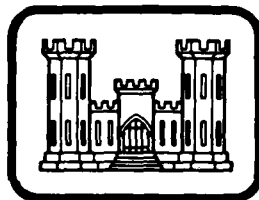


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FESA-T-2107

Review of "Vapormid" Catalytic Vapor Device

NUS Corporation  
4 Research Place  
Rockville, Maryland 20850

September, 1981

DEC 10 1981

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Final Report

Approved for Public Release, Distribution Unlimited

Prepared for:  
US Army Facilities Engineering Support Agency  
Technology Support Division  
Fort Belvoir, VA 22060

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Commander and Director  
US Army Facilities Engineering Support Agency  
Fort Belvoir, Virginia 22060

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CATALYTIC VAPOR DEVICE  
NUS Project No. 5397  
Prepared Under  
Contract No. DACA 31-80-D-0019  
Task Order A00002

Prepared for  
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Fort Belvoir, Virginia 22060

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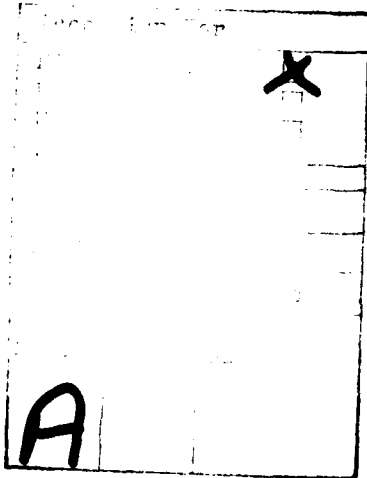
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independent organizations over the period of 1975 to 1980 yielded insufficient evidence to support these claims. Where an improvement in efficiency was noted, the reports tended to indicate that it was derived from fine tuning and adjustments performed on the burner system and not from the addition of the Vapormid.



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REVIEW OF "VAPORMID" CATALYTIC VAPOR DEVICE

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## 1.0 INTRODUCTION

This report is in response to Contract No. DACA 31-80-D-0019, Task Order A00002 with the U. S. Department of the Army, Baltimore District Corps of Engineers, Facilities Engineering Support Agency. This study is intended to cover Phase I of the work entitled "Technical and Economic Evaluation of Specific Vapor Device and Water and Water/Catalyst Systems" as a fuel oil additive to improve combustion and reduce sooting in boilers.

## 2.0 OBJECTIVES

The objective of Phase I is to evaluate the effectiveness of a catalytic vapor device sold under the trade name of Vapormid. The evaluation is to be done by means of a review of existing literature and test data and an analysis of the catalytic vapor device for technical merit, cost effectiveness, and potential applications.

## 3.0 SUMMARY OF FINDINGS

No credible evidence was found to indicate that the Vapormid is capable of producing significant energy savings by improvement of boiler operating efficiency. There is some indication that the device might be capable of reducing sooting of the boiler convection surface through increased combustion zone temperatures, which could lead to a long term efficiency gain and/or a reduction in cleaning costs. The cost effectiveness of this possibility is marginal on a generic basis. If the temperature increase can be proven through further testing to indeed exist, the cost effectiveness of the device would have to be re-evaluated on a case-by-case basis.

Based upon present knowledge however, NUS does not recommend further consideration of the device by the Department of the Army.

#### 4.0 DESCRIPTION OF CATALYTIC VAPOR DEVICE

The Vapormid is a device presently marketed by Conservation Technology International of Portsmouth, New Hampshire, the successor to Vaporpak, Inc., the original marketer. It is advertised by CTI as an energy conservation system which acts as a controlled bubble chamber to produce an ionized gas, and is sold in at least six sizes. It is physically a four-sided pyramidal device made of plastic which is connected across the boiler's forced draft fan by means of two plastic tubes. (A sketch of a typical application diagram, taken from the manufacturer's literature is shown in Figure 4.1). A portion of the combustion air, under the differential supplied by the forced draft fan, bubbles through distilled water in the bottom of the pyramid and then through a "non-miscible oil" catalyst floating on top of the water. Bubbling rate is controlled by the depth of insertion of the inlet tube into the water (and the subsequent static head of the water) and throttling valves located on the inlet and outlet tubes. According to the manufacturer's literature, the bursting bubbles formed as the air bubbles through the catalyst introduce an ionized gas into the combustion air stream which has the property of enhancing combustion of any fossil fuel, thereby increasing thermal efficiency, saving fuel, promoting cleaner burning flames with less inherent sooting and fouling of boiler heat transfer surfaces, reducing maintenance and downtime, and reducing stack emissions.

The water in the chamber is not introduced into the combustion process in any significant amount, as very infrequent refill or "topping" of the chamber is required. Similarly, the catalyst itself is apparently not used at a significant rate, since no mention is made in any of the literature obtained as to any

need to replace or refill it. According to the manufacturer, the water is used only to control and monitor the bubble rate, while the catalyst itself acts to create negative ions which are entrained by the combustion air and enter into the combustion process.

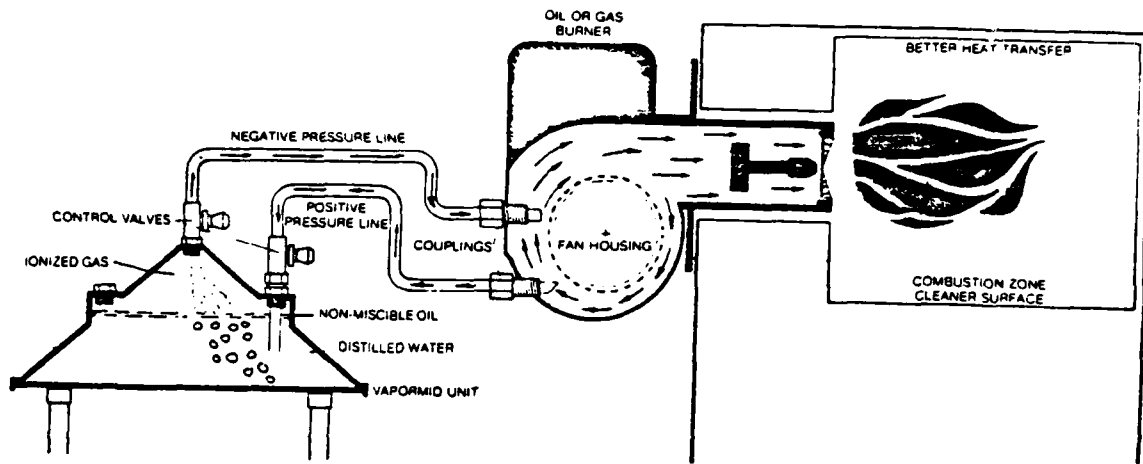


FIGURE 4.1 - VAPORMID CONVENTIONAL APPLICATION DIAGRAM

5.0 LITERATURE REVIEW

5.1 Listing of Test Reports Reviewed

The literature reviewed for the Phase I study included the following reports. Each of these reports is discussed more fully in Sections 5.2.1 through 5.2.8.

Report No. 1 (Reference Section 5.2.1)  
Vaporpak Test Report by General Measurements Company, Salem, New Hampshire, dated August 1975

This test report describes testing done in a specially constructed "weather house" using an oil-fired hot water domestic heating boiler, both with and without the Vapormid. The report includes extensive data and descriptions of test setups, test site determination and test period selection.

Report No. 2 (Reference Section 5.2.2)  
Vapormid System Fuel Efficiency Test for Vaporpak, Inc. by Associated Testing Laboratories, Inc., Clifton, New Jersey, dated August 1976

The test utilized a standard oil burner and a laboratory test furnace which was instrumented with thermometers and thermocouples for the measurement of water and gas temperatures. Measurements were made both with and without the Vapormid installed.

Report No. 3 (Reference Section 5.2.3)  
Report on Bubble Chamber Ion Generator Experiments by WEGOA Systems, Inc., Grand Rapids, Michigan, dated November 1979 to September 1980

These tests were run over a period of November 1979 to September 1980, and describe the "laboratory investigation of combustion changes, occurring when negative ions are supplied by means of a

bubble chamber ion generator connected to the combustion air supply."

Report No. 4 (Reference Section 5.2.4)  
Reports No. 772028 and 772415 for 21st Century Enterprises, Inc.,  
by Penniman and Browne, Inc., Baltimore, Maryland, dated  
January 1978

This is a report of a test run on a heating boiler at a Howard Johnson Motel in Baltimore and includes a summary of data taken over a period of about 2 1/2 months.

Report No. 5 (Reference Section 5.2.5)  
Performance Testing of "Vapormid Fossil Fuel Catalyzer" for  
Canadian Broadcasting Company; Report of Investigation Number  
ENG. 77-36381 by Ontario Research Foundation, Ontario Canada,  
dated October 1977

In this test series, a domestic oil-fired furnace was tested in ORF's Domestic Furnace Research Laboratory, both with and without the Vapormid device. The report contains equipment specifications, descriptions of test procedures used, and a summary of results and conclusions.

