Energy Efficiency and Air Quality Repairs at Lyonsdale Biomass

FINAL REPORT
Lewis County Industrial Development Agency
DE-EE-00003131
Prepared by
Michael R. Brower, Mosaic Federal Affairs LLC
May 29, 2012 (Amended 06/25/12)

Purpose of the Congressionally Designated Project

This project was designed to improve the heat and power production efficiency and air quality of the Lyonsdale Biomass Plant in Lyons Falls, New York. Additionally, the project included the first-ever U.S. commercial scale, wholly operational integration of purpose-grown shrub willow energy crops into commercial production of biomass heat and power.

Project Team

The Project Team was led by County of Lewis (NY) Industrial Development Agency in collaboration with Lyonsdale Biomass LLC and Catalyst Renewables LLC and included subcontractors Mitsubishi Power Systems Americas Inc., Turbine Generator Consulting, Inc., Atlantic Contracting & Specialties LLC, LC Precision, Acorn Instruments, Sach/Salverti, Peaker Services, Kaman Industrial Tech, DolHof Hardware, Safety Kleen, McMaster &Co, Applied Industrial Tech, M. Monks, Sherman Electrical, Boonville NAPA, NOCO Lube, Barney Builders, Pacemaker Pipe, Newark Electricians, Fastenal, and Rig-All

Approved Statement of Project Objectives

This project enabled Lyonsdale Biomass, LLC to effect analyses, repairs and upgrades for its biomass cogeneration facility located in Lewis County, New York and close by the Adirondack Park to reduce air emissions by improving combustion technique and through the overall reduction of biomass throughput by increasing the system's thermodynamic efficiency for its steam-electrical generating cycle. Project outcomes result in significant local, New York State, Northeast U.S. and national benefits including improved renewable energy operational surety, enhanced renewable energy efficiency and more freedom from foreign fossil fuel source dependence. Specifically, the reliability of the Lyonsdale Biomass 20MWe woody biomass combined-heat and power (CHP) was and is now directly enhanced. The New York State and Lewis County benefits are equally substantial since the facility sustains 26 full-time equivalency (FTE) jobs at the facility and as many as 125 FTE jobs in the biomass logistics supply chain. Additionally, the project sustains essential local and state payment in lieu of taxes revenues.

This project helps meet several USDOE milestones and contributes directly to the following sustainability goals:

- Climate: Reduces greenhouse gas emissions associated with bio-power production, conversion and use, in comparison to fossil fuels.
- Efficiency and Productivity: Enhances efficient use of renewable resources and maximizes conversion efficiency and productivity.

- Profitability: Lowers production costs.
- Rural Development: Enhances economic welfare and rural development through job creation and income generation.
- Standards: Develop standards and corresponding metrics for ensuring sustainable bio-power production.
- Energy Diversification and Security: Reduces dependence on foreign oil and increases energy supply diversity.
- Net Energy Balance: Ensures positive net energy balance for all alternatives to fossil fuels.

Project Scope

The scope of the project conducted turbine-generator efficiency improvements since the generator driver having operated for nearly twenty years was known to have lost efficiency.

Efficient improvements of at least 5% were anticipated. This effort contributed to the refurbishment of the turbine and help offset costs associated with mechanically upgrading the unit to "as new" condition. Additionally, a plantation fuel trial was conducted and hybrid willow was burned in varying proportions with typical biomass chips to demonstrate the efficacy of using woody energy crops in combination or alone for electrical power production. The trial, extending over multiple days and consumed 134 tons of willow chips, required use of the entire operating asset.

Tasks included were defined as Task B.1- Steam Turbine Efficiency Project and Task C.1- Plantation Fuel Burn both tasks had federal funding components. Task A-1 was the application submission. The prime recipient was responsible for overall project performance and oversight, contractual and legal matters, timely and correct reporting per contract.

Tasks Performed

Task B.1- Steam Turbine Efficiency Project made-up part of an integrated task conducted by Lyonsdale Biomass LLC, the sub-recipient. Task "B.1" received federal funding. Task B.1 took place during scheduled outage and restart trial and turned out to be essential to overall facility ability to operate based on the material condition discoveries of the turbine experts and consultants during their inspection of the idle turbine.

The outage was a pre-planned, scheduled period of turbine idle-time dedicated to project inspection/repairs/refurbishment.

This task effected examination, assessment and technical repairs directly related to improvement of future energy efficiency and air emissions quality improvement operations at the Lyonsdale biomass facility in Lewis County, New York to contribute to local economic vitality, environmental quality and energy independence through the production of heat and power from home-grown renewable energy feedstocks.

Compared to other base-load power generation facilities including coal, natural gas, and geothermal, biomass plants have more occasion to cycle-up and cycle-down for scheduled and unscheduled reasons. Such a routine lends itself to more wear and tear than other non-biomass facilities. Task B.1 found the Lyonsdale Biomass turbine to be in much poorer material condition than had been anticipated. A decision to fully repair the turbine using project funds to augment Lyonsdale Biomass LLC funds was approved by USDOE Golden.

Task B.1 moved in, set-up and prepared for outage. Task B.1 included turbine repair task identification to enhance energy efficiency and air quality, defined corrective action and repairs identified turbine repair matters to enhance energy efficiency and air quality. Task B-1 supported Start-Up and Turbine Energy Efficiency and Air Quality Improvements. Task B.1 deployed a more energy efficient turbine, which enhanced air quality. Task B.1 reported completion and outcome achievements to the prime recipient, who reported to USDOE, as agreed.

Task C.1-Plantation Fuel Trial – The commercial, operational plantation fuel trial was conducted by the sub-recipient and hybrid willow was burned in varying proportions with typical biomass chips to demonstrate the efficacy of using woody energy crops in combination or alone for heat and electrical power production. The trial, extending over multiple days and consuming several thousand tons of willow chips, required use of the entire operating asset. Task C.1 was an operational research and development energy efficiency and air quality task. Task C.1 included Facility Gate Feedstock Acceptance inspection, data collection and integration of willow biomass feedstock into the commercial handling system.

The task did not concern itself with the variety of willow clones, but rather was designed to accept willow in the same manner as forest wood chips regardless of species.

The task assessed chipped size, texture, moisture content and individual chip separation for compatibility with the operational environment. System received as many as 134 ton of willow biomass. Task C.1 included Feedstock Storage Trial to assesses various ages blends and homogeneous storage options to determine rates of decomposition and Handling Equipment Compatibility demonstrates feasibility and suitability of willow biomass feedstock with non-modified commercial woody biomass handling equipment. Task C.1 included Blending Trials with willow and mixed forest residue chips to develop operator competency and ability to integrate new feedstocks at appropriate ratios using existing commercial equipment and Instrumented Willow and Willow Blend Firing Trials converts willow blends and 100% willow into renewable electricity and thermal energy. Measured MMBTU, thermal values, effectiveness and efficiency compared to mixed forest residue chips and by technical comparison to coal. Task C.1 includes Instrumented Willow and Willow Blend Emissions Trials. Assessed Greenhouse Gas emissions of willow blends and 100% willow converted into renewable electricity and thermal energy. Tested side-by-side with mixed forest residue chips and by technical comparison to coal and Instrumented Willow and Willow Blend By-products Assessment compares PM2.5 and PM 10 and ash residues of willow blends and 100% willow converted into renewable electricity and thermal energy. Operations were tested side-by-side with mixed forest residue chips. Task-C.1 will clean up and demobilize. Task-C.1 reported completion and outcome achievements to the prime recipient, who reported to USDOE, as agreed.

Task D.1 Project Management and Reporting this task conducted by the prime recipient provided and delivered reports and other deliverables in accordance with the Federal Assistance Reporting Checklist following the instructions included therein. Task D.1 included a Project "kick-off meeting" hosted by the prime recipient and engaging all participant parties, which was conducted; Task Team Meetings, which are required at the start and end of each task; Project Review Meetings, which were conducted quarterly and a Final Wrap-Up Meeting, which was conducted and included review the draft final report and Project Final Report, which will be assembled by the Project Manager, endorsed by the prime recipient and filed with USDOE.

Accomplishments- Task B.1- Steam Turbine Efficiency Project

The integrated Turbine Task the Lyonsdale Biomass team moved-in, set-up and prepared for outage.

The team disassembled the turbine including removing the governor, bearing pedestal cover, turning gear pedestal cover, turning gear, the HP to Gear Reducer coupling guard, the HP to Gear Reducer coupling; measuring coupling alignment; removing the upper half journal bearings, unbolting main steam inlet flanges, removing the outer cylinder cover, flip cover, the upper half dummy rings, gland seal cases and diaphragms; measuring and recording the axial and radial rotor clearances; measuring the thrust bearing clearance and disassemble; removing the rotor, lower half diaphragms, lower half dummy rings and gland cases, seals from dummy rings, gland seal cases and diaphragms, lower half journal bearings. This task included detection of sources of steam leaks, energy efficiency repairs and detected significant unanticipated turbine repair issues. The team inspected the components including dust blast rotor, diaphragms, gland cases, dummy rings; NDE rotor, diaphragms, gland cases, and dummy rings; cleaning and NDE nozzle block, journal and thrust bearings; inspecting turning gear bearings, gears, backlash; dimensionally inspecting journals, bearings, and oil seals; cleaning and visually inspecting horizontal joint surfaces and main steam inlet flanges. This task included detection of sources of steam leaks energy efficiency repairs, detected more unanticipated turbine repair issues and the repair and replacement of turbine components

The team installed, assembled and measured the lower half diaphragms and internal alignment (Tight Wire); adjusted internal alignment as needed ; installed seals in dummy rings, gland seal cases and diaphragms; installed lower half journal bearings, inner glands, and dummy rings; rigs and installed the rotor; assembled the thrust bearing and measures clearance; measured and recorded axial and radial rotor clearances; installed and bolted upper half diaphragms; installed and bolted upper half inner gland cases and dummy rings; flipped, installed and bolted cylinder cover; bolted main steam inlet flanges measured HP to Gear Reducer coupling alignment and bolt coupling; installed coupling guard; installed and bolted upper half journal bearings; and installed and bolted the pedestal covers. This task included repair of steam leaks and repairs to the turbine components.

The team disassembled, inspected, and reassembled the gear reducer including removing oil seals and end caps; unbolting the Gear Reducer/Generator coupling; measuring Gear Reducer/Generator coupling alignment; removing gear cover assembly, bearing strong backs, bearing U/H's, pinion shaft, bull gear shaft, and L/H bearings; dimensionally inspected and NDE bearings and Journals, cleaned and inspected gear teeth, gear casing, and coupling faces; inspected tooth contact pattern, oil spray piping and nozzles; reassembled/installed L/H bearings, bull gear shaft, pinion shaft, bearing U/H's, bearing strong backs, gear cover assembly, and oil seals and end caps; measured Measure Gear Reducer/Generator coupling alignment and adjusting coupling alignments. This task identified significant turbine repair issues.

The team disassembled, inspected, and reassembled the High Pressure (HP) Stop Valves including disconnecting the stop valve actuators; unbolting the valve bonnet and removing the valve; and disassembling the stop valve; cleaning and NDE valve shaft and plug; dimensionally inspected the valve shaft, bushings, and seats; assembling the stop valve and recording clearances; assembled the stop valve into the bonnet; installed the valve bonnet; performed valve to seat blue checks for proper contact and reconnected the stop valve actuator; disconnecting the governor valve actuator; removed the governor valve linkage and spring assembly, governor valve rack from bonnet and the governor valve stems from rack; cleaned and inspected/NDE the valve shafts and plugs; dimensionally inspected valve shafts, bushings, and seats and reinstalling governor valves stems to rack, governor valve rack into bonnet and installed the valve bonnet; performed valve to seat blue checks for proper contact and installed linkage and spring assembly, connect actuator; disassembled, inspected and re-installed four non-return valves including removing top and side covers, valve stems, and clapper assemblies; cleaning and NDE disc, shaft, and seat; dimensionally inspected the shafts and bushings; reassembled and re-installed clapper assembly, valve stem and side covers; performed valve disc to seat blue check for proper contact and installed top cover. This task included the detection and repair of steam leaks, energy efficiency repairs and the repair and replacement of turbine components

The team conducted testing and inspections to minimize steam leaks and air in-leakage to maximize performance and efficiency. This effort also entailed providing startup support including controls engineering upon completion of the outage activities. The result of the activities yielded efficiency improvements of over 5% and demonstrated by a reduction in the total amount of steam required to generate electrical output.

The 5% performance improvement in the steam turbine corresponds to an overall facility efficiency improvement which can be considered as the ability to generate approximately 1,000 kW more post B.1 as before with the same quantity of steam or as a one-for-one reduction in fuel consumption post B.1 versus prior. Reducing fuel requirements proportionally reduces overall facility pollution emissions while reducing operating charges for fuel, a potential annual savings of $350,000 in today's market. Of equal importance, the amount of reduction in the woody biomass burned due to the B.1 5% efficiency improvement meant a direct corresponding reduction in overall facility emissions when producing pre-B.1 rates of heat and power. Reduced feedstock costs and air quality improvements appear to be more economically and socially beneficial than and additional 1,000kW of power.

Accomplishments- Task C.1-Plantation Fuel Trial

Regionally grown energy crops were evaluated for operational combustion attributes when comingled with sustainably harvested mixed hard/soft wood fuel and used to produce heat and electrical power for New York's wholesale market. This demonstration trial addressed the logistics, storage, feeding mechanics and combustion technology for plantation grown woody biomass in combination with base fuel comprised of mix northern hard and softwoods at commercial scale. Plantation fuel production economics were not evaluated as part of this trial. Varietal comparisons were not made as the trial focused on willow as field crops *en masse*.

The effort addressed the use of purpose woody energy crops in combination or alone for electrical power production. As designed, the willow trial was to be a 900-ton commercial trial, As designed the trial was to integrate optimally harvested, post-leaf-fall, dormant willow. Due to harvester availability, this task's scope was eventually conducted at 134 tons. Regardless, this was the first-ever, truly operational and commercial shrub willow "burn" ever conducted and important academic/technical testing outcomes were validated or discounted. Under this task, hybrid willow were mixed in varying proportions with typical forest biomass chips and the resulting mixture combusted. The effects of willow chips on the feedstock handling system were evaluated, including the impacts of various age blends and homogeneous storage options on rates of decomposition and handling equipment operation. Completion of this effort entailed the harvesting of locally grown energy-plantation crops, transportation to the Lyonsdale Biomass power plant, receipt and temporary storage, fuel blending prior to combustion, extended combustion at various proportions of willow, data collection and reporting.

Willow chips; harvested from within ten miles of the Lyonsdale facility and which were grown from hybrid clones produced by SUNY College for Environmental Science and Forestry (ESF) were used for this trial. Willow chips were produced during a two-day mid-October (13/14th) harvest, which occurred prior to a hard frost and prior to leaf drop, i.e., defoliation. Machinery availability dictated harvest schedule, weather conditions dictated harvest duration.

Lyonsdale Biomass' boiler system has an energy input of 290 million BTU per hour from which is generated 190,000 pounds per hour of high-pressure steam at 1200 psig and 950 °F. The steam is used to produce approximately 20,000 kilowatts per hour of net electrical power, which is competitively sold into the New York power market through a grid interconnection.

Approximately 134 tons (as received basis) of purpose grown willow chips were delivered to Lyonsdale from a local farm, Levans, located on the Tug Hill plateau some ten miles straight-line distance away on October 19 and 20, 2011.

A Case New Holland willow harvester was used to cut and chop field grown willow rods planted in 2006 and undergoing their first initial fuel production. Chips were blown from the harvester into dump wagons, which transported the chips to a temporary storage pile to await transport to Lyonsdale. A frontend loader was used to reclaim chipped material and load transporting vehicles.

Although a canvas ground barrier was used to segregate the chips from potential soil contamination, a large stone cobble is suspected to have been mistakenly included. Transportation was provided by Lyonsdale using dump trucks, which off-loaded the chips directly into the wood-yard where they remained stockpiled until being blended with whole tree chips just prior to combustion testing. The willow chips could not be offloaded through the plant's typical fuel receiving/handling system consisting of a hydraulic truck dumper, magnetic metal separator, screening, hog sizing and conveyor stack-out as dump trucks aren't compatible or suitable for the dumper.
A front-end loader would alternate buckets of willow chips and whole tree chips in proportion to that day's test recipe. The day-pile would then be turned several times ensure chip homogeneity.

The front-end loader is deposited a bucket of mixed material onto the reclaim pile directly above the under-pile Laidig reclaimer.

