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EVALUATION OF EMISSIONS FROM THE OPEN BURNING OF LAND-CLEARING DEBRIS

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FINAL REPORT

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ABSTRACT

The exposure of persons to combustion emissions during land-clearing activities has become an issue of increasing concern. This study identifies and quantifies a broad range of air pollutants that are discharged during small-scale, simulated, open combustion of land-clearing debris and reports these emissions relative to the mass of material combusted. Two types of land-clearing debris (representing the typical land-clearing debris found in Florida and Tennessee; primarily wood and other organic debris) were combusted in a facility designed to simulate open burning. One debris sample was also combusted in the same facility using a simulated air curtain incinerator. Volatile, semivolatile, and particulate-bound organics were collected and analyzed by gas chromatography/mass spectrometry (GC/MS). The emphasis of analyses was placed on the quantification of hazardous air pollutants listed in Title III of the Clean Air Act Amendments (CAAAs) of 1990, although further efforts were made to identify and quantify other major organic components. Fixed combustion gases (carbon dioxide, carbon monoxide, nitric oxide, oxygen, and total hydrocarbons) were monitored continuously throughout the test period.

This project succeeded in producing estimated emissions data for a broad range of atmospheric pollutants from a simulated open debris combustion process. Both air concentrations within the facility where combustion was taking place and estimated emissions expressed as mass of pollutant per mass of debris material consumed by combustion were reported for volatile, semivolatile, and particulate-bound organics, typical combustion gases, and particulate. Substantial emissions of a large number of pollutants including carbon monoxide, Particulate Matter less than 10 and 2.5 pm in diameter (PM_{10} and $PM_{2.5}$) , benzene, acetone, toluene, ethyl benzene, pinene, naphthalene, phenol, and 14 polycyclic aromatic hydrocarbons were observed.

These tests did not provide conclusive evidence regarding the effectiveness of air curtain combustors in reducing emissions. While the emissions of some pollutants seemed to be decreased, others were unchanged or, in a few cases, appeared to increase.

TABLE OF CONTENTS

Section Page

Table of Contents (Continued)

Section Page

LIST OF TABLES

Table Page

LIST OF FIGURES

(continued)

LIST OF FIGURES (cont.)

PREFACE

The CTC was established by EPA's Office of Research and Development (ORD) and Office of Air Quality Planning and Standards (OAQPS) to provide technical assistance to state and local air pollution control agencies. Three levels of assistance can be accessed through the CTC. First, a CTC HOTLINE (919-541-0800) has been established to provide telephone assistance on matters relating to air pollution control technology. Second, more in-depth engineering assistance can be provided when appropriate. Third, the CTC can provide technical guidance through publication of technical guidance documents, development of personal computer software, and presentation of workshops on control technology matters.

The technical guidance projects, such as this one, focus on topics of national or regional interest that are identified through contact with state and local agencies.

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SECTION 1.0

INTRODUCTION

Disposal of debris generated by land-clearing or landscaping activities has long been problematic. Land-clearing is required for a wide variety of purposes such as construction, development, and clearing after natural disasters. The resultant debris is primarily vegetative in composition, but may include inorganic material. Landscaping activities such as pruning often generate similar vegetative debris. This debris is often collected and disposed of by municipalities. Open burning or burning in simple air curtain incinerators is a common means of disposal for these materials, which has long been a source of concern. Air curtain incinerators use a blower to generate a curtain of air in an attempt to enhance combustion taking place in a trench or a rectangular shaped, open topped refractory box. For instance, in Detroit, the problem of municipal burning of brush, logs and stumps became so severe that in September 1958 the mayor appointed a committee to study this problem among others. This eventually led to the design and construction of a specially designed incinerator in 1961-62 for brush and log burning, which was more complex than an air curtain incinerator, at a cost of $250,000.[1] In many locations open burning or the use of simple "air curtain incinerators" is still the method of choice for the disposal of these materials.

An evaluation of literature on emissions from open air burning of debris shows a limited amount of information on emission factors for specific pollutants measured in such a way that emissions could be estimated and therefore modeled. However, Gerstle and Kemnitz[2] did measure emission factors for the open burning of "landscape refuse such as lawn clippings, leaves, and tree branches" for carbon dioxide (CO_2), carbon monoxide (CO), total hydrocarbons (THC), formaldehyde, total organic acids, nitric oxide (NO), total particulate and nine poly-aromatic hydrocarbons (PAHs) species. Emissions of PAH species detected ranged from 0.03 to 1.3 g/ton (units are original authors') of material initially present ($3x10^{-5}$ to $1.3x10^{-3}$ g/kg material initially present). THC emissions were measured as 30 lb/ton of original material (13 g/kg of original material) and total particulate emissions were measured as 17 lb/ton (units are original authors) of original material (7.6 g/kg of original material). EPA has compiled emissions factors from the prescribed burning of "Logging slash debris, Dozer piled Conifer" including estimates for $PM_{2.5}$, PM_{10}, total particulate, and CO.[3] These factors are provided for various fire conditions and soil contents. Values for total particulate range from 5 to 35 g/kg.

The literature on wood/biomass combustion under other circumstances can also provide some guidance for the levels of pollutants expected under open burning conditions. Smith and Thorneloe[4] have measured the following emission factors (g/kg dry fuel) for wood burned in a third world cook stove: CO_2 = 1620, CO = 99, CH_4 = 9, total nonmethane hydrocarbon = 12, total suspended particulate = 2. Boubel and coworkers[5] determined emission factors from burning grass stubble and straw for particulate, CO_2, CO, olefins, and ethylene. THC emissions ranged from 4 to 19 lb/ton (units are original authors') (2 to 9 g/kg) of grass burned and particulate ranged from 10 to 17 lbs/ton (4 to 8 g/kg). Emission factors from wood stove and wood in fireplaces have also been compiled[3,6,7,8] for PAHs, aldehydes, phenols and typical combustion gases. For instance, Cooper[6] reports emissions factors for fireplaces of 19 g/kg (42.5 lb/ton) of fuel for volatile hydrocarbons, 9.1 g/kg (20.3 lb/ton) for total particulate and 0.00018 g/kg (0.00040 lb/ton) to 0.01 g/kg (0.0216 lb/ton) for various PAH species. Radke *et al*.[9] estimate an emission factor of four percent or 40 g/kg (89.6 lb/ton) for total particulate from an "86 acre conifer slash fire of logging debris" based on airborne measurements. EPA has also compiled emission factors for forest fires[3] for total particulate, CO, THC, and NO_x. The value for total particulate is 8.5 g/kg (19.04 lb/ton) and for THC is 12 g/kg (26.88 lb/ton). Extensive literature on biomass burning from a global warming perspective exists;[10,11,12] however, most of these papers report estimated global total emissions or emissions ratios relative to CO_2 rather than emissions factors.

Several similarities can be drawn from the literature reviewed. Most of the available data focus on only a few classes of pollutants. The list of pollutants for which emission factors are available does not include most of the air toxic compounds listed in the Clean Air Act Amendments (CAAAs) of 1990. However, the rough order of magnitude agreement in the total particulate and THC emission factors reviewed over a wide variety of source types is notable.

Local air regulatory agencies, including those in Tennessee and Broward County, Florida, requested that more detailed information on the emissions from these processes be made available. Therefore, the Control Technology Center (CTC) steering committee proposed a research project examining emissions from the open burning of debris.

In response to these concerns, through the guidance of EPA's Air Pollution Prevention and Control Division (APPCD), a study was undertaken to measure emissions from the simulated open combustion of land-clearing debris. This study included replicated simulated open burning tests of debris from Florida and Tennessee and replicate tests with a simulated air curtain incinerator for the Tennessee debris. The study was designed to collect, identify, and quantify a wide range of air emissions and to report these emissions per mass of debris material combusted. The emphasis of these analyses was placed on the quantification of air toxics compounds listed in the CAAAs, although further efforts were made to identify and semiquantify other major organic components.

SECTION 2.0

EXPERIMENTAL APPROACH

2.1 SUMMARY OF EXPERIMENTAL APPROACH

The project consisted of a replicated study to collect and qualitatively and quantitatively characterize organic and particulate emissions resulting from the simulated open combustion of land clearing debris. Small quantities (11.3 to 17.8 kg [25 to 39 lb]) of wood, sticks, twigs, leaves and organic matter were combusted in a refractory lined pit within a test facility specifically designed to simulate open-combustion conditions. Sampling was conducted within the facility through a modified dichotomous sampler using 142 mm filter heads for $PM_{2.5}$ and PM_{10} particulate sampling. Volatile organics were sampled using SUMMA® canisters and semivolatiles were sampled using a PUF/XAD TO-13 sampling train. A portion of the combustion effluent was diverted to an adjacent sampling facility via an induced draft duct. A portion of the sample from the induced draft duct was also analyzed by a series of continuous emission monitors for CO_2, CO, nitric oxide (NO), oxygen (O_2), and THC. The organic constituents were analyzed both qualitatively and quantitatively using a gas chromatograph/mass spectrometer (GC/MS). Measured concentrations were related to dilution air volumes and measured net mass of debris combusted to derive emission rates. The EPA's Open Burning Simulation Facility used in this study is further described in Section 2.2. This facility has been used in similar projects.[13,14,15,16,17,18]

2.2 OPEN BURNING SIMULATION FACILITY

This facility consists of three primary components: the burn hut, the sample shed, and the Hazardous Air Pollutants Mobile Laboratory (HAPML).

2.2.1 Burn Hut

The burn hut (Figures 1 and 2) is an outbuilding with a 2.7 x 3.4 m (8.9 x 11.1 ft) floor area and a sloping roof with a minimum height of 1.9 m (6.3 ft) and a maximum height of 2.2 m (7.3 ft), modified for small-scale, open-combustion simulation experiments. The building has been fitted with an air handling system, which during this study delivered 43.6 to 45.4 m^3/min (1,540 to 1,603 ft^3/min). This air handling unit supplies air at ground level to both sides of the burn hut. The flow rate was sufficient to maintain an approximately constant positive pressure within the facility. Thus it could be assumed that the outflow rate from the facility was equal to this inflow rate. At this flow rate, the effective air exchange rate of the burn hut is 2.3 to 2.4 exchanges/min. Two residential type electric fans were placed in the hut to ensure thorough mixing. The test material for the burning of debris was combusted in a steel rectangular box lined with approximately one inch of refractory. The box dimensions were 91- x 46- x 41-cm deep (36- x 18- x 16-in deep). A pyramidal, metal deflector shield was located 0.9 to 1.2 m (3 to 4 ft) over the hearth to deflect flames, protect the ceiling, and enhance ambient mixing. The sample transport duct, 17-cm (6.6-in) OD stove pipe, was located directly over the deflector shield. This duct transported a representative sample from the burn hut atmosphere to the sampling shed located adjacent to the burn hut (Figure 1). To minimize heat loss and condensation of organics, the duct was insulated outside the burn hut. The inner walls and ceiling of the burn hut were covered with 1.6-mm (1/16 in) aluminum sheeting to provide an inert surface within the test facility. To provide a highly clean, inert surface within the test facility, all surfaces within the burn hut were completely lined with Tedlar® sheet material (approximately 0.06 mm thick) and sealed with HVAC grade aluminum faced tape (Part No. 6A062, W. W. Grainger).

A simulated air curtain combustor was constructed for the tests of this system based on an analysis of specifications of pilot- and full-scale units of this type.[19-23] Dimensions of this unit as built, as well as its location within the burn hut, are shown in Figures 3 and 4. The blower selected for this work was a Gast Model R4110-2. At 60 Hz this blower is capable of a maximum pressure of 52-in (13,000 pascals) of water and a maximum flow of 92 CFM (2600 l/min). The blower system was tuned based on a visual observation of the combustion performance during the preliminary test to accurately simulate the performance of known pilot- and full-scale units.[19-23] The flow was adjusted to enhance the combustion rate, avoid entraining ash out of the refractory lined pit, and to achieve a vortex shaped flame and smoke pattern as shown in the work of Witt[22] and Belcher.[20] The air curtain was tested using the Airdata multimeter with a flowhood system. The flow rate of the air was tested by placing the hood over the air curtain manifold and sealed to minimize air leaks. Velocities were checked using an Alnor© hot wire anemometer placed directly in front of the opening. Flow measurements for the air curtain system gave velocities ranging from 61 to 69 m/s

(200 to 225 ft/s or 136 to 153 mph) and flow rates of approximately 2.52 m^3/min (89 ft^3/min). These velocities appear to be comparable to full scale systems based on data from Hahne (85 to 100 mph)[19] and Ford and Rogers “up to 165 mi/h."[23]

Debris for these combustion tests was obtained with the assistance of state/local environmental personnel in two different jurisdictions. The samples were collected in solid wood crates and shipped to Research Triangle Park, NC. The material was stored at ambient temperatures and humidities and burned as received. The subsamples for each test were manually selected by test personnel to obtain, as representative as possible, a subsample while also arranging the materials in such a way as to ensure that the combustion process started easily. The materials were placed in the burn pit based on the technician's experience in laying fires, in a similar manner that a construction worker might arrange the materials from a small land clearing operation before ignition.

Visual observations of the debris samples were made and documented before combustion. The sample collected from the State of Tennessee included a wide range of different sizes of materials. A substantial percentage of the material (twigs, leaves, conifer needles, conifer cones, etc.) would act as "kindling" or "tinder." The balance of the material was larger branches or logs. At least one extremely large section of tree trunk was included that required splitting with hand tools before it could be introduced into the refractory burn pit. The sample received from the state of Florida appeared to include much less fine material. The vast majority of this sample was branches and limbs that appeared to be coated with soil and in some cases mold.

Attempts were made to measure the moisture content of the wood samples before combustion using a Delmehorst Instrument Company RDX-1 tester. These attempts were judged to be unreliable and unsuccessful because the instrument requires a setting dependent on the species of wood. The test personnel were unable to make conclusive identification of species and observed that the results varied strongly dependent on the instrument setting. Therefore, these results have not been reported. Given limited project resources no further attempts to measure the moisture content of the fuel wood were made.

Also located in the burn hut were inlets for various sampling devices; the inlet for the volatiles sampling train was located within the burn hut, the SUMMA® canister and balance of the sampling train were located on the exterior to the burn hut. The inlet and sampling media for the dichotomous sampler and particulate and semivolatile organic sampler were located within the burn hut. The meter box and pumps for these trains were located in an adjacent sample shed.

2.2.2 Sample Shed

The sample shed (Figure 1) contained the majority of the required sampling equipment: the particulate Dichot pump and meter box, the PUF/XAD-2 pumps and meter box, and the particulate removal device for the continuous emission monitors (CEMs). A digital readout/control for the platform scale was remotely operated from the sample shed. Volatiles were sampled using a n -in (0.64 cm) Teflon line inserted through a hole in the back of the burn hut. This line was filtered to 0.2 µm particle size and regulated using a 0 to 50 ml/min mass flow controller.

CEM samples were extracted from a sampling manifold within the duct. The manifold consists of 9.5-mm (3/8-in) OD stainless steel probes positioned in the sample transport duct so that the probe orifice faced the direction of sample flow. The sample stream was pulled from the burn hut into the sample shed under a vacuum by an induced draft (ID) fan located downstream of the sample manifold. A heated filter box and heated sample line carried the sample gas to the Hazardous Air Pollutants Mobile Laboratory (HAPML).

2.2.3 Hazardous Air Pollutants Mobile Laboratory (HAPML)

The HAPML (Figure 1) was used for the continuous monitoring of the fixed combustion gases. A heated (121 °C [250 °F]), particulate-free gaseous sample was extracted from the sample manifold and routed to individual analyzers for continuous measurement. A portion of the heated sample was routed to the THC analyzer. The remaining portion of the sample stream was further conditioned for moisture removal by a refrigeration condenser and silica gel before being routed to the O_2, CO_2, and CO analyzers. The gas stream for NO was obtained from a location between the refrigeration condenser and desiccant. The analog output of the individual analyzers was recorded by a computerized data acquisition system that recorded all readings at 30-s intervals. The data acquisition system was also used to record weights from the platform scale and a series of eight thermocouples located in the burn hut, air conditioner input ducts, and sample transport duct.

2.3 TEST PROCEDURE

Before each test, a sample of debris was removed from the crate of either Florida or Tennessee samples and placed in the refractory burn box (RBB). The wood and other materials were arranged in the RBB to allow for easy lighting and total consumption of burn material. For these tests 11.3 to 17.8 kg (25 to 39 lb) of material was placed in the RBB. Before and after each test, or before and after each change of sample media (if this occurred more frequently) all sampling trains were leak checked. Before the beginning of each test day at least 15 min of background data were acquired on the CEMs, thermocouples, and the scale platform. The burn was then ignited by a brief application of a handheld propane torch, which was removed before sampling began. During a typical test, sufficient combustion began after less than 5 min of torch operation. The air curtain was started immediately after the removal of the lighting torch in tests involving this system. All sampling started 2 min after removal of the torch from the burn hut. This 2 min period was designed to ensure exhaust of any propane combustion byproducts.

To allow an adequate time period for all necessary samples to be obtained, some tests had another charge of debris added. Combustion of charge was allowed to go to apparent completion (as signified by unchanging weight and near background concentrations of combustion gases) before completion of the run. Combustion of one charge was allowed to go to apparent completion before another charge was introduced.

A "hut blank" test, in which the propane torch was briefly introduced into the facility but no debris was combusted, was conducted for comparison purposes. In addition, various field and laboratory blank samples were collected for each sampling train, as appropriate.

All dry gas meters were calibrated against a Bell Prover or wet test meter. The air inputs into the hut from the air handling system were measured in triplicate before and after each set of tests using an Airdata backpressure/temperature compensated flowgrid airflow system. To make these measurements, a flowgrid (Airdata Flow Meter CFM-88, Shortridge Instruments Inc., Scottsdale, AZ) was placed in front of the air conditioner openings in a pattern to traverse the entire opening. During these tests, the door of the burn hut was closed with both air conditioners running to maintain, as nearly as possible, the conditions during a test.

2.4 SAMPLING AND ANALYSIS METHODS

2.4.1 CEMs and Thermocouples

Fixed combustion gases CO_2, CO, NO, O_2, and THC were monitored continuously throughout the test period through the sampling manifold. The analog voltage output from each CEM instrument, as well as, a set of eight K-type thermocouples was interfaced with a computerized data acquisition system (Labtech Notebook using two EXP-16 data acquisition boards). Data was collected over a 30-s timed average and were automatically stored electronically. Each CEM was calibrated prior to each test. The calibration consisted of at least three points: zero, span, mid-point. After introducing the zero and adjusting, span gases were used to adjust the gain, and a mid-point calibration gas was introduced to verify analyzer linearity. The instrument was considered linear if the measured value differs from the known by less than two percent of the full scale of the operating range. At the conclusion of testing for the day the response of the instrument was again checked by introducing all the span gases. The instrument was considered to have remained within adequate calibration if the response to this span gas was within 15 percent of its certified value. All span gases used were certified by the manufacturer. All span and zero gases were delivered at a constant pressure and flow identical to those used during sampling. This was done to avoid biasing the sample gas measurements with respect to the calibration gas measurements. A calibration gas was allowed to flow through the entire system from the heated filter box to the analyzer to test for system sample bias on one occasion. Thermocouples calibration checks were conducted once during the test sequence using an ice bath slurry and a boiling water bath.

2.4.2 Volatile Organic Sampling and Analysis

Volatile organics were sampled into SUMMA® canisters and analyzed according to Method TO-14.[24] The canisters were cleaned before each experiment by five sequential evacuations and refillings with purified nitrogen. Ten percent of each batch of canisters were tested before use to ensure adequate cleaning. The SUMMA® canisters were located exterior to the burn hut with a Teflon® sample probe drawing directly from the rear of the burn hut. The sample was collected through a train consisting of the Teflon® tubing probe followed by a particulate filter and mass flow controller. The dead volume of this system was minimal compared to the sample volume. A diagram of a similar sampling system is provided in the cited method (TO-14, Figure 2). The filter and delivery system was not heated because the area to be sampled from (the burn hut) was very close to ambient temperature. A field blank canister sample was obtained by filling a canister with zero grade air at the sampling site. Method TO-14's instructions for capillary column GC/MS analysis in the full scan mode were used, although Method TO-14 contains provisions for other analytical methods that were not used in this study. Compound identification was based on retention time and the agreement of the mass spectra of the unknown to mass spectra of known standards. A multipoint calibration was performed before analysis for a targeted group of analytes to establish response factors (RFs). Quantification was then based on an external standard method using these RFs and the integrated responses for each identified compound. Beyond those compounds targeted up to the 20 highest abundance peaks were to be tentatively identified based on spectra identification. The program used for this tentative identification attempts to identify all nontargeted peaks with areas greater then 10 percent of that of the nearest eluting standard.

2.4.3 Dichotomous Sampling for Total PM_{10} and $PM_{2.5}$ Particulate

The Dichotomous Sampler was operated in accordance with the operating manual[25] and the provisions of the EPA's "Reference Method for the Determination of PM_{10} in the Atmosphere."[26] The method of operation of the sampling train for this project differed from the operating manual in several respects: (1) due to constraints of facility size, the sampler location criteria in Section 5.1 was modified, (2) the flow through the sampler was measured by a separate dry gas meter as discussed in Section 4.2 of the facility manual rather than by rotameter as discussed in the operating manual and (3) the filter holders were modified to accept a 142 mm Teflon® filter. However, rotameters were used to provide an instantaneous real time readout of flow rate to guide flow adjustment. All filters were desiccated before taring and stored in a desiccator after sampling, until weighing.

2.4.4 Particulate/Semivolatile Organic Sampling

Total particulate-phase organics were sampled using a Graseby PS-1 sampler operated within the burn hut. This train which is designed to comply with EPA's ambient sampling method TO-13[27] consisted of an open-faced filter holder followed by a Polyurethane Foam (PUF) sandwiched XAD-2 bed vapor trap. The target flow rate for this sampler as stated in TO-13 is 200 to 280 l/min (7 to 9.8

ft^3/min). This flow rate is designed to achieve low detection limits for the quantification of generally dilute ambient concentrations. Because this sampler does not have a particulate size separation device, considerably lower flow rates can be used. Due to the expected high concentrations of analytes in these tests we operated this sampler at approximately 28.3 l/min (1 ft^3/min). The temperature of air entering the train and within the PUF cartridge was assessed during preliminary tests to decide if further precautions were necessary to cool the system. Due to high temperatures in the burn hut, additional cooling was required and a copper cooling coil was fabricated to enclose the exterior of the PUF module. The method of operation of this sampling train was different from method TO-13 in the listed respects: (1) due to constraints of facility size, the sampler location criteria in Section 11.3.2 of TO-13 were modified, (2) the flow through the sampler was measured by a separate dry gas meter as discussed in Section 4.2 of the Burn Hut Facility Manual rather than a venturi and magnehilic gauge as discussed in TO-13, (3) analysis will be as described in this document.

The PUF pieces were cleaned using methylene chloride in a Sohxlet extractor and stored in sealed Tedlar bags before preparation of the PUF/XAD-2® cartridge. The XAD-2 resin was cleaned and Quality Control checked (QC'd) as outlined in Lentzen.[28] XAD-2 was maintained under refrigeration (4 °C) in an amber bottle when not in use. Train recovery follows Draft Method 3542 to the greatest extent feasible.[29]

The semivolatile and particulate phase organic sample was collected with 110-mm diameter filters (Pallflex 2500 QAT-UP), and a glass and stainless steel cartridge containing PUF/XAD-2® resin sorbent. All semivolatile organic samples were stored in sealed Tedlar® bags and maintained under refrigeration (4 °C) before extraction. The filter and cartridge were then extracted together in methylene chloride. A Sohxlet extractor was constructed to house the PUF/XAD-2® catridge and keep the solvent rinse level above the rim of the cartridge. The samples were concentrated using a rotary evaporator until the volume was approximately 5 ml, then the sample was transferred to a nitrogen blowdown vial. The samples were then concentrated using a nitrogen blowdown and hot water bath until a final volume of 1 ml was obtained. The samples were then transferred to a 2-ml crimp cap vial with septum until injection on the GC/MSD. Analysis was based on EPA Method 8270.[30]

2.5 DATA PROCESSING

After the completion of the chemical analyses, analyte concentration data were coupled with sample volume, facility air flow, and combustible material mass loss data to derive estimated emissions (expressed as mass of analyte produced per mass of debris material consumed in the combustion process).

SECTION 3.0

DATA, RESULTS, AND DISCUSSION

3.1 COMBUSTION CONDITIONS, CEM, AND TOTAL PARTICULATE RESULTS

The mass of material combusted in each test and the mass of ash obtained are summarized in Table 1. Note that in test No. 4 (Figure 8) the starting weight was determined to be 14.4 kg even though some momentary perterbations were seen most likely due to activities of the test staff during fuel lighting. In test No. 6 the start mass is the sum of two additions of debris material. In Table 1 and subsequent tables and figures the tests with the air curtain incinerator operable have been designated as "with blower" for brevity. CEM data, weight loss data, and visual observations indicated that the vast majority of the combustion of each charge of Tennessee material in the no blower cases was completed in a 60 min time period. The majority of the Florida material in the no blower condition in each charge appeared to be consumed in 100 min. The majority of the Tennessee material in the with blower tests was consumed in 40 to 60 min per charge (Figures 5 through 10). When comparing the weight/time curves, it is clear that the use of blower results in a much faster burning rate (Figures 9 and 10) than that without the blower (Figures 5 and 6). In these and subsequent figures "time 0:" is the beginning time of debris material ignition. Table 2 summarizes the estimated emissions derived from real time measurements of CO, THC, and NO and the average concentrations during combustion of CO_2 and O_2. The data quality for these observations is generally good (see Appendix A); however, the results for O_2 in test No. 7 and NO in test No. 1 should be viewed with caution due to data quality indicator failures. The substantial observed CO emissions (Figures 11 through 18 and Table 2), are a concern because CO is believed to be the primary cause of death of most fire victims.[31] Substantial CO_2 production was also observed (Figures 19 through 26 and Table 2). High concentrations of THC were observed (Figures 27 through 34 and Table 2). This is in reasonable qualitative agreement with the results of GC/MS volatiles analysis (see Section 3.3). Oxygen in the burn hut atmosphere was not dramatically depleted during these tests (Figures 35 through 42 and Table 2). Low NO emission levels were observed (Table 2 and Figures 43 through 50).

The time profile of emissions of CO, CO_2, NO and THC shows a sharp, narrow peak over the first 20 min of the Tennessee sample, no blower tests. The time profile of the emissions of these pollutants is markedly different in the Florida sample, no blower and Tennessee sample with blower tests. In these two sets of tests, the emissions tend to rise and fall gradually with the maximum being reached from 20 to 80 minutes after the initiation of the test.

Estimated emissions on a mass emitted per mass consumed by combustion basis of CO and THC appear broadly similar for the Tennessee and Florida materials in the no blower case (Table 2). These values appear to agree within a factor of two with those measured by Gerstle and Kemnitz[2] for "Landscape Refuse." Estimated emissions of CO and THC for the Tennessee material appear to be little impacted or at best slightly decreased by the use of the air curtain incinerator (Table 2).

3.2 PARTICULATE MATTER RESULTS

Substantial emissions of PM_{10} and $PM_{2.5}$ particulate matter were observed with both types of debris materials combusted (Table 3). Particulate catches on a mass/volume basis during hut blank tests were at least 10 fold lower than during any actual combustion test (Table 3). This indicates that the majority of particulate collected was actual combustion emissions and not particulate being resuspended from the burn hut walls or present in the ambient air fed into the facility. Estimated emissions (on a mass particulate per mass material combusted basis) from the Tennessee material appeared to be substantially higher than those from the Florida material. The Tennessee material without the blower gave fairly consistent values in replicate tests. The Tennessee material with the blower, in one case, gave a value that appeared similar to the value without the blower. In the next (duplicate) test, it gave values somewhat lower than those typical without the blower. However, in this test the sample was only obtained for a short period due to an equipment malfuntion and the flowrate did not meet data quality indicator goals (see Appendix A). In other tests data quality was acceptable for this measurement. Data shown in Table 3 indicate that the use of air curtains result in higher particulate concentrations. Note that the Tennesse sample with blower tests showed somewhat higher facility air concentrations of particulate than the Tennesse sample, no blower tests. However this was compensated for by the higher mass combusted in the with blower tests resulting in similar estimated emissions with and without the blower. In almost all cases, regardless of source of material or use of blower a majority of the PM_{10} appears to be composed of very fine material (<2.5µm diameter). This is an important observation because many believe that fine particulate is more strongly associated with health effects then coarse particulate.[32,33] Our average estimated PM_{10} emissions agree within ±25 percent to those measured by Gerstle and Kimnitz[2] for total particulate, perhaps due to this predominance of fine particulate.

3.3 VOLATILE ORGANIC RESULTS

The volatile organic data set produced from these tests included concentration measurements for more than 55 targeted and several dozen tentatively identified species. Targeted species are defined as those for which the analytical instrument was specifically calibrated. Tentatively identified species are other compounds found in the sample that can be tentatively identified through searches of mass spectral libraries checked by investigator examination of the mass spectral match. Compounds for which this tentative identification process was not successful are listed as "unknown" along with the tentantively identified compounds. Approximately 19 of the targeted species were consistently detectable. The results of the volatiles analyses of the targeted analytes are presented in Table 4 in concentration terms and in Table 5 as estimated emissions on a mass of pollutant per mass of material consumed by combustion basis. The results of the volatiles analyses for tentatively identified analytes are presented in Table 6 in concentration terms and in Table 7 on an estimated emissions basis. Data quality indicators for volatile analyses were generally good (see Appendix A).

Various hydrocarbon, aromatic, and oxygenated species such as benzene, acetone, toluene, ethyl benzene, m,p-xylene, pinene, limonene, naphthalene and styrene were among the highest concentration targeted volatiles observed. In general, emissions of these species were higher with the Tennessee material than in the Florida material. This trend was most dramatic for pinene and limonene, two compounds which belong to the terpene group that is often isolated from plants.[34]

Several targeted chlorinated species also appear to be emitted at lower levels. These species show differing and more erratic patterns of emission. The high levels of chloromethane emissions seen during the Florida material tests are especially interesting.

The data set is inconclusive on the effect of the air curtain incinerator on volatiles emissions. Emissions of many compounds appear unchanged, and while some species appear to be emitted at a lower rate with the air curtain in operation, emissions of others may be increased.

Alkenes, ketones, heteroaromatics and alkyl substituted aromatics are prominent among the tentatively identified volatile compounds.

3.4 SEMIVOLATILE AND PARTICULATE BOUND ORGANIC RESULTS

More then 100 semivolatile species were targeted in these analyses. The results of these analyses are reported in Table 8 in terms of mass per sample, Table 9 in terms of mass per unit volume of air in the burn hut and in Table 10 in terms of mass emitted per mass of debris consumed by combustion (estimated emission). Data quality indicator goals for these analyses, discussed in detail in Appendix A indicate that concentrations reported in test No. 3 and 6 may be modestly over estimated. Approximately 23 of these species were consistently detected in the combustion samples at levels significantly above blank levels. Fourteen of these twenty-three species are Polycyclic Aromatic Hydrocarbons (PAHs). These have been detected in numerous studies of wood combustion (see Section 1.0) so their appearance in a study of the combustion of land clearing debris is expected. The range of estimated emissions reported in this document agree broadly with those reported by Cooper for various PAH species from wood combustion in fireplaces.[6] Four of the twenty-three species detected were phenol and its methyl substituted derivatives. Phenols have also been previously established as wood combustion byproducts (see Section 1.0). The values measured here for estimated emissions of phenol are slightly higher then those measured by Cooper for wood combustion in fireplaces.[6] The remaining five consistently detected species were biphenyl, styrene, cumene, 2-methylnapthalene and dibenzofuran.

The results of the tests without the air curtain incinerator showed that concentrations of individual semivolatile species were usually similar for the Florida and Tennessee materials, but a few species were emitted at a moderately higher rate from the combustion of the Tennessee material. A brief analysis of this data set suggests that for most semivolatile species no discernable difference in emission factor between the with and without air curtain incinerator tests can be observed. However for a few species, such as pyrene, benzo(a)pyrene and biphenyl the use of the air curtain does appear to reduce emissions.

The fact that the air curtain did not significantly alter emissions is an interesting observation. This is in spite of the fact that the combustion during air curtain runs was significantly improved from a visual standpoint. It may be that cooling by the forced air may quench some of the combustion reactions at the outer edges of the burning mass, and the high velocities carry the products of incomplete combustion away before they can react with the hot gases in the flames.

Numerous tentatively identified species were also identified in the semivolatile analyses (Table 11). Tentatively identified species are other compounds found in the sample that can be tentatively identified through searches of mass spectral libraries checked by investigator examination of the mass spectral match. Quantitation of these species should be considered approximate. Compounds for which this tentative identification process was not successful are listed as "unknown" along with the tentatively identified compounds. These species consist primarily of alkylated and oxygenated aromatics, heteroaromatics, and polyaromatics.

SECTION 4.0

SUMMARY AND CONCLUSIONS

This project succeeded in producing estimated emissions data for a broad range of atmospheric pollutants from a simulated open debris combustion process. Both air pollutant concentrations within the facility where combustion was taking place and estimated emissions expressed as mass of pollutant per mass of debris material consumed by combustion were reported for volatile, semivolatile, and particulate bound organics, typical combustion gases, and particulate. Substantial emissions of a large number of pollutants including CO, PM_{10}, $PM_{2.5}$, benzene, acetone, toluene, ethyl benzene, pinene, naphthalene, phenol, and fourteen polycyclic aromatic hydrocarbons were observed. These tests did not provide conclusive evidence of the effectiveness of air curtain blowers in reducing emissions. While the emissions of some pollutants seemed to be decreased slightly others were unchanged or, even in a few cases, appeared to increase. A definitive assessment of the value of the air curtain device requires a detailed statistical and relative risk analysis. Measurements of a variety of pollutants in the emissions of full-scale models of this device operating under realistic work site conditions would also be helpful.

This project has yielded estimated emissions values for open debris combustion processes that can be used to assess the risks of these processes.