Report No. 6 (Reference Section 5.2.6)  
Engineering Evaluation of the Vapormid Fossil Fuel Catalyzer,  
by Peabody Gordon-Piatt, Winfield, Kansas, dated October 1977

This is a summary of a test program performed by Peabody Gordon-Piatt as prepared by the test engineer. It includes test data, a list of materials and instruments used, sketches of the test setup, and the test engineer's description and comments on the test program, including a day-to-day log of the testing.

Report No. 7 (Reference Section 5.2.7)

Efficiency Test Report for: Vapormid H-800 by Brookhaven National Laboratory, Upton, New York, dated November 1978

This report summarizes testing performed by Brookhaven National Laboratory to investigate the Vapormid manufacturer's claim of increased combustion process efficiency on a residential type oil-fired vertical firetube boiler. The results of this test were used by Brookhaven to calculate the annual fuel use by means of procedures detailed in BNL's Annual Fuel Use and Efficiency Reference Manual.

Report No. 8 (Reference Section 5.2.8)

Energy Alliance letter and internal memorandum summarizing testing performed by Baltimore Gas and Electric Company, Baltimore, Maryland, dated April, 1978.

Summary of test work performed by BG&E on Vapormid and Energy-Pak devices. These tests were run on natural gas only. BG&E has never issued a formal report on this test work, with the exception of the summary presented in this newsletter and an accompanying internally circulated position paper. (Energy Alliance is a newsletter published by the Energy Services Division of BG&E).

In addition to the test literature and reports outlined above, NUS reviewed approximately 25 testimonial letters from users of the Vapormid device in various areas of the country (principally New England and Maryland areas).

5.2        Summary and Evaluation of Test Reports

5.2.1     Summary and Evaluation of Report No. 1

Ref:       Vaporpak Test Report by General Measurements Company

Tests were performed on an Arcoliner brand oil fired, domestic hot water heating boiler, with and without a Vapormid attached. Measurements were made of fuel consumption, stack gas analysis, smoke numbers, furnace temperatures, and dew point temperatures over two periods of 100 hours each of nearly identical weather conditions. The furnace was tuned to factory specifications before the first test run, without Vapormid, and data collected to be used as a baseline.

The Vapormid was then installed by manufacturer's representatives, and over a week was spent in adjusting and tuning the Vapormid/burner combination. Of the adjustments performed, the only one detailed in the report was the addition of a restrictor plate over the air intake of the furnace. This restrictor had the effect of reducing the excess air present in the combustion zone with the accompanying increased efficiency of combustion and temperature in the combustion chamber. The second test period was begun and data was recorded for another 100 hours. Comparisons of the test data accumulated in the two runs showed that 29.7% less fuel was consumed in the second test period, with Vapormid in service. In addition, CO<sub>2</sub> readings increased by an average of about 1.2%, O<sub>2</sub> decreased about 2.2%, and CO was lowered or undetectable. Combustion zone temperatures were increased an average of about 200F, and flue gas outlet temperatures were decreased by an average of about 50F. NO<sub>x</sub> was also monitored, and showed a substantial decrease.

### NUS COMMENTS

The reduction of excess air due to the brass restrictor plate in the combustion air inlet appears to be the main reason for the increase in efficiency. The report references one short test run of about 15 minutes in which this plate was removed, with Vapormid operating, and as would be expected, flue gas temperature climbed and combustion chamber temperature dropped. No mention is made of any effort to attempt an air restriction of this type without the Vapormid in service, to see whether or not a similar reduction in excess air would have resulted with acceptable furnace and stack conditions.

It is also stressed in the report that the Vapormid service representative performed extensive tuning and testing in conjunction with the Vapormid installation. There is no indication that an attempt was made to fine tune the burner without the Vapormid installed beyond its manufacturer's rating of 8.5% CO<sub>2</sub>. It is very likely that improvements could have been made over the baseline operation of the furnace if such extensive tuning had been attempted.

The report contains numerous errors, misrepresentations, and inconsistencies. Any one or even several of these by themselves would be considered insignificant. Taken together in the numbers in which they occur however, they create a strong impression that the authors are completely unfamiliar with either combustion testing or technical report writing. Some examples are cited below.

- o No concise summary of results is presented at any point in the report. It is necessary to sort through approximately 100 pages of assorted data and text to piece together the results. Raw data, in the form of photocopied strip charts (mostly illegible in the reviewed copy) are included in the body of the report, constituting at least twenty pages of

distractions. This data could, and should, be summarized in a concise table or graph in the body and either deleted in its raw form or included in an appendix. In addition there is no numbering system applied to the pages or sections of the report, making it extremely difficult to reference or find particular sections.

- o Little understanding is shown of flue gas testing and instrumentation. The fact that "Fyrite" tubes were even considered as a test instrument is indicative of this. These tubes are intended to be used by plant personnel as a "quick and dirty" indicator of stack conditions, and are by no means suitable for use in a test such as this.

Use of an Orsat as a reference gas analyzer is a good choice, as it is considered the standard for analysis of flue gas for  $\text{CO}_2$  and  $\text{O}_2$ . Even here, the authors display an unfamiliarity with the equipment in making a distinction between "Hays Orsat" and "Burrell Gas Analyzer", and in reporting 25 minutes to analyze a sample. Hays and Burrell are in fact different brands of the generic Orsat. Burrell manufactures, in addition to the all glass model referenced here, a sturdy metal and glass Orsat similar to the Hays model. An experienced Orsat operator can easily obtain and analyze a sample of flue gas in less than five minutes if a continuously purging pump is used.

In addition to the Orsat, flue gas analysis information should be monitored by some type of continuous monitor, suitable for connection to a strip chart recorder. Most combustion testing laboratories are equipped with such instruments, (they can even be rented in some places) as they have the advantages of providing continuous readout and recording of data, as well as being much more insensitive to operator error than the Orsat. They require calibration, (usually on the order of once each shift) by the use of suitable bottled referenced

gases, but can generally be counted upon to provide consistent, reliable readings between calibration. Any drift which occurs between calibrations can usually be corrected for by simple calculations, and the Orsat may be used as a backup reference if desired. Continuous monitors are available for most of the constituents present in flue gas from oil-fired combustion, and certainly for those species of interest in this test.

- o The authors appear to be confused also on the subject of  $\text{NO}_x$  generation. The two major forms of  $\text{NO}_x$  present in combustion in a furnace are indeed  $\text{NO}$  and  $\text{NO}_2$ , as reported. These gases, however, are nitric oxide and nitrogen dioxide respectively, not nitrogen oxide and nitric oxide as reported. Combustion in a furnace generates  $\text{NO}_x$  emissions which are typically 90 to 95%  $\text{NO}$ , the remainder being  $\text{NO}_2$ , so it is not surprising that no  $\text{NO}_2$  was measured. It is the extremely low level present which inhibits its measurement however, and not sulfur trioxide. Sulfur compounds can indeed inhibit measurement of  $\text{NO}_x$ , (both  $\text{NO}$  and  $\text{NO}_2$ ) with some instruments, and it is general practice to use a scrubbing chemical in the  $\text{NO}_x$  sampling line to remove the sulfur compounds. This is generally not necessary with No. 2 fuel oil however, since this fuel typically contains negligible amounts of sulfur.

The monitoring instruments used measure  $\text{NO}_x$  on a volumetric basis, so the reading obtained is in parts per million of an actual flue gas volume. If the excess air levels vary for the different runs as was the case in this test, the readings must be converted to a common basis in order to be meaningful. There is no indication that this conversion was made. Typical common bases used are 12%  $\text{CO}_2$ , 3%  $\text{O}_2$  or mass bases such as pounds  $\text{NO}_2/10^6$  BTU. Since most government point source emission regulations are written in the latter format, it is preferred by this author. When converted to

this basis, the  $\text{NO}_x$  levels reported with the Vapormid out of service average  $.070 \text{ LB-NO}_2/10^6 \text{ BTU}$ , while they average  $.050 \text{ LB-NO}_2/10^6 \text{ BTU}$  with Vapormid in service. This is a substantial reduction, and is not surprising in light of the reduced excess air used in the latter case.  $\text{NO}_x$  generation is, as mentioned in the test report, quite sensitive to excess air levels.

No discussion of the topic would be complete without mention of the fact that  $\text{NO}_x$  generation is sensitive to parameters such as furnace geometry and heat transfer configuration, flame temperatures, excess air levels, fuel and air mixing rates and patterns, and quantities and species of fuel bound nitrogen present. Numbers generated under one set of parameters are often not directly correlatable to a different set. It must be borne in mind that the excess air levels used in the test furnace are extremely high, even with the Vapormid in service, when compared to levels used in a modulating control industrial furnace. The dilution effect of this excessively high excess air would tend to have a great effect on  $\text{NO}_x$  generation patterns, and extrapolation of this data to other systems is risky.

