G E N E R A L   E L E C T R I C

NELA PARK

Cleveland, Ohio 44112

LIGHTING RESEARCH AND TECHNICAL SERVICES OPERATION

INSTALLATION OF A PROTOTYPE MEMBRANE OXYGEN ENRICHER IN THE LEXINGTON LAMP PLANT

R. A. Felice and I. E. Halt

November 11, 1977 Class ~~3~~ 1

November 11, 1977

INSTALLATION OF A PROTOTYPE MEMBRANE OXYGEN ENRICHER IN THE LEXINGTON LAMP PLANT

Abstract

The Membrane Oxygen Enricher is an on site device for the generation of 35% oxygen enriched air. A prototype unit has been installed in the Lexington Lamp Plant, and has performed satisfactorily over the first three months of operation. Fuel consumption has been reduced on the affected equipment by 42%.

LIGHTING RESEARCH AND TECHNICAL SERVICES OPERATION
Energy and Control Systems Laboratory

R. A. Felice

MINIATURE LAMP DEPARTMENT
Advance Engineering

I. E. Halt

Classification of Report 3

To be listed in TIS (Only if Class 1 or 2) Yes ____ No ✓

Managers' Approval [signature] [signature]

Date 11/14/77 11/14/77

Introduction

It is known that combustion processes utilizing pure oxygen or oxygen enriched air exhibit higher flame temperatures and burning velocities than those using ambient air. For a fixed industrial process where a given temperature is to be reached, the corollary is that a lesser amount of fuel is necessary if that fuel is burned with enriched air. Figure 1 is a graph of the savings available when utilizing oxygen enriched combustion air[1] in small burner applications.

One of the reasons that this method of energy savings has not been widely implemented in the past is that oxygen is approximately twice as expensive as natural gas. Another is the necessity of resupply. Since burners are usually not suitable for both atmospheric and enriched air, the source of oxygen must be extremely reliable, or a large holding capacity must be installed.

One method of potentially removing the above objections to oxygen enrichment would be the installation of an oxygen producer on site. A prototype unit, the Membrane Oxygen Enricher, jointly developed by CRD and LRTSO, was installed in the Lexington Lamp Plant in February of this year.

Membrane Oxygen Enricher

The Membrane[2] Oxygen Enricher (MOE), a schematic of which is shown in Figure 2, is a device designed to produce enriched air with an oxygen concentration of 35%. It consists of three basic systems: 1) a feed system, 2) an enrichment system, and 3) a control system. Their makeup is as follows:

The feed system, which supplies ambient feedstock air to the enricher, is composed of filters and blowers. The blowers draw air through a series of coarse and fine filters, across the membrane separators, and finally expel the detritus back to atmosphere. The capacity of this system is 1800 CFM of air filtered to exclude 80% of the particles one micron or larger.

The enrichment system is composed of these membranes and the vacuum pump. A trans-membrane pressure differential (supplied by the pump) is the driving force to allow both nitrogen and oxygen to diffuse through the membrane. The membrane has a relative permeability of O_2/N_2 of approximately 2. Thus the pump exhaust is enriched. The enrichment fraction is a function of the trans-membrane pressure, the relative permeability, and the oxygen content of the feedstock. All three of these parameters are in turn functions of ambient temperature, pressure, and humidity.

The control system consists of all those items needed to make the pump exhaust amenable to a combustion process. A relieving regulator supplies constant pressure, a cooler/condenser (drier) removes excess humidity, and a dopant circuit provides constant oxygen content in the face of varying atmospheric conditions.

The prototype unit is shown in Figure 3 as it is installed in the Lexington Lamp Plant. The output of this unit is 3000 CFH of enriched air. In this configuration, the MOE requires 140 square feet of floor space.

Phases of Oxygen Enrichment

The changeover from conventional to MOE operation was accomplished in three phases. Phase one consisted of conventional operation of the selected equipment for the accumulation of comparison data. Phase two involved the installation and operation of a commercial oxygen circuit, using bottled oxygen, as a test of feasibility. Phase three entailed both the installation and operation of the MOE.