A fuel blending and combustion procedure was developed by Lyonsdale's plant Management; it incorporates the following plan guidelines:

- Willow testing/combustion would be conducted during normal business hours when management, maintenance are typically available;
- Only Lyonsdale personnel are to operate or control the trial;
- Fuel mixtures of 10, 20, 30 40 and 50 percent will be blended for trial testing;
- Records will be maintained and emission trending charts will be provided.

The actual testing schedule is summarized in the following Table 1. Fuel blend feeding was interrupted early on the fourth day when a large stone cobble jammed the Laidig reclaim screw, damaging its flights and preventing further auto-fuel feeding until repaired.

During a four day testing period, 134 tons of willow chips were comingled in varying proportions with whole tree chips to produce five fuel blends of 7.7, 14, 20, 25 and 45 percent by weight of hybrid willow chips.

Willow chips were feed and burned in Lyonsdale's boiler for a total trial duration of 18.5 hours accumulated over a five-day testing period. Trial duration was steady-state operation established after weaning the boiler from base to trial fuel. Trial duration was limited by the availability of plantation fuel which was hampered by fuel-harvesting equipment availability.

Samples, collected on the first day of the trial test, of hybrid willow chips and whole tree chips were double-bag sealed and mailed to a fuels testing laboratory for ultimate and proximate analyses as well as size distribution assessment. Additionally, ultimate and proximate analyses were prepared for a sample of the 10:1 by volume (7.7 wt%) fuel blend.

Hazen Research Inc's analytical results were completed and reported as of December 8th in comparative format (see Appendices). Chip size distribution was examined on a cumulative weight percentage basis. Both willow and whole tree chips have similar distributions with willow being roughly ten-percent smaller –or having more fines.

Most significant analytical factors affecting the combustion characteristics of heat content and flue gas emissions are:
• Willow chips have significantly higher moisture content;
• Willow chips have higher ash content although within typical biomass values, its likely due to a higher proportion of bark material in the willow versus the larger diameter feedstock of the whole tree chips;
• A order of magnitude higher nitrogen content is believed due to leafy matter included with the harvested chips;
• Consequently, the willow chip gross heating value is decidedly lower than the base biomass fuel.

General Trial Observations, Trends- Task C.1-Plantation Fuel Trial

Charts for various performance parameters were developed for NOx emissions, CO emissions, stack O2, opacity, forced draft air, over fire air, steam pressure, steam temperature and steam flow. Each testing period was charted over the primary trial runs of November 15th , 16th , 17th and 21st, 2011. This contributed measurably to operational understanding of the effect of reduction of greenhouse gas emissions associated with bio-power production, conversion and use, in comparison to fossil fuels. (See Attachment E)

The charts consistently show elevated NOx production relative to base fuel operation likely owing to higher fuel bound nitrogen in the willow chips; higher carbon monoxide emissions resulting from poor combustion due to higher moisture content in the willow fuel. (shown in Attachment E). This implies a negative air quality effect, which was anticipated from past academic testing of green, wet willow and validated operationally. This contributed measurably to operational understanding of the effect of reduction of greenhouse gas emissions associated with bio-power production, conversion and use, in comparison to fossil fuels and to develop standards and corresponding metrics for ensuring sustainable bio- power production.

Evaluation of the events, analyses, operator logs and oral comments and trending charts conclude with the following findings:

• Hybrid willow chips harvested while in leaf have significantly higher nitrogen content than mixed northern whole tree chips; which helps measurably to develop standards and corresponding metrics for ensuring sustainable bio- power production

• Willow chips have higher moisture content and a lower heating value than typical forest biomass chip fuel; however, during this operational test, any increase in ash content was negligible to the operators and was not enough to garner mention. This helps enhance efficient use of renewable resources and understanding of what maximizes conversion efficiency and productivity

• When fully operational, the Case New Holland willow harvesting machinery produced chipped material in similar size range and distribution as commercially harvested whole tree chips; however, operational availability of the Case New Holland willow harvester and support machinery was not deemed commercially suitable or effective. This tells us something must be done to lowers production costs and enhance profitability.

• Material handling of willow chips is similar with whole tree chips and intermixing of chips is not problematic; which tells us we can achieve efficient use of renewable purpose grown willow feedstocks and maximize the handling efficiency and productivity, which can lead to lower production costs.

• Willow combustion perceptively increased NOx production although not directly proportional with willow feed rate; this contributed measurably to operational understanding of the effect of reduction of greenhouse gas emissions associated with bio-power production, conversion and use, in comparison to fossil fuels and to develop standards and corresponding metrics for ensuring sustainable bio- power production

• Carbon monoxide increased with willow chips but not directly proportional to willow feed rate; this contributed measurably to operational understanding of the effect of reduction of greenhouse gas emissions associated with bio-power production, conversion and use, in comparison to fossil fuels and to develop standards and corresponding metrics for ensuring sustainable bio- power production

• Operators reported no significant issues when combusting willow fuel concentration across the entire trial concluding at fifty-volume percent; this helps enhance efficient use of renewable resources and understanding of what maximizes conversion efficiency and productivity. Additionally, this outcome directly enhances economic welfare and rural development through job creation and income generation by showing a an operational way ahead for purpose grown woody biomass crops.

• Plantation grown, hybrid willow produces a suitable fuel for comingling with mix northern whole tree chips for electrical power production. This contributes to energy diversification and security by reducing dependence on foreign oil and increasing energy supply diversity.

• This trial demonstrates hybrid willow chips may be comingled with northern mix whole tree chips for biomass fueled energy production without prohibitive mechanical or thermodynamic consequence; this contributes to energy diversification and security by reducing dependence on foreign oil and increasing energy supply diversity.

• For this trial and despite significant investment of time and money by SUNY-ESF and their funding partners, the present harvesting system for plantation willow is still inefficient and inadequate for commercial operations.

• A more weather tolerant (robust) harvesting mechanism must be found for plantation willow harvest in order to ensure ready and optimum availability of material and to gain commercial acceptance as a traditional biomass fuel supplement; this helps develop standards and corresponding metrics for ensuring sustainable bio-power production.

• Willow harvesting would benefit from closer adherence to general logging practices which minimizes material handling, allows for foul weather harvesting and directly loads product into chip vans that can be conventionally off-loaded via a truck dump apparatus; this helps develop standards and corresponding metrics for ensuring sustainable bio- power production.

• For plantation grown hybrid willow to be a one-for-one replacement for northern mixed whole tree chips, harvested material should be defoliated prior to harvest and allowed sufficient time to lose moisture and attain higher gross heating values. Note, willow harvesting techniques in Ireland and elsewhere in Europe using stem harvesters and whole tree circumference banded willow stem bundles stacked off the ground for a season reduced inherent moisture by more than 80 percent and achieved total loss of leaf matter. Such bundles would most efficiently be processed through a standard whole tree chipper similar as round wood. This will help develop standards and corresponding metrics for ensuring sustainable bio- power production and enhance efficient use of renewable resources and help maximize conversion efficiency and productivity.

Conclusion

This successful project was an excellent example of a Congressionally Designated Project "done right:" completed on time with significantly important results. Federal funds leveraged an overall 5% energy efficiency gain equal to 1,000 kW for the Lyonsdale Biomass co-generation facility. Given today's market that equals $350,000, a significant savings, to Lyonsdale Biomass' bottom-line when producing heat and power at pre-project rates.

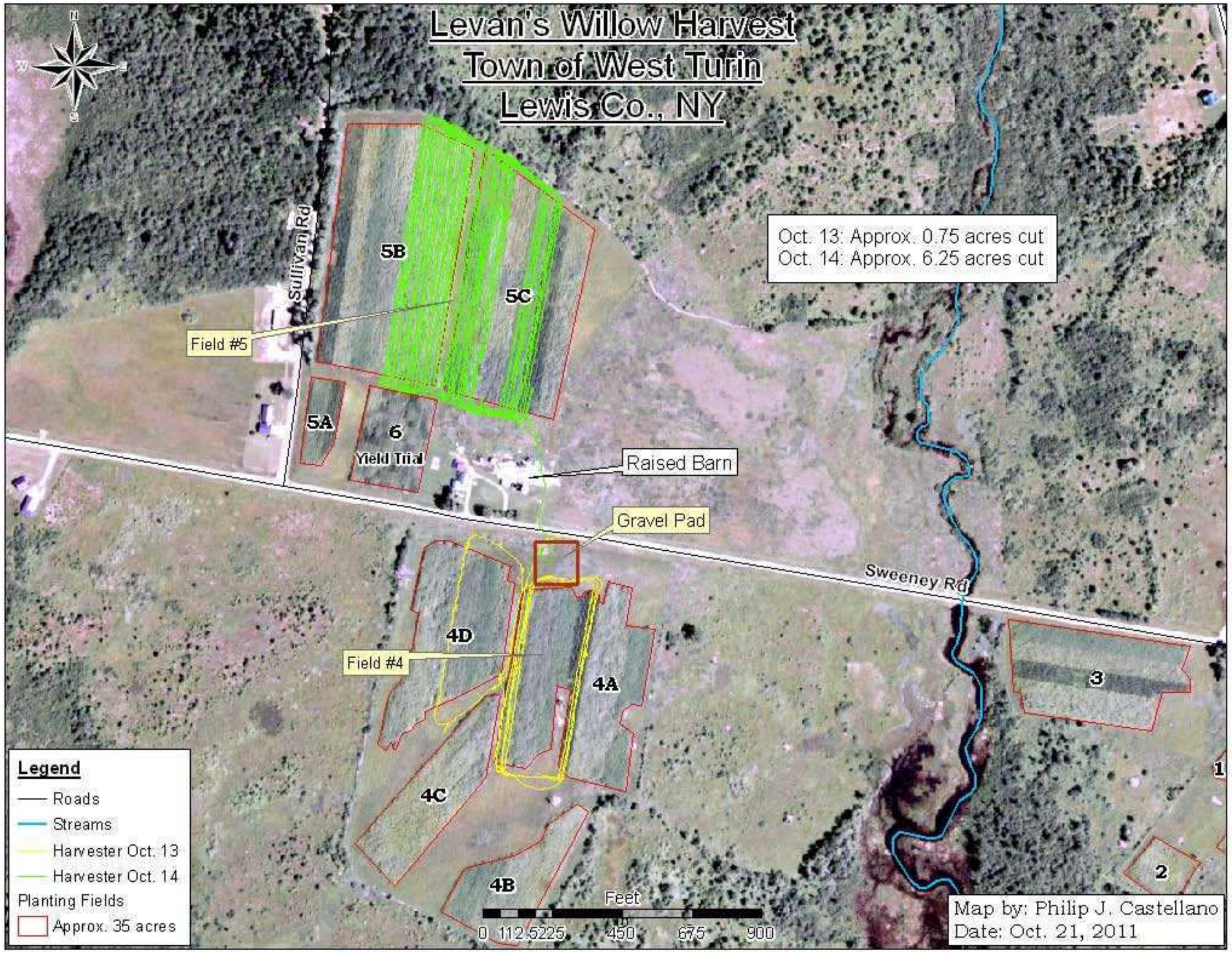
More subtly, but equally important; if this project had not happened in all likelihood, based on the disassembly inspectors' findings, the Lyonsdale turbine would have catastrophically failed potentially causing loss of life. Additionally, replacing a failed and "crashed" turbine would be not economically feasible or suitable and would result in a certain loss of livelihood among the 26 full-time equivalency (FTE) jobs at the facility and as many as 125 FTE jobs in the biomass logistics supply chain. The effect of losing the over $19,000,000 of Lyonsdale Biomass annual direct economic effect in the challenged rural economy of Lewis County would be difficult if not impossible to overcome.

The purpose grown willow biomass community has a role in the generation of heat and power. This first-ever, U.S. commercial burn demonstrates and validates much of what we knew based on our academic colleagues' suppositions; for example, the air quality imprudence of burning green willow and harvesting before leaf fall. This reality was driven solely by harvester availability. The designers of this project very much wanted a much larger burn and suggests a 900 ton commercial burn with defoliated, dry willow still needs to be conducted.

For whatever reason; be it other non-willow harvest tasks, maintenance issues, or weather; harvester non-availability is a “show-stopper” for purpose grown willow biomass for a commercial biomass generating plant. For practical and environmental (air quality) reasons, the U.S. purpose grown willow biomass community must seek out and embrace successful harvest technology, which has been academically and operationally vetted in Europe…we know of such equipment today successfully in continuous commercial practice, which is more compatible with existing forest wood chip biomass heat and power operations.

ATTACHMENT
–A-

Levan's Aerial View
Willow Harvest Areas


Levan's Willow Harvest
Town of West Turin
Lewis Co., NY
Oct. 13: Approx. 0.75 acres cut
Oct. 14: Approx. 6.25 acres cut
Sullivan Rd
5B
5C
Field #5
5A
6
Yield Trial
Raised Barn
Gravel Pad
Sweeney Rd
4D
Field #4
4A
3
1
4C
4B
2
Legend
Roads
Streams
Harvester Oct. 13
Harvester Oct. 14
Planting Fields
Approx. 35 acres
Feet
0 112.5225 450 675 900
Map by: Philip J. Castellano
Date: Oct. 21, 2011

ATTACHMENT
–B-

Willow Storage Pile

and

Fuel Blending Photos

Photo 1 Lyonsdale Biomass woodyard showing willow chip pile in background, whole tree chip pile to right in foreground (15Nov11)

Photo 2 Working face of willow chip pile, note steam near pile top and greenish tint from leafy matter (Lyonsdale Biomass 15Nov11)

Photo 3 Willow chips on working face of the storage pile (Lyonsdale Biomass 15Nov11)

Photo 4 Fuel mixture preparation, willow and whole tree chips being turned with a frontend loader (Lyonsdale Biomass 15Nov11)

Photo 5 Blended fuel mix being arranged on Laidig reclaimer , truck dumper and stackout conveyors in background (Lyonsdale Biomass 15Nov11)

Photo 6 Fuel being reclaimed by an under-pile screw, frontend loader dumping onto pile in background (Lyonsdale Biomass 15Nov11)

ATTACHMENT
–C-

Hybrid Willow Trial Burn
Procedure

ReEnergy Lyonsdale Hybrid Willow Trial Burn November 2011

SECTION 3 TRIAL BURN PROCEDURE

3.1 General

3.1.1 Only fully qualified personnel thoroughly familiar with operation and safety requirements are authorized to operate equipment.

3.1.2 The intent of this procedure is to determine what ratio of hybrid willow can be successfully blended homogenously and burned while maintaining full unit production with all emissions within limits. Test burns will be performed for six hours each at fuel blends of 10%, 15%, 20%, and 25% willow. One fuel blend ratio will be tested each day for four consecutive days. There is enough willow on site to perform these tests. Additional willow deliveries in the future will allow test burns at higher ratios.

3.1.3 Willow tends to absorb moisture, more so than most other species. Because of this natural tendency, operators must be aware that additional forced draft fan air flow will be required.

3.2 Blending Willow with Whole Tree Chips

3.2.1 Using the large bucket on the front end loader, fill the bucket with willow and weigh the loader with the willow fuel on the truck scales. Record this weight as W_{willow}.

3.2.2 Immediately after weighing the loader with the large bucket filled with willow fuel, empty the bucket in the willow fuel pile and weigh the front end loader with the large bucket empty. It's important to do this immediately after weighing the willow so that the front end loader fuel tank level will be close to the same and not skew the weight of the willow. Record this weight as W_{empty}.

3.2.3 Immediately after weighing the front end loader with the large bucket empty, fill the large bucket of the front end loader with whole tree chips from the area of the pile that is being reclaimed. Record this weight as W_{wtc}.

3.2.4 Bring the scale slips to the Plant Manager so that blending ratios can be determined.

3.2.5 Using the blending ratio sheet provided, blend and mix the corresponding number of buckets of willow fuel with whole tree chips. It's extremely important to ensure that the willow is thoroughly blended with the whole tree chips so that slugs of unmixed willow don't reach the firebox. This can cause extreme fuel piling on the grates and risk tripping the unit off line.

3.2.6 The different blends should be pre-mixed prior to commencing the test burn each day.

3.2.7 The Laidig reclaimer should be empty each day prior to commencing the trial burns.

3.3 Burning the Blended Fuel

3.3.1 Jim Morrison of Catalyst Renewables will be on site to direct/assist in the collection of necessary data.

3.3.3 When the Shift Supervisor is ready to commence burning the blended fuel, direct the Auxiliary Operator to fill the Laidig reclaimer with the premixed fuel blend.

3.3.4 The Shift Supervisor will start the Laidig reclaimer. As soon as the Shift Supervisor is confident that the Laidig reclaimer is providing adequate fuel to maintain load, the auxiliary hopper will be secured.

3.3.5 The Shift Supervisor will make necessary fuel, air, and grate speed adjustments for successful combustion.

3.3.6 At the end of the six hour test burn, the Shift Supervisor will switch back to burning the oldest whole tree chips from existing fuel piles.