- o The levels of CO reported are excessive, both with and without the Vapormid in service. A level of 0.1% CO corresponds to 10,000 ppm. It is extremely unlikely that 10,000 ppm CO would be developed in a properly adjusted furnace. This further points out the need for continuous monitoring equipment of greater sensitivity and precision than an Orsat. CO levels should never go above 100-200 ppm, especially with oil fuel which typically cracks to hydrocarbons first, and certainly not when operating at the 9 and 10%  $\text{O}_2$  level used here. (Again, it should be noted that CO emissions must be reported as corrected to a constant base, such as 12%  $\text{CO}_2$ .) It is felt that the CO levels reported here are probably due to operator inexperience with the Orsat.

- o There is no indication as to how the authors selected the two 100 hour test periods with virtually identical weather. It would have seemed logical to operate under test conditions for several weeks, and then go back and select appropriate comparable test periods, with and without Vapormid in operation. The report does not indicate that this was done. It seems to indicate instead that the second test period was begun as soon as proper operation was obtained with the Vapormid, and that the fact that the weather was so similar to the first test period was merely good fortune.
  
- o Throughout the text, the author's opinions and conclusions are injected into the body of the report, making it difficult to separate laboratory procedures from conclusions. Statements such as "This conclusively proves that....." and "It is our considered opinion that....." belong in a separate section of conclusions, summary, comments, or the like, not scattered throughout the discussion of test procedures.

#### Summary

It is NUS' judgement that any efficiency gains measured in the Vapormid run are due to fine tuning of the boiler and lowering of the excess air, not the addition of the Vapormid. Furthermore, the report contains so many instances of errors, misinterpretations, and lack of knowledge of the subject of combustion testing that it lacks any credibility.

5.2.2 Summary and Evaluation of Report No. 2

Ref: Vapormid System Fuel Efficiency Test for Vaporpak, Inc.,  
by Associated Testing Laboratories, Inc.

Tests were run by Associated Testing Laboratories, Inc. utilizing a standard oil burner and a test stand consisting of a water jacketed stainless steel firebox equipped with a variety of temperature monitoring instruments. Three runs of 30 minutes each were made without the Vapormid installed. After the last run, the Vapormid was installed, with no other adjustments being made, and three more 30 minute runs were made. Readings were taken during each of the runs of water and gas temperatures at various parts in the system as detailed in the report. In addition, smoke readings and CO<sub>2</sub> readings were taken through an access port in the flue, and a sample of flue gas was taken in a bottle or similar sample container for analysis by a separate laboratory.

The results showed an increase in efficiency with the Vapormid in operation as evidenced by increased water outlet temperatures, reduced flue gas temperature and improved CO<sub>2</sub> readings. In addition, higher flame temperatures and reduced water temperature stabilization times were recorded. The flue gas samples sent to the laboratory for analysis were judged by Associated Testing to be defective, and the readings obtained from them were not used, although they were included in the report.

NUS Comments

In general the tests performed appear to have used valid and repeatable procedures, and while it is doubtful that they would be completely approved by ASHRAE or ASME, they should give results that are consistent and documentable relative to each other.

Some questions arise regarding the test equipment used. No diagrams or detailed description of the test stand is given, but it is assumed to have sufficient insulation around the water jacketing to ensure that the heat is transferred primarily to the water and not to the surroundings. In addition, although it is not explicitly stated, it is implied that the water flow rate is the same for the three Vapormid runs as for the non-Vapormid runs. This would of course be a requirement for a valid test.

The use of a Bacharach "Fyrite" tube for measurement of CO<sub>2</sub> is a poor choice. This instrument is not intended for precision test work but rather for field use by operating personnel to give a general indication of stack conditions. An Orsat would have been a better choice, since more accurate readings can be obtained and O<sub>2</sub> readings can be obtained at the same time. An even better choice would be continuous monitors for CO<sub>2</sub> and O<sub>2</sub> (and preferably CO) with Orsat backup. (Reference the Discussion in Section 5.2.1)

No indication was given that the test system was adjusted for best burner performance. It is stated however, that no changes were made to the burner air adjustment between runs. This raises the question of how the excess air was lowered, as reflected by the higher CO<sub>2</sub> reading, in the second test run (with Vapormid). If the same airflow was entering the burner, the only way the excess air could be decreased is by increasing the BTU input. This could be explained by the catalytic action of the Vapormid if a large percentage of the heating value of the fuel were not being utilized in the first set of runs. However, in order to explain the large gains seen in this test, approximately 10% of the heating value of the oil would have to be passing through the furnace uncombusted. This would result in heavy black smoke, which was not reflected by the data (smoke spot readings were zero throughout all runs except the last run with Vapormid).

Another possible way in which excess air could be altered is by the addition of a second fuel source supplying more BTUs. However, supply of enough heat to post the gain shown in this test would require oil flow on the order of several ounces per hour, and would certainly have been noticeable as catalyst loss had it been coming from the Vapormid itself.

Since no diagram was provided of the test arrangement, it was assumed to be similar to that used in other Vapormid installations, whereby a portion of the combustion air is diverted and bubbled through the Vapormid. Thus, a slipstream of the main flow is taken from the fan discharge and recycled to the inlet, effectively reducing fan capacity. It is likely that, on a small system, this reduction would be sufficient to cause a measurable decrease in excess air. It is also possible that, as is typical in some small burner designs, the primary air aspirates the secondary air into the furnace, thus holding a relatively constant ratio between the two streams. If sufficient static head is added to the system via the Vapormid to decrease the primary airflow, then the secondary airflow and subsequently total airflow would decrease automatically.

By whatever mechanism, it is evident that either the fuel flow or the airflow changed from the first set of runs to the second, since excess air is a function of mass flows and not combustion characteristics inside the furnace (excluding grossly incomplete combustion). Catalytic action by itself cannot explain changes in excess air levels.

Catalytic action of the Vapormid could conceivably explain the increase seen in combustion chamber temperatures. Lowered excess air due to one of the mechanisms described above could explain it equally well, and in addition could explain the lower exit gas temperatures recorded, since the gas flow through the system would be lower and more heat transfer to the water would take place.

Summary

The test data presented here appears to be valid and well controlled. The results strongly suggest however that the Vapormid aids combustion not by catalytic action as suggested by its manufacturer, but by lowering of the excess air level in the burner with its attendant efficiency gains.

5.2.3 Summary and Evaluation of Report No. 3

Ref: Report on Bubble Chamber Ion Generator Experiments,  
19 November 1971 - 18 September 1980, WEGOA Systems, Inc.

Experiments were run by WEGOA Systems using two different test set-ups, on a laboratory scale, with the intent of showing that the addition of negative ions to the combustion air increases flame temperatures in the combustion zone.

Part I

In the first set of tests, the arrangement shown in Figure 5.1, as photocopied from this author's copy of the report, was used. No dimensions were provided for the combustor, or the thermocouple locations. According to the report, the optional location as shown was used for the pump during testing. It is assumed that this optional location is incorrect as shown, and that the pump was in actuality located in the combustion air line so as to draw combustion air from the ion generator. Test procedure was to operate the burner with the ion generator off, metering gas flow and measuring the temperatures at the various thermocouple points. The ion generator was then turned on, and the gas flow was throttled until the indicated temperatures (which had increased) were reduced to the same level as in the first run. The gas flow was recorded and showed a decrease of 14 to 18%. No indications are given of air flow levels or stack gas analysis for any of the test runs. During all test runs, an "electrometer" was used to monitor the ionization level of the primary air in the atmospheric plenum. No indications were given as to the readings obtained, except for the statement that "electrometer connections to the inner plenum indicated high negative charges".