Conventional Operation, Phase One

The equipment chosen for enriched air operation was a cover preheat machine (CPM) for PAR46 sealed beam automotive headlamps. The function of this machine is to preheat the lens and the seal area of the reflector to prevent thermal shock when the lens/reflector group enters the intense heat of the sealing machine. There are two groups of burners on the CPM, designated overhead and side burners.

The first phase of the enrichment procedure was to obtain control data. Parameters measured were rate of fuel use, and heat content and temperature distribution of the finished workpiece. In addition to the above, historical shrinkage data is available.

Commercial Oxygen Circuit, Phase Two

The next step was to install commercial oxygen mixing equipment to ascertain whether or not enriched air would provide for suitable operation of the CPM. An enrichment figure of 35% oxygen had previously been decided upon on the basis of both membrane considerations and potential fuel savings. Totally new burners were necessitated by this high enrichment figure.

Mixers

A dual system of venturi mixers in series was necessary to feed the overhead and side burners (see Figure 4). A description of one-half of the system will suffice, since both halves are identical except for flow rates. The entraining gas is compressed air at 4 psig. The air is controlled by a valve and measured volumetrically by a rotameter before entering the first venturi mixer. The aspirated gas at this mixer is oxygen, controlled at atmospheric pressure by a balanced zero regulator. Exiting gas, now 35% oxygen, enters a second venturi and entrains natural gas in a stoichiometric mixture. The natural gas is supplied through a valve and rotameter. The exiting gas of the second venturi is applied to a set of burners after passing a safety pressure relief diaphragm.

Burners

Since neither gas-air nor gas-oxygen burners could be found that worked well with 35% oxygen enriched air, new designs were mandatory. The higher flame propagation rate using enriched air led to the suggestion to use smaller than normal burners to increase the velocity of the gas mixture, thus balancing the flame speed.

For the overhead burners, Carlisle 204 cast iron ribbon burners were chosen to begin with because they were physically the correct size and their cost reasonable. By plugging all the main burner holes with piano wire and forcing most of the gas mixture through the pilot holes, a useful flame both for shape and thruput was developed. Some piloting was obtained from gas leakage through the corrugated burner face.

Early in the project it was thought that AGF 3141 brass burners could be used for the side burners but the brass would not have been able to withstand the hot environment. Taking as a model the simple jet burners used in PAR sealing, a burner with the appropriate jet area to give the needed flame size and thruput was selected that performed well. These jet burners are made of cold drawn mechanical tubing, typically about 4" long, inside diameter of .187", and the outside diameter .375".

Initial adjustment of flow rates in this new configuration was accomplished by matching the heat content of the workpiece to that value exhibited in the control data.

Results and Benefits of Commercial Oxygen

The commercial oxygen circuit was operated for five full months, September '76 - January '77. In that time, a 41% fuel reduction was observed. Shrinkage levels were slightly lower than those for the two months immediately preceding the test. The physical environment of the CPM was cooler and thus more comfortable for those working nearby.

From the third week of January to the first week of March the CPM was operated on a propane-air fuel mix. By the second week of February, burner deterioration was a serious problem. Flashbacks were commonplace and during operation several of the Carlisle ribbon burners were observed to glow red. The affected burners were found to warp in this environment, and it was surmised that this caused the flashback phenomena. In an attempt to increase the delivery pressure to the Carlisle (overhead) burners, and to lengthen their flame cone, four of twenty burners were removed. Unfortunately, this coincided with the delivery and installation of the MOE. Hence, shrinkage figures from the above mentioned change in the system to the present are not suitable for comparison with those prior to the change.

Notwithstanding the above problem, rooted in the difficulty in matching the heat delivery characteristics of propane to those of natural gas, the feasibility of using oxygen enriched air was proved from the standpoint of both fuel savings and process consideration.

Installation of MOE, Phase Three

The MOE was transported to Lexington from Cleveland, where it had been undergoing final systems interfacing and testing for the five months of the commercial oxygen phase, on February 4-7. On arrival, the MOE was reassembled on the manufacturing floor in an area that had previously been used for casual storage. Care was taken to pick a location with good ventilation, thereby insuring adequate feedstock for the process.

