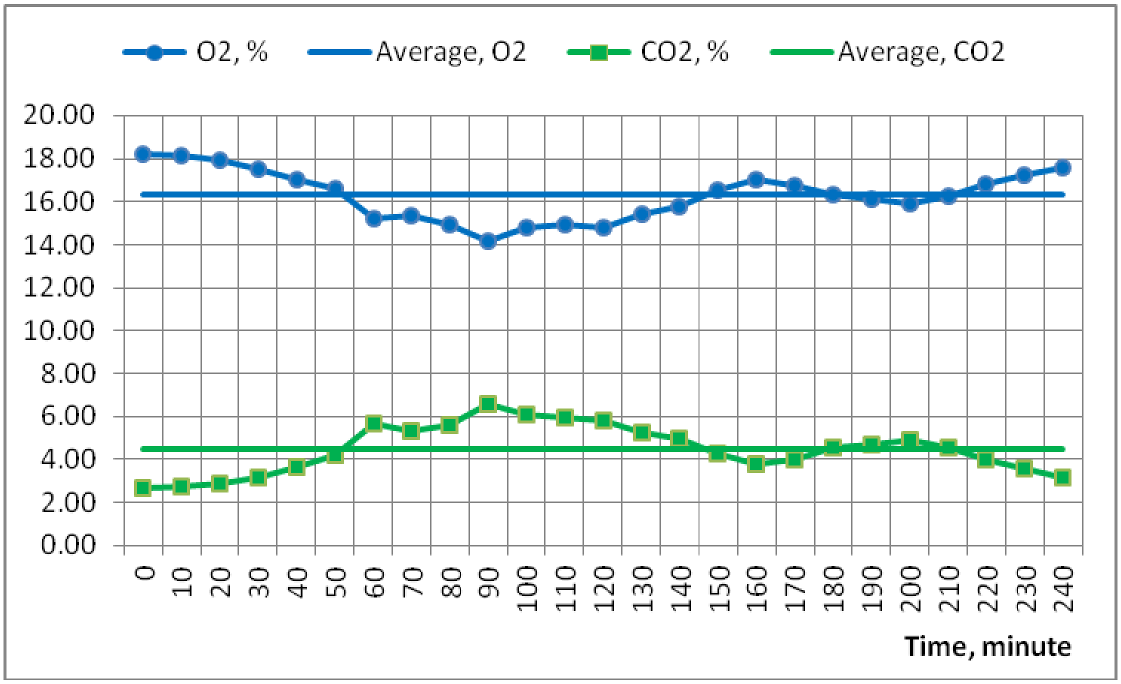
DZL- 1.4 boiler is the mechanic boiler that removes ash continuously and feeds coal continuously. The scrubber was operated throughout testing procedure.

Weather was warm the day test conducted. So the boilers were not fired at full their full capacity. Winter the boilers capacity will increase due to cold temperature. Coal consumption will increase related to capacity but emission concentration will not be changed. Capacity does not reflect to boiler emission directly.