SECTION 5.0

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TABLE 1. MASS OF DEBRIS BURNED DURING TESTING

Test No.	Test Conditions	Date	Start Mass (kg)	Final Mass (kg)	Mass Burned (kg)
1	TN No Blower	1/31/95	11.3	0.0	11.3
2	TN No Blower	2/1/95	12.3	2.4	9.9
3	FL No Blower	2/2/95	11.8	0.0	11.8
4	FL No Blower	2/3/95	14.4	0.9	13.5
5	Hut Blank	2/15/95	0.0	0.0	0.0
6	TN With Blower	2/22/95	20.3	0.0	20.3
7	TN With Blower	2/23/95	17.8	0.0	17.8
8	Hut Blank	2/24/95	0.0	0.0	0.0

TABLE 2. TYPICAL COMBUSTION GASES

		Average Concentration During Combustion				
Test No.	Test Description	CO ppm	NO ppm	CO_2 ppm	THC ppm	O_2 %
1	TN No Blower	43	0.7	509	29.5	21.7
2	TN No Blower	25	0.1	687	10.4	22.8
3	FL No Blower	37	0.1	431	17.5	21.9
4	FL No Blower	33	0.2	1153	9.5	22.2
5	Hut Blank	1	0.1	328	1.2	21.9
6	TN With Blower	40	-0.3	589	21.3	21.7
7	TN With Blower	34	0.7	427	17.4	19.5
8	Hut Blank	2	0.1	94	0.9	22.6
		Estimated Emissions				
Test No.	Test Description	CO g/kg	NO g/kg	CO_2 g/kg	THC g/kg	O_2 g/kg
1	TN No Blower	23	0.37	NA	16	NA
2	TN No Blower	16	0.05	NA	6	NA
3	FL No Blower	19	0.03	NA	9	NA
4	FL No Blower	15	0.09	NA	4	NA
5	Hut Blank	NA	NA	NA	NA	NA
6	TN With Blower	12	-0.10	NA	7	NA
7	TN With Blower	11	0.24	NA	6	NA
8	Hut Blank	NA	NA	NA	NA	NA

NA = Not Applicable

TABLE 3. PARTICULATE DATA

Test No.	Test Conditions	Concentration PM $_{2.5}$ mg/m^3	Concentration PM $_{10}$ mg/m^3	Estimated Emissions PM $_{2.5}$ g/kg	Estimated Emissions PM $_{10}$ g/kg
1	TN No Blower	30.51	36.30	14.13	16.81
2	TN No Blower	18.75	19.13	10.04	10.25
3	FL No Blower	3.95	17.54	1.75	7.75
4	FL No Blower	11.63	11.90	4.56	4.66
5	Hut Blank	0.11	0.29	NA	NA
6	TN With Blower	45.15	45.77	12.07	12.23
7	TN With Blower	35.73	37.82	8.33	8.82
8	Hut Blank	0.07	0.26	NA	NA

Note: Run 7 particulate data questionable due to flow rate problems (see Appendix A)

TABLE 4. TARGETED VOLATILE CONCENTRATIONS (ng\l)

Test No.			1	2	3	4	5	6	7	8
Sample ID			TN	TN	FL	FL	Hut	TN	TN	Hut
Compound Name	MDL	PQL	nb	nb	nb	nb	Blank	wb	wb	Blank
dichlorodifluoromethane	1.64	5.40	nd	nd	nd	nd	nd	nd	nd	nd
dichlorotetrafluoroethane	4.26	14.07	nd	nd	nd	nd	nd	nd	nd	nd
chloromethane	0.61	2.06	13	11	301	141	nd	14	18	nd
vinyl chloride	0.56	2.55	nd	nd	nd	nd	nd	nd	nd	nd
1,3-butadiene	0.22	2.23	304	216	245	104	nd	506	494	nd
bromomethane	0.44	3.88	nd	nd	4	nd	nd	nd	nd	nd
chloroethane	1.02	3.37	nd	nd	nd	nd	nd	nd	nd	nd
trichlorofluoromethane	0.62	5.61	nd	nd	nd	nd	nd	nd	nd	nd
dichlorotrifluoroethane	0.62	6.22	nd	nd	nd	nd	nd	nd	nd	nd
trichlorotrifluoroethane	0.46	7.67	nd	nd	nd	nd	nd	nd	nd	nd
1,1-dichloroethene	0.59	3.96	nd	nd	nd	nd	nd	nd	nd	nd
acetone	0.24	2.41	483	370	474	213	6	675	434	11
carbon disulfide	0.32	3.17	nd	nd	nd	nd	nd	nd	nd	nd
methylene chloride	1.70	5.62	8	7	nd	4	4	nd	nd	nd
3-methylpentane	0.35	3.53	nd	nd	nd	nd	nd	nd	nd	nd
1,1-dichloroethane	0.19	4.04	nd	nd	nd	nd	nd	nd	nd	nd
butyl methyl ether	0.42	4.18	nd	nd	nd	6	nd	nd	nd	nd
cis-1,2-dichloroethene	0.25	3.97	nd	31	71	84	nd	106	46	nd
2-butanone	0.30	2.98	91	68	92	41	nd	113	67	nd
ethyl acetate	0.36	3.61	91	68	92	41	nd	112	67	nd
chloroform	1.61	5.31	nd	nd	nd	nd	nd	nd	nd	nd
1,1,1-trichloroethane	0.39	5.45	nd	nd	nd	nd	nd	nd	nd	nd
carbon tetrachloride	2.17	7.17	nd	nd	nd	nd	nd	nd	nd	nd
benzene	1.03	3.40	747	606	585	337	nd	1023	956	4
1,2-dichloroethane	0.39	4.43	nd	nd	nd	nd	nd	nd	nd	nd
trichloroethene	0.46	5.46	nd	nd	nd	nd	nd	nd	nd	nd
1,2-dichloropropane	0.51	4.62	nd	nd	nd	nd	nd	nd	nd	nd
cis-1,3-dichloropropene	0.70	4.61	nd	nd	nd	nd	nd	nd	nd	nd
dimethyl disulfide	0.39	3.86	nd	nd	nd	nd	6	nd	nd	6
4-methyl-2-pentanone	0.41	4.10	nd	nd	nd	nd	nd	nd	nd	nd
octane	0.47	4.66	18	12	11	7	nd	nd	18	nd
toluene	0.38	3.77	447	333	332	166	nd	617	752	4
trans-1,3-dichloropropene	0.87	4.61	nd	9	nd	nd	nd	nd	nd	nd
1,1,2-trichloroethane	0.31	5.50	nd	nd	nd	nd	nd	nd	nd	nd
tetrachloroethene	0.35	6.78	nd	nd	nd	nd	nd	nd	nd	nd
butyl acetate	0.48	4.75	nd	nd	nd	nd	nd	nd	nd	nd
1,2-dibromoethane	0.51	7.68	nd	nd	nd	nd	nd	nd	nd	nd
chlorobenzene	0.22	4.60	nd	nd	nd	nd	nd	nd	nd	nd
nonane	0.52	5.20	nd	nd	nd	nd	nd	nd	nd	nd
ethyl benzene	0.37	4.34	80	54	47	24	nd	101	124	nd
m,p-xylene	0.23	4.34	193	130	103	46	8	324	533	nd
o-xylene	0.58	4.34	45	32	35	17	4	65	66	nd
styrene	0.31	4.26	165	130	90	43	nd	220	305	nd
pinene	0.56	5.57	117	255	nd	nd	nd	300	438	nd
1,1,2,2-tetrachloroethane	0.42	6.87	nd	nd	nd	nd	nd	nd	nd	nd
decane	0.58	5.80	nd	nd	nd	nd	nd	nd	7	nd
4-ethyltoluene	0.49	4.92	63	44	28	12	nd	102	181	nd
1,3,5-trimethylbenzene	0.54	4.92	11	7	7	nd	nd	13	19	nd
1,2,4-trimethylbenzene	1.11	4.92	39	26	25	11	nd	57	90	nd

TABLE 4. TARGETED VOLATILE CONCENTRATIONS (ng\l)

Test No. Sample ID Compound Name	MDL	PQL	1 TN nb	2 TN nb	3 FL nb	4 FL nb	5 Hut Blank	6 TN wb	7 TN wb	8 Hut Blank
limonene	0.56	5.57	213	157	nd	nd	nd	192	326	nd
1,3-dichlorobenzene	0.33	6.02	nd	nd	nd	nd	nd	nd	nd	nd
1,4-dichlorobenzene	0.23	6.02	nd	nd	nd	nd	nd	nd	nd	nd
benzyl chloride	0.52	5.18	5	nd	nd	nd	nd	7	10	nd
undecane	0.64	6.38	10	7	nd	nd	nd	9	21	nd
1,2-dichlorobenzene	0.25	6.02	nd	nd	nd	nd	nd	nd	nd	nd
dodecane	0.70	6.95	8	nd	nd	nd	nd	7	13	nd
1,2,4-trichlorobenzene	0.51	7.43	nd	nd	nd	nd	nd	nd	nd	nd
hexachlorobutadiene	0.40	10.68	nd	nd	nd	nd	nd	nd	nd	nd
naphthalene	0.53	5.29	148	136	109	60	nd	157	186	nd

nb = no blower, wb = with blower, nd = not detected

TABLE 5. TARGETED VOLATILE COMPOUNDS ESTIMATED EMISSIONS (mg\kg)

Test No.	1	2	3	4	5	6	7	8
Sample ID	TN	TN	FL	FL	Hut	TN	TN	Hut
Compound Name	nb	nb	nb	nb	Blank	wb	wb	Blank
dichlorodifluoromethane	<2	<3	<2	<2	NA	<1	<2	NA
dichlorotetrafluoroethane	<7	<8	<6	<6	NA	<4	<4	NA
chloromethane	6	6	133	55	NA	4	5	NA
vinyl chloride	<1	<1	<1	<1	NA	<1	<1	NA
1,3-butadiene	141	116	108	41	NA	135	140	NA
bromomethane	<2	<2	2	<2	NA	<1	<1	NA
chloroethane	<2	<2	<1	<1	NA	<1	<1	NA
trichlorofluoromethane	<3	<3	<2	<2	NA	<1	<2	NA
dichlorotrifluoroethane	<3	<3	<3	<2	NA	<2	<2	NA
trichlorotrifluoroethane	<4	<4	<3	<3	NA	<2	<2	NA
1,1-dichloroethene	<2	<2	<2	<2	NA	<1	<1	NA
acetone	224	198	209	84	NA	180	123	NA
carbon disulfide	<1	<2	<1	<1	NA	<1	<1	NA
methylene chloride	4	4	<2	2	NA	<2	<2	NA
3-methylpentane	<2	<2	<2	<1	NA	<1	<1	NA
1,1-dichloroethane	<2	<2	<2	<2	NA	<1	<1	NA
butyl methyl ether	<2	<2	<2	2	NA	<1	<1	NA
cis-1,2-dichloroethene	<2	16	31	33	NA	28	13	NA
2-butanone	42	36	40	16	NA	30	19	NA
ethyl acetate	42	36	40	16	NA	30	19	NA
chloroform	<2	<3	<2	<2	NA	<1	<2	NA
1,1,1-trichloroethane	<3	<3	<2	<2	NA	<1	<2	NA
carbon tetrachloride	<3	<4	<3	<3	NA	<2	<2	NA
benzene	346	325	258	132	NA	273	270	NA
1,2-dichloroethane	<2	<2	<2	<2	NA	<1	<1	NA
trichloroethene	<3	<3	<2	<2	NA	<1	<2	NA
1,2-dichloropropane	<2	<2	<2	<2	NA	<1	<1	NA
cis-1,3-dichloropropene	<2	<2	<2	<2	NA	<1	<1	NA
dimethyl disulfide	<2	<2	<2	<2	NA	<1	<1	NA
4-methyl-2-pentanone	<2	<2	<2	<2	NA	<1	<1	NA
octane	8	6	5	3	NA	<1	5	NA
toluene	207	179	147	65	NA	165	212	NA
trans-1,3-dichloropropene	<2	5	<2	<2	NA	<1	<1	NA
1,1,2-trichloroethane	<3	<3	<2	<2	NA	<1	<2	NA
tetrachloroethene	<3	<4	<3	<3	NA	<2	<2	NA
butyl acetate	<2	<3	<2	<2	NA	<1	<1	NA
1,2-dibromoethane	<4	<4	<3	<3	NA	<2	<2	NA
chlorobenzene	<2	<2	<2	<2	NA	<1	<1	NA
nonane	<2	<3	<2	<2	NA	<1	<1	NA
ethyl benzene	37	29	21	9	NA	27	35	NA
m,p-xylene	89	70	46	18	NA	86	151	NA

TABLE 5. TARGETED VOLATILE COMPOUNDS ESTIMATED EMISSIONS (mg\kg)

Test No. Sample ID Compound Name	1 TN nb	2 TN nb	3 FL nb	4 FL nb	5 Hut Blank	6 TN wb	7 TN wb	8 Hut Blank
o-xylene	21	17	15	7	NA	17	19	NA
styrene	76	70	40	17	NA	59	86	NA
pinene	54	137	<2	<2	NA	80	124	NA
1,1,2,2-tetrachloroethane	<3	<4	<3	<3	NA	<2	<2	NA
decane	<3	<3	<3	<2	NA	<2	2	NA
4-ethyltoluene	29	23	12	5	NA	27	51	NA
1,3,5-trimethylbenzene	5	4	3	<2	NA	4	5	NA
1,2,4-trimethylbenzene	18	14	11	4	NA	15	25	NA
limonene	99	84	<2	<2	NA	51	92	NA
1,3-dichlorobenzene	<3	<3	<3	<2	NA	<2	<2	NA
1,4-dichlorobenzene	<3	<3	<3	<2	NA	<2	<2	NA
benzyl chloride	2	<3	<2	<2	NA	2	3	NA
undecane	4	4	<3	<3	NA	2	6	NA
1,2-dichlorobenzene	<3	<3	<3	<2	NA	<2	<2	NA
dodecane	4	<4	<3	<3	NA	2	4	NA
1,2,4-trichlorobenzene	<3	<4	<3	<3	NA	<2	<2	NA
hexachlorobutadiene	<5	<6	<5	<4	NA	<3	<3	NA
naphthalene	69	73	48	24	NA	42	53	NA

nb = no blower, wb = with blower, NA = not applicable, nd = not detected

TABLE 6. CONCENTRATION OF TENATIVELY IDENTIFIED VOLATILES (ng/l)

Rentention Time (min)	Compound	1	2	3	4	5	6	7	8	9
	Test No.	TN	TN	FL	FL	Hut	TN	TN	Hut	Field
		nb	nb	nb	nb	Blank	wb	wb	Blank	Blank
6.79	2-methyl-1-propene	136	102	84		14	217	135	9	
7.72	unknown	188	159	207	154		391	275	12	
11.68	1,3-pentadiene		124	106	103	5		691	5	
11.82	furan						659			
12.34	unknown	133	98		72		291	185		
13.36	1,3-cyclopentadiene	76	67	55						
13.85	methyl ester acetic acid	354	262	319	261		388	90		
15.50	2,5-dihydro-furan		62							
15.88	2-methyl-2-propenal				28		113	90		
16.31	2-methyl-1,3-pentadiene						69			
16.50	2-methyl-furan	332	262	273	268		353	181		
17.01	3-buten-2-one	335	280	260	159		486	309		
17.36	2-butanone	162	138	222	178	7	262	125	3	
19.23	acetic acid					23			35	
20.03	3-methyl-2-buten-2-one	42	37	29	98		49	63		
20.29	2,5-dimethyl-furan			24						
20.64	2-pentanone	55		26						
23.14	1-(2-furanyl)-ethanone				11					
24.36	cyclopentanone			19	11				2	
25.79	2-furancarboxaldehyde	206	174	167	170	3	228	161	2	
25.91	2-cyclopenten-1-one	50	48	48	27		56			
26.56	1-(acetyloxy)-2-propanone	66	57				51	64		
27.52	2-methyl-2-cyclopenten-1-one			30	16		56			
27.68	1-(1H-pyrazol-4-yl)-ethenone			28	20					
28.22	unknown cyclic or unsaturated HC	34	61				125	127		
29.03	benzaldehyde	62		45	28		37	160		
29.13	5-methyl-2-furancarboxaldehyde	51	38	19	18	2				
29.45	benzofuran	40	33	34	22		52	44		
29.59	3-methyl-2-cyclopenten-1-one				20					
29.68	unknown	40				2	68		5	
30.33	phenol	61	77					51		
30.56	1,2-propadienyl-benzene	45	49	24	14		33	55		
31.00	methyl(1-methylethenyl)-benzene	41	41				32	57		
31.52	1-(1-propynyl)-cyclohexene				11		41			
31.67	2-methyl-phenol	43	50							
31.87	7-methyl-benzofuran		0	28	14			77		
32.25	3-methyl-phenol	44	46							
32.13	5,6-dimethyl-indan							60		
33.12	2-nitro-phenol			59	11					

nb = no blower, wb= with blower

TABLE 7. ESTIMATED EMISSIONS - TENATIVELY IDENTIFIED VOLATILES (mg/kg)

	Test No.	1	2	3	4	5	6	7	8	9
Rentention		TN	TN	FL	FL	Hut	TN	TN	Hut	Field
Time (min)	Compound	nb	nb	nb	nb	Blank	wb	wb	Blank	Hut
6.79	2-methyl-1-propene	63	55	37		NA	58	381	NA	NA
7.72	unknown	87	85	91	61	NA	105	777	NA	NA
11.68	1,3-pentadiene		66	47	40	NA		1954	NA	NA
11.82	furan					NA	176		NA	NA
12.34	unknown	62	53		28	NA	78	523	NA	NA
13.36	1,3-cyclopentadiene	35	36	24		NA			NA	NA
13.85	methyl ester acetic acid	164	140	141	102	NA	104	254	NA	NA
15.50	2,5-dihydro-furan		33			NA			NA	NA
15.88	2-methyl-2-propenal				11	NA	30	253	NA	NA
16.31	2-methyl-1,3-pentadiene					NA	18		NA	NA
16.50	2-methyl-furan	154	140	121	105	NA	94	512	NA	NA
17.01	3-buten-2-one	155	150	115	62	NA	130	874	NA	NA
17.36	2-butanone	75	74	98	70	NA	70	352	NA	NA
19.23	acetic acid					NA			NA	NA
20.03	3-methyl-2-buten-2-one	20	20	13	38	NA	13	177	NA	NA
20.29	2,5-dimethyl-furan			10		NA			NA	NA
20.64	2-pentanone	25		11		NA			NA	NA
23.14	1-(2-furanyl)-ethanone				4	NA			NA	NA
24.36	cyclopentanone			9	4	NA			NA	NA
25.79	2-furancarboxaldehyde	95	93	74	67	NA	61	454	NA	NA
25.91	2-cyclopenten-1-one	23	25	21	11	NA	15		NA	NA
26.56	1-(acetyloxy)-2-propanone	31	31			NA	14	182	NA	NA
27.52	2-methyl-2-cyclopenten-1-one			13	6	NA	15		NA	NA
27.68	1-(1H-pyrazol-4-yl)-ethenone			12	8	NA			NA	NA
28.22	unknown cyclic or unsaturated HC	16	33			NA	33	360	NA	NA
29.03	benzaldehyde	29		20	11	NA	10	452	NA	NA
29.13	5-methyl-2-furancarboxaldehyde	24	20	9	7	NA			NA	NA
29.45	benzofuran	18	18	15	9	NA	14	124	NA	NA
29.59	3-methyl-2-cyclopenten-1-one				8	NA			NA	NA
29.68	unknown	19				NA	18		NA	NA
30.33	phenol	28	41			NA		143	NA	NA
30.56	1,2-propadienyl-benzene	21	26	11	5	NA	9	154	NA	NA
31.00	methyl(1-methylethenyl)-benzene	19	22			NA	8	160	NA	NA
31.52	1-(1-propynyl)-cyclohexene				4	NA	11		NA	NA
31.67	2-methyl-phenol	20	27			NA			NA	NA
31.87	7-methyl-benzofuran			12	6	NA		217	NA	NA
32.25	3-methyl-phenol	20	25			NA			NA	NA
32.13	5,6-dimethyl-indan					NA		169	NA	NA
33.12	2-nitro-phenol					NA			NA	NA

nb= no blower, wb= with blower

TABLE 8. TARGETED SEMIVOLATILE COMPOUNDS, MASS PER SAMPLE (ug)

Test No.				1	2	3	4	5	6	7	8	9
			Solvent	TN	TN	FL	FL	Hut	TN	TN	Hut	Field
Target Compounds	MDL	PQL	Blank	nb	nb	nb	nb	Blank	wb	wb	Blank	Blank
Chlorobenzene	1.23		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Styrene	2.58		nd	130	75	31	nd	nd	nd	140	nd	nd
Cumene	1.02		nd	105	17	11	nd	nd	nd	150	nd	nd
1,1-Biphenyl	1.21		nd	29	19	17	nd	nd	nd	4	nd	nd
N-Nitrosodimethylamine	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
N-methyl-N-nitroso-Ethanamine	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
N-ethyl-N-nitroso-Ethanamine	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Bis(2-chloroethyl)ether		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Aniline	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Phenol		10	nd	210	400	370	290	34	110	790	29	nd
2-Chlorophenol		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,3-Dichlorobenzene	0.97		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,4-Dichlorobenzene	0.97		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,2-Dichlorobenzene	0.97		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Benzyl Alcohol		20	nd	nd	250	nd	nd	nd	nd	nd	nd	nd
Bis(2-chloroisopropyl)ether		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2-Methylphenol	5.14		nd	80	160	140	70	nd	40	260	nd	nd
Acetophenone	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Hexachloroethane		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Methyl-Benzenamine		20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3&4-methylphenol	10.62		nd	150	280	290	170	nd	90	300	nd	nd
N-nitrosodipropylamine		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Nitrobenzene	2.72		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1-Nitrosopiperidine	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Isophorone		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,4-Dimethylphenol		10	nd	60	nd	120	50	nd	30	140	nd	nd
Bis(2-chloroethoxy)methane		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,4-Dichlorophenol		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,2,4-Trichlorobenzene	1.15		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Naphthalene	1.21		nd	100	150	100	70	1	30	150	1	nd
4-Methoxybenzenamine		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

TABLE 8. TARGETED SEMIVOLATILE COMPOUNDS, MASS PER SAMPLE (ug)

Test No.				1	2	3	4	5	6	7	8	9
			Solvent	TN	TN	FL	FL	Hut	TN	TN	Hut	Field
Target Compounds	MDL	PQL	Blank	nb	nb	nb	nb	Blank	wb	wb	Blank	Blank
2-Nitrophenol		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,6-Dichlorophenol	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Hexachloropropene	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Chloroaniline		20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Hexachlorobutadiene		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
N-butyl-N-nitroso-butanamine	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-chloro-3-methyl-phenol		20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2-methylnaphthalene		10	nd	50	34	48	27	nd	86	43	nd	nd
4-chloro-2-methylbenzenamine	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,2,4,5-tetrachlorobenzene	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,3,5-trichlorophenol	4.73		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Hexachlorocyclopentadiene		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,4,6-trichlorophenol	4.32		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,4,5-Trichlorophenol	4.73		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,3,4-trichlorophenol	4.73		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2-chloronaphthalene	1.12		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1-chloronaphthalene	0.74		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-chloroquinoline	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2-nitroaniline		50	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3-nitroaniline		50	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Acenaphthylene	1		nd	68	29	38	27	nd	8	63	nd	nd
Dimethylphthalate		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,6-dinitrotoluene	2.38		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Acenaphthene	0.79		nd	nd	nd	nd	nd	nd	nd	11	nd	nd
4-nitroaniline		50	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,4-dinitrophenol		50	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dibenzofuran	0.86		nd	28	9	23	17	nd	12	38	nd	nd
Pentachlorobenzene	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,4-dinitrotoluene	2.38		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
5-nitroquinoline	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,3,4,6-tetrachlorophenol	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

TABLE 8. TARGETED SEMIVOLATILE COMPOUNDS, MASS PER SAMPLE (ug)

Test No.				1	2	3	4	5	6	7	8	9
			Solvent	TN	TN	FL	FL	Hut	TN	TN	Hut	Field
Target Compounds	MDL	PQL	Blank	nb	nb	nb	nb	Blank	wb	wb	Blank	Blank
2,3,5,6-tetrachlorophenol	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,3,4,5-tetrachlorophenol	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-nitrophenol		50	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Fluorene	0.83		nd	nd	4	17	10	nd	nd	19	nd	nd
Diethyl phthalate		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Chlorophenyl phenyl ether		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2-methyl-5-nitrobenzenamine	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
N-nitrosodiphenylamine		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2-methyl-4,6-dinitrophenol		50	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Azobenzene	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Diphenylamine	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Bromophenyl phenyl ether		10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Phenacetin	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Hexachlorobenzene	0.64		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pentachlorophenol	4.19		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pentachloronitrobenzene	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Phenanthrene	0.55		nd	33	48	23	23	1	68	51	nd	nd
Anthracene	0.59		nd	8	9	7	5	1	17	11	nd	nd
Azoxybenzene	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pentachloroaniline	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dibutyl phthalate		10	10	nd	nd	nd	1	nd	nd	nd	nd	nd
2-nitro-N-phenylbenzenamine	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-nitro-1-oxide-quinoline	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Methapyrilene	-	10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Fluoranthene	0.32		nd	13	15	1	nd	nd	18	12	nd	nd
Pyrene	0.33		nd	17	9	14	9	nd	9	7	nd	nd
N-methyl-4-(phenylazo)-benzenamine	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
P-dimethylaminoazobenzene	-	20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Benzyl butyl phthalate	-	10	nd	nd	nd	nd	nd	1	1	nd	nd	nd
N-2-fluorenylacetamide	-	10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Chrysene	0.23		nd	7	nd	5	3	nd	4	2	nd	nd

TABLE 8. TARGETED SEMIVOLATILE COMPOUNDS, MASS PER SAMPLE (ug)

Test No. Target Compounds	MDL	PQL	Solvent Blank	1 TN nb	2 TN nb	3 FL nb	4 FL nb	5 Hut Blank	6 TN wb	7 TN wb	8 Hut Blank	9 Field Blank
Benzo(a)anthracene	0.24		nd	5	nd	4	2	nd	3	2	nd	nd
Bis(2-ethylhexyl)phthalate		10	40	27	4	43	24	71	230	27	nd	22
Di-N-octyl phthalate		10	300	104	20	60	39	50	70	68	7	nd
Benzo(b)fluoranthene	0.52		nd	7	1	5	3	nd	6	3	nd	nd
7,12-Dimethylbenz(a)anthracene	-	10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Benzo(k)fluoranthene	0.7		nd	8	1	5	3	nd	7	3	nd	nd
Benzo(a)pyrene	0.28		nd	3	3	1	2	nd	2	1	nd	nd
3-methylcholanthrene	-	10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dibenz(a,j)acridine	-	10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Indeno(1,2,3-cd)pyrene	0.62		nd	2	2	2	nd	nd	3	1	nd	nd
Dibenz(a,h)anthracene	0.64		nd	nd	nd	nd	nd	nd	1	nd	nd	nd
Benzo(ghi)perylene	0.52		nd	3	4	4	3	3	2	1	nd	nd

nb= no blower, wb= with blower, nd = not detected

TABLE 9. TARGETED SEMIVOLATILE COMPOUNDS, CONCENTRATION IN BURN HUT (ug/m^3)

Test No.		1	2	3	4	5	6	7	8	9
	Solvent	TN	TN	FL	FL	Hut	TN	TN	Hut	Field
Target Compounds	Blank	nb	nb	nb	nb	Blank	wb	wb	Blank	Blank
Chlorobenzene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Styrene	NA	50.2	29.2	12.3	nd	nd	nd	59.5	nd	NA
Cumene	NA	40.6	6.6	4.4	nd	nd	nd	63.8	nd	NA
1,1-Biphenyl	NA	11.0	7.4	6.8	nd	nd	nd	1.7	nd	NA
N-Nitrosodimethylamine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
N-methyl-N-nitroso-Ethanamine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
N-ethyl-N-nitroso-Ethanamine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Bis(2-chloroethyl)ether	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Aniline	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Phenol	NA	81.1	155.7	147.0	111.7	13.3	44.6	335.8	11.7	NA
2-Chlorophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
1,3-Dichlorobenzene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
1,4-Dichlorobenzene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
1,2-Dichlorobenzene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Benzyl Alcohol	NA	nd	97.3	nd	nd	nd	nd	nd	nd	NA
Bis(2-chloroisopropyl)ether	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2-Methylphenol	NA	30.9	62.3	55.6	27.0	nd	16.2	110.5	nd	NA
Acetophenone	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Hexachloroethane	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Methyl-Benzenamine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
3&4-methylphenol	NA	58.0	109.0	115.2	65.5	nd	36.5	127.5	nd	NA
N-nitrosodipropylamine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Nitrobenzene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
1-Nitrosopiperidine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Isophorone	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2,4-Dimethylphenol	NA	23.2	nd	47.7	19.3	nd	12.2	59.5	nd	NA
Bis(2-chloroethoxy)methane	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2,4-Dichlorophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA

TABLE 9. TARGETED SEMIVOLATILE COMPOUNDS, CONCENTRATION IN BURN HUT (ug/m^3)

Test No. Target Compounds	Solvent Blank	1 TN nb	2 TN nb	3 FL nb	4 FL nb	5 Hut Blank	6 TN wb	7 TN wb	8 Hut Blank	9 Field Blank
1,2,4-Trichlorobenzene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Naphthalene	NA	38.6	58.4	39.7	27.0	0.5	12.2	63.8	0.4	NA
4-Methoxybenzenamine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2-Nitrophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2,6-Dichlorophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Hexachloropropene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
4-Chloroaniline	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Hexachlorobutadiene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
N-butyl-N-nitroso-butanamine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
4-chloro-3-methyl-phenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2-methylnaphthalene	NA	19.2	13.4	19.1	10.4	nd	34.9	18.3	nd	NA
4-chloro-2-methylbenzenamine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
1,2,4,5-tetrachlorobenzene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2,3,5-trichlorophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Hexachlorocyclopentadiene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2,4,6-trichlorophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2,4,5-trichlorophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2,3,4-trichlorophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2-chloronaphthalene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
1-chloronaphthalene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
4-chloroquinoline	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2-nitroaniline	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
3-nitroaniline	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Acenaphthylene	NA	26.2	11.1	15.1	10.4	nd	3.2	26.8	nd	NA
Dimethylphthalate	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2,6-dinitrotoluene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Acenaphthene	NA	nd	nd	nd	nd	nd	nd	4.7	nd	NA
4-nitroaniline	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA

TABLE 9. TARGETED SEMIVOLATILE COMPOUNDS, CONCENTRATION IN BURN HUT (ug/m^3)

Test No.		1	2	3	4	5	6	7	8	9
	Solvent	TN	TN	FL	FL	Hut	TN	TN	Hut	Field
Target Compounds	Blank	nb	nb	nb	nb	Blank	wb	wb	Blank	Blank
2,4-dinitrophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Dibenzofuran	NA	10.9	3.4	9.1	6.5	nd	4.9	16.2	nd	NA
Pentachlorobenzene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2,4-dinitrotoluene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
5-nitroquinoline	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2,3,4,6-tetrachlorophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2,3,5,6-tetrachlorophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2,3,4,5-tetrachlorophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
4-nitrophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Fluorene	NA	nd	1.7	6.8	3.9	nd	nd	8.1	nd	NA
Diethyl phthalate	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
4-Chlorophenyl phenyl ether	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2-methyl-5-nitrobenzenamine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
N-nitrosodiphenylamine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
2-methyl-4,6-dinitrophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Azobenzene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Diphenylamine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
4-Bromophenyl phenyl ether	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Phenacetin	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Hexachlorobenzene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Pentachlorophenol	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Pentachloronitrobenzene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Phenanthrene	NA	12.9	18.8	9.1	8.9	0.2	27.6	21.7	nd	NA
Anthracene	NA	3.1	3.6	2.8	1.9	0.3	6.9	4.7	nd	NA
Azoxybenzene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Pentachloroaniline	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Dibutyl phthalate	NA	nd	nd	nd	0.4	nd	nd	nd	nd	NA
2-nitro-N-phenylbenzenamine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA

TABLE 9. TARGETED SEMIVOLATILE COMPOUNDS, CONCENTRATION IN BURN HUT (ug/m^3)

Test No. Target Compounds	Solvent Blank	1 TN nb	2 TN nb	3 FL nb	4 FL nb	5 Hut Blank	6 TN wb	7 TN wb	8 Hut Blank	9 Field Blank
4-nitro-1-oxide-quinoline	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Methapyrilene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Fluoranthene	NA	4.9	5.6	0.4	nd	nd	7.3	5.1	nd	NA
Pyrene	NA	6.5	3.3	5.6	3.5	nd	3.7	3.0	nd	NA
N-methyl-4-(phenylazo)-benzenamine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
P-dimethylaminoazobenzene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Benzyl butyl phthalate	NA	nd	nd	nd	nd	0.2	0.4	nd	nd	NA
N-2-fluorenylacetamide	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Chrysene	NA	2.6	nd	2.0	1.2	nd	1.6	0.9	nd	NA
Benzo(a)anthracene	NA	2.0	nd	1.6	0.8	nd	1.2	0.9	nd	NA
Bis(2-ethylhexyl)phthalate	NA	10.3	1.5	17.1	9.2	27.9	93.3	11.5	nd	NA
Di-N-octyl phthalate	NA	40.3	7.7	23.8	15.0	19.7	28.4	28.9	2.8	NA
Benzo(b)fluoranthene	NA	2.8	0.4	2.0	1.2	nd	2.4	1.3	nd	NA
7,12-Dimethylbenz(a)anthracene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Benzo(k)fluoranthene	NA	3.2	0.5	2.0	1.2	nd	2.8	1.3	nd	NA
Benzo(a)pyrene	NA	1.0	1.0	0.4	0.8	nd	0.8	0.4	nd	NA
3-methylcholanthrene	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Dibenz(a,j)acridine	NA	nd	nd	nd	nd	nd	nd	nd	nd	NA
Indeno(1,2,3-cd)pyrene	NA	0.9	0.9	0.8	nd	nd	1.2	0.4	nd	NA
Dibenz(a,h)anthracene	NA	nd	nd	nd	nd	nd	0.4	nd	nd	NA
Benzo(ghi)perylene	NA	1.0	1.4	1.6	1.2	1.0	0.8	0.4	nd	NA

nb= no blower, wb = with blower, NA= not applicable, nd = not detected

TABLE 10. TARGETED SEMIVOLATILE COMPOUNDS, ESTIMATED EMISSIONS (mg/kg)

Test No. Target Compounds	Solvent Blank	1 TN nb	2 TN nb	3 FL nb	4 FL nb	5 Hut Blank	6 TN wb	7 TN wb	8 Hut Blank	9 Field Blank
Chlorobenzene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Styrene	NA	23.27	15.64	5.44	nd	NA	nd	16.84	NA	NA
Cumene	NA	18.79	3.55	1.93	nd	NA	nd	18.04	NA	NA
1,1-Biphenyl	NA	5.10	3.96	2.98	nd	NA	nd	0.48	NA	NA
N-Nitrosodimethylamine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
N-methyl-N-nitroso-Ethanamine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
N-ethyl-N-nitroso-Ethanamine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Bis(2-chloroethyl)ether	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Aniline	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Phenol	NA	37.58	83.43	64.93	43.77	NA	11.92	95.00	NA	NA
2-Chlorophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
1,3-Dichlorobenzene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
1,4-Dichlorobenzene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
1,2-Dichlorobenzene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Benzyl Alcohol	NA	nd	52.15	nd	nd	NA	nd	nd	NA	NA
Bis(2-chloroisopropyl)ether	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2-Methylphenol	NA	14.32	33.37	24.57	10.57	NA	4.34	31.27	NA	NA
Acetophenone	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Hexachloroethane	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Methyl-Benzenamine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
3&4-methylphenol	NA	26.84	58.40	50.89	25.66	NA	9.76	36.08	NA	NA
N-nitrosodipropylamine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Nitrobenzene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
1-Nitrosopiperidine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Isophorone	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2,4-Dimethylphenol	NA	10.74	nd	21.06	7.55	NA	3.25	16.84	NA	NA
Bis(2-chloroethoxy)methane	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2,4-Dichlorophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA

TABLE 10. TARGETED SEMIVOLATILE COMPOUNDS, ESTIMATED EMISSIONS (mg/kg)

Test No. Target Compounds	Solvent Blank	1 TN nb	2 TN nb	3 FL nb	4 FL nb	5 Hut Blank	6 TN wb	7 TN wb	8 Hut Blank	9 Field Blank
1,2,4-Trichlorobenzene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Naphthalene	NA	17.90	31.29	17.55	10.57	NA	3.25	18.04	NA	NA
4-Methoxybenzenamine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2-Nitrophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2,6-Dichlorophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Hexachloropropene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
4-Chloroaniline	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Hexachlorobutadiene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
N-butyl-N-nitroso-butanamine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
4-chloro-3-methyl-phenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2-methylnaphthalene	NA	8.88	7.18	8.42	4.08	NA	9.32	5.17	NA	NA
4-chloro-2-methylbenzenamine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
1,2,4,5-tetrachlorobenzene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2,3,5-trichlorophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Hexachlorocyclopentadiene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2,4,6-trichlorophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2,4,5-trichlorophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2,3,4-trichlorophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2-chloronaphthalene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
1-chloronaphthalene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
4-chloroquinoline	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2-nitroaniline	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
3-nitroaniline	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Acenaphthylene	NA	12.11	5.96	6.67	4.08	NA	0.87	7.58	NA	NA
Dimethylphthalate	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2,6-dinitrotoluene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Acenaphthene	NA	nd	nd	nd	nd	NA	nd	1.32	NA	NA
4-nitroaniline	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA

TABLE 10. TARGETED SEMIVOLATILE COMPOUNDS, ESTIMATED EMISSIONS (mg/kg)