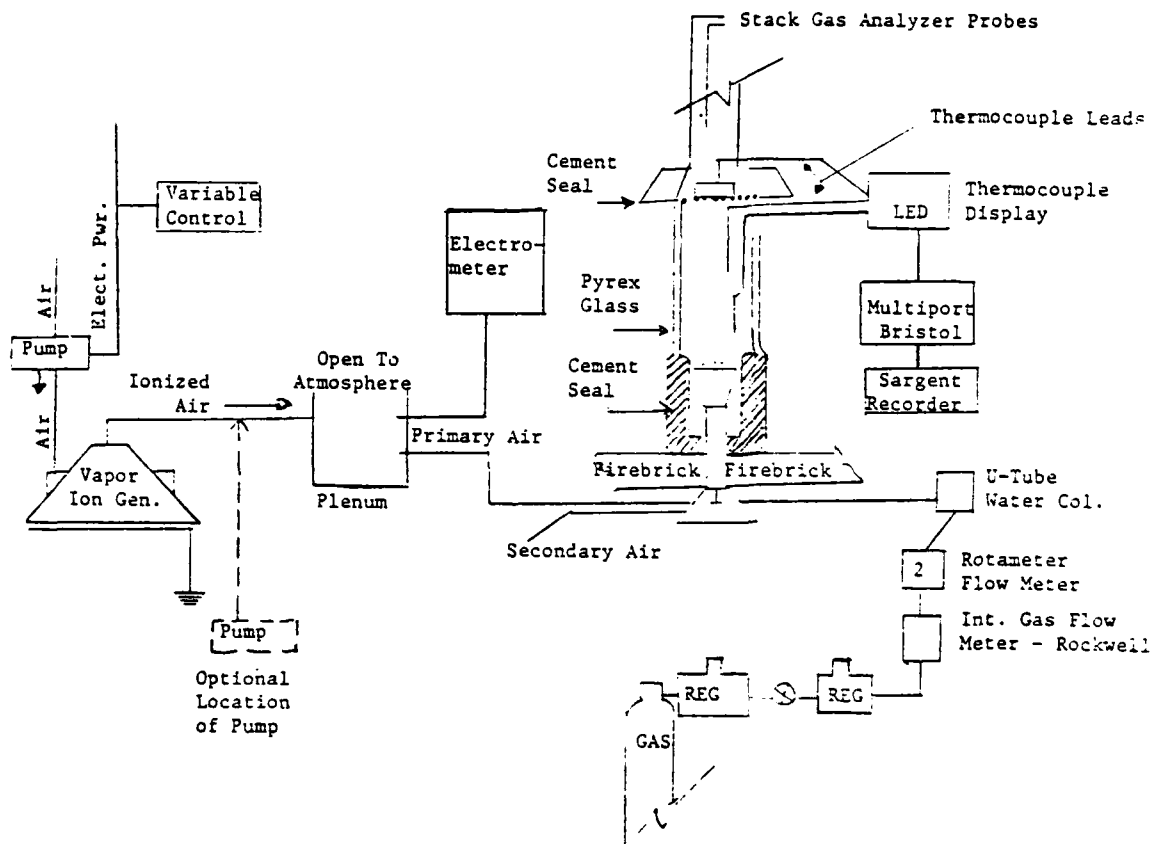


FIGURE 5.1 TEST ARRANGEMENT USED BY WEGO SYSTEMS  
IN PART I OF TEST REPORT NO. 3

### NUS Comments

The tests performed tend to indicate higher combustion chamber temperatures with the Vapormid in service. The temperatures measured are, however, very low (between 200 and 600 F) and obviously are measured at points after substantial heat transfer or dilution has taken place. No indication is given of the relationships between primary and secondary air, or of any quantitative measurement of ionization level of the air or stack gas analysis. There is also no indication that the fuel/air ratio was adjusted when the fuel flow was reduced, so there is some question as to whether or not constant stack conditions were maintained.

With the air pump discharging into the plenum, it would be possible depending upon the particular design used, to actually pressurize the plenum and increase excess air unless airflow adjustments were made. No pressure readings were included for any points in the flow path. It is also possible that the primary air coming from the bubble chamber in fact carries some heating value of its own due to its bubbling through the oil catalyst layer. This could account for the increase in temperatures seen, since it would have the affect of lowering the excess air level, if no further adjustments were made to airflow. This possibility is discussed more fully in the NUS comments to Part II of this test report.

Attempts were made to clarify some of the questions arising from this report, but no telephone listing could be found in Grand Rapids, Michigan for a WEGOA Systems, Inc.

## Part II

A second series of tests were performed utilizing a constant flow gas calorimeter. In this test series, a gas calorimeter was used to measure the BTU content of a certified gas, both with and without the Vapormid. With the Vapormid in the system, BTU increases of two to seven percent were noted, and attributed to the highly ionized state of the combustion air.

### NUS Comments

Cutler-Hammer, the manufacturer of the constant flow gas calorimeter, was contacted for information on the equipment. The device operates by completely combusting a sample of a fuel gas, and transferring the heat generated to a stream of air. The temperature rise of the air is monitored, and converted via the circuitry in the calorimeter to BTU per standard cubic foot of fuel. A detailed calibration and adjustment procedure must be followed to insure complete combustion of the fuel and correct readouts on the recording instrumentation. According to the manufacturer, the device is sensitive enough to react to such perturbations as paint fumes in the room in which it is being used, since it would measure the BTU content of these fumes as they entered with the combustion air, and attribute the BTUs to the fuel.

It is obvious, and was mentioned in the report, that the Vapormid can have no effect on the BTU content of the fuel gas in the cylinder. Therefore, the increase in BTU readings obtained must be attributed to either incomplete combustion of the fuel in the first run (i.e. incorrect adjustment of the calorimeter) or the addition of a second fuel source. "Ionization level of the air" can have no effect on the BTU reading obtained from a correctly adjusted calorimeter. Assuming that the calorimeter was indeed

properly adjusted, the only plausible explanation for the increase in BTUs reported by WEGOA is that the arrangement of test equipment is somehow supplying additional heating value to the combustion process. The most likely source of this heating value is the Vapormid device itself. It seems likely that some small amount of hydrocarbon is being carried over with the primary air as it bubbles through the catalyst layer. The calorimeter would measure the heat content of this hydrocarbon and attribute it to the fuel.

The amount of additional hydrocarbons required could probably be carried easily with the air bubbling through the Vapormid. Although no rigorous analysis of this was performed, Calculation 01 gives some indication as to the order of magnitude of oil quantities which would be required to supply the indicated BTU increase, and the time periods for which an assumed catalyst layer might last. Note that in the test method used in Part II, it is conceivable that the catalyst layer could supply the required heat input to the calorimeter for a time period on the order of 40 hours. Actual test time is not included in the report, however it appears to be on the order of a few hours for each run, including stabilization time. It is possible that the entire test program might be completed without a noticeable depletion of the catalyst.

If such a process is indeed taking place, the oil layer is of course not acting as a catalyst at all, but actually constitutes a separate source of fuel.

#### Summary

There is some indication from this test report that combustion chamber temperatures can be increased by the use of the Vapormid device. The report is too sketchy however, and too many questions exist as to the test methods used to lend it much credibility.

The conclusions drawn from the tests performed in Part II are erroneous, and a better explanation seems to be that the Vapormid itself is supplying enough additional heating value to the calorimeter to provide the measured increases. This explanation could also easily explain the results found in Part I.

5.2.4 Summary and Evaluation of Report No. 4

Ref: Penniman and Browne, Inc., Test Report No. 772028  
and 772415 for 21st Century Enterprises, Inc.

A data summary was obtained of testing performed by the above referenced testing company on a Heil, Model 29455 heating boiler firing No. 2 oil. Baseline data was gathered with the boiler in its initial condition. A Vapormid unit was then connected and additional tests were run over a period of approximately three months. No information was obtained regarding test procedures, except for an equipment list itemizing the test instruments used. An Orsat was used for gas analysis, with the other equipment being various types of commercial draft gauges, smoke spot testers, thermometers, and an optical pyrometer.

The testing results indicate an increase in furnace temperature with the installation of the Vapormid. Exit gas temperatures also increase significantly. No significant change was made in flue gas analysis at first. Additional adjustments were made a few weeks later and more tests were run, these tests showed greatly increased CO<sub>2</sub> levels and lower O<sub>2</sub>. Furnace temperatures increased an additional amount, as did exit gas temperatures.

NUS comments

No comments can be made on the procedures used, since NUS does not have copies of this information. Enough data was presented to calculate boiler efficiency for the various test runs. The results of these calculations are presented below in Table 5.1

Table 5.1 - Summary of Boiler Efficiencies as Presented in  
Test Report No. 4

Test Date	Test Conditions	Firebox Temp.	Flue Gas Temp.	% Excess Air	% Boiler Efficiency
9/21/77	W/o Vapormid	1545	400	146	76.62
9/21/77	W/Vapormid	1745	420	111	78.01
10/12/77	W/Vapormid No Adjustments	1860	490	115	73.55
12/13/77	W/Vapormid Minor Adjustments	2100	530	91	74.68
12/13/77	W/Vapormid 15 Minutes After Adjustments	2230	550	56	77.44

It can be seen that the installation of the Vapormid caused a decrease in excess air and an increase in boiler efficiency almost immediately. However, it should be noted that test data for this point was incomplete as no O<sub>2</sub> reading was available. Based on standard combustion charts and the given value of 6.6% CO<sub>2</sub>, an O<sub>2</sub> reading of 11.5 was estimated by NUS, and used in the calculations. When the next test run was made three weeks later, the O<sub>2</sub> level had returned to the pre-Vapormid level, flue gas temperature had further increased, and efficiency had dropped substantially below its original level.