The services necessary for operation were supplied. These include 440 VAC, 3 ϕ, 100 ampere electrical power, 18 gallons per minute of cooling/sealing water, compressed air at 21 psi, and oxygen at 30 psi. A 2" PVC drain to the water recirculating system carried away the used sealing water. The process line was also 2" PVC, installed overhead. The length of the run is approximately 150 feet. A 1/4" copper line monitors the far downstream pressure for use at the MOE.

To interface the enricher at the CPM, three-way valves were installed between the venturi mixers in each burner circuit. This insured the production capability of the CPM in the event of MOE failure.

The MOE had been designed to produce 35% enriched air. However, due to the manner in which this design was implemented, the output could be easily varied from 30-38%. This is accomplished by varying the set point of a 3-mode controller which governs the injection of pure oxygen through a dopant valve. Measurement of oxygen concentration on the commercial circuit prior to changeover to the MOE indicated that 33% enrichment was adequate for the process. Consequently, the MOE output was adjusted to supply 33% enrichment.

To prevent flashback at ignition, a three-way valve was installed just upstream of the branching for each burner circuit. The vent leg of this valve is supplied with a variable constriction which is adjusted to apply the same flow resistance as the two circuits in parallel. The MOE is started with this valve in the vent mode. This allows the MOE to achieve steady state operation before ignition, which is achieved by cycling the three-way valve to apply air to the burner circuits after a diffusion flame has been lit.

Results

With the system installed as described above, changeover from the commercial oxygen circuit was straightforward. For the first 3 months after installation, the CPM averaged a 42% reduction in fuel usage. The change in this figure reflects adjustments made to keep process parameters within certain limits. During this quarter, the MOE logged approximately 900 hours, with two minor hardware problems, both quickly repairable on site. MOE performance for the period August '76 - June '77 is graphed as oxygen concentration vs. time in Figure 5. Oxygen concentration is here defined as the volume percent oxygen produced with the dopant circuit off.

Acknowledgments

We wish to acknowledge the cooperation of the personnel of the Lexington Lamp Plant, and in particular William Anderkin, A. C. Bayer, and Leon Waters. We would also like to acknowledge the support of W. R. Browall of the Fluid Conversion Unit, CRD.

Included in this report are five figures.

LIGHTING RESEARCH AND TECHNICAL
SERVICES OPERATION
Energy and Control Systems Laboratory