Test No.		1	2	3	4	5	6	7	8	9
	Solvent	TN	TN	FL	FL	Hut	TN	TN	Hut	Field
Target Compounds	Blank	nb	nb	nb	nb	Blank	wb	wb	Blank	Blank
2,4-dinitrophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Dibenzofuran	NA	5.07	1.82	4.04	2.57	NA	1.30	4.57	NA	NA
Pentachlorobenzene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2,4-dinitrotoluene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
5-nitroquinoline	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2,3,4,6-tetrachlorophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2,3,5,6-tetrachlorophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2,3,4,5-tetrachlorophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
4-nitrophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Fluorene	NA	nd	0.89	2.98	1.51	NA	nd	2.28	NA	NA
Diethyl phthalate	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
4-Chlorophenyl phenyl ether	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2-methyl-5-nitrobenzenamine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
N-nitrosodiphenylamine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
2-methyl-4,6-dinitrophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Azobenzene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Diphenylamine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
4-Bromophenyl phenyl ether	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Phenacetin	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Hexachlorobenzene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Pentachlorophenol	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Pentachloronitrobenzene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Phenanthrene	NA	5.96	10.05	4.04	3.47	NA	7.37	6.13	NA	NA
Anthracene	NA	1.44	1.93	1.23	0.75	NA	1.84	1.32	NA	NA
Azoxybenzene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Pentachloroaniline	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Dibutyl phthalate	NA	nd	nd	nd	0.15	NA	nd	nd	NA	NA
2-nitro-N-phenylbenzenamine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA

TABLE 10. TARGETED SEMIVOLATILE COMPOUNDS, ESTIMATED EMISSIONS (mg/kg)

Test No.		1	2	3	4	5	6	7	8	9
	Solvent	TN	TN	FL	FL	Hut	TN	TN	Hut	Field
Target Compounds	Blank	nb	nb	nb	nb	Blank	wb	wb	Blank	Blank
4-nitro-1-oxide-quinoline	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Methapyrilene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Fluoranthene	NA	2.26	3.03	0.18	nd	NA	1.95	1.44	NA	NA
Pyrene	NA	3.03	1.79	2.46	1.36	NA	0.98	0.84	NA	NA
N-methyl-4-(phenylazo)-benzenamine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
P-dimethylaminoazobenzene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Benzyl butyl phthalate	NA	nd	nd	nd	nd	NA	0.11	nd	NA	NA
N-2-fluorenylacetamide	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Chrysene	NA	1.20	nd	0.88	0.45	NA	0.43	0.24	NA	NA
Benzo(a)anthracene	NA	0.94	nd	0.70	0.30	NA	0.33	0.24	NA	NA
Bis(2-ethylhexyl)phthalate	NA	4.79	0.78	7.55	3.62	NA	24.93	3.25	NA	NA
Di-N-octyl phthalate	NA	18.65	4.13	10.53	5.89	NA	7.59	8.18	NA	NA
Benzo(b)fluoranthene	NA	1.32	0.20	0.88	0.45	NA	0.65	0.36	NA	NA
7,12-Dimethylbenz(a)anthracene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Benzo(k)fluoranthene	NA	1.46	0.26	0.88	0.45	NA	0.76	0.36	NA	NA
Benzo(a)pyrene	NA	0.47	0.55	0.18	0.30	NA	0.22	0.12	NA	NA
3-methylcholanthrene	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Dibenz(a,j)acridine	NA	nd	nd	nd	nd	NA	nd	nd	NA	NA
Indeno(1,2,3-cd)pyrene	NA	0.43	0.48	0.35	nd	NA	0.33	0.12	NA	NA
Dibenz(a,h)anthracene	NA	nd	nd	nd	nd	NA	0.11	nd	NA	NA
Benzo(ghi)perylene	NA	0.45	0.74	0.70	0.45	NA	0.22	0.12	NA	NA

nb= no blower, wb = with blower, NA= not applicable, nd = not detected

TABLE 11. SEMIVOLATILE TENATIVELY IDENTIFIED COMPOUNDS

TN No Blower Test #1				
Compound	Retention Time (min)	Mass of Analyte (ug)	Concentration (ug/m^3)	Emission Factor (mg/kg)
dimethyl furan	5.2	12	4.6	2.15
ethylbenzene	5.66	2	0.6	0.27
m,p-xylene	5.87	7	2.5	1.17
alpha.-pinene	7.27	3	1.2	0.54
d-limonene	9.27	14	5.3	2.45
indene	9.58	6	2.4	1.09
dimethyl phenol isomer	12.04	3	1.2	0.54
methoxy methyl phenol	12.22	15	5.6	2.60
ethyl methoxy phenol	13.44	7	2.7	1.25
1-methyl naphthalene	13.83	1	0.4	0.18
methoxy propyl phenol	14.63	16	6.2	2.86
hydroxy-methoxy-benzaldehyde	15.26	6	2.3	1.07
dimethyl naphthalene isomer	15.29	3	1.2	0.54
dimethylbiphenyl	16.67	42	16.0	7.43
dimethoxy-propenyl phenol	17.56	3	1.2	0.54
hydroxy-dimethoxy-benzaldehyde	18.34	5	1.9	0.89
9h-fluoren-9-0ne	19.14	4	1.5	0.72
methyl anthracene isomer	21.02	3	1.2	0.54
dimethyl phenanthrene isomer	22.18	5	1.9	0.89
unknown hydrocarbon	22.92	60	23.2	10.74
unknown hydrocarbon	22.95	75	29.0	13.42
unknown hydrocarbon	22.99	29	11.0	5.10
unknown hydrocarbon	23.11	32	12.2	5.64
trimethyl phenanthrene isomer	23.14	20	7.7	3.58
tetrahydrochrysene	24.24	31	12.0	5.55
unknown hydrocarbon	24.9	52	20.1	9.31
triphenylphosphine oxide	26.44	154	59.5	27.57
TN No Blower Test #2				
ethylbenzene	4.49	6	2.1	1.15
m,p-xylene	4.65	39	15.2	8.13
alpha.-pinene	5.85	55	21.4	11.47
camphene	6.12	3	1.2	0.63
trimethyl benzene isomer	7.09	5	1.9	1.04
methyl-methylethyl cyclohexene	7.76	92	35.7	19.12
indene	8.03	30	11.7	6.26
methoxy phenol	9.06	21	8.2	4.38
tetramethylcyclohexadiene	9.57	4	1.6	0.83
methoxy methyl phenol	10.78	10	3.9	2.09
dimethoxy phenol	13.22	19	7.2	3.86
hydroxy methoxy benzaldehyde	13.96	3	1.2	0.63
ethenyl naphthalene	14.07	2	0.8	0.42
9h-fluorene-methyl	15.95	1	0.4	0.21
dimethoxy-propenyl-phenol	16.38	2	0.8	0.42
dimethylethyl-phenol	18.21	24	9.3	5.01
methyl phenanthrene isomer	19.66	10	3.9	2.09
methyl phenanthrene isomer	19.87	3	1.2	0.63
methyl phenanthrene isomer	19.91	9	3.5	1.88
tetrahydro naphthalene isomer	20.45	14	5.5	2.92
dimethyl phenanthrene isomer	21.14	10	3.9	2.09
tetramethyl phenanthrene isomer	22.77	14	5.5	2.92
phenanthrenecarboxylic acid	23.87	18	7.0	3.75
triphenyl phosphine oxide	25.69	27	10.5	5.63
anthracenedione-tetramethyl	26.5	1	0.4	0.21

TABLE 11. CONTINUED

FL No Blower Test #3				
Compound	Retention Time (min)	Mass of Analyte (ug)	Concentration (ug/m^3)	Emission Factor (mg/kg)
dimethyl furan	5.24	220	87.4	38.60
xylene	6.4	18	7.2	3.16
benzofuran	8.6	3	1.2	0.53
indene	9.55	48	19.1	8.42
methyl indene isomer	11.36	2	0.8	0.35
ethyl phenol	11.5	1	0.4	0.18
dimethyl phenol isomer	12.05	8	3.2	1.40
dimethoxy benzene isomer	12.17	6	2.4	1.05
methoxy-ethyl phenol isomer	13.32	1	0.4	0.18
methoxy-ethyl phenol isomer	13.43	5	2.0	0.88
dimethylnaphthalene isomer	15.07	3	1.2	0.53
dimethylnaphthalene isomer	15.1	2	0.8	0.35
methoxy-propenyl phenol isomer	15.16	3	1.2	0.53
dimethylbiphenyl	16.67	32	12.7	5.62
trimethylnapthalene isomer	17.04	12	4.8	2.11
dimethoxy-propenyl phenol isomer	18.67	2	0.8	0.35
ethanone,1-(4-hydroxy-3,5-dimethoxy)	19.13	4	1.6	0.70
1h-indene,1-phenyl isomer	20.7	1	0.4	0.18
methyl pyrene isomer	24.13	1	0.4	0.18
triphenylphosphine oxide	26.43	239	95.0	41.94
FL No Blower Test #4				
dimethyl furan	5.2	66	25.4	9.96
furanmethanol	5.85	7	2.7	1.06
2-furancarboxaldehyde,5-methyl	8.1	10	3.9	1.51
benzonitrile	8.47	2	0.8	0.30
benzofuran	8.65	7	2.7	1.06
methyl furan isomer	10.59	3	1.2	0.45
methoxy methyl phenol isomer	12.11	7	2.7	1.06
ethyl methoxy phenol isomer	13.37	7	2.7	1.06
1-methylnaphthalene	13.8	2	0.8	0.30
dimethoxy phenol isomer	14.38	32	12.3	4.83
dimethylnaphthalene isomer	15.04	1	0.4	0.15
dimethylnaphthalene isomer	15.07	3	1.2	0.45
methoxy propenyl phenol isomer	15.13	2	0.8	0.30
ethyl-biphenyl isomer	16.55	2	0.8	0.30
trimethylnaphthalene isomer	17.03	5	1.9	0.75
hydroxy-dimethoxy benzaldehyde isomer	18.31	3	1.2	0.45
phenol,2,6-dimethoxy-4-(2-propenyl)	18.64	4	1.5	0.60
9h-fluoren-9-0ne	19.11	4	1.5	0.60
bis-dimethylethyl phenol isomer	19.3	3	1.2	0.45
triphenyl phosphine	23.21	7	2.7	1.06
triphenylphosphine oxide	26.43	300	115.5	45.28
phenol,4,4'-butylidenebis[2-(1,1-dimethyl-5-methyl)	27.43	27	10.4	4.08

TABLE 11. CONTINUED

Hut Blank Test #5				
Compound	Retention Time (min)	Mass of Analyte (ug)	Concentration (ug/m^3)	Emission Factor (mg/kg)
unknown hydrocarbon	11.3	115	45.0	NA
unknown hydrocarbon	28.24	28	11.0	NA
TN With Blower Test #6				
dimethylfuran	5.42	16	6.5	1.73
xylene	5.99	18	7.3	1.95
.alpha.-pinene	7.39	26	10.5	2.82
benzofuran	8.78	12	4.9	1.30
limonene	9.34	21	8.5	2.28
indene	9.65	8	3.2	0.87
methoxy phenol isomer	10.76	15	6.1	1.63
dimethyl octatriene isomer	11.1	5	2.0	0.54
ethyl phenol isomer	12.29	15	6.1	1.63
methoxy methyl phenol isomer	12.32	7	2.8	0.76
ethyl methoxy phenol isomer	13.58	6	2.4	0.65
9h-fluoren-9-one	19.28	6	2.4	0.65
dimethyl phenanthrene isomer	22.3	4	1.6	0.43
1-phenanthrenecarboxylic acid,1,2,	24.8	7	2.8	0.76
hexyl naphthalene isomer	30.19	12	4.9	1.30

TABLE 11. CONCLUDED

Tenn. With Blower Test #7				
Compound	Retention Time (min)	Mass of Analyte (ug)	Concentration (ug/m^3)	Emission Factor (mg/kg)
xylenes	5.93	77	32.7	9.26
.alpha.-pinene	7.3	63	26.8	7.58
.beta.-pinene	8.24	8	3.4	0.96
.beta.-myrcene	8.29	4	1.7	0.48
tetramethylcyclohexadiene isomer	8.37	7	3.0	0.84
diethyl benzene isomer	9.2	35	14.9	4.21
trimethyl benzene isomer	9.24	42	17.9	5.05
indene	9.6	7	3.0	0.84
tetramethylbenzene isomer	9.83	2	0.9	0.24
azulene	11.55	3	1.3	0.36
ethyl phenol isomer	12.11	15	6.4	1.80
dimethylphenol isomer	12.13	6	2.6	0.72
cyclooctatetraene isomer	12.69	2	0.9	0.24
ethylmethoxy phenol isomer	13.47	6	2.6	0.72
methyl benzenediol isomer	14.35	4	1.7	0.48
ethenyl naphthalene isomer	15.47	4	1.7	0.48
methoxy-propenyl phenol isomer	15.81	9	3.8	1.08
methyl-biphenyl isomer	17.07	2	0.9	0.24
9h-fluoren-9-one	19.26	7	3.0	0.84
methyl phenanthrene isomer	20.86	4	1.7	0.48
methyl phenanthrene isomer	21.1	3	1.3	0.36
dimethylphenanthrene isomer	21.87	2	0.9	0.24
phenylnaphthalene isomer	22.28	10	4.3	1.20
phenylmethylnaphthalene isomer	23.11	3	1.3	0.36
phenylmethyl naphthalene isomer	23.62	22	9.4	2.65
tetramethylphenanthrene isomer	23.82	140	59.5	16.84
tetrahydrochrysene isomer	24.43	51	21.7	6.13
1-phenanthrenecarboxylic acid,1,2	24.78	70	29.8	8.42
triphenylphosphine oxide	26.76	10	4.3	1.20
tetrahydroxyanthracenedione isomer	27.4	9	3.8	1.08
Hut Blank Test #8				
none	NA	NA	NA	NA