Additional testing was performed about two months later with adjustments being made to either the burner or the Vapormid. No information is provided on the adjustments, but the data reflects drastically lowered O<sub>2</sub> levels, and increased gas temperatures, both in the combustion chamber and in the outlet flue. Even with the lower O<sub>2</sub> readings, the efficiency of the boiler is only slightly

improved (less than 1%) over its pre-Vapormid state, due to the greatly increased exit gas temperatures. There is no indication that any additional adjustments were attempted without the Vapormid in service.

Summary

The Vapormid by itself provided no improvement to boiler efficiency, and in fact efficiency dropped significantly until additional adjustments were made. These adjustments had the effect of lowering excess air and were sufficient to return the unit to its pre-Vapormid efficiency. NUS' judgement is that it is likely that proper adjustments and tuning could have provided the same results without the Vapormid in service.

5.2.5 Summary and Evaluation of Report No. 5

Ref: Report of Investigation No. ENG 77-36381  
Performance Testing of "Vapormid Fossil Fuel  
Catalyser" for Canadian Broadcasting Corporation

Ontario Research Foundation performed tests on a domestic oil fired furnace, with and without a Vapormid installed. The furnace was new, and installed specifically for the test in ORF's laboratories. In both sets of tests, the furnace was adjusted to give optimum performance. Adjustments on the Vapormid installation were performed by representatives of the manufacturer. Instrumentation and testing was in accordance with Canadian Standards B140.0-1971 and B140.4-1974. Measurements were made of flue gas analysis with a gas analyzer package including continuous monitors for CO<sub>2</sub>, O<sub>2</sub>, CO and hydrocarbons, and appropriate sample probes, filters, and driers. A Bacharach smoke tester was used to measure smoke number, and a positive displacement meter was used to measure oil flow. Temperature readings were recorded on continuous strip chart recorders.

Unfortunately, the raw data pages in the copy of the report obtained by NUS were illegible, so no direct analysis of the data was possible. ORF presented boiler efficiency calculation based upon the data. These calculations were performed in accordance with CSA Standard B140.0-1971, and utilized a heat loss method similar to that presented in ASME Power Test Codes. The results of these calculations indicate that lower excess air and improved thermal efficiency was possible without the Vapormid unit installed. According to the text, combustion chamber temperatures were also higher without the Vapormid, although this data was included on the pages that were illegible. A summary of the results is present in Table 5.2.

Table 5.2 - Summary of Results from Test Report No. 5

	<u>% Excess Air</u>	<u>% Efficiency</u>
Without Vapormid	39.05	77.42
With Vapormid	57.16	75.31

NUS Comments

The report has a high degree of credibility, due to the test procedures and equipment used and the reputation of the performing organization. The results indicate that the Vapormid offers no advantages over a furnace that is properly tuned and adjusted, and in fact, in this particular instance, caused an increase in excess air and a decrease in efficiency.

5.2.6 Summary and Evaluation of Report No. 6

Ref: Engineering Evaluation of the Vapormid Fossil Fuel  
Catalyser, by Peabody Gordon-Piatt

At the request of Norfolk and Western Railway Company, Peabody Gordon-Piatt Service Engineers ran a series of boiler efficiency tests on a Weil-McLain Model 1286 boiler firing No. 2 fuel oil. The equipment used to perform the tests was all standard commercially available equipment such as an Orsat gas analyzer, potentiometers and manometers. Tests were performed at steady state condition, and data was collected over a period of several days on Peabody Gordon-Piatt standard forms. Boiler efficiency was reported as percent losses. In addition, input and output BTUs are tabulated on the data sheets. Efficiency as calculated from the input and output data agrees with the heat loss data to within 1% in most cases, and to within 2% in all cases.

The first two test runs were made without the Vapormid in service. It is not explicitly stated in the report, but implied that Test 1, with a smoke number of 1, was the standard burner set-up. Test 2 was run with the burner set up so as to give a smoke reading of 3, and this smoke level was maintained throughout the rest of the test runs. In setting up for the higher smoke number, the CO<sub>2</sub> was raised slightly and boiler efficiency increased. The remainder of the test runs were all made at smoke levels of 3 or 4, with the Vapormid in operation.

The results of this test show no discernible difference between the boiler efficiency with or without the Vapormid. All parameters such as CO<sub>2</sub>, smoke number, temperature rise of the water, and stack temperature remained essentially constant within the probable accuracy of the test equipment

NUS Comments

The test covered by this report seem to have been run generally in accordance with ASME procedures, however it is felt that more data should have been accumulated at the various data points. Often only one set of data was taken to represent a test condition, whereas three or more would have better indicated that steady-state conditions had indeed been achieved. Since there was very slight fluctuation throughout the test period, the procedures used were probably adequate however. In addition, no sample calculations were included, at least in the copy reviewed by NUS. These could have been beneficial in reviewing the heat loss values reported.

The data indicated no significant variation in boiler efficiency for any of conditions tested. The slight variations that were seen showed no particular pattern and did not indicate any advantage to be gained with the Vapormid.

5.2.7 Summary and Evaluation of Report No. 7

Ref: Efficiency Test Report for Vapormid H-800 by  
Brookhaven National Laboratory

Brookhaven National Laboratory performed efficiency tests on a residential oil-fired heating system with and without a Vapormid system installed. The heating system tested was designed to provide both space heat and domestic hot water for residential and small commercial applications. The results of the efficiency tests were then evaluated by BNL using a computer program which they have developed to predict seasonal fuel usage from the measured boiler efficiency.

BNL measured boiler efficiency by two separate methods, input-output and heat loss. Detailed test procedures used are not described in the report. The Vapormid was installed and adjusted by a manufacturer's representative. At his recommendation a smaller nozzle was used in the oil burner with the Vapormid in service in order to avoid excessively high smoke numbers. All testing was performed at steady-state conditions.

BNL's testing indicated an increase in steady-state efficiency of the system with Vapormid installed of 1.1 percent, as measured by the input-output method. Efficiency as measured by heat loss method increased 2.5%. When evaluated using BNL's Annual Fuel Use and Efficiency program, this projected to a savings of 1.4% in fuel consumption for a typical domestic installation. BNL evaluates this savings as equal to 18 gallons of oil per year. The overall accuracy and reproducibility of the test system, as stated in the Reference Manual are 2.0% and 1% respectively. Thus the efficiency gains are noted as being within the measurement uncertainty of the test method.

NUS Comments

Since detailed test procedures were not included in the report, no comments are made on procedures. BNL's reputation as a testing laboratory lends credence to the data obtained however.

BNL's Annual Fuel Use and Efficiency calculations show a net savings of 18 gallons of oil to a typical residential user over one year, to which they assigned a value of \$9.00. Due to general inflation and increases in the cost of fuel oil since the time of this report, this cost savings would more likely be \$20.00 to \$25.00 per year. This would still be considered negligible savings, since Vapormid unit costs for the smaller sizes range typically from \$300 upward.

5.2.8 Summary and Evaluation of Report No. 8

Ref: Energy Alliance Report Summary to Energy Services  
Supervisors from G. H. Hoffman, dated February 24, 1978

The Vapormid and a similar device called Energy-Pak were tested by Energy Alliance, an arm of the Energy Conservation and Utilization Unit of Baltimore Gas and Electric. All testing was performed on gas fuel only, and the summary letter is specific in emphasizing that no extrapolation of the data to oil use should be made. The exact test procedures used are not itemized in the summary, except to say that the boiler was tuned by laboratory personnel prior to the testing, and that the Vapormid was installed by a manufacturer's representative. The data indicated no significant change in boiler efficiency. Sometimes the efficiencies were slightly higher with the device applied, sometimes slightly lower. Average efficiencies determined in a given test never differed by more than 1.6 percent, and efficiencies of individual runs in a given test never varied by more than 3 percent.

NUS Comments

Through conversations with representatives of Energy Alliance it was learned that they monitored both temperature change in the water and flue gas conditions. Efficiency calculations were based upon the water temperature gain (input-output method), rather than on the stack conditions. The testing period covered a span of several days, but no single run spanned an extended period. Since gas was the only fuel tested, no attempt was made to quantify soot-ing conditions.

### 5.3 Overall Summary of Literature

In the eight test reports reviewed by NUS, there was only one credible report (No. 2) which indicated a significant gain in efficiency with the use of the Vapormid. Even in this instance, there is a question as to whether the gain was really due to the "catalytic effect" of the device or whether it stemmed from effects of static head imposed on the primary air system and the subsequent lowered excess air levels.

All other credible test reports indicated either no significant gain or in a few cases, a slight loss in efficiency with the addition of the Vapormid alone, before additional tuning. Where efficiency gains were shown, they were only realized after additional fine tuning and adjustments to excess air levels. Wherever care was taken to properly tune the boiler for the baseline testing, efficiency gains were negligible or non-existent.