3.3.7 If at any point during the trial burn process the emissions cannot be maintained or load must be reduced below where it was prior to commencing the test, the trial is to be aborted. As is always the case in these situations, the Shift Supervisor will summons any assistance required to keep the plant on line.

3.3.8 Every effort should be made to make this trial successful.

ATTACHMENT

-D-

Ultimate / Proximate / Size Analyses

Whole Tree and Willow Chips

HAZEN

Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

Date	December 8 2011
HRI Project	002-DRC
HRI Series No.	K325/11-1
Date Rec'd.	11/28/11
Sample Date:	11/15/11

EnVector
J.A Morrison
5007 Fayetteville-Manlius Road
Manlius, NY 13104

Sample Identification
A-WTC "whole tree chips"

-

Reporting Basis >	As Rec'd	Dry	Air Dry
Proximate (%)			
Moisture	45.77	0.00	2.06
Ash	0.49	0.91	0.89
Volatile	46.89	86.46	84.68
Fixed C	6.85	12.63	12.37
Total	100.00	100.00	100.00
Sulfur	0.011	0.019	0.019
Btu/lb (HHV)	4487	8275	8105
Btu/lb (LHV)	3713		
MMF Btu/lb	4511	8357	
MAF Btu/lb		8351	
Ultimate (%)			
Moisture	45.77	0.00	2.06
Carbon	28.36	52.30	51.22
Hydrogen	3.27	6.03	5.91
Nitrogen	0.09	0.16	0.16
Sulfur	0.01	0.02	0.02
Ash	0.49	0.91	0.89
Oxygen*	22.01	40.58	39.74
Total	100.00	100.00	100.00
Chlorine**			

Air Dry Loss (%) 44.63

Forms of Sulfur, as S, (%)

	As Rec'd	Dry
Sulfate		
Pyritic		
Organic		
Total	0.01	0.02

Water Soluble Alkalies (%)

Na2O
K2O

Lb. Alkali Oxide/MM Btu=	
Lb. Ash/MM Btu=	1.10
Lb. SO2/MM Btu=	0.05
Lb. Cl/MM Btu=	
As Rec'd. Sp.Gr.=	
Free Swelling Index=	
F-Factor(dry),DSCF/MM Btu=	10,072

Report Prepared By:

Gerard H. Cunningham
Fuels Laboratory Supervisor

* Oxygen by Difference.
** Not usually reported as part of the ultimate analysis.

Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

Date	December 8 2011
HRI Project	002-DRC
HRI Series No.	K325/11-2
Date Rec'd.	11/28/11
Sample Date:	11/15/11

EnVector
J.A Morrison
5007 Fayetteville-Manlius Road
Manlius, NY 13104

Sample Identification
B-Levan Willow Chips

Reporting Basis >	As Rec'd	Dry	Air Dry
Proximate (%)			
Moisture	59.22	0.00	2.03
Ash	0.89	2.18	2.14
Volatile	33.85	82.98	81.30
Fixed C	6.04	14.84	14.53
Total	100.00	100.00	100.00
Sulfur	0.023	0.056	0.055
Btu/lb (HHV)	3372	8269	8101
Btu/lb (LHV)	2538		
MMF Btu/lb	3404	8468	
MAF Btu/lb		8453	
Ultimate (%)			
Moisture	59.22	0.00	2.03
Carbon	21.12	51.79	50.74
Hydrogen	2.42	5.93	5.81
Nitrogen	0.19	0.47	0.46
Sulfur	0.02	0.06	0.05
Ash	0.89	2.18	2.14
Oxygen*	16.14	39.57	38.77
Total	100.00	100.00	100.00
Chlorine**			

Air Dry Loss (%) 58.37

Forms of Sulfur, as S, (%)

	As Rec'd	Dry
Sulfate		
Pyritic		
Organic		
Total	0.02	0.06

Water Soluble Alkalies (%)

Na2O
K2O

Lb. Alkali Oxide/MM Btu=	
Lb. Ash/MM Btu=	2.64
Lb. SO2/MM Btu=	0.14
Lb. Cl/MM Btu=	
As Rec'd. Sp.Gr.=	
Free Swelling Index=	
F-Factor(dry),DSCF/MM Btu=	10,006

Report Prepared By:

Gerard H. Cunningham
Fuels Laboratory Supervisor

* Oxygen by Difference.
** Not usually reported as part of the ultimate analysis.

HAZEN

Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

Date	December 8 2011
HRI Project	002-DRC
HRI Series No.	K325/11-3
Date Rec'd.	11/28/11
Sample Date:	11/15/11

EnVector
J.A Morrison
5007 Fayetteville-Manlius Road
Manlius, NY 13104

Sample Identification
C-10% Willow-WTC Mixture

Reporting Basis >	As Rec'd	Dry	Air Dry
Proximate (%)			
Moisture	46.98	0.00	2.13
Ash	0.63	1.20	1.17
Volatile	46.09	86.94	85.09
Fixed C	6.30	11.86	11.61
Total	100.00	100.00	100.00
Sulfur	0.012	0.022	0.022
Btu/lb (HHV)	4473	8436	8256
Btu/lb (LHV)	3694		
MMF Btu/lb	4503	8546	
MAF Btu/lb		8538	
Ultimate (%)			
Moisture	46.98	0.00	2.13
Carbon	27.95	52.72	51.60
Hydrogen	3.18	5.99	5.86
Nitrogen	0.09	0.16	0.16
Sulfur	0.01	0.02	0.02
Ash	0.63	1.20	1.17
Oxygen*	21.16	39.91	39.06
Total	100.00	100.00	100.00
Chlorine**			

Air Dry Loss (%) 45.83

Forms of Sulfur, as S, (%)	As Rec'd	Dry
Sulfate		
Pyritic		
Organic		
Total	0.01	0.02

Lb. Alkali Oxide/MM Btu=	
Lb. Ash/MM Btu=	1.42
Lb. SO2/MM Btu=	0.05
Lb. Cl/MM Btu=	
As Rec'd. Sp.Gr.=	
Free Swelling Index=	
F-Factor(dry),DSCF/MM Btu=	9,974

Water Soluble Alkalies (%)

Na2O
K2O

Report Prepared By:

Gerard H. Cunningham
Fuels Laboratory Supervisor

* Oxygen by Difference.
** Not usually reported as part of the ultimate analysis.

HAZEN

Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

DATE	Dec. 8, 2011
HRI PROJECT	002-DRC
HRI SERIES NO.	K325/11
DATE REC'D	11/28/2011
Sample Date:	11/15/2011

EnVector
J.A. Morrison
5007 Fayatteville-Manlius Road
Manlius, NY 13104

SIEVE ANALYSIS REPORT

Sample Number: K325/11-1
Sample Identification: A-WTC "whole tree chips"

Mesh Size Pass - Retained *			Direct Weight, g	Direct Weight, %	Cum. Weight % Retained	Cum. Weight % Pass
	-	1.50"	0.0	0.00	0.00	100.00
1.50"	-	0.75"	79.7	19.25	19.25	80.75
0.75"	-	0.25"	259.3	62.63	81.88	18.12
0.25"	-	6	49.4	11.93	93.82	6.18
6	-	14	15.5	3.74	97.56	2.44
14	-	50	8.0	1.93	99.49	0.51
50	-	80	1.2	0.29	99.78	0.22
80	-	150	0.4	0.10	99.88	0.12
150	-	200	0.1	0.02	99.90	0.10
200	-	PAN	0.4	0.10	100.00	0.00
		Total	414.0	100.00		

* Tyler Sieve Sizes

By:
Gerard H. Cunningham
Fuel Laboratory Manager

Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

DATE	Dec. 8, 2011
HRI PROJECT	002-DRC
HRI SERIES NO.	K325/11
DATE REC'D	11/28/2011
Sample Date:	11/15/2011

EnVector
J.A. Morrison
5007 Fayatteville-Manlius Road
Manlius, NY 13104

SIEVE ANALYSIS REPORT

Sample Number: K325/11-2
Sample Identification: B-Levan Willow Chips

Mesh Size Pass		Retained *	Direct Weight, g	Direct Weight, %	Cum. Weight % Retained	Cum. Weight % Pass
	-	1.50"	0.4	0.13	0.13	99.87
1.50"	-	0.75"	18.3	6.04	6.17	93.83
0.75"	-	0.25"	205.0	67.68	73.85	26.15
0.25"	-	6	52.9	17.46	91.32	8.68
6	-	14	16.7	5.51	96.83	3.17
14	-	50	7.9	2.61	99.44	0.56
50	-	80	0.9	0.30	99.74	0.26
80	-	150	0.3	0.10	99.83	0.17
150	-	200	0.1	0.03	99.87	0.13
200	-	PAN	0.4	0.13	100.00	0.00
		Total	302.9	100.00		