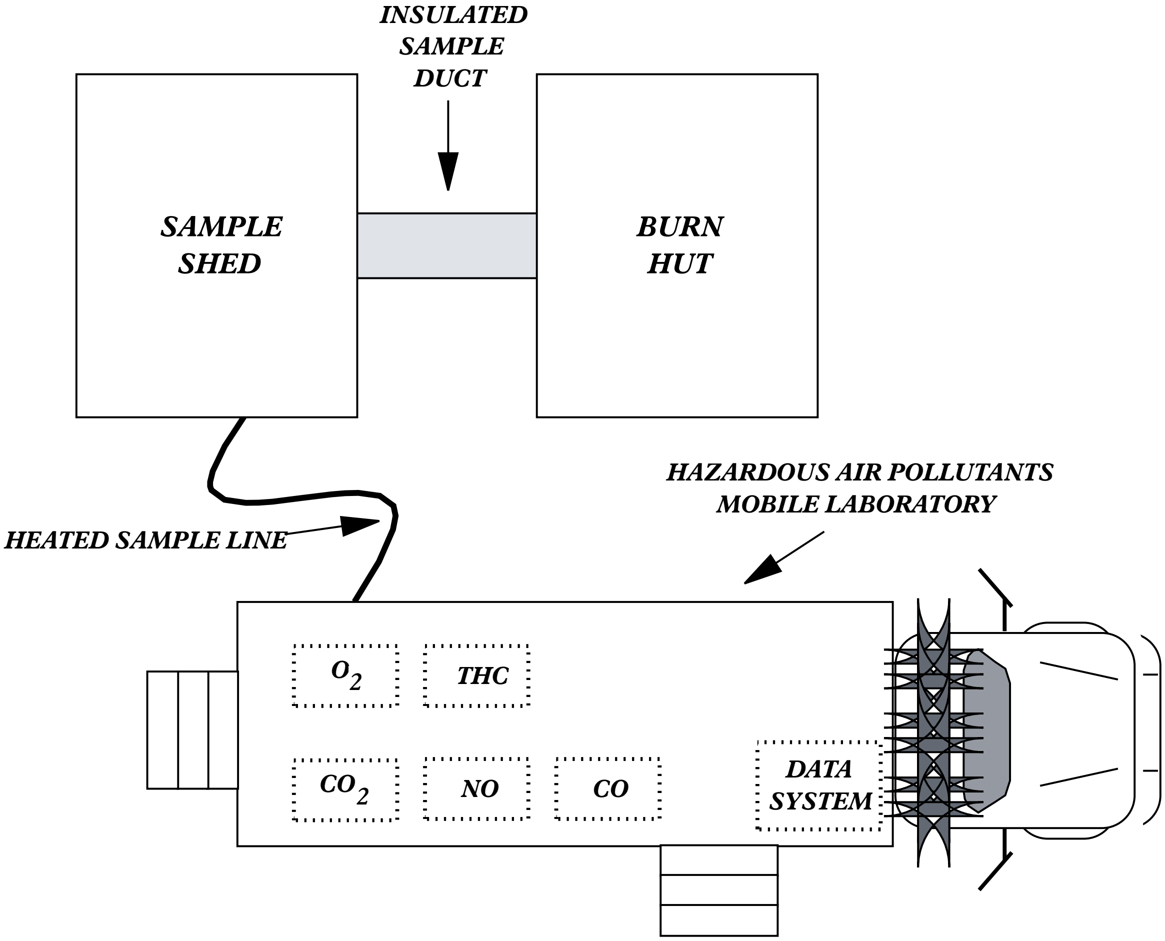

Figure 1. Aerial View of the Open Burning Simulation Facility

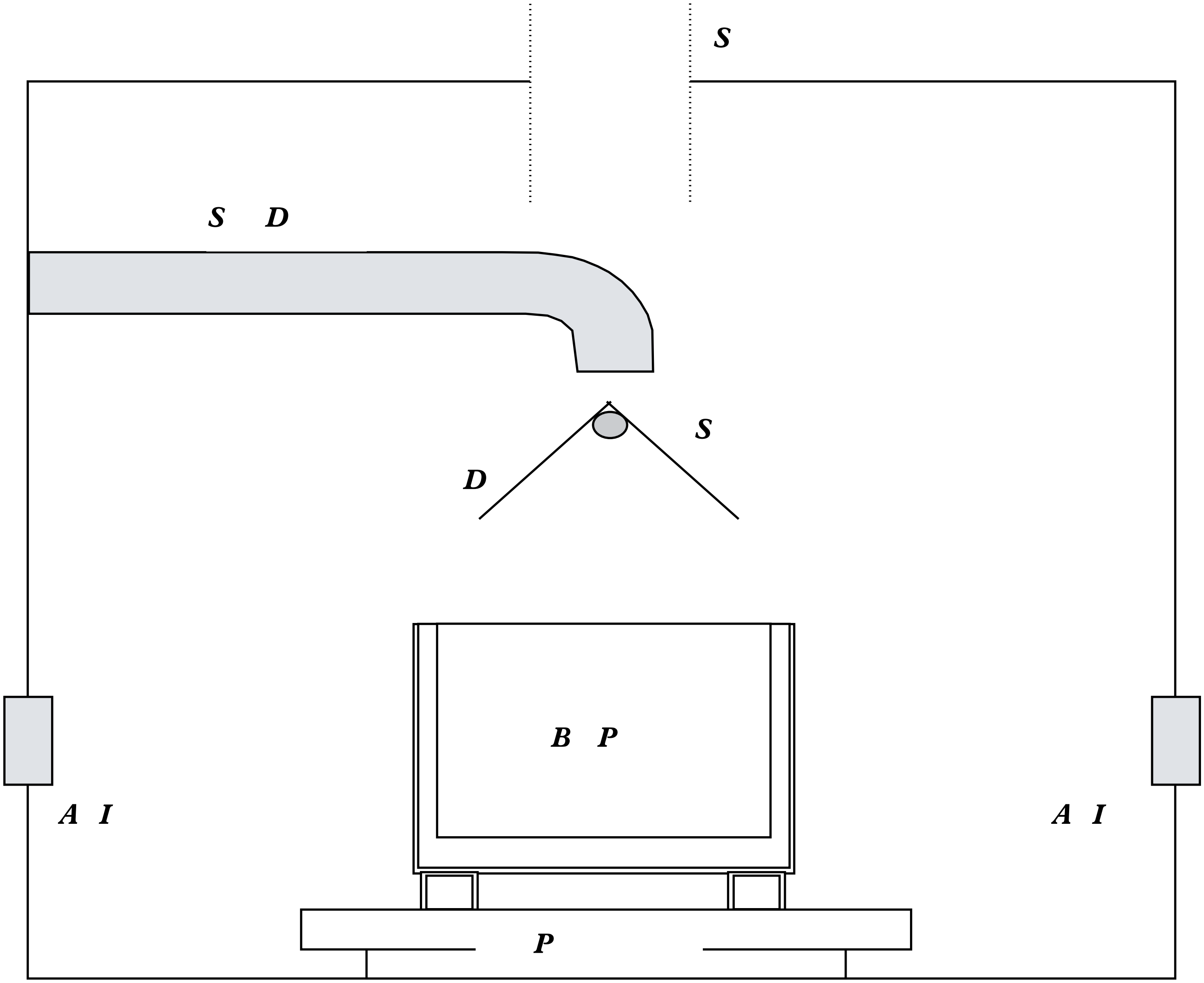

Figure 2. Schematic Diagram of Burn Hut

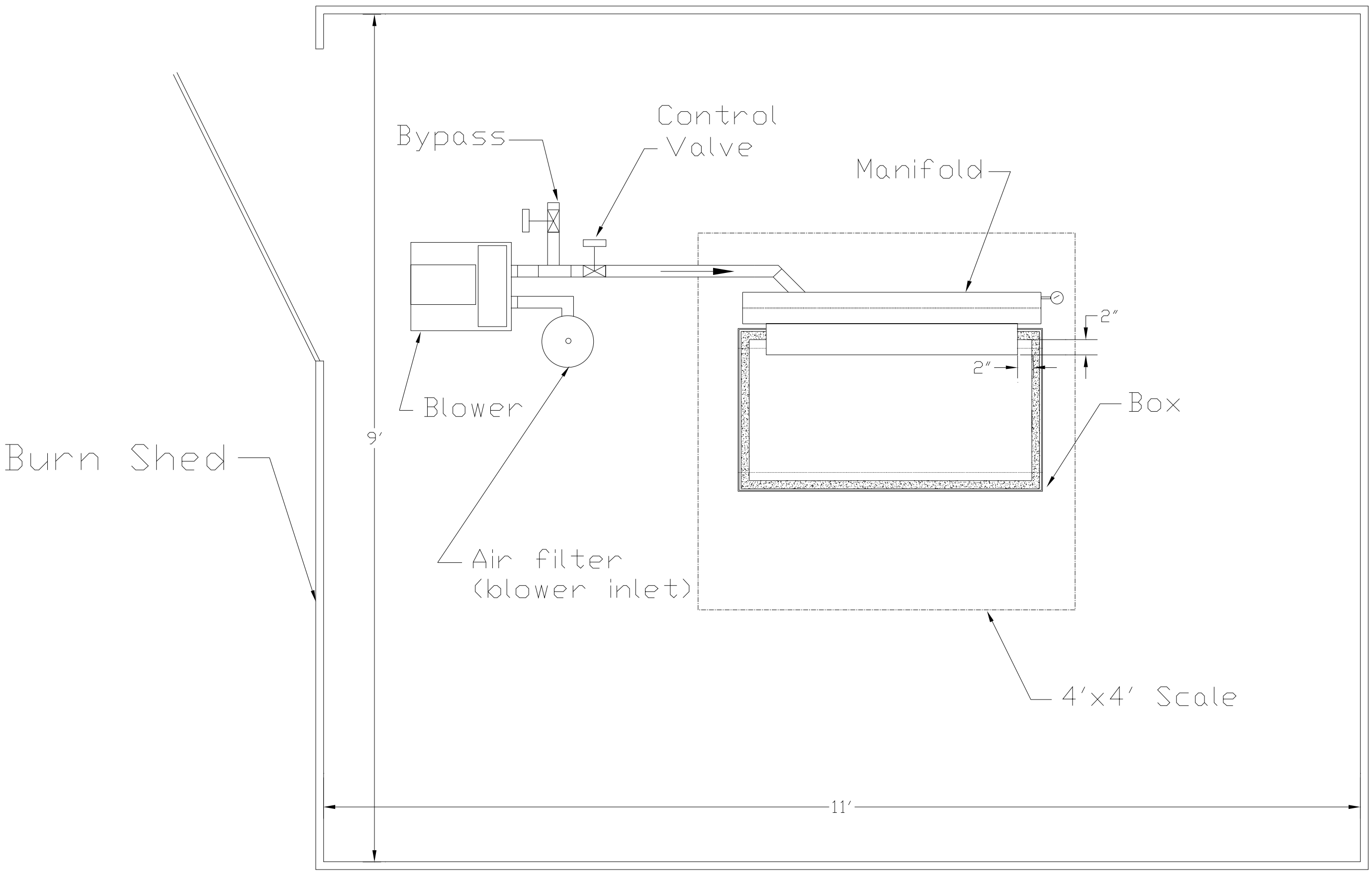

Figure 3. Blower Placement Detail

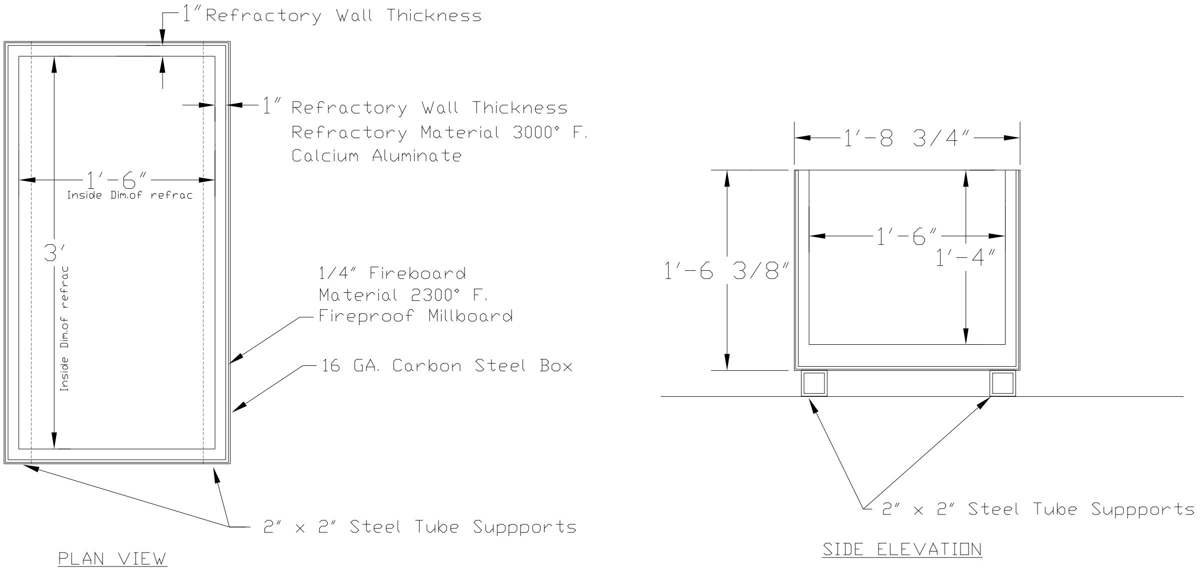

Figure 4. Box Details

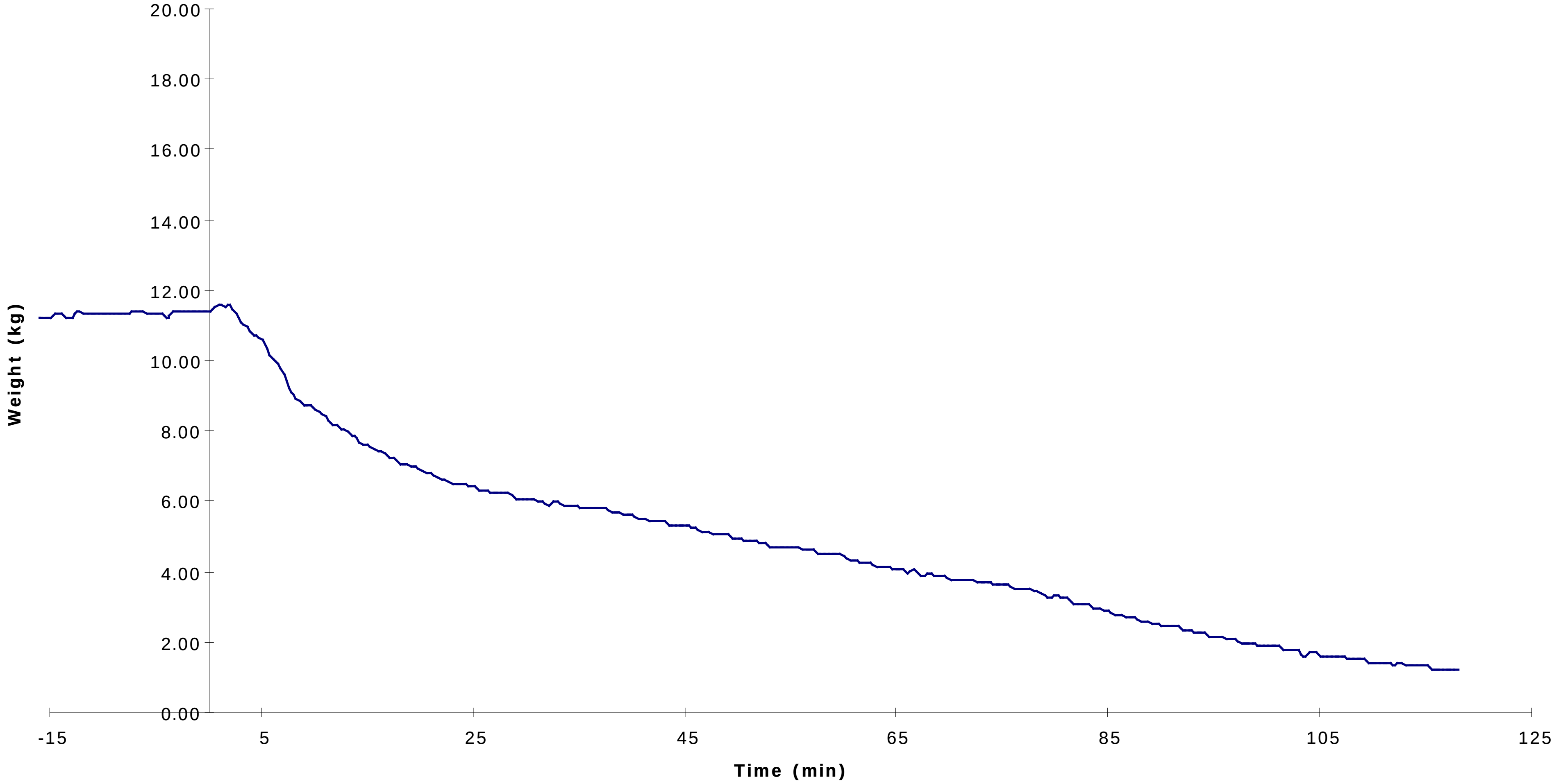

Figure 5. Weight of Burn Material for Test No. 1 - Tenn No Blower

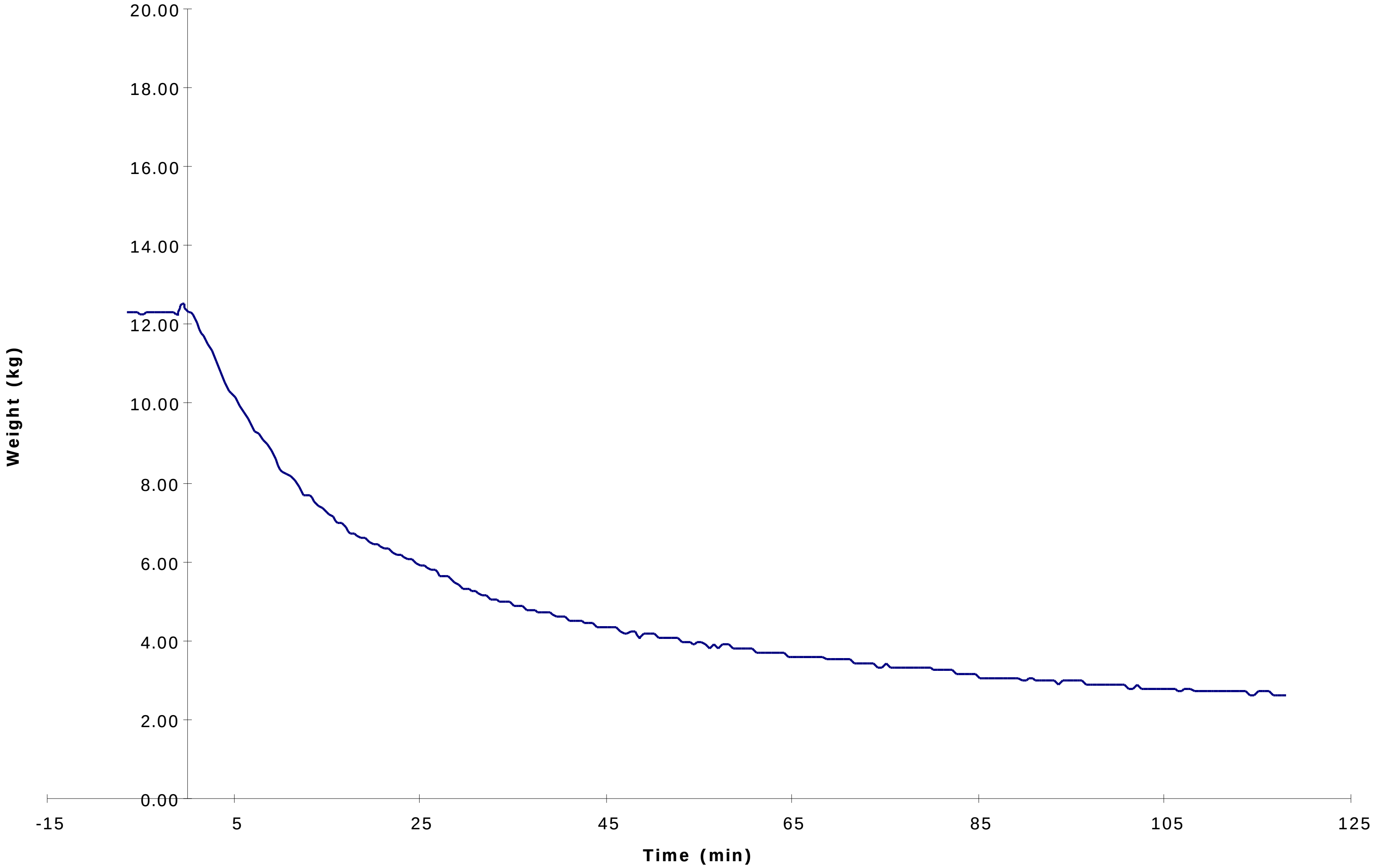

Figure 6. Weight of Burn Material for Test No. 2 - Tenn No Blower

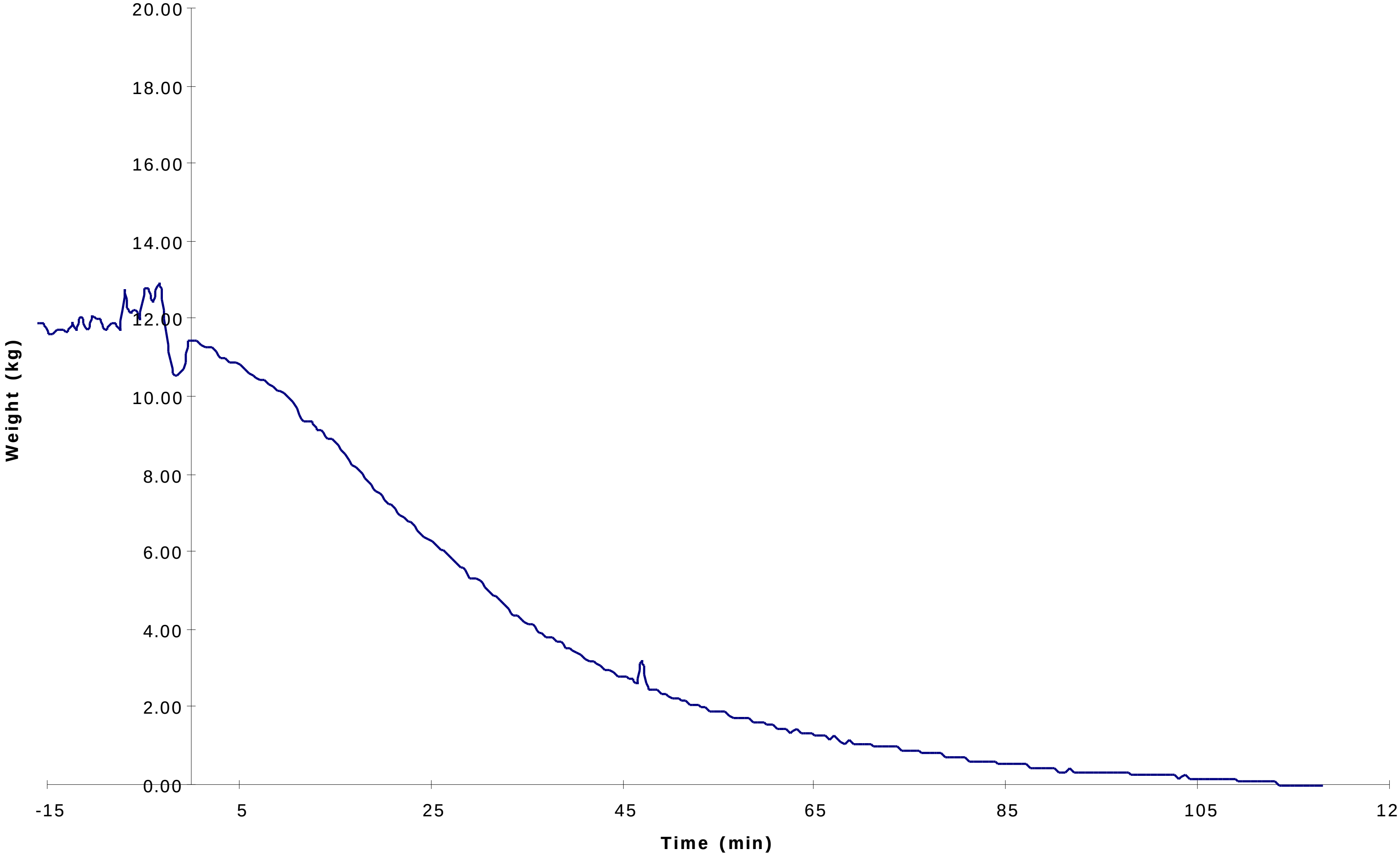

Figure 7. Weight of Burn Material for Test No. 3 - Florida No Blower

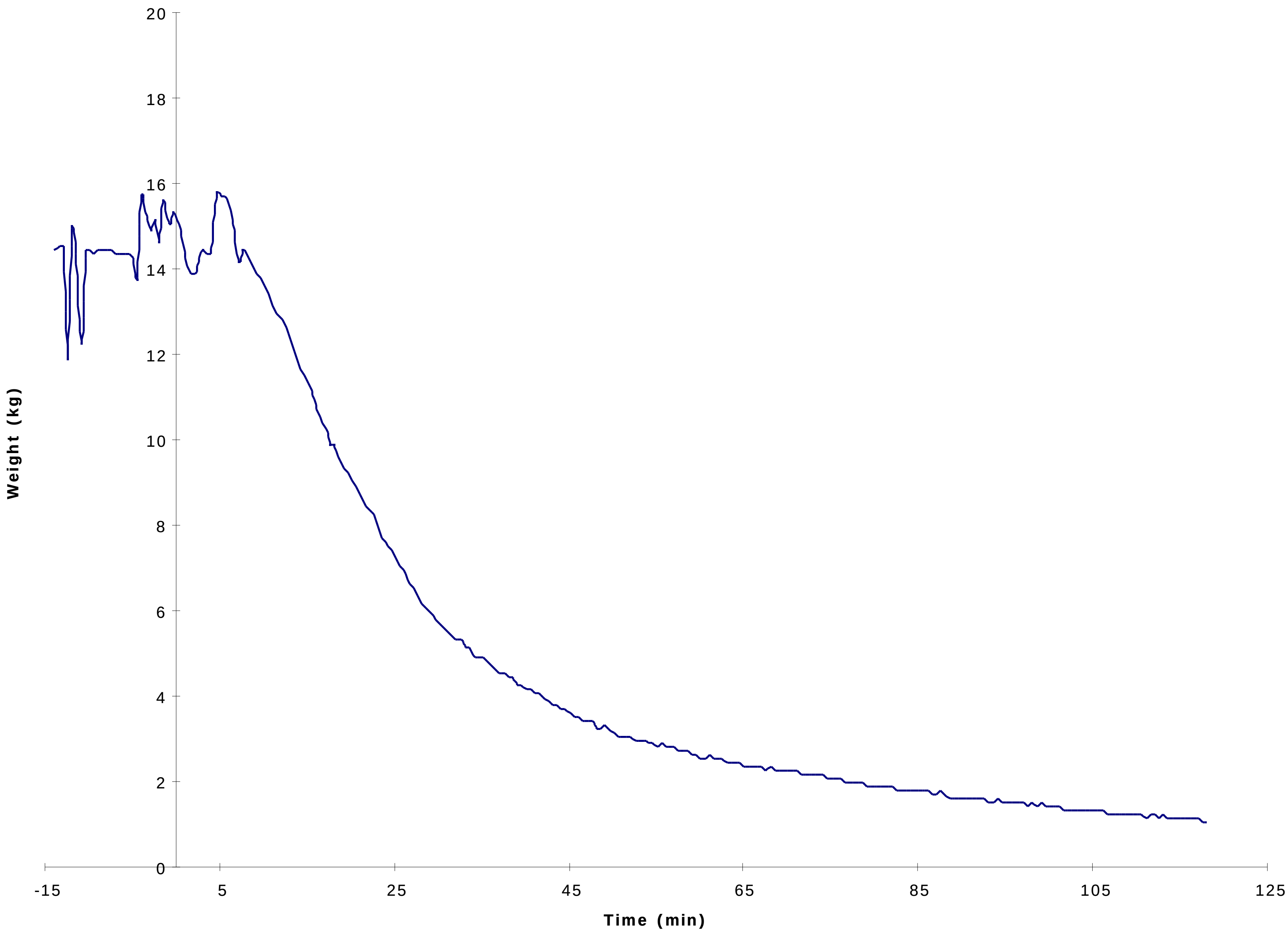

Figure 8. Weight of Burn Material for Test No. 4 - Florida No Blower

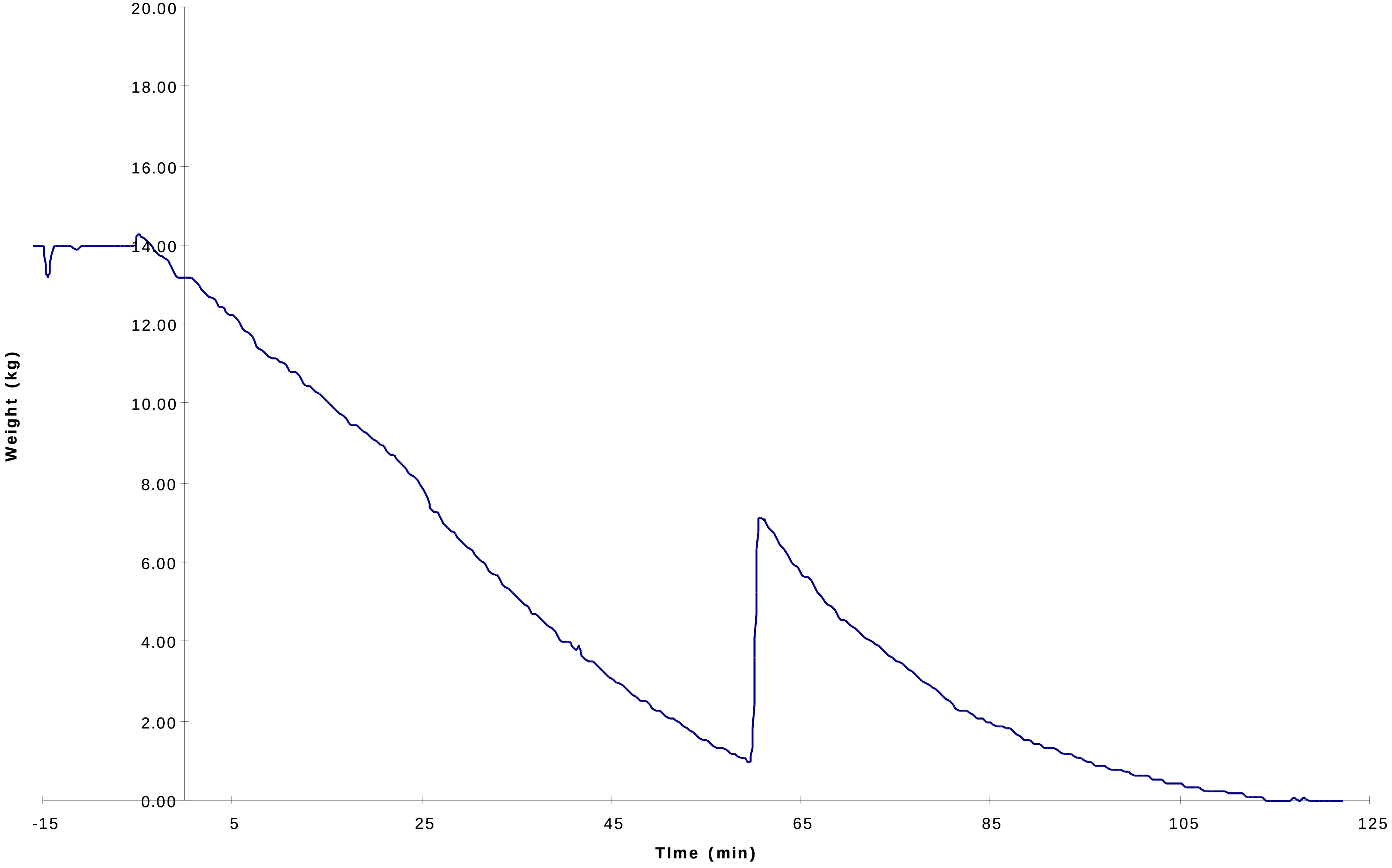

Figure 9. Weight of Burn Material for Test No. 6 - Tenn with Blower

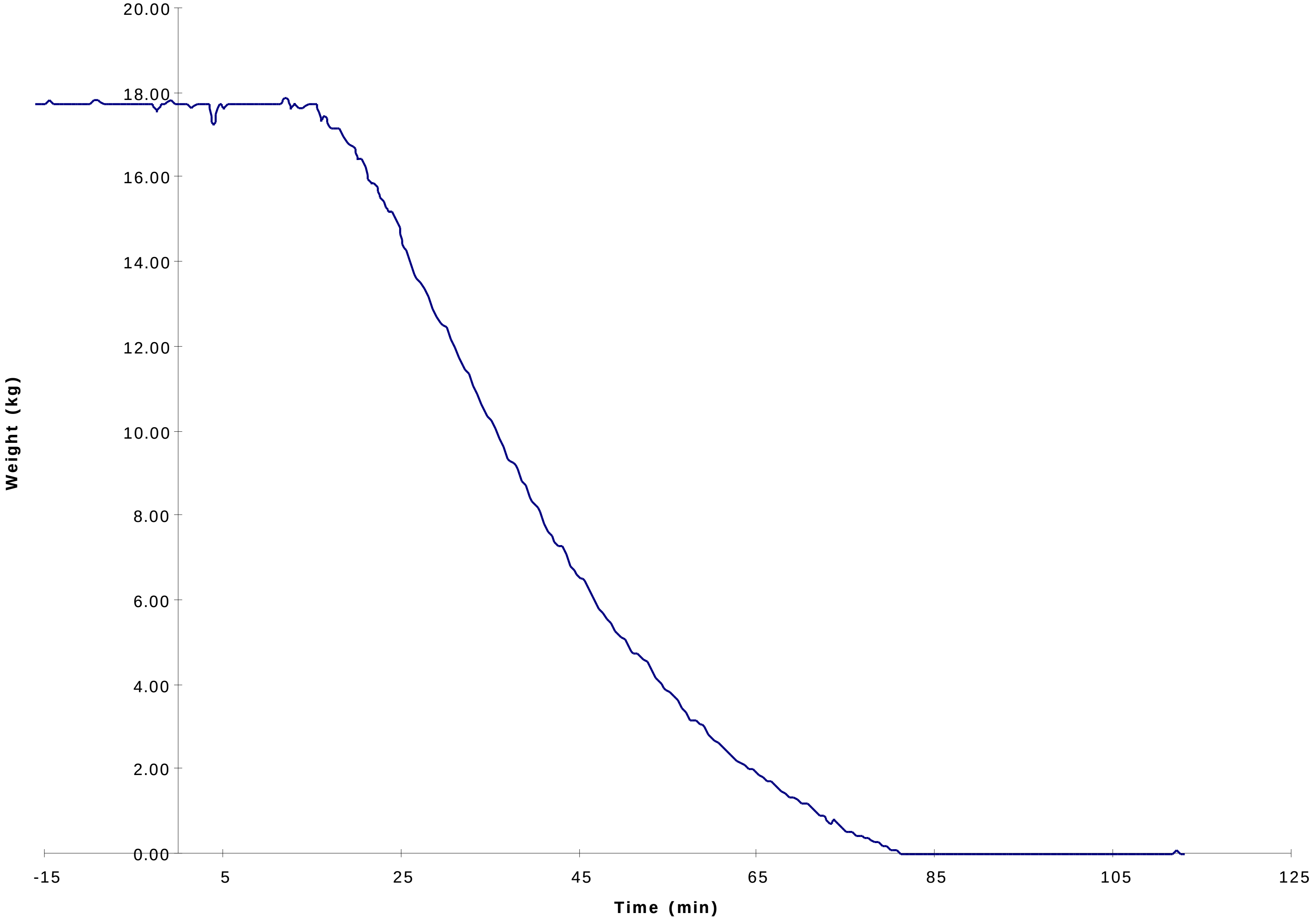

Figure 10. Weight of Burn Material for Test No. 7 - Tenn with Blower

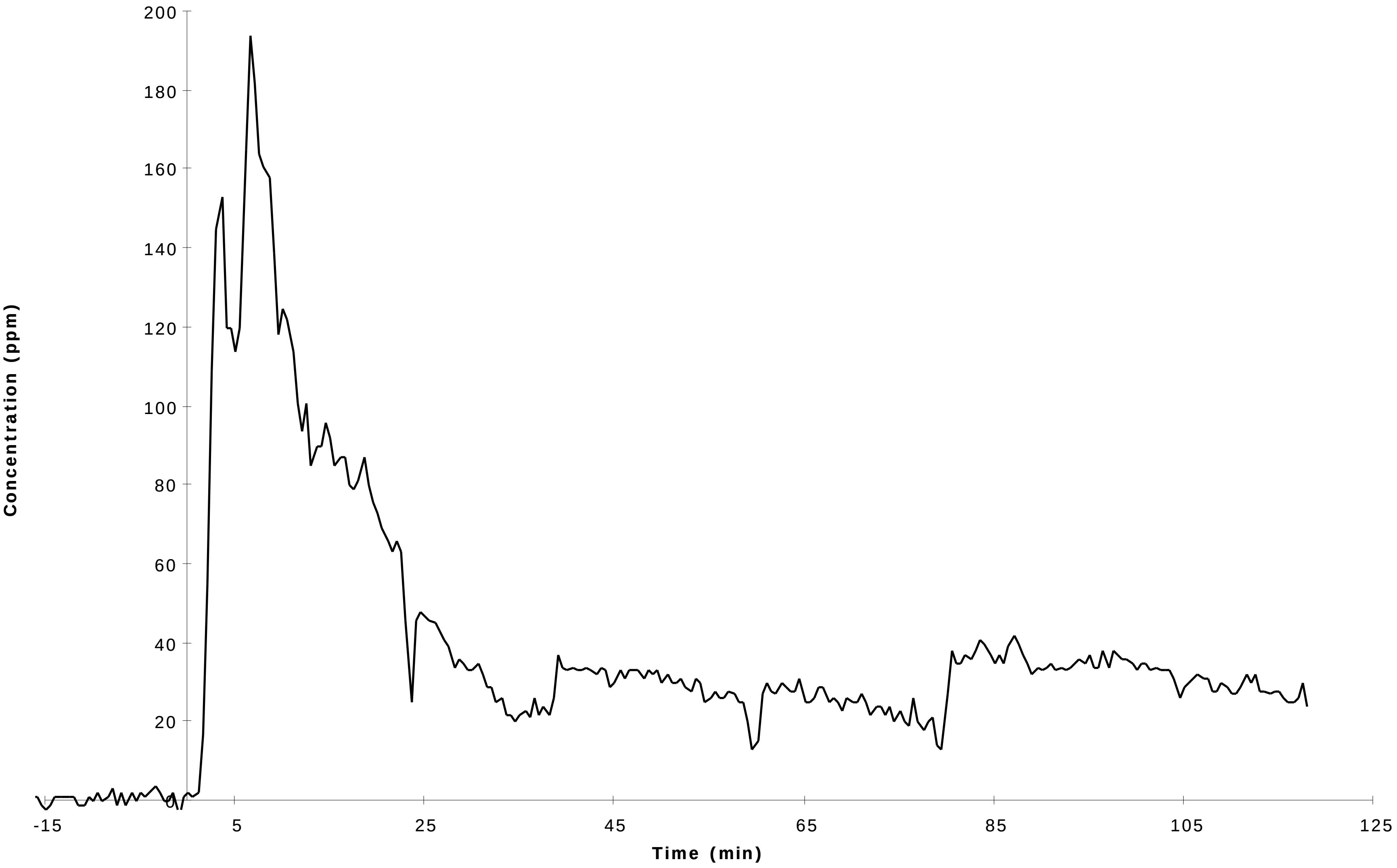

Figure 11. CO Concentration for Test No. 1 - Tenn no Blower

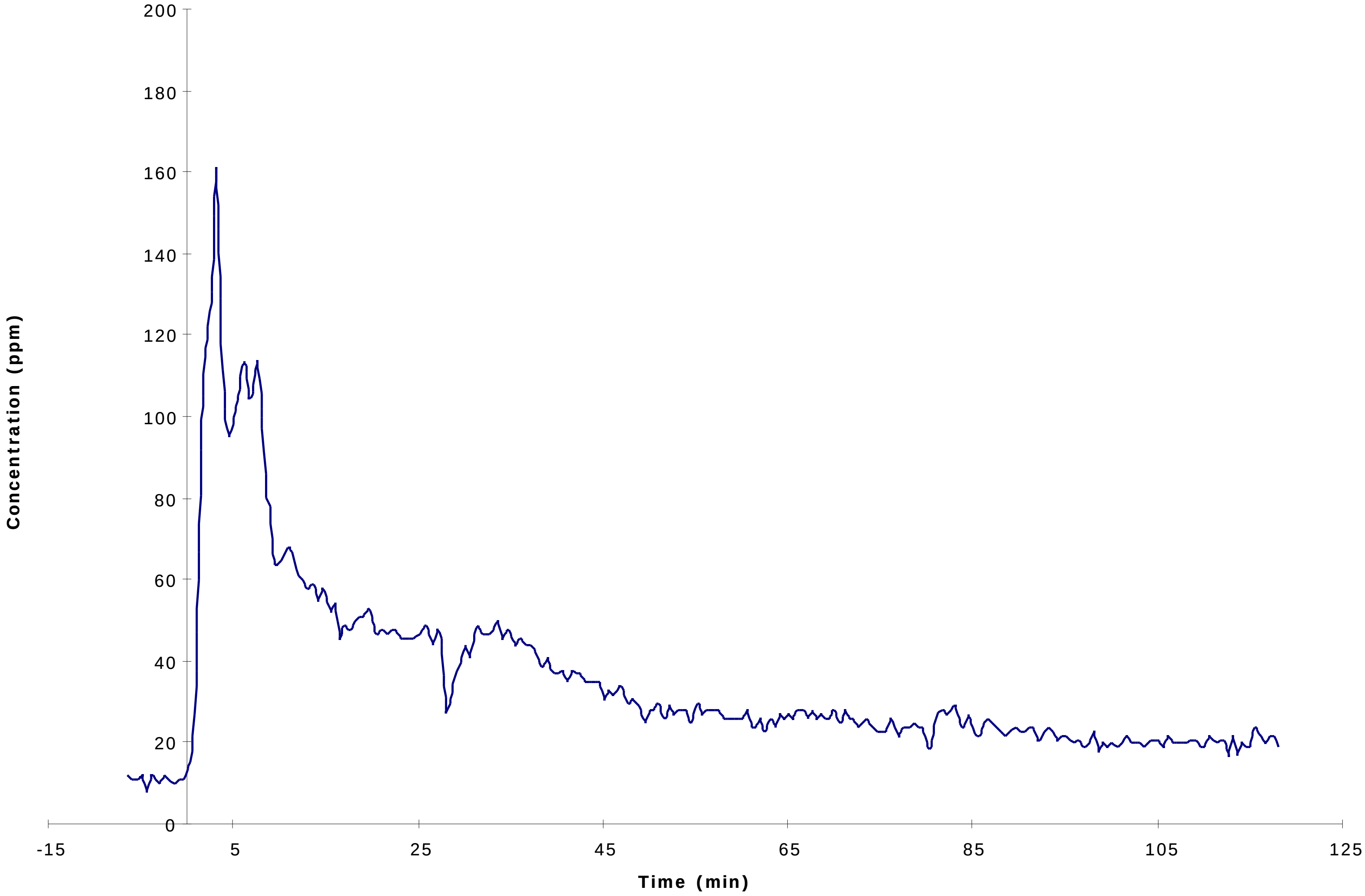

Figure 12. CO Concentration for Test No. 2 - Tenn no Blower

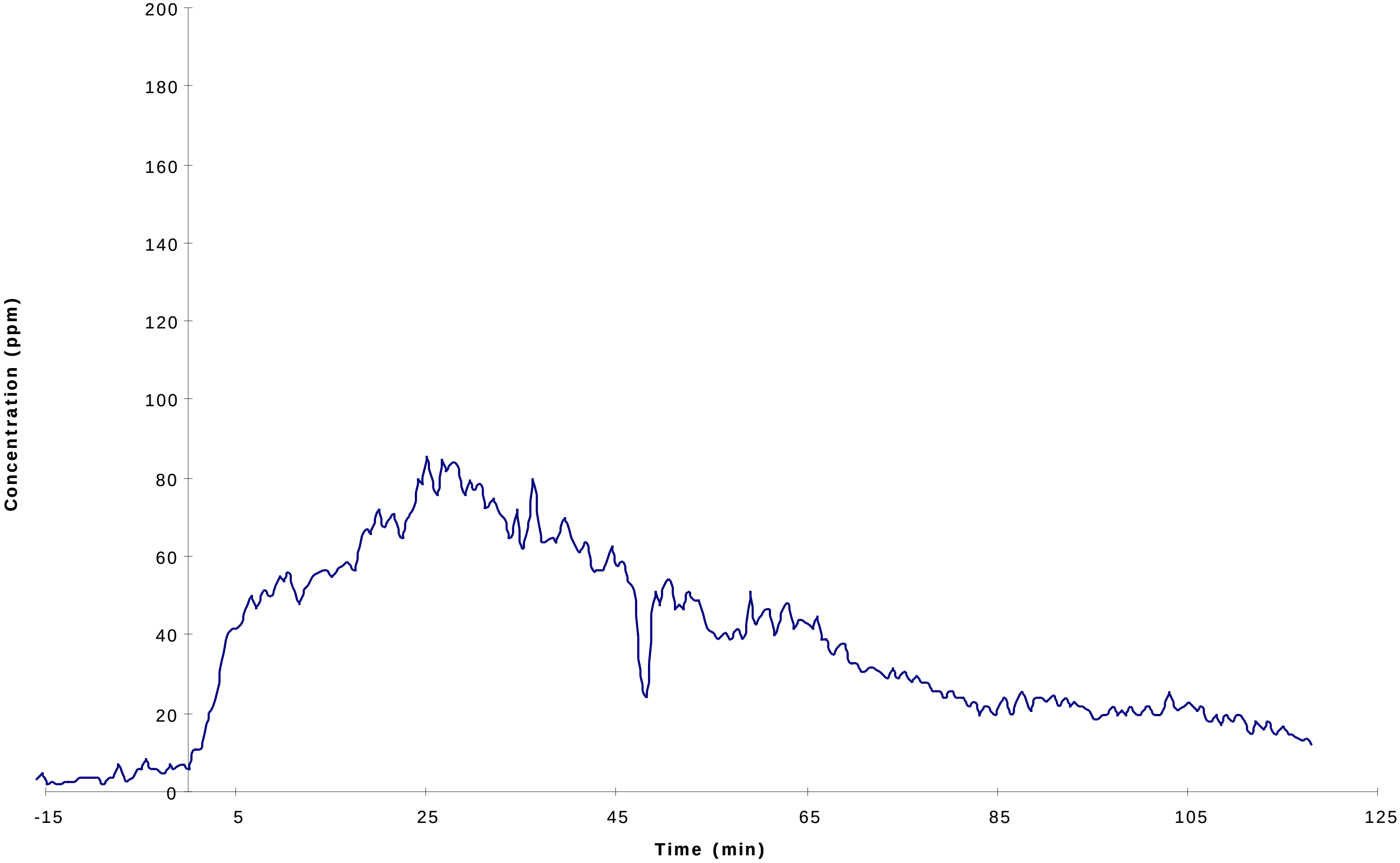

Figure 13. CO Concentration for Test No. 3 - Florida no Blower

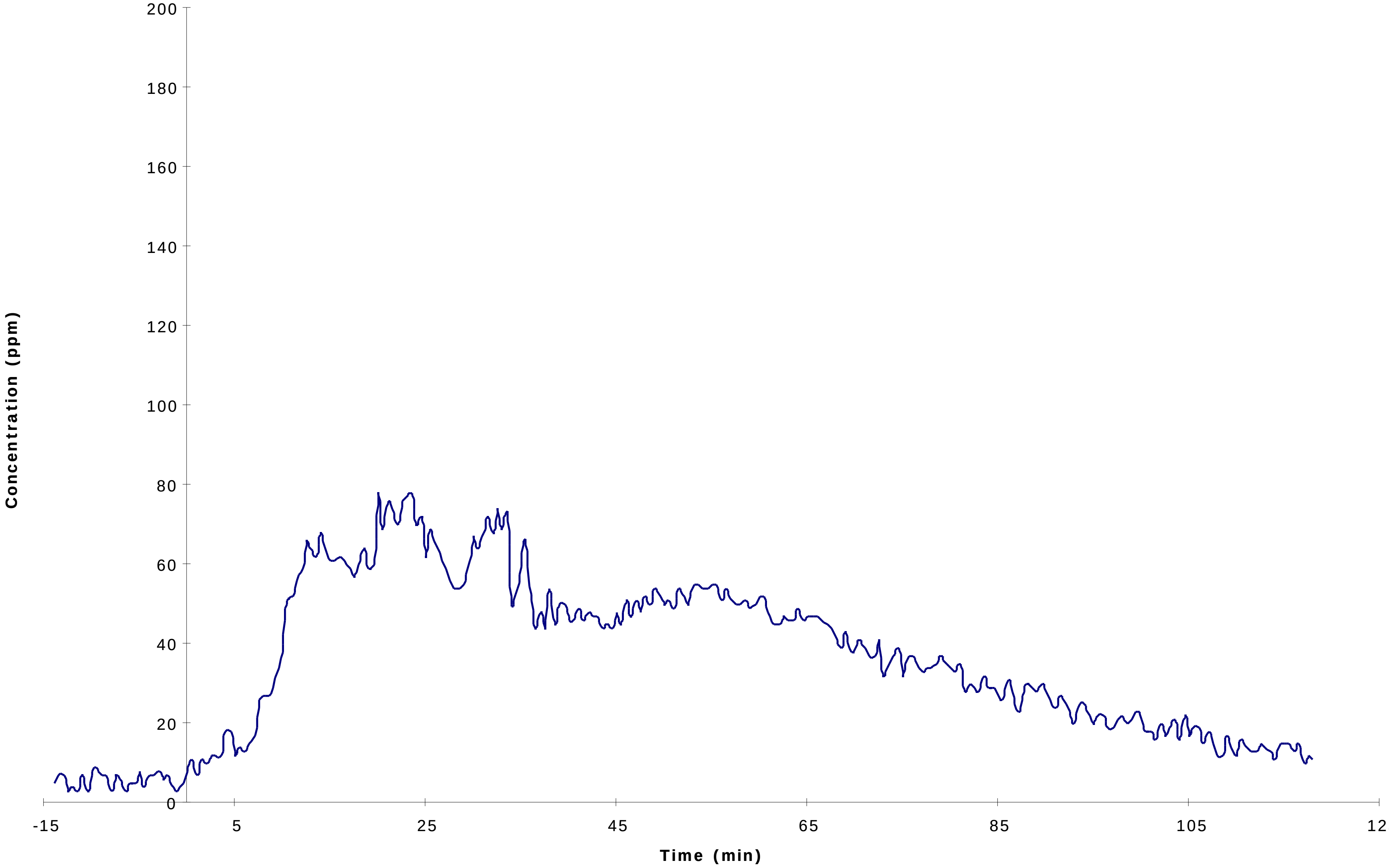

Figure 14. CO Concentration for Test No. 4 - Florida no Blower

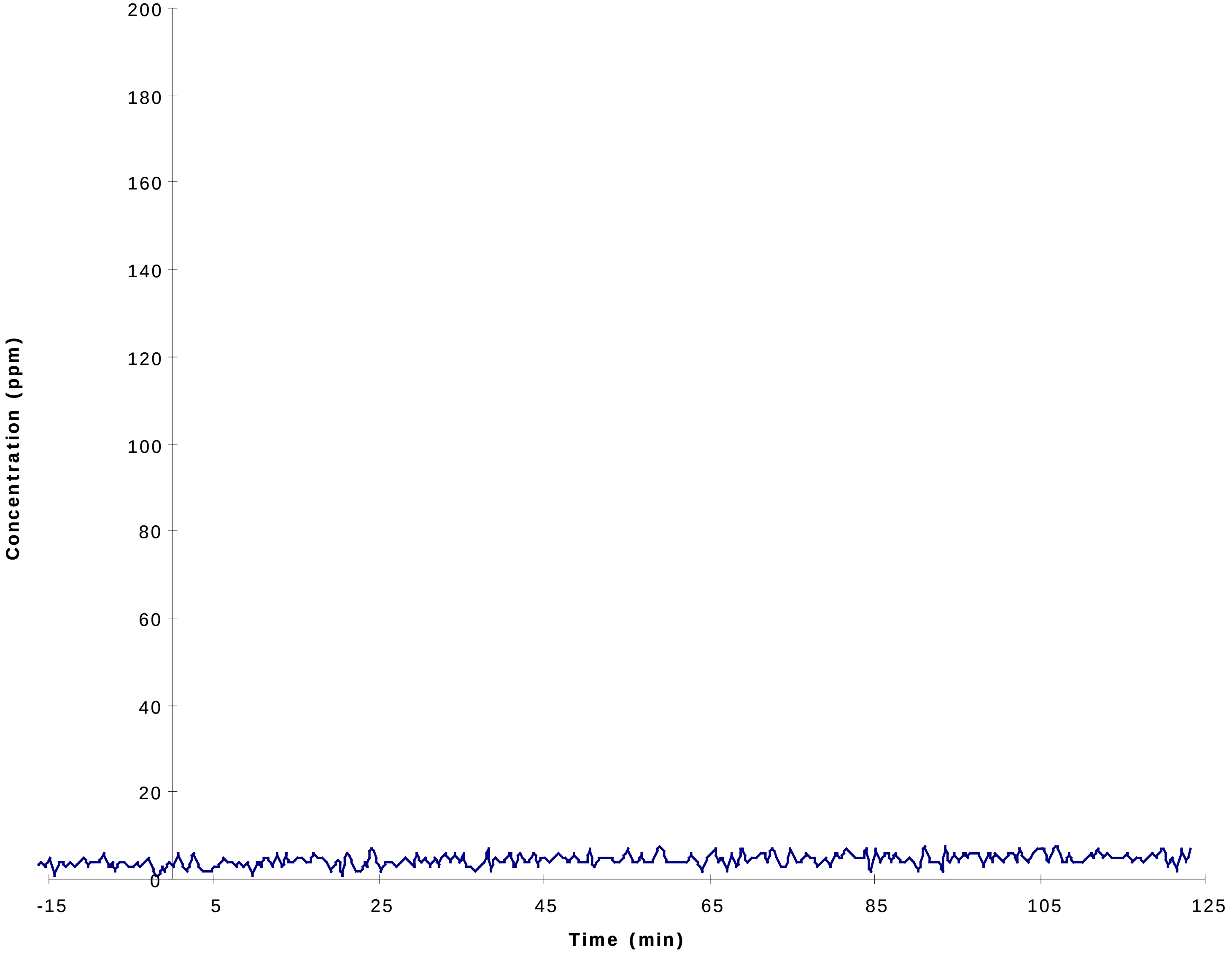

Figure 15. CO Concentration for Test No. 5 - Hut Blank

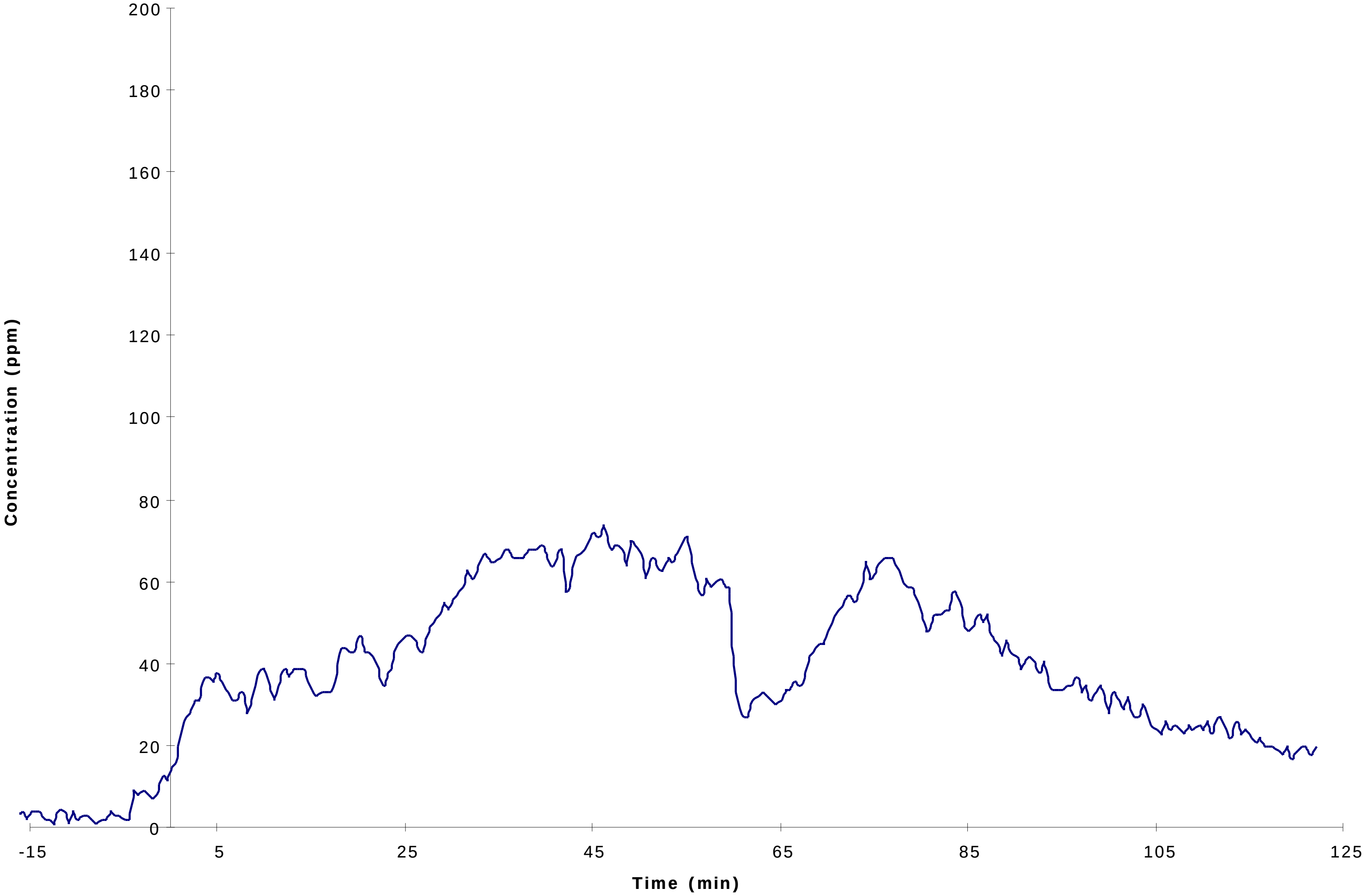

Figure 16. CO Concentration for Test No. 6 - Tenn with Blower

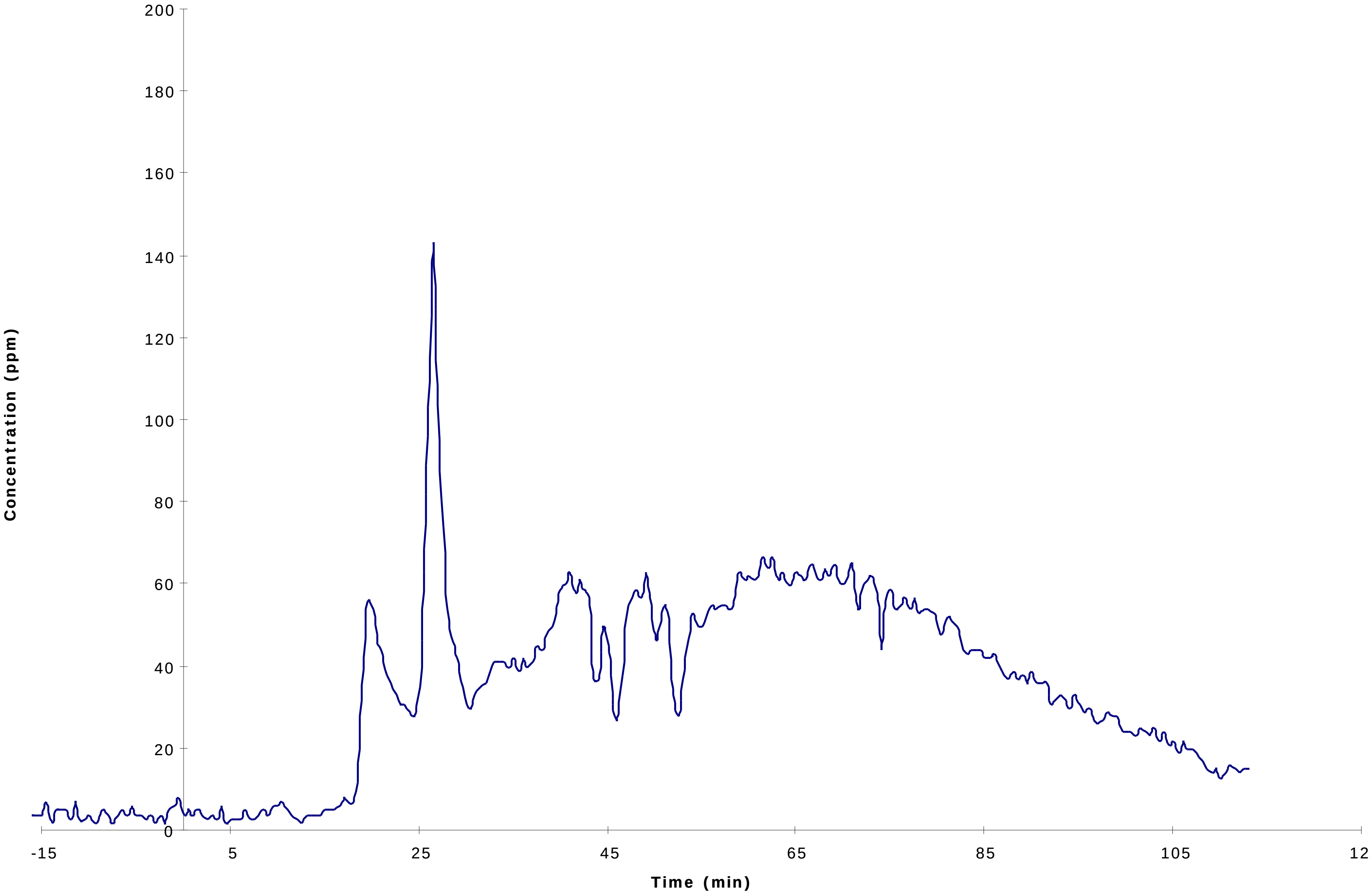

Figure 17. CO Concentration for Test No. 7 - Tenn with Blower

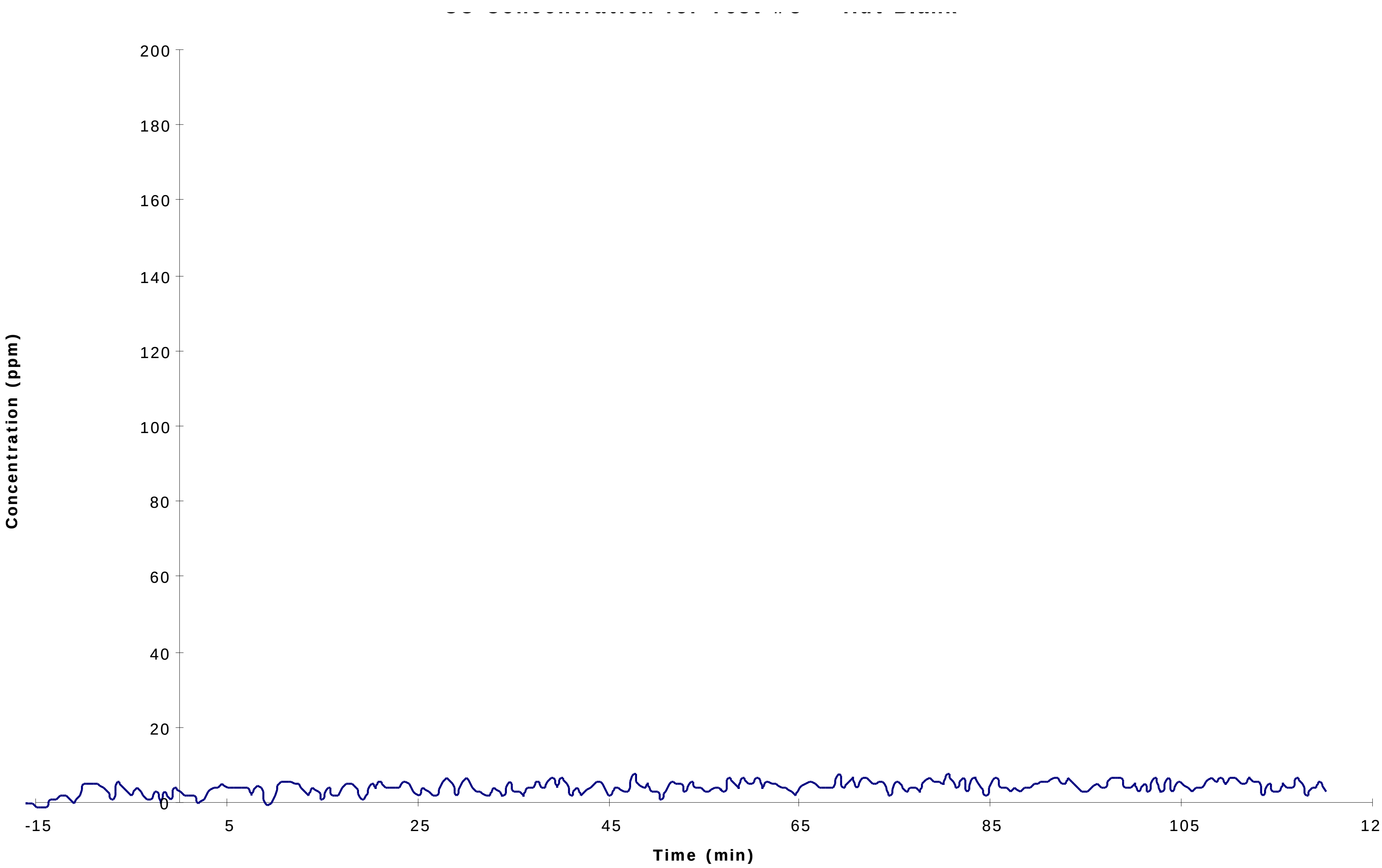

Figure 18. CO Concentration for Test No. 8 - Hut Blank

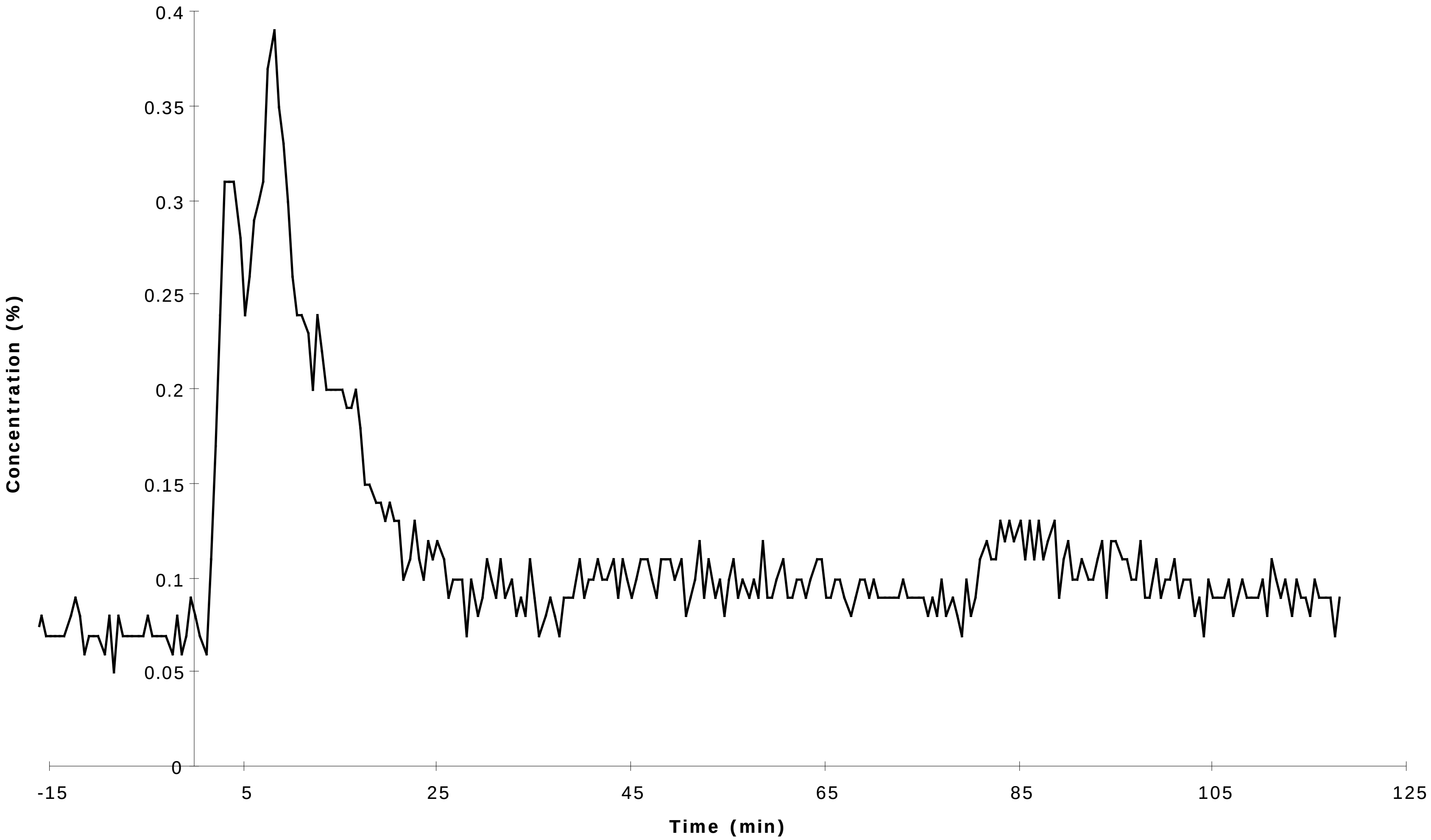

Figure 19. CO2 Concentration for Test No. 1 - Tenn no Blower

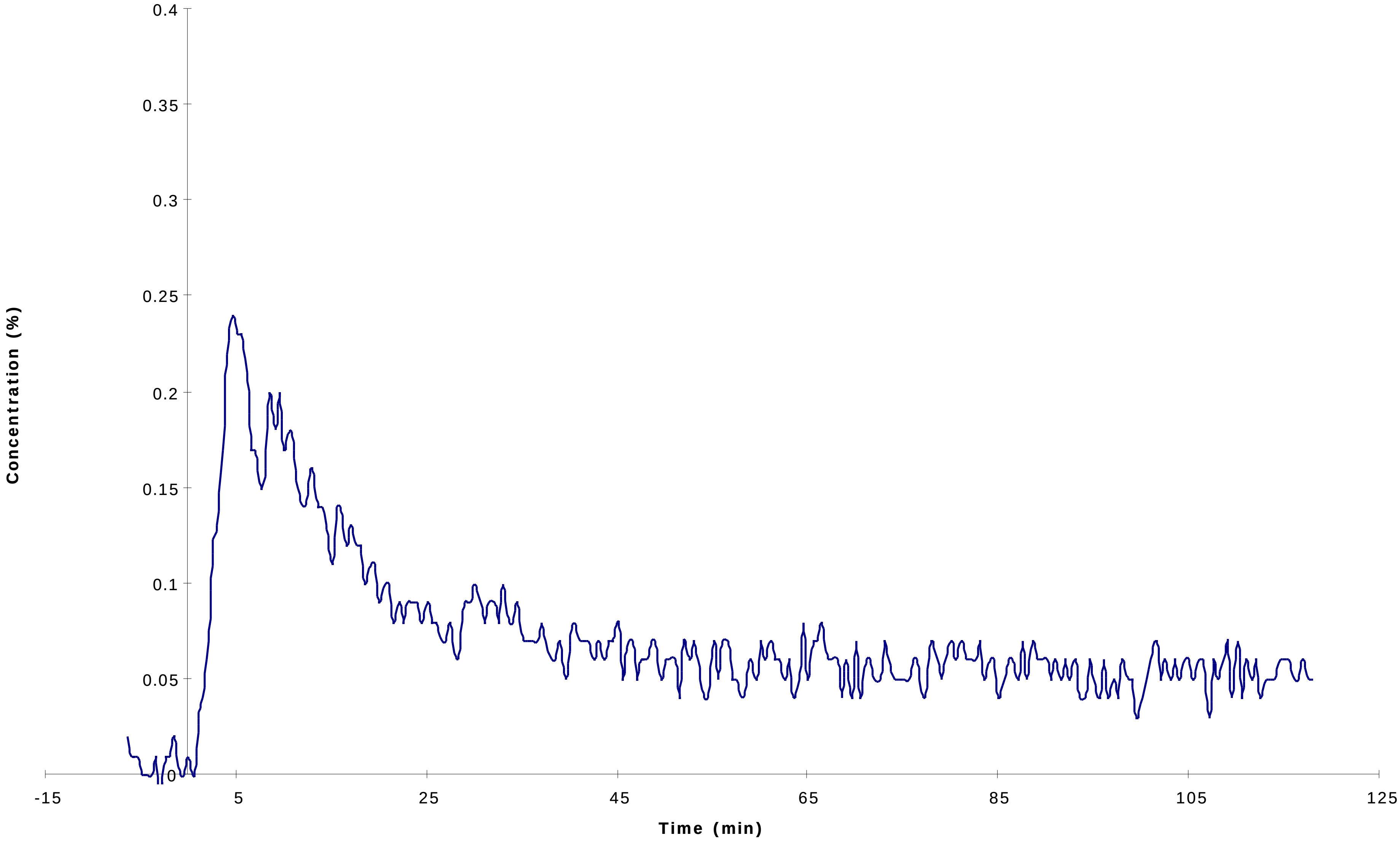

Figure 20. CO2 Concentration for Test No. 2 - Tenn no Blower

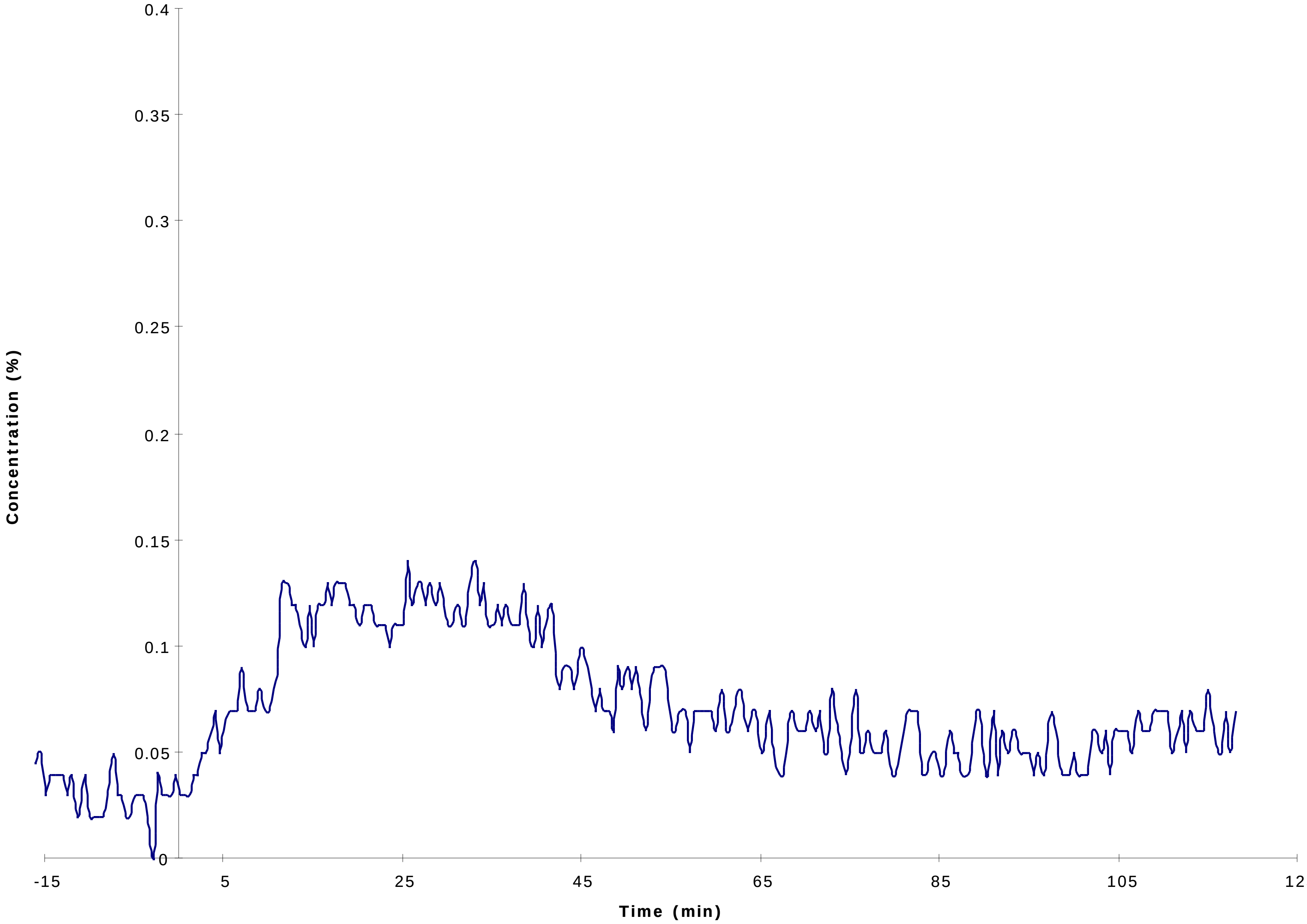

Figure 21. CO2 Concentration for Test No. 3 - Florida no Blower

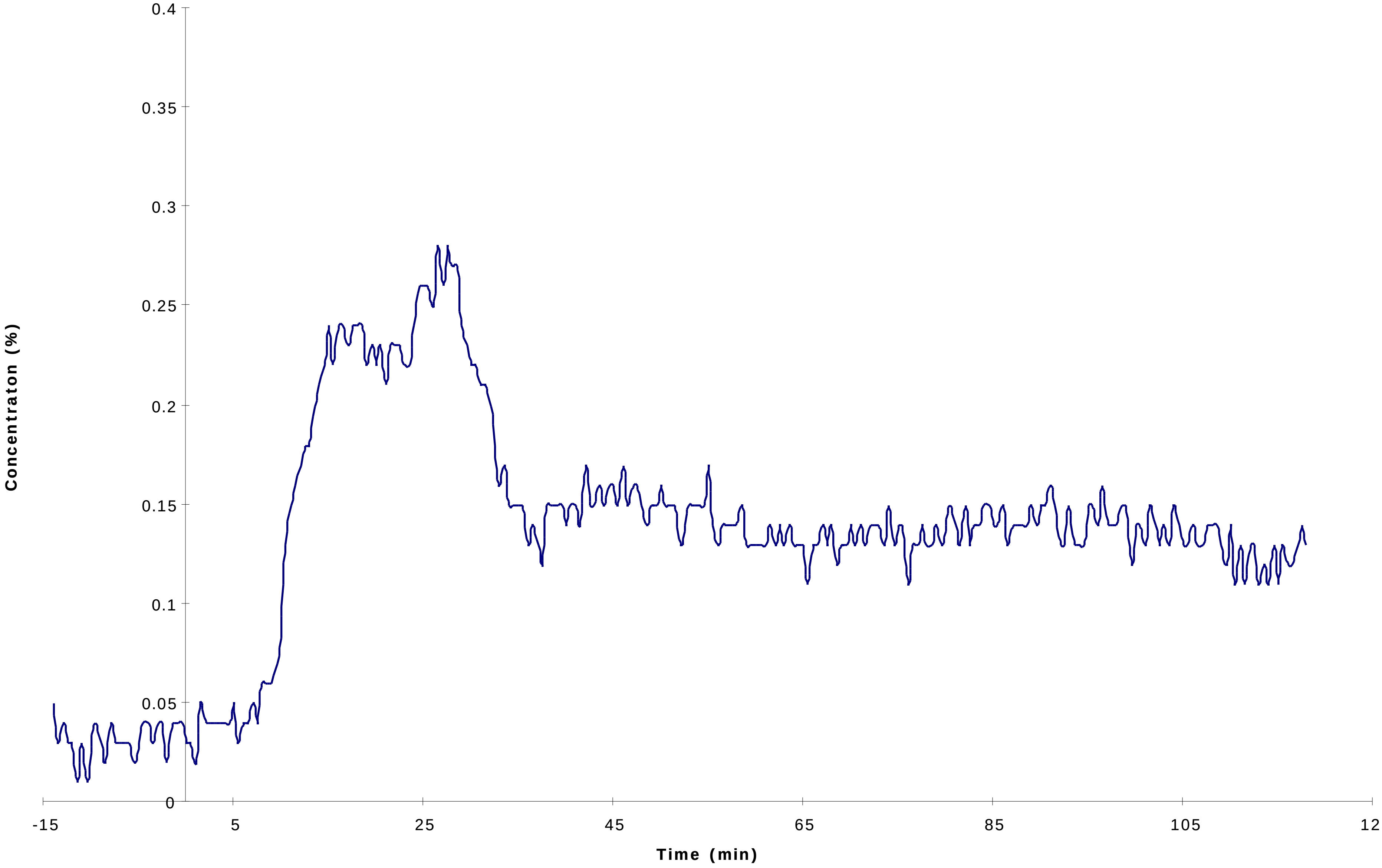

Figure 22. CO2 Concentration for Test No. 4 - Florida no Blower

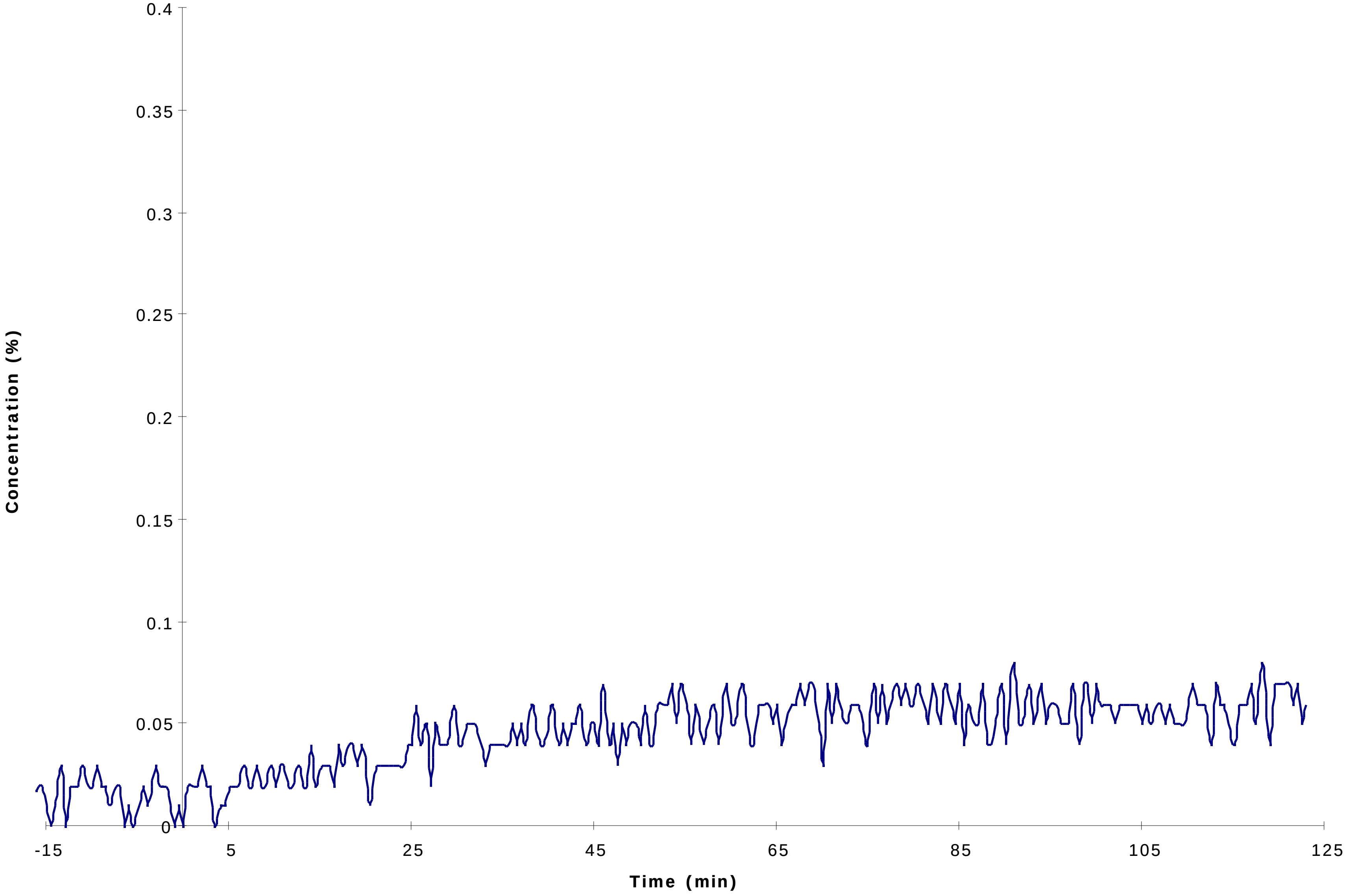

Figure 23. CO2 Concentration for Test No. 5 - Hut Blank

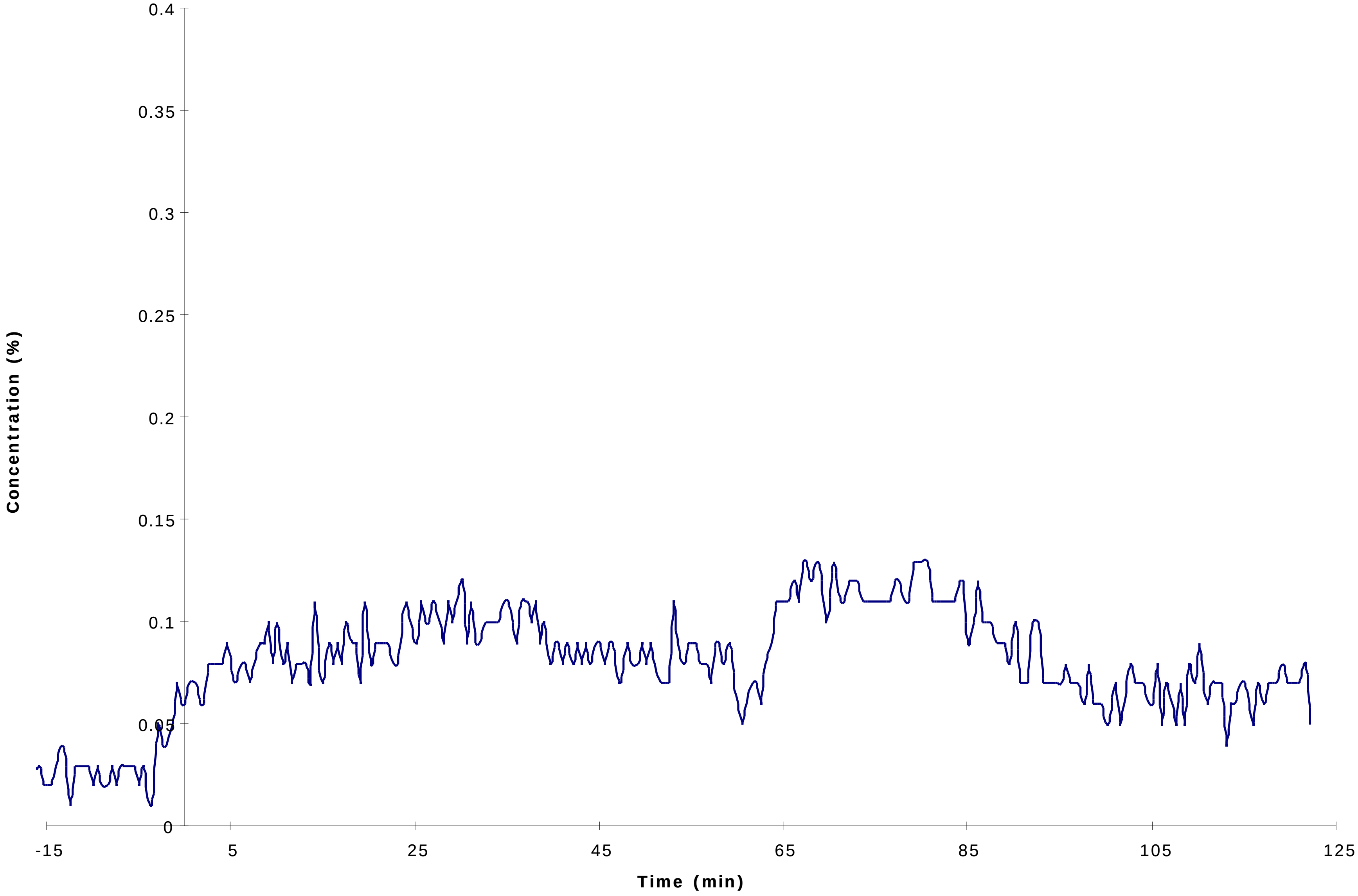

Figure 24. CO2 Concentration for Test No. 6 - Tenn with Blower

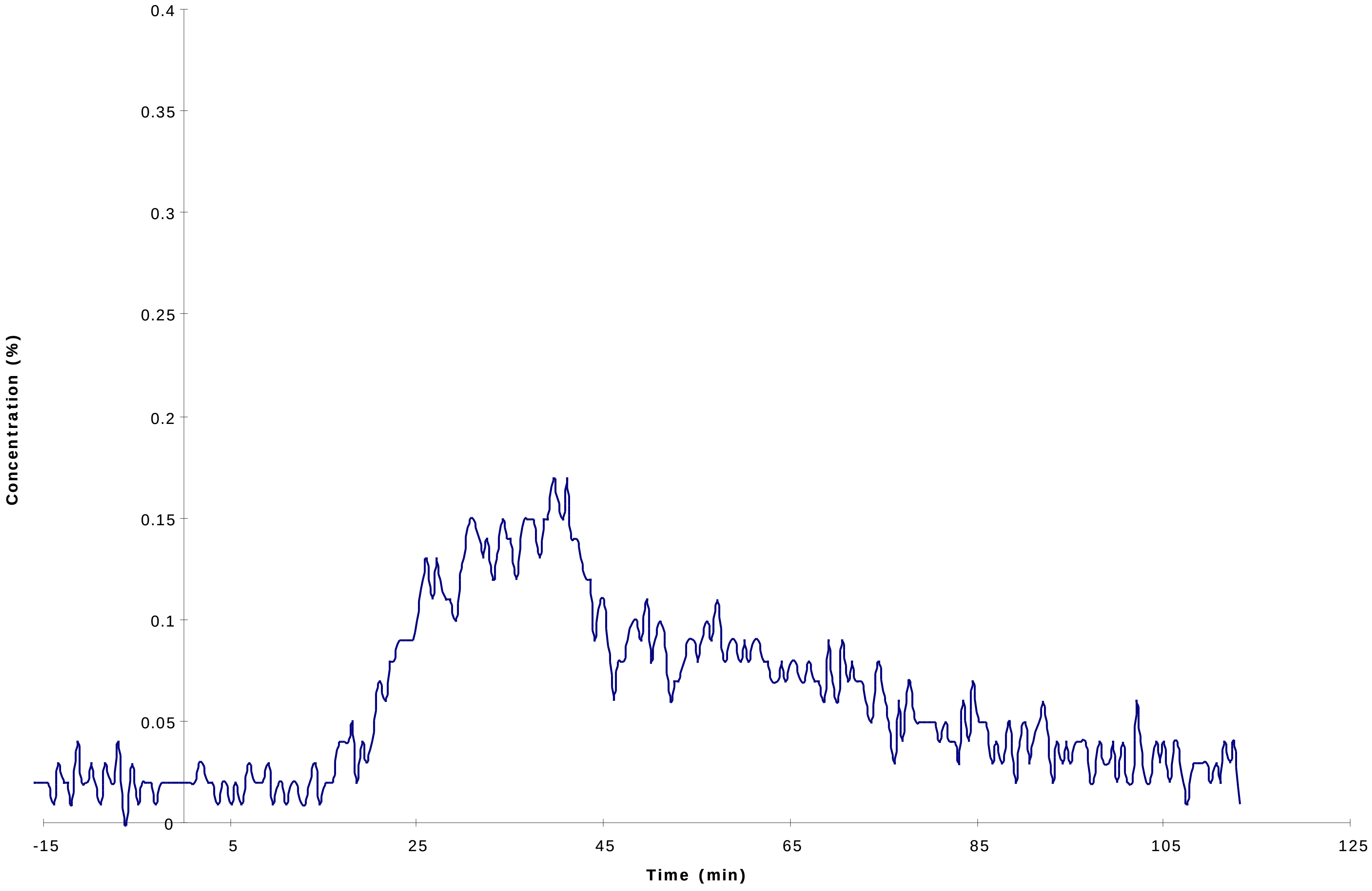

Figure 25. CO2 Concentration for Test No. 7 - Tenn with Blower

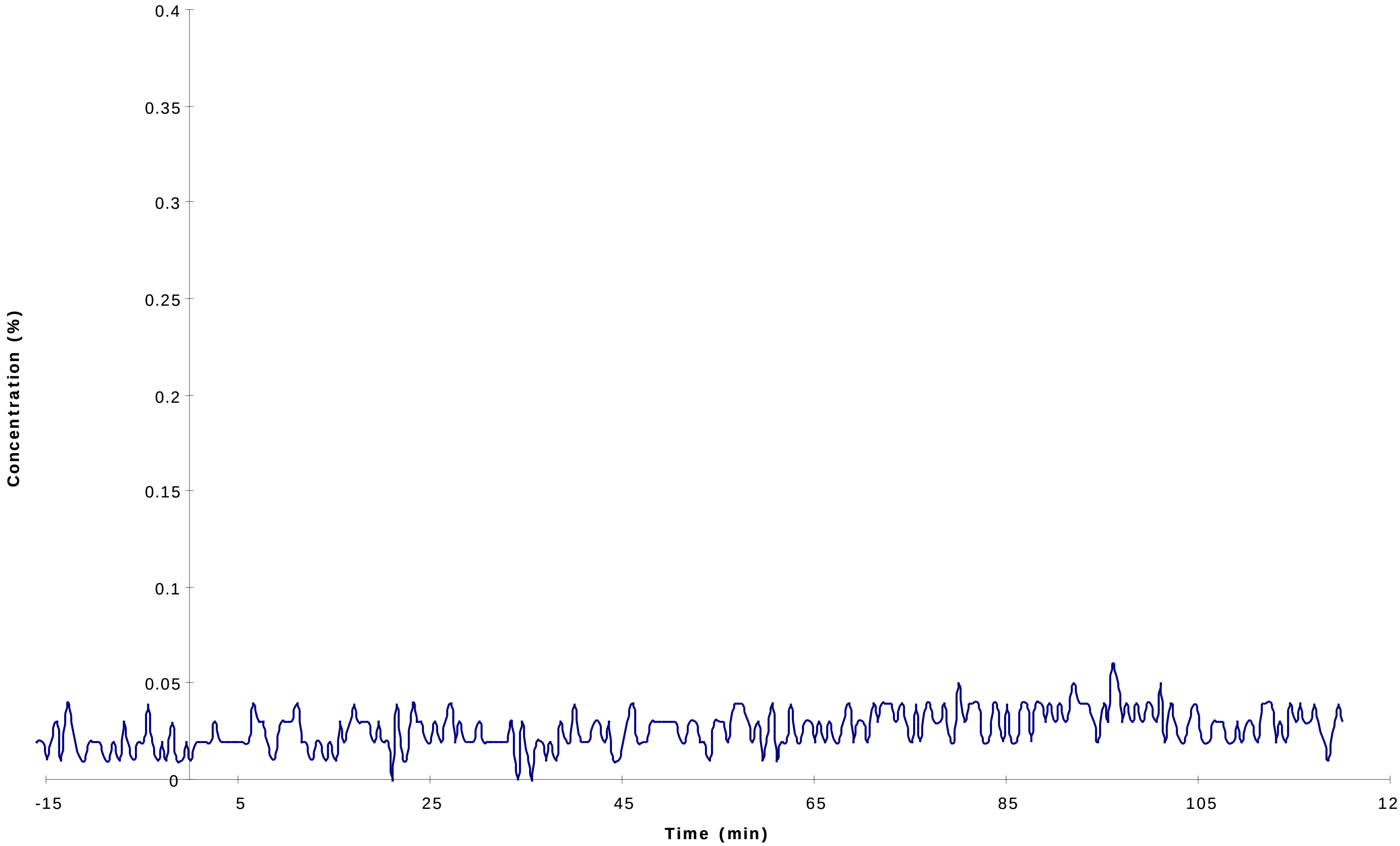

Figure 26. CO2 Concentration for Test No. 8 - Hut Blank 2

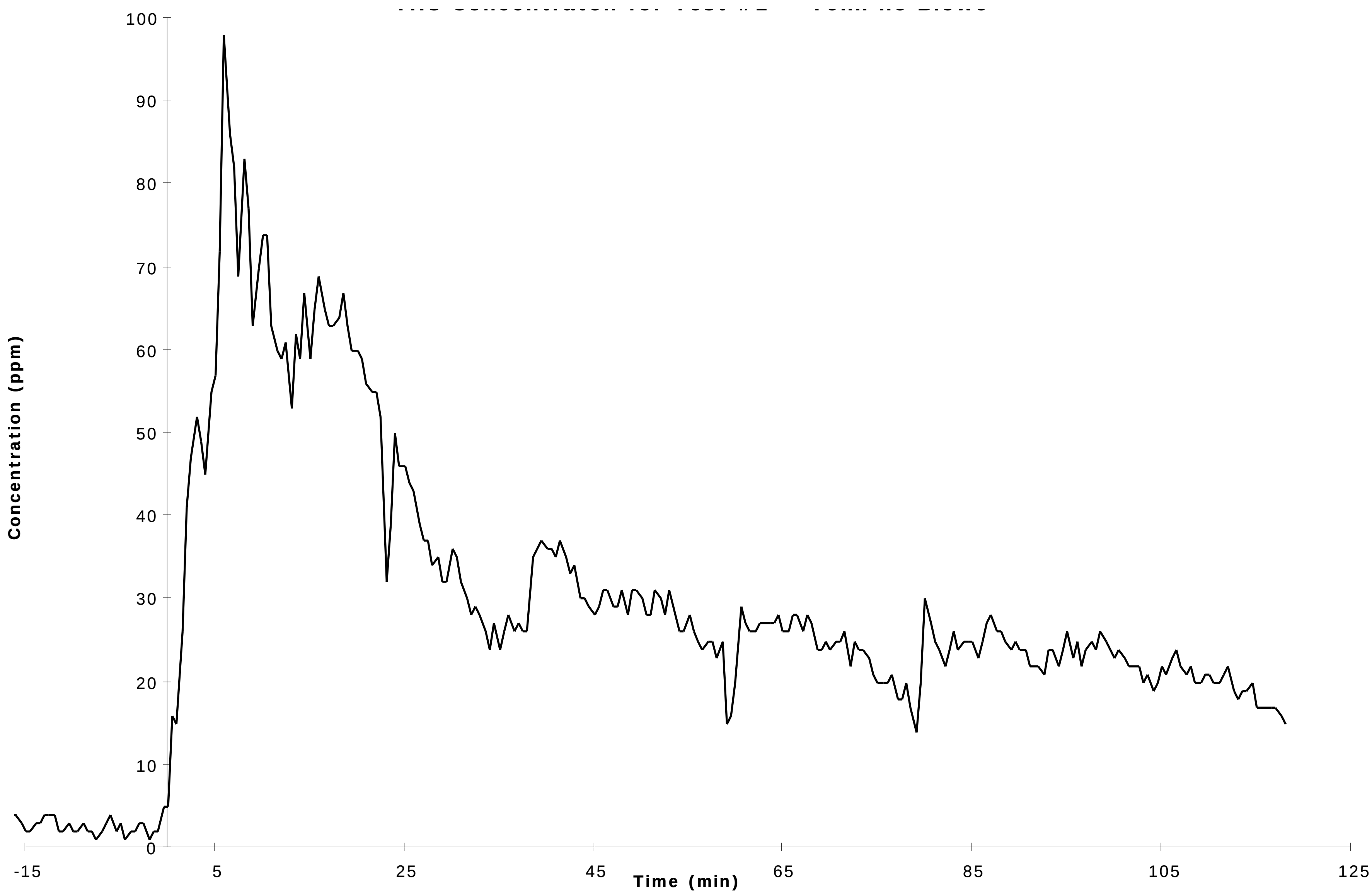

Figure 27. THC Concentration for Test No. 1 - Tenn no Blower

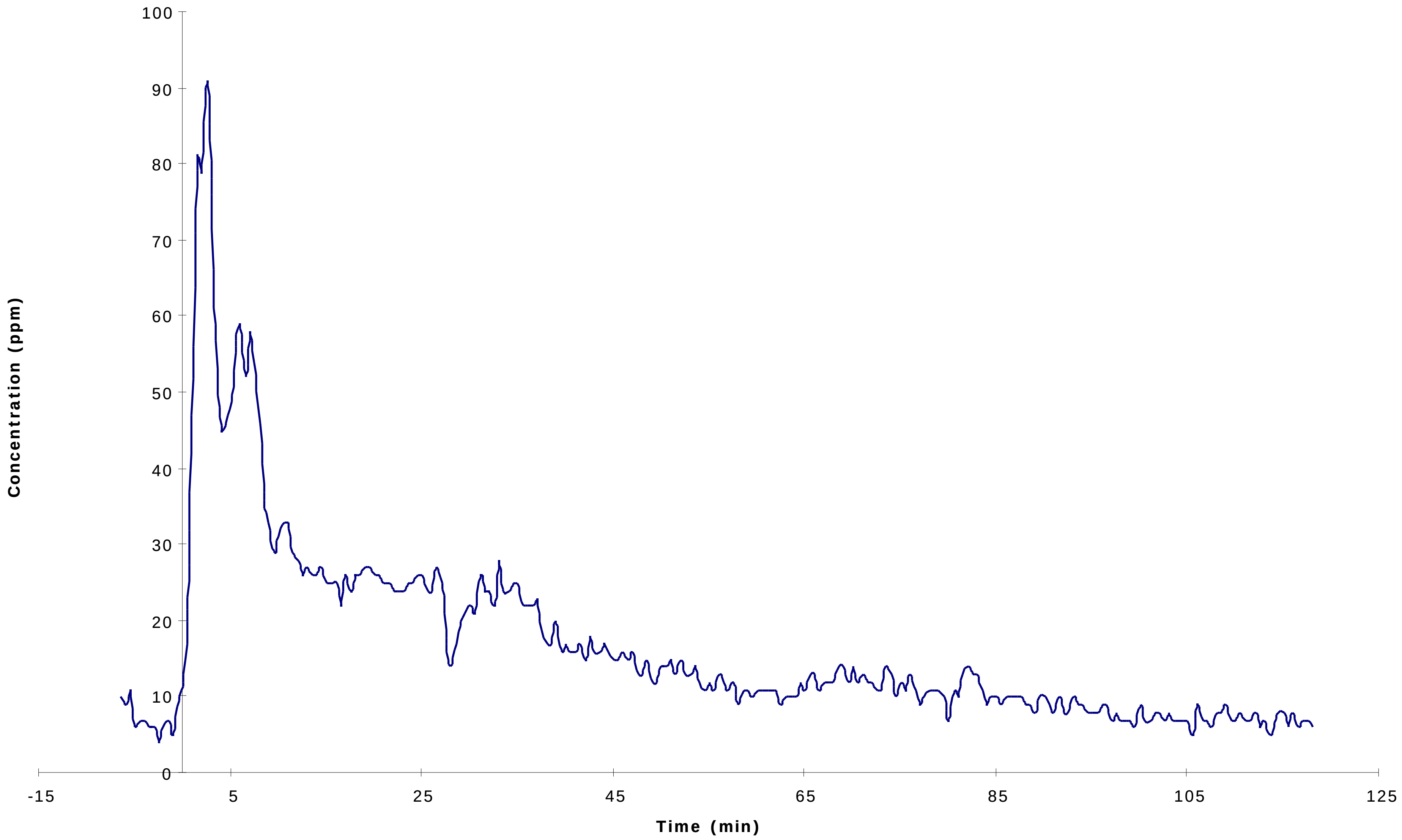

Figure 28. THC Concentration for Test No. 2 - Tenn no Blower

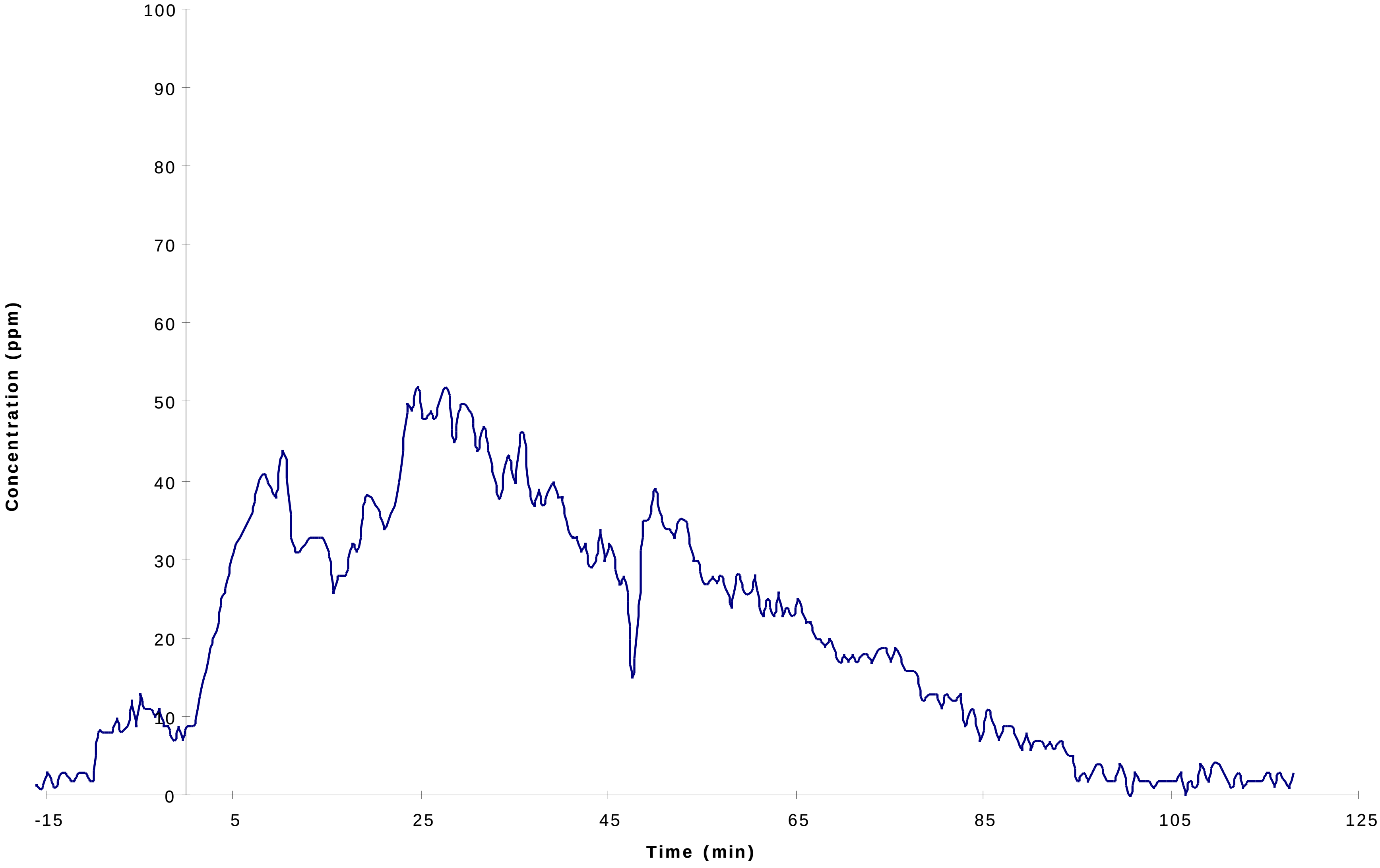

Figure 29. THC Concentration for Test No. 3 - Florida no Blower

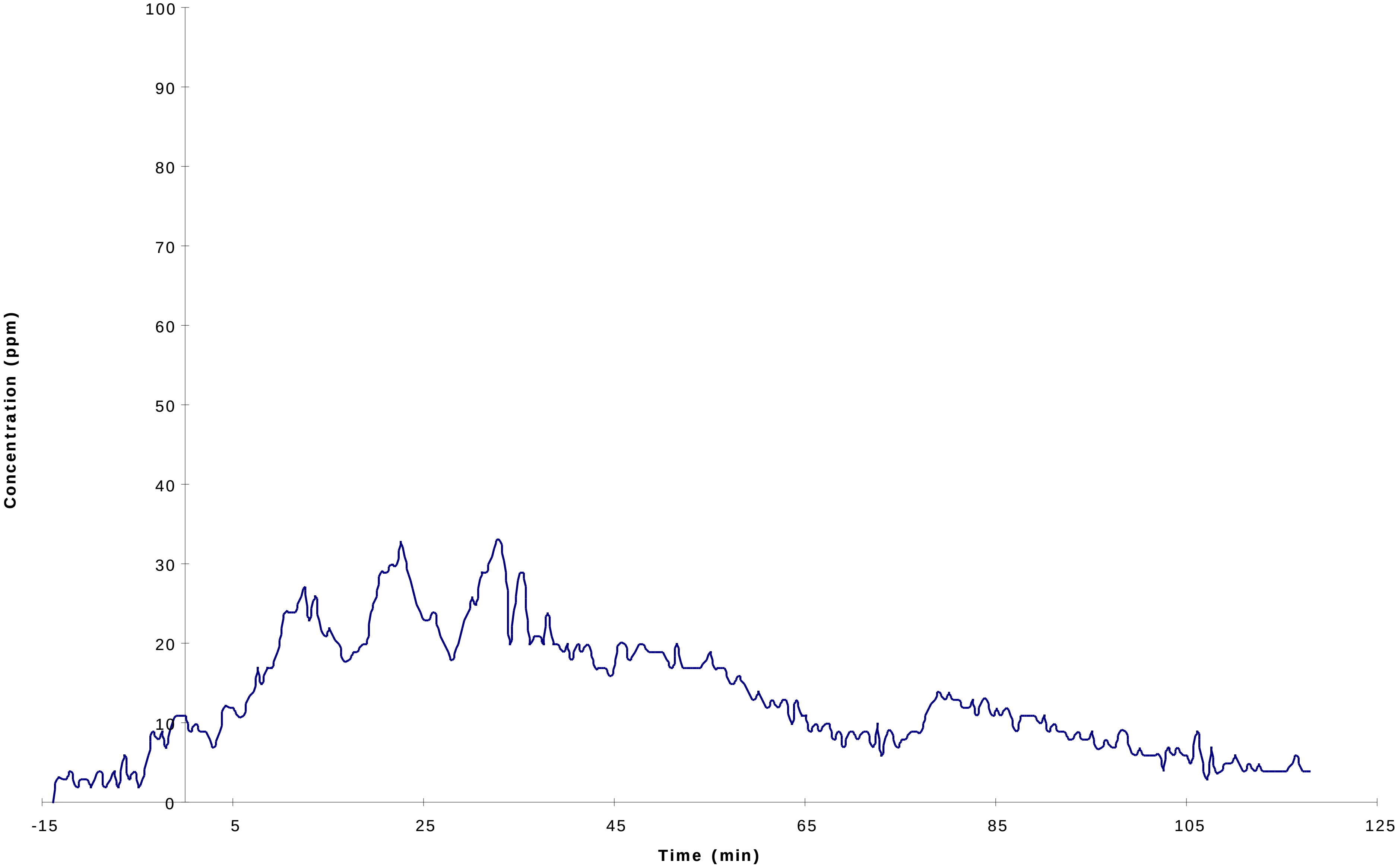

Figure 30. THC Concentration for Test No. 4 - Florida no Blower

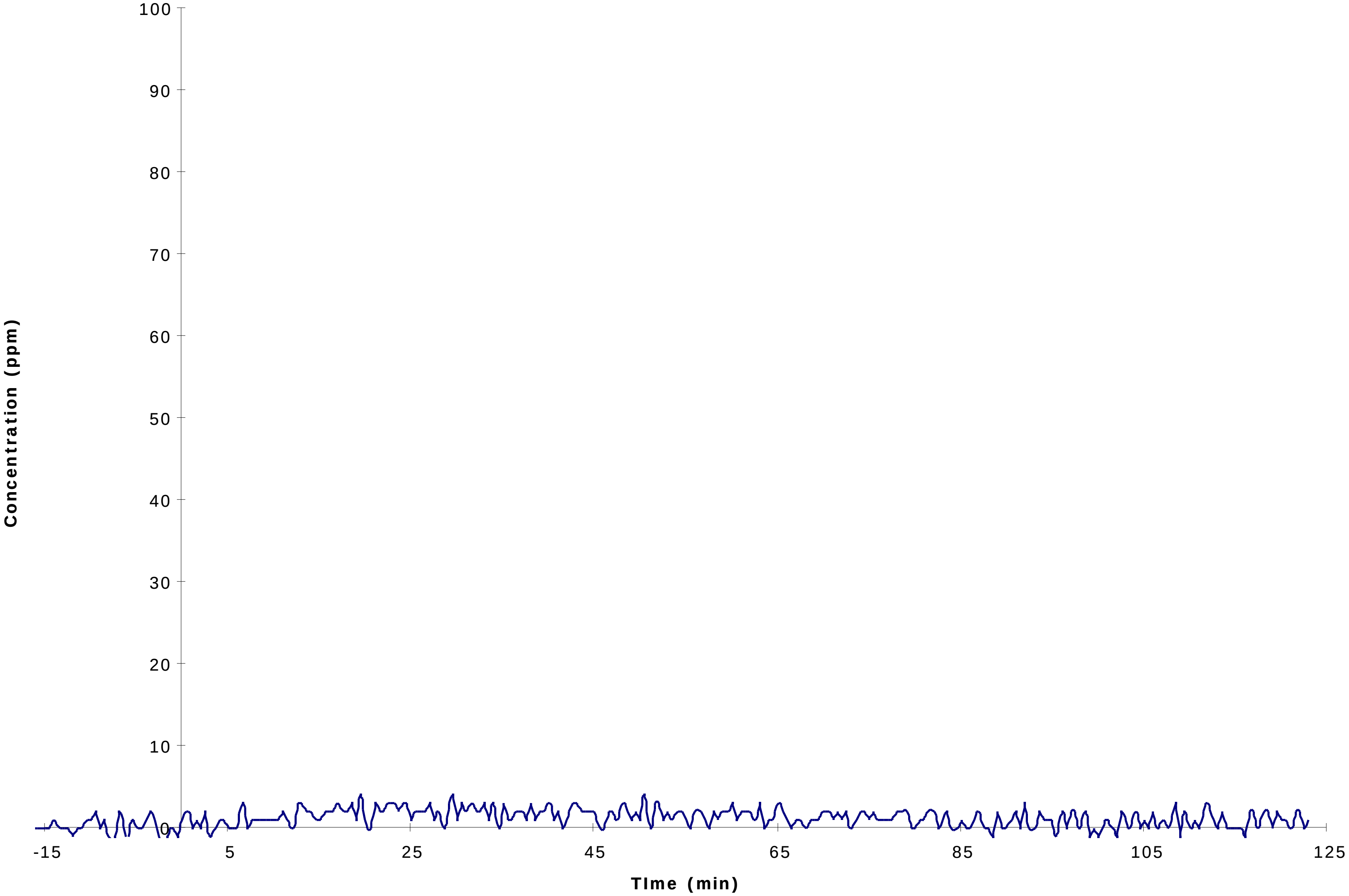

Figure 31. THC Concentration for Test No. 5 - Hut Blank

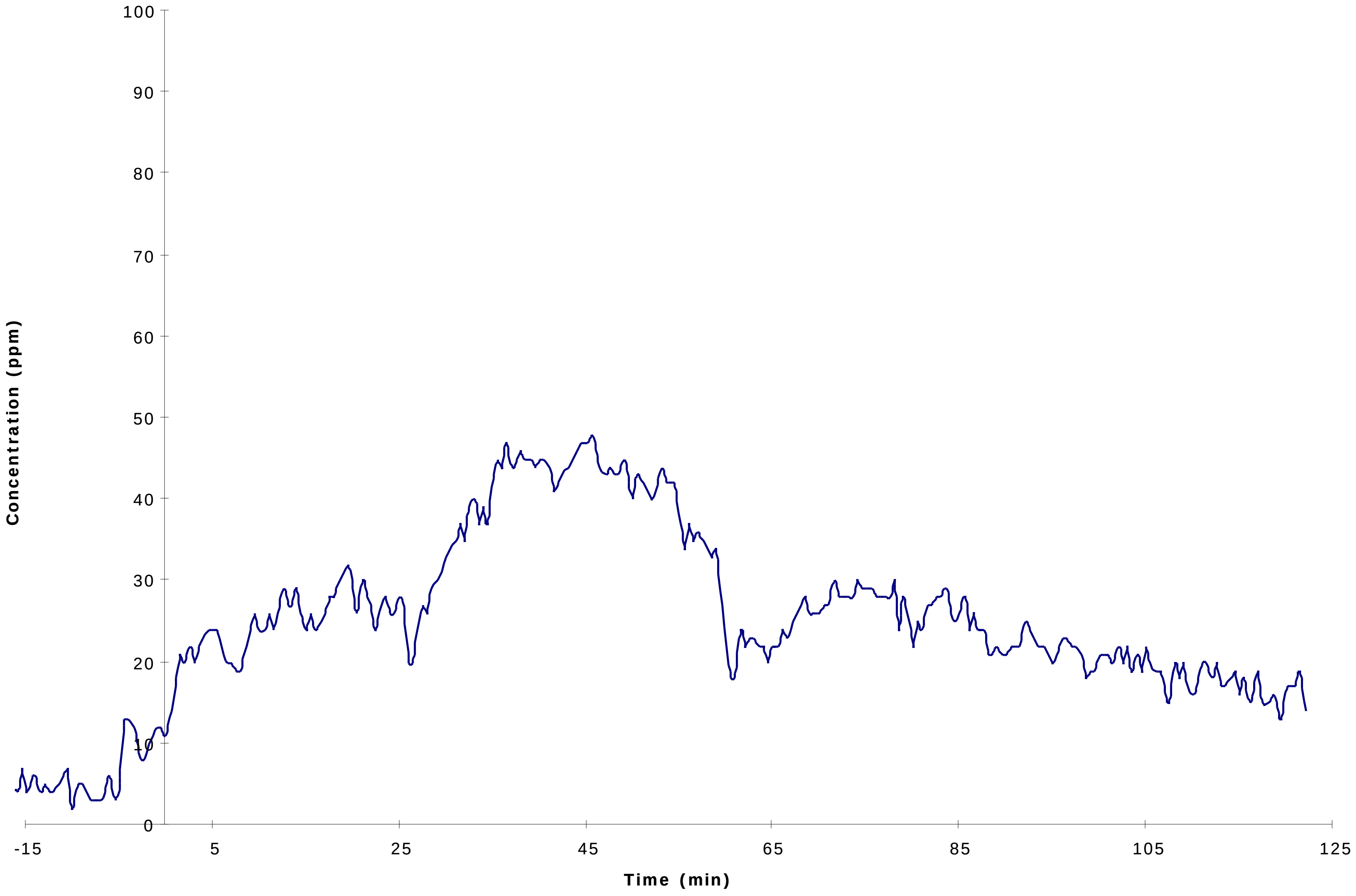

Figure 32. THC Concentration for Test No. 6 - Tenn with Blower

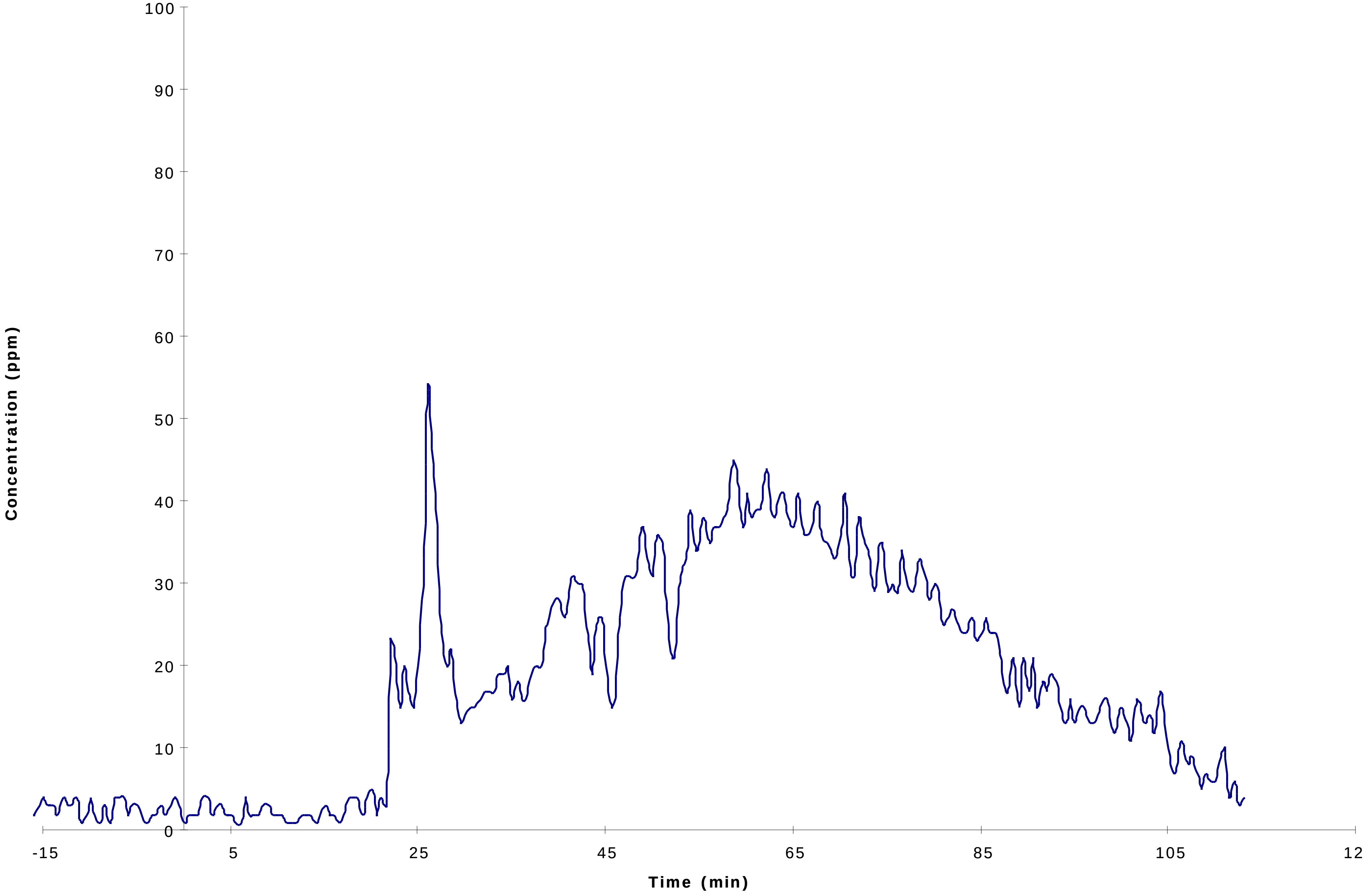

Figure 33. THC Concentration for Test No. 7 - Tenn with Blower

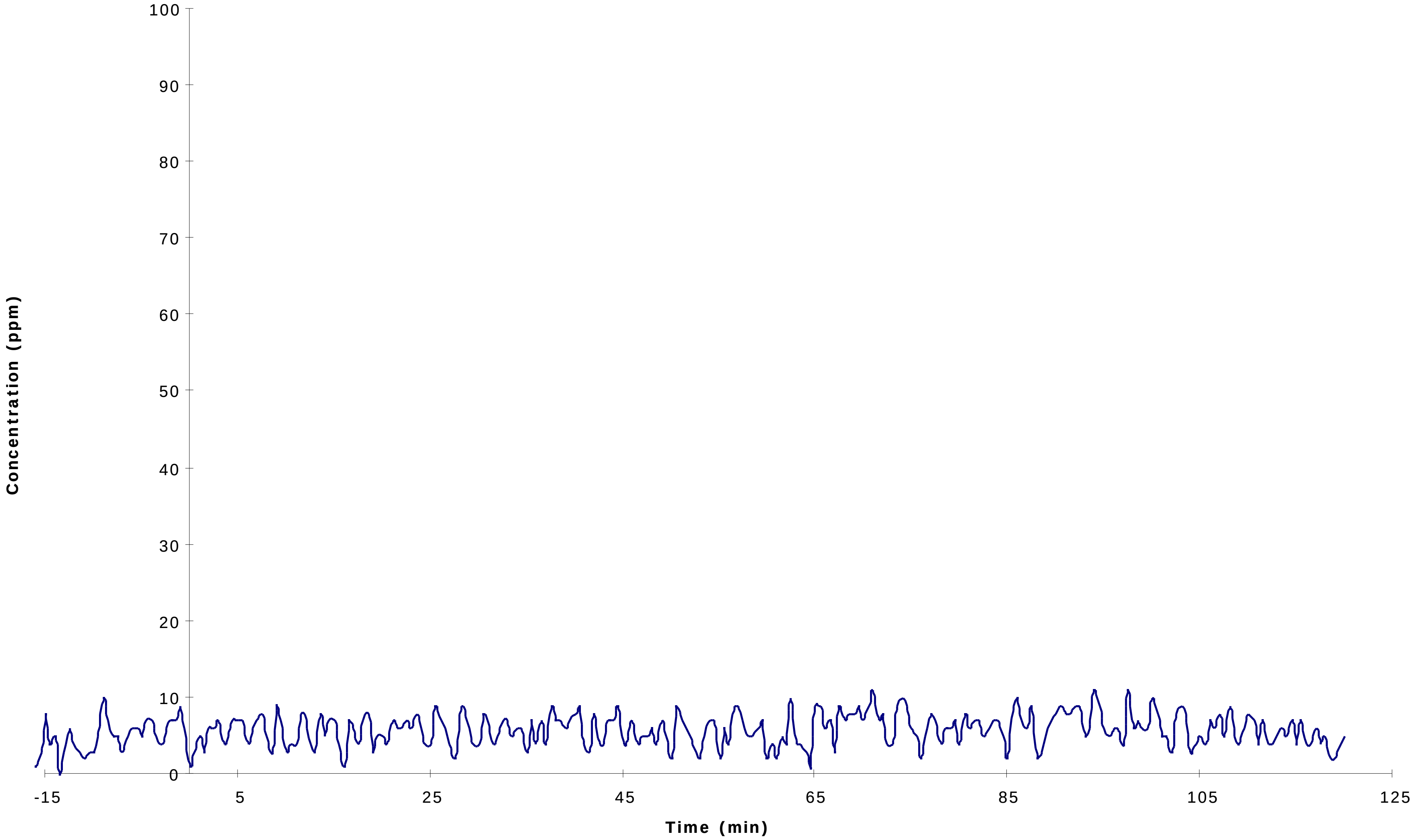