The most favorable results indicate that, at best, the Vapormid may be able to raise the combustion chamber temperature somewhat. While this does not have a direct measurable effect on furnace or boiler efficiency, it could have a long term effect in that it would promote more complete carbon combustion in the furnace and therefore less sooting and more efficient heat transfer in the convective sections. The literature is not very convincing, even on this point however, and it is NUS' judgement that the temperature increases seen were generally due to lowered excess air levels and/or other fine tuning performed on the boilers.

## 6.0 TECHNICAL EVALUATION

### 6.1 Boiler Efficiency Parameters

Overall efficiency of a boiler can be best measured by the use of standard techniques developed by ASME and presented in the Power Test Codes. The same parameters used by ASME in these measurements can be used to predict boiler efficiency. By means of simple calculations changes in efficiency resulting from changes to one or more of these parameters may be predicted. Figure 6.1, which is extracted from Steam/Its Generation and Use, by Babcock and Wilcox Company allows the calculation of boiler efficiency and adiabatic combustion temperature based upon ASME criteria. A detailed description of the use of this calculation method, as well as combustion calculations via modal methods, and the appropriate charts and figures to determine the necessary coefficients may be found in the above reference.

From an examination of Figure 6.1, it can be seen that the principal variables affecting combustion efficiency, for a given fuel analysis are:

- o Total Combustion Air
- o Inlet Air Temperature
- o Outlet Flue Gas Temperature
- o Moisture Content of Inlet Air
- o Unburned Fuel Loss
- o Radiation Loss
- o Unaccounted Losses

In the type of boiler to which the Vapormid device would be likely to be applicable (i.e. water or steam heating boilers up to about 125 psig) an air heater would be an unusual accessory, so no control is generally available over inlet air temperature. Likewise, unaccounted and radiation losses are a function of boiler design and operating conditions, and cannot be altered by add-on devices.

L I N E		FIG 6.1- Combustion Calculations Based on quantities per 10,000 Btu fuel input			L I N E	
1	Fuel—	Analysis As Fired		Conditions	Date	a
2						
3	Ultimate, % by Wt	Proximate, % by Wt		Total air	%	b
4	C	Moisture		Air temperature to heater	F	c
5	H <sub>2</sub>	Volatile		Air temperature from heater	F	d
6	S	Fixed carbon		Flue gas temperature leaving unit	F	e
7	O <sub>2</sub>	Ash		H <sub>2</sub> O per lb dry air	lb	f
8	N <sub>2</sub>	100.00		Unburned fuel loss	%	g
9	H <sub>2</sub> O			Unaccounted loss	%	h
10	Ash			Radiation loss (ABMA)	%	i
11	100.00					j
12	Btu per lb. as fired					k
Quantities per 10,000 Btu Fuel Input						13
14	Fuel burned, 100 (100 - line 10) - line 12; - .007 x line h			lb		14
15	Dry air, line b (value from Fig. 4, Table 11 or Eq. 5) - .03 x line h;			lb		15
16	H <sub>2</sub> O in air, line 15 x line f			lb		16
17	Wet gas, total, lines (14 - 15 + 16)			lb		17
18	H <sub>2</sub> O in fuel, 100 (8.94 x line 5 - line 9) - line 12, or Table 11			lb		18
19	H <sub>2</sub> O in flue gas, total, line 16 + line 18			lb		19
20	H <sub>2</sub> O in flue gas, total, in percent, (line 19 - line 17) x 100			%		20
21	Dry gas, total, line 17 - line 19			lb		21
Losses per 10,000 Btu Fuel Input						22
23	Unburned fuel, 10,000 x line h - 100			Btu		23
24	Unaccounted, 10,000 x line i - 100			Btu		24
25	Radiation, 10,000 x line j - 100			Btu		25
26	Latent Heat, H <sub>2</sub> O in fuel, 1040 x line 13			Btu		26
27	Sensible heat, flue gas, line 17 x Btu from Fig. 1 @ line e and line 20			Btu		27
28	Total losses, lines (23 - 24 - 25 - 26 - 27)			Btu		28
29	Total losses in percent, (line 28 - 10,000) x 100			%		29
30	Efficiency, by difference, 100 - line 29			%		30
Quantities per 10,000 Btu Fuel Input Combustion temperature, adiabatic						31
32	Heat input from fuel			Btu	10,000	32
33	Heat input from air, lines (15 - 16) x Btu from Fig. 8 @ line d temp			Btu		33
34	Heat input, total, lines 32 - 33			Btu		34
35	Less latent heat loss, H <sub>2</sub> O in fuel, line 26			Btu		35
36	Heat available, maximum			Btu		36
37	Less (lines 24 - 25) x 0.5*			Btu		37
38	Heat available, line 36 - line 37			Btu		38
39	Heat available per lb of flue gas, line 38 - line 17			Btu		39
40	Adiabatic temperature, from Fig. 1 for lines 20 & 39			F		40

\*Note: It is customary to reduce the maximum heat available, line 36, by from 10 to 15% of the unaccounted plus radiation losses, on the assumption that a portion of these losses occurs in the combustion zone.

Unburned fuel loss from oil-fired boilers, (especially those utilizing No. 2 oil) can be taken as negligible. Some soot or unburned carbon is indeed formed, even by a well adjusted burner, but its main harm is caused by its insulating effect on heat transfer surfaces and not in direct unburned losses. If enough soot is being formed by the burner to create significant unburned carbon efficiency loss, steps should be taken to have the burner adjusted or replaced. Thus the parameters available for control and efficiency improvement by add-on devices such as the Vapormid are:

- o Total Combustion Air
  - o Outlet Flue Gas Temperature
  - o Moisture Content of Inlet Air
- o Total Combustion Air - For a given fuel analysis, the quantity of air required to provide complete combustion may be easily calculated. This quantity is referred to as the stoichiometric or theoretical air, as it represents the minimum quantity of air which can, in theory, be used to completely burn all the combustible constituents in the fuel.

Each pound of air greater than this stoichiometric amount which passes through the burner and out the stack is called excess air and makes no contribution to the combustion process, yet it must be heated to the flue gas outlet temperature. This requires heat which could otherwise be utilized to raise the temperature of the steam or water, and thus represents an efficiency loss. A certain amount of excess air is a necessary evil, as it is required to insure complete mixing and therefore complete combustion. It can be seen from Figure 6.2, however, that at constant boiler exit gas temperature each 15% increase in excess air results in a one percent decrease in efficiency. In practice, the resulting efficiency loss is actually greater than this since the increase in excess air usually results in an

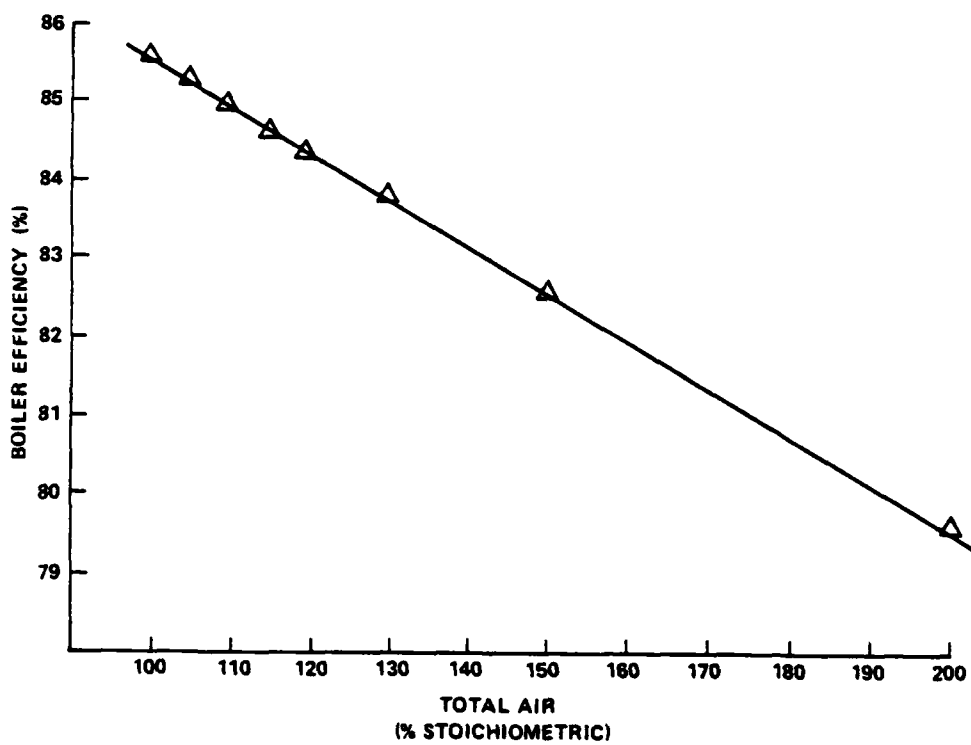


FIGURE 6.2 EFFECT OF TOTAL COMBUSTION AIR ON THERMAL EFFICIENCY

increase in boiler outlet flue gas temperature as well. It is obviously desirable, therefore, to maintain excess air at the lowest possible level.