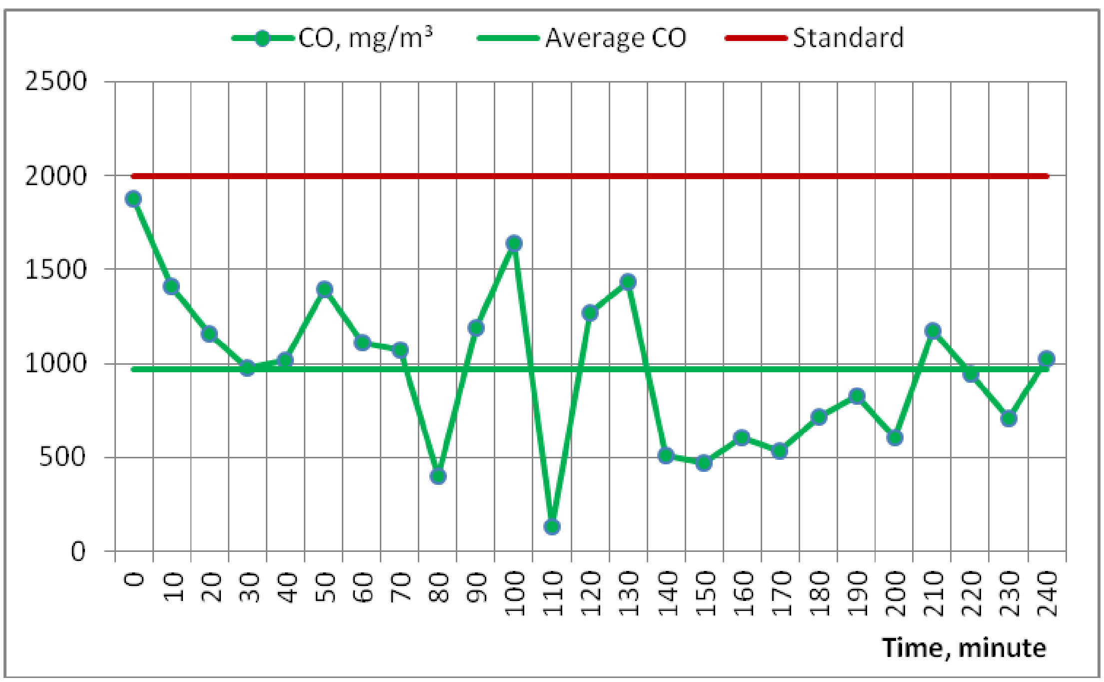
4. Emission test result

Equip	Emission	Unit	Measured Value	Standard value/ Perf Spec value	Note
Testo 350 XL	O2	%	16.3	NA	-
	CO2	%	4.48	NA	-
	CO	mg/m3	967.84	2000/2000	Passed/Passed
		kg/t	22.82	30.0	Passed
	NO	mg/m3	215.55	400	Passed
		kg/t	5.16	6.0	Passed
	SO2	mg/m3	365.64	600	Passed
		kg/t	8.83	9	Passed
TSI Dust Trak 8533	PM 10*	mg/m3	13.52	300/200	Passed/Passed
		kg/t	0.07282	4.5	Passed
	PM 2.5*	mg/m3	13.42	300/200	Passed/Passed
		kg/t	0.07323	4.5	Passed
Gravimetric filter	TSP	mg/m3	138.45	300/200	Passed/Passed
		kg/t	1.8	4.5	Passed
Infrared thermometer	Stack temp	˚C	125.7		-
Testo 350 XL	Excess air level	%	222		-

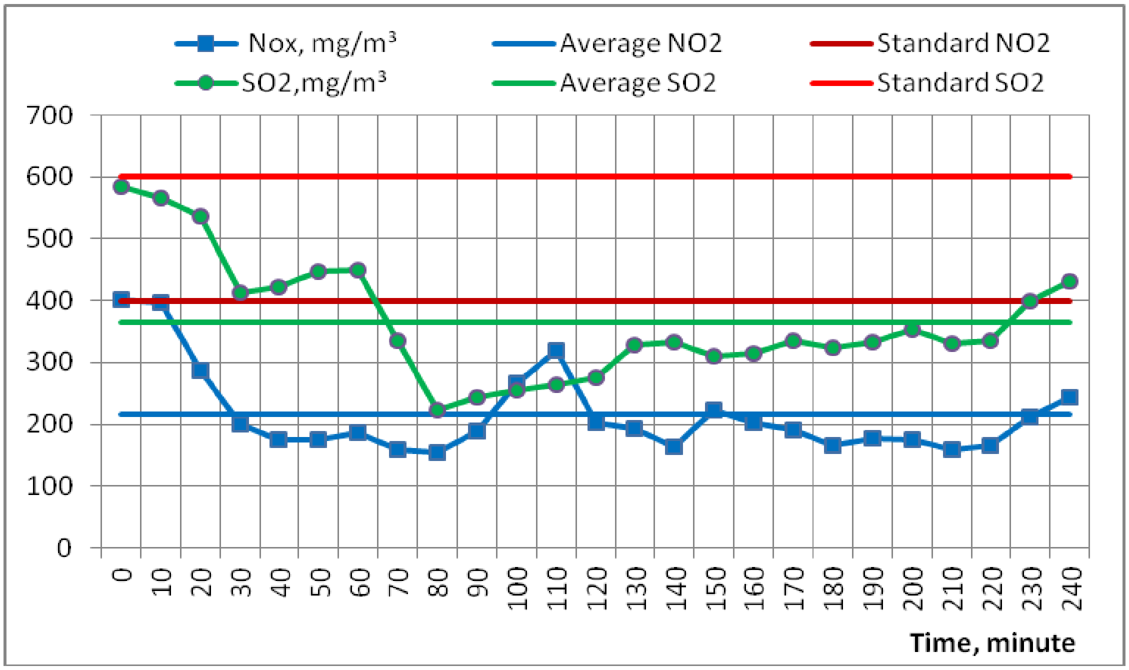
Test result shows converted calculation of the actual test result that assumes excess air level at 25%.



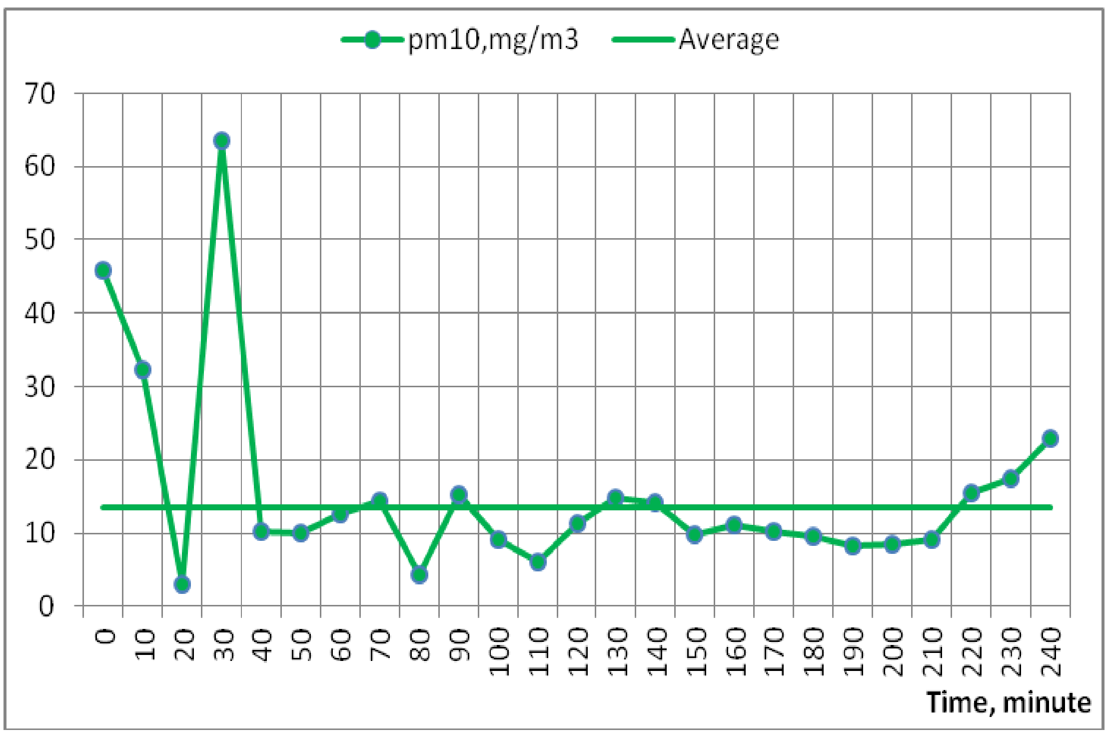
Graph1. O2 and CO2 emissions' results throughout testing