* Tyler Sieve Sizes

By: [signature]
Gerard H. Cunningham
Fuel Laboratory Manager

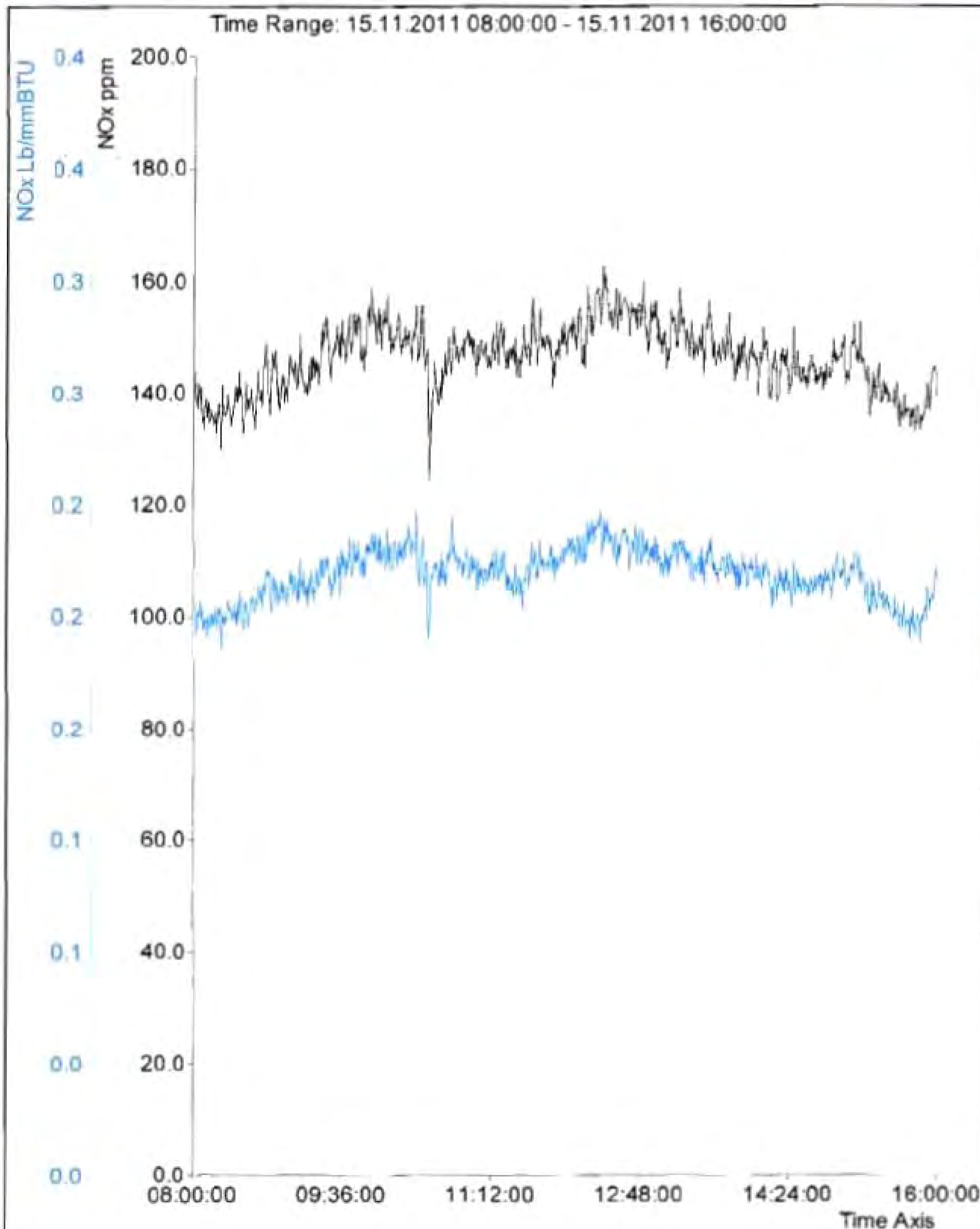
ATTACHMENT

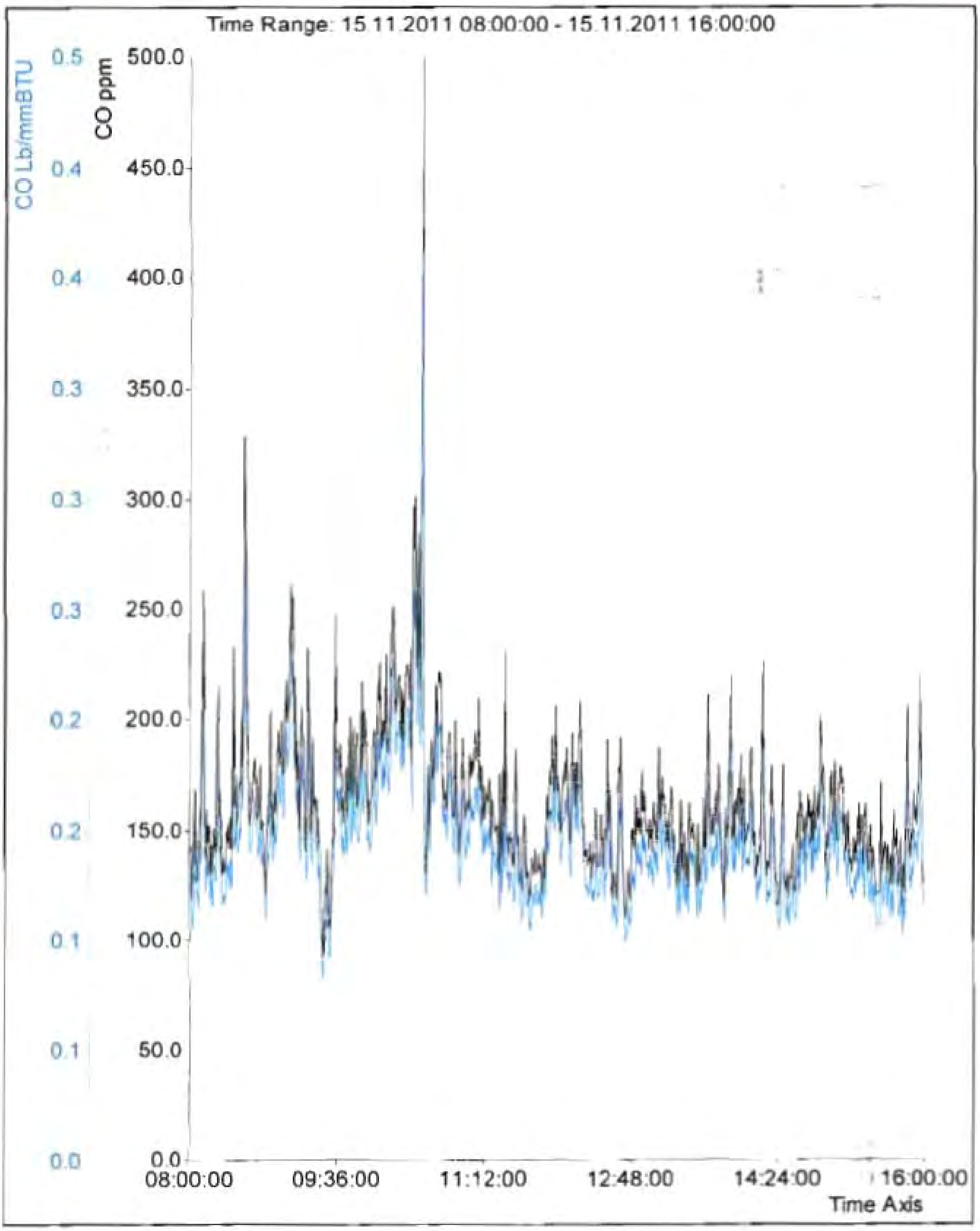
-E-

Trend Charts

NOx, CO, O2 and Gas Flows

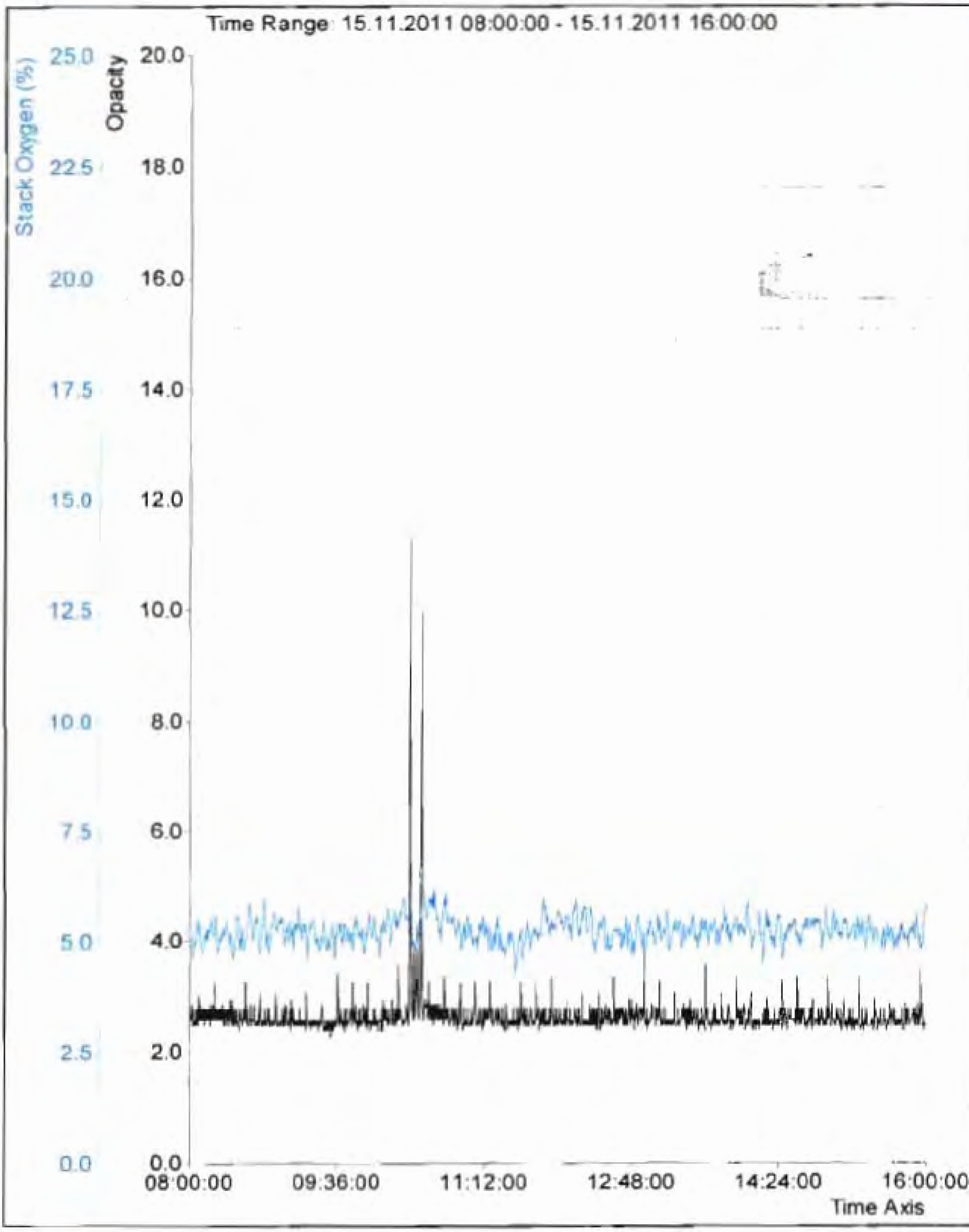
Trial Run #1 7.7 wt% willow:WTC
15nov11 start: 0915hrs stop: 1400hrs
with following 5 pages




Time Range: 15.11.2011 08:00:00 - 15.11.2011 16:00:00
CO Lb/mmBTU
CO ppm
0.5
0.4
0.4
0.3
0.3
0.3
0.2
0.2
0.1
0.1
0.0
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
08:00:00
09:36:00
11:12:00
12:48:00
14:24:00
16:00:00
Time Axis