- o Outlet Flue Gas Temperature - The amount of heat present in the flue gas, as indicated by flue gas temperature, is a function of heat input to the furnace and effectiveness of the boiler heat transfer surfaces. Heat transfer effectiveness for a given boiler design at a given firing rate and excess air is primarily a function of boiler cleanliness. It was mentioned previously that soot buildups on boiler heat transfer surfaces can act as an insulator and cause a loss in heat transfer efficiency, raising the temperature of the flue gas and decreasing overall boiler efficiency. A typical relationship between boiler exit gas temperature and efficiency is illustrated in Figure 6.3. Thus any method by which sooting or fouling of the boiler convective surfaces can be reduced will lead to an eventual increase in boiler efficiency.

Oil-fired water tube boilers are typically equipped with sootblowers capable of removing these soot deposits while the boiler is in operation, maintaining these efficiency losses at a low or negligible level. Firetube boilers on the other hand are not generally capable of being cleaned without shut-down, and control of soot buildups is an important factor in maintaining boiler efficiency.

- o Moisture Content of the Inlet Air - As with excess air, any moisture present in the inlet air must be heated to flue gas outlet temperature using heat which could otherwise be transferred to the water or steam. Again, this represents an efficiency loss. (Note that any water present in the fuel or formed from hydrogen in the fuel also represents an efficiency loss, however, this is dependent only upon fuel analysis and is not controllable by add-on devices.) Any moisture which is added to the combustion air in its liquid state must also be

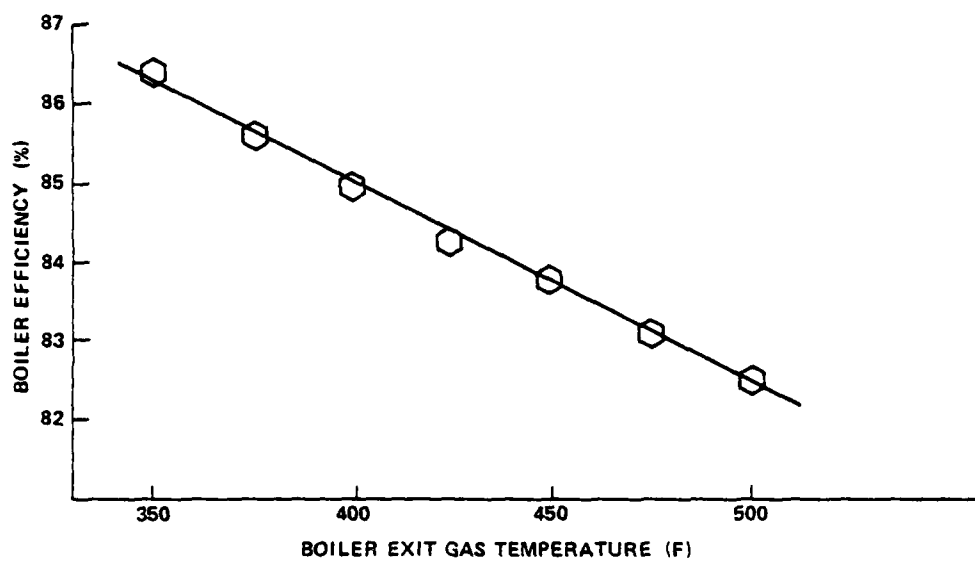


FIGURE 6.3 EFFECT OF BOILER EXIT GAS TEMPERATURE ON THERMAL EFFICIENCY

vaporized, thus consuming an additional 1040 BTU/Lb-water (the latent heat of vaporization of water) in addition to the heat required to raise its temperature to flue gas outlet temperature. The effect of additional moisture in the combustion air, while less striking than that of excess air or boiler exit gas temperature, must be considered in determining the effects of an add-on device to overall efficiency.

The three parameters described above are therefore the primary ones available for manipulation in any attempts to improve boiler efficiency. The Vapormid device must be able to cause an improvement in one or more of these parameters in order to bring about an efficiency gain.

#### 6.2 Application of the Vapormid to a Properly Tuned Boiler

A well tuned oil-fired boiler with a single burner and simple control system can usually be set up to operate at excess air levels of about 10-15 percent (corresponding to 2 to 3% O<sub>2</sub>) at full load and 20 to 25 percent at partial loads down to one quarter of rated capacity. These excess air levels may be reduced somewhat in multiple burner boilers, in boilers having sophisticated control systems or exotic "low excess burners", or sometimes in boilers which operate at very steady load demands. The excess air is required to insure complete mixing of the fuel and air and is usually limited by variability in air temperature, airflow patterns, fuel analysis or hysteresis in control systems that cannot maintain adequate repeatability to insure that substoichiometric conditions will never be encountered. There is no evidence in the literature that the Vapormid is capable of reducing excess air to levels less than these while still maintaining complete combustion. Even where reductions in excess air were reported, O<sub>2</sub> levels were in the range of 5 to 7 percent, and when well tuned boilers were used as baselines, no measurable improvement was documented.

Flue gas outlet temperature, another parameter which effects efficiency is primarily a function of boiler cleanliness and excess air, for a given boiler design. Since the Vapormid is not likely to aid in decreasing excess air, if it is to make any improvement in gas outlet temperature it must do so by improving boiler cleanliness. There is some evidence in the literature that Vapormid does increase the combustion zone temperature, effecting an improvement in carbon burnout and a subsequent improvement in cleanliness.

A properly tuned boiler firing No. 2 oil should generate almost no soot, and the amount of buildup, even over a long operating period, will be so small as to have a negligible effect upon heat transfer. The amount of soot expected is so small in fact, that many boilers designed for operation on No. 2 oil alone are not even equipped with sootblowers. No. 6 oil is a somewhat different story. There can be an appreciable amount of ash present, and if the oil happens to have a high carbon to hydrogen ratio or other qualities leading to poor combustion, a significant amount of boiler deposits, including both soot and ash, can build up over a long operating period. Water tube boilers typically have sootblowers installed which can remove any anticipated deposits by once-a-day or once-a-shift operation. The cost of operating and maintaining these sootblowers is minor, and can generally be said to be more cost effective than an add-on device such as a Vapormid. Fire tube boilers however normally require a shutdown to be cleaned. Assuming that this shutdown can be adequately scheduled into the operation of the heating plant its main cost is in the manpower required. Any ability of the Vapormid to decrease the frequency of these cleaning shutdowns, or eliminate them altogether would result in a manpower saving and cost advantage. This would appear to be one possible area in which the Vapormid might provide some technical advantage.

The economics of the above mentioned cleaning options are discussed in Section 7.

One other variable which can have an effect on boiler efficiency is moisture content of the air. However, based on the information available, the amount of water used by Vapormid, and thus added to the combustion process is miniscule and should have no measurable effect on either efficiency or operating problems such as corrosion.

From the above discussions, it would appear that the only application wherein a Vapormid might be advantageous for a properly tuned boiler would be a fire tube unit burning No. 6 oil. In this instance, it is possible that the maintenance costs for periodic cleaning of the boiler might be reduced due to the increased combustion temperature possible with the Vapormid.

### 6.3 Application of the Vapormid to a Poorly Tuned and Maintained Boiler

A poorly tuned boiler can have many different problems. Usually however, they can all be traced to improper relationship of fuel and air. This maladjustment may be in the form of high excess air with its attendant high gas weight and efficiency losses or low excess air with excessive unburned carbon losses, smoke, hydrocarbons and carbon monoxide. It could also be due to poorly adjusted burners which do not allow proper mixing of the fuel and air, even though they might be present in the correct proportions.

Since air-deficient operation can, under certain circumstances lead to explosive conditions in the furnace, boiler operators tend to operate with higher excess air than required, "just to be safe." No amount of "catalytic action" can change this, since it is determined only by mass flow of the fuel and air, and is set by the operator or the adjustments of the control system linkages. Very few combustion control systems are capable of trimming excess air without some input from the operator, and even those that can do so, normally take into account only fuel and air flows or O<sub>2</sub> level in the flue gas, not furnace conditions. Any reductions to excessively high excess air which might be possible through the use of

the Vapormid would still have to be implemented by the operator in the form of adjustments to the fuel air ratio. There is little reason to believe that a boiler operator who has never taken the time to make these adjustments previously (thus resulting in a "poorly tuned boiler") would begin to make them just because a Vapormid was added to the unit.

As has been mentioned previously, there is no indication in the literature that Vapormid is capable of reducing excess air below the 5-7% O<sub>2</sub> level, nor is there any credible evidence that it can improve mixing or substantially aid combustion at extremely low excess air levels. There would thus be no reason to expect any improvement to low excess air problems.

As was the case with a properly tuned boiler, there is some possibility that the Vapormid might be able to improve carbon burnout when firing No. 6 oil, and thus aid in reducing sooting of the boiler's convection surfaces. Sootblowers can remove this deposit effectively with most water tube boilers, so this would only be an advantage with firetube units.