Graph2. CO emission result throughout testing



Graph3. SO2 and NOx emissions' results throughout testing



Graph4. PM10 emission result throughout testing

Laboratory Results of Coal Used for Boiler Fuel:

Standard	Description	Coal source/ value		
				Nalaikh
MNS 655-79	Moisture %			23.2
MNS ISO 0652-79	Ash %			16.08
MNS 0669-87	Heat unit kcal/kg			6297.8
	Heat unit /tested/ kcal/kg			3824
MNS 0669-87	Heat unit kj/kg			26387.6
	Heat unit /tested/ kj/kg			16022.6
MNS 0669-87	Heat unit Btu/kg			24,444
	Heat unit /tested/ Btu/kg			16,421

Note: Coal to be used was tested.

Laboratory Results of Ash Sample:

№	Name of the location	% of flammable substance in the slag	% of flammable substance in the ash
	Ikh zasag University Law Department	27.3	8.61

Flow meter test result

Description	Unit	Value
Water was moving thru boiler at the rate	t/h	30.468
Supply water temperature leaving boiler	˚C	92.16
Return water temperature entering boiler	˚C	76.92
Temperature differential	˚C	15.24
Thermal output	kW	540.0

Efficiency calculation

Description	Unit	Value
Available heat content	kJ/kg	16022.6
Rate	kg/h	153.7
Heating potential	kW	684.07
Heat output	kW	540.0
Heat loss	kW	144.08
Efficiency (output/potential)	%	78.9

Heat content lost thru incomplete coal combustion and stack is the difference between input and output, in this case 144.08 kW, is wasted heat energy. 21.1 % of the potential heat energy is wasted. Approximately 21.7 % of the coal remains unburned in ash removed from boiler.

5. Conclusion

1. Climate of testing day was warm. So return water temperature was high due to less heat consumption. Regarding to this reason boiler was not fueled with its full capacity. This does not affect boiler emission and efficiency performance test result.
2. The Ikh zasag University Law Department site has received a very good performing boiler as confirmed by test results. Test result shows that the boilers are met with performance specification requirements as well as standard requirements.
3. Higher than standard efficiency is experience by current configuration. For each unit of money spent in heat energy of coal 78.9% of that unit is used, the remaining 21.1 % is lost in waste.
4. DZL-1.4 boiler tightness and body insulation is very good which reduces heat loss and improved its performance.
5. The TSP was reduced due to installation of a scrubber.

Followings are photo to show testing procedure at the kg zasag Law department.

Photo 1. Coal weighting

Photo 2. Coal feeding

a.

b.

Photo 3. a. Inlet water temperature; b. Outlet water temperature

Photo 4. PM measurement

Photo 5. TSP measurement

Photo 6. Gas analyze.

Photo 7. Measurement during the test

INVESTMENT DEPARTMENT OF THE CAPITAL CITY

EXPERIMENT AND RESEARCH CENTER FOR BOILER OF THE MUST

HOB TEST REPORT FOR US-15

Date:	**Developed by:** **Experiment and research center for boiler of the MUST**	**Tseyen-Oidov. O**
Date:	**Approved by:** **Investment Department of the Capital City**	**Zayamandakh. O**
Date:	**Accepted by:** **EEP, MCA-M**	**Mangal. S**

2012

1. Executive summary

   Emission test of the newly installed HOB was conducted through “The Research and Experiment Center for Boilers” regarding contract between IDCC and the center.

2. Purpose

   The objectives of the testing are:

   (i) to verify proper functioning of the equipment/system after installation; and

   (ii) to verify that the performance of the installed equipment/systems meet with the specified performance specification.

   (iii) to capture and record performance data of the whole installation as the baseline for future operation and maintenance.

3. General information

- **Testing team**

No	*Position*	*Name*	*Profession*
1	Testing team leader	J. Tseyen-Oidov	Thermal engineer
2	Testing team member	B. Battur	Thermal engineer
3	Testing team member	Sh. Jambaltsanjid	Thermal engineer
4	Testing team member	A. Tumenbayar	Thermal engineer
5	Testing team member	B. Ganzorig	HVAC engineer

- Site information

  HOB emission and efficiency test was conducted at the US-15 site. Old BZUI-100 HOBs were replaced with new DZL-1.4 HOB at the site by the Khurd Co., Ltd.

- Testing equipment

Following described equipments were used in the testing.