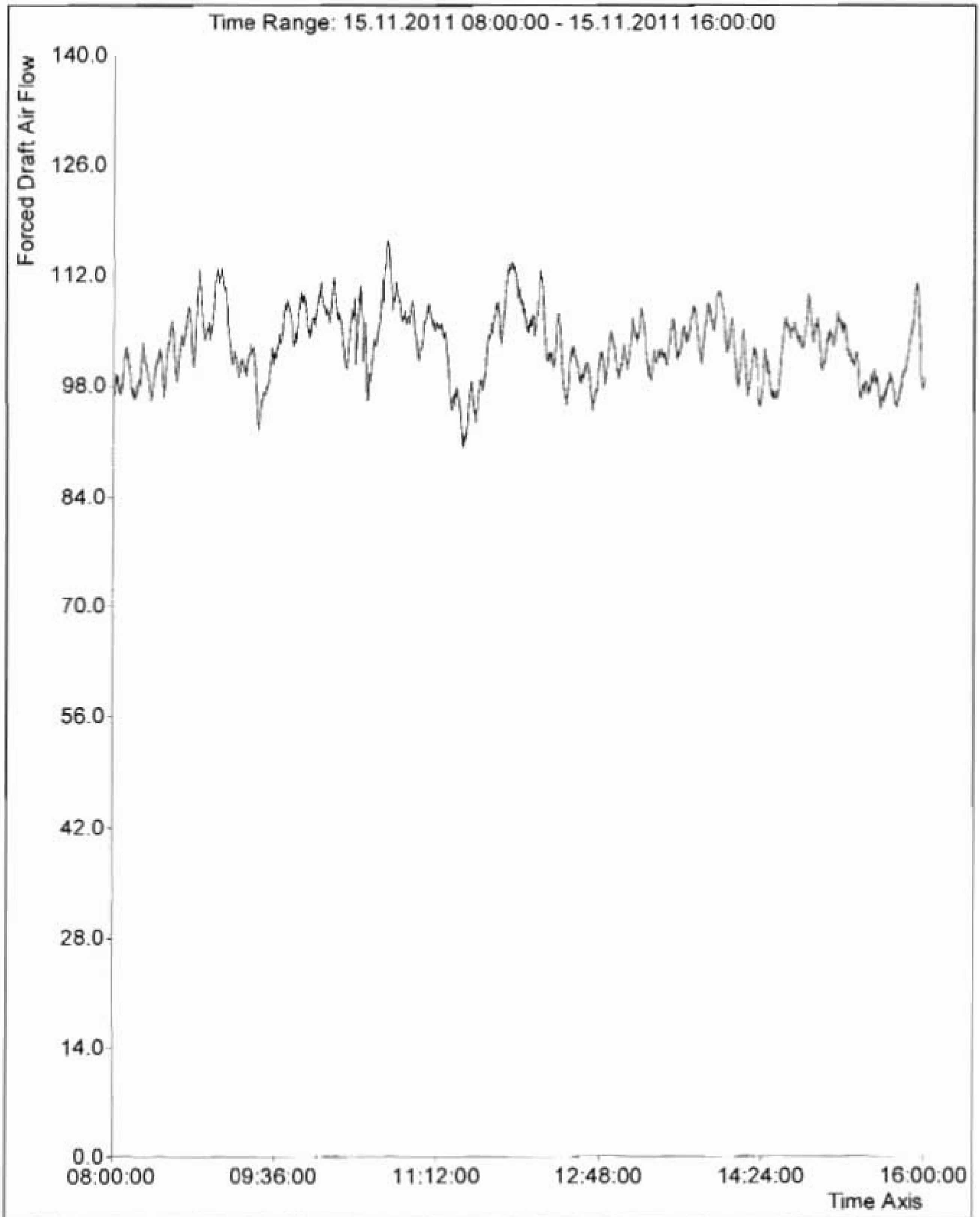
WinCC™ CSV-Provider - RT - Curves

\\OS1\WinCC60_Project_OS1\OS1.mcp



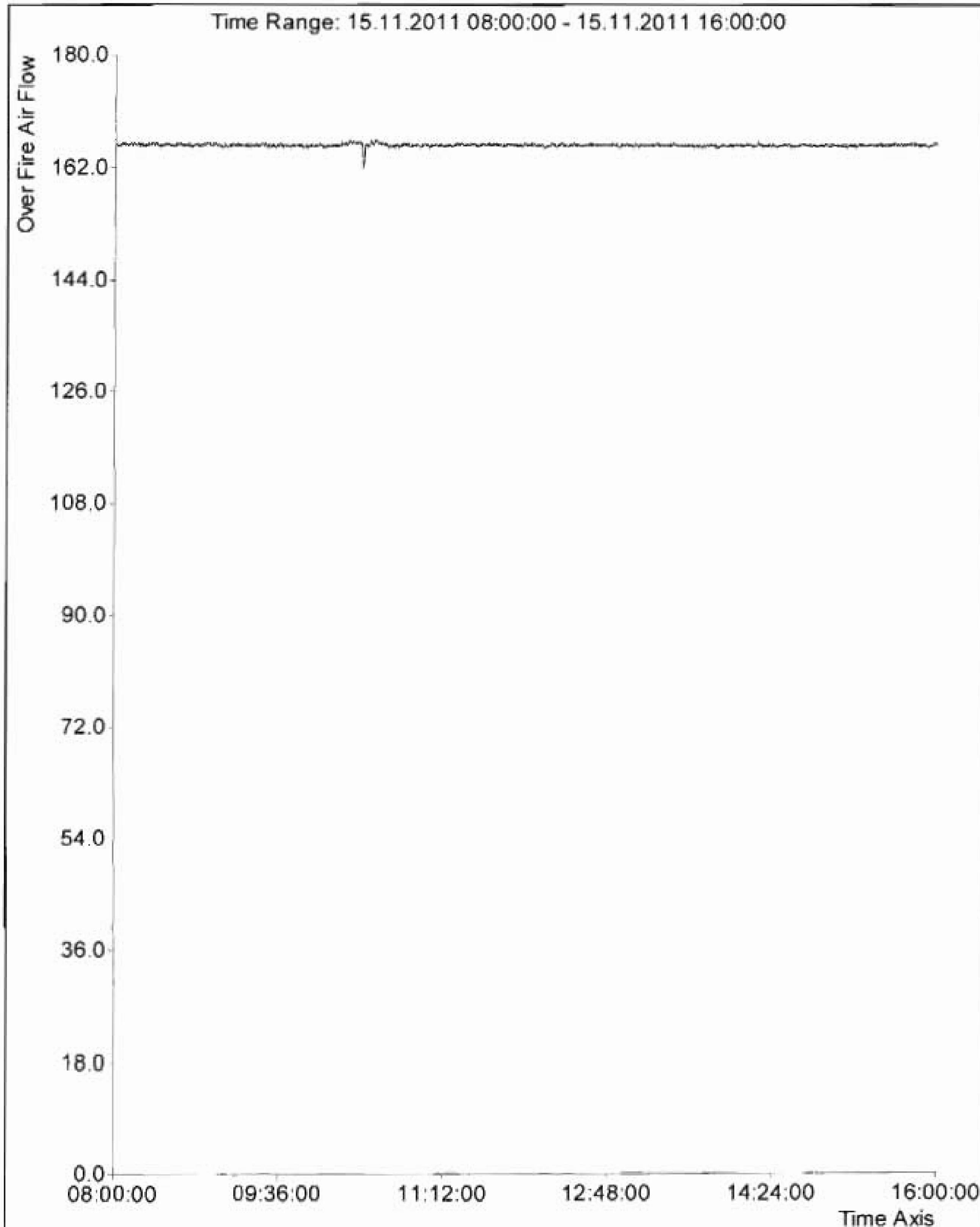
WinCC™ CSV-Provider - RT - Curves

\\OS1\WinCC60_Project_OS1\OS1.mcp



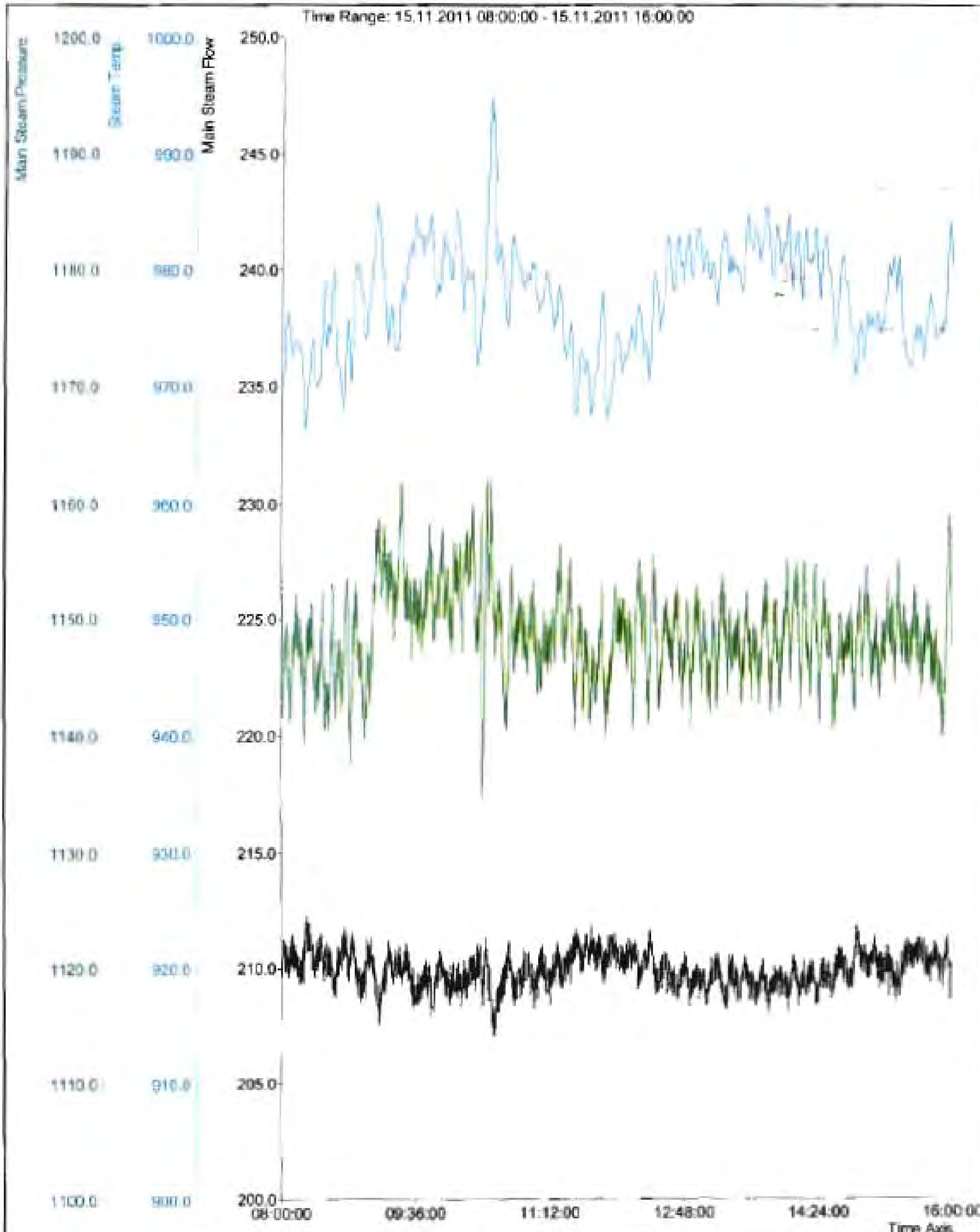
WinCC™ CSV-Provider - RT - Curves

\\OS1\WinCC60_Project_OS1\OS1.mcp

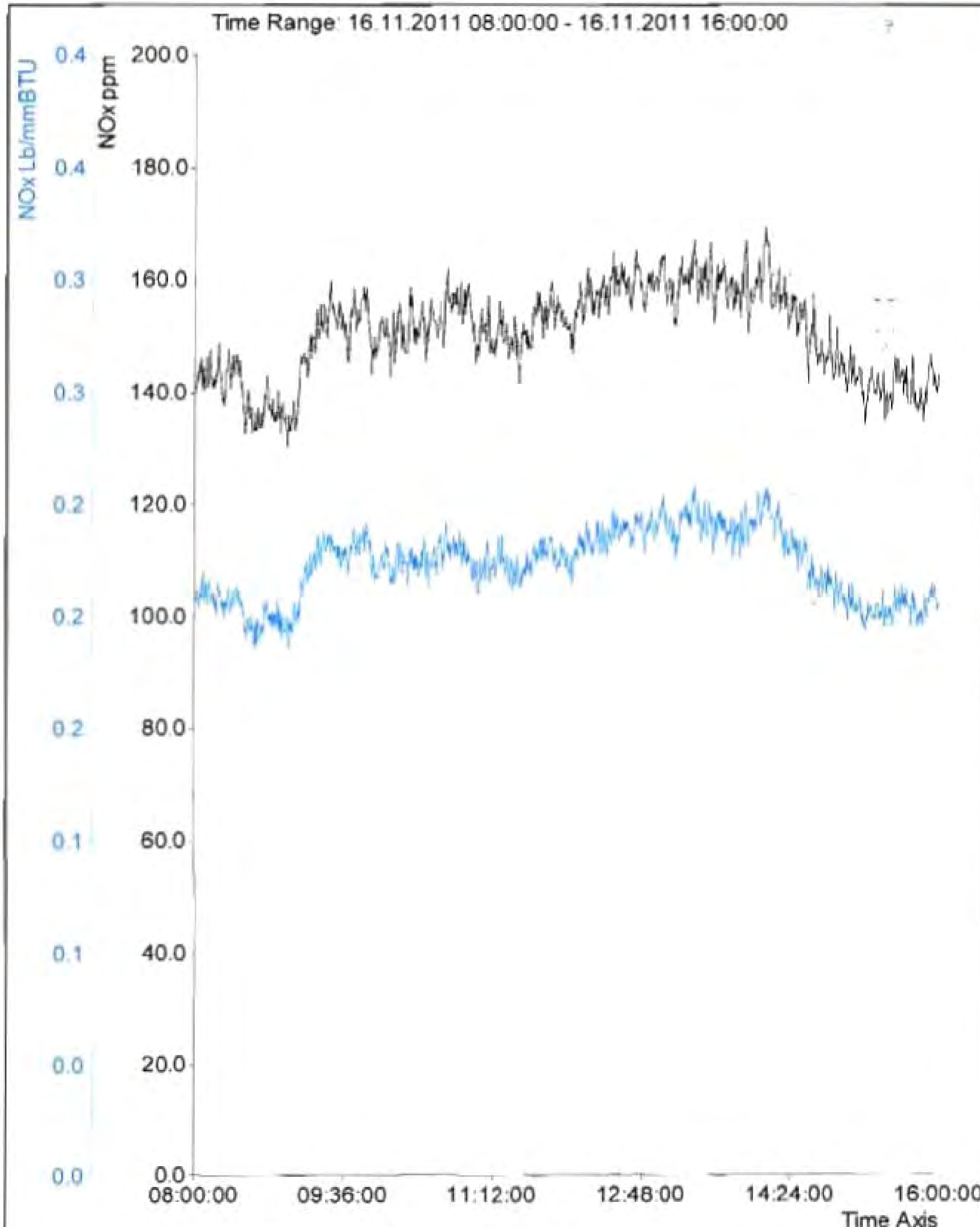


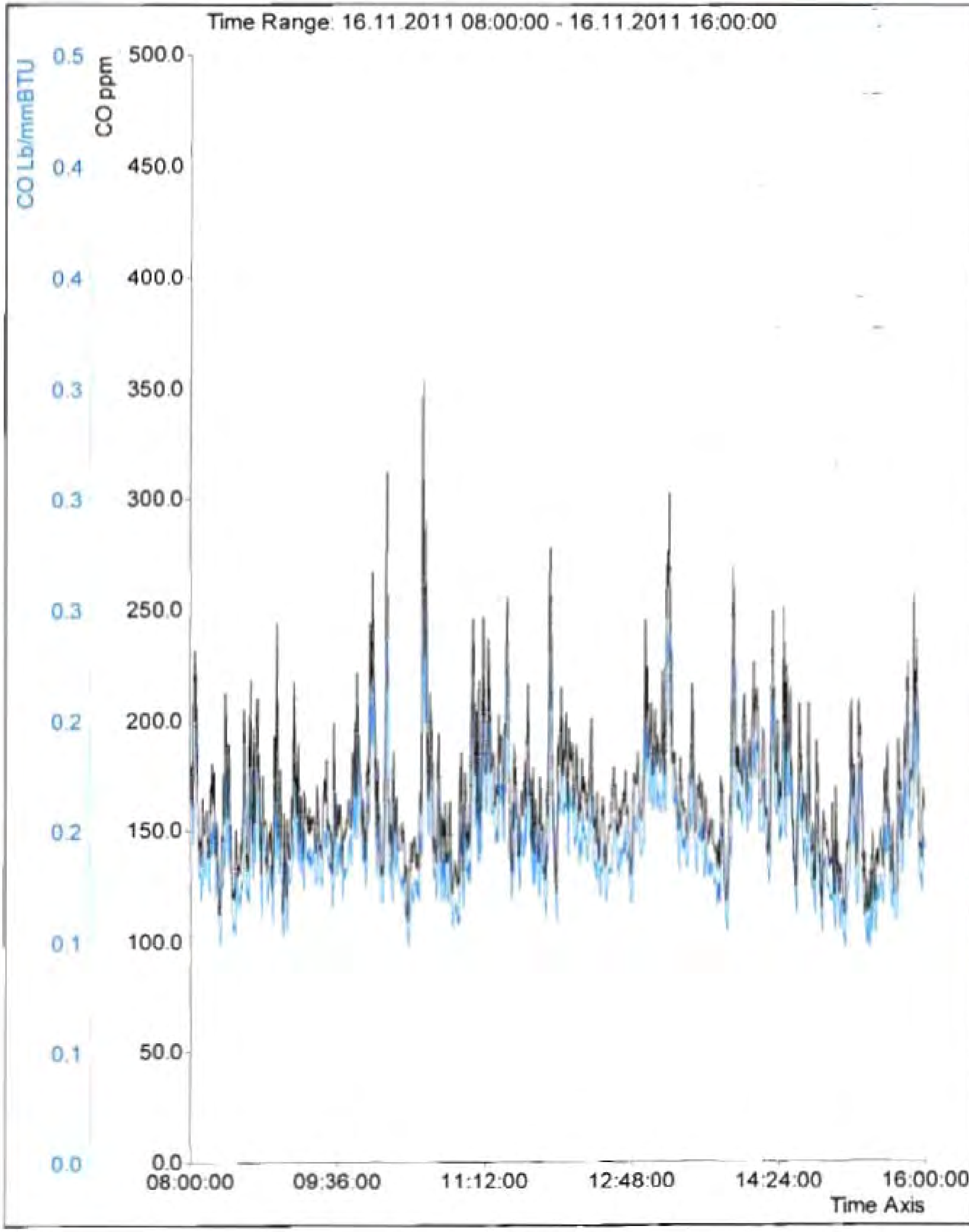
WinCC™ CSV-Provider - RT - Curves

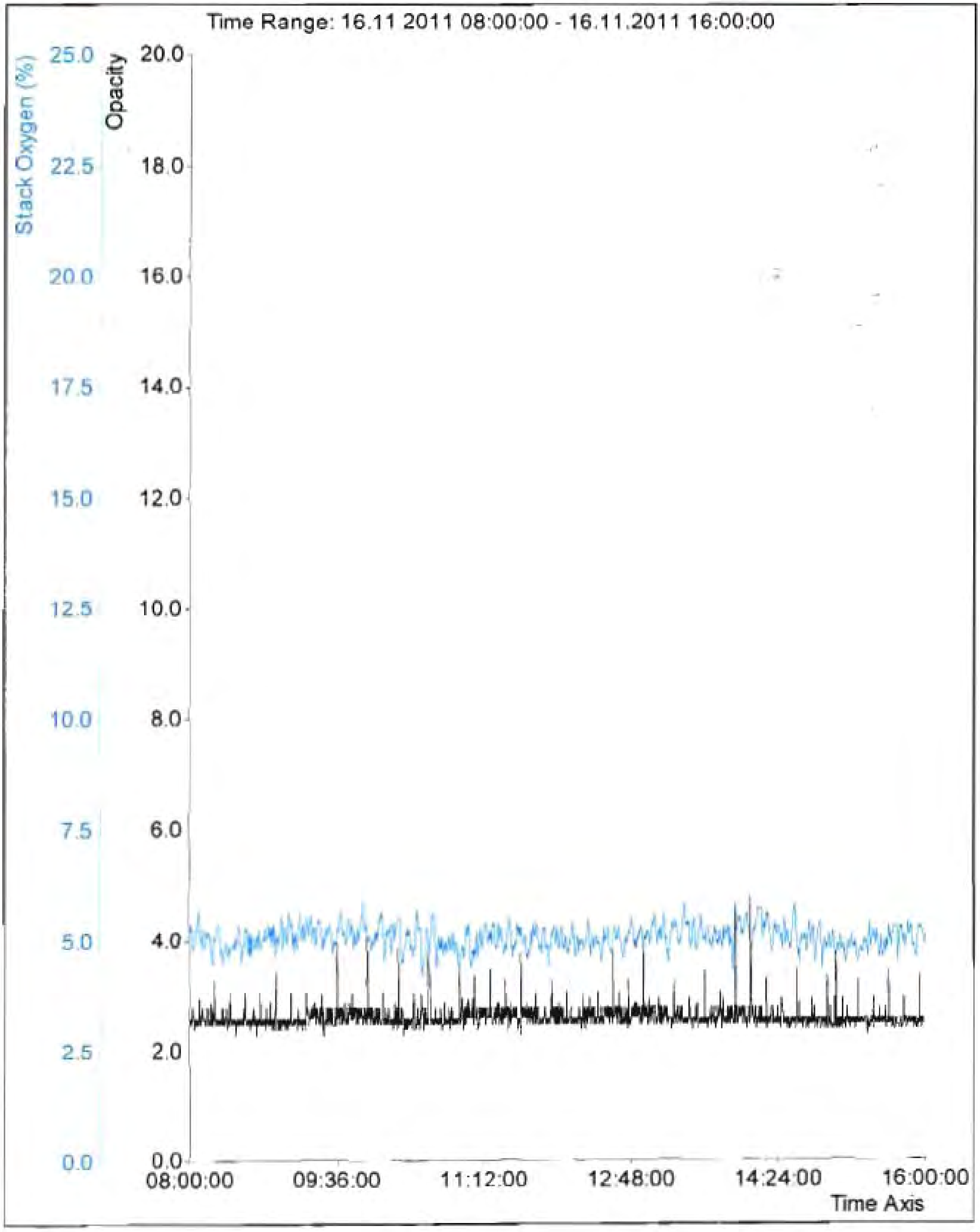
\\OS1\WinCC60_Project_OS1\OS1.mcp



Trial Run #2 14 wt% willow:WTC
16nov11 start: 0855hrs stop: 1409hrs
with following 5 pages



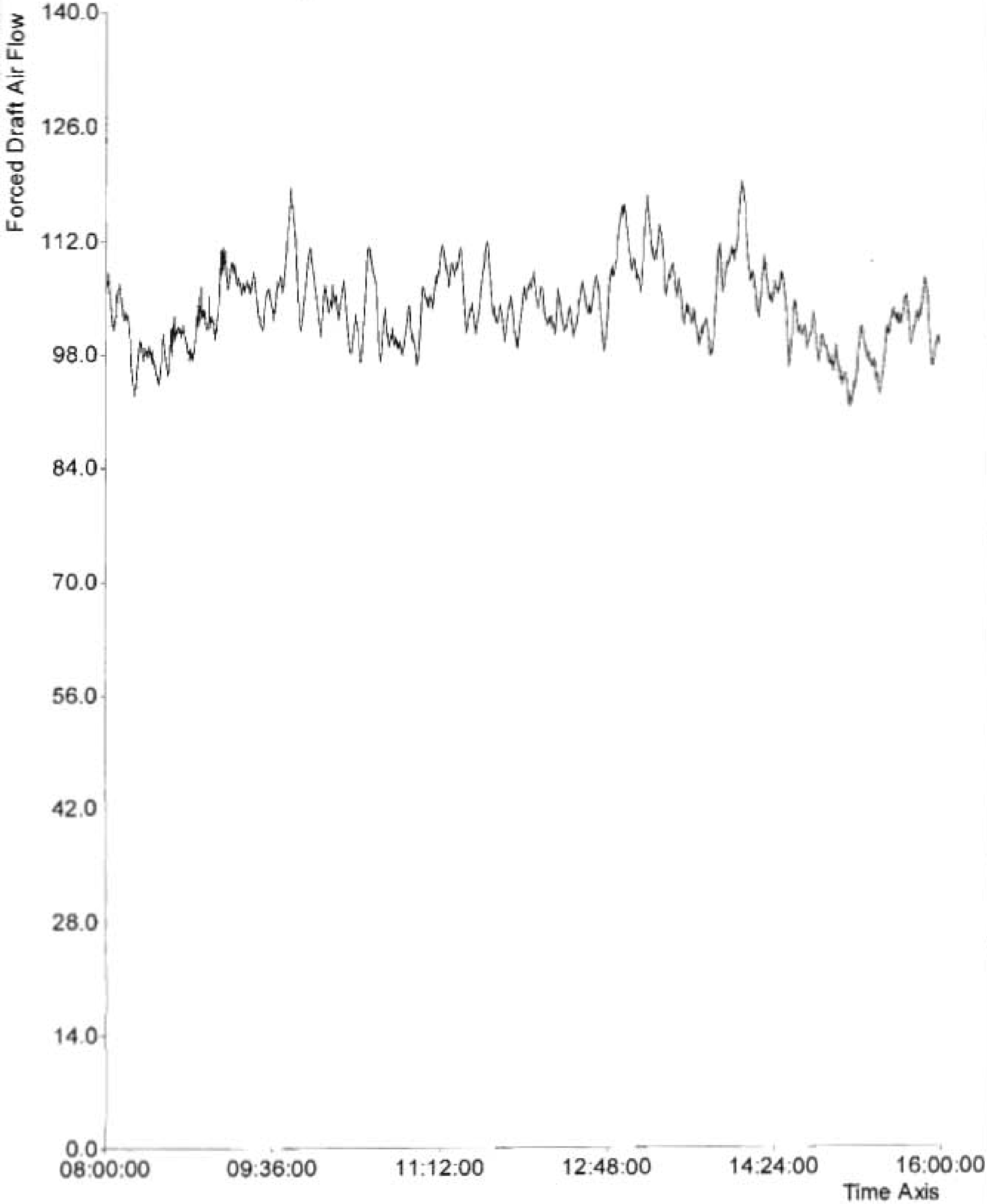

Time Range: 16.11.2011 08:00:00 - 16.11.2011 16:00:00
CO Lb/mmBTU
CO ppm
0.5
0.4
0.4
0.3
0.3
0.3
0.2
0.2
0.1
0.1
0.0
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
08:00:00
09:36:00
11:12:00
12:48:00
14:24:00
16:00:00
Time Axis