In summary, the only area in which there is a significant chance for efficiency improvement via a Vapormid would be a firetube boiler operating on No. 6 oil, where there is a chance to reduce unit downtime for cleaning.

## 7.0 ECONOMIC EVALUATION

The Vapormid units cost between about \$350 and \$4,000, depending upon size and application. The sizes required for typical Army applications such as heating boilers would be expected to cost between \$1,000 and \$3,000, again depending upon size and application. Installation is generally performed by the vendor and is included in the purchase price.

It has been shown that the only application for which the Vapormid might be expected to produce a reduction in boiler operating costs would be one in which it could reduce sooting of the boiler convection surfaces, and therefore decrease cleaning costs.

For a water tube boiler equipped with four Diamond Power G9B type sootblowers, the cost of sootblowing steam required through a nine-month heating season would be expected to be about \$1,300. Maintenance of these sootblowers is typically low, as they are normally hand operated and do not require any control. Maintenance is limited to occasional replacement of items such as packing or a sticking check valve and is generally easily accomplished by the boiler operators. Replacement of the lance is almost never required in this type of boiler. Based upon the estimated steam consumption and an assumed maintenance cost, the total cost of operating a sootblower system should be no more than about \$1,500 per year. Thus if the Vapormid could eliminate all sootblowing, the simple payback period could be in the range of one to two years. It is judged that this is unlikely, and at best, the sootblowing might be cut in half, so payback would be from two to four years.

For a firetube boiler, the cleaning costs are primarily labor costs associated with performing the work. This cost is estimated to be about \$1,000 per season, assuming two man-days required per cleaning and four cleanings per season. Since a Vapormid for a firetube boiler would be less expensive due to the smaller size required, the payback period would be shorter. Simple payback period could

be expected to be about 1 1/2 to 2 years, assuming a \$1,000 Vapormid unit that can reduce the required cleaning by one-half.

Based on the above estimates, the Vapormid could be cost effective if it could indeed be proven to perform as advertised by the manufacturer in eliminating or reducing sooting.

The costs of maintaining a boiler in good operating condition are actually quite minimal, and this is considered by NUS to be a more desirable approach than trying to compensate for poor performance by means of add-on devices. Typical boiler manufacturer service representatives cost from \$200 to \$500 per day, plus travel expenses, and one day's service time per year is normally all that is required to maintain the unit in good operating condition. In addition, the operators must be willing to maintain a more watchful eye on operating conditions and perform preventative maintenance of steam traps, filters, controls, etc., on a scheduled basis. The costs of scheduled maintenance have been shown over the years to be easily justifiable in terms of improved efficiency, availability, and general lessened operator headaches.

It must be emphasized that the cost estimates provided here are for generic guidance only. The actual costs associated with any given installation must be evaluated on a case-by-case basis in order to insure proper economic analysis of the many site specific factors involved.

## 8.0 CONCLUSIONS AND RECOMMENDATIONS

NUS' review of the Vapormid device does not show any clear-cut advantages to be obtained from its use. There is no credible evidence that the device is capable of causing any substantial increase in boiler efficiency through its advertised catalytic action. Although there is some evidence that furnace combustion temperatures might be increased slightly, the economic benefits to be gained from this are only marginal in most cases. Considering the weakness of the evidence, and the proven performance of existing equipment such as sootblowers, it would seem unwarranted to make the investment in a Vapormid. The more cost-effective course of action would be to properly tune and maintain the boilers and accessories. A device such as the Vapormid, even if it can be proven to work, should not be used as a substitute for good operating and maintenance practices.

APPENDIX A

CLIENT	FESA (Corps of Engineers)	CALC. No.	5397-M-01
SUBJECT	VAPORMID		

PROBLEM:	For Report No. 3, investigate the possibility that the oil layer on the Vapormid could be supplying additional BTU value to the test apparatus, thereby explaining the reported results.	AUDIT REMARKS
CHECKER'S REMARKS:		

APPROACH ASSUMPTIONS:	1. Determine the additional heat input required to explain the reported results ( $\Delta$ BTU) 2. Determine the length of time which this heat input could be supplied by the available catalyst layer.	AUDIT REMARKS
CHECKER'S REMARKS:		

SOURCES-DATA/EQUATIONS:	1. <u>Report on Bubble Chamber Ion Generator Experiments</u> , by WEGOA Systems, Inc. (Ref. No. 3 in NUS Report No. 5397). 2. Assume catalyst oil contains 150,000 BTU/GAL (typical for heavy fuel oil).	AUDIT REMARKS
CHECKER'S REMARKS:		

CONCLUSIONS:	Available catalyst layer could supply system of Part I for 9 + hours and Part II for 40 + hours.	AUDIT REMARKS
CHECKER'S REMARKS:		

AUDIT SUMMARY		CALCULATED BY	DATE
CHECKS	CORRECTIVE ACTION TAKEN BY	<i>Paul Attick</i>	6/1/81
INFRACTIONS	DATE	CHECKED BY	DATE
		Preliminary	
		AUDITED BY	DATE

ED 500 2 80



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DATE 6/1/81

CLIENT FESA FILE NO. 5397-01 BY Paul Utterback

SUBJECT VAPORMID Checked By Preliminary

Problem - Estimate the length of time for which the oil layer reported in the Vapormid could supply the additional BTUs required to provide the results shown in Report No. 3.

From Report, Gas Flow without Vapormid is listed as 1 Ft<sup>3</sup>/23 min-26 sec. Assuming 1000 BTU/Ft<sup>3</sup>,

$$GF1 = \frac{(1000 \text{ BTU})}{23 \text{ min}-26 \text{ sec}} \times 60 \frac{\text{min}}{\text{hr}} = 2560 \text{ BTU/hr}$$

Similiary, with Vapormid,

$$GF2 = \frac{1000 \text{ BTU}}{28 \text{ min} - 24 \text{ sec}} \times 60 \frac{\text{min}}{\text{hr}} = 2112 \text{ BTU/hr}$$

To supply the difference in BTU input with an oil (such as the catalyst oil) would require:

$$\Delta \text{BTU,} = (2560 - 2112) = 448 \text{ BTU/hr}$$

Note that supplying the differential BTUs in a different fuel would not necessarily guarantee the same flame temperatures depending upon hydrogen and moisture content of the fuel, and heat transfer characteristics of the apparatus used. It should be considered a general indication only.



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DATE 6/1/81

CLIENT FESA FILE NO. 5397-01 BY Paul Utterback

SUBJECT VAPORMID Checked By Preliminary

Assuming an oil of 150,000 BTU/gal, the following flow rate would be required to supply the differential BTUs:

$$\begin{aligned} \text{OF}_1 &= \frac{\Delta \text{BTU}_1}{150,000 \text{ BTU/gal}} = \\ &= \frac{448 \text{ BTU/hr}}{150,000 \text{ BTU/gal}} = 2.99 \times 10^{-3} \text{ gal/hr} \\ &= 49.8 \times 10^{-6} \text{ gal/min} \end{aligned}$$

From the data sheet included with the report, the Vapormid contains 3 1/2 oz. oil. Assuming this is fluid ounces, then the  $\Delta \text{BTU}$  could be supplied for the following time period.

$$T_1 = \frac{3.5 \text{ oz}}{128 \text{ oz/gal} \times 2.99 \times 10^{-3} \text{ gal/hr}} = 9 + \text{Hours}$$

In Part II of the same report, a gas calorimeter is used instead of a burner. Based on Cutler-Hammer literature, the heat input to the calorimeter is 1100 to 1300 BTU/hr. The BTU reading increases, as reported in this test, were on the order of 2 to 7%. (1000 to 1022 and 984 to 1050 BTU/SCF).



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DATE 6/1/81

CLIENT FESA FILE NO. 5397-01 BY Paul Utterback  
SUBJECT VAPORMID Checked By Preliminary

To supply this  $\Delta BTU_2$  with an oil would require:

$$\begin{aligned}\Delta BTU_2 &= .07 \times 1300 \text{ BTU/hr} \\ &= 91 \text{ BTU/hr}\end{aligned}$$

And the corresponding oil flow of:

$$\begin{aligned}OF_2 &= \frac{\Delta BTU_2}{150,000 \text{ BTU/gal}} \\ &= \frac{91 \text{ BTU/hr}}{150,000 \text{ BTU/gal}} = .61 \times 10^{-3} \text{ gal/hr} \\ &= 10.1 \times 10^{-6} \text{ gal/min}\end{aligned}$$

Assuming the same quantity of oil in the Vapormid, the catalyst layer could supply the required heat input to the calorimeter for:

$$T_2 = \frac{3.5 \text{ oz}}{128 \text{ oz/gal} \times .61 \times 10^{-3} \text{ gal/hr}} = 44.8 \text{ hours}$$

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