SIGNATURE WITNESSED

Sue Vincelli 11-18-77

Ralph A. Felice

R. A. Felice 11/18/77

MINIATURE LAMP DEPARTMENT
Advance Engineering

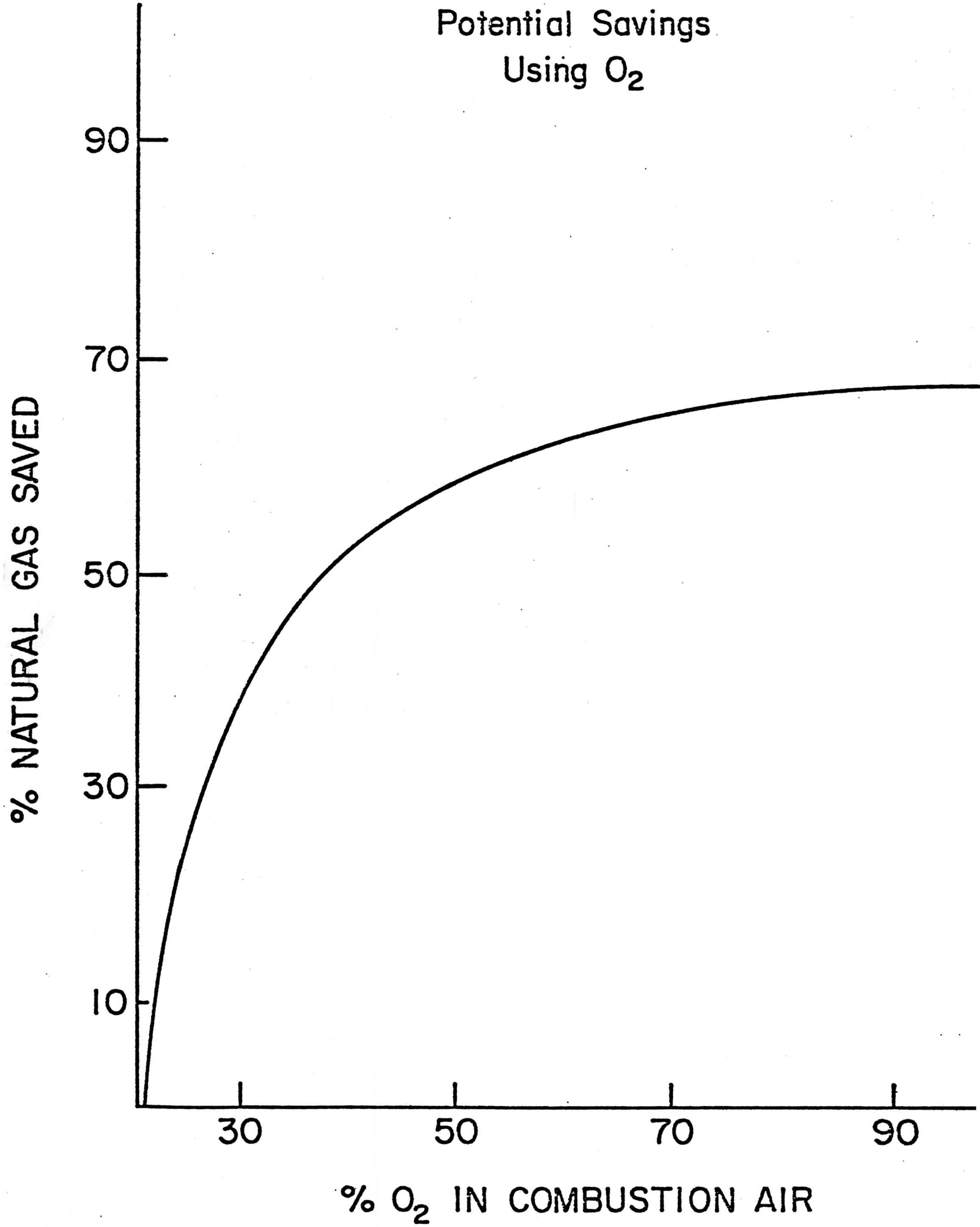
SIGNATURE WITNESSED

Sue Vincelli 11-21-77

Ira E. Halt

I. E. Halt 11/21/77

RAF/IEH/ss



Potential Savings
Using O_2
90
70
50
30
10
% NATURAL GAS SAVED
30
50
70
90
% O_2 IN COMBUSTION AIR

Figure 1.