Num	Equipment name or mark	Measurement description	Calibration due date
1	Testo 350 XL	Emissions- CO, CO2, NOx, SOx, O2 Combustion Efficiency- % by volume	December 2012
2	TSI Dust Trak 8533 w/diluter and air blower	Particulate Matter Counter- PM10, PM2.5	Calibrated before every test
3	Portaflow PT500	Energy Flow Metering- HWS & HWR Temperatures, Fluid Flow rate, & BTU/Hr	July 2013
4	Gravimetric filter	Particulate Matter TSP	Calibrated before every test
5	Testo 405 anemometer	Air speed to determine combustion air	August 2013
6	Electric scale	To weigh coal to be fed	July 2013
7	Infrared thermometer	To determine boiler surface temperature (Boiler tightness)	May 2014

- Testing procedure

Testing was conducted on 11.10.2012

Outdoor temperature during testing was approximately 3.5 ^{o}C

Boilers were fired for 4 hours starting 21:40 completing at 02:40 am. The DZL-1.4 boilers are mechanically fed rate of 177.5 kg per hour, 168.75 kg per hour and 184 kg per hour. The ashes were removed continuously. DZL- 1.4 boiler is the mechanic boiler that removes ash continuously and feeds coal continuously.

Boilers were tested at the same time. Equipment that used in the first boiler was transferred to the third boiler since there were two sets of testing equipment. One time testing duration for the specific testing was 10min for the boiler one and three. The scrubber was operated throughout testing procedure.

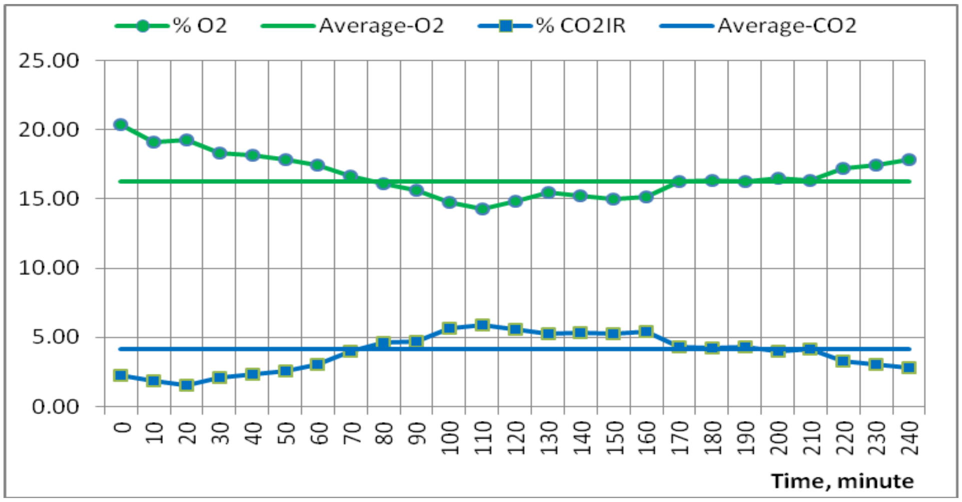
Weather was warm the day test conducted. So the boilers were not fired at full their full capacity. Winter the boilers capacity will increase due to cold temperature. Coal consumption will increase related to capacity but emission concentration will not be changed. Capacity does not reflect to boiler emission directly.