Figure 34. THC Concentration for Test No. 8 - Hut Blank 2

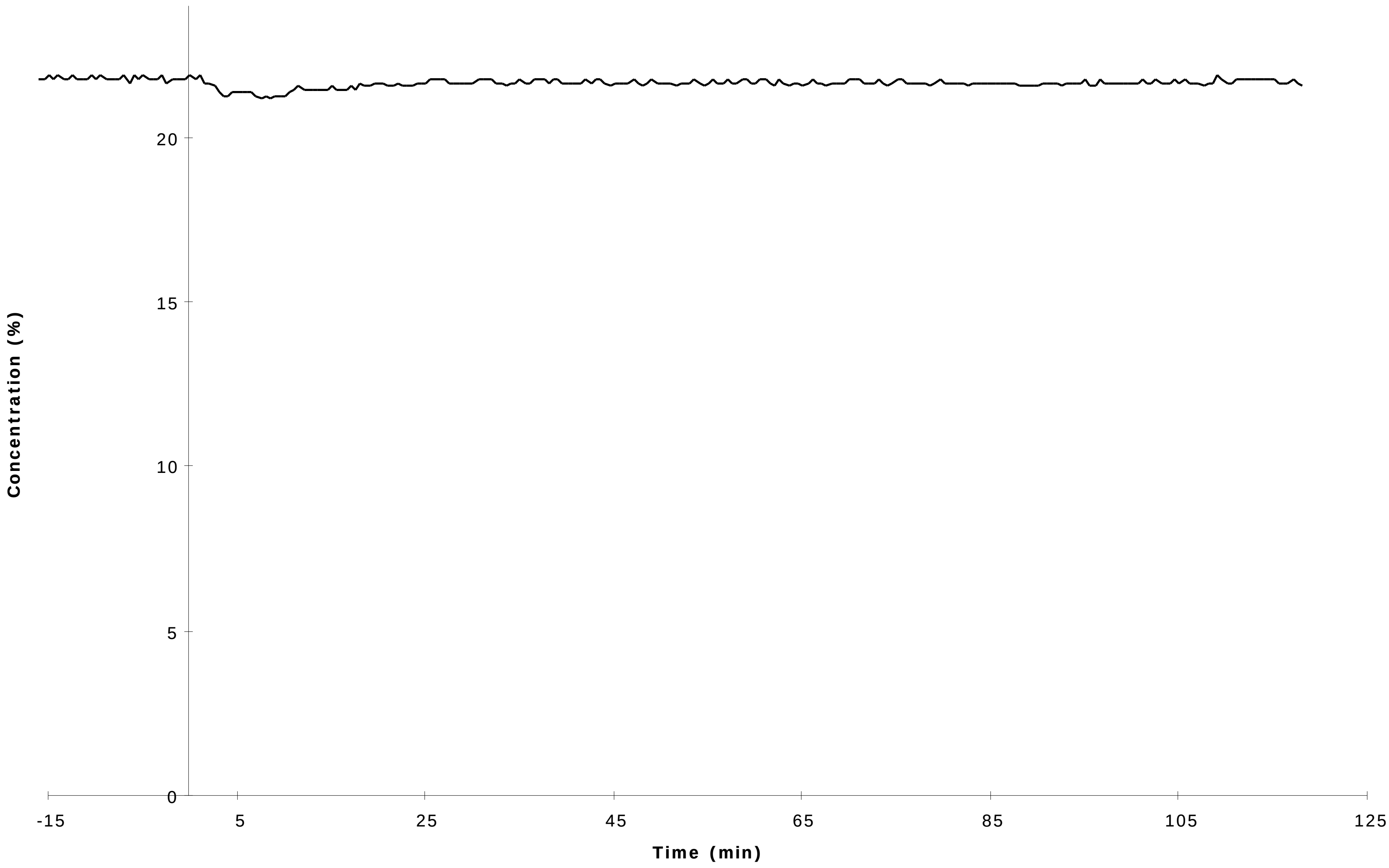

Figure 35. Percent O2 Concentration for Test No. 1 - Tenn no Blower

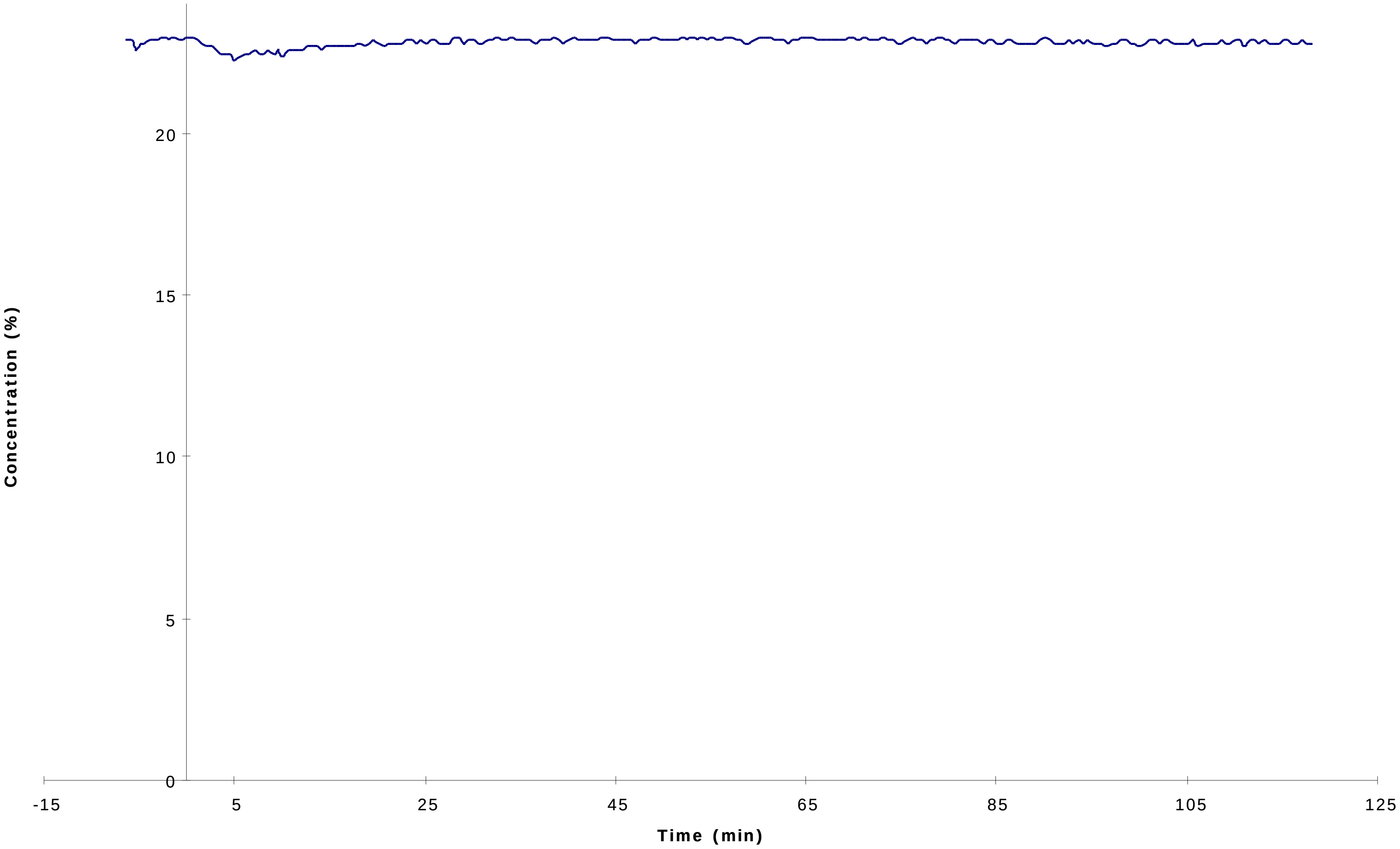

Figure 36. Percent O2 Concentration for Test No. 2 - Tenn no Blower

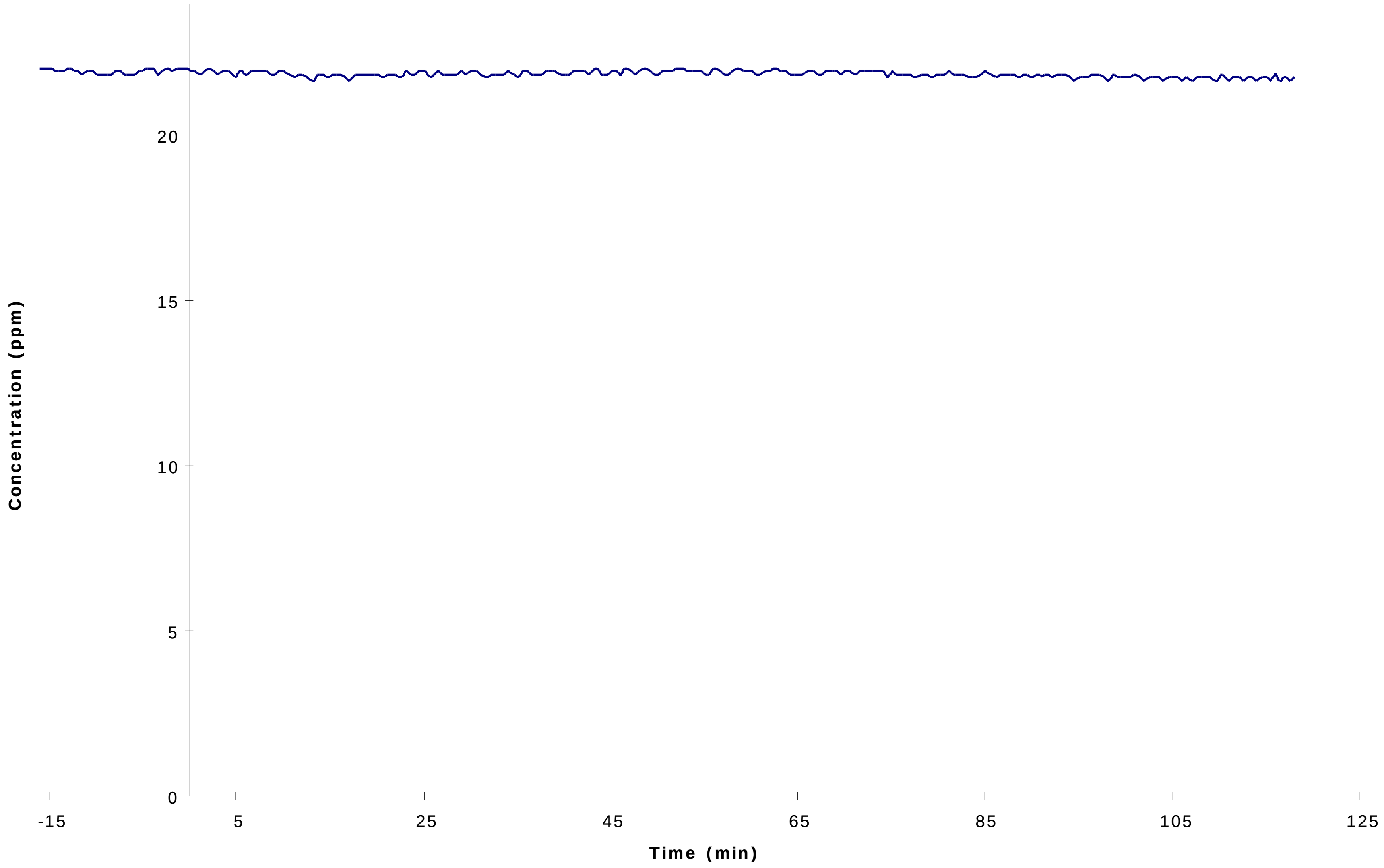

Figure 37. Percent O2 Concentration for Test No. 3 - Florida no Blower

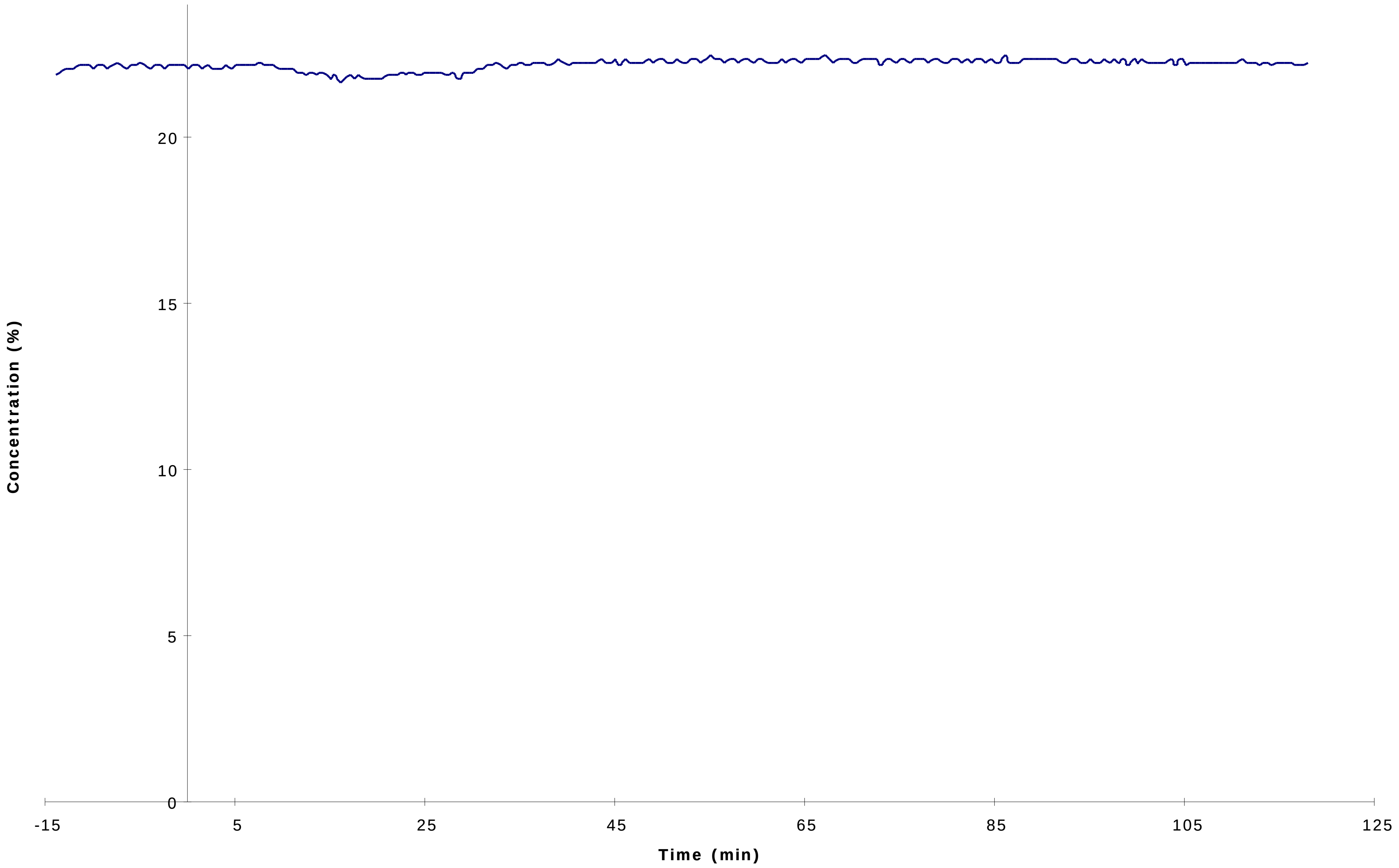

Figure 38. Percent O2 Concentration for Test No. 4 - Florida no Blower

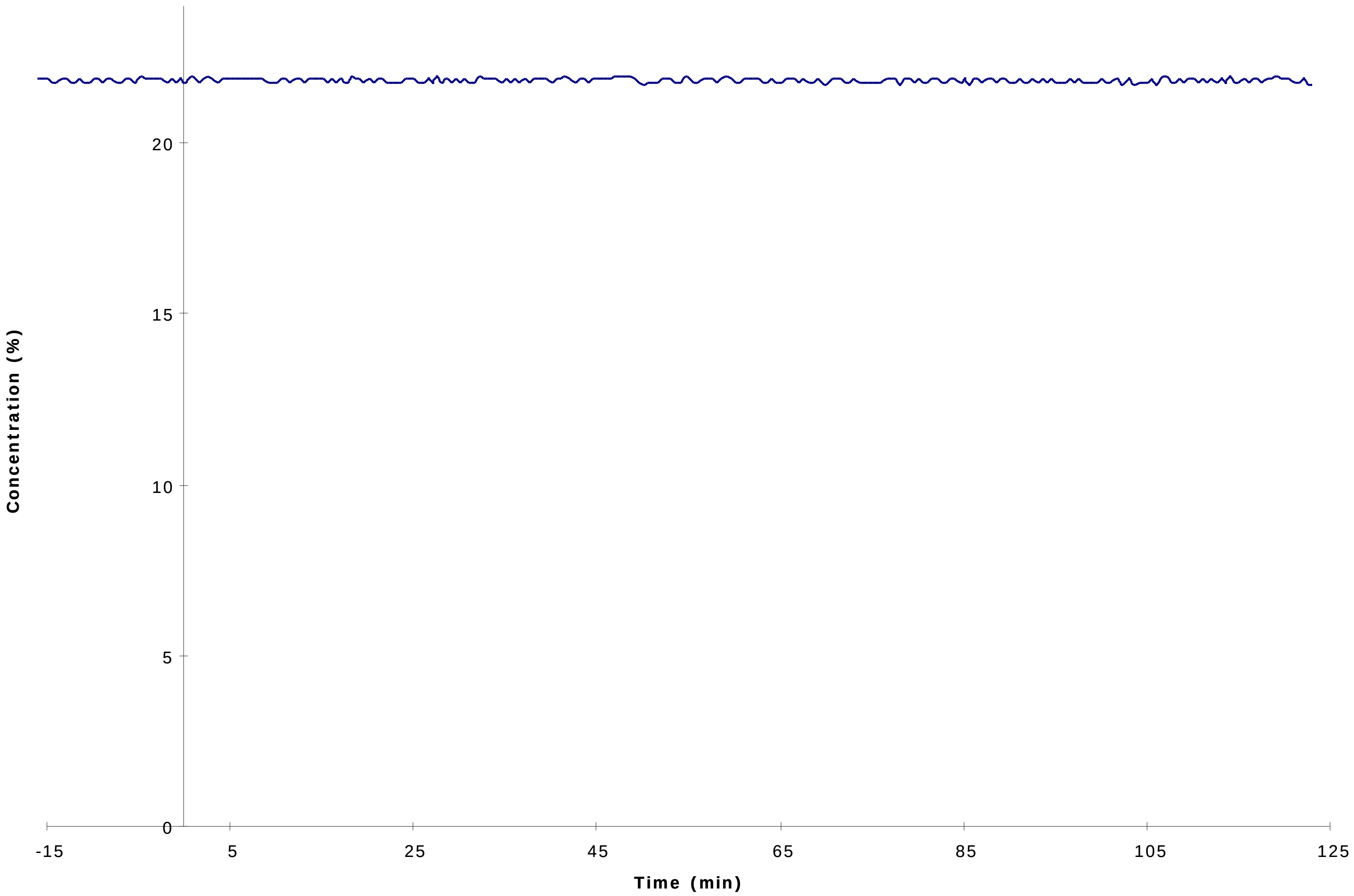

Figure 39. Percent O2 Concentration for Test No. 5 - Hut Blank

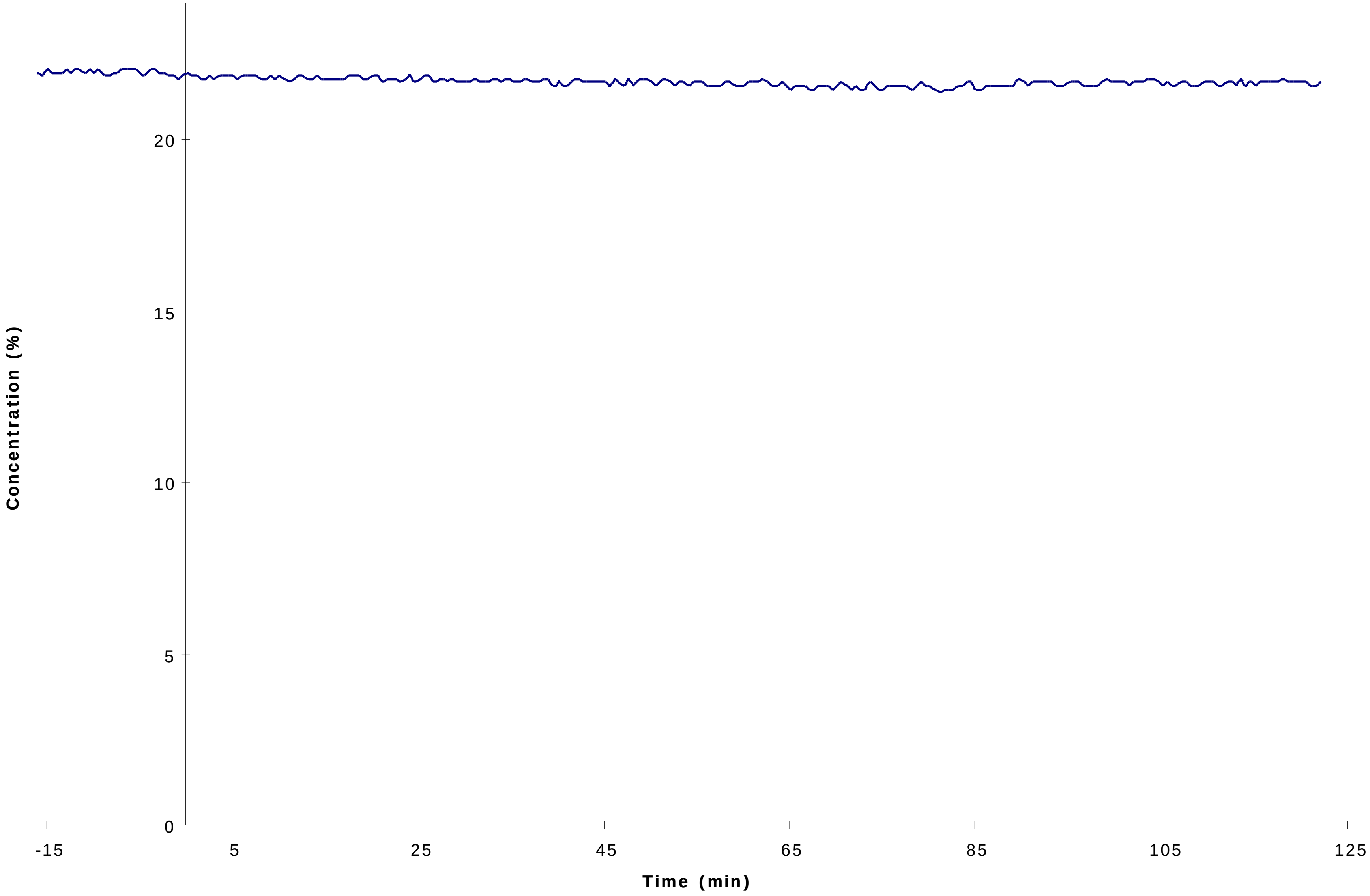

Figure 40. Percent O2 Concentration for Test No. 6 - Tenn with Blower

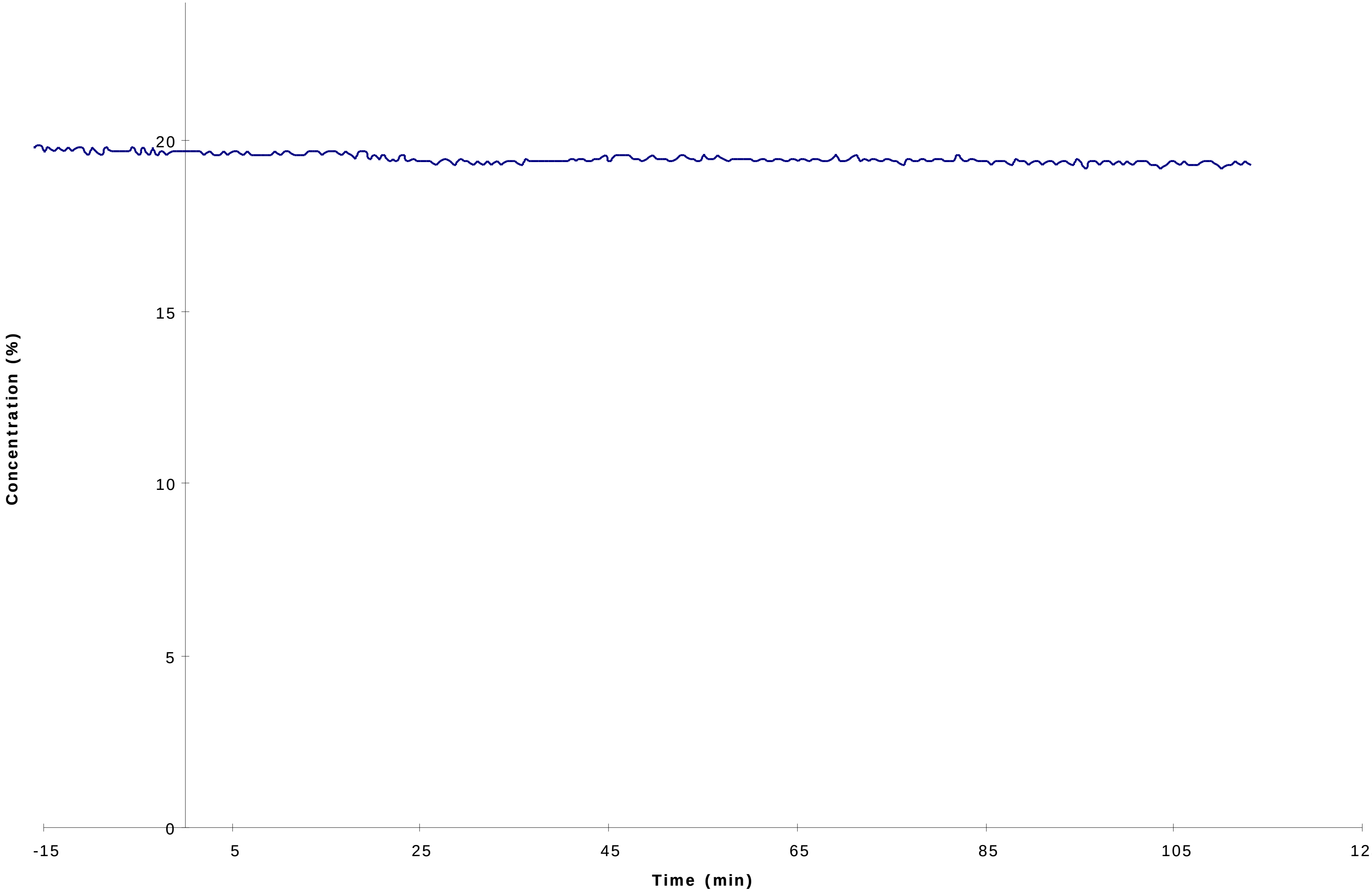

Figure 41. Percent O2 Concentration for Test No. 7 - Tenn with Blower

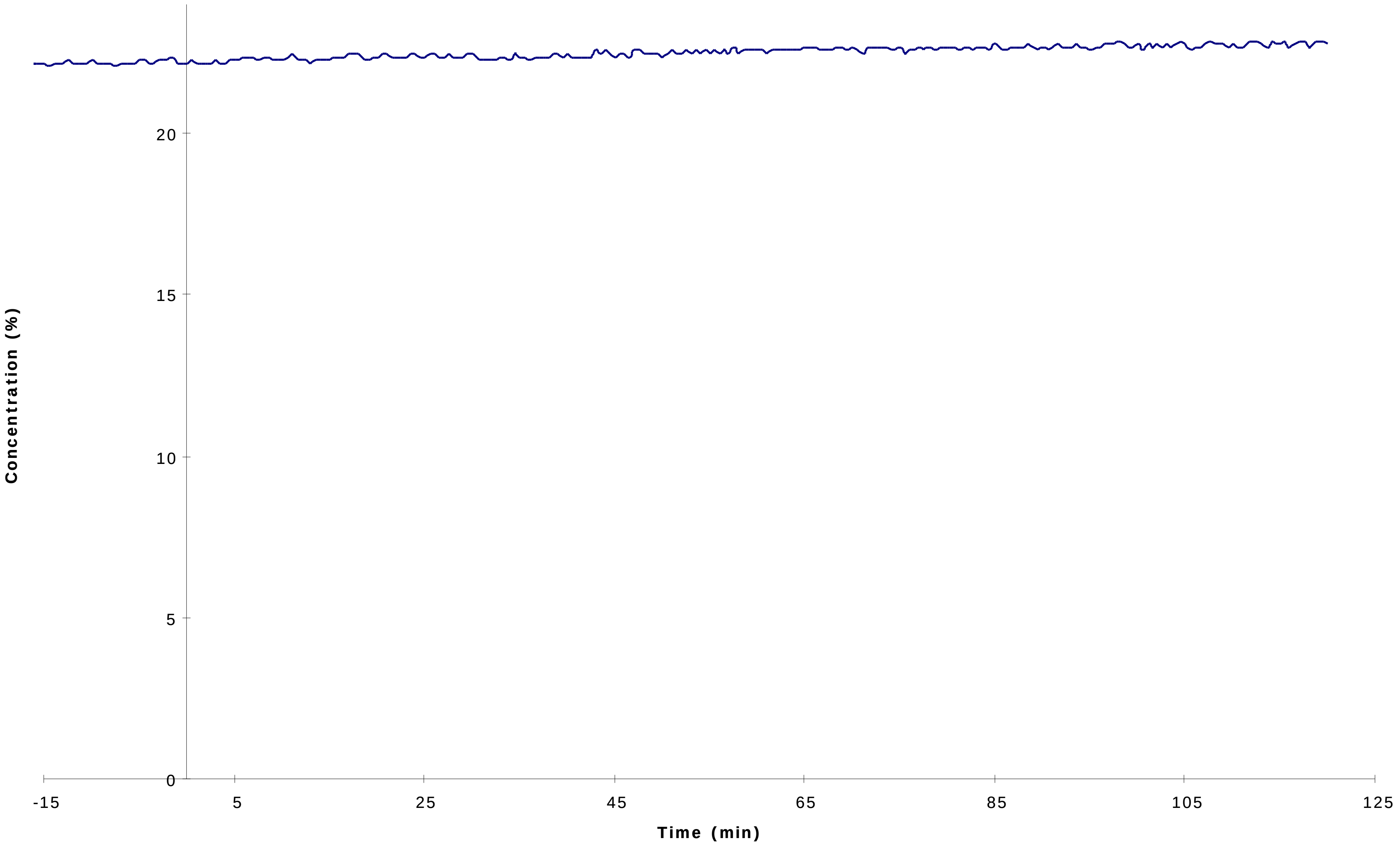

Figure 42. Percent O2 Concentration for Test No. 8 - Hut Blank 2

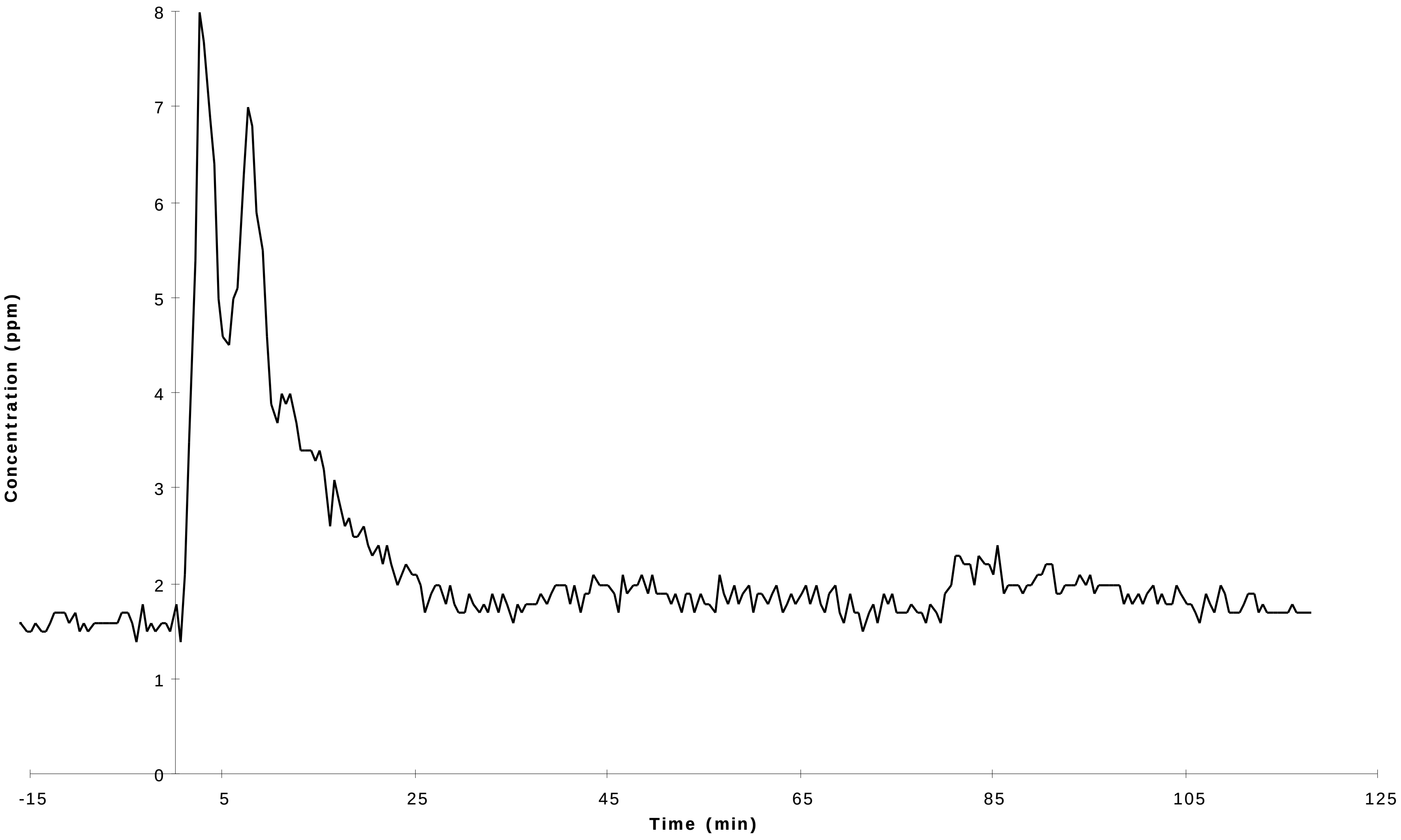

Figure 43. NO Concentration for Test No. 1 - Tenn no Blower

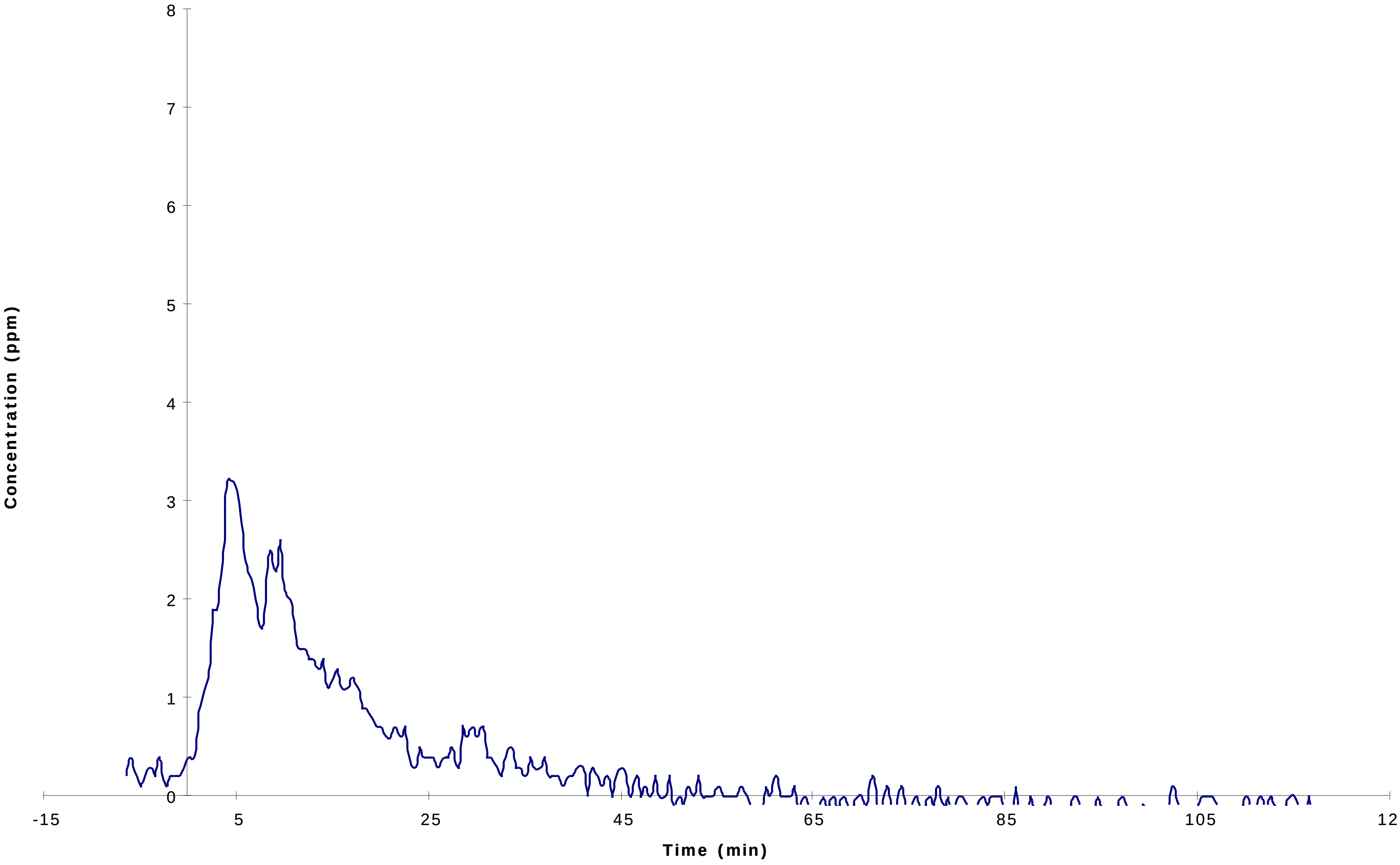

Figure 44. NO Concentration for Test No. 2 - Tenn no Blower

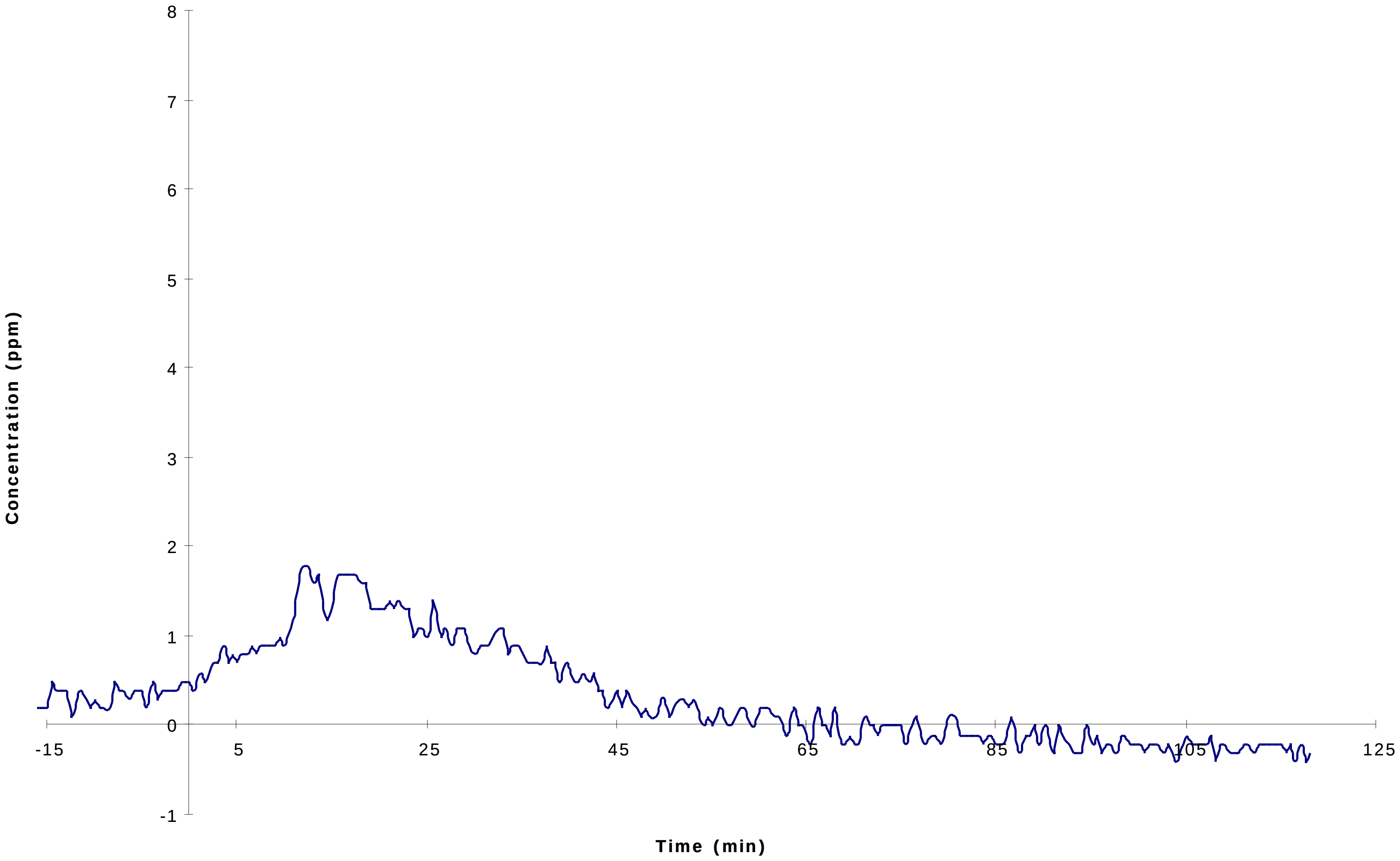

Figure 45. NO Concentration for Test No. 3 - Florida no Blower

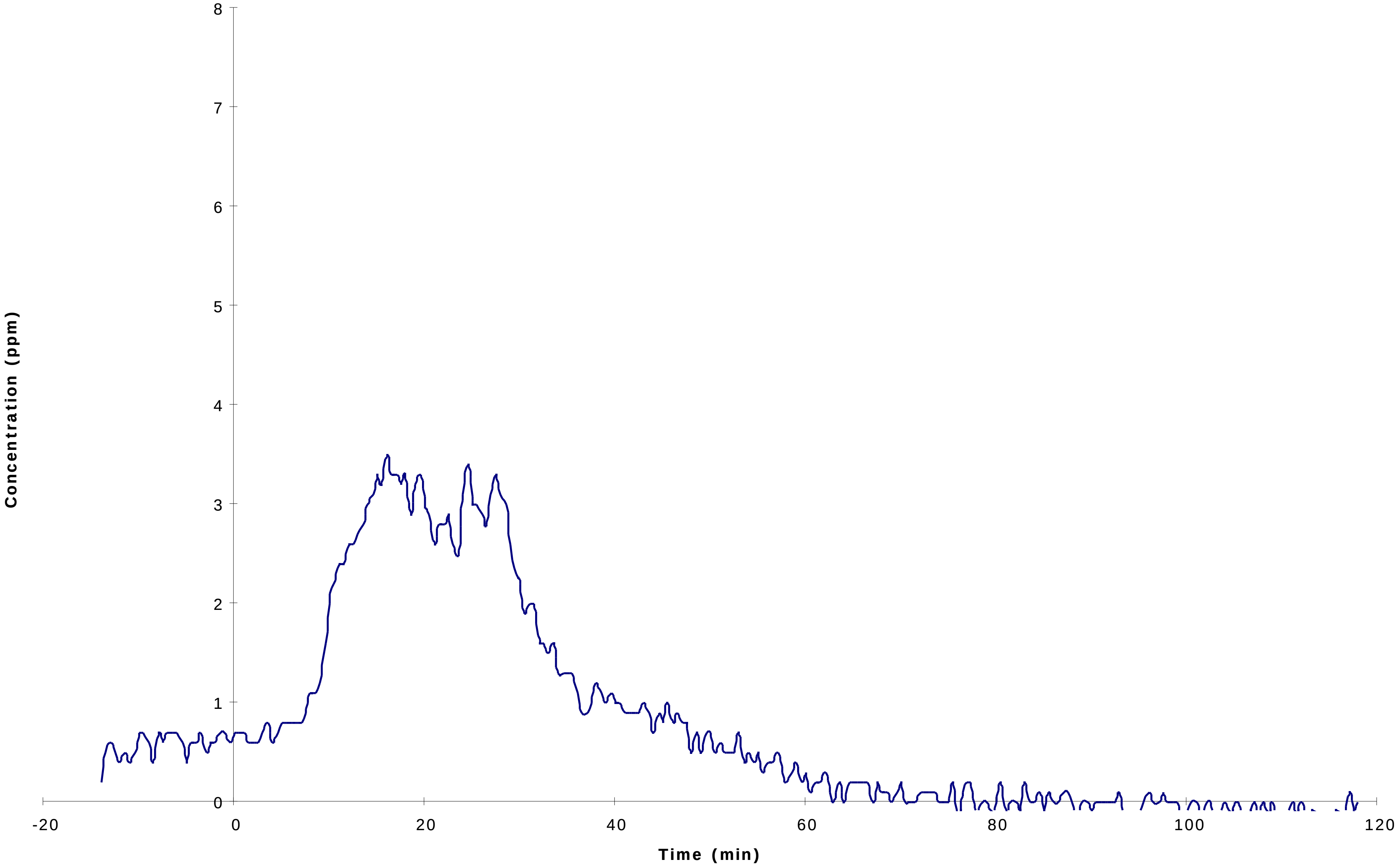

Figure 46. NO Concentration for Test No. 4 - Florida no Blower

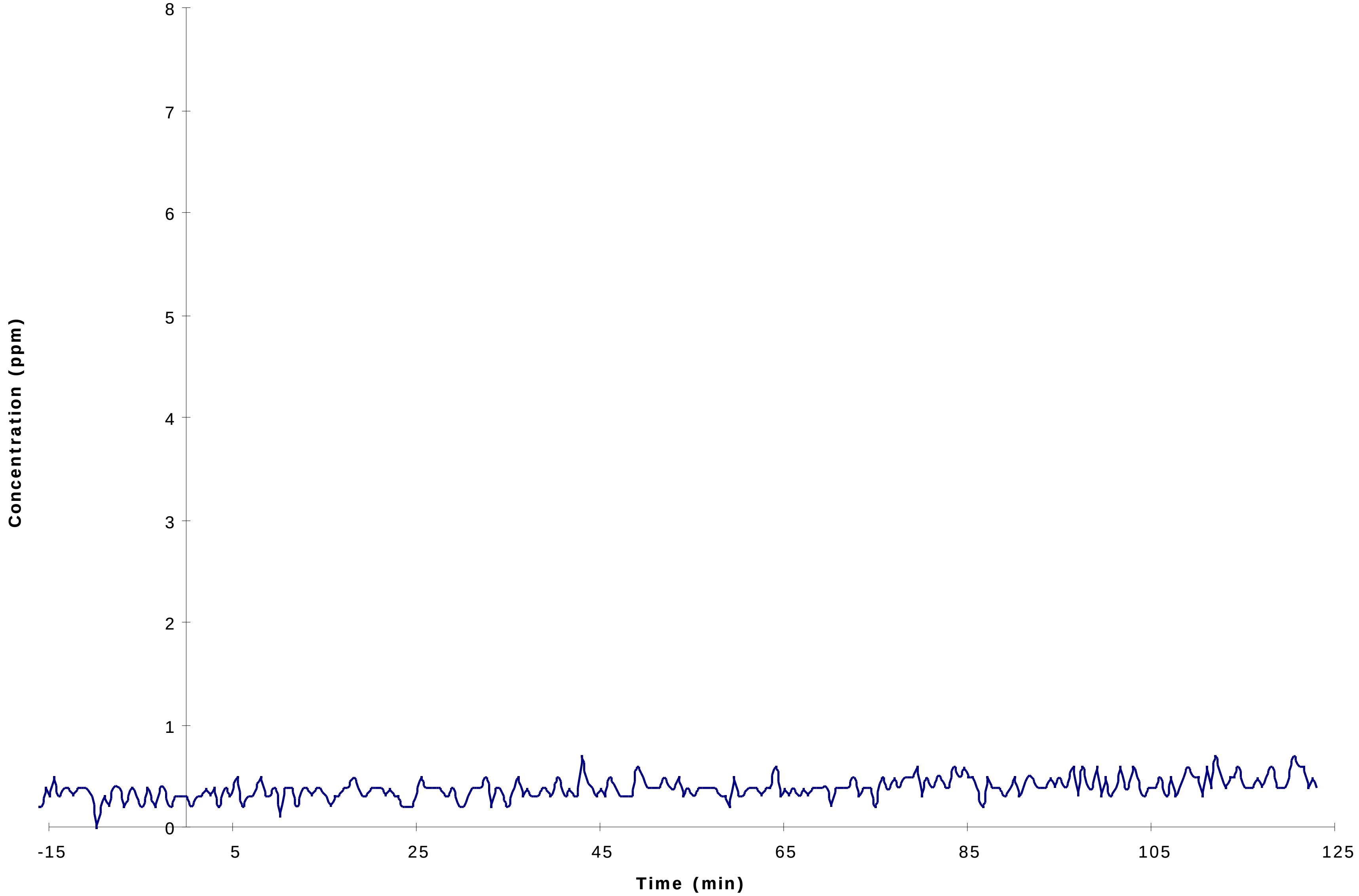

Figure 47. NO Concentration for Test No. 5 - Hut Blank

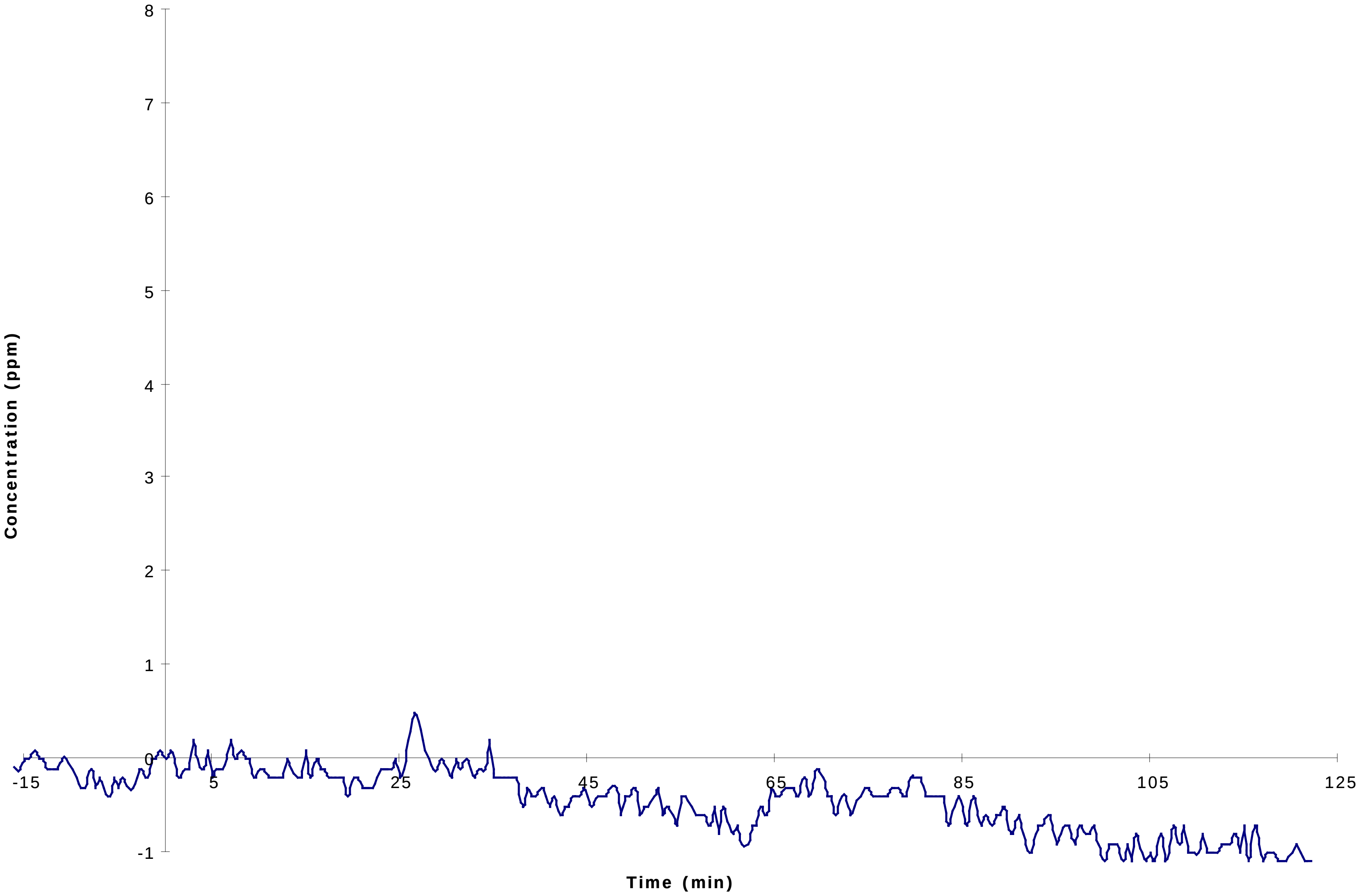

Figure 48. NO Concentration for Test No. 6 - Tenn with Blower

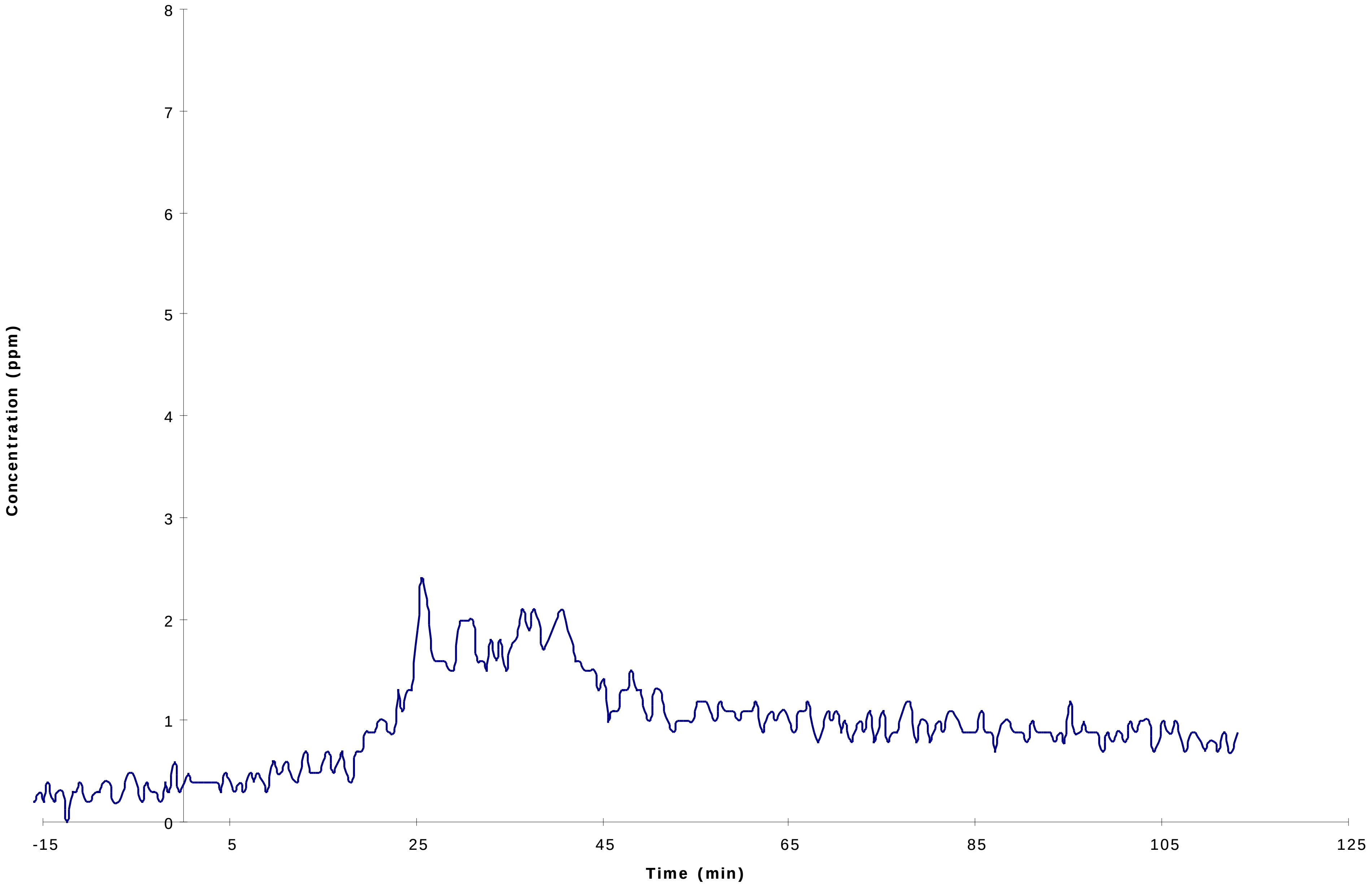

Figure 49. NO Concentration for Test No. 7 - Tenn with Blower

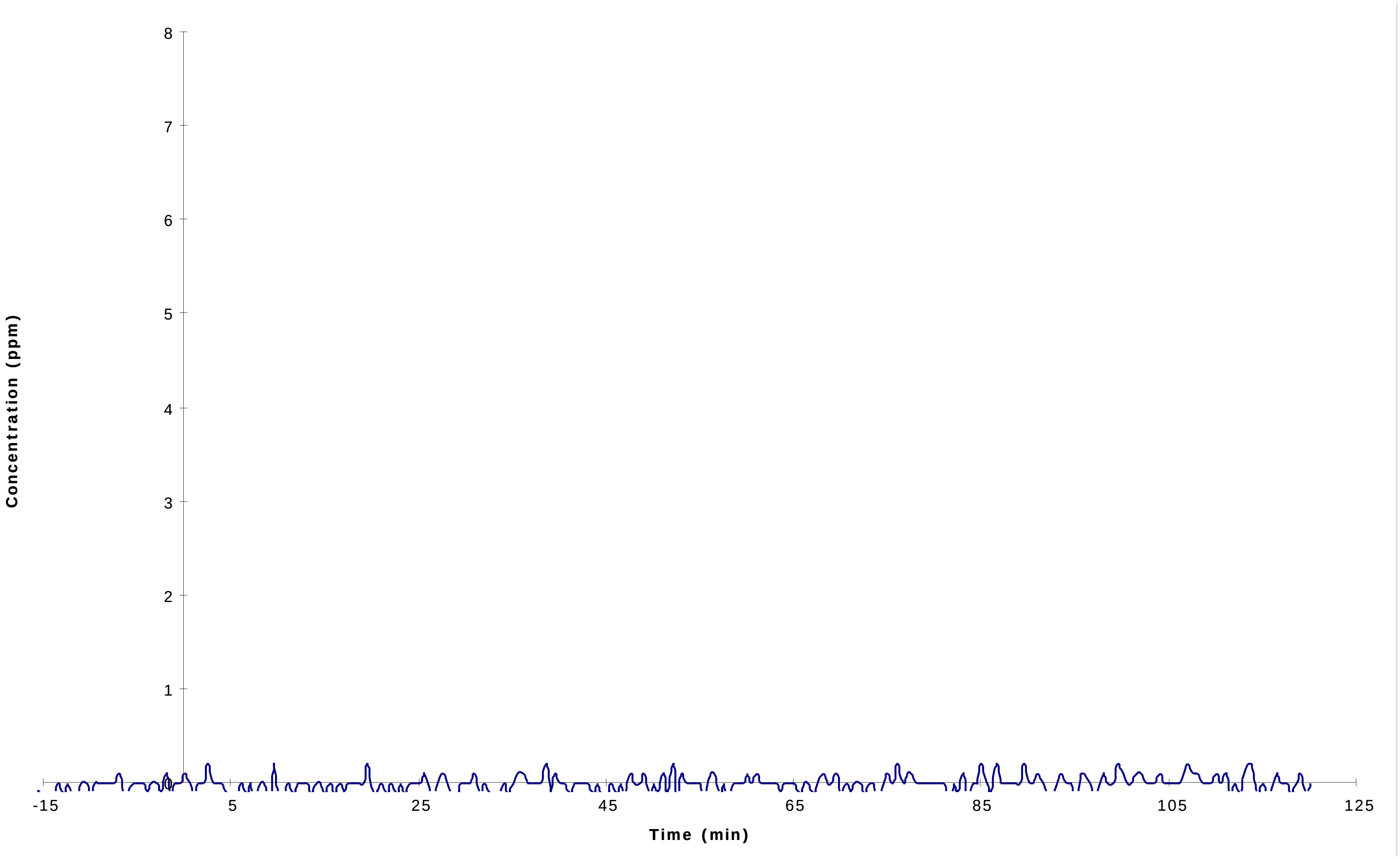

Figure 50. NO Concentration for Test No. 8 - Hut Blank 2

APPENDIX A

QUALITY CONTROL EVALUATION REPORT

This project was conducted under the guidance of an EPA-approved QA Test Plan (APPCD Category III) and an approved Facility Manual for the test facility. These documents establish data quality objectives suitable for this study. The quality control measures employed during this study were used to ensure that the data collected would be suitable to measure air emissions resulting from a debris open burning process.

Table A-1 presents the data quality indicator (DQI) summaries for accuracy, precision, and completeness achieved during testing along with the planned DQI goals for each measurement or analysis performed. In general, the intended DQI goals were achieved. In several instances, however, targeted DQI goals were not achieved or could not be assessed from the available data.

The achieved data quality for CEMs is summarized in Table A-1 and detailed in Tables A-2 and A-3. The CEM precision almost always passed the five percent of full scale criterion established. In several tests one of the multiple span gases checked failed, but was only slightly beyond the expected range. In two test/instrument (O_2 for test 7 and NO for test 1) combinations, the observed failures were so severe as to cast serious doubt on the usefulness of the data.