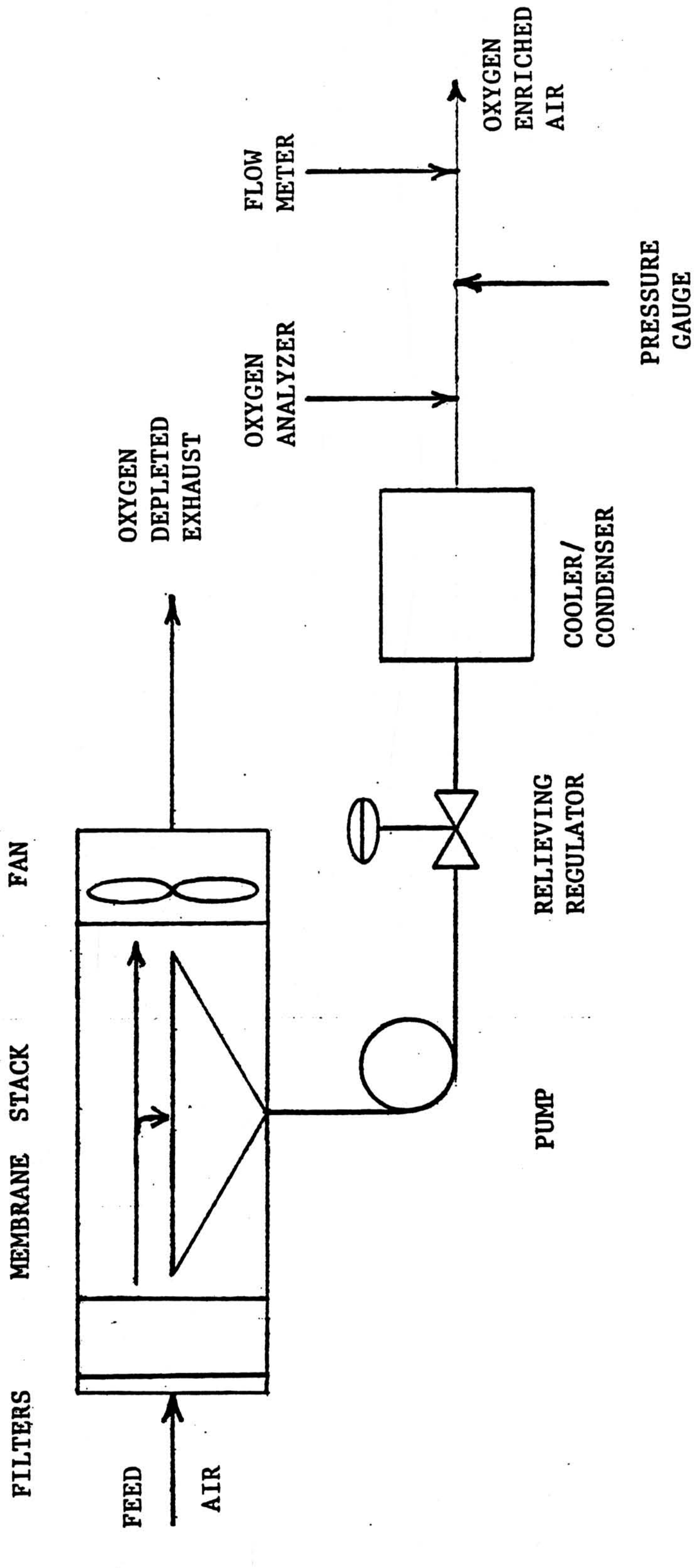
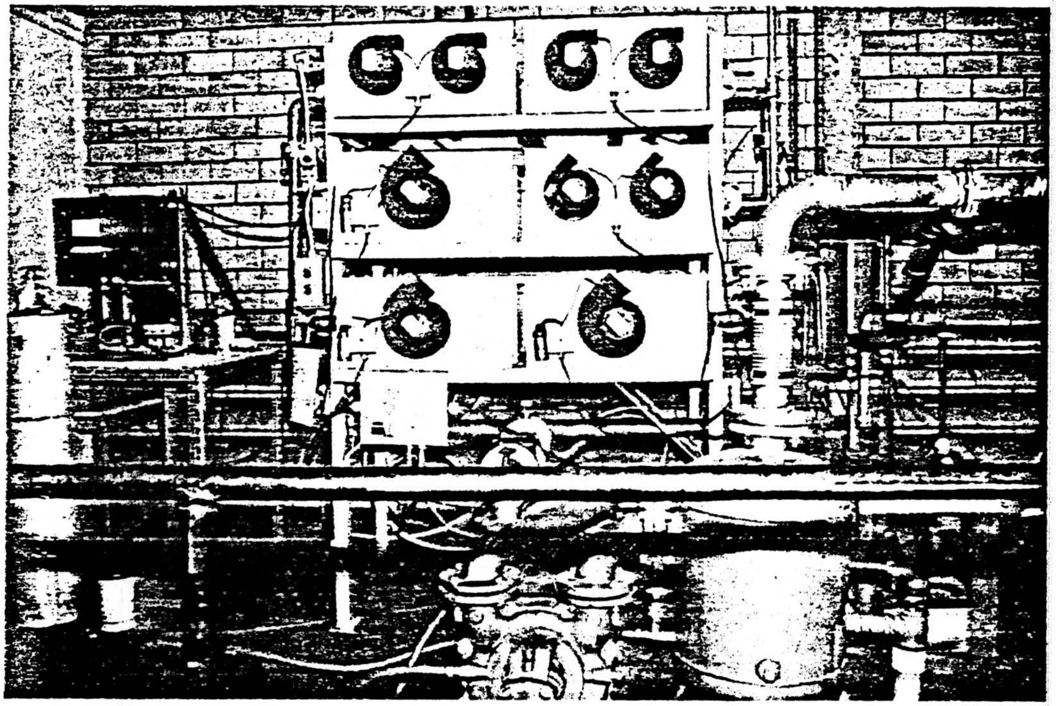