4. Test result

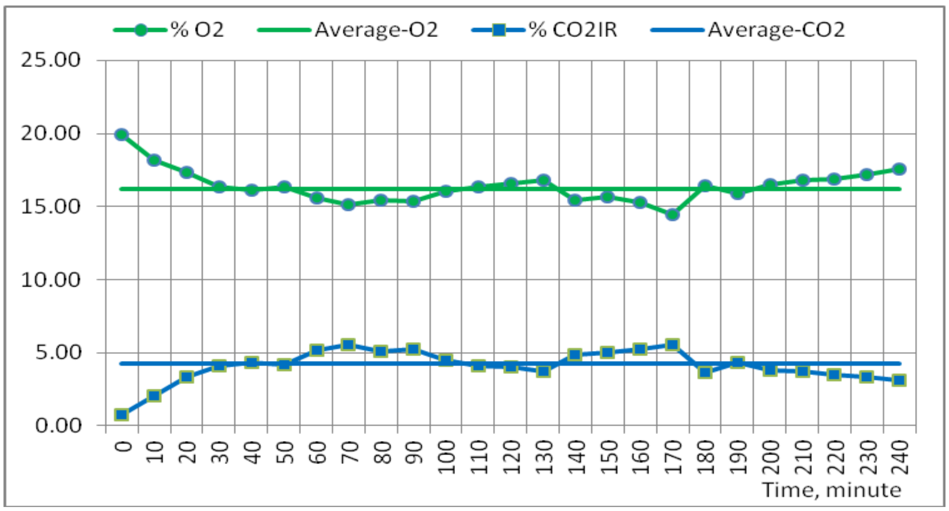
- Emission test result

Equip	Emission	Unit	Measured Value			Standard value/ Perf Spec value	Note
			Boiler No1	Boiler No2	Boiler No3		
Testo 350 XL	O_2	%	16.32	16.24	16.15	NA	-
	CO_2	%	4.18	4.23	4.44	NA	-
	CO	mg/m3	1164.8	1177.5	1154.7	2000/2500	Passed/Passed
		kg/t	28.69	26.52	25.97	30.0	Passed
	NO	mg/m3	245.59	258.92	251.88	400	Passed
		kg/t	5.65	5.81	5.71	6.0	Passed
	SO_2	mg/m3	346.05	373.63	378.17	600	Passed
		kg/t	8.23	8.43	8.52	9	Passed
TSI Dust Trak 8533	PM 10	mg/m3	15.687	14.318	13.819	400/200	Passed/Passed
		kg/t	0.0747	0.0688	0.644	4.5	Passed
	PM 2.5	mg/m3	15.894	14.272	13.775	400/200	Passed/Passed
		kg/t	0.0758	0.0686	0.642	4.5	Passed
Gravimetric filter	TSP	mg/m3	81.84	89.8	98.74	300/200	Passed/Passed
		kg/t	0.955	1.034	1.0599	4.5	Passed
Infrared thermomet	Stack temp	˚C	121.8	115.49	112.57	-	-
Testo 350 XL	Excess air level	%	252.6	240.7	262.65	-	-

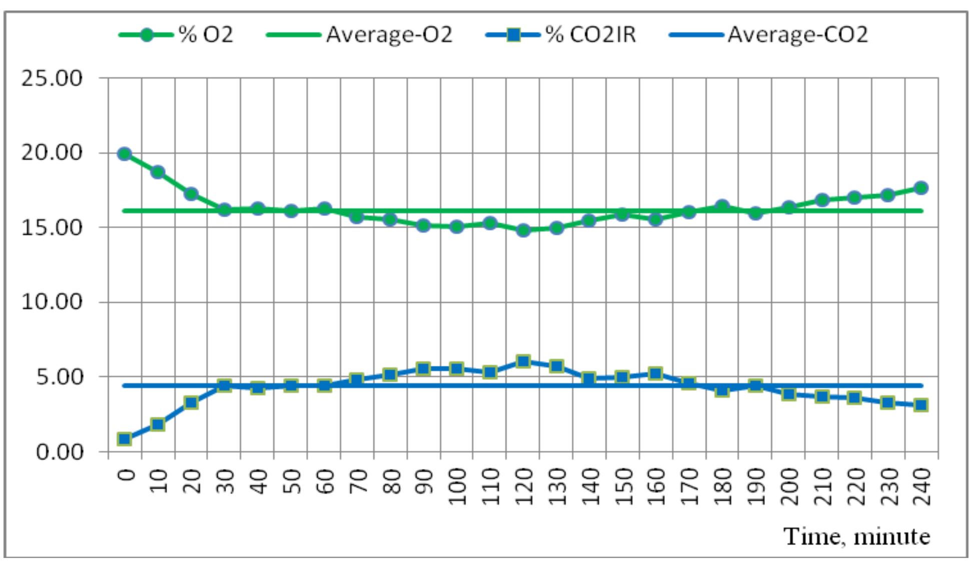
Test result shows converted calculation of the actual test result that assumes excess air level at 25%.



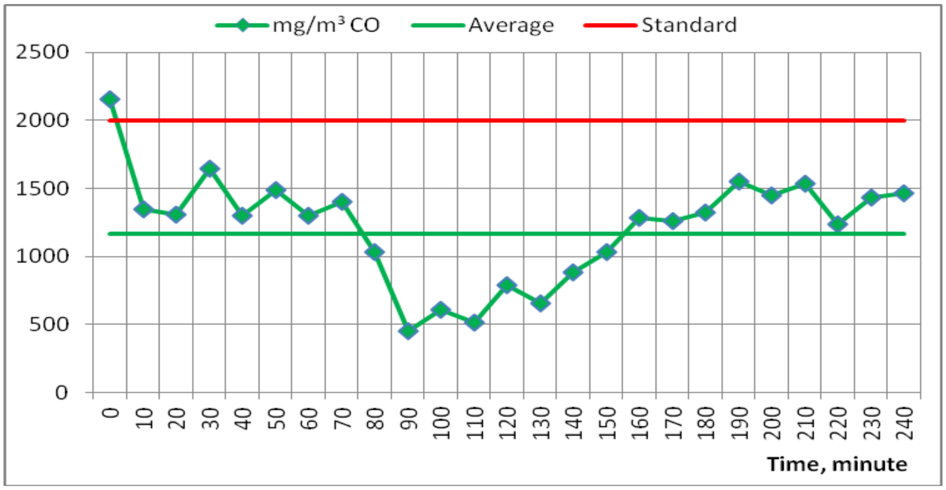
Graph1. O2 and CO2 emissions' results throughout testing for boiler No1



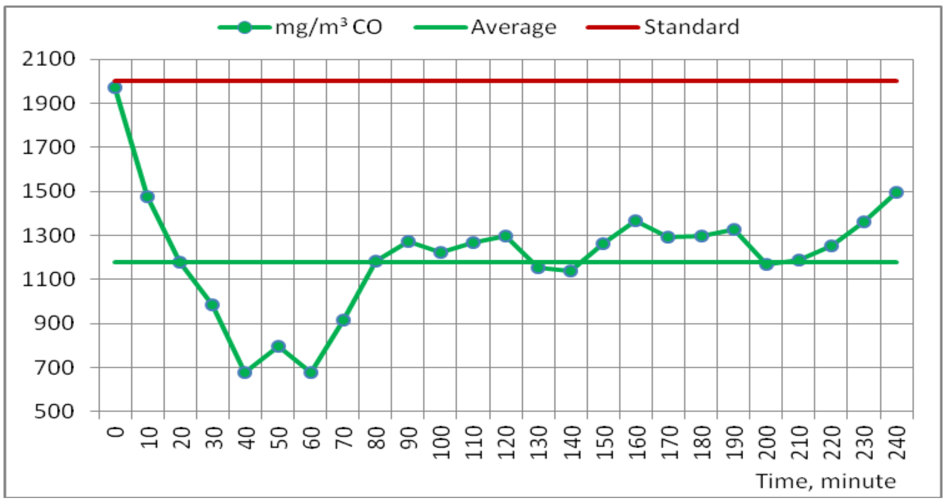
Graph2. O2 and CO2 emissions' results throughout testing for boiler No2