The observed accuracy was calculated based on a flow-through test of the entire sampling system and was compared to a five percent of full scale criterion. The analyzers passed this criterion in all instances. It should be noted, however, that the formulation of this criterion masks a significant negative bias (when viewed in terms of percent of measured value or actual concentration) for the upper part of the calibrated range, on the CO_2 analyzer. The measured values for CO_2 did not approach the upper part of the calibrated range however. A significant variability also exists (when viewed in terms of percent of measured value or actual concentration) in the performance of the NO analyzer.

The achieved data quality for volatile organic measurements is summarized in Table A-1 and detailed in Tables A-4 and A-5. Accuracy measurement based upon a laboratory prepared field control VOC canister which was taken into the field and returned for analysis is shown in Table A-4.

Acceptable accuracy was achieved for 56 of the 59 compounds tested. Recovery measurements for the volatile samples were acceptable in all instances (Table A-5). Data were not available to assess volatile organic analysis precision.

The achieved data quality for semivolatile samples is summarized in Table A-1 and detailed in Table A-6. The analytical staff failed to prepare matrix spike samples or spike surrogates (which would normally be done post sampling but before analysis). This limits the degree to which the data quality of these measurements can be evaluated. Recovery data for a presampling surrogate were available, however, and passed the criterion (18-120 percent) in five of seven instances. The two failures of this recovery surrogate were exceedances of the recovery criterion (135 and 173 percent). This would tend to indicate that reported concentrations and estimated emissions for semivolatile compounds in these two tests may be modestly overestimated.

The achieved data quality for particulate (dichotomous) sampler flowrate is summarized in Table A-1 and detailed in Table A-7. The accuracy of this flow rate easily met the 25 percent bias criterion in all but one of eight instances. In test 7 the flow rate was substantially inaccurate due to the melting of the sample line. Thus it is not surprising that the precision between replicate tests was well within criterion for three or four pairs of tests, but not acceptable for the Tennessee with blower pair which includes test 7.

The achieved data accuracy for the weight measurements is detailed in Table A-8. The high capacity scale (>1,000 lb) used is readable only to +/- 0.2 lb. It meets the stated 15 percent accuracy criterion over the vast majority of the range of interest for these tests (seven of eight masses tested). It is somewhat less accurate (25 percent), due to readability, for the lowest test weight used. However, in these tests the primary application of this device was to measure weight changes over the entire course of a test in which the mass change was between 11 and 20 kg (24 and 44 lb). An examaniation of Table A-8 will show that this scale would have measured the weight change quite adequately in this application. For instance, using the lightest and heaviest calibration weights reported as the hypothetical preburn and postburn weights would yield a measured weight change of 29.4 lb compared to a true weight change of 29.5 lb.

Although it is not a data quality objective, the close agreement noted in many places in the test to previous studies of combustion of similar wood based materials is a valuable crosscheck on overall data quality. In summary, the data quality objectives set forth have been adequately met in most cases, and the data collected from this study are sufficent to meet project objectives.