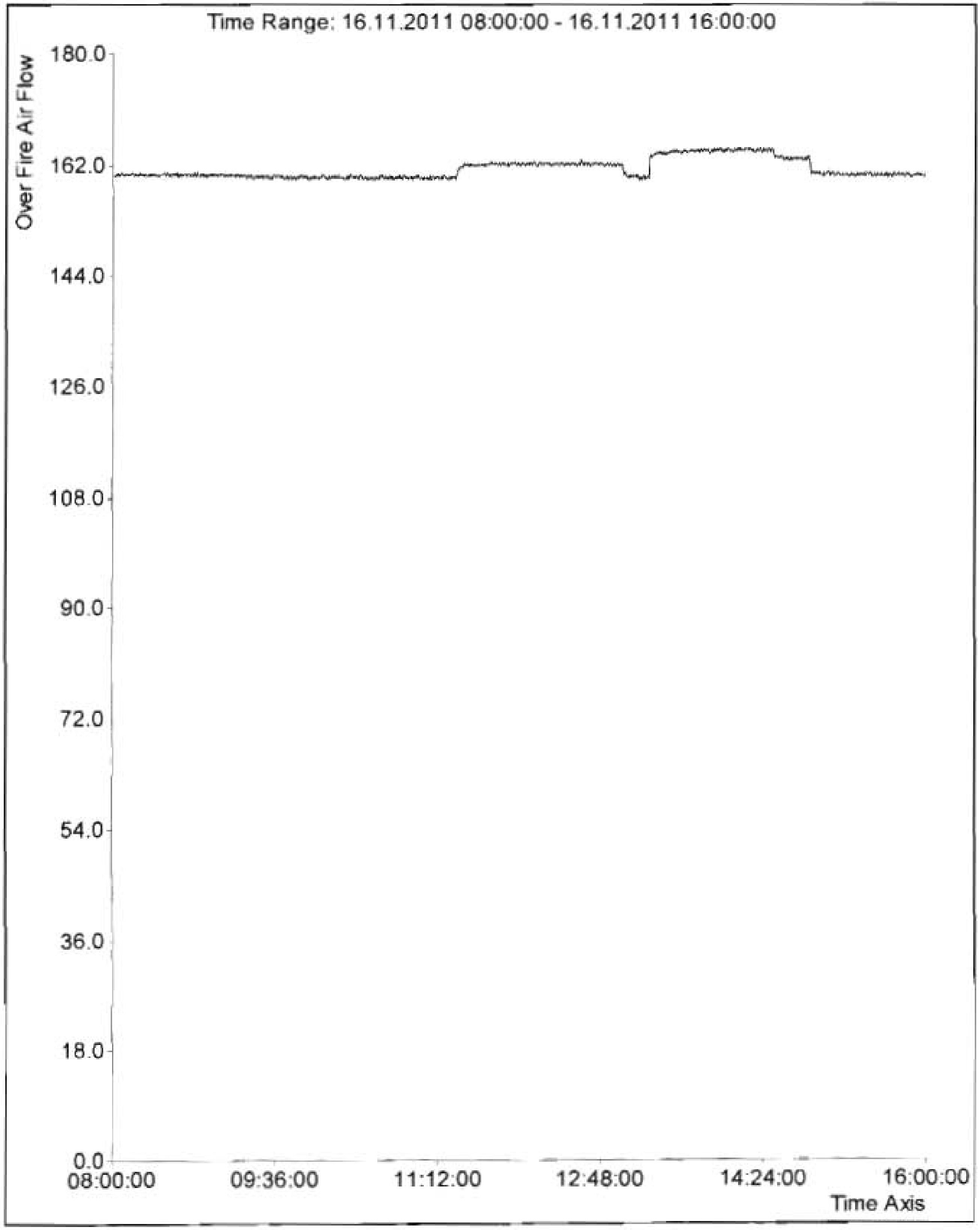

Time Range: 16.11 2011 08:00:00 - 16.11.2011 16:00:00
Stack Oxygen (%)
Opacity
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
08:00:00
09:36:00
11:12:00
12:48:00
14:24:00
16:00:00
Time Axis

WinCC™ CSV-Provider - RT - Curves

\\OS1\WinCC60_Project_OS1\OS1.mcp

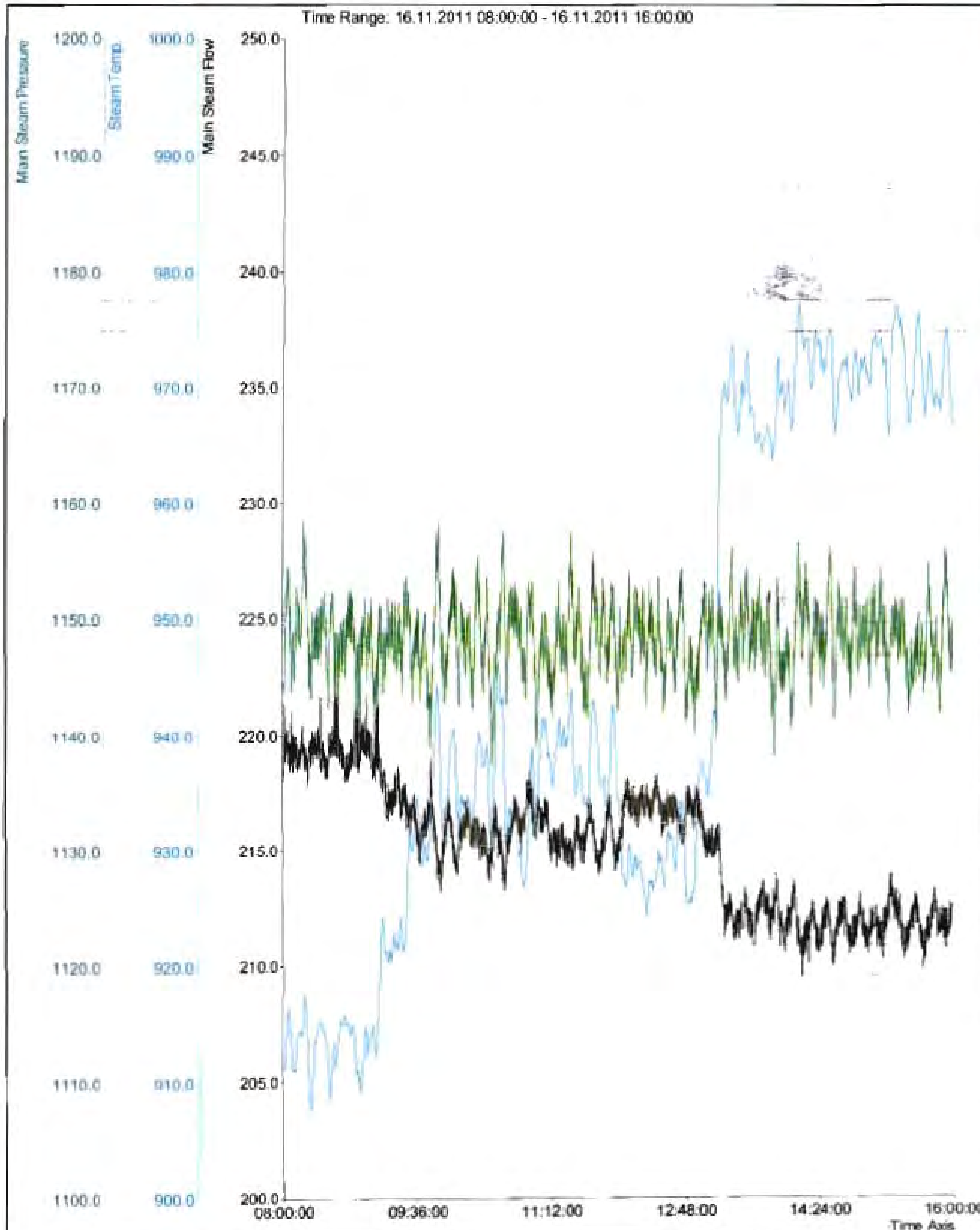
Time Range: 16.11.2011 08:00:00 - 16.11.2011 16:00:00



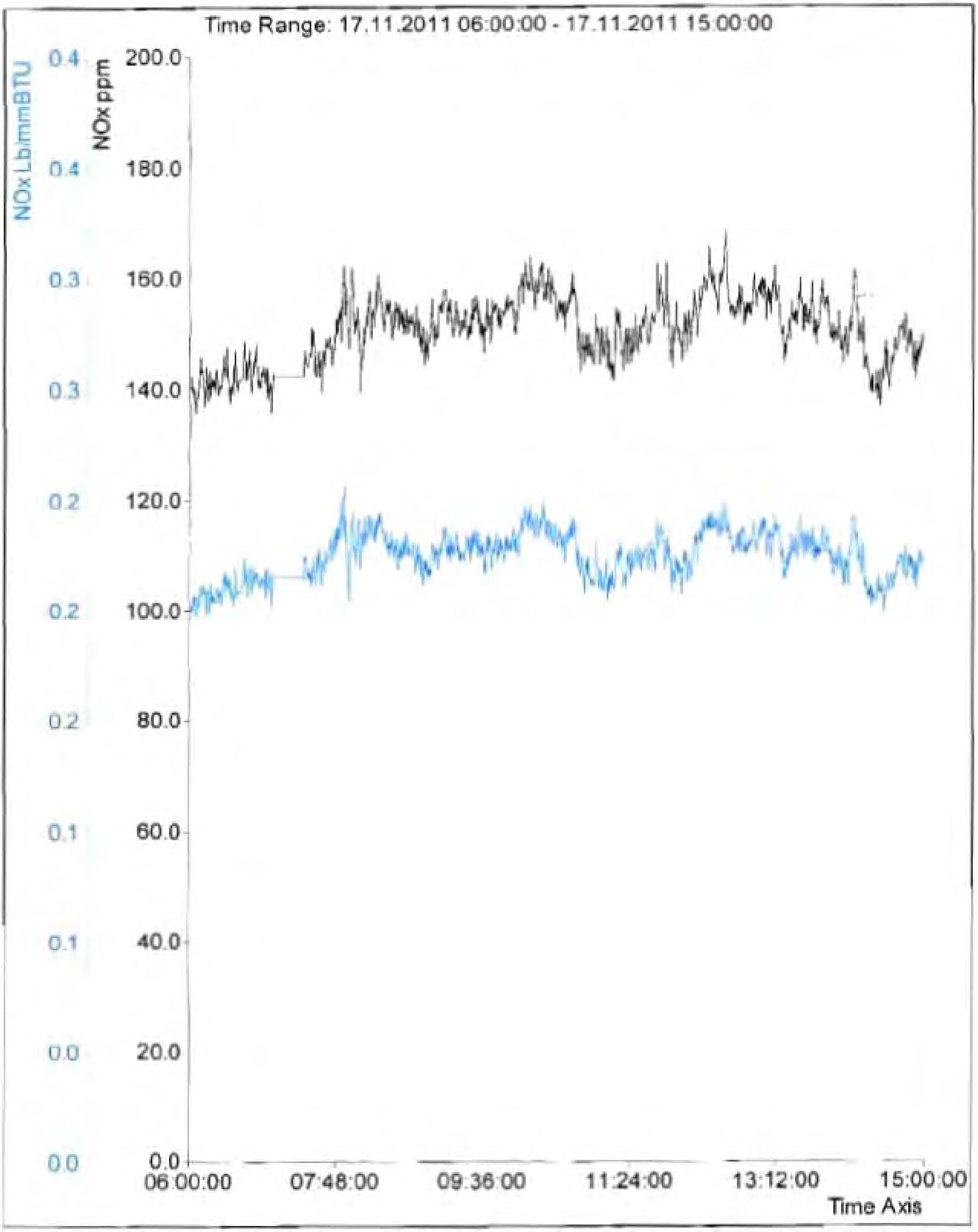

Time Range: 16.11.2011 08:00:00 - 16.11.2011 16:00:00
Over Fire Air Flow
180.0
162.0
144.0
126.0
108.0
90.0
72.0
54.0
36.0
18.0
0.0
08:00:00
09:36:00
11:12:00
12:48:00
14:24:00
16:00:00
Time Axis

WinCC™ CSV-Provider - RT - Curves

\\OS1\WinCC60_Project_OS1\OS1.mcp



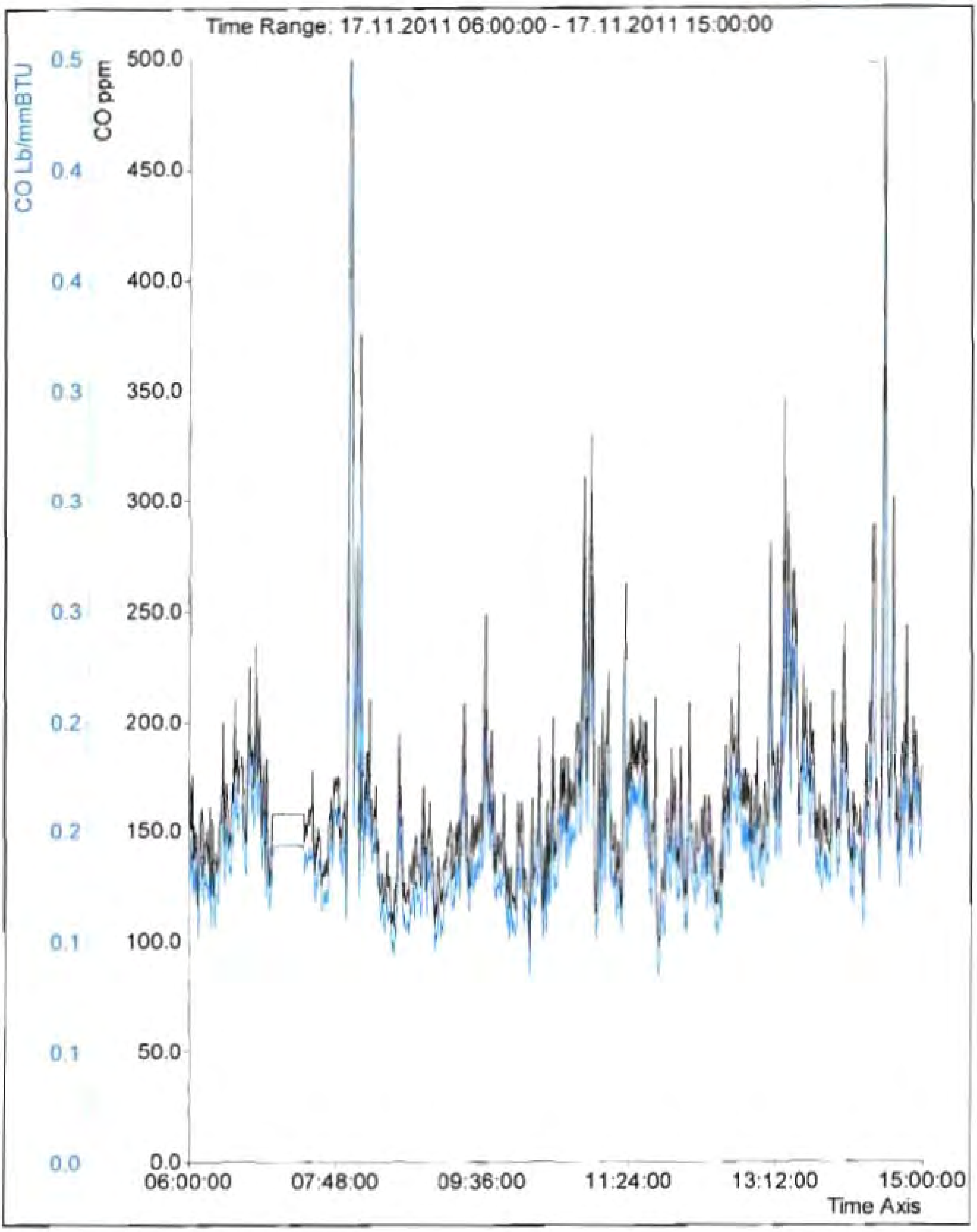
Trial Run #3a 20 wt% willow:WTC
17nov11 start: 0740hrs stop: 1135hrs
Trial Run #3b 25 wt% willow:WTC
17nov11 start: 1135hrs stop: 1320hrs
with following 5 pages