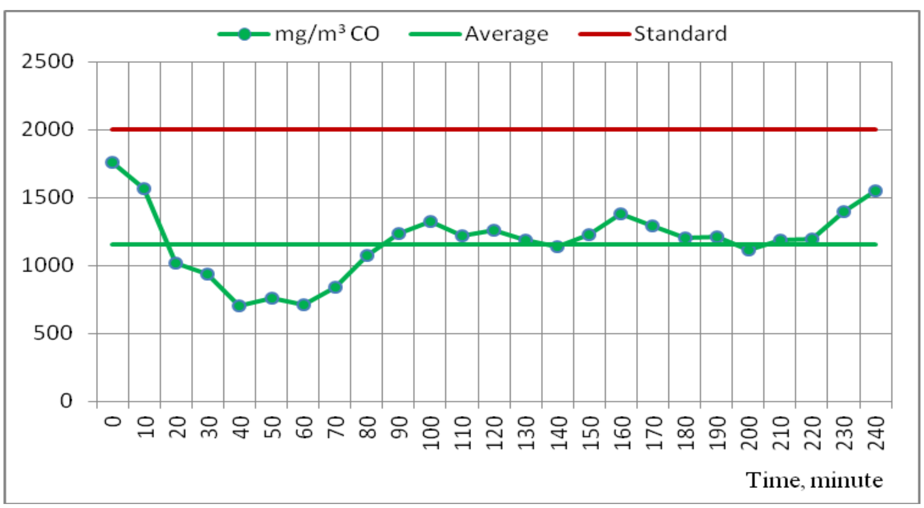
Graph3. O2 and CO2 emissions' results throughout testing for boiler No3



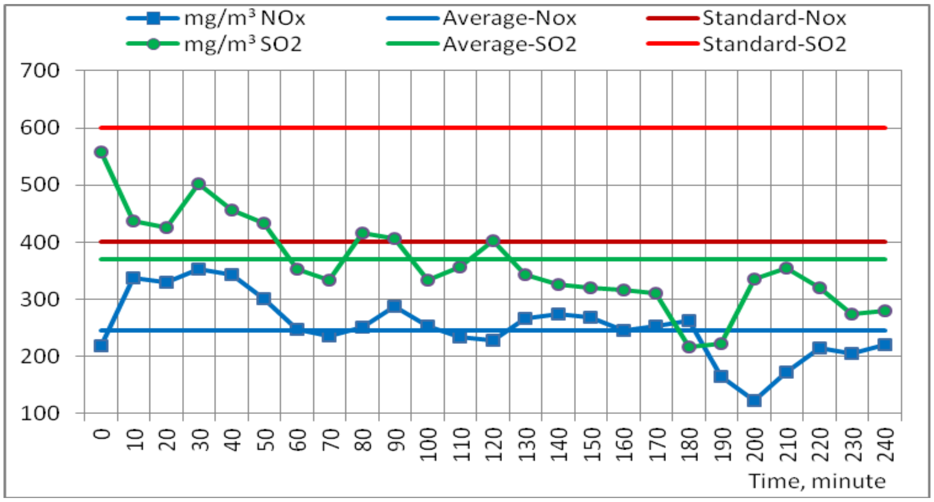
Graph4. CO emission result throughout testing for boiler No1



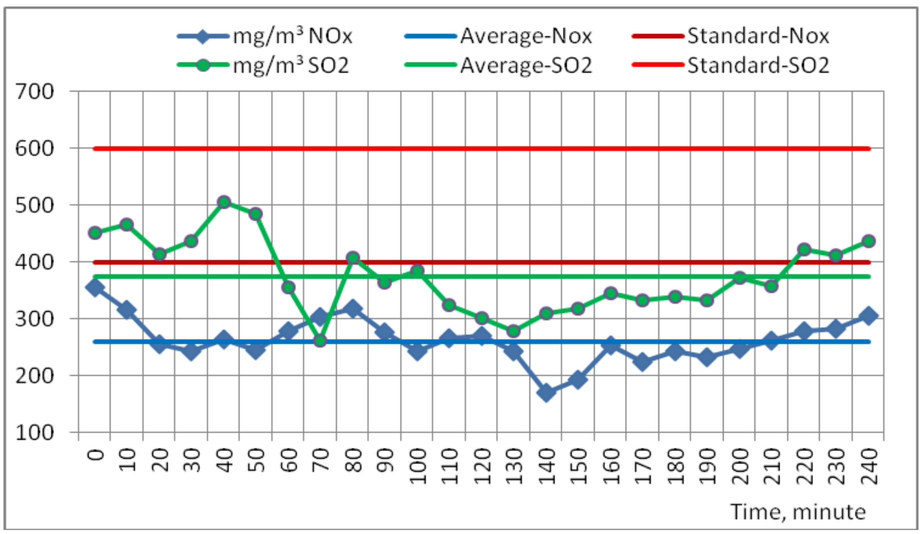
Graph5. CO emission result throughout testing for boiler No2