QA\QC requirements apply to this project. Data are supported by QA\QC documentation as required by the U.S. EPA's QA Policy.

TABLE A-1. DATA QUALITY INDICATOR SUMMARY FOR CRITICAL MEASUREMENTS

Measurement	Objective Accuracy (%) Bias	Objective Acccuracy as QA/QC Recovery (%)	Objective Precision %RPD	Objective Recovery (%)	Objective Completeness (%)	Achieved Accuracy (%) Bias	Achieved Accuracy as QA/QC Recovery (%)	Achieved Precision (%) RPD	Achieved Recovery (%)	Achieved Completeness (%)
O2	5	NA	5	NA	70	4	NA	-2.6	NA	88
CO2	5	NA	5	NA	70	1	NA	0.6	NA	100
CO	5	NA	5	NA	70	1	NA	1.2	NA	100
THC	5	NA	5	NA	70	1	NA	-0.2	NA	100
NO	5	NA	5	NA	70	1	NA	1.1	NA	88
Volatile Organic Analysis	NA	40-120	30	50-150	75	NA	SOT[1]	NM	SOT[2]	100
Semivolatile and Particulate Bound Organic Analysis	NA	40-120	30	18-120	70	NA	NM	NM	SOT[3]	100
Dichotomous Sampler Flow Rate	25	NA	25	NA	90	SOT[4]	NA	SOT[4]	NA	88
Weight	15	NA	15	NA	100	SOT[5]	NA	NM	NA	100

Note: SOT = See Other Table, NM = not measured, NA = not applicable

[1] See table A-4
[2] See table A-5.
[3] See table A-6.
[4] See table A-7.
[5] See table A-8.

TABLE A-2. CEM CALIBRATION PRECISION BASED ON % RPD BETWEEN PRE AND POST CALIBRATION

Test Number	Test Conditions	DATE	O_2	CO	CO_2	NO	THC
1	TN No Blower	1/31/95	3 / 0	2 / 1M	4 / 0	3 / 1H[1]	4 / 0
2	TN No Blower	2/1/95	3 / 0	3 / 0	4 / 0	4 / 0	4 / 0
3	FL No Blower	2/2/95	3 / 0	2 / 1H	4 / 0	3 / 1H	4 / 0
4	FL No Blower	2/3/95	3 / 0	3 / 0	4 / 0	4 / 0	4 / 0
5	Hut Blank	2/15/95	3 / 0	3 / 0	4 / 0	3 / 0	4 / 0
6	TN With Blower	2/22/95	2 / 1L	3 / 0	4 / 0	3 / 0	4 / 0
7	TN With Blower	2/23/95	0 / 3HML	3 / 0	4 / 0	3 / 0	4 / 0
8	Hut Blank	2/24/95	3 / 0	3 / 0	4 / 0	3 / 0	4 / 0

Note: # cals to pass / # cals to fail, QA test plan states a 5% of full scale precision requirement

L -- low span gas or zero failed on post calibration
M -- mid range span gas failed on post calibration
H -- high range span gas failed on post calibration

Table A-3. ACCURACY OF CEMs

Gas Used	Concentration	System Bias Result	% Difference of Full Scale
O2 (%)	17.3	17.9	3
	18.4	19.2	4
	19.9	20.7	4
CO (ppm)	0	0	0
	251	269	2
	510	518	1
NO (ppm)	0	0	0
	5	6.3	1
	10	8.3	-2
CO2 (%)	0	0	0
	0.46	0.42	0
	1	1	0
	1.56	1.2	-4
THC (ppm)	0	0	0
	31	34	0
	90	73	-2
	449	439	-1

Note: QA test plan states a 5% of full scale accuracy DQO.
% Difference is calculated off full scale.
These data based on a flow through check of sampling system.

TABLE A-2. CEM CALIBRATION PRECISION BASED ON % RPD BETWEEN PRE AND POST CALIBRATION

Test Number	Test Conditions	DATE	O_2	CO	CO_2	NO	THC
1	TN No Blower	1/31/95	3 / 0	2 / 1M	4 / 0	3 / 1H[1]	4 / 0
2	TN No Blower	2/1/95	3 / 0	3 / 0	4 / 0	4 / 0	4 / 0
3	FL No Blower	2/2/95	3 / 0	2 / 1H	4 / 0	3 / 1H	4 / 0
4	FL No Blower	2/3/95	3 / 0	3 / 0	4 / 0	4 / 0	4 / 0
5	Hut Blank	2/15/95	3 / 0	3 / 0	4 / 0	3 / 0	4 / 0
6	TN With Blower	2/22/95	2 / 1L	3 / 0	4 / 0	3 / 0	4 / 0
7	TN With Blower	2/23/95	0 / 3HML	3 / 0	4 / 0	3 / 0	4 / 0
8	Hut Blank	2/24/95	3 / 0	3 / 0	4 / 0	3 / 0	4 / 0

Note: # cals to pass / # cals to fail, QA test plan states a 5% of full scale precision requirement

L -- low span gas or zero failed on post calibration
M -- mid range span gas failed on post calibration
H -- high range span gas failed on post calibration

Table A-5. SURROGATE RECOVERIES FOR VOC CANISTERS

Compound	Field Control %	Test No. 1 %	Test No. 2 %	Test No. 3 %	Test No. 4 %	Test No. 5 %	Test No. 6 %	Test No. 7 %	Test No. 8 %	Field Blank %