FEED AIR
FILTERS
MEMBRANE STACK
FAN
OXYGEN DEPLETED EXHAUST
PUMP
RELIEVING REGULATOR
COOLER/ CONDENSER
OXYGEN ANALYZER
PRESSURE GAUGE
FLOW METER
OXYGEN ENRICHED AIR

Figure 2.

Membrane Oxygen Enricher, Front View



Oblique View

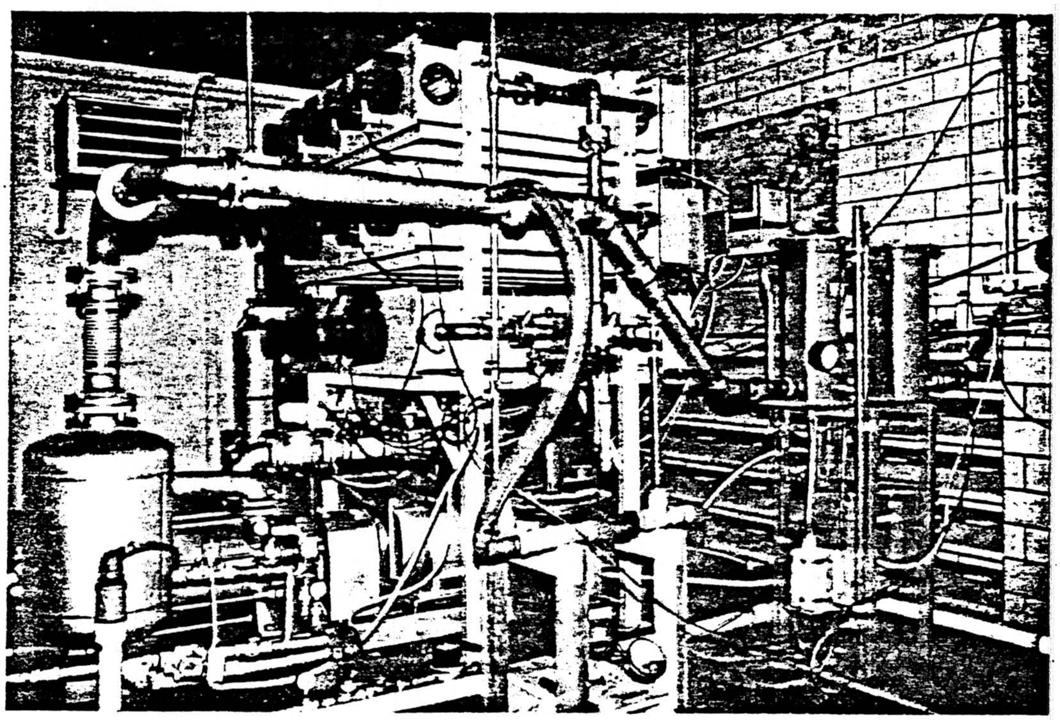


Figure 3.