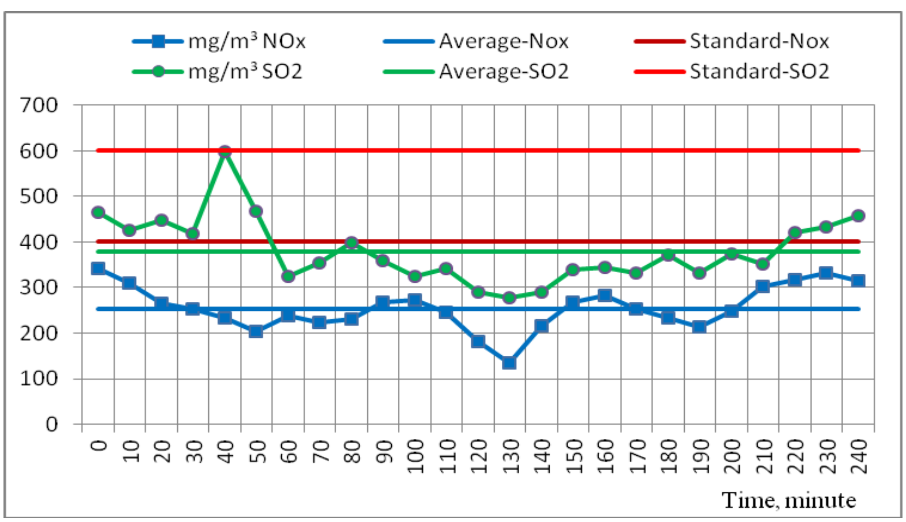
Graph6. CO emission result throughout testing for boiler No3



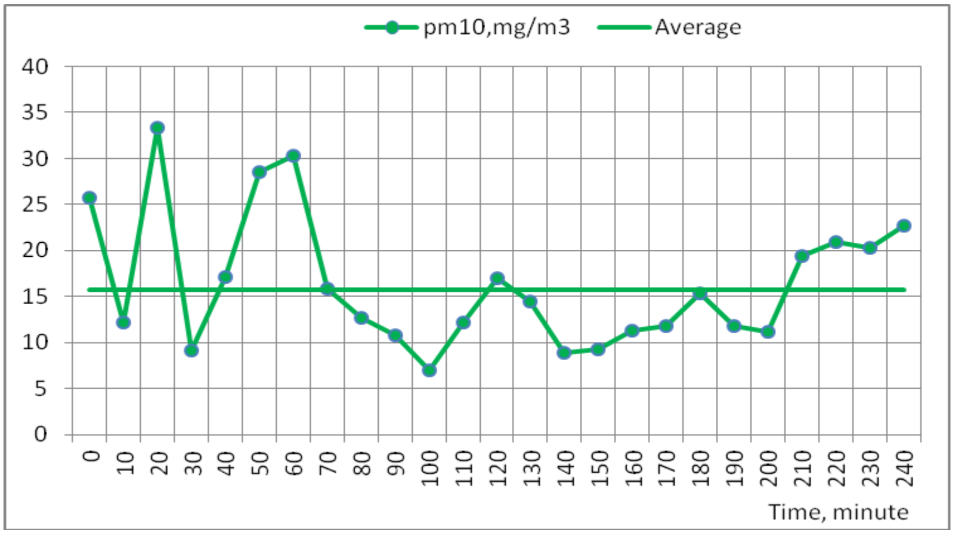
Graph7. SO2 and NOx emissions' results throughout testing for boiler No1



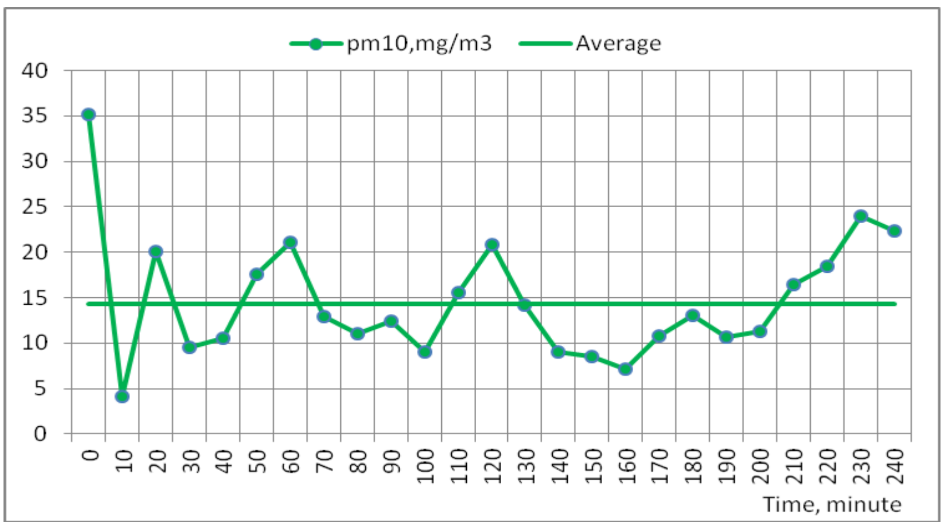
Graph8. SO2 and NOx emissions' results throughout testing for boiler No2