WinCC™ CSV-Provider - RT - Curves

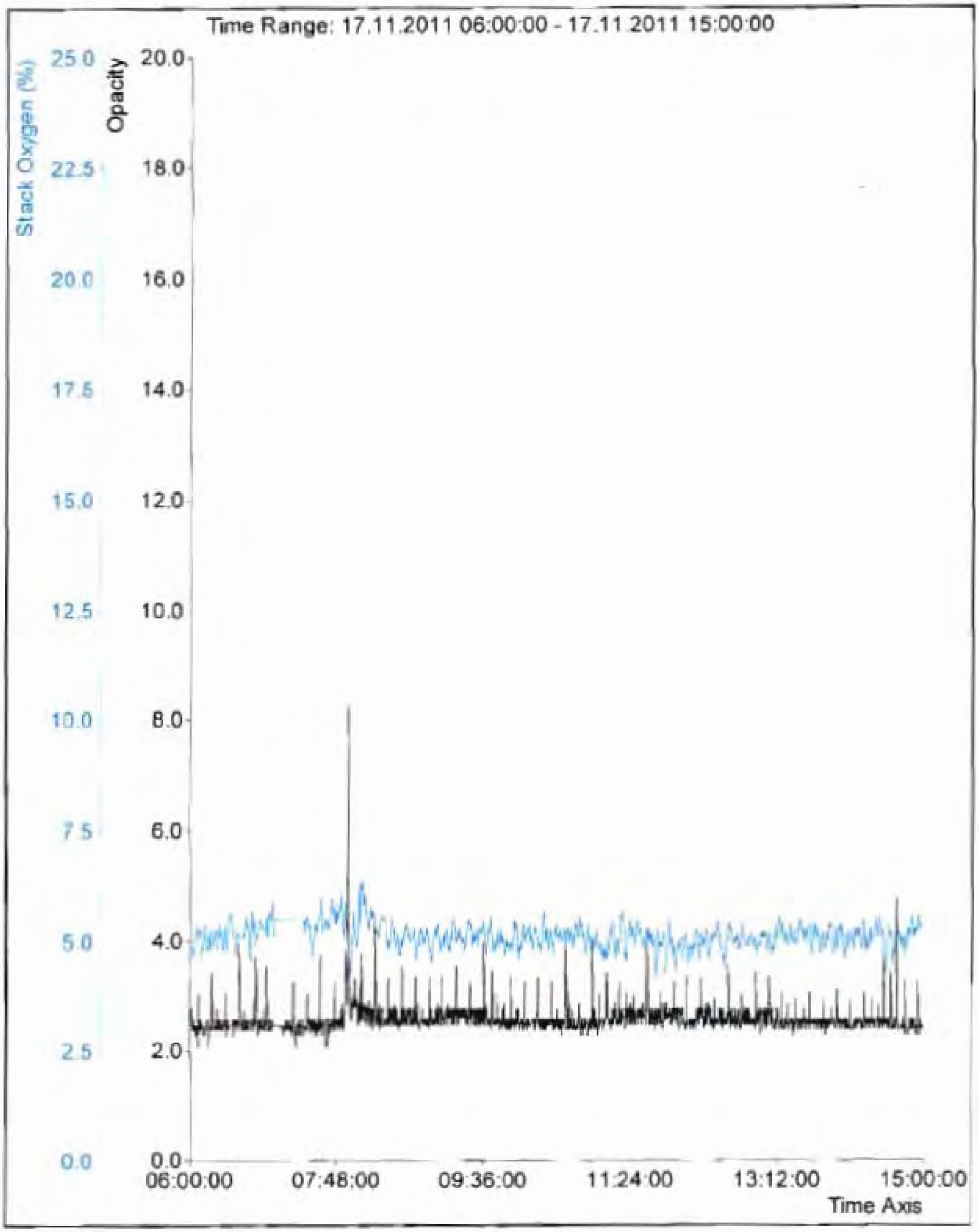
Copyright (c) 1994-2005 by SIEMENS AG

\\OS1\WinCC60_Project_OS1\OS1.mcp



WinCC™ CSV-Provider - RT - Curves

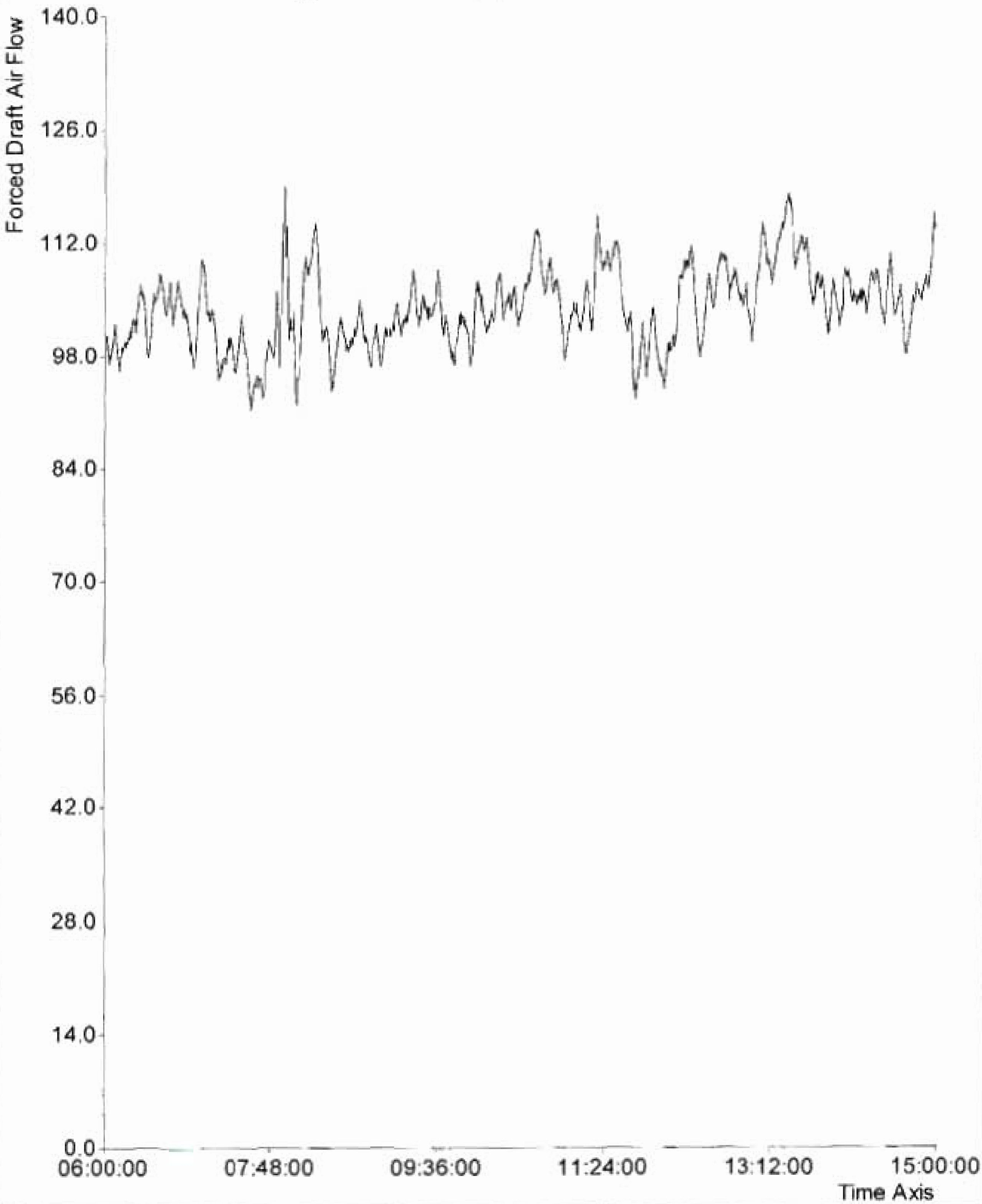
\\OS1\WinCC60_Project_OS1\OS1.mcp



WinCC™ CSV-Provider - RT - Curves

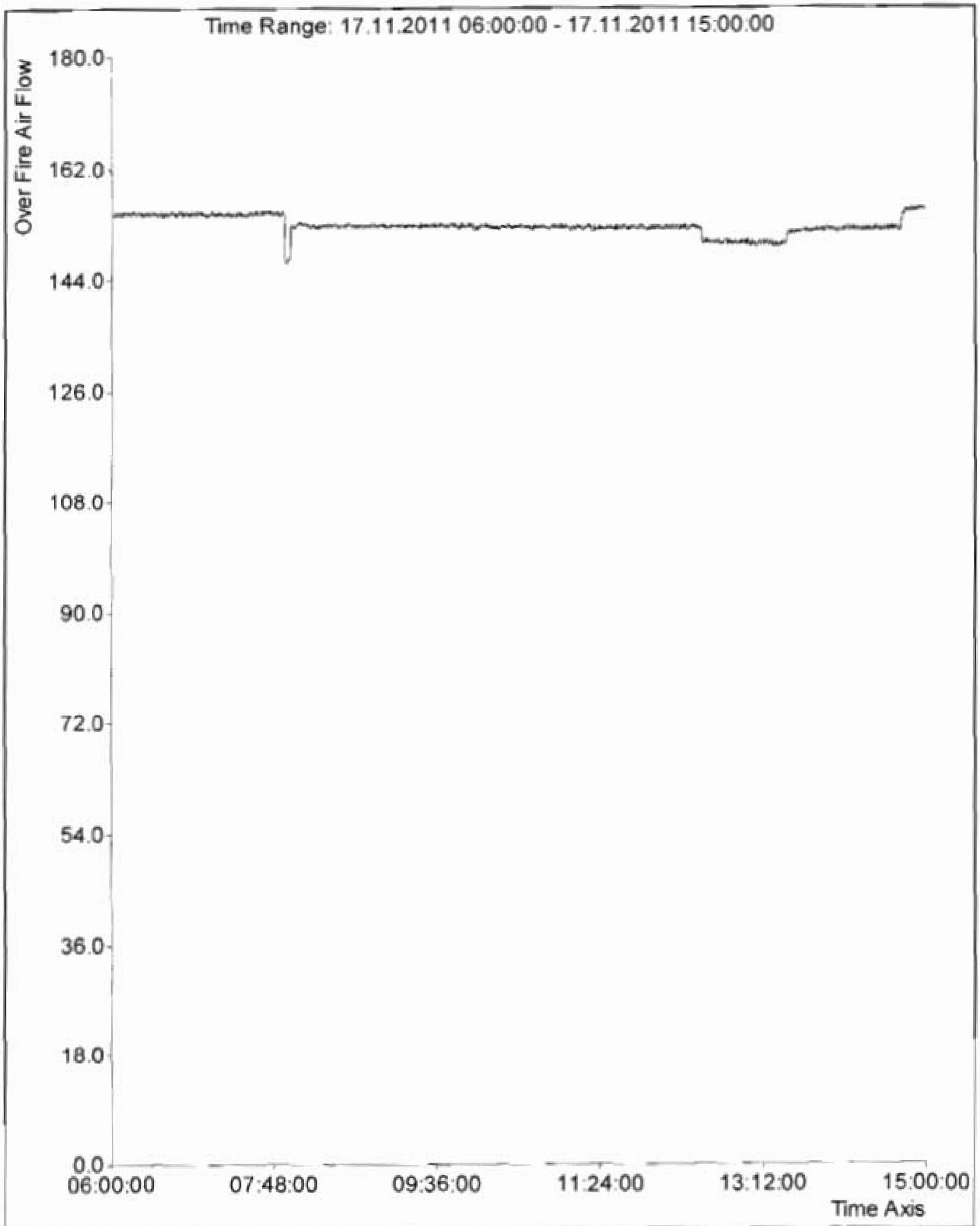
\\OS1\WinCC60_Project_OS1\OS1.mcp

Time Range: 17.11.2011 06:00:00 - 17.11.2011 15:00:00



WinCC™ CSV-Provider - RT - Curves

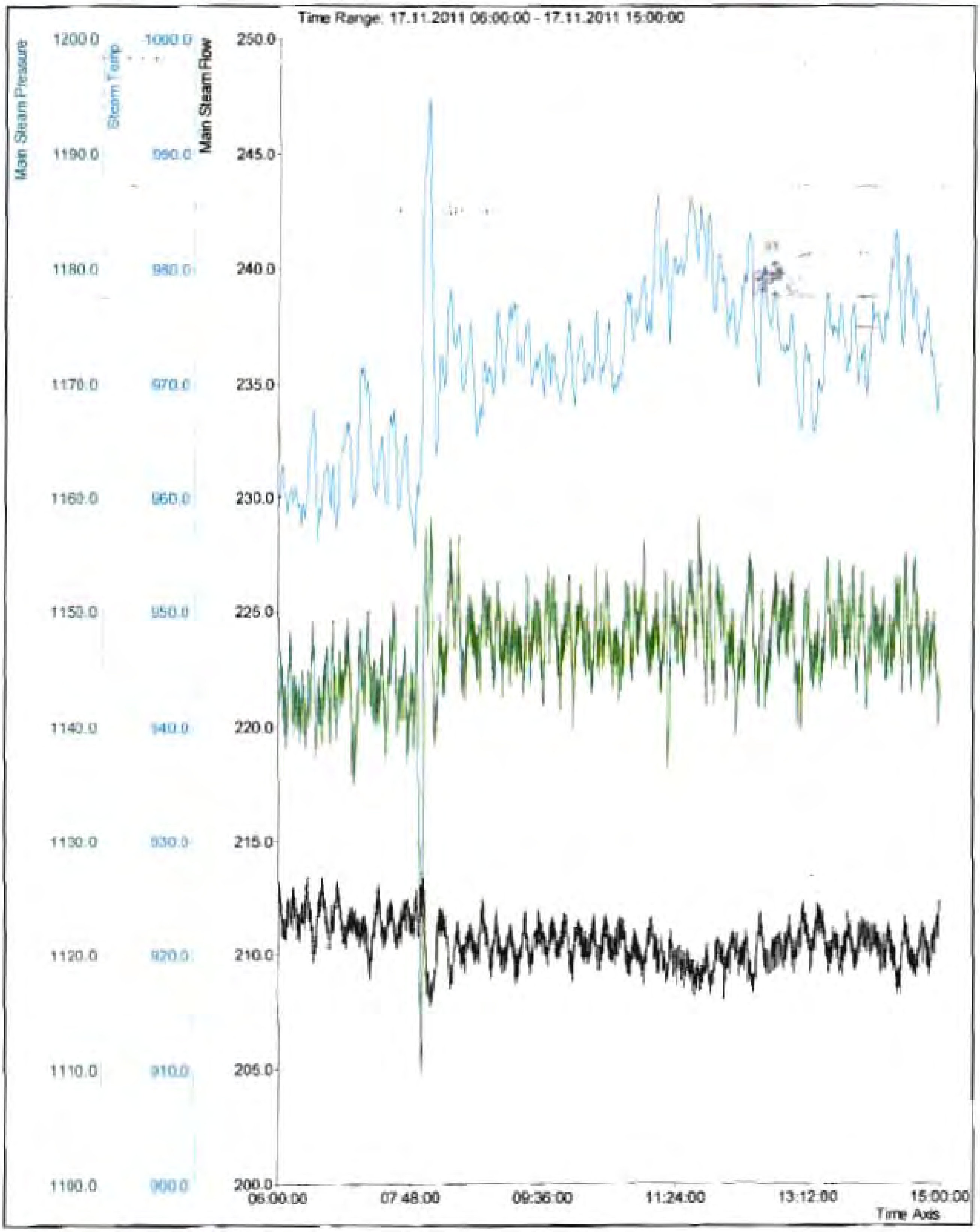
\\OS1\WinCC60_Project_OS1\OS1.mcp



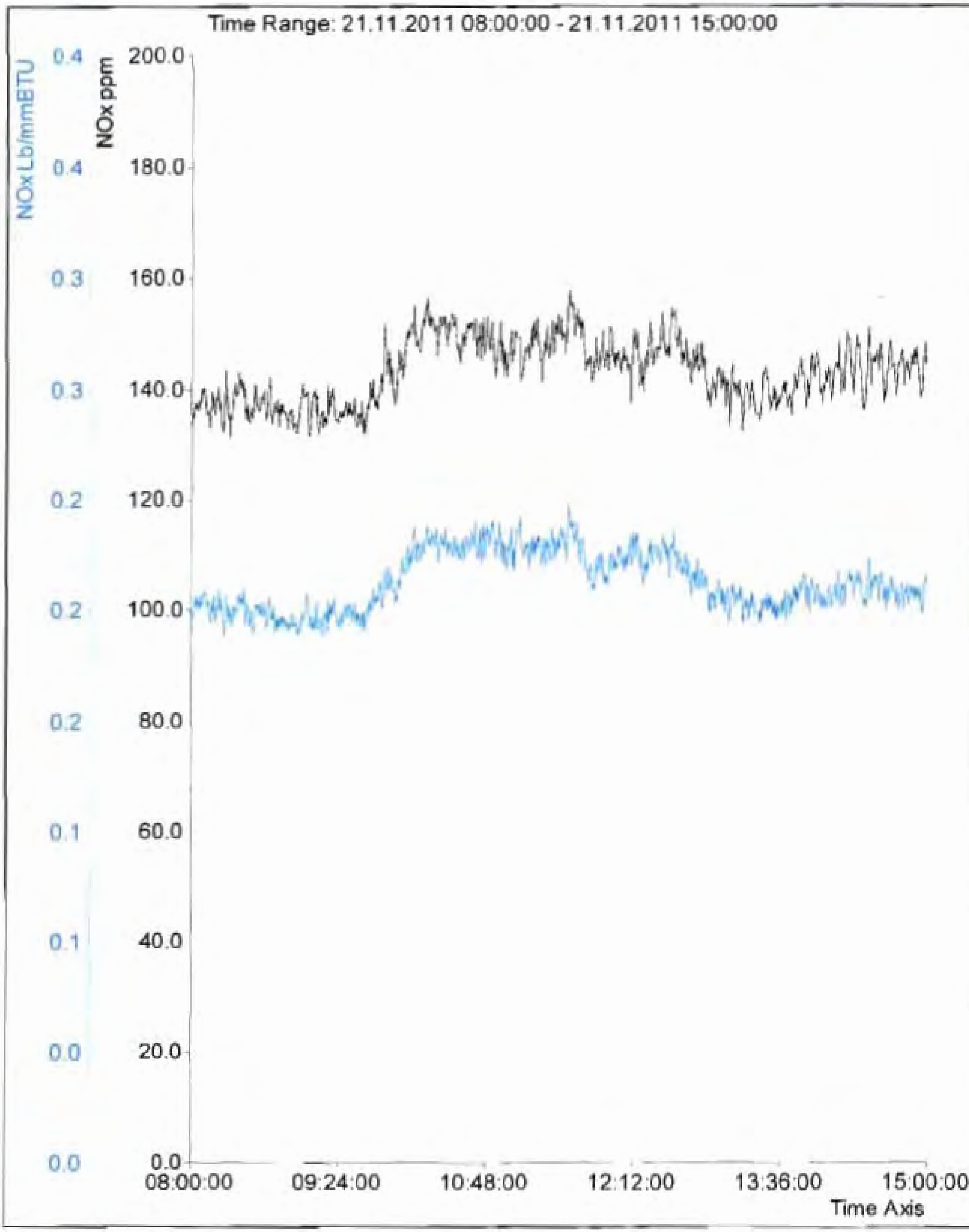
WinCC™ CSV-Provider - RT - Curves

Copyright (c) 1994-2005 by SIEMENS AG

\\OS1\WinCC60_Project_OS1\OS1.mcp



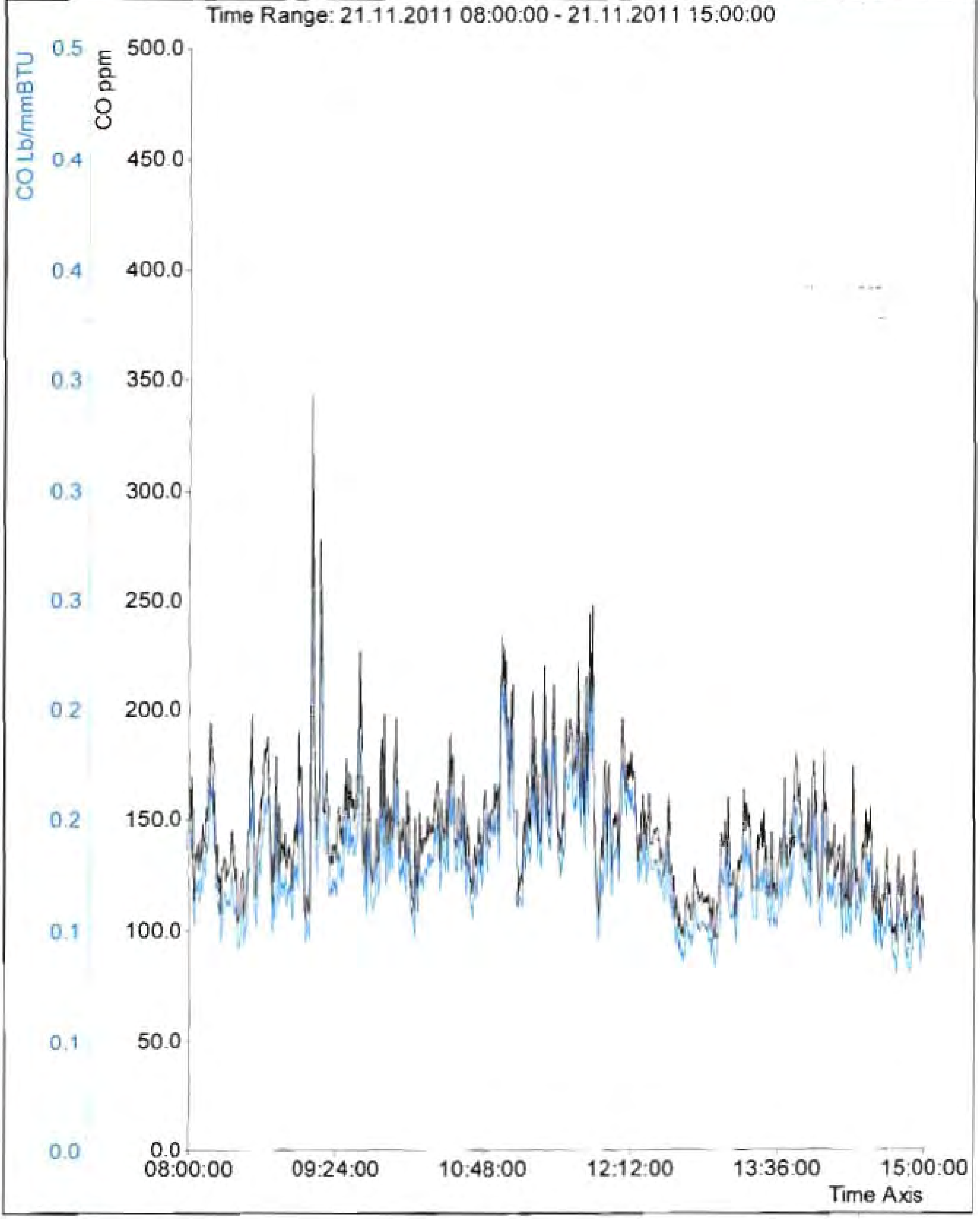