bromochloromethane	110	90	101	96	95	90	87	85	86	100
d4-1,2-dichloroethane	99	91	97	94	93	95	88	96	91	98
1,4-difluorobenzene	101	97	100	97	97	96	95	91	92	97
d8-toluene	104	94	106	102	100	96	94	91	90	100
d5-chlorobenzene	102	99	105	102	99	98	97	92	89	99
4-bromofluorobenzene	97	98	107	100	95	93	99	95	97	94

Note: QA test plan states a 50-150% recovery criterion

TABLE A-6. RECOVERIES OF $^{13}C_{12}$ BENZO(ghi) PERYLENE PRE-SAMPLING SPIKE

Test Number	Test Conditions	Date	Amount Spiked (ng)	Amount Recovered (ng)	Amount Recovered (%)	Pass / Fail (P/F)
1	TN No Blower	1/31/95	NS	0.06	NA	NA
2	TN No Blower	2/1/95	10	5.55	55.5	P
3	FL No Blower	2/2/95	5	8.65	173	F
4	FL No Blower	2/3/95	5	5.58	111.6	P
5	Hut Blank	2/15/95	5	5.21	104.2	P
6	TN With Blower	2/22/95	5	6.75	135	F
7	TN With Blower	2/23/95	5	4.88	97.6	P
8	Hut Blank	2/24/95	5	4.98	99.6	P

Note: QA test plan states a 18-120% recovery criterion, NS = not spiked, NA = not applicable

TABLE A-7. PARTICULATE FLOWRATE DQIGs

Test Conditions	Date	Accuracy (%)	Precision (%)
TN No Blower	1/31/95	-3.9	0.1
TN No Blower	2/1/95	-4.0	
FL No Blower	2/2/95	-7.4	3.5
FL No Blower	2/3/95	-4.8	
Hut Blank	2/15/95	-0.8	
TN With Blower	2/22/95	-8.6	-84.3
TN With Blower	2/23/95	-48.5	
Hut Blank	2/24/95	-7.1	-3.3

TABLE A-8. WEIGHT ACCURACY CHECK		
Test Weight lbs	Observed Weight lbs	Bias (% of measured value)
1	0.8	25.00
3	2.8	7.14
6.1	5.6	8.93
6.6	6.6	0.00
7.4	7.2	2.78
11	11	0.00
17	16.8	1.19
30.5	30.2	0.99

Note: The QA Test Plan states a 15% bias DQ

TECHNICAL REPORT DATA
Please read Instructions on the reverse before completing)

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16. ABSTRACT

The report identifies and quantifies a broad range of pollutants that are discharged during small-scale, simulated, open combustion of land-clearing debris and reports these emissions relative to the mass of material combusted. Two types of land-clearing debris (representing the typical land-clearing debris found in Florida and Tennessee; primarily wood and other organic debris) were combusted in a facility designed to simulate open burning. One debris sample was also combusted in the same facility using a simulated air curtain incinerator. Volatile, semivolatile, and particulate-bound organics were collected and analyzed by gas chromatography/mass spectrometry. The emphasis of analyses was on the quantification of hazardous air pollutants listed in Title III of the Clean Air Act Amendments of 1990, although further efforts were made to identify and quantify other major organic components. Fixed combustion gases (carbon dioxide, carbon monoxide, nitric oxide, oxygen, and total hydrocarbons) were monitored continuously throughout the test period. The project produced estimated emissions data for a broad range of atmospheric pollutants from a simulated open debris combustion process. Tests did not provide conclusive evidence of the effectiveness of air curtain combustors in reducing emissions: some emissions decreased, others were unchanged, still others seemed to increase.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Incinerators	Pollution Prevention	13B
Combustion		Stationary Sources	21B
Land		Open Burning	05C
Emission		Land Clearing	14G
Wood		Debris	11L
Organic Compounds	Air Curtains	Hazardous Air Pollutants (HAPs)	07C
			13M

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