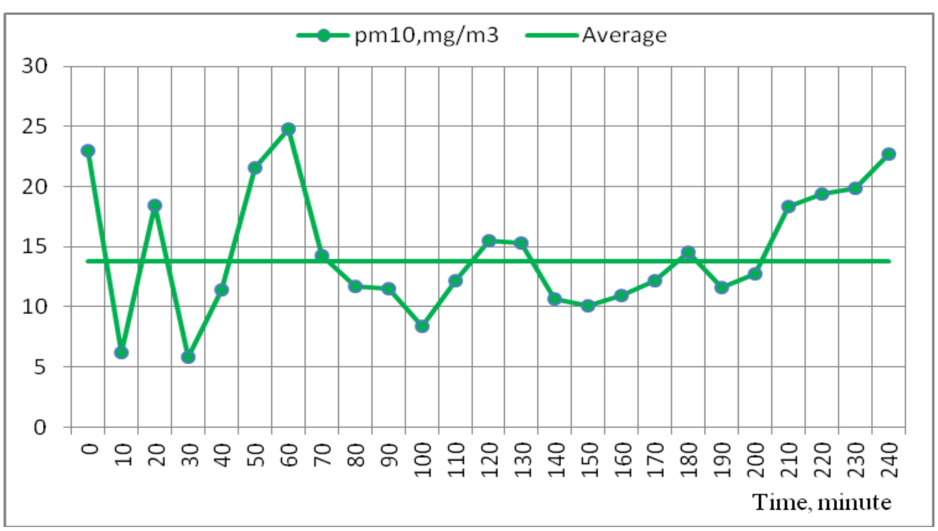
Graph9. SO2 and NOx emissions' results throughout testing for boiler No3



Graph10. PM10 emission result throughout testing for boiler No1



Graph11. PM10 emission result throughout testing for boiler No2



Graph12. PM10 emission result throughout testing for boiler No3

- **Laboratory Results of Coal Used for Boiler Fuel:**

Standard	Description	Coal source/ value		
				Alagtolgoi
MNS 655-79	Moisture %			23.5
MNS ISO 0652-79	Ash %			15.4
MNS 0669-87	Heat unit kcal/kg			6284.7
	Heat unit /tested/ kcal/kg			3840
MNS 0669-87	Heat unit kj/kg			26333
	Heat unit /tested/ kj/kg			16089
MNS 0669-87	Heat unit Btu/kg			24,958.9
	Heat unit /tested/ Btu/kg			15,249.5

Note: Coal to be used was tested.

- **Laboratory Results of Ash Sample:**

№	Name of the location	% of flammable substance in the slag	% of flammable substance in the ash
1	Boiler No1	19.89	11.55
2	Boiler No2	20.34	12.48
3	Boiler No3	18.1	14.65

- **Flow meter test result**

Description	Unit	Value		
		Boiler No1	Boiler No2	Boiler No3
Water was moving thru boiler at the rate	t/h	41.44	40.19	39.11
Supply water temperature leaving boiler	˚C	81.12	80.6	82.75
Return water temperature entering boiler	˚C	68.36	68.16	68.67
Temperature differential	˚C	12.76	12.44	14.08
Thermal output	kW	615.79	581.7	641.9

- **Efficiency calculation**

Description	Unit	Value		
		Boiler No1	Boiler No2	Boiler No3
Available heat content	kJ/kg	16089.6	16089.6	16089.6
Rate	kg/h	177.5	168.75	184.0
Heating potential	kW	793.3	754.2	822.36
Heat output	kW	615.78	581.71	641.9
Heat loss	kW	177.52	172.49	180.46
Efficiency (output/potential)	%	77.62	77.13	78.06

Heat content lost thru incomplete coal combustions and stack are the difference between input and output, in these cases 177.52 kW, 172.49 kW and 180.46 kW are wasted heat energy accordingly. 22.38 %, 22.87 % and 21.94 % of the potential heat energies are wasted accordingly. Approximately 17.4 % , 17.98 % and 17.065 % of the coals remain unburned in ashes removed from boilers.

5. Conclusion

1. Climate of testing day was warm. So return water temperatures were high due to less heat consumption. Regarding to those reason boilers were not fueled with their full capacities. This does not affect boiler emission and efficiency performance tests' results.
2. The US-15 Ulaanbaatar city heating stoves regulatory authority site has received very good performing boilers as confirmed by test results. Test result shows that the boilers are met with performance specification requirements as well as standard requirements.
3. Higher than standard efficiencies are experienced by current configuration. For each unit of money spent in heat energy of coal 78.06 % of that unit is used, the remaining 21.96 % is lost in waste for the boiler number 3. For each unit of money spent in heat energy of coal 77.13% of that unit is used, the remaining 22.87% is lost in waste for the boiler number 2. For each unit of money spent in heat energy of coal 77.62 % of that unit is used, the remaining 22.38% is lost in waste for the boiler number1.
4. DZL-1.4 boiler tightness and body insulation is very good which reduces heat loss and improves its performance.
5. The TSP was reduced due to installation of a scrubber.

Followings are photos to show testing procedure at the US -15site.

Photo. 1. Coal weighting

Photo. 2. Coal combustion

a. b.

Photo 3. a. Inlet water temperature; b. Outlet water temperature.

Photo 4. PM measurement

Photo 5. TSP measurement

Photo 6. Gas analyze.

Photo 7. Water rate measurement

Photo 8. Air velocity measurement   Photo 9. Testing procedure