Trial Run #5 45 wt% willow:WTC
21nov11 start: 0930hrs stop: 1220hrs
with following 5 pages



WinCC™ CSV-Provider - RT - Curves

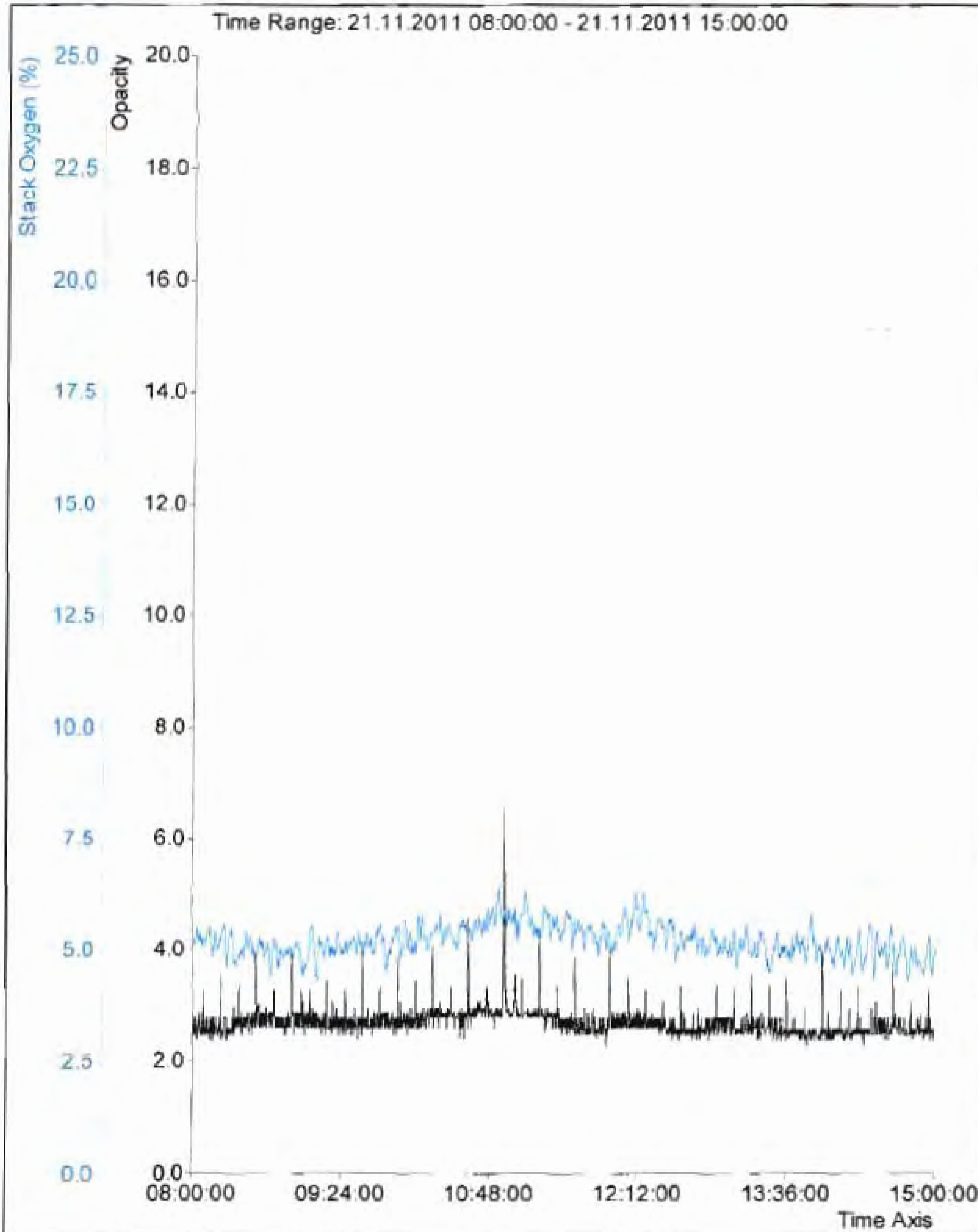
Copyright (c) 1994-2005 by SIEMENS AG

\\OS1\WinCC60_Project_OS1\OS1.mcp



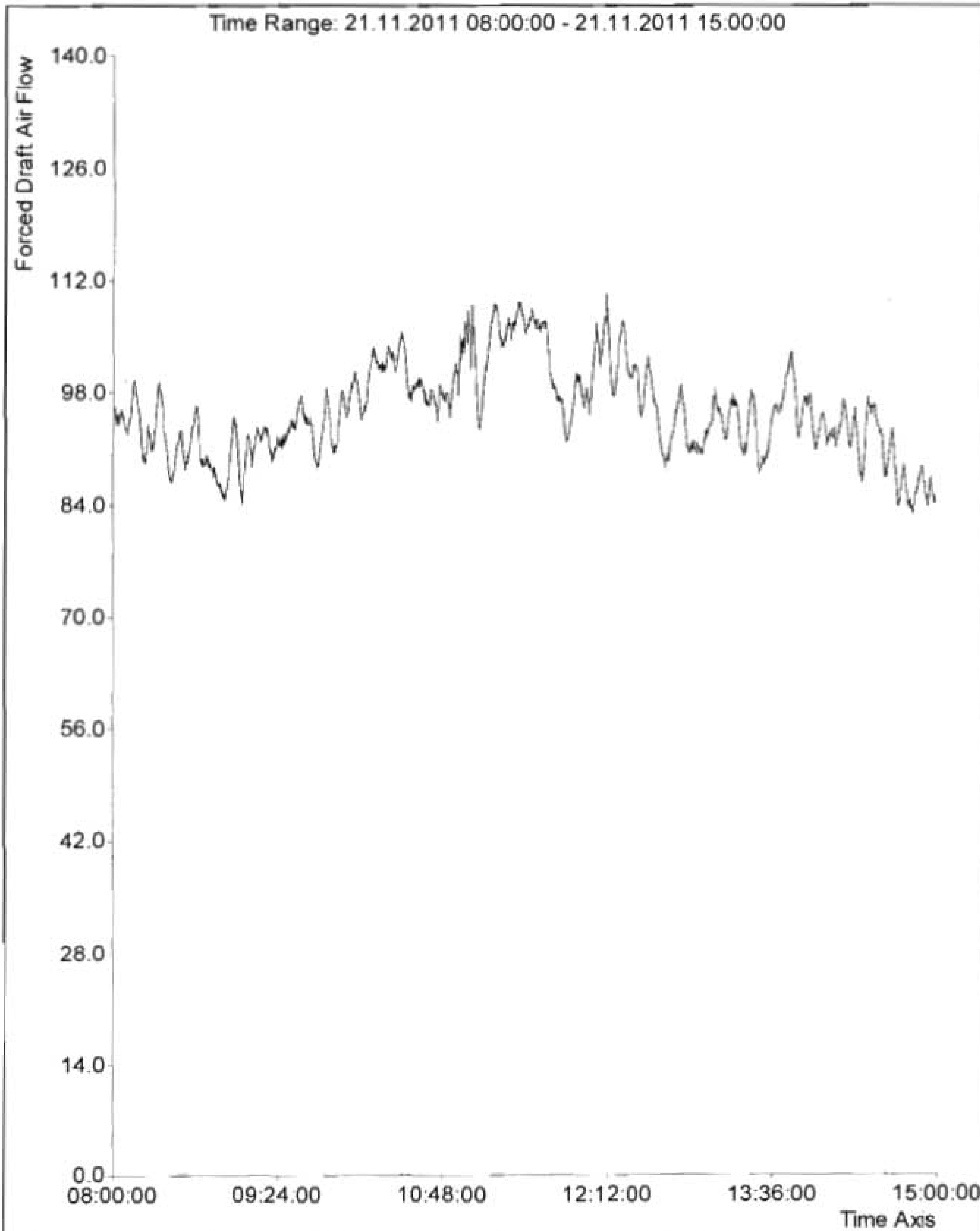
WinCC™ CSV-Provider - RT - Curves

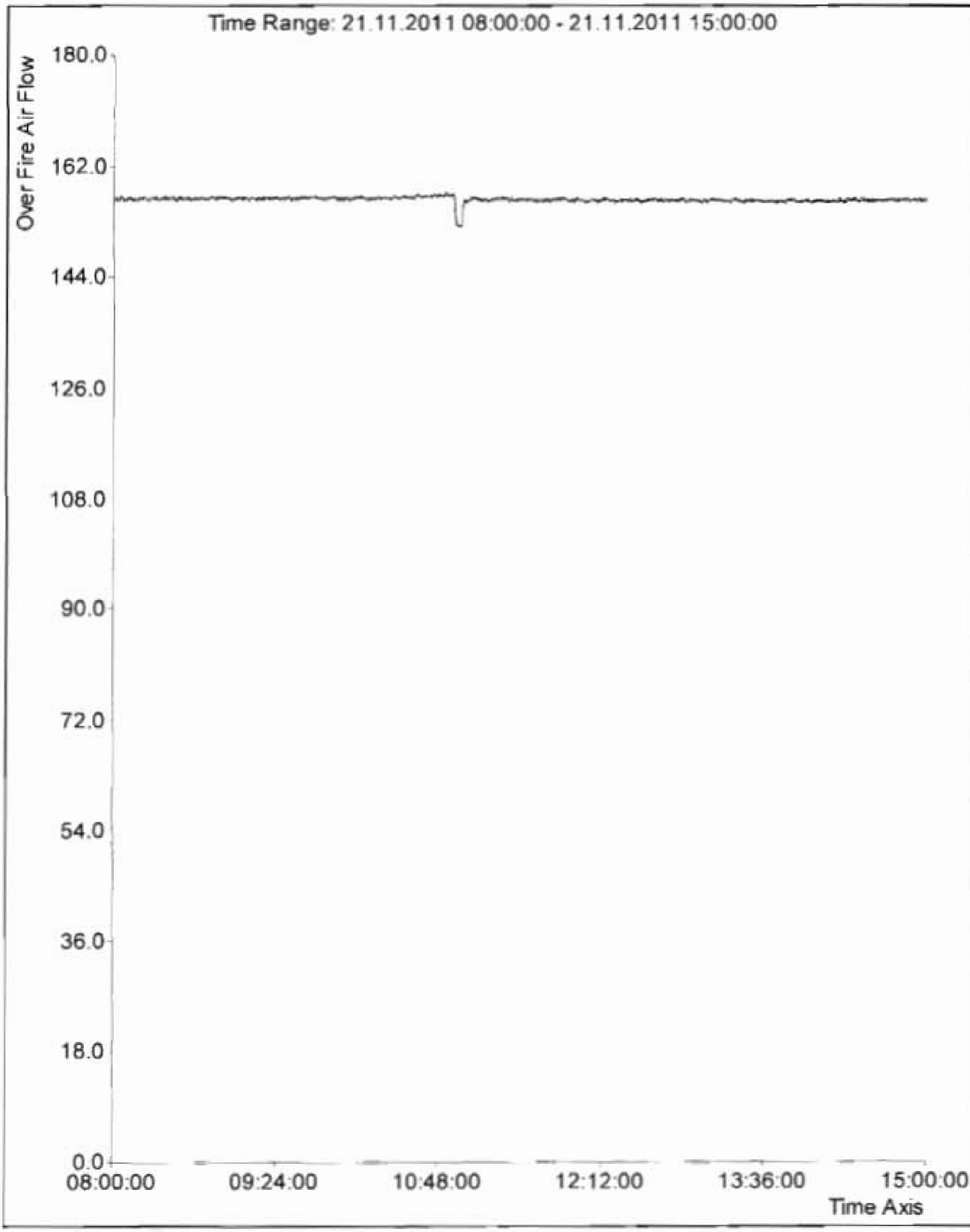
\\OS1\WinCC60_Project_OS1\OS1.mcp



WinCC™ CSV-Provider - RT - Curves

\\OS1\WinCC60_Project_OS1\OS1.mcp




Time Range: 21.11.2011 08:00:00 - 21.11.2011 15:00:00
Over Fire Air Flow
180.0
162.0
144.0
126.0
108.0
90.0
72.0
54.0
36.0
18.0
0.0
08:00:00
09:24:00
10:48:00
12:12:00
13:36:00
15:00:00
Time Axis

WinCC™ CSV-Provider - RT - Curves

\\OS1\WinCC60_Project_OS1\OS1.mcp