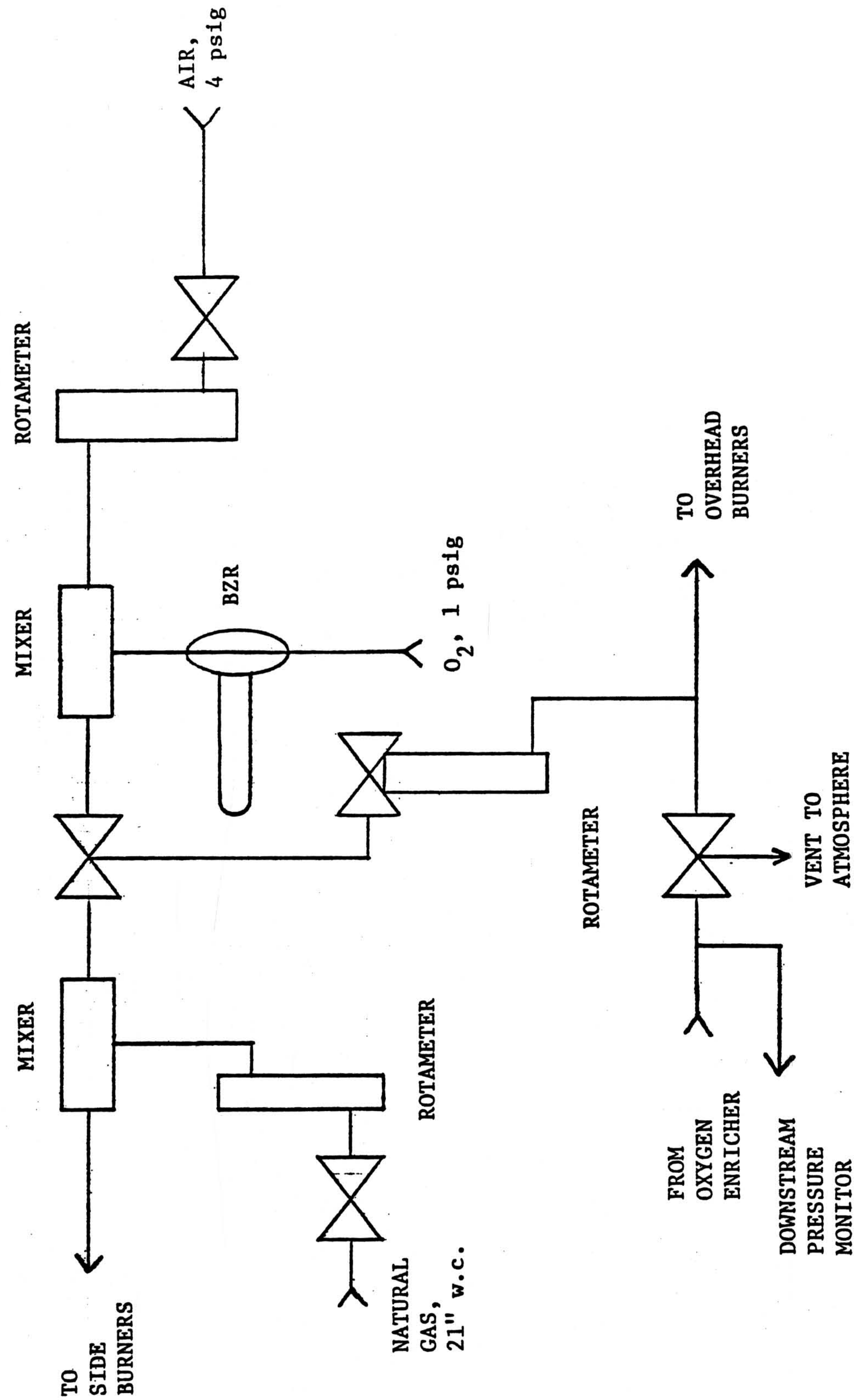
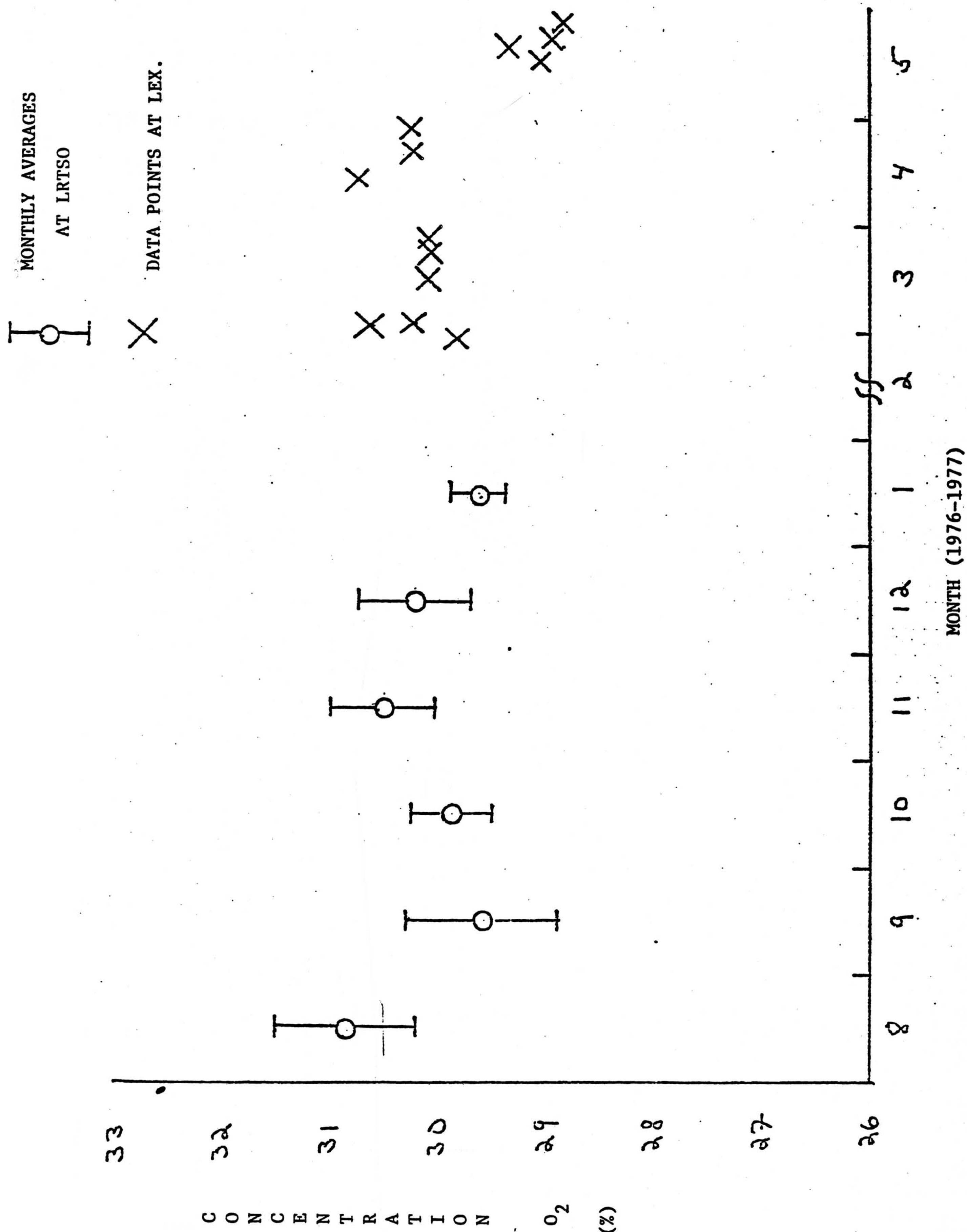

AIR,
4 psig
ROTAMETER
MIXER
BZR
O_2, 1 psig
TO
OVERHEAD
BURNERS
ROTAMETER
VENT TO
ATMOSPHERE
MIXER
ROTAMETER
FROM
OXYGEN
ENRICHER
DOWNSTREAM
PRESSURE
MONITOR
TO
SIDE
BURNERS
NATURAL
GAS,
21" w.c.

Figure 4.

Figure 5.


MONTHLY AVERAGES
AT LRTSO
DATA POINTS AT LEX.
MONTH (1976-1977)
8
9
10
11
12
1
2
3
4
5
33
32
31
30
29
28
27
26
CONCENTRATION O_2 (%)

References

1. S. G. Kimura, J. E. Breen and W. J. Ward, III, General Electric TIS Report 75CRD116.

2. W. R. Browall and S. G. Kimura, General Electric TIS Report 74CRD263.